FITCHBURG

Catalytic Project:

No Increase in Post Development Run-Off Volume - City of Fitchburg, WI

Prepared by:

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Dec. 26, 2012

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The work that provided the basis for this publication was supported by funding under an award with the U.S. Department of Housing and Urban Development. The substance and findings of the work are dedicated to the public. The author and publisher are solely responsible for the accuracy of the statements and interpretations contained in this publication. Such interpretations do not necessarily reflect the views of the Government.

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1 EXECUTIVE SUMMARY

In 2011, the City of Fitchburg and the Capital Area Regional Planning Commission (CARPC) received a grant from the federal Sustainable Communities Regional Planning Grant Program to conduct a catalytic project. The goal of the catalytic project is to determine which combination(s) of volume control Best Management Practices (BMPs) will enable future development to meet standard established by CARPC in the McGaw Neighborhood Area, an area slated for development: The following control post development runoff volumes to be equal to or less than pre-development runoff volumes for the one-year average annual rainfall period as well as the five year average rainfall period as defined by WDNR. Emmons & Olivier Resources, Inc. was retained by the City to conduct this catalytic project which consists of four parts:

1. Review of the McGaw Neighborhood Plan and Local Regulations;
2. Literature Review of Volume Control Best Management Practices;
3. Modeling Analysis (to develop stormwater management plans and evaluate ability to meet standards under various development scenarios); and a
4. Design Charrette (to review proposed stormwater management plans with the local development community).

This report summarizes all four aspects of the project. The main body addresses the findings of the Modeling Analysis and Design Charrette. Deliverables developed for the Review of the McGaw Neighborhood Plan and Local Regulations and the Literature Review can be found in the appendices.

As **Figure 1** illustrates, the McGaw Park Neighborhood Area is located in the Wards 14 and 16 of the City of Fitchburg and is approximately bounded by:

- South: Utility easement north of Irish Lane
- North: Lacy Road
- East: South Branch of Swan Creek
- West: Fish Hatchery Road

Figure 1. Location Map for McGaw Park Neighborhood

In order to demonstrate how a stormwater management plan could be designed to meet the CARPC volume control standard, the City decided to develop stormwater management plans for two hypothetical blocks in the McGaw Neighborhood Area: a Medium-Density Residential Development (identified as R2 in the McGaw Neighborhood Plan) and a Transit-Oriented Development (identified as TOD in the McGaw Neighborhood Plan).

The hypothetical blocks selected for the modeling analysis were analyzed assuming that they were located within that portion of the McGaw Neighborhood Area that the CARPC standards apply to (the portion of the neighborhood area that has already been brought into the Urban Services Area). By locating these hypothetical blocks in the McGaw Neighborhood Area the physical characteristics of the site (e.g. soils, depth to the water table, and proximity to other natural features) were taken into consideration during the modeling analysis.

Over the course of the project, two rounds of stormwater management plans were developed: the initial design (Design Team's Approach) and the final design (Design Charrette Input). The initial design was developed using as many volume control BMPs in the toolbox as possible. The intent of this design was to spark conversation at the Design Charrette which was hosted by the City of Fitchburg. The goal of the charrette was to bring together landowners, local developers, members of the design community, local government unit personnel and appointed/elected City officials to better understand CARPC's requirements for the McGaw Neighborhood Adjustment Area and to solicit feedback on the initial design for the proposed stormwater management plans. The final design was developed using feedback received at the Design Charrette. This design was developed more strategically and incorporated only those BMPs that meeting participants felt were suited for the City and the proposed landuse. In addition, the final design was a more optimized design in that it just met the stormwater management requirements (versus exceeding the requirements as was the case for the initial design).

The results of this project demonstrate that the CARPC requirement for volume control can be met by applying a distributed approach to stormwater management. This distributed approach results in a number of BMPs being used throughout the site to capture and treat stormwater runoff as close to the source as possible. While the CARPC does not establish a cap for the amount of area used to meet the volume control standard, it has been demonstrated that by locating BMPs in the roadways, private or public right-of-ways or underground, a stormwater management plan can be developed that does not exceed these caps.

2 INTRODUCTION & OBJECTIVES

The objective of the modeling analysis is to demonstrate how a stormwater management plan can be designed to meet the volume control requirements for the McGaw Neighborhood Area. As the memorandum titled "Review of McGaw Neighborhood Plan and Local Regulations" dated February 13, 2012 states (Appendix A), the most restrictive standard for this area is the standard set by the Capital Area Regional Planning Commission (CARPC): "Control post development runoff volumes to be equal to or less than pre-development runoff volumes for the one-year average annual rainfall period as well as the five-year average rainfall period as defined by the Wisconsin Department of Natural Resources." This analysis demonstrates how compliance with the volume control standard achieves the rate, volume, recharge and water quality standards set forth by the City as well as the other regulatory bodies.

In order to demonstrate how this standard can be met in a realistic fashion, the City wanted to see how the standard might be applied in two higher density development scenarios found in the McGaw Neighborhood Plan: Medium-Density Residential Development (identified as R2 in the McGaw Neighborhood Plan) and Transit-Oriented Development (identified as TOD in the McGaw Neighborhood Plan).

The volume control Best Management Practices (BMPs) used to develop the stormwater management plans for these two development scenarios are described in the document titled "Update on the Science of Volume Control BMPs: A Literature Review for a Northern Climate" dated October 2012 (Appendix B). This document presents the most up-to-date information regarding the performance, cost, design, and suitability of BMPs with volume reduction benefits.

While the development of the stormwater management plans for the two hypothetical blocks (R2 and TOD) took the available information regarding physical site characteristics into account, additional information may need to be collected and evaluated for the development of final design plans. For example, the soil boring information used to determine infiltration rates for this analysis was collected in proximity to the hypothetical development sites. For actual design purposes, a minimum number of borings or pits shall be constructed for each infiltration device as stated in the Wisconsin Department of Natural Resources Conservation Practice Standards: Site Evaluation for Stormwater Infiltration (1002).

Results of the modeling analysis were presented to the development community at a design charrette: an intensive, hands-on workshop where the results of the first stormwater management plan were presented and the group discussed the feasibility of the BMPs used to meet the standards. The initial stormwater management plan was re-evaluated based on feedback received at the design charrette and a final stormwater management plan was developed for his project. The City of Fitchburg intends to use these hypothetical stormwater management plans to demonstrate how future development in the McGaw Neighborhood Area can be achieved and the implications of the standards.

3 SELECTION OF HYPOTHETICAL BLOCKS

In order to demonstrate how a stormwater management plan could be designed to meet the CARPC volume control standard, the City decided to design stormwater management plans for two hypothetical blocks in the McGaw Neighborhood Area. Since one of the City's goals was to demonstrate how the volume control standard can be met on higher density development, it selected the following two development scenarios for application of the standard: Medium-Density Residential Development (identified as R2 in the McGaw Neighborhood Plan) and Transit-Oriented Development (identified as TOD in the McGaw Neighborhood Plan).

The layout for these two hypothetical blocks were chosen from a charrette produced design option on Fish Hatchery Road which presents opportunities for new development, redevelopment and infill in a well-established and well served portion of the City. Selecting previously developed concept plans for the modeling analysis ensures an evaluation of BMPs in a realistic and previously reviewed setting. **Figure 2** and **Figure 3** illustrate the hypothetical blocks selected for this analysis while **Table 1** and **Table 2** summarize the land use characteristics for each block.

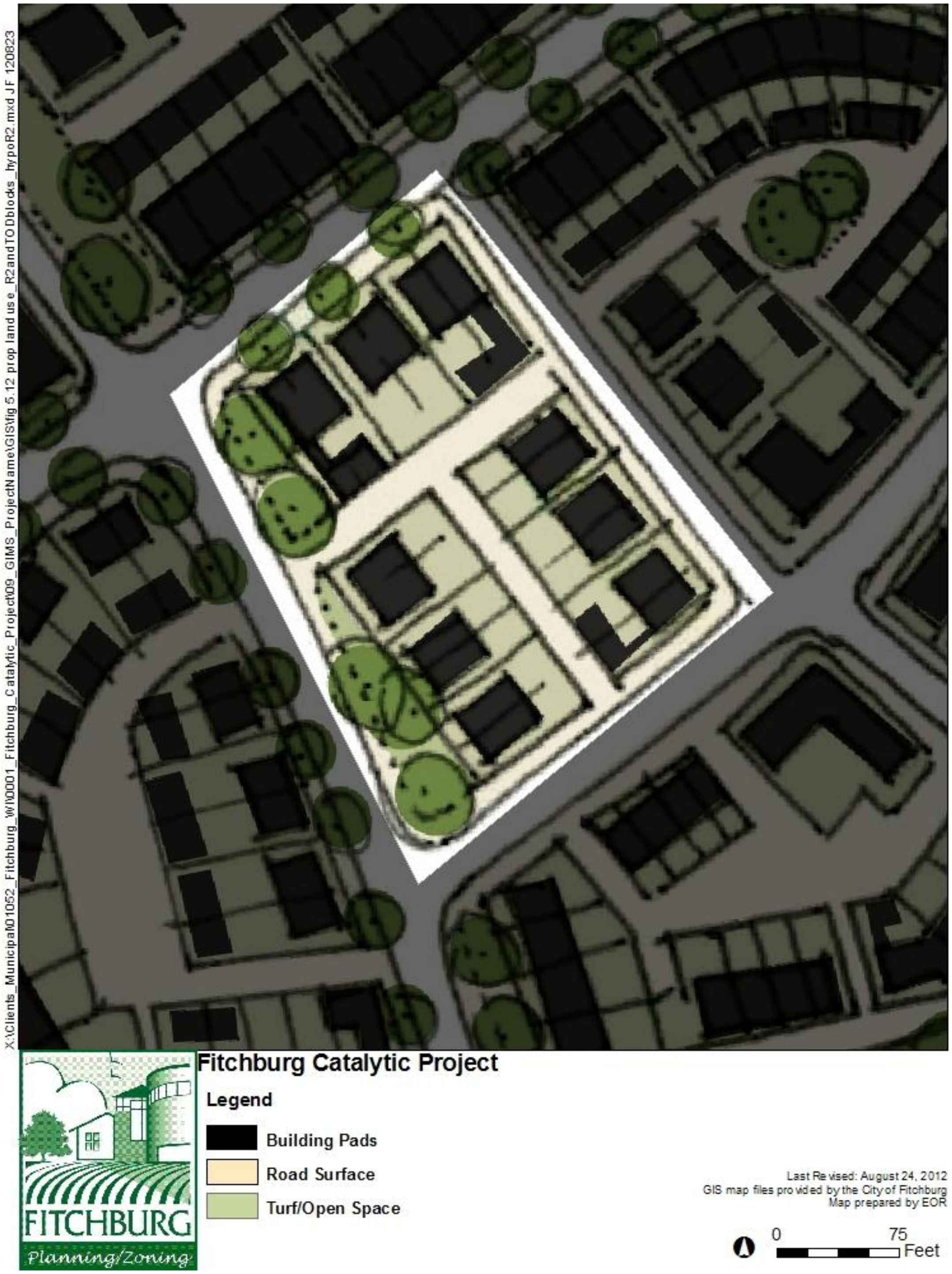

Figure 2. Hypothetical Block for R2 Development

Table 1. Medium-Density Residential (R2) Development Land Cover Summary

Total Area [Acres]	Total Impervious Area [Acres]	Percent Impervious [%]	Impervious Area: Buildings [Acres]	Impervious Area: Parking/Roads [Acres]	Pervious Area: Open Space [Acres]
1.91	1.01	53	0.44	0.57	0.90

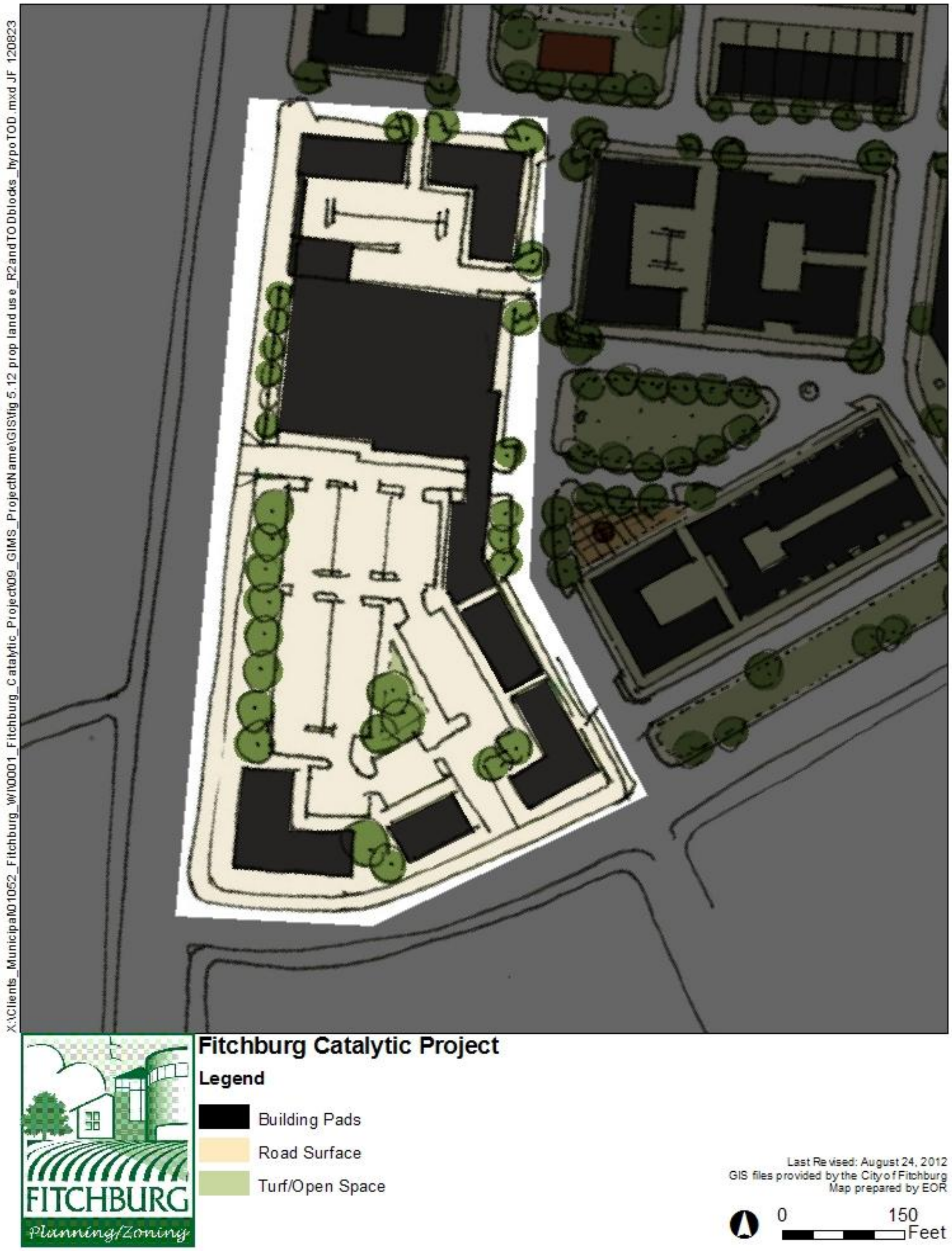

Figure 3. Hypothetical Block for TOD Development

Table 2. Transit-Oriented Development (TOD) Land Cover Summary

Total Area [Acres]	Total Impervious Area [Acres]	Percent Impervious [%]	Impervious Area: Buildings [Acres]	Impervious Area: Parking/Roads [Acres]	Pervious Area: Open Space [Acres]
9.83	9.26	94	3.04	6.22	0.57

The hypothetical blocks selected for the modeling analysis were analyzed assuming that they were located within that portion of the McGaw Neighborhood Area that the CARPC standards apply to (the portion of the neighborhood area that has already been brought into the Urban Services Area). By locating these hypothetical blocks in the McGaw Neighborhood Area the physical characteristics of the site (e.g. soils, depth to the water table, and proximity to other natural features) were taken into consideration during the modeling analysis. The proposed layout for an R2 development was applied to Area 22 of the McGaw Neighborhood Plan and the proposed layout for the TOD development was applied to Area 15 of the McGaw Neighborhood Plan (**Figure 4**).

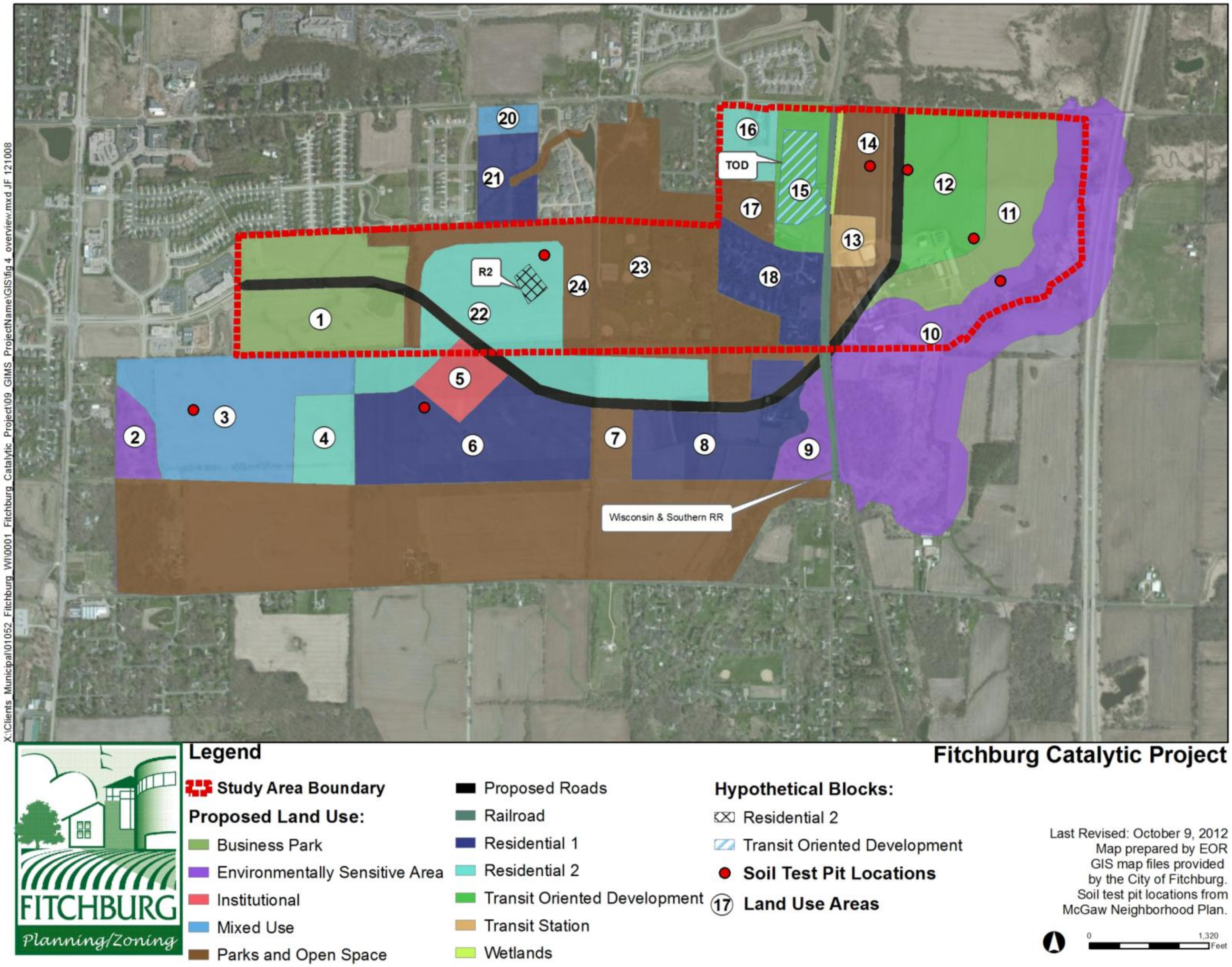

Figure 4. Location of Hypothetical Blocks within McGaw Neighborhood Area

The following site characteristics played a role in the evaluation of the stormwater management plan and BMPs for each development scenario:

Medium-Density Residential Development (R2)

- **Soils** – According to the Natural Resources Conservation Service (NRCS) soil survey the following two soil types appear on this site: Ringwood Silt Loam and Griswold Loam. The McGaw Neighborhood Plan also includes soil borings at various locations throughout the site.
- **Infiltration Rates** – Results of a preliminary site soil evaluation conducted for the McGaw Park Neighborhood Plan were used for the assignment of infiltration rates. The soil boring log for test pit #7 (closest to Area 22) indicates that the subsurface materials are gravely loamy sand (see Appendix D).
- **Depth to the Water Table** – Evidence of a local (shallow) water table can be derived from the preliminary site soil evaluation conducted for the McGaw Park Neighborhood Plan. The soil boring log for test pit #7 indicates that there was no evidence of a seasonally high water table within 10 feet of existing grade.
- **Area Geology and Hydrogeology -** The uppermost bedrock in the area is sandstone. Above the sandstone are variable, poorly sorted silt, sand, and gravel typical of glacial terrains. The depth to bedrock is shallow (less than 10 feet) in the eastern part of the site (as topography falls towards the stream features) and deeper in the western part of the site. None of the soil pits in the west part of the site (Soil Pits 3 – 7) encountered bedrock.

  The water table in the area is in the sandstone bedrock. The sandstone is part of the Upper Paleozoic regional aquifer (Wisconsin Geological and Natural History Survey, 1999). Water table elevations range from about 910 feet in the west to about 880 feet in the eastern part of the site. The depth to water from the surface ranges from about 106 feet to 32 feet below ground surface. However, some soil pits encountered “very moist to wet” soils and indicators of seasonally high water tables. These indicate low-permeability layers that might restrict infiltration locally and create localized areas of perched groundwater.

Transit-Oriented Development (TOD)

- **Soils -** According to the Natural Resources Conservation Service (NRCS) soil survey the following three soil types appear on this site: Griswold Loam, Plano Silt Loam and Elburn Silt Loam. The McGaw Neighborhood Plan also includes soil borings at various locations throughout the site.
- **Infiltration Rates -** Results of a preliminary site soil evaluation conducted for the McGaw Park Neighborhood Plan were used for the assignment of infiltration rates. The soil boring log for test pit #4 (closest to Area 15) indicates that the subsurface materials are loamy sand (see Appendix D).
- **Area Geology and Hydrogeology –** See description provided above.
- **Wetlands -** There is a wetland located downstream of Area 15 on the east side of Syene Road. Drainage patterns and runoff volume changes to this wetland need to be considered.
- **Wellhead Protection** – Area 15 is in the vicinity of a public drinking water supply. The wellhead protection plan requires oil and grease removal for the 0.5” event using the best removal technology available.

4 MODEL SELECTION

Five different models were used to conduct the modeling analysis for this project: each was selected to perform a specific evaluation of the stormwater management plan developed for the two hypothetical blocks. Two of the models (XP-SWMM and P8), which will likely be required by the City of Fitchburg and other regulatory bodies, were used to evaluate the main hydrologic and hydraulic parameters in question (rate, volume, and water quality). The next two models (RECARGA and Hantush), which are more simplistic in nature and may or may not be required by the City of Fitchburg and other regulatory bodies, were used to evaluate the groundwater aspects of the stormwater management plan. The final model (Rainwater Harvesting Assessment) was used to design the rainwater harvesting system being proposed for the TOD hypothetical block for me initial design. *Section 12 Conclusions & Recommendations* provides additional discussion of the need to use all of these models to demonstrate compliance with the standards. A detailed account of each model can be found in the modeling input table in Appendix C.

4.1 Hydrology and Hydraulics

The City of Fitchburg selected the XP-SWMM model to evaluate the hydrology and hydraulics of the proposed stormwater management plans for this project since it is considering this model for the development of a city-wide tool. XP-SWMM is the Environmental Protection Agency's (EPA) Storm Water Management Model (SWMM) engine with enhancements. It is a dynamic rainfall-runoff simulation model which can be used for single-event to long-term (continuous) simulation of the hydrology from urban and suburban areas. The hydrology portion of the model is developed by explicitly defining impervious surfaces and using curve numbers for the pervious land area. The XP-SWMM model was used to ensure that flow rates did not increase (from pre-development conditions) for the 1, 2, 10 and 100-year rainfall events.

Annual runoff volumes were analyzed using the City of Fitchburg's existing condition P8 (Program for Predicting Polluting Particle Passage thru Pits, Puddles and Ponds) model (described below) to ensure that post development runoff volumes were equal to or less than pre-development runoff volumes for the one-year average annual rainfall period and the 5-year rainfall period as defined by the Wisconsin Department of Natural Resources. While P8 is typically used for water quality modeling purposes, it also is set up to track volumes for a continuous simulation making it ideal for showing if the CARPC volume requirement is met. While XP-SWMM can be used to track runoff volumes, the previously developed P8 model was used for this purpose.

4.2 Water Quality and Volume Control

Water quality modeling was conducted using the City of Fitchburg's existing condition P8 model. While the City and other regulatory bodies prefer to have stormwater calculations submitted using WinSLAMM, the latest version (WinSLAMM 10) could not be used as it was still in beta testing at the time of this report. After discussing the status of the final testing of WinSLAMM and its anticipated release date with PV & Associates, LLC (developer of WinSLAMM) and the City of Fitchburg, it was decided that this analysis would be conducted using the existing P8 model. Given some of the limitations of P8 (e.g. model does not account for the re-suspension of pollutants), it is anticipated that final design plans for the McGaw Neighborhood Area will be conducted using WinSLAMM 10 (subsequent version).

The P8 model was defined using the same curve numbers and impervious coverage as the XP-SWMM model. The P8 model was used to evaluate the ability of the stormwater management plan to reduce the total suspended solids (TSS) load by 80 percent based on the average annual rainfall, as compared to no controls.

4.3 Annual Recharge Rate

The RECARGA model can be used to estimate the amount of groundwater recharge from raingardens. For this project, equations from the RECARGA model were used to ensure that the recharge rate requirement of 9.5 inches/year was met. While this is a relatively quick calculation to perform, it may not be necessary given the volume control standards required by CARPC. Additional discussion of modeling recommendations is provided in *Section 12 Conclusions and Recommendations* of this report.

4.4 Groundwater Mounding

Groundwater mounding below stormwater infiltration BMP's is a concern for the following reasons:

- the groundwater mound can intersect the bottom of the BMP modifying its capacity to infiltrate;
- a portion of the mound can intersect the basement of adjacent structures if adequate separation has not been provided between the BMP and the structures; and
- the potential for groundwater contamination with a reduced unsaturated zone.

To address these potential issues the Wisconsin Department of Natural Resources requires a groundwater mounding analysis be conducted for certain BMPs to determine the vertical separation from the infiltration surface to the highest anticipated groundwater elevation (as specified in Chapter NR 151 Runoff Management). While a groundwater mounding analysis was not required for the stormwater management plans developed for this project since the drainage areas to the BMPs are so small (less than 2 acres) it was conducted to demonstrate how it would be performed and to confirm whether there would likely be any issues with the proposed layouts.

A groundwater mounding analysis was performed for each of the BMP's selected for the Hypothetical Block Scenarios. The analyses were conducted using a model developed by Hantush (1967). This model is available on the WDNR's web-site for use in conducting groundwater mounding analyses. AQTESOLV (2012) software was used for the calculations. Each basin was modeled as a rectangle that infiltrates water at a constant rate for a 24-hr period (meeting WDNR's drawdown requirements). The maximum mounding occurs at the center of the rectangle after 24 hours (T = 24 hrs). The groundwater mound decreases rapidly after infiltration.

The mean hydraulic conductivity of the Upper Paleozoic (sandstone) aquifer is 4 ft/day (0.17 ft/hr or 2.0 in/hr) (Wisconsin Geological and Natural History Survey, 1999). The lower range of the hydraulic conductivity values for sandy loam in the soil survey is 0.11 ft/hr (1.3 in/hr). This value was used in the mounding analyses as a conservative estimate of the hydraulic conductivity that may be found throughout the area.

A value of 0.21 was used for the specific yield of the sandstone (Johnson, 1967). This is a conservative (low) number for other soils found across the site, so larger values with lower mounding may be encountered in this area.

The saturated thickness of the water table aquifer was estimated to be 10 ft. This is a very conservative estimate for the sandstone aquifer, but may be appropriate when localized confining layers above the sandstone are considered, as described below.

Initial depth to the water table was calculated based on the elevation of the bottom of the BMP and a simulated water table based on current conditions (McGaw Neighborhood Plan, 2009). The water table elevations also agree with values reported by the Wisconsin Geological and Natural History Survey (1999).

4.5 Rainwater Harvesting Assessment

Hydrologic, hydraulic and water quality models (including XP-SWMM and P8) generally do not have a standardized method to account for the stormwater benefit of rainwater harvesting and reuse. To account for the benefits of this practice toward stormwater management goals, an expected annual reduction in stormwater volume was calculated using a Stormwater Reuse Model (SRM) and then a storage facility was built in XP-SWMM and P8 that matches the annual volume and peak flow reduction calculated in the SRM.

The SRM is a spreadsheet-based model developed by Emmons & Olivier Resources, Inc. (EOR) for the Mississippi Watershed Management Organization/Minnehaha Creek Watershed District in 2012. This model can be used to estimate the runoff volume reduction and water quality benefits of stormwater reuse using a daily time step mass balance of stormwater runoff volume and phosphorus load assuming non-conservative phosphorous mixing (Walker 1987 phosphorus sedimentation equations). The model simultaneously calculates annual volume reduction and phosphorus removal as a percent of the annual watershed load, in addition to annual evaporation losses and phosphorus sedimentation over a dry, average, and wet year.

5 APPROACH USED TO EVALUATE COMPLIANCE WITH STANDARDS

5.1 Standards

A summary of the standards being evaluated for this analysis can be found in the memorandum titled “Review of McGaw Neighborhood Plan and Local Regulations” February 13, 2012 (**Appendix A**).

5.2 Modeling Assumptions

A number of assumptions were made in evaluating the stormwater management plans developed for each site. This section of the report describes the assumptions made to address site suitability, BMP siting and sizing, and specific development scenarios.

5.2.1 Site Suitability

The following assumptions were made taking Areas 15 and 22 of the McGaw Neighborhood Area Plan (**Figure 4**) into account:

Grading/Topography– Given “the project area has nearly level to sloping relief, with evaluated slopes ranging from 1 – 11 %”[1], it was assumed that the hypothetical blocks were graded at a consistent 2% slope so that flow is towards downstream drainage ways (e.g. wetlands, drainage channels, creeks). A detailed grading plan was not created for this project as it was deemed unnecessary for this level and type of analysis.

Infiltration Rates – As Section 3.0 *Selection of Hypothetical Blocks* indicates, there were multiple soil types identified in the NRCS soil survey in both hypothetical block locations. In general terms there was a combination of loam and silt loam on both sites. Soil test pits (see Appendix D) conducted in the vicinity of the hypothetical block locations (#4 and #7) indicate that there is loamy sand and gravely loamy sand approximately 4 feet below existing grade, therefore the use of an infiltration rate of 1.63 inches/hour was appropriate. To maintain a conservative approach, in locations that the NRCS soil survey identifies loam (Griswold Loam: NRCS assigned infiltration rate of 1.3 inches/hour), an infiltration rate of 0.5 inches/hour was assumed per the WDNR Conservation Practice Standard 1002 for the modeling analysis and where the soils survey identifies silt loam (Ringwood Silt Loam: NRCS assigned infiltration rate of 4 inches/hour, Plano Silt Loam: NRCS assigned infiltration rate of 3.3

[1] McGaw Park Neighborhood Plan. City of Fitchburg, WI. June 9, 2009.

inches/hour or Elburn Silt Loam: NRCS assigned infiltration rate of 3.3 inches/hour), an infiltration rate of 1.63 inches/hour was assumed per the WDNR Conservation Practice Standard 1002. This distribution of rates was based upon the following text from the McGaw Neighborhood Plan which states:

> "Infiltration rates mapped by the NRCS range from 1 to 4 in/hr, with the lower rates more common in the western and southeastern portions of the Neighborhood. To be conservative, rates assumed in the ordinance model analysis (conducted for the McGaw Neighborhood Plan) were reduced significantly. Where a rate of 1.3 in/hr was listed in the soil survey, a rate of 0.5 in/hr was assumed, where a rate equaling 3 in/hr or more was listed in the soil survey, a rate of 1.63 in/hr was assumed. These values correspond with infiltration rates listed in the WDNR Conservation Practice Standard 1002 for sandy loam and loamy sand, respectively."

It should be noted that the gravely loamy sand located at the bottom of soil pit #7 is likely weathered bedrock (indicated in the notes as "scattered rotten rock"). Use of an infiltration rate of 1.63 inches/hour was acceptable to the Wisconsin Department of Natural Resources given the small size of BMPs and contributing drainage areas being treated in the vicinity of these underlying soils.

Depth to Water Table – One of the activities conducted during the development of the McGaw Neighborhood Plan was a simulation of groundwater levels for existing conditions. Using this information, it was determined that the depth to the regional groundwater table in the vicinity of the Medium-Density Residential (R2) development is approximately 100 feet while the depth in the vicinity of the Transit-Oriented Development (TOD) is approximately 35 feet. Information regarding the depth to the seasonally high water table can be found in the soil test pits (conducted during the development of the McGaw Neighborhood Plan). The soil test pits conducted in the vicinity of the hypothetical block schematic locations (#4 and #7) indicates that the seasonally high water table was not encountered within 10 feet of existing grade (see Appendix D).

Soil Profile – Using the information collected for the McGaw Neighborhood Plan (soil test pits) it was assumed that there were no layers which would restrict the flow of water in the vertical direction. Even if more restrictive (less permeable) material were encountered, it is not expected to affect the capacity of the BMPs used for stormwater management given the distributed nature of the layout and the total volumes of stormwater runoff being infiltrated at any given location.

5.2.2 BMP Siting and Sizing Parameters

The following assumptions were made when siting and sizing volume control BMPs in the stormwater management plans developed for each Hypothetical Block Schematic:

BMP Design – It is assumed that at a minimum all BMPs will be graded to the depth required to make contact with the more permeable underlying materials based on the soil test pits conducted for the McGaw Neighborhood Plan. This corresponds to a depth of approximately 3.25 feet for the BMPs located in the Medium-Density Residential Development and a depth of approximately 4.75 feet for the BMPs located in the Transit-Oriented Development (see Appendix D). Shallower BMPs (e.g. raingardens and bioretention facilities) will be backfilled with bioengineered soils to allow for the appropriate BMP depths.

- The total depth of the bioretention facilities (engineered raingardens) is a combination of the ponding area depth, an engineered soil planting bed and a storage layer (Figure 5). Underground BMPs (tree trenches, below-ground recharge systems, and pervious pavement systems) contain only a storage layer. The maximum BMP depths were established using the underlying soil type(s) and type of practice as described in Wisconsin Department of Natural Resources Conservation Practice Standards 1002, 1003, 1004, and 1007.

- A ponding depth drawdown of 24-hours was used for bioretention devices. Up to one foot of live storage was allowed above the ponding depth to provide rate control.
- A maximum of a 4 foot storage layer thickness for either soil type under bioretention devices (Wisconsin Department of Natural Resources Conservation Practice Standard 1004, Bioretention for Infiltration)
- A maximum of an 8 foot total depth for below-ground recharge systems: 5 foot storage layer below the outlet and 3 feet of storage above the outlet. The design team established a maximum depth of 8 feet to ensure adequate vertical separation from groundwater/bedrock. Additional site investigation would dictate if deeper storage layers would be possible.
- A total device drain time for all practices of 72 hours (Wisconsin Department of Natural Resources Conservation Practice Standard 1004, Bioretention for Infiltration)
- All bioretention devices contain 3.0 feet of engineered soil.
- The drawdown and sizing assumptions for the rainwater harvesting system was set such that a 20% annual volume removal was obtained per the stormwater reuse model.

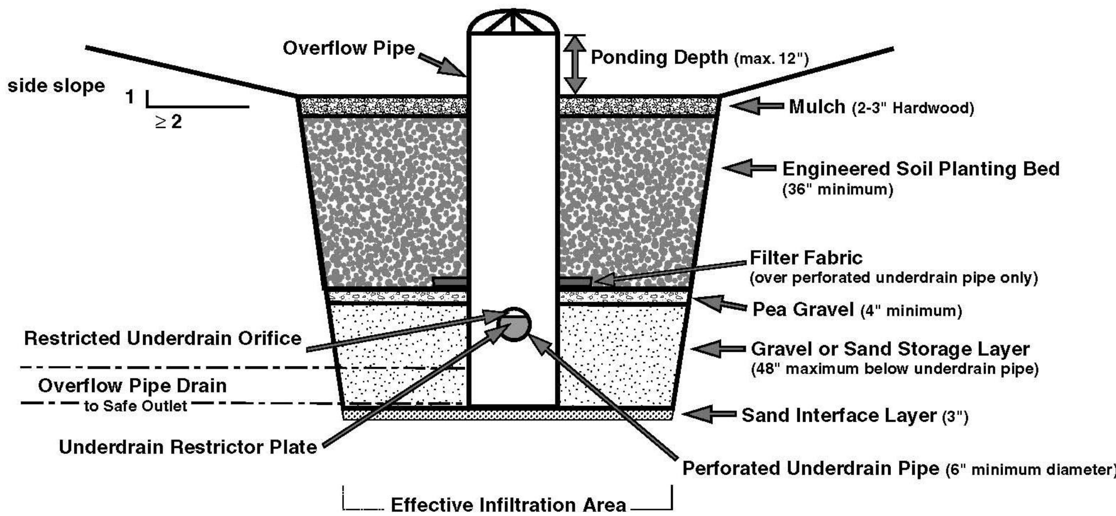

Figure 5. Typical Bioretention Cross Section
(WDNR Conservation Practice Standard 1004, Bioretention for Infiltration)

Pretreatment – The need for pretreatment and the pretreatment requirements vary by BMP as follows:

- ***Pervious Pavement Systems:*** In communications with the WDNR it was understood that runoff from pervious areas needs to be treated for sediment removal to prevent clogging of the system. In addition, the WDNR would like to limit the amount of impervious area being routed to the pervious pavement system without treatment. The WDNR is in the process of developing Conservation Practice Standards for the design and construction of pervious pavement systems.
- ***Green Roof:*** Pretreatment is not required for the rainwater being intercepted and used by the green roof.
- ***Bioretention Devices:*** According to the WDNR standards, pretreatment is not required for BMPs that have a contributing drainage area that is less than 2 acres in size and that have bioengineered soils. As a result, there is no pretreatment provided for the bioretention devices used in either of the proposed stormwater management plans.

- ***Tree Trenches:*** According to the WDNR standards, pretreatment is not required for BMPs that have a contributing drainage area that is less than 2 acres in size. As a result, there is no pretreatment provided for the tree trenches used in either of the stormwater management plans.
- ***Below-Ground Recharge Systems:*** 80% TSS removal (WDNR Conservation Practice Standard 1007, Infiltration Trench) has been provided using an underground stormwater filter for below-ground recharge systems of the TOD site. A P8 model was used to size this feature to ensure TSS removal was met.
- ***Rainwater Harvesting:*** Pretreatment is not required for rainwater harvesting as the source of water being collected and used for irrigation purposes is relatively clean.
- ***Green Roof Sizing:*** As is the case for rainwater harvesting, typical models do not contain green roofs as explicit components. Although designs vary considerably, typical green roofs can accommodate 3 inches of water storage in the planting media and void space[2]. To model this, the green roof was simulated as a storage facility with 3 inches of depth and assigned an infiltration rate of 0.5 in/hr to remove water from the green roof over time.

5.2.3 Development Scenarios

The following assumptions were made for the Medium-Density Residential Development (R2) scenario:

- Assumed an average of 10 dwelling units/acre for medium-density residential development
- Parking provided on-site in garages or in underground parking
- Curbed streets
- Impervious calculations include half of the road
- Care is needed to avoid utility conflicts

The following assumptions were made for the Transit-Oriented Development (TOD) scenario:

- Assumed a minimum Commercial Floor Area Ratio (FAR) of 0.5 and a minimum Residential FAR of 0.62 for TOD
- Impervious calculations include half of the road
- Curbed streets
- Assumed same number of parking stalls as original concept plan
- Care is needed to avoid utility conflicts
- Not addressing potential hydrologic impacts to wetlands

5.3 Modeling Approach

While development in the McGaw Neighborhood Area requires compliance with a number of entities' standards (e.g. City of Fitchburg, Dane County, WDNR) the most stringent requirement is the CARPC's volume control standard which states: "Control post development runoff volumes to be equal to or less than pre-development runoff volumes for the one-year average annual rainfall period as well as the five-year average rainfall period as defined by the Wisconsin Department of Natural Resources". Within this standard, the period-of-record that drives the design of the stormwater management plan is the one-year average annual rainfall period (measured rainfall from March 12 – December 2, 1980) due to the total volume of rainfall delivered over the year, and the size and spacing of rainfall events throughout the year. The five-year average annual rainfall period (1980-1984) was included in the standard to address the limitations of water quality models to accurately simulate street sweeping as a BMP.

As a result, the modeling analysis used the one-year average annual rainfall period as the baseline for design of the stormwater management plans assuming that all of the other standards (rate, volume, water quality and recharge) would subsequently be met with minor modifications to the plan.

6 BMP SELECTION: INITIAL DESIGN (DESIGN TEAM'S APPROACH)

The overall goal for the first round of designing the stormwater management plans for each hypothetical block scenario was to select an assortment of BMPs. While this assortment is intended to reflect a cost-effective solution to meeting the stormwater management requirements for each site, it is also intended to reflect the variety of BMPs that can be used in these settings. This section discusses how BMPs were selected, which BMPs were selected for each development scenario and what pretreatment measures will be required.

6.1 Source Control Aspects Not Accounted for in Modeling Analysis

While the City of Fitchburg and the CARPC are interested in evaluating as many volume control BMPs in the modeling analysis as possible, there are some source controls (described in the literature review, Appendix B) that are more difficult to evaluate and quantify. As a result, these BMPs were not included in the modeling analysis. The exclusion of these source controls results in a more conservative plan for addressing the stormwater management requirements since there are other practices that could be used to mitigate the increase in stormwater runoff under post-development conditions.

For example, source control techniques such as tree canopy interception and downspout disconnection were not modeled in this analysis. The benefits of these techniques are realized primarily under smaller storm events and the relative benefits decrease with increasing storm intensities. Modeling techniques such as compositing or reducing curve numbers, modifying rainfall intensities or allowing for higher depressional storage in the landscape (runoff generating calculations) could all be used to account for the benefit of source controls.

6.2 BMP Selection for Medium-Density Residential Development (R2)

The volume control BMPs selected for the residential development stormwater management plan were chosen because they are well suited for this development scenario:

- They are an appropriate size for drainage area and treatment volume requirements;
- They are commonly accepted and understood by the general public and municipal staff; and
- They have been demonstrated to increase property values by enhancing the aesthetic of the development.

The BMPs used for the residential development stormwater management plan are illustrated in **Figure 8** and are described (within the context of the stormwater management plan) as follows:

Figure 6. Argenta Hills (source EOR)

Pervious Pavement Systems – It is proposed that the entire 9,000 square foot alley be constructed using pervious pavement with a variable depth storage layer (average depth 0.5 feet). Using a variable depth storage layer allows the WDNR drainage area requirement to be met without oversizing the practice. Excess stormwater runoff (overflow) would run along the road to the down gradient bioretention device (engineered raingarden). As stated previously, pretreatment is provided by upstream bioretention for the additional drainage (pervious) area routed to this practice.

Bioretention Devices / Engineered Raingardens – It is proposed that a total of seven bioretention devices (engineered raingardens) be located in the R2 development to meet the standards. These bioretention devices (engineered raingardens) are typically located along the front of each parcel and they collect storm water from open, grassy areas, rooftops and impervious roads. In total, the bioretention devices (engineered raingardens) cover 1,850 square feet of the area and each bioretention device (engineered raingarden) contains a 12-inch ponding depth and an 36-inch engineered soil depth. The depth of the storage layer varies between 2.5 and 4 feet depending on the infiltration rate and contributing drainage area. A 3-inch draintile outlet is provided near the bottom of the ponding layer so the practice can provide both volume and rate control benefits. Excess stormwater runoff (overflow) runs into the gutters to the next down gradient BMP or is routed offsite. Pretreatment is provided by forebays and filter strips to collect large debris and sediment.

Figure 7. Private Residence in Minneapolis, MN
(source EOR)

Tree Trenches – A series of tree trenches covering 470 square feet on the north side of the development collect storm water from the surrounding green space, street drainage and roof tops as well as overflow from the up-gradient BMPs. The tree trench is 1 foot deep and infiltrates at a rate of 0.5 inches per hour. These tree trench designs reflect ideas developed by Björn Embrén, an engineer with the Stockholm, Sweden Traffic Department. *Planting Beds in the City of Stockholm: A Handbook* from 2009 describes how Embrén uses layers of various soils, large and small rock, porous pavers, and ventilation to create urban environments conducive to healthy trees. Pretreatment will be provided by sump manholes for the direct drainage area to collect large debris and coarse sediment.

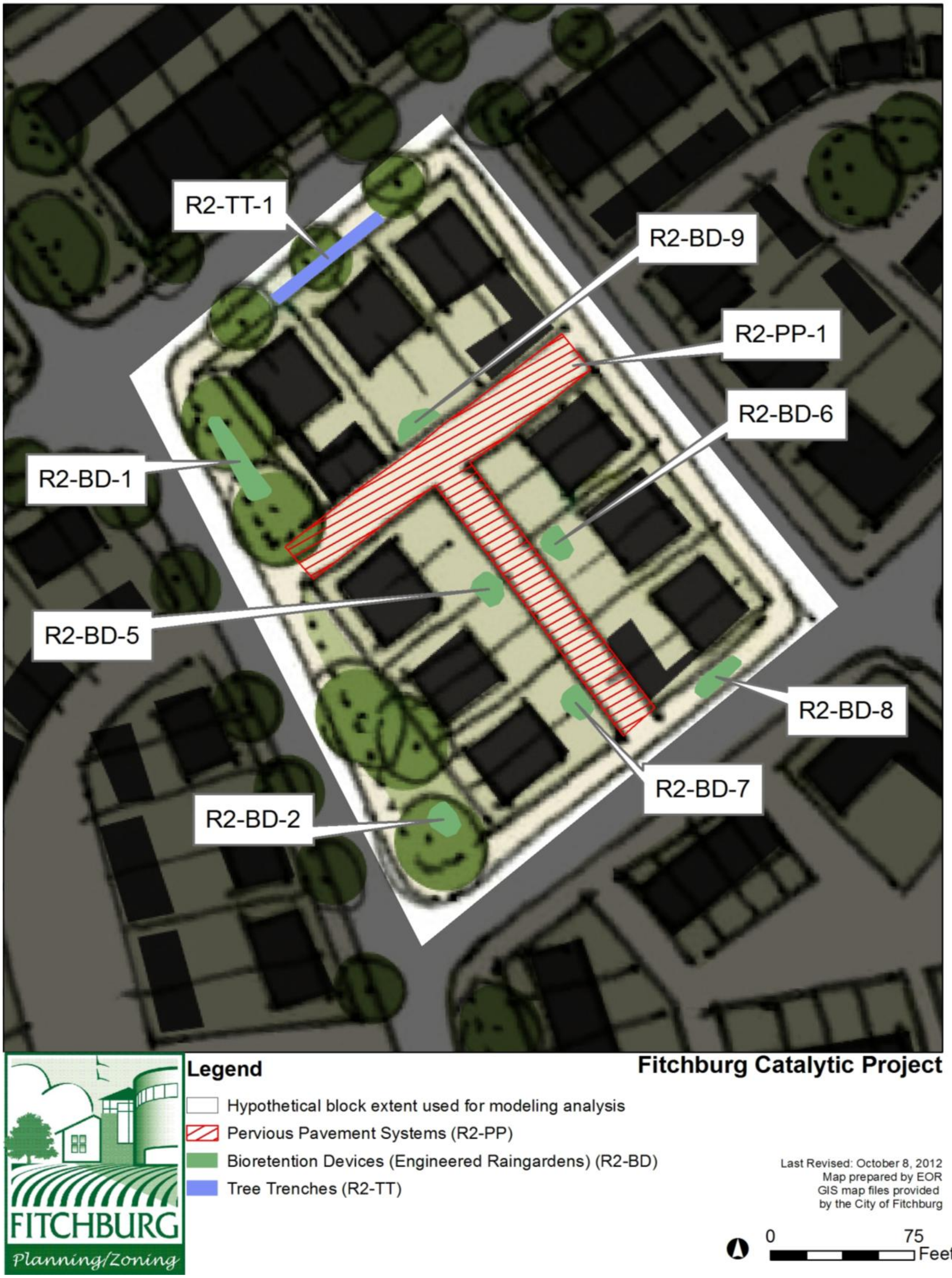

Figure 8. Stormwater Management Plan for R2 Development (Initial Design)

Table 3 contains a summary of the BMPs sizing and drainage area characteristics for each individual BMP in the proposed stormwater management plan.

Table 3. BMP Summary for the Medium-Density Residential Development (R2) Scenario

*BMP Category	BMP Type	BMP ID	BMP Area [sq. ft.]	Total Storage Depth [ft]	BMP Volume [cu. ft.]	Infiltration Rate [in/hr]	Drainage Area (ac)			
							Building	Open Space	Parking /Road	Total
Source Control/ Surface Treatment**	Pervious Pavement System	R2-PP-1	9,148	0.20	436	0.5	NA	NA	0.21	0.21
Surface Treatment	Bioretention Device	R2-RG-1	472	1.40	710	0.5	0.09	0.07	NA	0.15
	Bioretention Device	R2-RG-2	225	2.60	584	1.63	0.04	0.29	0.24	0.57
	Bioretention Device	R2-RG-5	227	1.40	317	0.5	0.07	0.07	NA	0.14
	Bioretention Device	R2-RG-6	218	1.40	305	0.5	0.04	0.10	NA	0.14
	Bioretention Device	R2-RG-7	218	2.60	567	1.63	0.03	0.06	NA	0.10
	Bioretention Device	R2-RG-8	218	1.40	351	0.5	0.06	0.04	NA	0.10
	Bioretention Device	R2-RG-9	210	1.40	294	0.5	0.11	0.12	NA	0.23
	Tree Trench	R2-TB-1	470	1.00	493	0.5	NA	0.15	0.13	0.28

*Routing BMPs, Subsurface BMPs and Reuse BMPs not used in this development.

** In the cases where pervious pavement treats more than just the volume of water that falls on it, the BMP should be considered a surface treatment practice.

6.3 BMP Selection for Transit Oriented Development (TOD)

The volume control BMPs selected for the Transit-Oriented Development stormwater management plan were chosen because they are well suited for this development scenario:

- They are the appropriate size for the drainage area and treatment volume requirements;
- They provide treatment while maintaining infrastructure and parking requirement; and
- They create a more aesthetically pleasing public space.

The BMPs used for the Transit-Oriented Development stormwater management plan are illustrated in **Figure 16** and are described (within the context of the stormwater management plan) as follows:

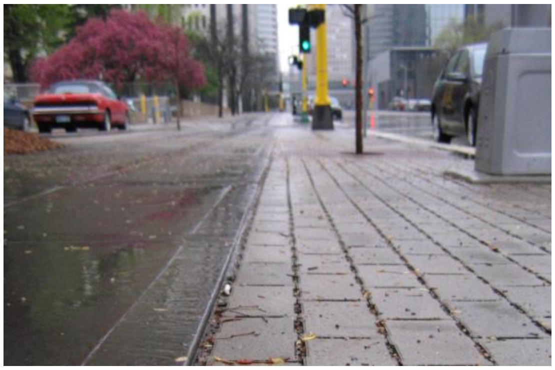

Figure 9. Pervious Pavers
(source: City of Minneapolis)

Pervious Pavement Systems –Two public plazas will be partially constructed with 450 square feet of pervious pavement. Porous pavers, asphalt or concrete are options. The stormwater runoff treated by this practice comes from rooftops in the southern part of the development. The pervious pavement is modeled as a 34-inch deep basin with an infiltration rate of 1.63 inches per hour. Overflow runs on the ground to a rain garden. Given that the drainage area is composed of rooftops, pretreatment will consist of removing accumulated debris from paver surface.

Bioretention Devices / Rain Gardens - There are seven bioretention devices totaling 7,800 square feet in the hypothetical stormwater management plan for the Transit-Oriented Development. These bioretention devices are typically located along the perimeter green space; one sits in the middle of a parking lot. As in the R2 site, the ponding depth of the bioretention facilities is set to 1 foot and the rest of the volume occurs underground. Unlike the R2 site, rate control is provided by underground facilities completely and not within bioretention devices. Because of existing soil conditions, two rain gardens have a water depth of 1.4 feet deep (infiltration rate 0.5 inches/hour); the other 5 are modeled as 2.6 feet deep (1.63 inches/hour). Overflow runs overland to the next downstream rain garden although overflow could be conveyed via a standpipe without significant changes to the overall stormwater plan. The stormwater runoff treated from these practices comes from parking lots, green space, and rooftops. Routine pretreatment is provided by sediment forebays. In large storms, runoff might receive pre-treatment in one BMP before overflowing and running downstream.

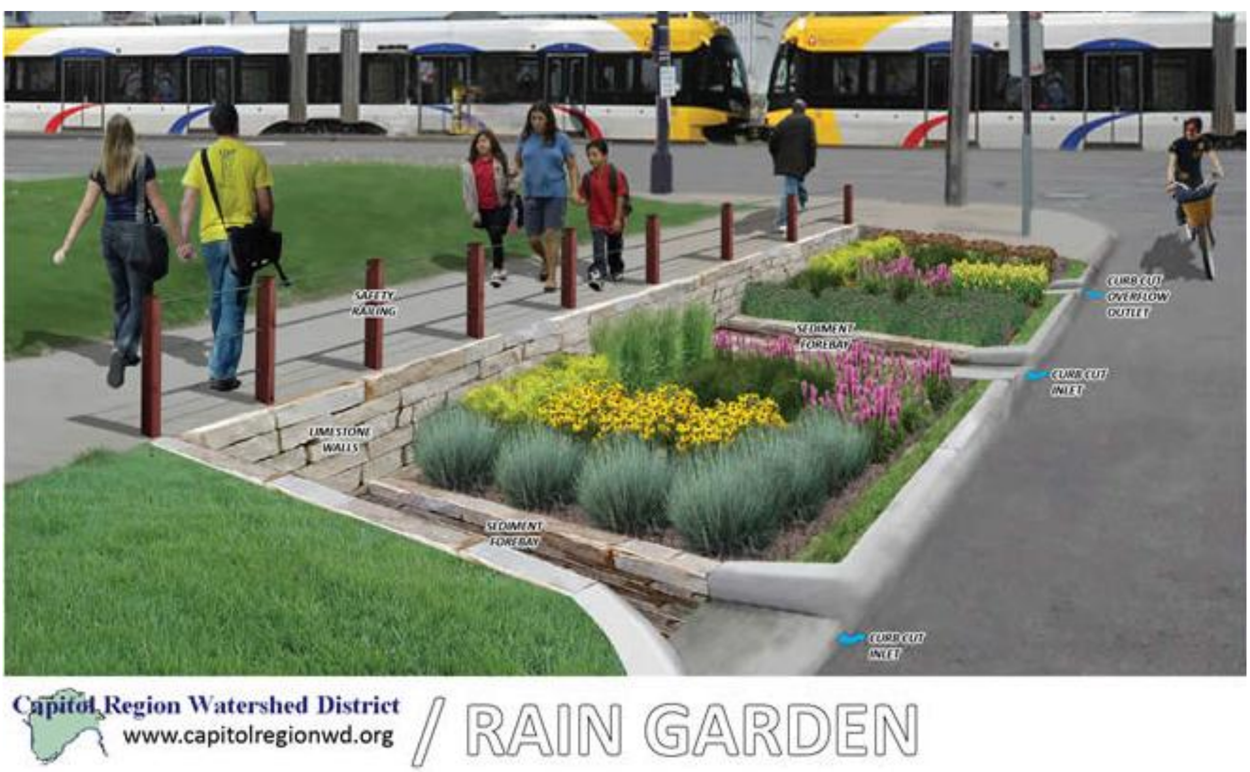

Figure 10. Bioretention Device (Engineered Raingarden) rendering for the CRWD
(source: CRWD / EOR)

Figure 11. Bioretention Device (Engineered Raingarden) during construction (source: EOR)

Tree Trenches – Four tree trench galleries are situated in parking lot islands to provide infiltration for the surrounding impervious pavement runoff. There is an underground sand filter that pre-treats parking lot runoff before it gets to the tree trenches. The hypothetical stormwater management plan for the Transit-Oriented Development scenario includes one other tree trench along the north side perimeter to treat runoff from roads. Total tree trench area is 2,200 square feet. In the model, because of better soils, this northern trench is 2.8 feet deep and infiltrates at 1.63 inches/hour. The four trenches in the parking lot are 12 inches deep and infiltrate at 0.5 inches/hour. Overflow drains along the ground to the next down gradient BMP. These tree trench designs reflect ideas developed by Björn Embrén, an engineer with the Stockholm, Sweden Traffic Department. *Planting Beds in the City of Stockholm: A Handbook* from 2009 describes how Embrén uses layers of various soils, large and small rock, porous pavers, and ventilation to create urban environments conducive to healthy trees. Pretreatment will be provided by sump manholes for the direct drainage area to collect large debris and coarse sediment.

Figure 12. Tree Trench rendering from the Capitol Region Watershed District (source: CRWD)

Figure 13. Underground Infiltration System installation, Bradshaw Development - Stillwater, MN
(source: EOR)

Below-ground Recharge Systems – There are three underground infiltration practices in this modeling analysis: two beneath the southern parking lot (6 inches deep, 0.5 inches/hour infiltration rate),and one beneath the parking lot on the north side (2.8 feet deep, 1.63 inches/hour). The total area for these practices is 13,477 square feet. Underground infiltration consists of chambers (plastic or metal pipe with no bottom) that allow water to percolate into the soil. All three collect runoff from the surrounding impervious parking lots and roads. The two on the south side receive overflow storm water from the bioretention devices and pervious pavement in the southeast section of the TOD. Overflow from the underground infiltration goes to a down gradient rain garden or drains offsite. Pretreatment is provided by an underground sand filter.

Figure 14. Cistern - Minneapolis, MN
(source: MWMO)

Rainwater Harvesting – A rainwater harvesting system was assumed for the Transit-Oriented Development scenario. The 10,000 gallon cistern collects water from a 1.3-acre roof just north of the development's center. The sizing of the cistern is based on watering an acre of grass with 1.5 inches per week from April through October. The roof generates 500,000 gallons of water per year, allowing 20% to be reused for irrigation. Overflow (the other 80%) from the cistern is routed to the underground infiltration BMP (UI-3). This BMP does not require pretreatment.

Figure 15. Green Roof designed for the Amery Regional Medical Facility - Amery, WI
(source: EOR)

Green Roofs – A green roof has been located on one of the buildings to the north of the site. It was assumed that the top of this building is at a lower grade (relative to adjacent buildings) thereby providing opportunities to view the green roof from adjacent buildings. This green roof (which has an area of 4,300 square feet) has been modeled to collect stormwater from approximately 30,000 square feet of the building. The overflow for this system drains to a rain garden located to the north of the building. Given the quality of the water being treated, pretreatment is not necessary for green roofs.

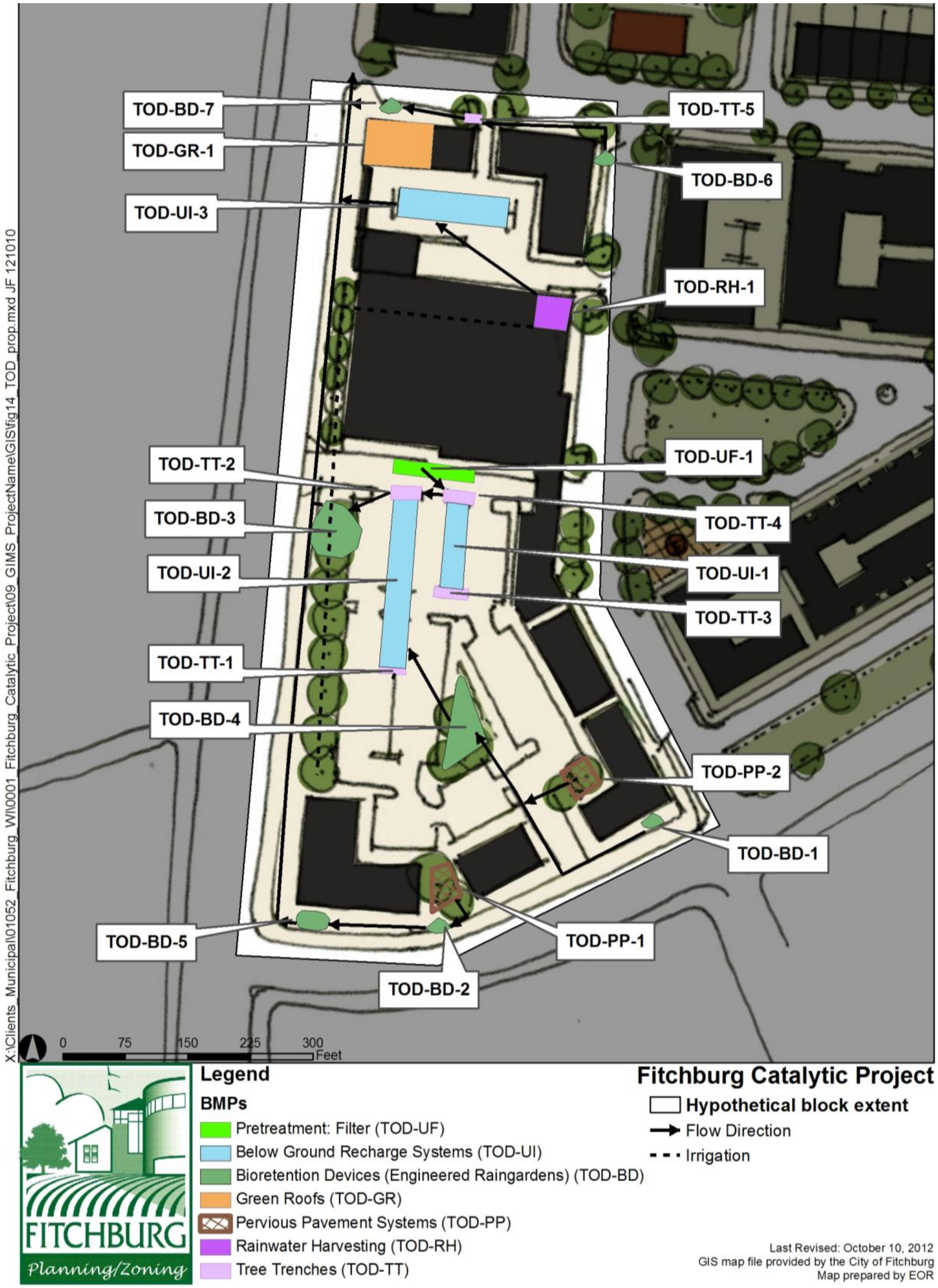

Figure 16. Stormwater Management Plan for TOD Development (Initial Design)

Table 4 contains a summary of the BMPs sizing and drainage area characteristics for each individual BMP in the proposed stormwater management plan.

Table 4. BMP Summary for the Transit-Oriented Development (TOD) Scenario

BMP Category*	BMP Type	BMP ID	BMP Area (sf)	Total Storage Depth (ft)	BMP Volume (cf)	Infiltration Rate (in/hr)	Drainage Area (ac)			
							Building	Open Space	Parking/road	Total
Source Control	Green Roof	TOD-GR-1	4,331	0.30	1,299	0	0.67	0	0	0.67
	Pervious Pavement System	TOD-PP-1	1,362	2.80	3,736	1.63	0.44	0.07	0	0.51
	Pervious Pavement System	TOD-PP-2	1,199	1.00	1,208	1.63	0.2	0	0.052	0.25
Surface Treatment	Bioretention Device	TOD-BD-1	332	2.60	790	1.63	0	0	0.158	0.16
	Bioretention Device	TOD-BD-2	332	2.60	862	1.63	0	0	0.207	0.21
	Bioretention Device	TOD-BD-3	3,093	1.40	4,330	0.50	0	0.277	1.304	1.58
	Bioretention Device	TOD-BD-4	2,615	2.60	8,138	1.63	0.41	0.222	0.837	1.47
	Bioretention Device	TOD-BD-5	776	2.60	2,016	1.63	0	0	0.429	0.43
	Bioretention Device	TOD-BD-6	332	1.40	464	1.63	0	0	0.075	0.08
	Bioretention Device	TOD-BD-7	332	2.60	862	1.63	0	0	0.118	0.12
	Tree Trench	TOD-TT-1	243	1.00	243	0.50	*	*	*	*
	Tree Trench	TOD-TT-2	596	1.00	596	0.50	*	*	*	*
	Tree Trench	TOD-TT-3	526	1.00	526	0.50	*	*	*	*
	Tree Trench	TOD-TT-4	576	1.00	576	0.50	*	*	*	*
	Tree Trench	TOD-TT-5	227	2.80	635	1.63	0	0	0.173	0.17
Subsurface	Below-Ground Recharge System	TOD-UI-1	2,690	0.5	1,345	0.50	*	*	*	*
	Below-Ground Recharge System	TOD-UI-2	6,147	0.5	3,073	0.50	*	*	*	*
	Below-Ground Recharge System	TOD-UI-3	4,640	2.80	12,992	1.63	0	0	1.184	1.18
Reuse	Rainwater Harvesting	TOD-WH-1	1,425	0	0	0	1.32	0	0	1.32

7 RESULTS: INITIAL DESIGN (DESIGN TEAM'S APPROACH)

7.1 R2 Results and Compliance with Standards

This section demonstrates how the proposed stormwater management plan could meet the standards set by the City of Fitchburg, CARPC, Dane County and the Wisconsin Department of Natural Resources.

7.1.1 Evaluation of Land Dedicated to Stormwater Management

The proposed stormwater management plan meets all of the requirements identified in the memorandum titled "Review of McGaw Neighborhood Plan and Local Regulations" dated February 13, 2012 (Appendix A). In general terms, the volume control BMPs selected for this first round of analysis take up approximately 6 percent of the developable space for this hypothetical block. As the results demonstrate, there is room in the system to treat additional stormwater runoff in the event some BMPs are more desirable than others (e.g. bioretention devices versus permeable pavements), treatment from adjoining properties is required and/or more conservative infiltration rates are applied than those recommended by the Wisconsin Department of Natural Resources.

Table 5 summarizes the total area of land dedicated to the stormwater management plan for the Medium-Density Residential Development Hypothetical Block Scenario. **Figure 17** illustrates the volume of treatment provided by each type of BMP used in the stormwater management plan. This information tells us that 80% of the area dedicated to stormwater management mitigates approximately 11% of the volume through the use of pervious pavement systems, approximately 16% of the area mitigates 77% of the volume through the use of bioretention and approximately 4% of the area mitigates 12% of the volume through the use of tree trenches. For this particular setting, use of BMPs such as pervious pavement systems and tree trenches concentrates stormwater management in areas dedicated to public use and/or infrastructure (e.g. roads/alleys and sidewalks). This leaves more of the site available for use by the residents and businesses of the community. Placement of infrastructure beneath the BMPs that are subsurface should be done with care and therefore integrated site design is necessary.

While the WDNR, Dane County and the City of Fitchburg have caps on the amount of area dedicated to volume control practices, CARPC does not have a cap for the McGaw Neighborhood Adjustment Area. Since the CARPC requirements are what future Permit applicants will need to meet in portions of the McGaw Neighborhood Adjustment Area there would be no cap on the extent of infiltration areas. However, it is worth noting that the stormwater management plan for both scenarios approximately meets the WDNR cap requirements if the location of BMPs is taken into account. As **Table 5** indicates, 2% of the total area is planned to be dedicated to bioretention devices (engineered raingardens) while the other BMPs (pervious pavement systems and tree trenches) are located within the roadway and/or right-of-way. This distribution of BMP matches what the cap requirements for the site would have been if they applied: for Medium-Density Residential Development the cap requirement would be 2%.

Table 5. Summary of BMP Areas Proposed for the R2 Development (Initial Design)

BMP	BMP Area [sq. ft.]	% of BMP Area	% of Total Area*
Pervious Pavement Systems	9,148	80%	11%
Bioretention Device	1,855	16%	2%
Tree Trenches	493	4%	1%
Total	**9,717**	100%	14%

* Total area for the R2 Development Hypothetical Block Scenario is 83,200 square-feet or 1.9 acres.

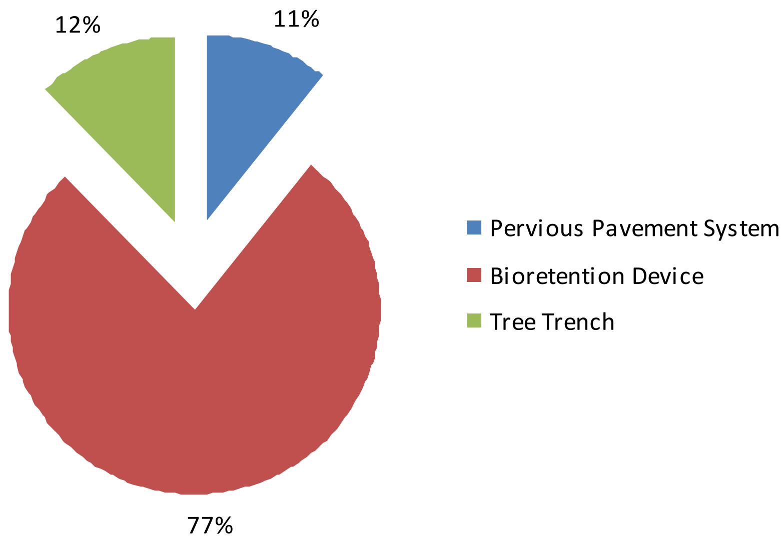

Figure 17. Summary of BMP Storage Volume for the R2 Development

7.1.2 Rate Control Standard

Section 1.c. of the CARPC standard requires that the 1, 2, 10 and 100-year 24-hour design storm be limited to pre-development conditions. **Table 6** summarizes the XP-SWMM results and shows no increase in peak discharge for any of the design storms.

Table 6. XP-SWMM Modeled Peak Discharge Rates from the R2 Block (Initial Design)

24-hour event	Peak Flow Rate (cfs)		
	Pre-development	Post-development	Change
1 year (2.5”)	0.5	0.2	-0.4
2 year (2.9”)	0.8	0.4	-0.4
10 year (4.2”)	2.0	2.0	-0.1
100 year (6.0”)	4.0	3.9	-0.2

7.1.3 Volume Control Standard

Section 1.d. of the CARPC standard requires no increase in runoff volume from the 1-year or 5-year average runoff periods. **Table 7** summarizes the results of the P8 volume analysis and shows no increase in runoff volumes under either timeframe.

Table 7. P8 Modeled Runoff Volumes from the R2 Block (Initial Design)

Time Frame	P8 Model Runoff (acre-feet) per time frame		
	Pre-development	Post-development	Change
1-year (1981)	0.4	0.4	0.0
5-year (1980-1984)	2.4	1.3	-1.1

7.1.4 Water Quality Standard

Section 1.b. of the CARPC standard and the WDNR require 80% TSS reduction based on the average annual rainfall as compared to no controls. **Table 8** summarizes the results of the P8 TSS analysis and shows this threshold is greatly surpassed by the stormwater management plan.

Table 8. P8 Modeled TSS Reduction from the R2 Block (Initial Design)

TSS leaving site (lb/year)		
No Controls	With BMPs	Reduction (%)
1030	28	97%

7.1.5 Groundwater Recharge Standard

Section 1.e. of the CARPC standard requires that 9 to 10 inches of groundwater recharge be maintained from pre- to post-development conditions. **Figure 18** summarizes the results of the RECARGA analysis for both soil types and shows this threshold is surpassed by the stormwater management plan. The current site plan that uses 12% for stormwater infiltration provides a recharge depth of 15 inches.

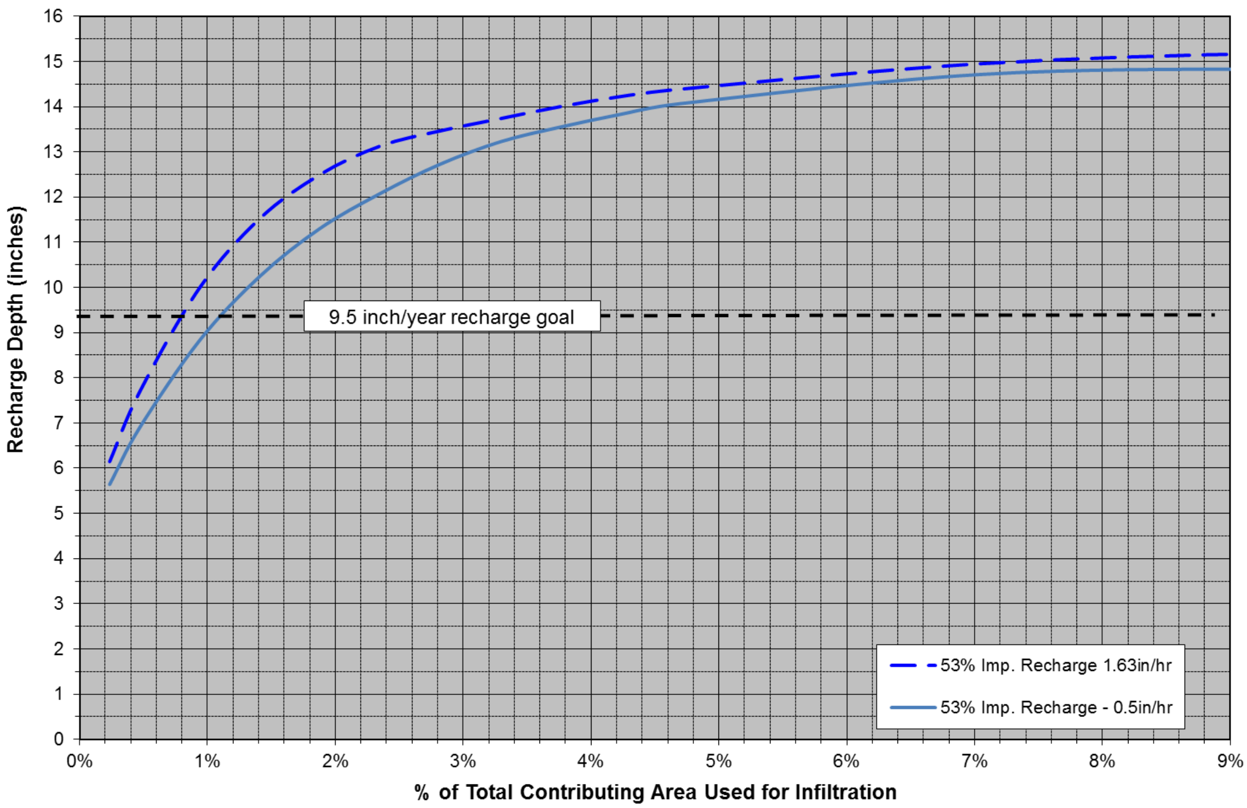

Figure 18. Groundwater Recharge as Modeled in RECARGA from the R2 Block Assuming Residential

7.1.6 Groundwater Mounding Analysis

The results of the groundwater mounding analysis are summarized in **Table 9**. All the calculated groundwater mounds are less than 10 feet. The minimum distance from the bottom of a BMP to the mounded water table was 96 feet. This indicates that the proposed BMP's meet the design limit of 5 feet of unsaturated soil above the water table.

Table 9. Hantush Groundwater Mounding Analysis for the R2 Block (Initial Design)

Type	BMP ID	Ksat (in/hr)	Total Storage Depth (in)	Simulated Water Table Elevation (ft)	Depth from Bottom of BMP to Water Table (ft)	Max. Mound Height After 24 hr. (ft)	Depth from Bottom of BMP to Groundwater Mound (ft)
Pervious Pavement System	R2-PP-1	1.	2	893	102	3.4	99
Bioretention Device	R2-BD-1	1.3	17	893	98	1.8	96
Bioretention Device	R2-BD-2	1.3	31	893	104	4.7	99
Bioretention Device	R2-BD-5	1.3	17	893	102	1.6	100
Bioretention Device	R2-BD-6	1.3	17	893	102	1.6	100
Bioretention Device	R2-BD-7	1.3	31	893	104	4.7	99
Bioretention Device	R2-BD-8	1.3	17	893	106	1.6	104
Bioretention Device	R2-BD-9	1.3	17	893	102	NA	NA
Tree Trench	R2-TT-1	1.3	12	893	98	1.4	97

7.2 TOD Results and Compliance with Standards

This section demonstrates how the proposed stormwater management plan could meet the standards set by the City of Fitchburg, CARPC, Dane County and the Wisconsin Department of Natural Resources.

7.2.1 Evaluation of Land Dedicated to Stormwater Management

The proposed stormwater management plan meets all of the requirements identified in the memorandum titled "Review of McGaw Neighborhood Plan and Local Regulations" dated February 13, 2012 (Appendix A). In general terms, the volume control BMPs selected for this first round of analysis take up approximately 7 percent of the developable space for this hypothetical block. As the results demonstrate, there is room in the system to treat additional stormwater runoff in the event some BMPs are more desirable than others (e.g. bioretention devices versus permeable pavements), treatment from adjoining properties is required and/or more conservative infiltration rates are applied than those recommended by the Wisconsin Department of Natural Resources.

Table 10 summarizes the total area of land dedicated to the stormwater management plan for the Transit-Oriented Development Hypothetical Block Scenario. **Figure 19** illustrates the volume of treatment provided by each type of BMP used in the stormwater management plan. This information tells us that 42% of the area dedicated to stormwater management mitigates approximately 39% of the volume through the use of underground infiltration systems, approximately 26% of the area mitigates 38% of the volume through the use of bioretention, approximately 7% of the area mitigates 6% of the volume through the use of tree trenches and approximately 26% of the area mitigates the remaining 17 percent of the volume through the use of pervious pavement systems (11%), rainwater harvesting (3%) and green roofs (3%). For this particular setting, use of BMPs such as underground infiltration systems, pervious pavement systems, tree trenches, green roofs and rainwater harvesting concentrates stormwater management in areas dedicated to public use and/or public or private infrastructure (e.g. roads/alleys and sidewalks). This leaves more of the site available for use by the residents and businesses of the community by stacking functions in portions of the development already dedicated to infrastructure or communal space. Ultimately the intent is to maintain the existing function of the space while creating vibrant streetscapes: providing both function and aesthetics. Placement of infrastructure beneath the BMPs that are subsurface should be done with care and therefore integrated site design in necessary.

While the WDNR, Dane County and the City of Fitchburg have caps on the amount of area dedicated to volume control practices, CARPC does not have a cap for the McGaw Neighborhood Adjustment Area. Since the CARPC requirements are what future Permit Applicants will need to meet in the McGaw Neighborhood Adjustment Area there would be no cap on the extent of infiltration areas. However, it is worth noting that the stormwater management plan for both scenarios approximately meets the WDNR cap requirements if the location of BMPs is taken into account. As **Table 10** indicates 2% of the total area is dedicated to bioretention devices (engineered raingardens) while the other BMPs (pervious pavement systems, green roof, tree trenches, below-ground recharge systems and rainwater harvesting) are located within the roadway, right-of-way or on the buildings themselves. This distribution of BMP matches what the cap requirements for the site would have been if they applied for transit-oriented development the cap requirement would be 2%.

Table 10. Summary of BMP Areas Proposed for the TOD Development (Initial Design)

BMP	BMP Total Areas [sf]	% of BMP Area	% of Total Area*
Porous Pavement	2,542	8%	1%
Green Roof	4,331	13%	1%
Rain Garden	8,299	26%	2%
Tree Trench	2,168	7%	1%
Underground Infiltration	13,477	42%	3%
Harvesting	1,559	5%	0%
Total	32,376	100%	8%

* Total area for the TOD Development Hypothetical Block Scenario is 428,195 square-feet or 9.8 acres.

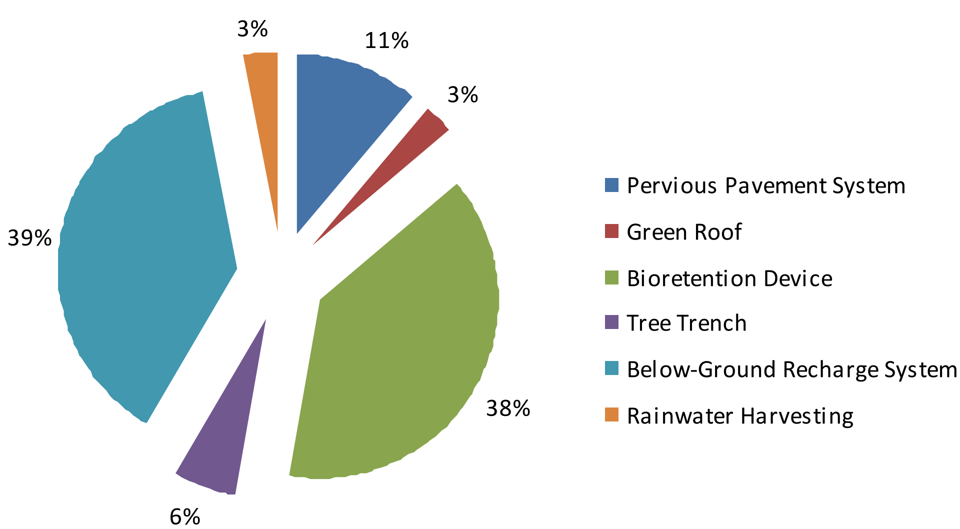

Figure 19. Summary of BMP Storage Volume for the TOD development

7.2.2 Rate Control Standard

Section 1.c. of the CARPC standard requires that the 1, 2, 10 and 100-year 24-hour design storm be limited to pre-development conditions. **Table 11** summarizes the XP-SWMM results and shows no increase in peak discharge for any of the design storms.

Table 11. XP-SWMM Modeled Peak Discharge Rates from the TOD Block (Initial Design)

24-hour event	Peak Flow Rate (cfs)		
	Pre-development	Post-development	Change
1 year (2.5")	2.8	0.9	-1.9
2 year (2.9")	4.1	1.7	-2.5
10 year (4.2")	9.7	7.7	-2.0
100 year (6.0")	19.2	18.9	-0.3

7.2.3 Volume Control Standard

Section 1.d. of the CARPC standard requires no increase in runoff volume from the 1-year or 5-year average annual runoff periods. **Table 12** summarizes the results of the P8 volume analysis and shows no increase in runoff volumes under either timeframe.

Table 12. P8 Modeled Annual Runoff Volumes from the TOD Block (Initial Design)

P8 Model Runoff (acre-feet) per time frame			
Time Frame	Pre-development	Post-development	Change
1-year (1981)	3.3	3.2	-0.1
5-year (1981-1984)	20.8	12.0	-8.8

7.2.4 Water Quality Standard

The WDNR require 80% TSS reduction based on the average annual rainfall as compared to no controls. **Table 13** summarizes the results of the P8 TSS analysis and shows this threshold is greatly surpassed by the stormwater management plan.

Table 13. P8 Modeled TSS Reduction from the TOD Block (Initial Design)

P8 Model TSS leaving site (lb/year)		
No Controls	With BMPs	Reduction (%)
9346	249	97%

7.2.5 Groundwater Recharge Standard

Section 1.e. of the CARPC standard requires that 9 to 10 inches of groundwater recharge be maintained. **Figure 20** summarizes the results of the RECARGA analysis for both soil types and shows this threshold is surpassed by the stormwater management plan. The current site plan that uses 8% for stormwater infiltration provides a recharge depth of 19.0 inches.

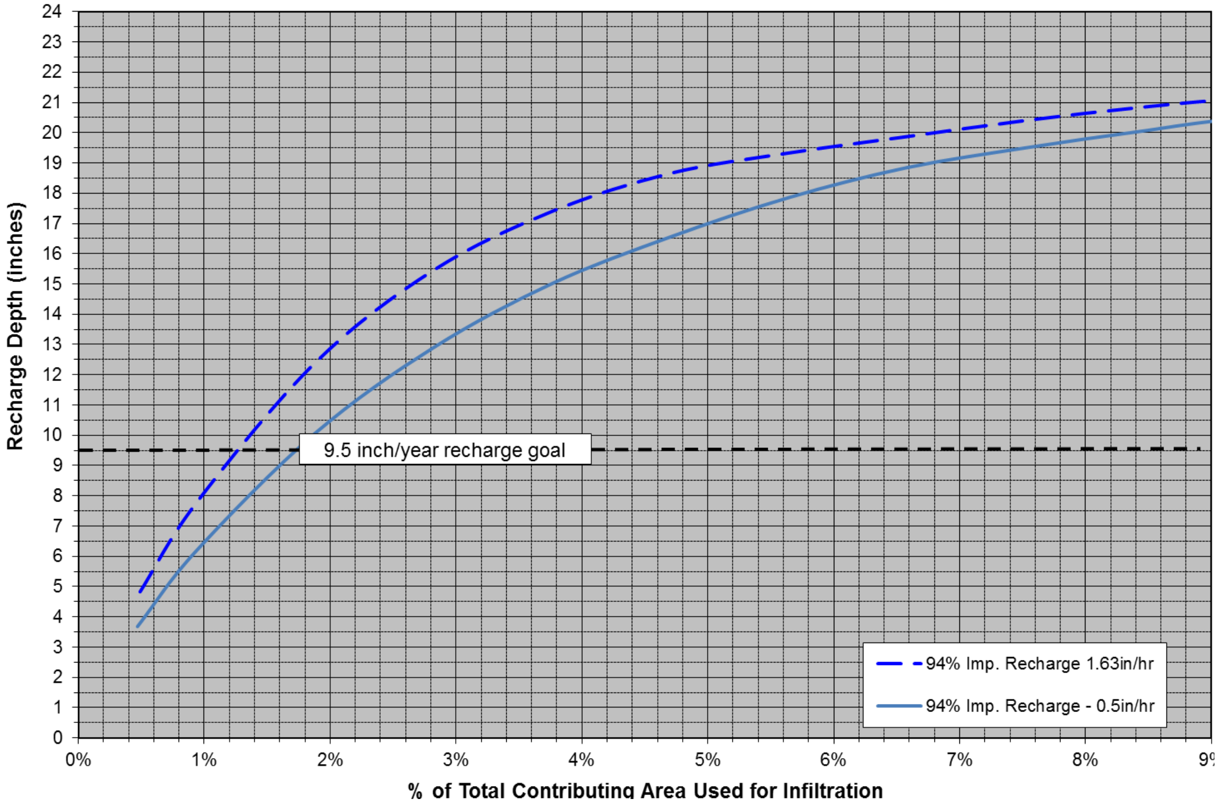

Figure 20. Groundwater recharge as modeled in RECARGA from the TOD block assuming residential

7.2.6 Groundwater Mounding Analysis

The results of the groundwater mounding analysis are summarized in **Table 14**. All the calculated groundwater mounds are less than 10 feet. The minimum distance from the bottom of a BMP to the mounded water table was 22 feet. This indicates that the proposed BMP's meet the design limit of 5 feet of unsaturated soil above the water table.

Table 14. Hantush Groundwater Mounding Analysis for the TOD Block (Initial Design)

Type	BMP ID	Ksat (in/hr)	Total Storage Depth (in)	Simulated Water Table Elevation (ft)	Depth from Bottom of BMP to Water Table (ft)	Max. Mound Height After 24 hr. (ft)	Depth from Bottom of BMP to Groundwater Mound (ft)
Pervious Pavement Systems	TOD-PP-1	1.3	34	883	38	4.7	33
Pervious Pavement Systems	TOD-PP-2	1.3	12	882	39	4.7	34
Bioretention Device	TOD-BD-1	1.3	31	882	39	5.5	34
Bioretention Device	TOD-BD-2	1.3	31	883	38	5.5	33
Bioretention Device	TOD-BD-3	1.3	17	882	37	4.4	33
Bioretention Device	TOD-BD-4	1.3	31	882	39	11.7	27
Bioretention Device	TOD-BD-5	1.3	31	883	34	8.5	26
Bioretention Device	TOD-BD-6	1.3	17	881	32	5.5	27
Bioretention Device	TOD-BD-7	1.3	31	881	32	5.5	27
Tree Trench	TOD-TT-1	1.3	12	882	36	2.7	33
Tree Trench	TOD-TT-2	1.3	12	882	36	4.9	31
Tree Trench	TOD-TT-3	1.3	12	882	36	4.5	32
Tree Trench	TOD-TT-4	1.3	12	882	36	4.9	31
Tree Trench	TOD-TT-5	1.3	34	881	32	4.5	28
Below Ground Recharge System	TOD-UI-1	1.3	6	882	36	7.4	29
Below Ground Recharge System	TOD-UI-2	1.3	6	882	36	7.8	28
Below Ground Recharge System	TOD-UI-3	1.3	34	881	32	10.5	22

7.3 BMP Cost Considerations

The development community is required to meet new challenges in the form of evolving stormwater management requirements, established to protect receiving waters. While there are number of surface runoff best management practices (BMPs) that will meet the requirements, it is difficult to know which of these BMPs (individually or in combination) will be most effective and economically sustainable in meeting the overall project goals. This section of the report describes the issues involved in the development of planning level cost estimates for BMPs and provides the reader with a current list of tools being used by the stormwater management community today.

7.3.1 Availability of Cost Information

As the literature review of volume control BMPs illustrates there are many factors that need to be taken into consideration when evaluating cost-benefit information. Stormwater management plans designed to address local requirements and impairments depend on a number of factors including local climatic conditions, physical conditions of the site and BMP construction and maintenance activities. Because these factors will vary from site to site, data and information are not readily available to develop dollar estimates of costs and benefits for individual types of BMPs.

Given all of the costs that go into the development of a site (e.g. design, contingency and permitting costs, construction costs, geotechnical testing, land costs, operation and maintenance costs, etc.) the only way to conduct a cost-benefit analysis is to compare a traditional development plan against the same plan developed using Low Impact Development techniques. Since CARPC has already established stormwater management standards for future development in the McGaw Neighborhood Area, a true cost-benefit analysis to evaluate the justification/feasibility of a project is unnecessary: any development plan in the McGaw Neighborhood Area will have to include volume control stormwater management to meet the standards. Rather, the main drivers will be the site characteristics (soils, depth to the shallow groundwater table, downstream resources) or the density of development. What the development and design community needs is planning level information to assess which of the tools in the BMP toolbox are going to meet the requirements for the lowest cost. To the extent that cost information is available, it is presented in the following sections.

Table 15 summarizes some typical unit costs (dollars per cubic foot of treated water volume) and some associated benefits for the volume control Best Management Practices (BMPs) used in developing the stormwater management plans for the two Hypothetical Block Scenarios. This information could be used by a developer or a designer to conduct a cost-benefit analysis when designing a particular stormwater management plan. The information presented in this table was taken from local sources where available. If local information was not available, a review of published information was conducted to provide a typical range or value. Given that these BMPs were selected to provide stormwater retention, attenuate peak flow rates and reduce pollutant loads, the benefits identified in this table are in addition to the stormwater management benefits. When conducting this comparison, it should be noted that the use of these volume control BMPs decreases the need to construct, expand or rebuild stormsewer system infrastructure downstream due to a decrease in total hydraulic loads.

Maintenance costs are also important to consider, both in budget/financing future needs as well as selecting practices that are cost-effective long-term. From the literature review, there does not appear to be a strong database yet informing or analyzing what relative maintenance costs are. Qualitatively some inferences can be made. For example, porous pavements in streets require regular maintenance (3 to 6 times/year) to operate effectively and prevent clogging. This can be a significant commitment. If the community had already considered a street sweeping program to help with aesthetics and/or improve water quality, the street sweeping needed on porous pavement may not pose a large additional burden.

If total construction costs for a development plan are known, one could use the information provided in the **Table 15** developed by the U.S. EPA. **Table 16** summarizes annual maintenance costs for a number of stormwater management BMPs as a percent of construction cost.

Table 15. Annual Maintenance Costs[1]

BMP	Annual Maintenance Cost (% of Construction Cost)	Source(s)
Retention Basins & Constructed	3%-6%	Wiegand et al, 1986; Schueler, 1987; SWRPC, 1991
Detention Basins[9]	<1%	Livingston et al, 1997; Brown and Schueler, 1997b
Constructed Wetlands[9]	2%	Livingston et al, 1997; Brown and Schueler, 1997b
Infiltration Trench	5%-20%	Schueler, 1987; SWRPC, 1991
Infiltration Basin[9]	1%-3%	Livingston et al, 1997; SWRPC, 1991
	5%-10%	Wiegand et al, 1986; Schueler, 1987; SWRPC, 1991
Sand Filters[9]	11%-13%	Livingston et al, 1997; Brown and Schueler, 1997b
Swales	5%-7%	SWRPC, 1991
Bioretention	5%-7%	(Assumes the same swales)
Filter strips	$320/acre (maintained)	SWRPC, 1991

Table 16. Cost-Benefit Information for Volume Control BMPs Used in this Evaluation

BMP	Unit Cost per square foot	O&M Costs	Volumetric Cost for Treatment ($/cf)	Other Benefits
Source Control BMPs				
Pervious Pavement	$2 - $3/square foot[2] $9.50/square foot for excavation, installation, materials and labor[3] • Porous asphalt is 10-15% higher than regular asphalt • Porous concrete is approximately 25% greater than regular concrete • Pavers can be as much as four times the expense of either regular concrete or asphalt.4 Installation cost of $7 - $15 per square foot, including underground infiltration bed (CRWA).[5]	$200/acre/year (1999 dollars)[4] Pervious pavement needs to be vacuum swept three to four times a year to prevent pores from becoming clogged and precluding infiltration. Approximately $400 - $500/yr. for vacuum sweeping of a half-acre parking lot.[5]	Average $21/cf[8]	• Reduced thermal pollution • Reduced irrigation of are plantings based on seepage of stormwater runoff into soil profile • Reduced glare and automobile hydroplaning accidents • Reduce pavement ice buildup • Require less land set aside and cost for development of other stormwater BMPs

[1] Preliminary Data Summary of Urban Storm Water Best Management Practices. United States Environmental Protection Agency. Office of Water, Washington, DC 20460. EPA-821-99-012. August 1999.
[2] Stormwater Manager's Resource Center (SMRC) Stormwater Management Fact Sheet: Porous Pavement. http://www.stormwatercenter.net/Assorted%20Fact%20Sheets/Tool6_Stormwater_Practices/Infiltration%20Practice/Porous%20Pavement.htm
[3] Ramsey Washington Metro Watershed District: Technical Series on District Office Demonstration Features: Porous Asphalt Parking Lot (2006)
[4] Lake Superior Duluth Streams.org: Pervious Pavement. http://www.lakesuperiorstreams.org/stormwater/toolkit/paving.html
[5] Charles River Watershed Association: Low Impact Best Management Practice (BMP) Information Sheet. http://www.crwa.org/projects/bmpfactsheets/crwa_permeable_pavement.pdf (2008)

BMP	Unit Cost per square foot	O&M Costs	Volumetric Cost for Treatment ($/cf)	Other Benefits
Green Roofs	$10 - $15[6] Note: Although green roofs initially cost more than conventional roofs, they are competitive on a life-cycle basis because of reduced maintenance and replacement costs.	0.2% of the initial cost of roof[7]		• Extended roof life span • Energy savings • Property values • Urban heat island effect • Acoustic insulation • Absorb CO_2 • Provide urban wildlife habitat • Quality of life benefits
Routing BMPs				
NA				
Surface Treatment BMPs				
Bioretention Devices / Rain Gardens	$10-$14/sf[8]	$1/sf/year[8] Vegetation maintenance, remove sediment and trash, replace mulch.	$9-$11/cf based on typical depths	• Urban wildlife habitat • Aesthetics • Urban heat island mitigation • Carbon sequestration • Air quality
Tree Trenches	$16-$40/sf based on typical depths and Blair-Griggs bid.	$500/year[9] Maintenance activities include inspection, litter and minor debris removal, drain back-wash, sweep vault inlet, upfilling mulch and growth media.	$16/cf[10]	• Improved boulevard tree health • Aesthetics (streetscape) • Property values • Urban heat island mitigation • Carbon sequestration • Air quality
Subsurface Treatment BMPs				
Below-ground Recharge Systems	NA	Sediment and debris removal, backflushing. Cost is low if city uses own vacuum truck to remove sediment.	$4-$8/cf Lower range based on 12,000 cf unit in Burnsville.[11] Upper range based on City of St. Paul Estimate10	• Reduces temperature

[6] U.S. Green Building Council: Cascadia Chapter. Fact Sheet: Green Roofs. Source of cost comparison information: Bureau of Environmental Services estimates based on City of Portland demonstration projects, and information obtained from roof contractors.

[7] Toronto and Region Conservation. 2008. An Economic Analysis of Green Roofs: Evaluating the costs and savings to building owners in Toronto and surrounding regions.

[8] Engineers estimate of project cost for the Comfort Lake-Forest Lake Watershed District Sunrise River Water Quality Flowage Project - 2011

[9] EPA Low Impact Development. (2005). Quality Assurance for Nonpoint Source Best Management Practices: Tree vault Filters.

[10] City of St. Paul Bid for Blair-Griggs Residential Improvements (2011)

[11] City of Burnsville Park Place Stormwater Improvements bid tabulation (2012)

BMP	Unit Cost per square foot	O&M Costs	Volumetric Cost for Treatment ($/cf)	Other Benefits
Reuse BMPs				
Rainwater Harvesting	NA	$2,500/year[12]	$16.83-$29.92/cf[13]	• Reduce potable water use

7.3.2 Stacked Functions

An important consideration for the development and design community to consider when developing stormwater management plans to meet the volume control standard is the stacked function of these BMPs in the urban landscape. While green infrastructure consists of site-specific management practices designed to maintain natural hydrologic functions by absorbing and infiltrating precipitation where it falls, it is important to recognize that these BMPs can serve multiple purposes. For example, pervious pavement systems provide the following stacked functions: (1) serve as primary pavement for parking areas or low-traffic roadways (e.g. alleys); (2) reduce stormwater runoff; (3) improve aesthetic of the development and increase marketing advantage; and (4) reduce ice build-up and winter safety concerns. Locating BMPs in the roadway/right-of-way retains the amount of developable land (and open space) within the community. In terms of cost estimating, the multiple benefits of these BMPs can also be a complicating factor. Where does one allocate costs when a BMP accomplishes multiple objectives? In some cases, stormwater BMP costs may be overstated given the multiple things they add to a site.

Figure 21 illustrates relative costs of the BMPs used in the development of the stormwater management plans for the R2 and TOD scenarios and highlights those BMPs that do not necessarily require dedicated land (see the BMPs underneath the bar). In reality the costs can vary widely, in part due to the physical site conditions (e.g. less permeable soils requiring shallower and larger BMPs) and due to design variations (e.g. permeable asphalt versus permeable pavers). It should be noted that the information presented in **Figure 21** represents total costs. This figure does not attempt to account for the fact that some BMPs off-set otherwise necessary costs such as porous pavement systems replacing a conventional pavement systems or green roofs replacing traditional roof systems. Nor does the information presented in **Figure 21** account for other savings on a site or regionally such as reduced infrastructure costs (e.g. reductions in stormsewer pipe or detention ponds).

[12] Eckles, Klayton City of Woodbury: A Public Works Perspective on the Cost vs. Benefit of Various Stormwater Management Practices (2008)
[13] WERF Final Report BMP and LID Whole Life Cost Models (2009)

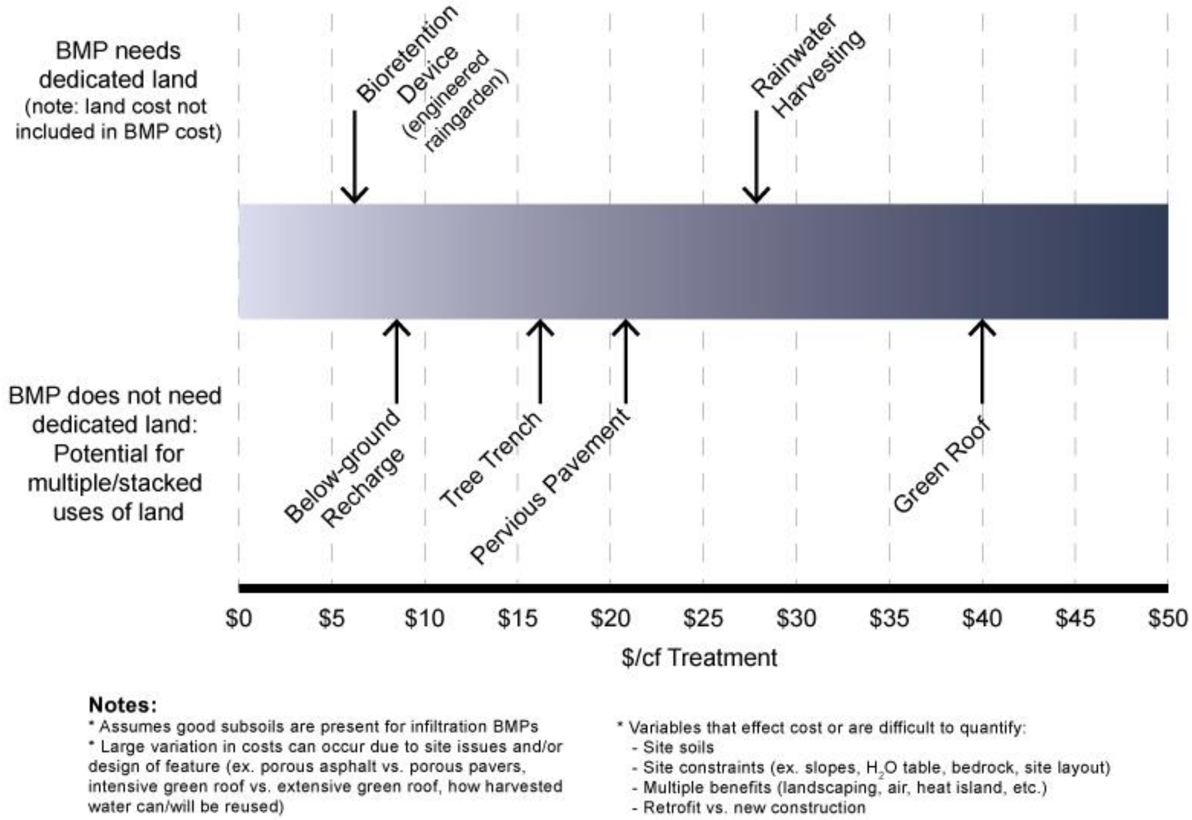

Figure 21. General Comparative Costs of Various Volume Control BMPs

7.3.3 Stormwater BMP Cost Effectiveness Tools

In an effort to help the stormwater planning and management community select BMPs that will be effective and economically sustainable, a number of entities have begun developing tools which can be used to assess stormwater BMP cost effectiveness. Currently these tools are in their infancy. While there are a few tools available that facilitate this type of analysis, there are varying levels of limitations with each that must be understood by the user. The US EPA is currently conducting a study to evaluate these modeling and optimization tools in the Midwest which should provide guidance to users in the near future. In the meantime, this section identifies a few tools available today for the City and its design and development community to consider as they develop stormwater management plans to address the CARPC requirement.

- **BMP and LID Whole Life Cost Models: Version 2.0**
  Water Environment Research Foundation (WERF)
  http://www.werf.org/i/a/Ka/Search/ResearchProfile.aspx?ReportId=SW2R08

  A set of spreadsheet tools help users identify and combine capital costs and ongoing maintenance expenditures in order to estimate whole life costs for stormwater management. The models provide a framework for calculating capital and long-term maintenance costs of individual best management practices and low impact development techniques. Models are included for: retention ponds, extended detention basins, swales, permeable pavement, green roofs, large commercial cisterns, residential rain gardens, curb-contained bioretention, and in-curb planter vaults. Published by WERF. 32 pages. Online PDF of user's guide and spreadsheet tools. (2009)

- **Green Values National Stormwater Management Calculator**
  Center for Neighborhood Technology (CNT)

http://greenvalues.cnt.org/national/calculator.php

The National Green Values™ Calculator is an on-line tool for quickly comparing the performance, costs, and benefits of Green Infrastructure, or Low Impact Development (LID), to conventional stormwater practices. The GVC is designed to take you step-by-step through a process of determining the average precipitation at your site, choosing a stormwater runoff volume reduction goal, defining the impervious areas of your site under a conventional development scheme, and then choosing from a range of Green Infrastructure Best Management Practices (BMPs) to find the combination that meets the necessary runoff volume reduction goal in a cost-effective way.

- **BMP-REALCOST Model: Rational Estimation of Approximate Likely Costs of Stormwater Treatment**
  Developed at Colorado State University
  http://udfcd.org/downloads/software/BMP-REALCOST_v1.0.zip

  A spreadsheet tool for evaluating BMP effectiveness and life cycle costs. *BMP-REALCOST* was developed to assist engineers, planners, developers, consultants and decision makers in determining the life cycle costs and effectiveness of structural stormwater runoff best management practices (BMP) as they are applied within an urban/suburban setting.

  This model is built into Microsoft Excel format and many of the operations are performed using macros written in Visual Basic for Applications. The model operates by first having the user input information describing the physical characteristics of a watershed that affect runoff quality and quantity (e.g., contributing area, land use, imperviousness, etc.). Second, the user enters information that describes what type(s) of BMP(s) will be applied to the watershed/development and the area (number of impervious acres) from which each BMP will receive runoff. Next the user decides whether to use default cost and BMP effectiveness values, or input their own. The model then takes the user-entered (or default) information and estimates the size of each BMP, determines the number of BMP(s) needed to treat the watershed, produces estimates of average annual runoff quality and quantity for the entire watershed/development, and calculates life cycle costs for the BMP(s) selected.

- **SUSTAIN**
  US Environmental Protection Agency
  http://www.epa.gov/nrmrl/wswrd/wq/models/sustain/

  SUSTAIN is a decision support system to facilitate selection and placement of Best Management Practices (BMPs) and Low Impact Development (LID) techniques at strategic locations in urban watersheds. It was developed to assist stormwater management professionals in developing implementation plans for flow and pollution control to protect source waters and meet water quality goals. From an understanding of the needs of the user community, *SUSTAIN* was designed for use by watershed and stormwater practitioners to develop, evaluate, and select optimal BMP combinations at various watershed scales on the basis of cost and effectiveness. *SUSTAIN* is a tool for answering the following questions:

  - How effective are BMPs in reducing runoff and pollutant loadings?
  - What are the most cost-effective solutions for meeting water quality and quantity objectives?
  - Where, what type of, and how big should BMPs be?

- **L-THIA**
  Purdue University and U.S. Environmental Protection Agency
  https://engineering.purdue.edu/~lthia/

L-THIA/LID is an easy to use screening tool that evaluates the benefits of LID practices. The Long-Term Hydrologic Impact Assessment (L-THIA) model estimates the average annual runoff and pollutant loads for land use configurations based on more than 30 years of daily precipitation data, soils, and land use data for an area.

The L-THIA/LID model consists of two screening levels for the LID approach. **Basic** screening allows the users to adjust the percent of imperviousness for particular landuses. **Lot-level** screening consists of a suite of LID practices such as bio-retention (rain gardens), porous pavement, narrowing impervious surfaces (streets, sidewalks and driveways) and vegetated rooftops. These practices intercept, redirect, and slow the movement of runoff and pollutants moving through a watershed.

L-THIA/LID will generate estimated runoff volumes, depths, and expected nonpoint source pollution loadings to waterbodies, based on the information provided by the user. Results can be displayed in tables, bar graphs, and pie charts.

- **BMP Decision Support System (BMPDSS)**
  Prince George's County and US Environmental Protection Agency

  The BMPDSS is a decision-making tool for placing BMPs at strategic locations in urban watersheds on the basis of integrated data collection and hydrologic, hydraulic, and water quality modeling. The key questions that can be addressed by the analysis system are as follows:

  - What is the benefit of management?
  - What is the difference between management options/scenarios including one or more practices?
  - What is the cost? That is, what is the difference in cost versus the measures of benefit described in questions 1 and 2?

  The potential users of this system include local and county government planners; state, and federal regulatory reviewers; public concerned citizen/stakeholder groups; private industry; consultants; and academics.

8 DESIGN CHARRETTE

On Monday November 12, 2012 the City of Fitchburg conducted a design charrette for the Catalytic Project. The goal of the charrette was to bring together landowners, local developers, members of the design community, local government unit personnel and appointed/elected City officials to better understand CARPC's requirements for the McGaw Neighborhood Adjustment Area and to solicit feedback on the initial design for the proposed stormwater management plans. Additional goals for the charrette included:

- Meeting participants should come away with a good understanding of the volume control standard (and why the standard is important from a stormwater management perspective)
- Participants should understand which volume control Best Management Practices (BMPs) can be used to meet the standard (including differences between the various BMPs)
- Participants should understand how a stormwater management plan can be designed to demonstrate compliance with the volume control standard

The charrette was attended by a total of thirteen participants including local landowners, members of the design community, a CARPC representative, a City Council member and City Staff. The first half of the charrette was dedicated to talking about why stormwater matters and reviewing the information provided in the literature review of volume control BMPs. The second half of the charrette was spent reviewing the initial design for the proposed stormwater management plans and discussing the ability of these plans to meet the various stormwater management standards. During the second half of the Charrette meeting participants were asked to complete a survey which was designed to get a better understanding of the group's familiarity with volume control BMPs and identify preferences for certain BMPs over others.

8.1 Summary of Survey Results

A total of six surveys were completed during the Design Charrette. This section of the report summarizes the results of these surveys. See Appendix E for the individual surveys completed at the Charrette. Information collected in the surveys as well as the discussion that took place during the group review of the surveys was used to develop the final proposed stormwater management plan for the Catalytic Project.

1. **Which of the volume control Best Management Practices (BMPs) have you had experience using on new development or redevelopment projects? Do you have a preference for some of these BMPs over others?**

Volume Control BMP	Experience Using BMP			Preferred BMP
	Yes	No	Not Sure	
Soil Amendments/Decompaction	4	1		√√
Pervious Pavement Systems	3	1		√√
Downspout Disconnection	6			√√√
Green Roofs		2		√
Vegetated Swales	6			√√
Bioretention Devices/Raingardens	5			√√√
Tree Trenches	1	3		√√√
Infiltration Basins	5	1		√√
Below-ground Recharge Systems	1	3		√√√
Rainwater Harvesting	4	1		√√
Other				

2. **What ideas or elements of the draft design concepts are the most exciting to you?**

<u>General Comments</u>:

- BMP must be cost-effective and fit in the development layout

<u>Comments specific to Medium-Density Residential Development (R2)</u>:

- Raingardens are most suitable for the medium-density residential development
- Appreciate the use of pervious alleys
- Would like to see heavier use of bioretention terraces

<u>Comments specific to Transit-Oriented Development (TOD)</u>:

- Concerned about the potential for dependence on surface parking area for BMPs. Would like to be more confident that the volume control standard can be met in a development setting where buildings are four to six stories high and parking provided by a central parking structure.
- Below-ground recharge systems are most suitable for transit-oriented development

<u>Comments specific to Both Development Scenarios</u>:

- Tree trenches are suitable for both applications: medium-density residential development and transit-oriented development
- Ensure zoning codes allow for the application of more/all tools (BMPs)

3. **Is there anything you would change about the draft design concept?**

<u>General Comments</u>:

- Need to address stormwater swales as a BMP

<u>Comments specific to Medium-Density Residential Development (R2)</u>:

- Add intersection bump-outs with sidewalk ramps to calm traffic, fill remaining no-parking area by stop signs and bus stops with bioretention BMPs.
- Suggest the use of tree trenches all around the Hypothetical Block

Comments specific to Transit-Oriented Development (TOD):

- Additional information as applicable for costs: initial implementation; on-going maintenance; replacement (if necessary); training of maintenance personnel.

Comments specific to Both Development Scenarios:

- Explore the feasibility of locating all BMPs in the public right-of-way

4. **Are some of these volume control BMPs better suited for a particular application (land use) than others?**
   - Bioretention (Engineered Raingardens) are more suitable for all applications
   - Bioretention practices work better downstream of parking areas since they provide pretreatment
   - Tree trenches would work well in the right-of-way
   - Below-ground recharge systems would work under lawns/parking lots
   - The more expensive BMPs are more suitable for higher density applications where there is less space available for treatment
   - Rainwater harvesting is a BMP that should be avoided as it is difficult to determine how much credit to give for its use
   - Infiltration basins do not add to the aesthetics of the development site

5. **What multi-use functions can be combined with stormwater BMPs (e.g. Parking)?**
   - Parking, side-walks or green roofs can serve a dual purpose for development & stormwater management.
   - Green roofs
   - Pervious pavement
   - Bump-out calm traffic which improves walkability and health
   - Amenities that add design elements and aesthetics to the development
   - Pervious pavement is interesting by we need standards and perhaps more resilient materials to make this BMP work well

6. **What are the biggest obstacles to including stormwater BMPs on a project?**
   - Cost and maintenance: must fit within the development budget and on-going operating budget
   - Cost
   - Determining needs for pretreatment and designing pretreatment into the development scenario
   - Conservative thinking in public work departments with respect to terraces and alleys
   - Waterways not addressed. Most developments of any acreage require handling these (waterways). We need BMPs for these in addition to prairie and acreage.

Revisions to the stormwater management plan discussed and approved by participants at the design charrette were used to evaluate a revised (final) stormwater management plan for both the residential and transit-oriented development sites. The main recommendations from the group were to:

- Increase the usage of tree trenches along the streetscape in the public right-of-way making sure that trees do not block sightlines to signage on buildings.
- Add bump-outs for traffic calming at no parking areas and at intersections and incorporate raingardens within these bump-out areas.
- Increase the usage of raingardens along the perimeter of the development sites and incorporate them into the landscaping plan making sure not to block street access for pedestrian traffic.

9 BMP SELECTION: FINAL DESIGN

As the previous section describes, the City of Fitchburg held a design charrette to get feedback from landowners, local developers, members of the design community and appointed/elected City officials on the initial design for the proposed stormwater management plans. Information shared at the charrette was used to develop a second and final proposed stormwater management plan for each of the development scenarios. This final design has been developed in a more optimized fashion: where the initial stormwater management plan was developed to illustrate as many of the tools in the BMP toolbox as possible (for discussion purposes), the final design has been developed to just meet the standards using the preferred BMPs in the setting/application discussed at the charrette. The approach in both land uses was more focused on the street corridor and a more consistent green infrastructure streetscape.

9.1 Final BMP Selection for Residential Development (R2)

The main changes to the medium-density residential stormwater management plan (**Figure 22**) include:

- eliminated the pervious pavement system and the raingardens located interior to the development; and
- concentrated all stormwater management in tree trenches located along the street right-of-way and in bioretention facilities (engineered raingardens) located in one of the existing open space areas.

Table 17 summarizes the main differences between the initial stormwater management plan and the final stormwater management plan.
Table 18 contains a summary of the BMPs sizing and drainage area characteristics for each individual BMP in the final proposed stormwater management plan.

Table 17. Comparison of BMPs used on Initial Design and Final Design for Residential Development Scenario

*BMP Category	BMP Type	INITIAL DESIGN			FINAL DESIGN		
		# of BMPs	BMP Area [sq. ft.]	BMP Volume [cu. ft.]	# of BMPs	BMP Area [sq. ft.]	BMP Volume [cu. ft.]
Source Control/ Surface Treatment**	Pervious Pavement System	1	9,148	436	0	0	0
Surface Treatment	Bioretention Device (Engineered Raingardens)	7	1,788	3,128	1	1,437	2,012
	Tree Trench	1	470	493	6	1,740	2,784
TOTAL		9	11,406	4,057	7	3,177	4,796

Table 18. BMP Summary for the Final Medium-Density Residential Development (R2) Scenario

*BMP Category	BMP Type	BMP ID	BMP Area [sq. ft.]	Total Storage Depth [ft]	BMP Volume [cu. ft.]	Infiltration Rate [in/hr]	Drainage Area (ac)			
							Bldg.	Open Space	Parking/ Road	Total
Surface Treatment	Bioretention Device	R2-BD-1	1437	1.4	2,012	0.5	0.10	0.35	0.21	0.66
	Tree Trench	R2-TT-1	290	2.8	812	1.63	0.02	0.03	0.02	0.07
	Tree Trench	R2-TT-2	290	2.8	812	1.63	0.02	0.03	0.02	0.07
	Tree Trench	R2-TT-3	290	1	290	0.5	0.05	0.08	0.05	0.19
	Tree Trench	R2-TT-4	290	1	290	0.5	0.07	0.11	0.07	0.25
	Tree Trench	R2-TT-5	290	1	290	0.5	0.09	0.14	0.09	0.31
	Tree Trench	R2-TT-6	290	1	290	0.5	0.10	0.16	0.11	0.38

*Routing BMPs, Subsurface BMPs and Reuse BMPs not used in this development.

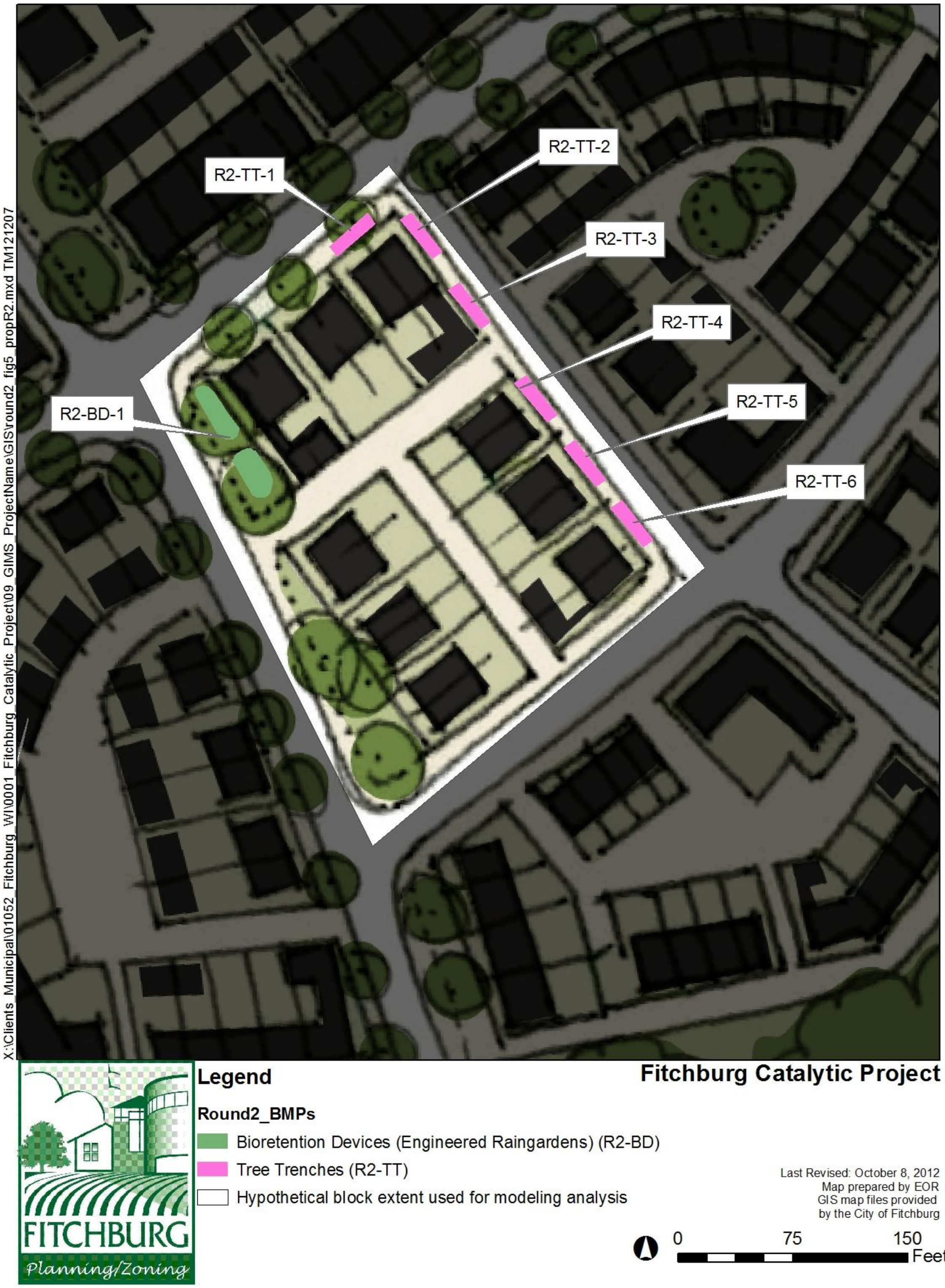

Figure 22. Stormwater Management Plan for R2 Development Scenario (Final Design)

9.2 Final BMP Selection for Transit Oriented Development (TOD)

The main changes to the Transit-Oriented Development (TOD) stormwater management plan **(Figure 23)** include:

- eliminated all of the pervious pavement systems, green roof, and rainwater harvesting from the plan; and
- concentrated the stormwater management in tree trenches located along the street right-of-way and increased the number of bioretention facilities (engineered raingardens) locating them in bump outs along the no-parking section of the streets.

Table 19 summarizes the main differences between the initial stormwater management plan and the final stormwater management plan. **Table 20** contains a summary of the BMPs sizing and drainage area characteristics for each individual BMP in the final proposed stormwater management plan.

Table 19. Comparison of BMPs used on Initial Design and Final Design for Transit-Oriented Development Scenario

*BMP Category	BMP Type	INITIAL DESIGN			FINAL DESIGN		
		# of BMPs	BMP Area [sq. ft.]	BMP Volume [cu. ft.]	# of BMPs	BMP Area [sq. ft.]	BMP Volume [cu. ft.]
Source Control/ Surface Treatment**	Green Roof	1	4,331	1,299	0	0	0
	Pervious Pavement System	2	2,561	4,944	0	0	0
Surface Treatment	Bioretention Device (Engineered Raingardens)	7	7,812	16,672	6	13,216	27,053
	Tree Trench	5	2,168	2,576	15	8,205	16,085
Subsurface Treatment	Below-Ground Recharge System	3	13,477	17,410	1	5,096	5,096
Reuse	Rainwater Harvesting	1	1,425	0	0	0	0
TOTAL		19	31,774	42,901	22	26,517	48,234

Table 20. BMP Summary for the Final Transit-Oriented Development (TOD) Scenario

BMP Category*	BMP Type	BMP ID	BMP Area (sf)	Total Storage Depth (ft)	BMP Volume (cf)	Infiltration Rate (in/hr)	Drainage Area (ac)			
							Building	Open Space	Parking/road	Total
Surface Treatment	Bioretention Device	TOD-BD-1	6,092	1.4	8529	0.5	0	0.28	0.71	0.98
	Bioretention Device	TOD-BD-2	3,130	2.6	8138	1.63	0.2	0.22	0.75	1.18
	Bioretention Device	TOD-BD-3	863	2.6	2244	1.63	0	0	0.14	0.14
	Bioretention Device	TOD-BD-4	863	2.6	2244	1.63	0	0	0.07	0.07
	Bioretention Device	TOD-BD-5	1,134	2.6	2949	1.63	0	0	0.08	0.08
	Bioretention Device	TOD-BD-6	1,134	2.6	2949	1.63	0	0	0.16	0.16
	Tree Trench	TOD-TT-1	547	2.8	1532	1.63	0	0	0.19	0.19
	Tree Trench	TOD-TT-2	547	1	547	0.5	0	0	0.19	0.19
	Tree Trench	TOD-TT-3	547	2.8	1532	1.63	0.34	0	0.38	0.72
	Tree Trench	TOD-TT-4	547	2.8	1532	1.63	0.34	0	0.38	0.72
	Tree Trench	TOD-TT-5	547	1	547	0.5	0.04	0	0.06	0.11
	Tree Trench	TOD-TT-6	547	1	547	0.5	0.06	0	0.10	0.16
	Tree Trench	TOD-TT-7	547	1	547	0.5	0.10	0	0.16	0.26
	Tree Trench	TOD-TT-8	547	1	547	0.5	0.12	0	0.19	0.32
	Tree Trench	TOD-TT-9	547	1	547	0.5	0.02	0	0.03	0.05
	Tree Trench	TOD-TT-10	547	1	547	0.5	0.06	0	0.10	0.16
	Tree Trench	TOD-TT-11	547	2.8	1532	1.63	0.04	0	0.09	0.14
	Tree Trench	TOD-TT-12	547	2.8	1532	1.63	0.07	0	0.13	0.20
	Tree Trench	TOD-TT-13	547	2.8	1532	1.63	0.11	0	0.21	0.34
	Tree Trench	TOD-TT-14	547	2.8	1532	1.63	0.13	0	0.26	0.41
	Tree Trench	TOD-TT-15	547	2.8	1532	1.63	0.09	0	0.24	0.33
Subsurface	Below-Ground Recharge System	TOD-UI-1	5,096	1	5096	0.5	1.32	0	1.68	3.00

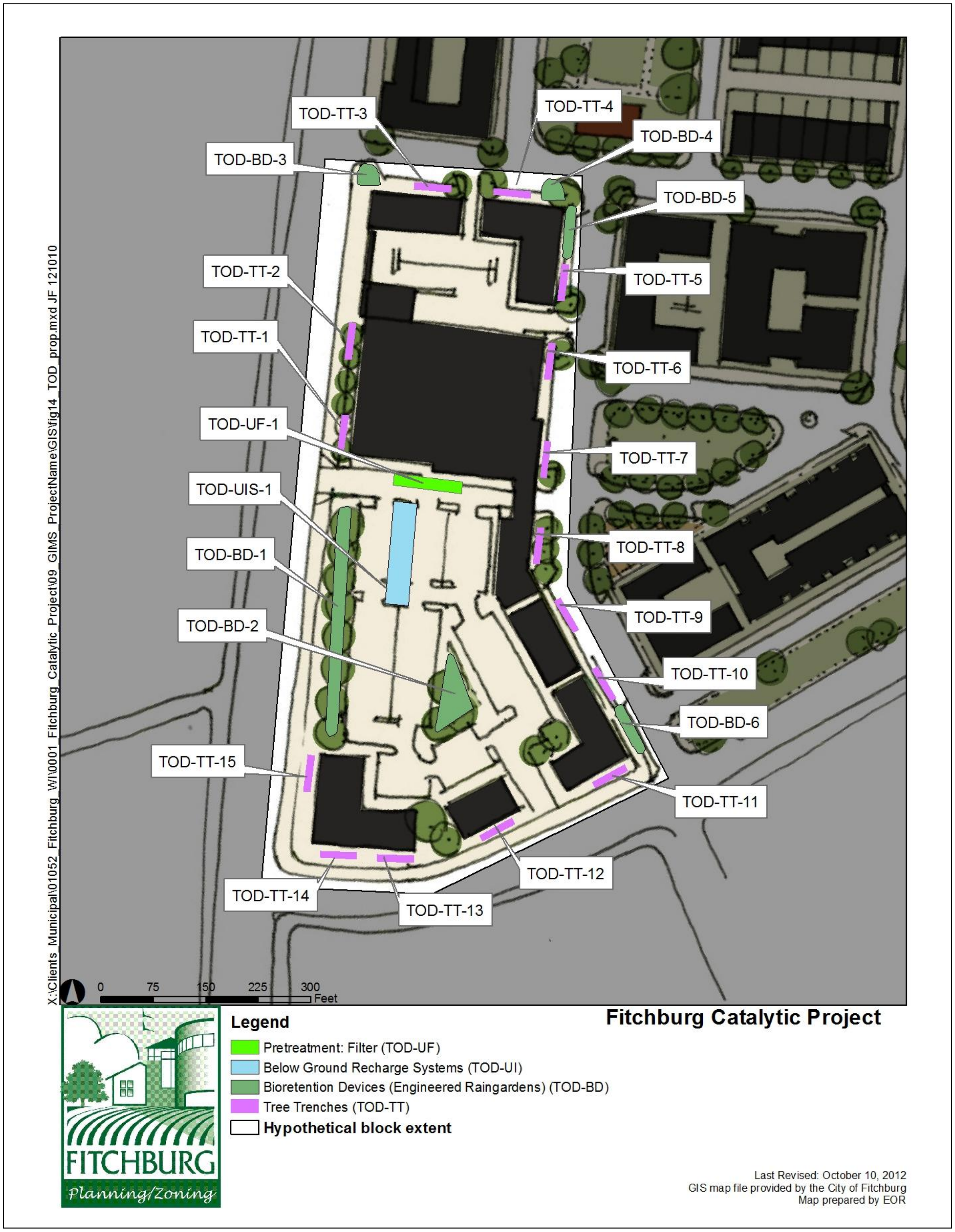

Figure 23. Stormwater Management Plan for TOD Development Scenario (Final Design)

10 RESULTS: FINAL DESIGN (DESIGN CHARRETTE INPUT)

10.1 R2 Results and Compliance with Standards

This section demonstrates how the final/"better optimized" stormwater management plan could meet the standards set by the City of Fitchburg, CARPC, Dane County and the Wisconsin Department of Natural Resources.

10.1.1 Evaluation of Land Dedicated to Stormwater Management

The final proposed stormwater management plan meets all of the requirements identified in the memorandum titled "Review of McGaw Neighborhood Plan and Local Regulations" dated February 13, 2012 (Appendix A). In general terms, the volume control BMPs selected for this final round of analysis take up approximately 4 percent of the developable space for this hypothetical block (compared to 6 percent consumed by the initial design).

Table 21 summarizes the total area of land dedicated to the stormwater management plan for the Medium-Density Residential Development Hypothetical Block Scenario. **Figure 24** illustrates the volume of treatment provided by each type of BMP used in the stormwater management plan. This information tells us that 55% of the area dedicated to stormwater management mitigates approximately 58% of the volume through the use of tree trenches while the remainder of the area (45%) mitigates the remaining 42% of the volume through the use of bioretention devices. This final plan concentrates all of the BMPs in areas dedicated to public use and/or infrastructure (e.g. roads/alleys and sidewalks) leaving most of the developable space available for future build-out of the site.

While the WDNR, Dane County and the City of Fitchburg have caps on the amount of area dedicated to volume control practices, CARPC does not have a cap for the McGaw Neighborhood Adjustment Area. Since the CARPC requirements are what future Permit Applicants will need to meet in the McGaw Neighborhood Adjustment Area there would be no cap on the extent of infiltration areas. However, it is worth noting that the final proposed stormwater management plan for the medium-density residential development meets the WDNR cap requirements for medium density residential development if the location of BMPs is taken into account. Only the bioretention devices are proposed to be located in the developable/usable portion of the site: the remaining BMPs, the tree trenches, are located in the street right-of-way.

Table 21. Summary of BMP areas proposed for the R2 development (Final Design)

BMP	BMP Area [sq. ft.]	% of BMP Area	% of Total Area*	% of Usable Area
Bioretention Device	1,437	45%	2%	2%
Tree Trench	1,740	55%	2%	--
Total	**3,177**	**100%**	**4%**	**2%**

* Total area for the R2 Development Hypothetical Block Scenario is 83,200 square-feet or 1.9 acres.

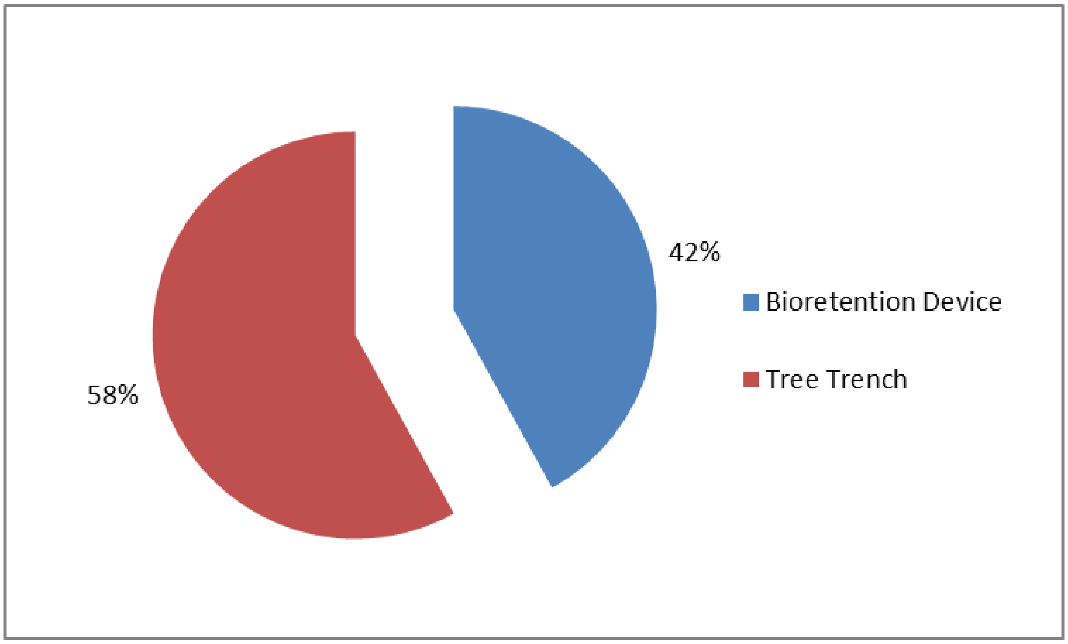

Figure 24. Summary of BMP Storage Volumes for the R2 development

10.1.2 Rate Control Standard

Section 1.c. of the CARPC standard requires that the 1, 2, 10 and 100-year 24-hour design storm be limited to pre-development conditions. **Table 23** summarizes the XP-SWMM results and shows no increase in peak discharge for any of the design storms.

Table 22. XP-SWMM modeled peak discharge rates from the R2 block (Final Design)

24-hour event	Peak Flow Rate (cfs)		
	pre-development	Post-development	Change
1 year (2.5")	0.5	0.0	-0.5
2 year (2.9")	0.8	0.4	-0.4
10 year (4.2")	2.0	1.6	-0.4
100 year (6.0")	4.0	3.6	-0.4

10.1.3 Volume Control Standard

Section 1.d. of the CARPC standard requires no increase in runoff volume from the 1-year or 5-year average runoff periods. **Table 23** summarizes the results of the P8 volume analysis and shows no increase in runoff volumes under either timeframe.

Table 23. P8 modeled runoff volumes from the R2 block (Final Design)

Time Frame	**P8 Model Runoff (acre-feet)**		
	pre-development	Post-development	Change
1-year (1981)	0.4	0.3	-0.1
5-year (1981-1984)	2.4	1	-1.4

10.1.4 Water Quality Standard

Section 1.b. of the CARPC standard and the WDNR require 80% TSS reduction based on the average annual rainfall as compared to no controls. **Table 24** summarizes the results of the P8 TSS analysis and shows this threshold is greatly surpassed by the stormwater management plan.

Table 24. P8 modeled TSS reduction from the R2 block (Final Design)

TSS leaving site (lb/year)		
No Controls	**With BMPs**	**Reduction (%)**
1,030	19	98%

10.1.5 Groundwater Recharge Standard

Section 1.e. of the CARPC standard requires that 9 to 10 inches of groundwater recharge be maintained from pre- to post-development conditions. Given the input received from the Wisconsin Department of Natural Resources during the review of the proposed initial design, based on the small, diffuse nature of the BMPs, a groundwater mounding analysis was not conducted for the final design.

10.2 TOD Results and Compliance with Standards

This section demonstrates how the final/"better optimized" stormwater management plan could meet the standards set by the City of Fitchburg, CARPC, Dane County and the Wisconsin Department of Natural Resources.

10.2.1 Evaluation of Land Dedicated to Stormwater Management

The final proposed stormwater management plan meets all of the requirements identified in the memorandum titled "Review of McGaw Neighborhood Plan and Local Regulations" dated February 13, 2012 (Appendix A). In general terms, the volume control BMPs selected for this first round of analysis take up approximately 6 percent of the developable space for this hypothetical block (compared to 7 percent consumed by the initial design).

Table 25 summarizes the total area of land dedicated to the stormwater management plan for the Transit-Oriented Development Hypothetical Block Scenario. **Figure 25** illustrates the volume of treatment provided by each type of BMP used in the stormwater management plan. This information tells us that 50% of the area dedicated to stormwater management mitigates approximately 56% of the volume through the use of bioretention, 31% of the area mitigates 33% if the volume through tree trenches and the remaining 19% of the area mitigates 11% of the volume through the use of below-ground recharge systems. This final plan also concentrates all of the BMPs underground or in areas dedicated to public use and/or infrastructure (e.g. roads/alleys and sidewalks) leaving most of the developable space available for future build-out of the site.

While the WDNR, Dane County and the City of Fitchburg have caps on the amount of area dedicated to volume control practices, CARPC does not have a cap for the McGaw Neighborhood Adjustment Area. Since the CARPC requirements are what future Permit Applicants will need to meet in the McGaw Neighborhood Adjustment Area there would be no cap on the extent of infiltration areas. However, it is worth noting that the final proposed stormwater management plan for the transit-oriented development meets the WDNR cap requirements if the location of BMPs is taken into account. While most of the BMPs are proposed to be located underground or in the street right-of-way, two of the bioretention devices (TOD-BD-1 and TOD-BD-2) are proposed to be located in the developable/usable portion of the site. These two BMPs consume a little less than 2 percent of the total site.

Table 25. Summary of BMP areas proposed for the TOD development (Final Design)

BMP	BMP Total Areas [sf]	% of BMP Area	% of Total Area*	% of Usable Area
Bioretention Device	13,212	50%	3%	2%
Tree Trench	8,205	31%	2%	--
Below-Ground Recharge System	5,096	19%	1%	--
Total	**26,513**	**100%**	**6%**	**2%**

* Total area for the TOD Development Hypothetical Block Scenario is 428,195 square-feet or 9.8 acres.

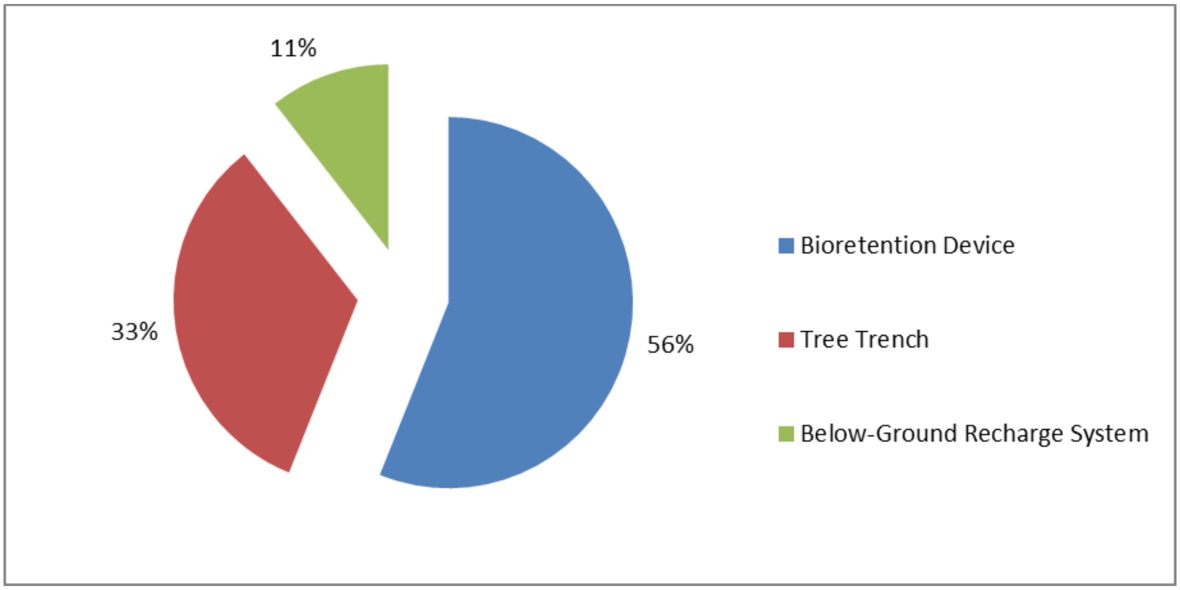

Figure 25. Summary of BMP Storage Volumes for the TOD Development

10.2.2 Rate Control Standard

Section 1.c. of the CARPC standard requires that the 1, 2, 10 and 100-year 24-hour design storm be limited to pre-development conditions. **Table 26** summarizes the XP-SWMM results and shows no increase in peak discharge for any of the design storms.

Table 26. XP-SWMM modeled peak discharge rates from the TOD block (Final Design)

24-hour event	Peak Flow Rate (cfs)		
	Pre-development	Post-development	Change
1 year (2.5”)	2.8	1.8	-1.0
2 year (2.9”)	4.1	2.9	-1.2
10 year (4.2”)	9.7	7.9	-1.8
100 year (6.0”)	19.2	18.0	-1.2

10.2.3 Volume Control Standard

Section 1.d. of the CARPC standard requires no increase in runoff volume from the 1-year or 5-year average annual runoff periods. **Table 27** summarizes the results of the P8 volume analysis and shows no increase in runoff volumes under either timeframe.

Table 27. P8 modeled annual runoff volumes from the TOD block (Final Design)

P8 Model Runoff (acre-feet)			
Time Frame	Pre-development	Post-development	Change
1-year (1981)	3.3	3.2	-0.1
5-year (1981-1984)	20.8	13.2	-7.6

10.2.4 Water Quality Standard

The WDNR require 80% TSS reduction based on the average annual rainfall as compared to no controls. **Table 28** summarizes the results of the P8 TSS analysis and shows this threshold is greatly surpassed by the stormwater management plan.

Table 28. P8 modeled TSS reduction from the TOD block (Final Design)

P8 Model TSS leaving site (lbs/year)		
No Controls	With BMPs	Reduction (%)
9,346	354	96%

10.2.5 Groundwater Recharge Standard

Section 1.e. of the CARPC standard requires that 9 to 10 inches of groundwater recharge be maintained. Given the input received from the Wisconsin Department of Natural Resources during the review of the proposed initial design, based on the small, diffuse nature of the BMPs, a groundwater mounding analysis was not conducted for the final design.

11 STORMWATER ANALYSIS GUIDELINES AND TEMPLATES

To facilitate future compliance with the CARPC volume control standard in the McGaw Neighborhood Area, a number of documents will be made available for the development and design community to use. These documents are provided in the appendices of this report:

A document describing the principles and techniques of **Better Site Design** (BSD) as well as a **worksheet** that can be used to facilitate the incorporation of BSD techniques early in the plan development process are provided in Appendices F and G of this report.

Mini Guides for each of the BMPs discussed in the document *Update on the Science of Volume Control BMPs: A Literature Review for the McGaw Catalytic Project* are provided in Appendix B of this report. While the sources for these Mini Guides vary, they basically contain the following useful information:

- General Description
- Associated Benefits
- Design Guidance
- Siting and Layout Considerations
- General Specifications
- Construction Considerations
- Operation and Maintenance Considerations
- Typical Costs
- Common Concerns

More detailed **BMP Cost Estimate Worksheets**, **Construction Inspection Checklists** and **Operation & Maintenance Checklists** are provided for the following BMPs in Appendices H, I and J:

- Bioretention Devices
- Infiltration Basins

While the Wisconsin Department of Natural Resources provides comprehensive guidance on the evaluation and selection of design infiltration rates, the City may want to consider providing supplemental guidance in this area. Interpretation of soil borings and additional data (grain size analysis) is often necessary to ensure an achievable infiltration rate is used in the design of volume control BMPs. Grain size analysis, either alone or in conjunction with a hydrometer analysis should be used to verify the ASTM classification of the soil material controlling the rate of infiltration (the least permeable within 5 feet of the bottom of the proposed practice) at each proposed practice. **Table 29** summarizes the soil lab analysis and identifies when each should be used.

Table 29. Soil Analysis – Lab Tests

Lab Test	Description	Use it When
Grain Size Analysis	Provides a distribution of particle size greater than 75μm (sand size which correlates to the number 200 sieve)	Always
Hydrometer Analysis	Provides a distribution of particle size less than 75μm (silt- and clay-sized particles)	Sample has greater than 10% fines as identified in the field or by lab test AND all soils classified as silty sand or SM

A typical issue encountered is the classification of soil material as silty sand, or SM. The ASTM definition of a SM soil is sand with fines and fines classified as silt. In order to determine if a soil is a true SM, a grain size analysis and hydrometer analysis is needed to identify the % of fines and whether the fines within the sample are silt or clay sized particles. For soils that are field identified as SM, or silty sand, a hydrometer analysis should be required for approval of an infiltration rate higher than 0.2 inches per hour. A combined grain size and hydrometer analysis cost is approximately $145 per sample.

Table 30 contains hydrometer analysis results and recommended design infiltration rates based on percent and classification of fines, assuming an initial classification of silty sand or SM in the soil boring logs.

Table 30. Hydrometer Analysis and Recommended Design Infiltration Rates

% Fines	Fines Identified as Silt or Clay	ASTM Classification	Recommended Design Infiltration Rate [in/hr]
5 - 12	Silt	SP – SM	0.7
12 - 25	Silt	SM	0.6
> 25	Silt with <5% Clay	SM	0.3
5 - 12	Clay	SP – SC	0.2
>12	Clay	SC	< 0.2*
>12	Silty Clay[1]	SC – SM	< 0.2*

[1] *Per ASTM Classification*

** If more than 50% of the sample passes the No. 200 sieve (sand sized), then the sample will be classified as fine grained and a design infiltration rate of <0.2 in/hr should be used, depending on soil material, or other BMPs should be considered per the sequencing of rule C.5(e).*

As the application of volume control BMPs in the City increases, City Staff may want to consider the development of a Program Evaluation Tool that can be used to effectively convey BMP performance and the operation and maintenance needs of a BMP at a particular point in time. Appendix K contains an example of a report template found to be very effective by the Rice Creek Watershed District, a special government unit in Minnesota established to protect the surface water and groundwater resources of the state.

12 CONCLUSIONS

12.1 Conclusions

The modeling analysis conducted for the Fitchburg Catalytic Project illustrates that medium to high density development in the McGaw Neighborhood Area can meet the Capital Area Regional Planning Commissions (CARPC) stormwater management standards for the area. This was demonstrated on both a medium-density residential development hypothetical block as well as a Transit-Oriented Development hypothetical block. The standards were met using a number of volume control Best Management Practices (BMPs) to demonstrate the application of a distributed approach to stormwater management using a range of BMPs. In both cases, there was room to either reconfigure the stormwater management plan or room for additional treatment on the site.

One of the components of the project was to solicit feedback on the proposed stormwater management plan (initial design) from landowners, local developers, members of the design community, local government unit personnel and appointed/elected City officials. This was accomplished during a design charrette which was held on Monday November 12, 2012. During the course of this charrette, meeting participants expressed their preferences for certain BMPs over others and the desire to focus stormwater management in the street corridor by developing a more uniform green infrastructure streetscape.

The main recommendations of the group were to:

- Increase the usage of tree trenches along the streetscape in the public right-of-way making sure that trees do not block sightlines to signage on the buildings.
- Add/use bump-outs for traffic calming at no parking areas and at intersections and incorporate raingardens within these bump-out areas.
- Increase the usage of raingardens along the perimeter of the development site and incorporate them into the landscaping plan making sure not to block street access for pedestrian traffic.

Following the design of the proposed stormwater management plans (initial and final) for the medium density residential development and the transit-oriented development, one can provide guidance on the design process and model selection for future development efforts in the McGaw Neighborhood Area. This guidance is provided in **Figure 26**.

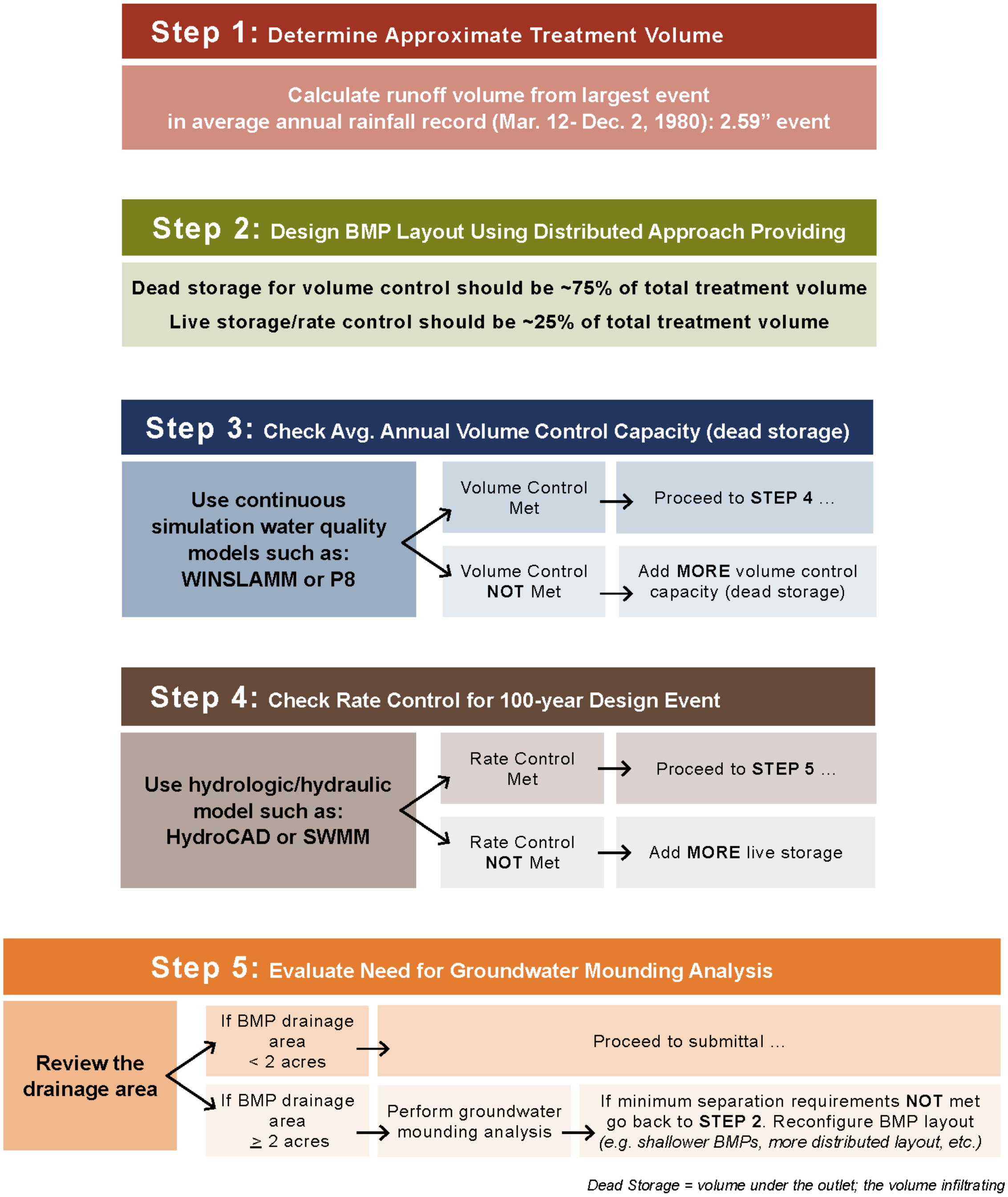

Figure 26. Design Process & Model Selection to Meet CARPC Standards

12.2 Recommendations

Over the course of this analysis, a number of items came up that warrant further consideration by the City of Fitchburg as well as the CARPC. This section of the report articulates these items, or next steps that the City may want to consider moving forward with in preparation for future development in the McGaw Neighborhood Area. Items that were raised during the design charrette are highlighted.

12.2.1 Site Investigation Needs

- **Soils Investigation** - The proposed BMP designs were based on geologic and hydrogeologic data from soil pits located a considerable distance from the BMP location. Considerable variation in hydrogeologic parameters is typical of glacial terrains and should be expected across the site. The presence of low-permeability layers that could restrict infiltration and even create a mound of perched water below a BMP must be investigated at each BMP site. Each BMP site should have a soil boring completed to at least 15 feet below the bottom of the BMP and a grain size analysis of each soil layer as there was some evidence of potential perched situations in some of the soil borings conducted on site.

- **Grain Size Analysis/Groundwater Mounding Analysis** - If the grain size analysis indicates soil layers that will likely have a lower saturated hydraulic conductivity than the sandy loam in the soil survey (1.3 in/hr), then the mounding analysis should be reconsidered. Hydraulic conductivity should be measured using laboratory permeameter or appropriate field test. The mounding analysis described above should be performed for this perched situation to determine if the appropriate separation will be maintained below the bottom of the BMP and the water table.

  Given the predicted magnitude of the groundwater mounds below the BMP's (<12 ft) it is very likely that potential problems due to groundwater mounding could be remedied with changes to the BMP design such as soil amendments.

12.2.2 Additional Hydrologic Analysis: Area-Wide Modeling Efforts

- **Regional Treatment** - Identify the most suitable areas for regional treatment (e.g. based on soil types, surrounding land-use under proposed conditions, etc.) so the City can evaluate options for securing property in the McGaw Neighborhood Area. This will create flexibility for developers and create plaza/open space area (multi-functional) community nodes.

- **Landlocked Basins** – Landlocked basins are basins or localized depressions that do not have a natural outlet at or below the water elevation of the 10-day precipitation event with a 100-year return frequency (typically). These basins play a role in stormwater management by either retaining more stormwater runoff than pre-development calculations may predict or by creating downstream conditions that warrant higher standards upstream. In the event that the City conducts an area-wide or city-wide modeling analysis it should consider the impacts that landlocked basins will play in future build-out scenarios.

- **Wetland Impacts** – Future development scenarios should evaluate hydrologic impacts to wetlands (hydrograph matching) and identify opportunities to offset short-term alterations in wetland hydrology.

- **Climate Change** - Evaluate climate change impacts and assess the need to develop adaptation strategies related to stormwater management: checking design standards and models to see how the system would respond to increases in rainfall.

12.2.3 Additional Cost-Benefit Analysis

- **Cost-Benefit Analysis** - In order to conduct a true cost-benefit analysis a comparison of a conventional development plan for a Hypothetical Block to a Low Impact Development (LID) or Better Site Design (BSD) should be made. This could include an evaluation of the incremental cost savings of including BMPs that replace conventional site features or infrastructure.

- **BMP Cost Effectiveness** - Consider applying the stormwater BMP cost effectiveness tools (described in Section 7.3.3) to the hypothetical blocks. This will allow the City to evaluate more stormwater management scenarios for each site and may serve as a tool for developers/designers to use as they evaluate options for meeting CARPC requirements for the area.

- **Explore Range of Scenarios** - The analysis conducted for the catalytic project may have limitations in its applicability to other parts of the City where there are less permeable soils. In areas where there are less permeable soils or shallow depth to groundwater or bedrock the stormwater management plan may have to rely on tools that are on the more expensive range of BMPs. It is recommended that this analysis be conducted on a range of soil types to compare the relative costs of developing stormwater management plans to meet the CARPC standard for all potential site conditions. Based on this analysis, the City and CARPC may need to consider the development of an alternative compliance process for development or redevelopment on less permeable soils.

12.2.4 Guidance Tools/Documents

- **Evapotranspiration** – Evapotranspiration (ET) is the sum of evaporation and plant transpiration from the Earth's land surface to the atmosphere. When Low Impact Development techniques are applied in the landscape, there is a reduction in stormwater runoff due to evapotranspiration: certain practices such as green roofs, rain gardens, native landscaping have higher ET than others. The City should consider the development of a credit calculator for green/evapotranspiration BMPs.

- **Source Control and Routing BMPs Guidance** – Develop source control guidance so that future Permit Applicants understand how to get credit for practices such as vegetated swales, filter strips and downspout disconnection.

- **Green Infrastructure Streetscape Standard Plates** - Develop green infrastructure streetscape standard plates (unique to a variety of road classifications). Include example cross sections. Emphasize tree trenches, incorporating rain gardens and/or permeable pavement sections.

Appendix A:

Review of McGaw Neighborhood Plan and Local Regulations

651 Hale Avenue North Oakdale, Minnesota 55128 telephone: 651.770.8448 facsimile: 651.770.2552 www.eorinc.com

Date | February 13, 2012

To | City of Fitchburg

cc | Jason Schmidt, City of Fitchburg Resource/Project Planner

From | Camilla Correll

Regarding | Review of McGaw Neighborhood Plan and Local Regulations

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The objective of this memorandum is to summarize the key points of the McGaw Neighborhood Plan (2009) as well as review local regulations. Before EOR initiates the modeling and analysis portion of the project we want to be sure that we have a solid understanding of the volume control requirements, how these standards/design guidelines are applied (by the State, Dane County and the City of Fitchburg) and the physical characteristics/suitability of the McGaw Neighborhood area that may impact the application of volume control Best Management Practices (BMPs). As a result, this memorandum covers the following topics:

I. Review of McGaw Neighborhood Plan
   1. McGaw Neighborhood Plan Vision
   2. Rationale for Using Volume Control BMPs in McGaw Neighborhood Area
   3. Evaluation of Physical Characteristics Identified in McGaw Neighborhood Area
   4. Suitability for Stormwater Infiltration per McGaw Neighborhood Plan
   5. Conclusions

II. Review of Local Regulations

I. Review of McGaw Neighborhood Plan

1. McGaw Neighborhood Plan Vision

The vision for the 712-acre McGaw Neighborhood Plan is as follows: Develop an urban, green, sustainable, transit-oriented, mixed use, and economically vibrant neighborhood that offers a variety of land uses to serve everyday living needs, as well as a housing stock to serve all levels of age and income, which will not affect the existing on-site natural resources.

McGaw Park Neighborhood planning initiative provides land use, transportation, infrastructure and environmental guidelines for the extension of the urban service boundary. This Plan was developed as an amendment to the City's Comprehensive Plan. The planning process began with an understanding of the environmental resources: the goals and policies of the plan reflect a desire to preserve the existing natural resources and plan development around the most environmentally sensitive areas.

The McGaw Neighborhood Park seeks to become a benchmark example of a sustainable neighborhood, aiming to be a participant in the U.S. Green Building Council's LEED-Neighborhood Development (LEED-ND) program. The LEED-ND Rating System integrates principles of "green", mixed-use, transit-oriented development by utilizing a point system.

Seeking LEED-ND for the McGaw park Neighborhood was a priority of the City and the McGaw Neighborhood Steering Committee. The Plan is not being driven by seeing LEED-ND status; rather the established goals and objectives of the Plan lend itself to seeking certification under LEED-ND.

2. Rationale for using Volume Control BMPs in McGaw Neighborhood Area

In reviewing the McGaw Neighborhood Plan it is evident that there are a number of drivers for using volume control in the McGaw Neighborhood Area aside from meeting local regulations. It is important to have a good understanding of all the drivers so that the proposed stormwater management plans can take these factors into consideration. The main drivers identified in the McGaw Neighborhood Plan include:

- The vision statement developed by the residents of the City of Fitchburg include: "Integration of development with nature" and "Green technology and infrastructure" (page 2-11). This infers that residents would like to see future development incorporate open space and environmentally sensitive areas but it could extend beyond this to include green infrastructure (including volume control BMPs) creating a more uniform look throughout the development.
- The McGaw Neighborhood Park is seeking LEED for Neighborhood Development (LEED-ND) and likely will pursue credits for activities such as water efficiency, reduced irrigation, and water reuse. These activities will all play a part in a comprehensive stormwater management plan for proposed development in the area.
- The ordinance compliance model results summarize the total area required for stormwater management features. These results suggest that it will be necessary to reduce the effective impervious area in some of the subwatershed (e.g. "McGaw_NWI") via the use of green roofs, pervious pavement systems, or other low impact development approaches. Again, these types of practices will be evaluated in the development of a comprehensive stormwater management plan for proposed development in the area: the overall goal being to reduce the amount of stormwater runoff generated under any development scenario to facilitate meeting the volume control standards as well as meeting other objectives for the neighborhood.
- The headwaters of Swan Creek, a groundwater-fed resource, are located within the McGaw Neighborhood Area. Maintaining or enhancing recharge in the McGaw Park Neighborhood is important for baseflow in Swan Creek as well as other groundwater-dependent natural resources (e.g. groundwater-dependent wetlands identified in the area). It will also be important to evaluate the impact of stormwater discharges to these resources through development of the stormwater management plan.

3. Suitability for Stormwater Infiltration per McGaw Neighborhood Plan

One of the first design considerations when evaluating the use of volume control Best Management Practices (BMPs) is the underlying soils. This section of the memorandum summarizes the findings of the soils evaluation and infiltration rate analysis conducted for the McGaw Neighborhood area.

Soil Evaluation – A preliminary soil investigation was conducted throughout the study area within select locations (see Figure 1.2 of the McGaw Neighborhood Plan) by digging seven backhoe pits. The primary objective was to assess the range of soil types across the site in order to evaluate stormwater infiltration suitability. Soils in the study area generally consist of silt loam loess (26-31 inches for Pits 1, 2, 6 & 7 and 51-61 inches for Pits 3, 4 & 5) underlain by sandy loam parent material (to 9-10 feet) deposited by the Green Bay Lobe during the last part of the Wisconsin Glaciation. The soils that have formed from these glacial deposits are typically well-drained and fertile. Evidence of a seasonal high water table was found from 26-95 inches (Pit 6) and 45-61 inches (Pit 5). In the study area, these glacial sediments were deposited over sandstone bedrock, which is typically at relatively substantial depths across the site (greater than 10 feet). As a result, the soils across the site are highly suitable for natural infiltration of stormwater with some exceptions: wetlands and wetland margins and select areas of the site that contain shallow bedrock.

Infiltration Rates - Infiltration rates mapped by the NRCS range from 1 to 4 in/hr, with the lower rates more common in the western and southeastern portions of the Neighborhood. To be conservative, rates assumed in the ordinance model analysis (conducted for the McGaw Neighborhood Plan) were reduced significantly. Where a rate of 1.3 in/hr was listed in the soil survey, a rate of 0.5 in/hr was assumed, where a rate equaling 3 in/hr or more was listed in the soil survey, a rate of 1.63 in/hr was assumed. These values correspond with infiltration rates listed in the WDNR Conservation Practice Standard 1002 for sandy loam and loamy sand, respectively.

4. Evaluation of Physical Characteristics Identified in McGaw Neighborhood Area

The development of a successful and sustainable stormwater management plan should also take the physical characteristics of the site into consideration (e.g. existing topography, on-site and downstream natural resources, soils, depth to the water table, location of existing/proposed infrastructure, etc.). Physical characteristics can be opportunities for stormwater management or they can be constraints on the types of stormwater BMPs that can be used in a particular location. This section of the memorandum identifies those items that will not be a constraint to the development of stormwater management plans in the area as well as those items that need to be considered carefully when applying volume control BMPs in the area.

The following physical characteristics were determined not to be constraints to stormwater management planning as they were not located in the project area or are already being protected from future development:

- Rare species;
- Cultural resources; and
- Steep slopes (designated as Environmentally Sensitive Areas).

The following are physical characteristics/items that need to be considered in developing stormwater management plans as the area develops:

- **Wetland Impacts**. There are three wetlands located in the McGaw Neighborhood area. Two (W-1 and W-2) of the wetlands appear to be seasonally saturated or inundated; indicating that groundwater inflow to them could be significant during part of the year. Priorities for water management are to maintain groundwater supply to the wetlands and to minimize changes in runoff volume and frequency. The third wetland (W-3) appears to be permanently inundated due to surface runoff. Minimizing changes in runoff volume to this closed depression wetland will be a primary management objective.
- **Swan Creek**. The creek, with its relatively cool water characteristics, should be protected from the thermal impacts of stormwater inputs. Development of a stormwater management plan should also consider maintaining baseflow to the headwaters of this system as well as potential impacts of stormwater outfalls which concentrate flows.
- **Groundwater Resources**. According to the Nine Springs Inset Model (NSIM), local springs are primarily fed from the shallow sandstone aquifer, particularly highly permeable layers in the Tunnel City Formation. Historical loss of spring flow in the area appears to be primarily related to land use changes that have affected recharge of the shallow aquifer. While groundwater pumping has caused widespread lowering of groundwater levels throughout the

region this does not appear to be a significant factor in the City of Fitchburg which obtains drinking water from the deep sandstone aquifer below the Eau Claire Shale.

- **Flooding**. As the McGaw Neighborhood Plan states, "Stormwater infiltration and the potential to increase recharge rates has raised concerns about exacerbating groundwater driven flooding in some areas that are in close proximity to the McGaw Park Neighborhood Plan area, particularly in wet years, such as was the case in 2008".

A review of the physical characteristics for the two development scenarios (Transit-Oriented Development and Medium-Density Residential) was conducted to determine the specific physical characteristics that may need to be taken into consideration for the modeling analysis. To make the modeling analysis and hypothetical block schematics as "real" as possible, it is recommended that the City select a specific parcel (for each development scenario) from the Growth Model in which to place the hypothetical block so we can use the physical parameters at for these areas.

- **Transit-Oriented Development (TOD)**
- TOD 13 and 15
  - Surrounded by Wetland #2: a wet meadow and shrub-carr community with a farmed wetland component located in the north central portion of the study area along a railroad corridor. W-2 drains to the west via a culvert under the railroad tracks to an upland roadside ditch that does not connect to any waterway. W-2 is an isolated wetland. The main source of hydrology to the wetland is runoff from adjacent agricultural fields.
  - Soil boring/test pit #4 is located in this area (TOD 13). The soil log indicates that more permeable material (design infiltration rate of 1.63 in/hr) located 57-120 inches (4.75-10 feet) below grade. Review of the soil borings does not indicate whether or not there is evidence of a seasonally high water table in the soil profile (as evidenced by mottling or oxidation of the soils). Given the nature of the soils (well-drained) one can assume that the fact that this information was not provided in the well log means it was not encountered.

- TOD 12
  - Contains two drainage ways which ultimately discharge to Swan Creek. Swan Creek is designated as an Area of Special Natural Resource Interest by the WDNR. The WDNR considers Swan Creek to be a Warm Water Forage Fishery. However, both warm water fish and coldwater fish have been caught in Swan Creek: the groundwater-fed headwaters are cold, and the stream warms downstream as it approaches Lake Waubesa.
  - Soil boring/test pit #3 is located in this area. The soil log indicates that more permeable material (design infiltration rate of 1.63 in/hr) located 90-115 inches (7.5-9.5 feet) below grade. Review of the soil borings does not indicate whether or not there is evidence of a seasonally high water table in the soil profile (as evidenced by mottling or oxidation of the soils). Given the nature of the soils (well-drained) one can assume that the fact that this information was not provided in the well log means it was not encountered.

Design Implications: The presence of Wetland #2 means there is less developable land to work with this this area and there may be restrictions on the design and construction of stormwater BMPs located within the wetland buffer. There are varying depths to the more permeable soils: TOD 13 has the shallowest depth ranging from 4.75 – 10 feet while TOD 12 has depths ranging from 7.5-9.5 feet.

- **Medium-Density Residential (R2)**
- These areas are adjacent to a number of Environmentally Sensitive Areas.
- Some of these areas may drain to a non-navigable drainage way.

- There is one soil boring/pit (#7) location in R2 area. More permeable material (design infiltration rate of 1.63 to 3.60 in/hr) located 39-120 inches (3.25-10 feet) below grade. Review of the soil borings does not indicate whether or not there is evidence of a seasonally high water table in the soil profile (as evidenced by mottling or oxidation of the soils). Given the nature of the soils (well-drained) one can assume that the fact that this information was not provided in the well log means it was not encountered.

Design Implications: No major design implications for any of the areas designated for R2 development.

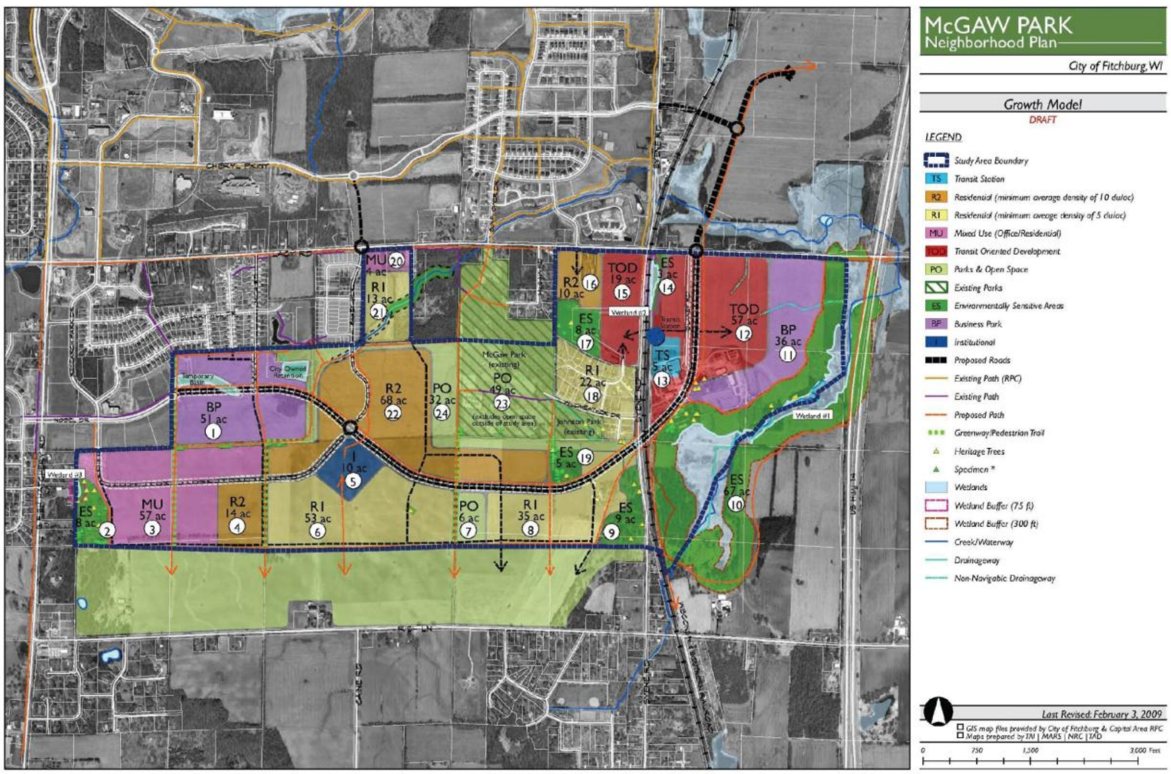

Figure 1.3: Growth Model

II. Review of Local Regulations

This section of the memorandum summarizes local stormwater management regulations. While it is clear what the Capital Area Regional Planning Commission (CARPC) requires for volume control in the McGaw Neighborhood area, it is important to note additional local requirements/recommendations that may impact the overall stormwater management plan for the site (e.g. pretreatment requirements, design requirements, etc.). This summary is provided in tabular format (see Table 1). Regulatory requirements are ranked from the most stringent requirement (1) to the least stringent requirement (3) for the following categories: Volume Control; Peak Flow Rate; Water Quality & Pretreatment, and Cap Requirements. The following local regulations were reviewed for this project:

- City of Fitchburg
- Capital Area Regional Planning Commission (CARPC) Resolution 2009-15
- Dane County - Chapter 14 - Manure Management, Erosion Control and Stormwater Management

- Wisconsin Department of Natural Resources (WDNR)
- McGaw Park Neighborhood-Specific Recommendations (MPNP)

Table 1. Summary of Stormwater Requirements/Recommendations for Fitchburg, CARPC, Dane County, WDNR and the McGaw Neighborhood Plan

	Volume Control	Peak Flow Rate	Water Quality & Pretreatment	Cap Requirements	Soil Restoration Requirements	Construction Requirements	Exclusions
Fitchburg	Residential development. Infiltrate sufficient volume so that post-development infiltration volume shall be at least 90 percent of the predevelopment infiltration volume, based upon average annual rainfall. Non-residential development. Infiltrate sufficient volume so that post-development infiltration volume shall be at least 60 percent of the predevelopment infiltration volume, based on average annual rainfall. ❸	Maintain peak discharge rates such that the post-development peak runoff rate does not exceed the pre-development peak runoff rate for the 2-year (2.9 inches), 10-year (4.2 inches) and 100-year (6.0 inches) 24-hour design storm events ❷	Treat the first 0.5 inches of runoff for oil and grease using the best removal technology available. Before infiltrating runoff, pretreatment shall be required for parking lot runoff and for runoff from new road construction in commercial, industrial and institutional areas that will enter an infiltration system. The pretreatment shall be designed to protect the infiltration system from clogging prior to scheduled maintenance and to protect groundwater quality. ❶	If the effective infiltration area reaches the State "cap" (1% for residential and 2% for nonresidential) prior to meeting the infiltration goal, then designers have the option of meeting either the infiltration goal or an alternative goal of meeting a recharge rate of 7.6 inches/year. ❷	Deep tilling or similar practices shall be implemented to restore soil structure to pre-development conditions.	The design of all best management practices designed to meet the requirements of this article shall comply with the following technical standards: (1) Natural Resources Conservation Service's "Wisc. Field Office Technical Guide, Chapter 4" or its successor; (2) Applicable construction or erosion control standards by the WDNR; and (3) The "Dane County Erosion Control and Stormwater Management Manual" or any other technical methodology approved by the Dane County Conservationist.	*Same exclusions as those contained in Chapter NR 151 (see WDNR content).*
CARPC	Control post development runoff volumes to be equal to or less than pre-development runoff volumes for the one-year average annual rainfall period as well as the five year average rainfall period as defined by WDNR. ❶	Control peak rates of runoff for the 1, 2, 10, and 100-year 24-hour design storm to "pre-development" levels (i.e. maximum Runoff Curve Number = 68 for hydrologic soil group B). ❶	Provide at least 80% sediment control for the amendment area in accordance with existing ordinances ❷	Maintain at least, the WGNHS pre-development groundwater recharge rates (currently identified as 9 to 10 inches per year for the amendment area) with no caps on the extent of infiltration areas. ❶	Provide deep tilling to restore all areas compacted during construction.	Install stormwater practices in each phase prior to other land disturbing activities in that phase, and protect these practices from compaction and sedimentation during land disturbing activities or restore them after land disturbing activities are completed.	None specified.
Dane County	For both residential and nonresidential developments, design practices to infiltrate sufficient runoff volume so that post-development infiltration volume shall be at least 90% of the pre-development infiltration volume, based upon average annual rainfall. ❷	Maintain predevelopment peak runoff rates for the 2-year, 24-hour storm event (2.9 inches over 24-hour duration). Maintain predevelopment peak runoff rates for the 10-year, 24-hour storm event (4.2 inches over 24-hour duration). Safely pass the 100-year 24-hour storm event (6.0 inches over 24-hour duration). ❷	For new development, design practices to retain soil particles greater than 5 microns on the site (80% reduction) resulting from a one-year 24-hour storm event (2.5 inches over 24-hour duration), according to approved procedures, and assuming no sediment resuspension. For all stormwater plans for commercial or industrial developments and all other uses where the potential for pollution by oil or grease, or both, exists, the first 0.5 inches of runoff will be treated using the best oil and grease removal technology available. Before infiltrating runoff, pre-treatment shall be required for parking lot runoff and for runoff from new road construction in commercial, industrial and institutional areas that will enter an infiltration system. The pre-treatment shall conform to the design standards in s. 14.53 and be designed to protect the infiltration system from clogging prior to scheduled maintenance and to protect groundwater quality. ❶	If, when designing appropriate infiltration systems, more than two percent (2%) of the site is required to be used as effective infiltration area, the applicant may alternately design infiltration systems and pervious surfaces to meet or exceed the annual pre-development recharge rate. The annual pre-development recharge rate shall be determined from the Wisconsin Geological and Natural History Survey's 2009 report, *Groundwater Recharge in Dane County, Estimated by a GIS-Based Water-Balanced Model* or subsequent updates to this report, or by a site specific analysis using other appropriate techniques. If this alternative design approach is taken, at least 2% of the site must be used for infiltration. ❷	None specified.	The design of all best management practices designed to meet the requirements of this article shall comply with the following technical standards: (1) Natural Resources Conservation Service's "Wisc. Field Office Technical Guide, Chapter 4" or its successor; (2) Applicable construction or erosion control standards by the WDNR; and (3) The "Dane County Erosion Control and Stormwater Management Manual" or any other technical methodology approved by the Dane County Conservationist.	*Same exclusions as those contained in Chapter NR 151 (see WDNR content).*

	Volume Control	Peak Flow Rate	Water Quality & Pretreatment	Cap Requirements	Soil Restoration Requirements	Construction Requirements	Exclusions
WDNR	For residential land use, infiltrate a sufficient volume of runoff such that the post-development annual stay-on volume is at least 90% of the pre-development stay-on volume, or infiltrate at least 25% of the 2-year, 24-hour storm. For commercial, industrial, or mixed land uses, infiltrate a sufficient volume of runoff such that the post-development annual infiltration (stay-on) volume is at least 60% of the pre-development annual stay-on volume, or infiltrate at least 10% of the 2-year, 24-hour storm. ❸	Maintain peak discharge rates such that the post-development peak runoff rate does not exceed the pre-development peak runoff rate for the 2-year, 24-hour design storm event. ❸	Reduce the Total Suspended Solids (TSS) load by 80% based on an average annual rainfall, as compared to no controls. Before infiltrating runoff, pretreatment shall be required for parking lot runoff and for runoff from new road construction in commercial, industrial and institutional areas that will enter an infiltration system. The pretreatment shall be designed to protect the infiltration system from clogging prior to scheduled maintenance and to protect groundwater quality in accordance with subd. 8. ❷	For residential land use no more than 1% of the project site (entire area) is required to be used as effective infiltration area. For commercial, industrial, or mixed land uses no more than 2% of the project site (impervious area only) is required to be used as effective infiltration area. ❸	None specified.	None specified.	Infiltration systems may not be installed in the following areas: a) Areas associated with tier 1 industrial facilities identified in NR 216.21(2)(a), Wis. Admin. Code, including storage, loading, rooftop and parking; b) Storage and loading areas of tier 2 industrial facilities identified in s. NR 216.21(2)(b), Wis. Admin. Code; c) Fueling and vehicle maintenance areas; d) Areas within 1,000 feet up gradient or within 100 feet down gradient of karst features; e) Areas with less than three feet separation distance from bottom of the infiltration system to the elevation of seasonal high groundwater or the top of bedrock, except that this provision does not prohibit infiltration of roof runoff; f) Areas with runoff from industrial, commercial and institutional parking lots and roads and residential arterial roads with less than five feet separation distance from the bottom of the infiltration system to the elevation of seasonal high groundwater or the top of bedrock; g) Areas within 400 feet of a community water system well as specified in s. NR 811.16(4), Wis. Admin. Code, for runoff infiltrated from commercial, industrial and institutional land uses or regional devices for residential development; h) Areas where contaminants of concern, as defined on s. NR 720.03(2), Wis. Admin. Code, are present in the soil through which infiltration will occur; i) Any area where the soil does not exhibit one of the following characteristics between the bottom of the infiltration system and the seasonal high groundwater and top of bedrock: at least a 5 foot soil layer with 10% fines or greater. This provision does not apply where the soil medium within the infiltration system provides an equivalent level of protection and does not prohibit infiltration or roof runoff.
MPNP	Development sites shall maintain a recharge rate of 7.6 inches/year under post-development conditions, and maintain a post-development annual stay-on volume of at least 90% of the pre-development stay-on (infiltration) volume. This criterion is based on the desire to maintain base flow discharge to streams and wetlands.	Post-development peak runoff rate does not exceed the pre-development peak runoff rate for the 2-year (2.9 inches), 10-year (4.2 inches) and 100-year (6.0 inches) 24-hour design storm events.	Total Suspended Solids (TSS) load shall be reduced by 80% based on an average annual rainfall, as compared to no controls, and the first 0.54 inches of runoff shall be treated for oil and grease using the best removal technology available.	The maximum size of effective infiltration areas where soil infiltration rate is less than 0.6 in/hr is 4% of the total development site.	None specified.	None specified.	The exclusions and exemptions defined in the State and County standards shall apply, except that no exemption from infiltration requirements for areas where the soil infiltration rate is less than 0.6 ins/hr will apply. This criteria is based on the recognition that water quality treatment and runoff volume reduction through evapotranspiration may be feasible with biofiltration systems even in areas of low-permeability soil.

Appendix B:

Update on the Science of Volume Control BMPs: A Literature Review for a Northern Climate

Update on the Science of Volume Control BMPs:

A Literature Review for the McGaw Catalytic Project

October 2012

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INTRODUCTION

Stormwater volume reduction

Issues related to urban stormwater runoff begin when impervious cover of any type is placed over natural landscapes. In a natural system, most precipitation that falls to the ground is evaporated, transpired, or recharged into the soil, with approximately 10% of rainfall converted to runoff. Roadways, roofs, sidewalks, and tightly compacted soils under grass lawns and parking lots increase the amount of runoff that leaves an area as it urbanizes. In a traditional urban system with large amounts of impervious areas, most precipitation is converted directly to runoff which reduces infiltration, increases flows to downstream systems, and degrades water quality. Therefore, there is a greater realization by scientists and stormwater managers that anything that can be done to retain water where it falls in the watershed will help to mitigate these impacts by maintaining the natural hydrology of the site.

Developing stormwater management plans with an emphasis on volume control and runoff reduction will go a long way toward maintaining the natural hydrology of a site under post-development conditions. A volume reduction best management practice (BMP) is any technique that:

- Allows stormwater runoff to be absorbed (or recharged) into the ground;
- Makes water available for evaporation and/or transpiration;
- Stores water for re-use; or otherwise
- Diverts stormwater away from the downstream drainage system.

This basic concept is the premise behind such common sense approaches as Sustainable Development, Better Site Design (BSD), Low Impact Development (LID) and "design with nature". While volume reduction of runoff is increasingly becoming an important goal of stormwater management, less is known about the performance, cost, and design of stormwater BMPs with a primary benefit of volume reduction compared to pollutant removal and peak flow reduction.

Objective of literature review

The objective of this literature review was to seek the most up-to-date information regarding the performance, cost, design, and suitability of BMPs with volume reduction benefits for the City of Fitchburg as well as the Capital Area Regional Planning Commission (CARPC). Since the focus on volume reduction as a key stormwater treatment approach is a relatively recent trend, the information related to volume reduction BMPs is an emerging and growing area of research. Given that an emphasis was placed on local sources of information, the findings presented in this literature review will be transferrable to other local units of government in the greater Madison Area.

The City of Fitchburg's objective for conducting this literature review stems from CARPC's volume control requirement for a portion of the McGaw Neighborhood Area. This literature review and the corresponding literature review matrix will be one of the tools developed by the City of Fitchburg to demonstrate how best the volume control standard can be met as the McGaw Neighborhood Area develops. As explained below, the literature review and corresponding matrix are intended to be used by City Staff, developers, engineers and designers as stormwater management plans are developed and reviewed for the McGaw Neighborhood Area.

Fates of infiltrated stormwater

Stormwater infiltration is a key mechanism for reducing stormwater runoff volume. From the groundwater management perspective, stormwater that reaches the water table or aquifer ("recharge") can be a key variable of interest. However, some infiltrated stormwater can be evaporated from soils or be transpired through plants. In this way, infiltrated water has many different fates within the hydrologic cycle (Figure 1). Surface water managers are often not as specific about the fate of the water that does not run off, so there can be some ambiguity in using the term "infiltration." To clarify the terminology in a hydrologic sense, precipitation that does not run off can have one of the following fates:

- Evaporation from wetted surfaces, soils, ponded water, and snowpack (sublimation),
- Transpiration through plants,
- Recharge of soil groundwater and aquifers.

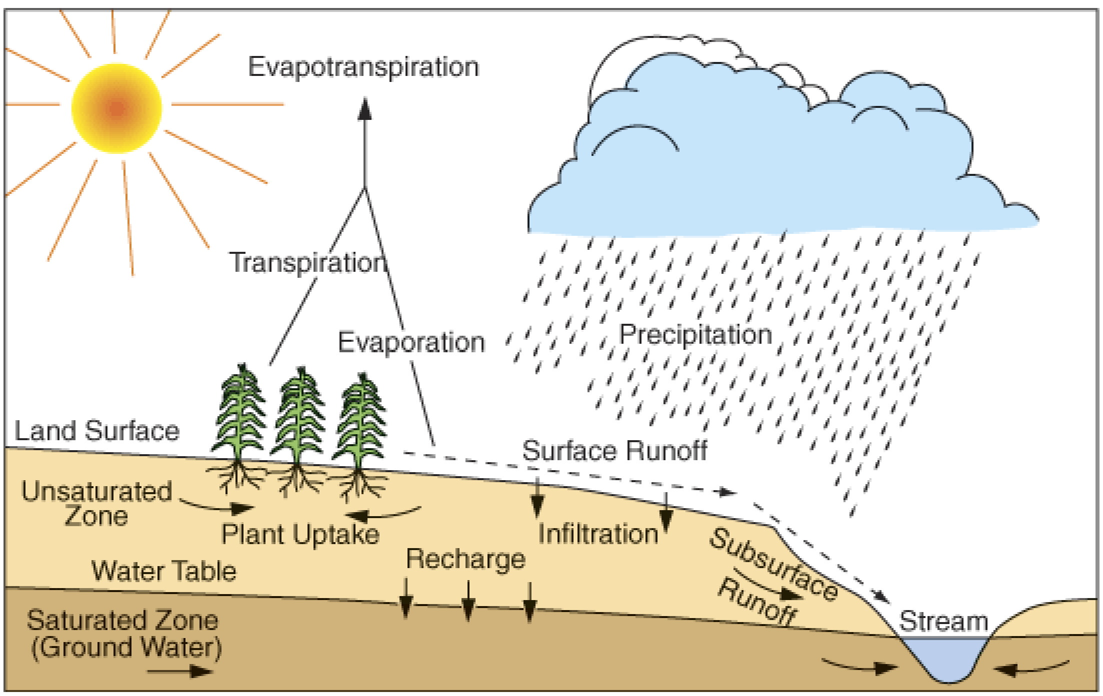

Figure 1. Fates of precipitation in the hydrologic cycle.
(Reproduced from the online Kansas Geological Survey, Public Information Circular (PIC) 22; <http://www.kgs.ku.edu/Publications/pic22/pic22_2.html>)

For many BMPs, stormwater runoff volume is reduced by a variety of the above mechanisms. As a result, we have grouped volume reduction BMPs by their type or location in the landscape:

1. **Source Control BMPs**: mimic natural conditions by catching precipitation or soaking rainfall into the ground close to where it falls
2. **Routing BMPs**: intercept stormwater runoff via surface soils and vegetation where it can be recharged, evaporated, or transpired
3. **Surface Treatment BMPs**: utilize landscaping and soils to treat stormwater by collecting runoff in shallow vegetated depressions for recharge, evaporation, or transpiration
4. **Subsurface Treatment BMPs**: mediate the recharge of stormwater runoff into underlying soils and eventually the water table or aquifers.
5. **Reuse BMPs**: store runoff for later irrigation, household, municipal or industrial uses

Harvesting and reuse of rainwater and stormwater are included separately because they represent an area of renewed interest in stormwater management. In addition, water reuse plays many roles in the hydrologic cycle, including source control of roof runoff (rainwater harvesting), reduction in potable water extraction and wastewater stream (in-building reuse), and evapotranspiration and/or recharge from irrigation reuses.

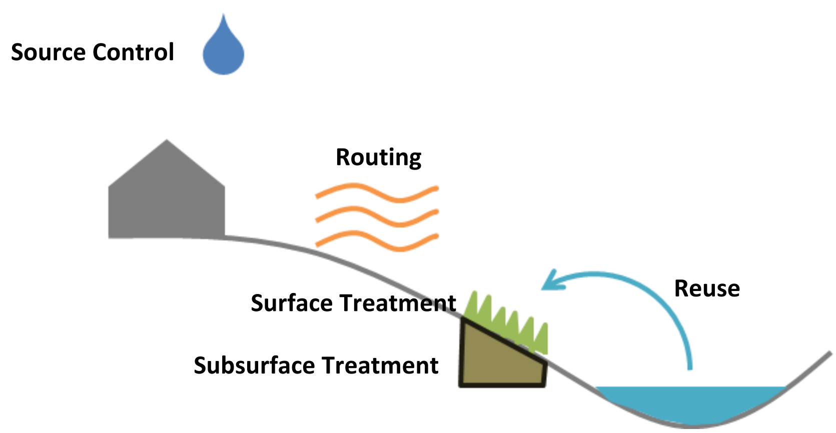

Figure 2. Volume reduction BMPs and their location in the landscape.
Source control BMPs (blue raindrop); Routing BMPs (orange wavy lines); Surface Treatment BMPs (green vegetation); Subsurface Treatment BMPs (brown soil); and Reuse BMPs (turquoise pond and arrow).

Format and use of document

This literature review is divided into 7 sections according to the following topics: Description, Performance, Cost-Benefit, Maintenance, Design Guidelines, Site Suitability, and Cold Climate Suitability. Each section includes an introduction of the topic, main findings for each BMP, and a reference summary that describes the hierarchy of most relevant sources and how they were chosen. This literature review was not intended to be a new, in-depth BMP manual, but rather a synthesis of existing BMP manuals and stormwater BMP literature reviews that are recent, local, and/or have a strong focus on the volume reduction benefits of stormwater BMPs in cold climates. Cited manuals and reports are conveniently linked throughout the text in brackets to the cited reference numbered list at the end of the document. Primary research papers are cited by author and publication year with complete bibliographic information listed at the end of the literature review.

A summary of the literature review is also available in matrix form in Excel. The content of the matrix was designed to be used by City Staff, developers, engineers and designers. The technical information contained in the matrix can be expanded or contracted, depending on the audience.

Terminology

One of the challenges in doing a literature review throughout a large area is that definitions of stormwater terminology can vary widely both in time (year) and in space (location). Since this Update is being presented as part of a project in the City of Fitchburg, Wisconsin (Dane County), the current local, county, and state regulatory definitions are included below, along with a synopsis of terminology generally used in the area.

Best Management Practice (BMP) - structural or non-structural measure, practice, technique or device employed to avoid or minimize soil, sediment or pollutants carried in runoff to waters of the state (*from NR 151 & NR 216*). A practice, technique, or measure that is an effective, practical means of preventing or reducing soil erosion or water pollution, or both, from runoff both during and after land development activities. These can include structural, vegetative or operational practices (*from Dane County Chap. 14 and Fitchburg Chap. 30, Article II*).

Biofiltration swale (or Bioswale) - A long, gently sloped, vegetated ditch designed to filter pollutants from stormwater. Grass is the most common vegetation, but wetland vegetation can be used if the soil is saturated.

Bioretention – A water quality practice that utilizes landscaping and soils to treat stormwater by collecting it in shallow depressions and then filtering it through a planting soil media.

Design storm – A hypothetical discrete rainstorm characterized by a specific duration, temporal distribution, rainfall intensity, return frequency and total depth of rainfall (*from NR 151*). The precipitation amounts that occur over a 24-hour period that have a specified recurrence interval for Dane County, Wisconsin. For example, one-year, two-year, 10-year and 100-year storm events mean the precipitation amounts that occur over a 24-hour period that have a recurrence interval of one, two, 10 and 100 years, respectively (*from Dane County Chap. 14 and Fitchburg Chap. 30, Article II*).

Groundwater - Water below the earth's surface, usually between saturated soil and rock. Groundwater usually originates from the recharge component of infiltration. In some instances groundwater may discharge to springs at the ground surface or directly into streams, creeks, and rivers.

Hydrologic cycle - The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation, storage, evaporation, and transpiration.

Impervious surface – An area that releases as runoff all or a large portion of the precipitation that falls on it, except for frozen soil. Rooftops, sidewalks, driveways, parking lots and streets are examples of surfaces that typically are impervious (*from NR 151*). Any land cover that prevents rain or melting snow from soaking into the ground, such as roofs (including overhangs), roads, sidewalks, patios, driveways and parking lots. For purposes of this chapter, all road, driveway or parking surfaces including gravel surfaces, shall be considered impervious, unless specifically designed to encourage infiltration and approved by the City Engineer (*from Fitchburg Chap. 30, Article II*).

Infiltration – The entry and movement of precipitation or runoff into or through soil (*from NR 151*). Any precipitation that does not leave the site as surface runoff (*from Dane County Chap. 14 and Fitchburg Chap. 30, Article II*).

Infiltration System – A device or practice such as a basin, trench, rain garden or swale designed specifically to encourage infiltration, but does not include natural infiltration in pervious surfaces such as lawns, redirecting of rooftop downspouts onto lawns or minimal infiltration from practices, such as swales or road side channels designed for conveyance and pollutant removal only (*from NR 151, NR 216, Dane County Chap. 14, and Fitchburg Chap. 30, Article II*).

Peak flow – The maximum rate of flow of water at a given point in a channel, watercourse, or conduit resulting from the predetermined storm or flood (*from Fitchburg Chap. 30, Article II*).

Pervious surface – An area that releases as runoff a small portion of the precipitation that falls on it. Lawns, gardens, parks, forests or similar vegetated areas are examples of surfaces that typically are pervious (*from NR 151*). Any land cover that permits rain or melting snow to soak into the ground (*from Fitchburg Chap. 30, Article II*).

Recharge - The portion of the average annual rainfall that infiltrates the soil and becomes groundwater. Recharge does not include evaporation, transpiration, or runoff from the site (*from Dane County Chap. 14 and Fitchburg Chap. 30, Article II*).

Runoff - Storm water or precipitation including rain, snow, ice melt or similar water that moves on the land surface via sheet or channelized flow (*from NR 151*). The waters derived from rains falling or snowmelt or icemelt occurring within a drainage area, flowing over the surface of the ground and collected in channels, watercourses or conduits (*from Dane County Chap. 14 and Fitchburg Chap. 30, Article II*).

Sediment - Settleable solid material that is transported by runoff, suspended within runoff or deposited by runoff away from its original location (*from NR 151 & NR 216*). Solid earth material, both mineral and organic, that is in suspension, is being transported, or has been moved from its site of origin by air, water, gravity or ice, and has come to rest on the earth's surface at a different site (*from Fitchburg Chap. 30, Article II*).

Stormwater – Runoff from precipitation including rain, snow, ice melt or similar water that moves on the land surface via sheet or channelized flow (*from NR 216*). The flow of water which results from, and which occurs during and immediately following, a rainfall, snow- or ice-melt event (*from Fitchburg Chap. 30, Article II*).

Stormwater facility - Facilities that control the quantity and/or quality of stormwater discharge. Stormwater facilities included storage facilities (ponds, vaults, underground tanks, and infiltration systems); water quality facilities (wet ponds, biofiltration swales, constructed wetlands, sand filters, and oil/water separators); and conveyance systems (ditches, pipes, and catchbasins).

Once constructed, stormwater facilities require on-going maintenance to ensure they continue to perform as intended. Maintenance of storage facilities typically includes the removal of accumulated sediment and debris, routine mowing, and minor repairs to mechanical appurtenances. Management of water quality facilities is more complex, requiring intensive vegetation management, inspection and maintenance of flow control features, and restoration or replacement of filter media.

Stormwater management - Any measures taken to permanently reduce or minimize the negative impacts of stormwater runoff quantity and quality after land development activities (*from Fitchburg Chap. 30, Article II*).

Watershed - A geographic area in which water, sediments, and dissolved materials drain to a common outlet, typically a point on a larger stream, a lake, an underlying aquifer, an estuary, or an ocean. A watershed is also sometimes referred to as the "drainage basin" of the receiving waterbody.

Wetland - An area inundated or saturated by ground or surface water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas (*U.S. Army Corps of Engineers Regulation 33 CFR 328.3 (1988)*).

I. DESCRIPTION

Introduction

Fifteen volume reduction BMPs were encountered in the literature and were the focus of this literature review, grouped into five major categories: Source Control, Routing, Surface Treatment, Subsurface Treatment, and Reuse. Commonly used stormwater BMPs that were not included in the literature review because they have already been well documented and only have volume reduction benefits as a secondary or incidental factor were: wet swales, stormwater wetlands, and detention ponds. A short description of the five major BMP categories and the associated volume reduction BMPs are given below. Other common names for the volume reduction BMPs are given in parantheses after the description title and are used in this literature review in summaries of reference material as they appear in the cited work. Key references available for each BMP are summarized in the following section and in Table 1 at the end of the section.

Volume Reduction Best Management Practices (BMPs)

A volume reduction BMP is any technique that reduces stormwater runoff through recharge into underlying soils, evaporation and/or transpiration, water re-use, or in any way diverts stormwater away from the drainage system or downstream.

Source Control BMPs

Source control BMPs mimic natural conditions by catching precipitation or soaking rainfall into the ground close to where it falls.

Impervious Cover Reduction

Impervious cover reduction is the practice of reducing the total area of impervious cover created at a development site, including: narrower streets, slimmer sidewalks, smaller cul-de-sacs, shorter driveways, and smaller parking lots. This includes incorporating natural and reintroduced vegetation in a landscape to intercept and infiltrate rainfall and reduce stormwater runoff volume.

Soil Amendments/ Decompaction

Post-development soil amendments (media, compost, etc.) and/or decompaction improve soil porosity and increase soil moisture holding capacity (reduce water demand of lawns and landscaping), thereby increasing infiltration and reducing runoff.

Pervious Pavement Systems

Pervious pavement systems increase recharge through load-bearing surfaces, including:
1) *Pervious Pavements* – pervious surfaces that recharge water across the entire surface (i.e. pervious asphalt and pervious concrete pavements);
2) *Pervious Pavers* – impervious modular blocks or grids separated by spaces or joints that water drains through (i.e. block pavers, plastic grids, etc.);
3) *Pervious Turf Systems* – lattice structure in the soil to distribute loads and avoid compaction with turf growing in the voids.
There are also hybrids and variations on the above systems, but this provides an overview of most commonly used pervious pavement systems.

Downspout Disconnection
Downspout disconnection is the process of separating roof downspouts from the sewer system or away from connected impervious surfaces (e.g. driveways) and redirecting roof runoff onto pervious surfaces, most commonly a lawn.

Green Roofs
Green roofs consist of a series of layers that create an environment suitable for plant growth that reduce roof runoff by collecting rainwater and releasing it via plant evapotranspiration.

Routing BMPs
Routing BMPs intercept runoff via surface soils and vegetation where it can be recharged, evaporated, or transpired.

Level Spreaders
Level spreaders are structures such as flush curbs that spread flow evenly over the same grade and mediates infiltration of riparian buffers, downslope vegetated filter strips or bioretention devices.

Filter Strips
Filter strips are the use of vegetation to slow runoff velocities and filter out sediment and other pollutants from urban stormwater but require the presence of sheet flow across the entire strip to be effective.

Dry Swales
Dry swales are structural stormwater channels that capture, temporarily store, and route stormwater runoff through a prepared soil filter bed often using check dams. Vegetated swales are usually long, gently sloped, vegetated ditches designed to filter pollutants from stormwater. Grass is the most common vegetation, but other vegetation can be used depending on soil conditions.

Surface Treatment BMPs
Surface treatment BMPs utilize landscaping and soils to treat stormwater by collecting it in shallow vegetated depressions for recharge, evaporation, or transpiration.

Bioretention Devices (also called Bioretention Cells or Raingardens)
A bioretention device is an infiltration device consisting of an excavated area that is back-filled with an engineered soil, covered with a mulch layer and planted with a diversity of woody and herbaceous vegetation. Storm water directed to the device percolates through the mulch and engineered soil, where it is treated by a variety of physical, chemical and biological processes before it is recharged, evaporated, or transpired. If the native soil has low infiltration rates, under drains can be added to aid recharge. Bioretention devices can be placed in a variety of locations including in yards, parking lot islands, road medians, and traffic islands.

Tree Trenches (also called Tree Box Filters or Tree Filters)
Tree trenches are in-ground structural systems typically filled with bioretention type soil media with street trees planted in the trenches in urban areas. Runoff is directed to the tree trench,

where it is filtered by vegetation and soil before either being taken up and used by the tree (natural irrigation) or infiltrating (if underlying soils are suitable) or entering a catch basin.

Infiltration Basins

An infiltration basin is defined as an open impoundment (greater than 15 feet wide in its minimum dimension) created either by excavation or embankment with a flat, densely vegetated floor dedicated to the infiltration of runoff through the ground surface.

Subsurface Treatment BMPs

Subsurface treatment BMPs mediate the infiltration and recharge of stormwater runoff into underlying soils and eventually the water table or aquifers. Since they typically do not have much if any vegetation component, water lost to evapotranspiration is not a treatment mechanism.

Below-ground Recharge Systems (also called Infiltration Trenches and Chambers)

Below-ground recharge systems are underground trenches or linear soakaways that mediate recharge of runoff into underlying native soils, including:
1) *Perforated Pipe Systems* – perforated pipes installed in clean granular stone beds; and
2) *Recharge Trenches* or *Soakaways (Dry Wells)* – rectangular or circular excavations filled with clean granular stone or other void forming material.

Reuse BMPs

Reuse BMPs store runoff for later irrigation, household, municipal or industrial uses.

Rainwater Harvesting

Rainwater harvesting and reuse is the practice of collecting rain water from relatively uncontaminated impervious surfaces, such as rooftops, and storing for future high quality water uses, such as household and municipal uses. There are a number of systems used for the collection and storage of rainwater including rain barrels and cisterns. Collected rainwater generally has high water quality and can be used for irrigation, toilet flushing, and machine washing with little to no pre-treatment.

Stormwater Harvesting

Stormwater reuse is similar to harvesting but typically the input water quality is less controlled. The relatively new practice in non-arid areas consists of collecting stormwater runoff from impervious surfaces and pervious landscapes and storing for future low quality water uses, such as irrigation and industrial operations. A number of systems are used for the collection and storage of stormwater, including wet ponds, detention basins, and above ground or underground cisterns. Distribution systems vary according to stormwater reuse.

Relevant Manuals and Databases

Many stormwater BMP manuals and literature reviews already exist and the objective of this literature review was not to repeat those efforts. The following references were chosen for their recent and local nature, and/or strong focus on stormwater BMPs with volume reduction benefits. Individual guidelines are not yet widely available for Stormwater Reuse, Tree Trenches, and Soil Amendments/ Decompaction as they are relatively new stormwater BMPs. A visual summary of the key references used in this literature review is found in Table 1. Sources are listed below in order of importance/relevance, with a description from each source.

General BMP Manuals:

[1] The **2008 Minnesota Stormwater Manual** contains detailed design guidance for Low Impact Development and traditional stormwater BMPs in the context of Minnesota climate and regulations. This reference contains information on the following volume reduction stormwater BMPs:

- Bioretention
- Filtration
- Infiltration

[2] The pollution prevention fact sheets contained in the **Pollution Prevention and the MS4 Program Guide on Utilizing Pollution Prevention Activities to Meet MS4 General Permit Requirements** provide communities regulated under the Minnesota Municipal Separate Storm Sewer Systems (MS4) General Permit with basic tools and information that will lead to increased use of pollution prevention activities within stormwater pollution prevention programs and local stormwater programs. This reference contains information on the following volume reduction stormwater BMPs:

- Reducing Impervious Surfaces
- Pervious Pavement Systems
- Volume Control Using Compost Materials/ Soil Amendments
- Green Roofs
- Rainwater Harvesting/ Stormwater Reuse & Rain Barrel Programs
- Urban Forestry & Stormwater Management
- Vegetated Swales & Buffer Strips

[3] The **Credit Valley Conservation/ Toronto and Region Conservation Authority (CVC/TRCA) 2010 Low Impact Development Planning and Design Guide** contains detailed design guidance for Low Impact Development activities in the context of the Toronto climate and regulations. The CVC is noted for its progressive use of Low Impact Development site design strategies. This reference contains information on the following volume reduction stormwater BMPs:

- Low Impact Development Site Design Strategies
- Permeable Pavement
- Downspout Disconnection
- Soakaways, Infiltration Trenches and Chambers
- Vegetated Filter Strips
- Dry Swales
- Bioretention

- Green Roofs
- Rainwater Harvesting

[4] The **Wisconsin DNR Technical Note for Sizing Infiltration Basins and Bioretention Devices to meet State of Wisconsin Stormwater Infiltration Performance Standards** includes several tools approved by the Wisconsin Department of Natural Resources to design infiltration basins and bioretention devices capable of meeting the state of Wisconsin stormwater infiltration performance standards contained in ss. NR 151.12(5)(c) and NR 151.24(5), Wis. Adm. Code. This reference contains the following volume reduction stormwater BMP Conservation Practice Standards:

- Site Evaluation for Stormwater Infiltration (1002)
- Infiltration Basin (1003)
- Bioretention for Infiltration (1004)

[5] The **Charles River Watershed Association (CRWA) 2008 Low Impact Best Management Practice (BMP) Information Sheets** provide summaries of the current understanding of the benefits, performance, installation costs, maintenance needs and costs, and additional concerns regarding several Low Impact Development BMPs. In addition, the CRWA developed three matrices to help municipal officials, developers and others with the selection of stormwater BMPs, including stormwater management goals, physical and site specific constraints and opportunities, and installation, operational, and maintenance costs and requirements. This reference contains information on the following volume reduction stormwater BMPs:

- Pervious Pavement (Concrete, Asphalt)
- Pervious Pavers
- Rain Gardens (Bioretention)
- Tree Filter
- Vegetated Swale
- Green Roof
- Rainwater Harvesting

[6] The **2001 Minnesota Urban Small Sites BMP Manual** provides information on tools and techniques to assist Twin Cities' municipalities and Watershed Management Organizations (WMOs) in guiding development and redevelopment. The manual includes detailed information on 40 BMPs that are aimed at managing stormwater pollution for small urban sites in a cold-climate setting. This reference contains information on the following volume reduction stormwater BMPs:

- Impervious Surface Reduction (Cul-de-Sac, Parking Lot, and Street Design)
- Turf Pavers
- Green Rooftops
- Bioretention Systems
- Filter Strips
- Infiltration Basins
- On-lot Infiltration
- Infiltration Trenches

Individual BMP Guidelines:

Stormwater Harvesting

[7] The **Mississippi WMO-Minnehaha Creek WD Joint Watershed Research 2012 Stormwater Reuse Feasibility Study** quantifies the volume reduction and phosphorus removal benefits of stormwater and reuse for a range of land use and drainage size typical of Minneapolis, Minnesota.

[8] The **Metropolitan Council 2012 Stormwater Reuse Guide** provides step-by-step instructions and introduces effective alternative techniques for stormwater reuse for the purpose of reducing demand on Twin Cities metropolitan area potable water supplies. Tailored for city planners, engineers, and green thinkers, the Guide describes how to bring a stormwater reuse project from concept through assessment to implementation.

Tree Trenches and Soil Amendments

[9] The **2007 City Trees: Sustainability Guidelines & Best Practices (Pilot Version)** were developed to support the new and innovative project, Hawthorne Eco Village, in the City of Minneapolis. The guidelines were specifically developed to work in conjunction with and build on the Green Communities Criteria and the accompanying Minnesota Overlay (www.greencommunitiesonline.org/Minnesota). The goal of these guidelines was to provide much-needed direction and recommendations for how to accommodate, care for, and locate urban trees, both within the public right-of-way and on private property.

[10] The **2008 Managing Stormwater for Urban Sustainability Using Trees and Structural Soils Manual** is the result of a series of research studies carried out at Virginia Tech, Cornell University, and the University of California at Davis. This research evaluated multiple aspects of the novel stormwater BMPs Trees and Structural Soils. This manual introduces the stormwater management system and its attributes and limitations, provides information on designing a system with structural soils and trees based on the needs of individual sites, and describes surface treatments that can be used in conjunction with this stormwater management BMP, namely turf and pervious pavement.

Table 1. Summary of key reference manuals for volume reduction BMPs
Note: An '**X**' denotes the inclusion of a BMP in the guidance manual. Shaded boxes denote the source of the summary fact sheet found in the appendices at the end of this document.

<table>
<tr><th></th><th></th><th>Minnesota Stormwater Manual [1]</th><th>Pollution Prevention Fact Sheets [2]</th><th>Low Impact Development Planning and Design Guide [3]</th><th>Wisconsin Conservation Practice Standards [4]</th><th>CWRA LID BMP Information Sheets [5]</th><th>Minnesota Urban Small Sites BMP Manual [6]</th><th>BMP Specific [7, 8, 9, 10]</th></tr>
<tr><td rowspan="5">SOURCE CONTROL</td><td>Impervious Cover Reduction</td><td></td><td>X</td><td>X (LID)</td><td></td><td></td><td>X</td><td></td></tr>
<tr><td>Soil Amendments/ Decompaction</td><td></td><td>X</td><td></td><td>X</td><td></td><td></td><td>X</td></tr>
<tr><td>Pervious Pavement Systems</td><td></td><td>X</td><td>X</td><td></td><td>X</td><td>X</td><td></td></tr>
<tr><td>Downspout Disconnection</td><td></td><td></td><td>X</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Green Roofs</td><td></td><td>X</td><td>X</td><td></td><td>X</td><td>X</td><td></td></tr>
<tr><td rowspan="3">ROUTING</td><td>Level Spreaders</td><td></td><td></td><td rowspan="2">X</td><td></td><td></td><td></td><td></td></tr>
<tr><td>Filter Strips</td><td>X</td><td>X</td><td rowspan="2">X</td><td></td><td>X</td><td></td></tr>
<tr><td>Dry Swales</td><td>X</td><td>X</td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td rowspan="3">SURFACE TREATMENT</td><td>Bioretention Devices</td><td>X</td><td></td><td>X</td><td>X</td><td>X</td><td>X</td><td></td></tr>
<tr><td>Tree Trenches</td><td></td><td>X</td><td></td><td></td><td>X</td><td>X</td><td>X</td></tr>
<tr><td>Infiltration Basins</td><td>X</td><td></td><td>X</td><td>X</td><td></td><td>X</td><td></td></tr>
<tr><td>SUB-SURFACE TREATMENT</td><td>Below-ground Recharge Systems</td><td></td><td></td><td>X</td><td>X</td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">REUSE</td><td>Rainwater Harvesting</td><td></td><td>X</td><td>X</td><td></td><td>X</td><td></td><td></td></tr>
<tr><td>Stormwater Harvesting</td><td></td><td></td><td></td><td></td><td></td><td></td><td>X</td></tr>
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II. PERFORMANCE

Introduction

The performance of volume reduction stormwater BMPs was assessed based on the following metrics:

1. *Runoff Reduction*: the percent of runoff volume reduced through evaporation, plant transpiration, and recharge (volume reduction);
2. *Surface Water Pollutant Removal*: the percent reduction of major nutrient and heavy metal concentrations (or loads) from BMP surface outflow; and
3. *Soil and Groundwater Quality*: the potential impacts of BMP outflow on soil and groundwater quality.

The results from this analysis are summarized below and in Table 2.

Main Findings

Runoff Reduction

The runoff volume reduction of a BMP is the fraction of stormwater captured by a BMP that is not released to downstream waters. Many studies have published data on the runoff volume reduction performance of BMPs but these depend on the sizing of a BMP. Not knowing the sizing parameters used, the underground recharge basin, recharge depression, and bioretention device (without an under drain) BMPs had the highest stormwater runoff volume reduction performance, followed by, in order of decreasing performance, green roofs, pervious pavement systems, and soil amendments. These BMPs are designed to enhance infiltration into the soil for recharge or evapotranspiration, and consequently have a greater ability to reduce overall stormwater runoff volumes than other BMPs.

BMPs with lower reported volume reduction performance were downspout disconnection, impervious cover reduction, filter strips, dry swales, bioretention devices with under drains, and rainwater harvesting. The benefits of downspout disconnection and impervious cover reduction are difficult to quantify due to wide variations in their design. The volume reduction performance of rainwater and stormwater harvesting is directly related to storage size and so the actual reported performance may be less than the potential performance due to storage size limitations and costs. Filter strips and dry swales are expected to perform poorly with respect to stormwater runoff volume reduction because their primary benefit is nutrient removal through filtration. Filter strips and dry swales may more correctly be considered as pretreatment for volume control BMPs as part of a treatment train approach.

Surface Water Pollutant Removal

The specific pollutant removal performance of individual stormwater BMPs has been compiled and discussed extensively by other reviews (listed in the next section) and a brief summary of these data are provided in Table 2. However, pollutant removal data has many inconsistencies and biases due to discrepancies between load-based versus concentration-based estimates and the lack of correlation between influent nutrient loads and percent removal. For example, BMPs with high percent removal rates can still have high effluent concentrations due to high influent concentrations. As a result the International Stormwater Database, the leader in synthesizing

BMP performance studies and data, has recently omitted the use of percent removal as a measure of BMP performance. The data reported in Table 2 should be used with caution and are provided in this literature review for reference only. More information on this topic can be found in the white paper titled “Why does the International Stormwater BMP Database Project omit percent removal as a measure of BMP performance?” [15]

One prominent source of available data was excluded from Table 2 as potential outliers were from one of the first studies on the effectiveness of LID when LID was relatively new and not widespread [16]. Most of the available data were from studies using simulated rainfall events in Prince George's County, Maryland, and the report noted that the analysis of actual long-term rainfall events would produce more reliable data. Nutrient percent removals from this report ranged from 0–87% reductions in phosphorus, 37–80% reductions in Total Kjeldahl Nitrogen, <0–92% reductions in ammonium, and <0–26% reductions in nitrate. These nutrient reduction ranges were more variable than ranges from other more recent studies included in Table 2.

Table 2. Volume Reduction BMP Performance Summary

Volume Reduction BMP		Runoff Volume Reduction	Surface Water Pollutant Removal				Notes
			TP	*TN*	*TSS*	*Metals*	
SOURCE CONTROL	**Impervious Cover Reduction**	[12] 40% [17] 40%	[12] 55% [17] 30%	[12] 64%			[17] Values for parking lot wetland depressions
SOURCE CONTROL	**Soil Amendments/ Decompaction**	[12] 50-75%	[12] 50-75%	[12] 50-75%			
SOURCE CONTROL	**Pervious Pavement Systems**	[3] 45-85% [12] 45-75%	[1] 80% [12] 59-81% [22] 30-65%	[1] 80% [12] 59-81%		[1] 90%	[3] Range lists reduction for systems without an under drain (low estimate) to systems with an under drain (high)
SOURCE CONTROL	**Downspout Disconnection**	[12] 25-50%	[12] 25-50%	[12] 25-50%			
SOURCE CONTROL	**Green Roof**	[3] 45-55% [5] 70-90% [12] 45-60%	[1] 100% [3] -248% [12] 45-60%	[1] 20% [3] 91% [12] 45-60%	[1] 90% [3] 69-86% [5] 90%	[1] 80% [5] 80%	[3] reductions based on a green roof relative to a conventional roof; higher TP in green roof runoff due to leaching of the growing medium; TN reduction based on nitrate only
ROUTING	**Level Spreaders**	[12] 50-75% [13] 52 (18-85)%	[12] 50-75%	[12] 50-75%			
ROUTING	**Filter Strips**	[3] 25-50% [12] 50-75% [13] 37 (0-88)%	[1] 30-55% [22] 50-80%	[1] 35%	[1] 75-90%	[1] 80%	[3] Reductions depend on soil type
ROUTING	**Dry Swales**	[3] 10-20% [12] 40-60% [13] 48 (19-85)%	[12] 52-76% [22] 15-45%	[12] 55-74%			[3] Reductions depend on soil type; Reductions listed for grass channel

Volume Reduction BMP		Runoff Volume Reduction	Surface Water Pollutant Removal				Notes
			TP	*TN*	*TSS*	*Metals*	
SURFACE TREATMENT	**Bioretention Devices (without under drain)**	[3] 85% [12] 80% [13] 65 (35-94)%	[12] 90%	[12] 92%		[3] 30-99%	
SURFACE TREATMENT	**Bioretention Devices (with under drain)**	[3] 45% [12] 40%	[1] 65% [12] 55%	[1] 45% [12] 64%	[1] 85%	[1] 95%	
SURFACE TREATMENT	**Tree Trenches**	[5] variable	[5] 74%	[5] 68%	[5] 85%	[5] 82%	[5] Systems usually designed to capture runoff from small, frequently-occurring storms
SURFACE TREATMENT	**Infiltration Basins**	[12] 50-90%	[12] 63-93% [22] 15-45%	[12] 57-92%			
SUB-SURFACE TREATMENT	**Below-ground Recharge Systems**	[3] 85%	[3] 50-70% [22] 50-80%	[3] 40-70%	[3] 70-90%	[3] 70-90%	
REUSE	**Rainwater Harvesting**	[3] 40% [12] 40%	[12] 40%	[12] 40%			[3] Reductions listed for dual use cisterns
REUSE	**Stormwater Harvesting**	[7] 22-74%	[7] 46-95%				[7] Reductions based on systems designed for high performance

Note: Values reported as medians, or median - 75th percentile.
Total phosphorus (TP); Total nitrogen (TN); Total suspended solids (TSS)

Impacts on Soil and Groundwater Quality

With the emphasis on volume control BMPs in recent years, the issue of soil and groundwater contamination is gaining much more attention as reflected in the increasing number of research projects. Stormwater runoff from urban areas has much higher concentrations of pollutants than from natural sources for many constituents. Many stormwater BMPs are designed to filter out pollutants from stormwater runoff, but accumulating pollutants in soils and groundwater adjacent to stormwater BMPs is a growing concern among water resource managers, especially when large amounts of stormwater runoff are recharged in areas with sandy soils or shallow water tables. The following is a brief summary of recent research studies that have investigated the impacts of stormwater recharge on groundwater quality.

Paved areas are sources of metals, hydrocarbons, and chloride, and some studies of stormwater BMPs have found some decrease in groundwater quality due to stormwater recharge. A recent study on the effects of urban runoff on groundwater quality found a clear link between increased groundwater recharge rates and decreased groundwater quality downstream of an urban area ([33] Carlson *et al.* 2011). Infiltration basins draining light industrial and residential areas have underlying groundwater that are well within drinking water guidelines for toxic metals, nutrients, and pesticides ([26] Appleyard 1993), but infiltration basins and vegetative filter strips draining major roads often have soils contaminated with heavy metals in depths of 30 cm up to 1.5 m ([28] Barraud *et al.* 1999, [42] Legret *et al.* 1999, [64] Winiarski *et al.* 2006, [45] Mikkelsen *et al.* 1997). In addition, other studies have shown higher chloride levels ([63] Wilde 1994, [60] USEPA 2009) and greater hydrocarbon and pesticide detection frequency ([39] Fischer *et al.* 2003) in groundwater, and accumulation of lead ([50] Nightingale 1987), metals, hydrocarbons, and nutrients in soils underlying stormwater BMPs ([29] Barraud *et al.* 2005; [36] Dechesne *et al.* 2005). However, the leaching of heavy metals into groundwater may be limited ([45] Mikkelsen *et al.* 1997) due to the immobility of lead in soil ([51] Norrström 2005). Soil cores below bioretention devices during the first 5 years of operation in the Greater Toronto Area showed comparable metal and hydrocarbon levels to un-impacted sites ([58] TRCA 2008). BMPs receiving runoff from metal roofs have been found to be at high risk for zinc contamination of soils ([65] Zimmermann *et al.* 2005).

However, recent research has improved the outlook on the risks of soil and groundwater contamination due to stormwater recharge. While pavements are a source of hydrocarbons to runoff, naturally occurring microbial communities growing on pervious pavements are capable of degrading hydrocarbons. Moreover, research has shown that microbial degradation of hydrocarbons is assisted by the geotextile layer below the base course layer of pervious pavements ([48, 49] Newman *et al.* 2006a, b). Another study found that the levels of road salt derived chlorides in groundwater dropped quickly during the spring and eventually leveled out in the summer due to dilution with runoff low in chlorides ([41] Kwiatkowski *et al.* 2007). Finally, long-term (20 years or more) studies of groundwater below infiltration basins have shown no adverse effects from infiltrating stormwater ([56] Salo *et al.* 1986; [44] Mikkelsen *et al.* 1994) and other monitoring data indicate that small distributed stormwater infiltration practices do not contaminate underlying soils, even after 10 years of operation ([58] TRCA 2008). Due to the lack of observations of significant contamination of underlying groundwater after 20 years of service ([20] TRCA 2009), it has been noted that "the risk of groundwater contamination from infiltration practices can be properly managed through appropriate screen of suitability, siting, and design."

To reduce potential for groundwater contamination due to stormwater infiltration, [52] Pitt *et al.* (1999) recommended diverting the first runoff following periods of pollutant build-up, such as periods of dry weather and spring snowmelt. In addition, pretreatment of stormwater runoff from critical pollutant source areas was recommended.

The Low Impact Development Stormwater Management Planning and Design Guide [3] has developed specific guidelines for the treatment and use of stormwater for infiltration systems based on the quality of stormwater runoff generated from various urban sources. A summary of the risks for groundwater contamination from infiltration BMPs discussed in this guide is provided below:

Stormwater infiltration practices should:

- Not receive runoff from high traffic areas where large amounts of de-icing salts are applied (e.g., busy highways), nor from pollution hot spots (e.g., source areas where land uses or activities have the potential to generate highly contaminated runoff such as vehicle fuelling, servicing or demolition areas, outdoor storage or handling areas for hazardous materials and some heavy industry sites).
- Prioritize infiltration of runoff from source areas that are comparatively less contaminated such as roofs, low traffic roads and parking areas.
- Apply sedimentation pretreatment practices (e.g., oil and grit separators) before infiltration of road or parking area runoff.

Also included in this guide is a summary table of guidelines for appropriate stormwater BMPs according to stormwater source area and runoff characteristics (Table 3).

Systems Performance

Other research has been conducted on the general performance of stormwater BMPs. Summaries of a few recent studies are included. For example, the publication of a recent analysis indicated that infiltration-based LID technologies were more effective than storage-based BMPs for small storms, but storage-based BMPs were more effective for managing runoff from more intense storms ([34] Damodaram *et al.* 2010). These results suggest that a combination of infiltration and storage BMPs are needed to address all stormwater runoff from developed sites.

Transpiration rates have also been studied in different stormwater management systems. One study measured transpiration rates of urban trees in structural soil and found that transpiration rates were reduced under slow soil drainage conditions ([30] Bartens *et al.* 2009). Other work investigated the variability of green roof plant transpiration under water stressed conditions and found some evidence for decreased transpiration rates when plants were subjected to periodic water stress ([62] Voyde *et al.* 2010).

Table 3. Guidelines for appropriate stormwater BMPs based according to stormwater source area
From: Table 2.8.1 in Low Impact Development Stormwater Management Planning and Design Guide [3]

Stormwater Source Area	Runoff Characteristics	Opportunities	Principles
Foundation drains, slab underdrains, road or parking lot underdrains	Relatively clean, cool water.	Suitable for infiltration or direct discharge to receiving watercourses.	Should not be directed to stormwater management facility that receives road or parking lot runoff.
Roof drains, roof terrace area drains, overflow from green roofs	Moderately clean water, contaminants may include asphalt granules, low levels of hydrocarbons and metals from decomposition of roofing materials, animal droppings, natural organic matter and fall out from airborne pollutants, potentially warm water.	- Infiltration; - Filtration; - Harvesting with rain barrels or cisterns and use for non-potable purposes (*e.g.*, irrigation, toilet flushing) after pretreatment; - Attenuation and treatment in wet pond or wetland detention facility.	Runoff should be treated with a sedimentation and/or filtration practice prior to infiltration. Where possible, runoff should not be directed to end-of-pipe facilities to capitalize on potential for infiltration or harvesting. Flow moderation (quantity control) prior to discharge to receiving watercourse is required.
Low and medium traffic roads and parking lots, driveways, pedestrian plazas, walkways	Moderately clean water, contaminants may include low levels of sediment, de-icing salt constituents, hydrocarbons, metals and natural organic matter. Typically warm water.	- Infiltration after pretreatment; - Filtration after pre-treatment; - Harvesting with cisterns or permeable pavement reservoirs and use for outdoor non-potable purposes (*e.g.*, vehicle washing, irrigation) after pretreatment; - Attenuation and treatment in wet pond or wetland detention facility.	Runoff should be treated with a sedimentation and/or filtration practice prior to infiltration. Flow moderation (quantity control) prior to discharge to receiving watercourse is required. Water quality should be tested prior to use for non-potable purposes.
High traffic roads and parking lots	Potential for high levels of contamination with sediment, de-icing salt constituents hydrocarbons and metals. Typically warm water.	- Filtration after sedimentation pre-treatment; - Attenuation and treatment in wet pond or wetland detention facility; - Infiltration after pretreatment only where groundwater uses are limited.	Runoff should be treated with a sedimentation and/or filtration pretreatment practice prior to infiltration.
Pollution hot spots* such as vehicle fueling, servicing or demolition areas, outdoor storage and handling areas for hazardous materials, some heavy industry sites	Potential for high levels of contamination with sediment, de-icing salt constituents, hydrocarbons, metals, and other toxicants.	- Attenuation and treatment in wet pond, wetland or hybrid detention facility; - Potential requirement for sedimentation pretreatment; - Infiltration and harvesting practices not recommended.	Runoff from these sources should not be infiltrated or used for irrigation. Spill containment or mitigation devices recommended contingent on size of storage facilities.

* *Pollution hot spots* are areas where certain land uses or activities have the potential to generate highly contaminated runoff (*e.g.*, vehicle fuelling, service or demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites).

Relevant Manuals and Reports

Several pre-existing literature reviews and databases on studies that measured the volume reduction and pollutant removal benefits of stormwater BMPs were used in this literature review. Sources are listed in order of importance/relevance, with key references boxed. A description of each source, as reported by that source, is given below. Primary research papers on the impacts of recharge systems on soil and groundwater quality are listed in alphabetical order at the end of the literature review.

Runoff Reduction and Pollutant Removal

[12] The **2008 Center for Watershed Protection Technical Memorandum: The Runoff Reduction Method** contains an extensive literature review of studies measuring runoff reduction and pollutant removal efficiencies of stormwater BMPs, including low-impact development techniques. **Appendix B** summarizes runoff reduction results by BMP. **Appendix F** summarizes runoff reduction results by individual study, including study description, methodology, runoff reductions, pollutant reductions, and implications for design.

[13] The **Wright Water Engineers and Geosyntec Consultants 2011 International Stormwater Best Management Practices (BMP) Database Volume Reduction Technical Summary** contains data from 1,930 events and 47 studies passing primary and secondary screening that was analyzed for stormwater runoff volume reduction ([event inflow – event outflow]/event inflow).

[14] The **Wright Water Engineers and Geosyntec Consultants 2011 International Stormwater Best Management Practices (BMP) Database Pollutant Removal Technical Summary** contains data on event inflow and event outflow pollutant concentrations. A percent removal has been derived for the purpose of this literature review from International BMP Database reported mean inflow and outflow concentrations, but this value is not supported by the International BMP Database Project due to inconsistencies and biases associated with this metric (See reference 15 for more information).

[15] **Wright Water Engineers and Geosyntec Consultants 2007 Frequently Asked Questions Fact Sheet for the International Stormwater BMP Database**: **Why does the International Stormwater BMP Database Project omit percent removal as a measure of BMP performance?** is a paper that summarized key shortcomings associated with percent removal as a tool to assess BMP performance.

[1] The **2008 Minnesota Stormwater Manual** contains detailed design guidance for Low Impact Development and traditional stormwater BMPs in the context of Minnesota climate and regulations.

[3] The **Credit Valley Conservation/ Toronto and Region Conservation Authority (CVC/TRCA) 2010 Low Impact Development Planning and Design Guide** contains

detailed design guidance for Low Impact Development activities in the context of the Toronto climate and regulations.

[5] The **Charles River Watershed Association 2008 Low Impact Best Management Practice (BMP) Information Sheets** include summaries of other published estimates of pollutant removal efficiencies for various stormwater BMPs.

[16] The **2000 U.S. EPA Low-Impact Development (LID) Literature Review** was an early study on the availability and reliability of data to assess the effectiveness of Low Impact Development (LID) practices for controlling stormwater runoff volume and reducing pollutant loadings to receiving waters.

[17] The **2010 University of Minnesota Stormwater Treatment: Assessment and Maintenance** guidelines present case studies submitted by practitioners outlining monitoring and assessment results for various stormwater treatment practices.

[22] The **2005 MN DOT Report: The Cost and Effectiveness of Stormwater Management Practices** evaluated urban stormwater management practices for cost and effectiveness in removing suspended sediments and phosphorus.

Available in the Future:

[19] The **Online U.S. EPA Urban Stormwater BMP Performance Tool** has been developed to provide stormwater professionals with easy access to approximately 220 studies assessing the performance of over 275 BMPs. Additional studies will be added to this collection periodically. This Tool presents information previously compiled by the International Stormwater BMP Database and by the State of California in an easy to use search and sort format. In the future, EPA hopes to add more studies to this collection, particularly ones that evaluate the performance of "green infrastructure" or "Low Impact Development" BMPs.

Impacts on Soil and Groundwater Quality

[20] The Toronto Region and Conservation Authority (2009) **Review of the Science and Practice of Stormwater Infiltration in Cold Climates** is a literature review of infiltration based stormwater management, with particular emphasis on peer reviewed journal articles and published reports from jurisdictions with climate and soil conditions similar to Ontario, covering risks of groundwater contamination and cold climate performance monitoring.

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III. COST-BENEFIT

Introduction

One of the deciding factors in choosing stormwater BMPs is the cost per benefit. Unfortunately many benefits of stormwater BMPs have various values that are not easily monetized. These benefits include wildlife habitat, added beauty to a community, improved air quality, reduced thermal impacts, and restoration of natural features, such as wetlands, forest, natural drainage features, original topography, undisturbed soils, and open space. In this way, the true cost per benefit of a stormwater BMP is very difficult to quantify.

One measure of the cost per benefit of a stormwater BMP that is used is the total capital construction costs and annual operation and maintenance (O&M) costs averaged over the life of the BMP (whole life cycle cost). This extensive analysis is out of the scope for this literature review, but the reader is encouraged to check the 2009 Water Environment Research Foundation BMP and LID Whole Life Cost Model [24], an online standardized tool useful for estimating whole life costs for stormwater BMPs and LID practices in their projects.

Reported in this literature review are several publicly available reports that calculated capital and O&M costs for a range of stormwater BMPs. The draft report from the EPA: Achieving More Cost-Effective Stormwater Plans Using Low-Impact Development (LID) Strategies [25] contains the most up-to-date cost estimates for Low Impact Development BMPs, but cannot be reproduced until the final draft is published. The reader is encouraged to look for the final draft of this report in the future.

Main Findings

Cost estimates for stormwater BMPs are tightly linked to design capacity, estimated life expectancy of the BMP, and current costs of materials and land. As a result, caution must be used when comparing cost estimates from different reports and different years. Because no single report presents cost estimates for all of the volume reduction BMPs in this literature review, the data from each report is presented separately below and in Table 4 through Table 7. Historical costs were converted to 2012 dollars using the Historical Cost Index.

The 1991 Costs of Urban Nonpoint Source Water Pollution Control Measures compared capital and annual operating and maintenance costs for 5 BMPs: infiltration trench, infiltration basin, pervious pavement, grassed (dry) swale, and grassed filter strips (Table 4). Capital costs ranged from $12,000 to $118,000 per acre for infiltration basins and pervious pavement systems, and less than $10 to greater than $100 per lineal foot for infiltration trenches, swales and filter strips. Capital costs for pervious pavement were greater than infiltration basins, but the annual O&M costs were much less. Capital and O&M costs for filter strips and swales were much less than infiltration trenches.

The Charles River Watershed Association 2008 Installation and Maintenance Costs and Requirements Matrix presented capital and annual O&M costs for pervious pavement systems, rain garden (bioretention device), tree filter, vegetated swale, green roof, and rainwater harvesting cistern (Table 5). Capital costs ranged from $5 to $25 dollars per square foot for pervious pavement and pavers, rain gardens, vegetated swales, and green roofs, and less than

$1,000 to greater than $10,000 per tree box filter or rainwater harvesting cistern system. Annual O&M costs for pervious pavements and pavers, tree trenches, and rainwater harvesting cisterns ranged from $100 to $550 per year. Annual O&M costs for rain gardens and green roofs were similar to traditional landscaping costs.

The MN DOT 2005 Cost and Effectiveness of Stormwater Management Practices report compared capital and 20 year O&M costs (20-year life cycle cost) per volume of treated stormwater for a dry detention basin, infiltration trench, and bioinfiltration filter (Table 6). The 20-year life cycle cost per treated stormwater volume decreased as the amount of treated stormwater increased. In addition, the infiltration trench was the most expensive and the dry detention basin the least expensive.

The 2000 Economics of Low Impact Development Literature Review estimated the number of gallons of stormwater management per $1,000 invested for several Low Impact Development stormwater BMPs, including: green streets, street trees, green roofs, and rain barrels (Table 7). Green streets and street trees were able to manage the most gallons of stormwater per $1,000 invested, and green roofs were able to manage the least.

Reporting of costs relative to benefits has not been standardized nor adopted within stormwater studies. Comparison of costs across studies should be done with caution due to the multiple variables that impact costs, such as:

- What aspects of the project are included (for example is land cost included)?
- What is the relative performance of the BMP (and is it removing pollutants in its optimal design range)?
- Are O&M costs considered and if so, how they are calculated over time?

It should be noted that many costs are provided as simple costs per unit of BMP, which is separate from the removal benefits thus making the connection to benefit difficult. Ideally, costs could be calculated to give a cost ($) per unit area treated to a certain standard or per unit of pollutant removed. There are still some important nuances that should be considered when looking at cost effectiveness of a specific BMP. For example, is the overriding water treatment goal and/or site constraint such that certain BMPs must be used and do the BMPs need to be used outside of their optimal range to gain a higher level of needed treatment?

Table 4. Southwestern Wisconsin Regional Planning Commission Capital and Annual Operation and Maintenance Costs by BMP in 1991 and 2012 dollars ($)
(From the Costs of Urban Nonpoint Source Water Pollution Control Measures, 21)

BMP	Size/ Assumptions	Capital Costs		Annual O&M Costs	
		1991 dollars	2012 dollars	1991 dollars	2012 dollars
Infiltration Trench	3’ × 4’ × 100’	$24 - $74 per lineal foot	$48 - $147 per lineal foot	$285	$568
	6’ × 10’ × 100’	$71 - $167 per lineal foot	$141 - $333 per lineal foot	$615	$1,225
Infiltration Basin	3’ deep, 0.25 acre	$12,000 - $35,000	$24,000 - $70,000	$917	$1,827
	3’ deep, 1 acre	$38,000 - $107,000	$76,000 - $213,000	$2,468	$4,916

BMP	Size/ Assumptions	Capital Costs		Annual O&M Costs	
		1991 dollars	2012 dollars	1991 dollars	2012 dollars
Pervious Pavement	Asphalt	$40,000 per acre	$80,000 per acre		
	Pervious Pavement	$80,000 - $118,000 per acre	$159,000 - $235,000 per acre	$200 per acre	$400 per acre
Grassed Swale	1.5’ × 10’ × 1000’	$6,400 - $17,100	$12,700 - $34,100	$0.58 per lineal foot	$1.16 per lineal foot
	3’ × 21’ × 1000’	$12,900 - $33,400	$25,700 - $66,500	$0.75 per lineal foot	$1.49 per lineal foot
Grassed Filter Strips	25’ × 1000’	$9 - $23 per lineal foot	$18 - $46	$0.51 per lineal foot	$1.02 per lineal foot
	50’ × 1000’	$17 - $43 per lineal foot	$34 - $86	$0.91 per lineal foot	$1.81 per lineal foot
	100’ × 1000’	$32 - $82 per lineal foot	$64 - $163	$1.71 per lineal foot	$3.41 per lineal foot

Table 5. Charles River Watershed Association Capital and Annual Operation and Maintenance Costs by BMP in 2008 dollars ($)
(From the CRWA Installation and Maintenance Costs and Requirements Matrix C, 5)

BMP	Capital Costs		Annual O&M Costs	
	2008 dollars	2012 dollars	2008 dollars	2012 dollars
Pervious Pavement	$7 - $15 per square foot	$7 - $16 per square foot	$400 - $500	$427 - $534
Pervious Pavers	$8 - $12 per square foot	$9 - $13 per square foot	$400 - $500	$427 - $534
Bioretention (Rain Garden)	$10 - $12 per square foot	$11 - $13 per square foot	Similar to traditional landscaping	
Tree Filter	$8,000 - $10,000 per system $1,500 - $6,000 installation	$8,500 - $10,700 per system $1,600 - $6,400 installation	$100 - $500 per system	$107 - $534 per system
Vegetated Swale	~$7 per square foot	~$7.50 per square foot	$200	$214
Green Roof	$5 - $25 per square foot	$5 - $27 per square foot	$1,200 per year over lifetime of roof	$1,280 per year over lifetime of roof
Rainwater Harvesting Cistern	$600 - $13,000 depending on extent of accompanying plumbing system‡	$640 - $13,900	$550	$588

‡ No cistern sizing information reported by source

Table 6. Minnesota Department of Transportation 20-year life cycle costs based on treated water volume in 2005 dollars ($)
(From the MN DOT Cost and Effectiveness of Stormwater Management Practices, 22)

Capital costs + 20-year O&M costs, excluding land costs:		Treated Water Volume (ft^3)		
		3,000	10,000	30,000
Dry Detention Basin	2005 dollars	$22,000	$46,000	$91,000
	2012 dollars	$28,000	$58,500	$116,000
Infiltration Trench	2005 dollars	$84,000	$226,000	$554,000
	2012 dollars	$107,000	$287,500	$705,000
Bioinfiltration Filter	2005 dollars	$49,000	$122,000	$286,000
	2012 dollars	$62,000	$155,000	$364,000

Table 7. Gallons of stormwater managed per $1,000 invested (data from Plum and Seggos 2007) (From the Economics of Low Impact Development Literature Review, 23)

LID Stormwater Practice	Gallons of stormwater managed per $1,000 invested (2007 dollars)	Gallons of stormwater managed per $1,000 invested (2012 dollars)
Conventional storage tanks	2,400	2,110
Green Streets	14,800	13,010
Street Trees	13,170	11,580
Green Roofs	810	710
Rain Barrels	9,000	7,910

Relevant Manuals and Reports

Sources used to estimate the costs of volume reduction BMPs are listed below in order of importance/relevance, with a description of each source, as reported by that source. The two boxed sources at the end were not used in this literature review, but the reader is encouraged to utilize these tools in the future to estimate specific costs of volume reduction BMPs.

[21] The **1991 Southwestern Wisconsin Regional Planning Commission Technical Report: Costs of Urban Nonpoint Source Water Pollution Control Measures** provides guidance for estimating the capital and annual operation maintenance costs of urban nonpoint source control measures including: wet detention basins, infiltration trenches, infiltration basins, grassed swales, vegetated filter strips, pervious pavement, catch basin cleaning, and street sweeping.

[5] The **Charles River Watershed Association 2008 Low Impact Best Management Practice (BMP) Information Sheets** provide summaries of the current understanding of the benefits, performance, installation costs, maintenance needs and costs, and additional concerns regarding several Low Impact Development BMPs.

[22] The **2005 MN DOT Report: The Cost and Effectiveness of Stormwater Management Practices** evaluated urban stormwater management practices for cost and effectiveness in removing suspended sediments and phosphorus. Construction and annual operating and maintenance cost data was collected and analyzed for dry detention basins, wet basins, sand filters, constructed wetlands, bioretention filters, infiltration trenches, and swales using literature that reported on existing BMP sites across the United States.

[23] The **2007 ECONorthwest Economics of Low-Impact Development Literature Review** summarizes the literature that identifies and measures the economic costs and benefits of managing stormwater using LID, or that compares costs or benefits, or both, between LID and conventional controls.

Final report available soon:

[25] The **2011 EPA DRAFT Report: Achieving More Cost-Effective Stormwater Plans Using Low-Impact Development (LID) Strategies** presents four detailed comparative case studies that compare the established LID design to an alternative conventional design with respect to 1.) Stormwater Performance Assessment, 2.) Capital Cost Comparisons, 3.) Life Cycle Cost Assessments, and 4.) Cost-Effectiveness Comparisons. Four additional case studies are presented that compare capital costs only. The information presented in this draft report cannot be reproduced, please refer to the final draft when available.

Available online:

[24] The **2009 WERF BMP and LID Whole Life Cost Models** is an online tool to assist planners, developers, and engineers with estimating whole life costs for stormwater BMPs and LID practices.

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IV. MAINTENANCE

Introduction

The long term performance of BMPs is also reliant on proper operation and regular maintenance. High failure rates of stormwater infiltration practices from the 1980s have been attributed to inadequate buffer strips (i.e., pretreatment), infrequent inspections, and poor overall maintenance which resulted in sediment accumulation and clogging ([43] Lindsey *et al.* 1982). Therefore, it is highly recommended that site designers communicate how to maintain stormwater BMPs in an Operation & Maintenance (O&M) Manual. Owners and maintenance staff will be able to reference this manual, for example, when they have questions about sediment removal, valve operation, or capacity for future site expansion. Contents of an O&M manual could include: as-built plans, operating instructions for weirs and valves, vegetation list, vegetation maintenance schedule, and maintenance checklists.

Main Findings

Recommended maintenance activities and frequency for the non-structural volume reduction BMPs are listed in the following tables (Table 8 to Table 19). Where available, maintenance checklists are also included. BMPs that were source control and did not require maintenance were impervious surface reduction and soil amendments. For the other volume reduction BMPs, typical maintenance activities include:

1. Sediment and debris removal
2. Vegetative upkeep
3. Site erosion control
4. Mechanical system upkeep and repairs (if applicable)
5. Annual inspections for performance

In general, maintenance requirements tend to be greater in the first few years following construction to ensure proper establishment of vegetation. After vegetation is established, maintenance requirements are often less burdensome, but it depends on the amount of sediment and debris that accumulates and needs to be removed, the upkeep demand of plant species, the susceptibility of a site to erosion and degradation, and whether the BMP uses a mechanical system.

Source Control BMPs

Impervious Cover Reduction

Table 8. Vegetated landscaping recommended maintenance activities and frequency.

Maintenance and Inspection Activity [From: 1,6]	Frequency
☐ Water plants. ☐ Re-mulch void areas. ☐ Treat diseased trees and shrubs. ☐ Prune and weed to maintain appearance.	As needed [1]
☐ Inspect soil and repair eroded areas. ☐ Remove litter and debris.	Monthly [6]
☐ Add additional mulch.	Annually [6]

Pervious Pavement Systems

Table 9. Pervious pavement recommended maintenance activities and frequency.

Maintenance and Inspection Activity [From: 3]	Frequency
☐ Reservoir dewatering within 72 hours.	After major storms
☐ Inlet Structures: Drainage pipes and structures within or draining to the subsurface bedding beneath pervious pavement should be cleaned out on regular intervals.	As needed, frequent
☐ Grid pavers: Should be mowed regularly with grass clippings removed. May require periodic watering and fertilization to establish and maintain healthy vegetation.	As needed, frequent
☐ Drainage Areas: Impervious areas contributing to the pervious pavement should be regularly swept and kept clear of litter and debris. Flows from any landscaped areas should be diverted away from the pavement or be well stabilized with vegetation.	Semiannual
☐ Surface Sweeping: Sweeping should occur once or twice a year with a commercial vacuum sweeping unit to mitigate sediment accumulation and ensure continued porosity. Pervious pavement should not be washed with high pressure water systems or compressed air units, because they will push particles deeper into the pavement.	Annual to semiannual
☐ Inspection of pavement surface for deterioration.	Annually
☐ Heavy Vehicles: Trucks and other heavy vehicles can grind dirt into the porous surface and lead to clogging. These vehicles should be prevented from tracking or spilling dirt onto the pavement. Signage and training of facilities personnel is suggested.	Operation recommendation
☐ Construction and Hazardous Materials: Due to the potential for groundwater contamination, all construction or hazardous material carriers should be prohibited from entering a pervious pavement site.	Operation recommendation
☐ Winter Maintenance: No sand. Deicers used in moderation – pilot studies have found that pervious pavements require 75% less de-icing salt than convention pavement.	Operation recommendation

Downspout Disconnection

Table 10. Downspout disconnection recommended maintenance activities and frequency.

Maintenance and Inspection Activity [From: 3]	Frequency
Maintain infiltration capacity of soil: ☐ Plant shrubs or trees along perimeter to prevent traffic. ☐ If ponding of water remains longer than 24 hours, dethatch and aerate, or if ponding still occurs, regrade or till to reverse compaction and/or add compost to improve soil moisture retention.	Annually

Green Roofs

Table 11. Green roof recommended maintenance activities and frequency.

Maintenance and Inspection Activity [From: 3,5]	Frequency
☐ Leak detection. Electronic leak detection systems recommended.	After rain events [3]
☐ Watering based on actual soil moisture conditions as plants are designed to be drought tolerant.	As needed [3]
☐ Repair underlying roofing and waterproofing materials.	As needed [5]
☐ Monitor vegetation to ensure dense coverage.	Monthly in first 2 years, then biannual [3]
☐ Weeding to remove volunteer seedlings of trees and shrubs and debris removal. ☐ Keep overflow conveyance system clear.	Biannual [3]

Routing BMPs

Filter Strips and Level Spreaders

Table 12. Filter strip and level spreader recommended maintenance activities and frequency.

Maintenance Activity [From: 6]	Frequency
☐ Mow turf grass with low ground pressure equipment to a three- or four-inch height. Cut only when soil is dry to prevent tracking damage to vegetation, soil compaction, and flow concentrations.	Regular (frequent)
☐ Remove sediment and replant in areas of buildup. ☐ Limit fertilizer applications based on plant vigor and soil test results.	Regular (infrequent)
☐ Remove built-up sediment from pea gravel diaphragm/level spreader. ☐ Inspect for rills and gullies. Immediately fill rills and gullies with topsoil, install erosion control blanket and seed or sod. ☐ In areas without well-established vegetation, prepare soil and reseed or replace with alternative species. Install erosion control blanket.	Annual (Semiannual Year 1)
Inspection Checklist [From: 1]	**Frequency**
1. Debris Cleanout ☐ Contributing areas clean of litter and vegetative debris. ☐ Inlet and outlet clear. ☐ Filtration facility clean.	Monthly
2. Check Dams or Energy Dissipators ☐ No evidence of flow going around structures. ☐ No evidence of erosion at downstream toe.	Annual After Major Storms
3. Vegetation ☐ Minimum mowing depth not exceeded. ☐ Undesirable vegetation removed. ☐ No evidence of erosion.	Monthly
4. Dewatering ☐ Dewaters between storms within 48 hours.	Monthly
5. Sediment Deposition ☐ Clean of sediment. ☐ Winter accumulation of sand removed each spring. ☐ Contributing drainage area stabilized and free of erosion.	Annual
6. Outlet/Overflow Spillway ☐ Good condition, no need for repairs. ☐ No evidence of erosion. ☐ No evidence of blockage.	Annual

Dry Swales

Table 13. Dry swale recommended maintenance activities and frequency.

Maintenance Activity [From: 6]	Frequency
☐ Mow turf grass to 4 inches. ☐ Mow native grasses once a year early in spring – mowing in first year is critical to eliminate competition from annual weeds.	Frequent as needed
☐ Remove sediment buildup on the bottom of swale once it has accumulated to 25 percent of original design volume. ☐ Reseed as necessary to maintain dense vegetation. ☐ Fertilize rarely to avoid unnecessary export of nutrients, if necessary based on soil test, apply in cool spring or fall weather and with no phosphorus.	Infrequent as needed
☐ Ensure grass cover establishes – reseed. ☐ Remove excess sediment from pea gravel diaphragm ☐ Remove trash and debris.	Annual
Inspection Checklist [From: 1]	**Frequency**
1. Debris Cleanout ☐ Contributing areas clean of litter and vegetative debris. ☐ Inlet and outlet clear. ☐ Filtration facility clean.	Monthly
2. Check Dams or Energy Dissipators ☐ No evidence of flow going around structures. ☐ No evidence of erosion at downstream toe.	Annual After Major Storms
3. Vegetation ☐ Minimum mowing depth not exceeded. ☐ Undesirable vegetation removed. ☐ No evidence of erosion.	Monthly
4. Dewatering ☐ Dewaters between storms within 48 hours.	Monthly
5. Sediment Deposition ☐ Clean of sediment. ☐ Winter accumulation of sand removed each spring. ☐ Contributing drainage area stabilized and free of erosion.	Annual
6. Outlet/Overflow Spillway ☐ Good condition, no need for repairs. ☐ No evidence of erosion. ☐ No evidence of blockage.	Annual

Surface Treatment BMPs

Bioretention Devices

Table 14. Bioretention device recommended maintenance activities and frequency.

Maintenance Activity [From: 1,6]	Frequency
☐ Water as necessary during dry periods. Treat diseased trees and shrubs. Prune and weed to maintain appearance. Mow filter strip.	As needed after first growing season [1,6]
☐ Remove any sediment and debris build-up in pre-treatment areas. ☐ Remove as necessary build-up of road sand associated with spring melt period and replant areas that have been impacted by sand/salt build up.	Annually [1]
☐ Replace mulch over the entire area. ☐ Replace pea gravel diaphragm or filter fabric if warranted. ☐ Test soil for pH. Modify soil to main soil pH of 5.2 – 8.0.	2 to 3 years [1]
Inspection Checklist [From: 1]	**Frequency**
1. Debris Cleanout ☐ Contributing areas clean of litter and vegetative debris. ☐ No dumping of yard wastes into practice. ☐ Bioretention areas clean of litter and vegetative debris.	Monthly
2. Vegetation ☐ Plant height taller than design water depth. ☐ Undesirable vegetation removed. ☐ Grass height less than 6 inches. ☐ No evidence of erosion.	Monthly
3. Dewatering ☐ Dewaters between storms within 48 hours. ☐ No evidence of standing water.	Monthly
4. Check Dams/Energy Dissipators/Sumps ☐ No evidence of sediment buildup. ☐ Sumps should not be more than 50% full of sediment. ☐ No evidence of erosion at downstream toe of drop structure.	Annual After major storms
5. Outlet/Overflow Spillway ☐ Good condition, no need for repair. ☐ No evidence of erosion. ☐ No evidence of any blockages.	Annual After major storms
6. Sediment Deposition ☐ Pretreatment areas clean of sediments. ☐ Contributing drainage area stabilized and clear of erosion. ☐ Winter sand deposition evacuated every spring.	Annual
7. Integrity of Filter Bed ☐ Filter bed has not been blocked or filled inappropriately.	Annual

Tree Trenches

Table 15. Tree trench recommended maintenance activities and frequency.

Maintenance and Inspection Activity [From: 5]	Frequency
☐ Inspect plants and structural components. ☐ Clean inflow and outflow mechanisms. ☐ Test mulch and soil for build-up of pollutants that may be harmful to the vegetation.	Periodic
☐ Replace mulch.	Biannual
☐ Complete replacement of filter.	25 years

Infiltration Basins

Table 16. Infiltration basin recommended maintenance activities and frequency.

Maintenance Activity [From: 1, 3, 6]	Frequency
☐ Clean out leaves, debris and accumulated sediment caught in pretreatment device, inlets and outlets.	Annually [3]
☐ Sediment removal should be performed when sediment is dry enough to crack and readily separate from the basin floor. Light equipment which will not compact the underlying soil, should be used to remove the top layer of sediment. The remaining soil should be tilled and re-vegetated as soon as possible.	As needed [6]
☐ Vegetation should be maintained to control weed growth and maintain the health of the vegetation in the basin. Weed once monthly during the first two growing seasons. After that, weeding two or three times per growing season.	Monthly to biannually [6]
☐ Disc or otherwise aerate basin bottom. De-thatch basin bottom.	Annually [1]
☐ Scrape basin bottom and remove sediment. Restore original cross-section and infiltration rate. Seed or sod to restore cover.	Every 5 years [1]
Inspection Checklist [From: 1]	**Frequency**
1. Debris Cleanout ☐ Contributing drainage area clear of litter and vegetative debris.	Monthly
2. Dewatering ☐ Basin dewaters between storms.	Monthly
3. Vegetation ☐ Minimum growing depth not exceeded. ☐ Undesirable vegetation removed. ☐ No evidence of erosion.	Monthly
4. Sediment Deposition of Basin ☐ Clean of sediment. ☐ Winter accumulation of sand removed each spring. ☐ Contributing drainage area stabilized and free of erosion.	Annual
5. Inlets ☐ Good condition. ☐ No evidence of erosion.	Annual
6. Outlet/Overflow Spillway ☐ Good condition, no need for repair. ☐ No evidence of erosion.	Annual

Subsurface Treatment BMPs

Below-ground Recharge Systems

Table 17. Below-ground recharge system recommended maintenance activities and frequency.

Maintenance Activity [From: 1]	Frequency
☐ Replace clogged pea gravel/topsoil and top surface filter fabric.	As needed
☐ Remove sediment and oil/grease from pre-treatment devices, as well as overflow structures. ☐ Mow grass filter strips should be mowed as necessary. Remove grass clippings. ☐ Repair undercut and eroded areas at inflow and outflow structures.	Monthly
☐ Remove trees that start to grow in the vicinity of the trench.	Semi-annual inspection
☐ Perform total rehabilitation of the trench to maintain design storage capacity. Excavate trench walls to expose clean soil.	Upon failure
Inspection Checklist [From: 1]	**Frequency**
1. Debris Cleanout ☐ Contributing drainage area clear of litter and vegetative debris. ☐ Trench surface and inlet area clean. ☐ Inflow pipes and overflow spillway clear.	Monthly
2. Dewatering ☐ Trench dewaters between storms.	Monthly
3. Sediment Traps or Forebays ☐ Evidence of trapping sediment. ☐ Greater than 50% of storage volume remaining.	Annual
4. Sediment Cleanout of Trench ☐ No evidence of sedimentation in gravel filter. ☐ Sediment accumulation doesn’t yet require cleanout.	Annual
5. Inlets ☐ Good condition. ☐ No evidence of erosion.	Annual
6. Outlet/Overflow Spillway ☐ Good condition, no need for repair. ☐ No evidence of erosion.	Annual
7. Aggregate Repairs ☐ Surface of aggregate clean. ☐ Top layer of stone does not need replacement. ☐ Trench does not need rehabilitation.	Annual

Reuse BMPs

Rainwater Harvesting

Table 18. Rainwater harvesting recommended maintenance activities and frequency.

Maintenance and Inspection Activity [From: 3]	Frequency
☐ Regular inspections.	Every 6 months (spring and fall)
☐ Keep leaf screens, eavestroughs and downspouts free of leaves and other debris. ☐ Check screens and patch holes or gaps. ☐ Clean and maintain first flush diverters and filters, especially those on drip irrigation systems. ☐ Inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots. ☐ Replace damaged components. ☐ Mosquito control: If screening is not sufficient to deter mosquitoes, vegetable oil can be used to smother larvae.	As needed

Stormwater Harvesting

Table 19. Stormwater harvesting recommended maintenance activities and frequency.

Maintenance and Inspection Activity [From: 7]	Frequency
☐ Inspect operation of the stormwater harvesting system to assure that the pump, flow meter, and filter system are operating properly and achieving desired flow volumes. ☐ Inspect operation of the irrigation system to assure that the pump, timer, distribution lines, and sprinkler heads are working properly.	Monthly and after major storm events
☐ Submit a maintenance log including the following: – Stormwater volume harvested using a flow meter specifying the day, time, and volume – Stormwater volume irrigated or otherwise used using a flow meter specifying the day, time, and volume used – Observations of the stormwater harvesting system operation, maintenance, and a list of parts that were replaced – Observations of the irrigation system operation, maintenance, and a list of parts that were replaced – Dates on which the stormwater harvesting and irrigation (or other use systems) were inspected and maintenance activities conducted	Every 2 years

Relevant Manuals

Because of the fundamental nature of maintenance, every stormwater manual includes some description of the required operation and maintenance for individual BMPs. Due to the large overlap in O&M requirements across sources, the maintenance recommendations in this literature were derived from one or two key references for each BMP, summarized below:

[1] The **2008 Minnesota Stormwater Manual** contains detailed design guidance for Low Impact Development and stormwater BMPs in the context of Minnesota climate and regulations.

[3] The **CVC/TRCA 2010 Low Impact Development Planning and Design Guide** contains detailed design guidance for Low Impact Development activities in the context of the Toronto climate and regulations. The CVC is noted for its progressive use of LID.

[5] The **Charles River Watershed Association 2008 Low Impact Best Management Practice (BMP) Information Sheets** provide summaries of the current understanding of the benefits, performance, installation costs, maintenance needs and costs, and additional concerns regarding several Low Impact Development BMPs. In addition, the CRWA developed three matrices to help municipal officials, developers and others with the selection of stormwater BMPs, including stormwater management goals, physical and site specific constraints and opportunities, and installation, operational, and maintenance costs and requirements.

[6] The **2001 Minnesota Urban Small Sites BMP Manual** provides information on tools and techniques to assist Twin Cities' municipalities and WMOs in guiding development and redevelopment. The manual includes detailed information on 40 BMPs that are aimed at managing stormwater pollution for small urban sites in a cold-climate setting.

V. DESIGN GUIDANCE

Introduction

Detailed design specifications can be found for each volume reduction BMP in Appendix A at the end of the literature review. The guidelines found in Appendix A were chosen from the source with the most current or extensive summary of BMPs with a focus on volume reduction that are in a cold climate. Only one or two guidelines were chosen for each BMP. Additional information can be found in the sources listed in Table 1.

Main Findings

There are a variety of proposed design guidances on BMPs. Some guidelines are technical in nature due to the physical settings where they are implemented. The fact sheets listed below are not detailed to the level of design drawings and specifications, but were chosen for their broad target audience and are a good overview of the BMP. Note: The information found in the guidelines listed below should be reviewed with the Wisconsin Conversation Standards for compliance with location specific regulations.

Source Control BMPs

Impervious Cover Reduction

- Pollution Prevention Fact Sheet: Reducing Impervious Surfaces [2]
- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Low Impact Development Site Design Strategies [3]

Soil Amendments/ Decompaction

- Pollution Prevention Fact Sheet: Volume Control Using Compost Materials/ Soil Amendments [2]

Pervious Pavement Systems

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Permeable Pavement [3]

Downspout Disconnection

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Downspout Disconnection [3]

Green Roofs

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Green Roof [3]

Routing BMPs

Level Spreaders and Filter Strips

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Vegetated Filter Strips [3]

Dry Swales

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Dry Swale [3]

Surface Treatment BMPs

Bioretention Devices

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Bioretention [3]

Tree Trenches

- Charles River Watershed Association Low Impact Best Management Practice Information Sheet: Stormwater Tree Pit [5]

Infiltration Basins

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Soakaways, Infiltration Trenches and Chambers [3]

Subsurface Treatment BMPs

Below-ground Recharge Systems

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Soakaways, Infiltration Trenches and Chambers [3]

Reuse BMPs

Rainwater (Stormwater) Harvesting

- CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Rainwater Harvesting [3]
- No fact sheets are available for stormwater reuse, but similar principles apply for stormwater reuse as rainwater reuse.

Relevant Manuals

Detailed design guidelines have been created for many states and municipalities. These guidelines are often summarized in shorter fact sheets to help choose appropriate stormwater BMPs for a given site. Over ten guides are listed in Section VII that are more commonly referred to in the upper Midwest area. The fact sheets included in the appendices at the end of this literature review were chosen from two sources and were chosen for being the most recent and comprehensive for volume reduction BMPs for cold climates.

[2] The pollution prevention fact sheets contained in the **EOR 2008 Guide on Utilizing Pollution Prevention Activities to Meet MS4 General Permit Requirements** provide communities regulated under the Minnesota Municipal Separate Storm Sewer Systems General Permit with basic tools and information that will lead to increased use of pollution prevention activities within stormwater pollution prevention programs and local stormwater programs. This reference contains information on the following BMPs:

- Reducing Impervious Surfaces
- Pervious Pavement Systems
- Volume Control Using Compost Materials/ Soil Amendments
- Green Roofs
- Rainwater Harvesting/ Stormwater Reuse & Rain Barrel Programs
- Urban Forestry & Stormwater Management
- Vegetated Swales & Buffer Strips

[3] The **CVC/TRCA 2010 Low Impact Development Planning and Design Guide** contains detailed design guidance for Low Impact Development activities in the context of the Toronto climate and regulations. The CVC is noted for its progressive use of LID. This reference contains information on the following BMPs:

- Low Impact Development Site Design Strategies
- Permeable Pavement
- Downspout Disconnection
- Soakaways, Infiltration Trenches and Chambers
- Vegetated Filter Strips
- Dry Swales
- Bioretention
- Green Roofs
- Rainwater Harvesting

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VI. SITE SUITABILITY

Introduction

Selecting the most appropriate volume control BMP is dependent on site conditions. Optimal site characteristics, including site topography, distance to water table, soil type, drainage area, and setbacks, were summarized by BMP in tables in the following section (Table 20 to Table 30). The site requirements reported in this literature review are not comprehensive but represent the broad range of requirements for each volume reduction BMP. Detailed site requirements can be found for each volume reduction BMP in the appendices at the end of the literature review and in the references listed in Table 1. Note: The information found in the guidelines listed below should be reviewed with the Wisconsin Conversation Standards for compliance with location specific regulations.

Main Findings

One major feature of the site is the slope of the drainage area. Slope can be a factor in BMP suitability due to the physical configuration of the BMP and that steeper slopes can create challenges to the design of the BMP. The ranges provided are guidelines. Designing outside the typical slope ranges can be accomplished, but more design effort will be needed accommodate that type of BMP. Dry swales and pervious pavements work well in low slope settings (1-3%), filter strips and bioretention devices can be used in slighter higher slopes (1-5%), green roofs can be built on roofs with slopes up to 10%, and infiltration basins can be built in sites with the greatest slopes (up to 15%).

Another important feature of the site is the distance to the seasonally high water table. As discussed in the previous section regarding groundwater quality, stormwater BMPs with high recharge capacity have the risk to degrade groundwater quality, especially at depths less than 5 feet. As a result, most BMPs require a separation from the bottom of the treatment system to the top of the seasonally high water table of at least 5 feet.

In order to properly function for stormwater volume reduction, stormwater BMPs without under drains must be constructed in soil with adequate infiltration rates. Pervious pavements, dry swales, infiltration systems, and bioretention devices perform best in Hydrologic Soil Groups A and B, or in soils amended to achieve an infiltration rate of at least 0.6 inches per hour and connected to a pervious layer. BMPs in less pervious soils can also be used, but under drains will be an important part of the design and volume reduction will be driven more by evaporation and transpiration than by recharge.

Other considerations include drainage areas relative to BMP surface area and other zoning or setback requirements. These vary considerably by BMP and are specific to local runoff characteristics and regulations. **The site suitability data presented in Tables 20 – 30 below were primarily drawn from the City of Toronto.** These site considerations should be viewed as a starting point for possible site considerations specific to the City of Fitchburg and Dane County.

Infiltration suitability

Contexts where infiltration practices should not be used ([38] Ferguson 1994):

- Soil as impervious as the roofs and pavements that will be placed upon it;
- Highly contaminated soils (e.g., toxic waste or saline deposits);
- Steep unstable slopes; and,
- Land in close proximity to water supply wells, septic tanks, basements or other sensitive structural foundations.

In these contexts, evaporation and harvesting are more appropriate management techniques ([20] TCRA 2009).

Source Control BMPs

Impervious Cover Reduction

Table 20. Impervious cover reduction site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	Useful for steep topography
Water Table	N/A
Soil	N/A
Drainage Area	N/A
Setbacks	Residential street minimum width requirements. Front yard setback requirements. Area zoning ordinance requirements for outside roadway radii and right-of-ways.

Pervious Pavement Systems

Table 21. Pervious pavements site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	At least 1% and no greater than 5%
Water Table	Greater than 5 feet above seasonally high water table or top of bedrock elevation
Soil	Infiltration rate of native soils greater than 0.6 inches per hour. Systems located in native soils with an infiltration rate less than 0.6 inches per hour require a perforated pipe under drain
Drainage Area	Impervious area treated should not exceed 1.2 times the area of pervious pavement which receives the runoff
Setbacks	Located downslope from building foundations Recommended minimum setback of 12 feet If pavement does not receive runoff from other surfaces, no setback required

Downspout Disconnection

Table 22. Downspout disconnection site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	Discharge to gradual slope (1 – 5 %) that conveys runoff away from the building.
Water Table	Disconnect only where minimum depth to the seasonally high water table is at least 5 feet below the surface
Soil	Infiltration rates adequate to prevent ponding water following rain events.
Drainage Area	N/A
Setbacks	N/A

Green Roofs

Table 23. Green roof site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	N/A
Water Table	N/A
Soil	N/A
Drainage Area	N/A
Setbacks	N/A
Other	Roofs with slopes up to 10%

Surface Treatment BMPs

Level Spreaders and Filter Strips

Table 24. Level spreader and filter strip site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	Runoff from ground-level impervious surfaces that generate sheet flow. Flow path length across filter strip should be at least 15 feet with 1 to 5 % slope.
Water Table	Greater than 5 feet above seasonally high water table or top of bedrock elevation
Soil	All soil types. Heavily compacted soils should be tilled to a depth of 12 inches and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume.
Drainage Area	Maximum flow path length across contributing impervious surfaces less than 100 feet.
Setbacks	N/A

Dry Swales

Table 25. Dry swale site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	Longitudinal slopes ranging from 0.5 to 4%. On slopes steeper than 3%, check dams should be used.
Water Table	Greater than 5 feet above seasonally high water table or top of bedrock elevation
Soil	Hydrologic soil groups A and B are preferable, or located in portions of the site with the highest native soil infiltration rates. Where infiltration rates are less than 0.6 inches per hour, an underdrain is required.
Drainage Area	Typically treat drainage areas of two hectares or less. Typical ratios of impervious drainage area to swale surface area range from 5:1 to 15:1.
Setbacks	Facilities should be setback a minimum of twelve (12) feet from building foundations unless an impervious liner and underdrain is used.
Other	Proximity to underground utilities. Swale length between culverts should be 15 feet or greater.

Surface Treatment BMPs

Bioretention Cells

Table 26. Bioretention cell site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	Contributing slopes should be between 1 to 5 %.
Water Table	The bottom of the system should be vertically separated by 5 feet from the seasonally high water table or top of bedrock elevation.
Soil	Hydrologic soil groups A and B are preferable, or located in portions of the site with the highest native soil infiltration rates. Where infiltration rates are less than 0.6 inches per hour, an underdrain is required.
Drainage Area	Typical contributing drainage areas are between 1000 square feet and 1 acre. The maximum recommended contributing drainage area is 2 acres. Typical ratios of impervious drainage area to swale surface area range from 5:1 to 15:1.
Setbacks	Facilities should be setback a minimum of twelve (12) feet from building foundations unless an impervious liner is used.
Other	Proximity to underground utilities and overhead wires (if trees are used)

Tree Trenches

Table 27. Tree trench site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	None given
Water Table	None given
Soil	None given
Drainage Area	Should not be placed at low points as they are not designed to collect large volumes of runoff.
Setbacks	None given
Other	Proximity to underground utilities and overhead wires.

Subsurface Treatment BMPs

Below-ground Recharge Systems

Table 28. Below-ground recharge system site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	Slopes less than 15%
Water Table	The bottom of the system should be vertically separated by 5 feet from the seasonally high water table or top of bedrock elevation.
Soil	Hydrologic soil groups A and B are preferable, or located in portions of the site with the highest native soil infiltration rates.
Drainage Area	Impervious drainage area to treatment system area ratio between 5:1 and 30:1 A maximum ratio of 10:1 is recommended for facilities receiving road or parking lot runoff
Setbacks	Facilities should be setback a minimum of twelve (12) feet from building foundations.
Other	Proximity to underground utilities.

Reuse BMPs

Rainwater Harvesting

Table 29. Rainwater harvesting and reuse site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	None given
Water Table	None given
Soil	All soils
Drainage Area	Variable
Setbacks	None given

Stormwater Harvesting

Table 30. Stormwater harvesting and reuse site considerations (adapted from: 3)

Site Characteristic	Considerations
Site Topography	None given
Water Table	None given
Soil	All soils
Drainage Area	Variable
Setbacks	None given

Relevant Manuals

Site suitability guidelines were drawn from the fact sheets included in the appendices at the end of this literature review, listed below. See Design Guidelines for rationale in choosing these two sources.

[2] The pollution prevention fact sheets contained in the **EOR 2008 Guide on Utilizing Pollution Prevention Activities to Meet MS4 General Permit Requirements** provide communities regulated under the Minnesota Municipal Separate Storm Sewer Systems General Permit with basic tools and information that will lead to increased use of pollution prevention activities within stormwater pollution prevention programs and local stormwater programs. This reference contains information on the following BMPs:

- Reducing Impervious Surfaces
- Pervious Pavement Systems
- Volume Control Using Compost Materials/ Soil Amendments
- Green Roofs
- Rainwater Harvesting/ Stormwater Reuse & Rain Barrel Programs
- Urban Forestry & Stormwater Management
- Vegetated Swales & Buffer Strips

[3] The **CVC/TRCA 2010 Low Impact Development Planning and Design Guide** contains detailed design guidance for Low Impact Development activities in the context of the Toronto climate and regulations. The CVC is noted for its progressive use of LID. This reference contains information on the following BMPs:

- Low Impact Development Site Design Strategies
- Permeable Pavement
- Downspout Disconnection
- Soakaways, Infiltration Trenches and Chambers
- Vegetated Filter Strips
- Dry Swales
- Bioretention
- Green Roofs
- Rainwater Harvesting

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VII. COLD CLIMATE SUITABILITY

Introduction

Stormwater managers in cold climates must recognize that runoff from snowmelt has characteristics different than those of rainfall runoff, and that BMP design criteria addressing only rainfall runoff might not work well during cold periods. This becomes a major problem because a substantial percentage of annual runoff volume and loading can come from snowmelt in years when snowfall is high. The heart of the problem with snowmelt runoff is that water volume in the form of snow and ice builds for several months and suddenly releases with the advent of warm weather in the spring or during short interim periods all winter long. The interim melts generally do not contribute a significant volume of runoff when compared to the large spring melt. Note that snowmelt peaks are substantially less than those from rainfall, but the total event volume of a snowmelt, although it occurs over a much longer period, can be substantially more. Ignoring the contribution of large spring melts to the annual runoff and pollution loading analysis could be a major omission in a watershed analysis.

The following section details cold climate conditions and associated design challenge for stormwater BMPs in cold climates, addresses the suitability of volume reduction BMPs in cold climates, and discusses design considerations and modifications necessary for proper operation of volume reduction BMPs in cold climates.

Main Findings

Cold Climate Challenges

The 1997 Stormwater BMP Design Supplement for Cold Climates identified the following cold climate conditions and associated BMP design challenges:

1. Cold Temperatures
    - Pipe freezing
    - Permanent pool ice-covered
    - Reduced biological activity
    - Reduced oxygen levels during ice cover
    - Reduced settling velocities
2. Deep Frost Line
    - Frost heaving
    - Reduced soil infiltration
    - Pipe freezing
3. Short Growing Season
    - Short time period to establish vegetation
    - Different plant species appropriate to cold climates than moderate climates
4. Significant Snowfall
    - High runoff volumes during snowmelt and rain-on-snow
    - High pollutant loads during spring melt
    - Other impacts of road salt/deicers
    - Snow management may affect BMP storage

Pollution Prevention

One major concern for the design of stormwater BMPs in cold climates is accommodating high pollutant loads during spring melt. Section 8 of the 1997 Stormwater BMP Design Supplement for Cold Climates discussed options for controlling pollution from sand and other abrasives, road deicers (commonly road salt, NaCl) and airport deicers. Three measures were proposed to reduce pollution from sand application:

1. use of a clean sand source,
2. street sweeping during and immediately after the spring runoff, and
3. operator training focusing on application of the minimum amount of sand necessary.

In addition, several changes were also proposed to reduce pollution from traditional deicing:

1. apply less salt,
2. apply alternate deicers,
3. use additives to reduce deicer application,
4. change the timing of application,
5. modify spreaders, and
6. implement salt storage regulations.

Recent Research

One cold climate concern for stormwater BMPs is that road salt runoff can mobilize heavy metals increasing the potential for ground and surface water contamination from infiltration BMPs. Results from infiltration experiments conducted at two highway infiltration pond sites in Washington indicated that sodium chloride resulted in the release of copper and lead. Using magnesium salt instead of sodium salt had less of an effect on lead and copper but had a much greater effect on the mobilization of cadmium. Releases of metals during or immediately following salt application produced concentrations that ranged from 50% to 1000% greater than the concentrations released from the control experiments ([47] Nelson *et al.* 2009).

Another cold climate concern is variability in seasonal performance of infiltration BMPs due to freezing temperatures. Variability in seasonal performance of infiltration BMPs has been related to temperature dependence of the viscosity of water ([37] Emerson and Traver 2008) and hydraulic conductivity of the soil ([31] Braga *et al.* 2007). Pervious asphalts in Sweden were found to have a 50% reduction in surface infiltration rates when temperatures decreased from 20°C to 0°C ([27] Bäckström and Bergstrom 2000). However, other studies suggest no reduction in performance during cold season months. A field study of a pervious-pavement system found minimal performance reduction from frozen media and attributed this to the well-drained nature of the pavement and underlying soil ([55] Roseen *et al.* 2012). They had also previously found that infiltration chambers perform optimally during the cold season when they are located well below the frost line ([54] Roseen *et al.* 2009). In addition, a multi-year study of pervious concrete over infiltration silt/sand beds showed that infiltration rates of the sand were lower during colder periods, but pollutant reduction to surface waters was greater than 90% due to infiltration to natural soils below the BMP ([40] Horst *et al.* 2011). Seasonal performance evaluations at the University of New Hampshire Stormwater Center field facility indicated that

LID designs have a high level of functionality during winter months and that frozen filter media do not reduce performance ([54] Roseen *et al.* 2009).

In a Minnesota study ([35] Davidson *et al.* 2008), experimental bioretention devices functioned for the majority of the winter season but infiltration stopped when air temperatures were well below freezing. They recommended the following design guidelines to optimize cold climate performance:

1. Use engineered soils devoid of silt or clay particles
2. Keep pool depths less than 1 foot deep that draw down to the frost line within 12 hours to minimize potential for freezing
3. Install an under drain system with a valve to permit operation as an infiltration or filtration system depending on conditions.

Cold Climate Suitability

The suitability of volume reduction BMPs with respect to the cold climate conditions is summarized in Table 31. A more detailed description of cold climate suitability and considerations for each volume reduction BMP is provided below. Specific design modifications for stormwater BMPs that address the design challenges listed above can be found in the 1997 Stormwater BMP Design Supplement for Cold Climates, the Minnesota Stormwater Manual, and the Low Impact Development Stormwater Management Planning and Design Guide.

Cold Climate Design Recommendations

(From the CVC/TRCA 2010 Low Impact Development Planning and Design Guide. Excerpts denoted by quotes and include cited references.)

Pervious Pavement Systems

"For cold climates, well-designed mixes can meet strength, permeability, and freeze-thaw resistance requirements. In addition, experience suggests that snow melts faster on a porous surface because of rapid drainage below the snow surface. Also, a well-draining surface will reduce the occurrence of black ice or frozen puddles ([32] Cahill Associates, 1993; [53] Roseen, 2007). Systems installed in the Greater Toronto Area have generally not suffered from heaving or slumping ([58] TRCA, 2008). Pervious pavement is typically designed to drain within 48 hours. If freezing should occur before the pavement structure has drained, then the large void spaces in the open graded aggregate base creates [an insulating] barrier to freeze-thaw. Pervious pavers have the added benefit of having enough flexibility to handle minor heaving without being damaged. Pervious pavement can be plowed, although raising the blade height 25 mm may be helpful to avoid catching pavers or scraping the rough surface of the pervious pavement. Sand should not be applied for winter traction on pervious pavement as this can quickly clog the system."

Green Roofs

"Green roofs are a feasible BMP for cold climates. Snow can protect the vegetation layer and once thawed, will percolate into the growing medium and is either absorbed or drained away just as it would during a rain event. No seasonal adjustments in operation are needed."

Level Spreaders and Filter Strips

Filter strips adjacent to roads and parking lots can act as a pervious snow storage area. Additional maintenance may be needed to remove accumulated sand and to replace vegetation damaged by road de-icing salts.

Bioretention Devices

"Performance studies show that bioretention effectively captures and treats runoff during winter months with average daily temperatures in the -5 to 10 ºC range ([59] Traver, 2005; [61] UNHSC, 2005, [54] Roseen *et al.*, 2009). Frost penetration of filter media varied from zero to 17 cm in studies at the University of New Hampshire ([53] Roseen, 2007). Year round monitoring of a bioswale in the Greater Toronto Area showed the facility continued to function during winter, with temperatures in the filter bed remaining above zero at a depth of 50 cm below the surface ([58] TRCA, 2008). While bioretention frequently accepts runoff containing high chloride concentrations, the dissolved chloride will pass through to the groundwater without treatment. Cold climate adaptation for bioretention designs include:

- extending the filter bed and underdrain pipe below the frost line,
- oversizing the underdrain to reduce the freezing potential, and
- selecting salt-tolerant vegetation.

Some bioretention design variants, such as stormwater planters and curb extensions, are new to cold climates and have not been monitored in winter conditions. Stormwater planters that are wholly above ground should be given special consideration, as the underdrain and other conveyance structures will be more susceptible to freezing."

Below-ground Recharge Systems

"Soakaways, infiltration trenches and chambers will continue to function during winter months if the inlet pipe and top of the facility is located below the local maximum frost penetration depth ([46] MTO, 2005)."

Rainwater Harvesting

"Rainwater harvesting systems can be used throughout the year if they are located underground or indoors to prevent problems associated with freezing, ice formation and subsequent system damage. Alternatively, an outdoor system can be used seasonally." [3]

Table 31. Cold climate suitability of volume reduction stormwater BMPs
(From: Table 9.3 in the Minnesota Stormwater Manual)

	Volume Reduction BMP	Cold Climate Suitability	Notes
SOURCE CONTROL	**Impervious Surface Reduction**	Yes	Preserving pervious areas for meltwater to infiltrate is an effective way to control volume and to minimize mobilization of pollutants
	Soil Amendments	Yes	Enhancing soil permeability will increase recharge of meltwater
	Pervious Pavement Systems	Yes	Recent research has shown this approach to be successful in cold climates when properly installed and maintained, and when sanding is kept to a minimum
ROUTING	**Filter Strips**	Marginal	Vegetative filtering is reduced once vegetation dies back in fall; some physical filtering will occur if vegetation density and depth are sufficient
	Dry Swales	Yes	Routing meltwater over a pervious surface will yield some reduction in flow and improved water quality
SURFACE TREATMENT	**Bioretention Devices**	Yes-to-Marginal	These can provide needed storage during the cold season and for spring runoff events; vegetation will not be a factor during winter
	Tree Trenches	Marginal	These are designed for the growing season, but some do provide a sump area for runoff to collect and will infiltrate some of the volume
	Green Roofs	Yes	Recent research has shown that slow melting in the spring reduces the volume running off of roof surfaces
SUB-SURFACE TREATMENT	**Below-ground Recharge Systems**	Yes with Caution	Effective as long as the system is installed below the frostline to avoid ice build-up and designed, installed and maintained properly; caution applies to limitations on source area to avoid high concentrations of chloride and toxics
REUSE	**Rainwater Harvesting**	Yes with Caution	Capturing meltwater from a building can perform at higher levels and will reduce volume but ice build-up could be a problem unless collection occurs below frostline

Relevant Manuals and Reports

Three reports and many primary research papers were used to identify cold climate considerations for volume reduction BMPs. The Center for Watershed Protection 1997 Stormwater BMP Design Supplement for Cold Climates is the primary reference for design of traditional BMPs in cold climates. The Minnesota Stormwater Manual devotes a chapter to a detailed discussion regarding cold climate design challenges and recommended BMP considerations and modifications. The CVC/TRCA 2010 Low Impact Development Planning and Design Guide supplements these works with cold climate considerations of new BMPs.

[11] The **Center for Watershed Protection 1997 Stormwater BMP Design Supplement for Cold Climates** identifies cold climate design challenges, provides detailed guidance on design modifications for traditional stormwater BMPs in cold climates, and recommends pollution prevention techniques for cold climate unique pollutants, such as salt, sand, and de-icers.

[1] The **2008 Minnesota Stormwater Manual** contains detailed design guidance for Low Impact Development and stormwater BMPs in the context of Minnesota climate and regulations.

[3] The **CVC/TRCA 2010 Low Impact Development Planning and Design Guide** summarizes in detail cold climate considerations for Low Impact Development BMPs.

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Appendix A. Volume Reduction Best Management Practice Design Guides

The following design guides are included in a separate document:

Impervious Cover Reduction
Pollution Prevention Fact Sheet: Reducing Impervious Surfaces
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Low Impact Development Site Design Strategies

Soil Amendments/ Decompaction
Pollution Prevention Fact Sheet: Volume Control Using Compost Materials/ Soil Amendments

Pervious Pavement Systems
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Permeable Pavement

Downspout Disconnection
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Downspout Disconnection

Green Roofs
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Green Roof

Level Spreaders and Filter Strips
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Vegetated Filter Strips

Dry Swales
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Dry Swale

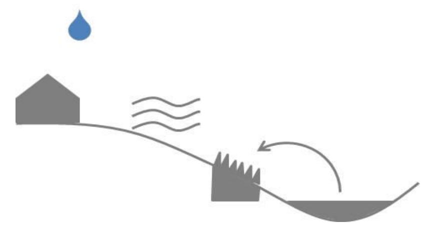
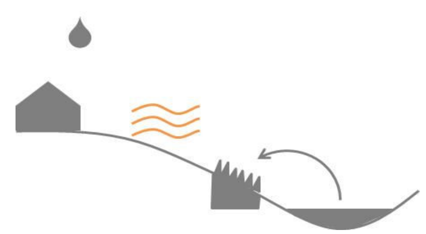
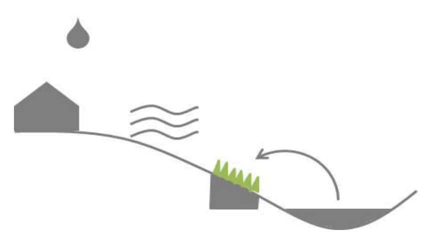
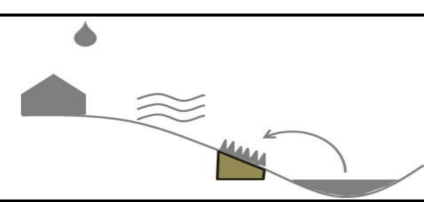
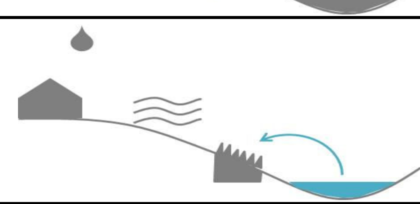
Bioretention Devices
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Bioretention

Tree Trenches
Charles River Watershed Association Low Impact Best Management Practice Information Sheet: Stormwater Tree Pit

Below-ground Recharge Systems
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Soakaways, Infiltration Trenches and Chambers

Rainwater (Stormwater) Harvesting
CVC/TRCA Low Impact Development Planning and Design Guide Fact Sheet: Rainwater Harvesting

Volume Reduction BMP Summary Matrix

	VOLUME REDUCTION BMP	LOCATION IN THE LANDSCAPE	HYDROLOGIC BENEFITS: INFILTRATION	HYDROLOGIC BENEFITS: EVAPO-TRANSPIRATION	HYDROLOGIC BENEFITS: RUNOFF VOLUME REDUCTION	SURFACE WATER POLLUTANT REMOVAL: TP	SURFACE WATER POLLUTANT REMOVAL: TN	SURFACE WATER POLLUTANT REMOVAL: TSS	SURFACE WATER POLLUTANT REMOVAL: Metals	GROUNDWATER CONTAMINATION RISK
SOURCE CONTROL	Impervious Cover Reduction		✔	✔	40%	30-55%	64%			
	Soil Amendments/ Decompaction		✔	✔	50-75%	50-75%	50-75%			
	Pervious Pavements		✔		45-85%	30-80%	60-80%		90%	♦
	Downspout Disconnection		✔	✔	25-50%	25-50%	25-50%			
	Green Roofs			✔	45-90%	highly variable	20-90%	70-90%	80%	
ROUTING	Level Spreaders		✓	✓	50-75%	50-75%	50-75%			
	Filter Strips		✓	✓	25-75%	30-80%	35%	75-90%	80%	
	Dry Swales		✓	✓	10-60%	15-75%	55-75%			
SURFACE TREATMENT	Bioretention Devices (without under drain)		✔	✔	65-85%	90%	90%		30-99%	♦
	Bioretention Devices (with underdrain)			✔	40-45%	55-65%	45-65%	85%	95%	
	Tree Trenches		✔	✔	variable	75%	70%	85%	80%	
	Infiltration Basins		✔	✔	50-90%	15-90%	60-90%			♦
SUBSURFACE TREATMENT	Below-ground Recharge Systems		✔		85%	50-80%	40-70%	70-90%	70-90%	♦
REUSE	Rainwater Harvesting				40%	40%	40%			
	Stormwater Harvesting		✓	✔	20-75%	45-95%				
NOTES			(With suitable soils) ✔ Primary Benefit ✓ Little Benefit		Reduction ranges represent variations in design and site conditions across multiple studies. As a result, comparisons between BMPs across different studies may not reflet true performance. Please refer to the individual references reported in Literature Review Table 2 for more information on how the volume and pollutant reductions were calculated.					♦= Pretreatment/siting restrictions needed to address groundwater contamination risk

Volume Reduction BMP Summary Matrix (continued)

	VOLUME REDUCTION BMP	MAINTENANCE: LIFESPAN	MAINTENANCE: REQUIREMENTS	SITE SUITABILITY: TOPOGRAPHY	SITE SUITABILITY: WATER TABLE	SITE SUITABILITY: SOIL TYPE	SITE SUITABILITY: DRAINAGE AREA: BMP AREA RATIO	SITE SUITABILITY: OTHER	OTHER CONSIDERATIONS: COLD CLIMATES	OTHER CONSIDERATIONS: CONTAMINATED SITES	OTHER CONSIDERATIONS: ULTRA URBAN
SOURCE CONTROL	Impervious Cover Reduction	> 30 years	L			All		☑; Zoning restrictions		M	L
	Soil Amendments/ Decompaction	> 30 years	L			All		☑		M	M
	Permeable Pavements	15-25 years	M	0-3%	≥ 5' separation	Infiltration ≥0.6 in/hr	1.2	☑	❄	L	H
	Downspout Disconnection	> 30 years	L	1-5%	≥ 5' separation	All		☑		L	L
	Green Roofs	Asphalt lifespan + 20 years	M	Roof slope <10%		All				H	H
ROUTING	Level Spreaders	10-20 years	L			All				M	L
	Filter Strips	> 30 years	L	1-5%	≥ 5' separation	All	< 100' wide	☑		H	H
	Dry Swales	> 30 years	M	0.5-3%	≥ 5' separation	A or B preferred	5 - 15 (< 2 ac)	☑		M	M
SURFACE TREATMENT	Bioretention Devices (without under drain)	> 20 years	M	1-5%	≥ 5' separation	A or B preferred	5 - 15 (0.5 - 2 ac)	Setback required	❄	L	H
	Bioretention Devices (with underdrain)	> 20 years	M			All	5 - 15 (0.5 - 2 ac)	Setback required	❄	H	H
	Tree Trenches	25 years	M			All		Utilities	❄❄	H	H
	Infiltration Basins	20-30 years	M	<15%	≥ 5' separation	A or B	5 - 30 (10 for roads)	☑, Setback required	❄	L	L
SUBSURFACE TREATMENT	Below-ground Recharge Systems	20-30 years	H	<15%	≥ 5' separation	A or B	5 - 30 (10 for roads)	Width≥Depth Setbacks required	❄	M	M
REUSE	Rainwater Harvesting	25 years	H			All			❄❄	H	H
	Stormwater Harvesting		H			All			❄❄	H	H
NOTES		**Estimates from:** CRWA EOR	**Relative ranking:** **L** - Low **M** - Medium **H** - High	**Source:** CVC/TRCA 2010	**Source:** Dane County	**Soil Types** **A** **B**	**Source:** CVC/TRCA 2010	**Source:** CVC/TRCA 2010 ☑ public right-of-way suitable	❄ design mod. required ❄❄ reduced performance	**Suitability:** **L** - Low **M** - Medium **H** - High	**Suitability:** **L** - Low **M** - Medium **H** - High

Reducing Impervious Surfaces

Reducing stormwater runoff through the use of alternative design standards and ordinance development

Impervious areas such as road and parking pavement, building surfaces, and walkways/driveways significantly increase stormwater runoff volumes, which in turn causes flooding and streambank erosion. Impervious surfaces also facilitate the wash-off and transport of pollutants like oil, grease and sediment into downstream rivers, lakes and wetlands. This fact sheet identifies methods and design standards used to achieve a reduction in the total runoff volume from impervious surfaces and gives examples of municipal ordinances that foster the reduction of impervious surfaces.

Benefits / Pollution Reduction

Reduced imperviousness results in smaller stormwater discharges which enhances flood control, reduces erosion and increases infiltration. Any reduction in runoff volume translates into reduced pollutant loads to downstream waters. Reduced runoff can also reduce the size and cost of stormwater management systems. Increased greenspace can facilitate recreational and community activities that enhance the quality of life of residents/employees.

Program Development & Implementation

Managing the extent of impervious area of buildings, roads and parking pavements occurs through the site planning and design process. Example methods to reduce imperviousness include but are not limited to, narrower road sections, alternative road layouts, reduced application of sidewalks and on-street parking, cul-de-sac design, parking lot design, house setbacks, structure/building impervious area limits and driveway designs. These methods are a component of design methodologies such as low impact development, design with nature, sustainable development and conservation design, and could become a part of standard building codes.

Design for Reducing Imperviousness

This strategy relies on several techniques to reduce the total area of rooftops, parking lots, streets, sidewalks and other types of impervious cover created at a development site. The basic approach is to reduce each type of impervious cover by downsizing the required minimum geometry specified in current local codes, keeping in mind that there are minimum requirements that must be met for fire, snowplow and school bus operation.

Image Courtesy of Emmons & Olivier Resources, Inc.

Trees and vegetation in the landscape of a cul-de-sac.

Impervious area can also be effectively removed by routing runoff flow to an area that will absorb the water, such as a yard, swale or bioretention area. Below are several techniques that can be used to reduce imperviousness. The City of Inver Grove Heights, MN, has implemented several of these techniques in its ordinance for the Northwest Area.

Narrower streets

Many communities require residential streets that are much wider than needed to support travel lanes, on-street parking, and emergency access. Some communities currently require residential streets as wide as 32 to 40 feet, which provide two parking lanes and two moving lanes.

Local experience has shown that residential streets can have pavement widths as narrow as 22 to 26 feet, and still accommodate all access and parking needs (ITE, 1997). Even narrower access streets or shared driveways can be used when only a handful of homes are served. The City of Inver Grove Heights Northwest Area requires a 28 foot paved local public street in addition to a sidewalk or trail on one side of the street. Local private streets have a 24-foot width requirement. Narrower streets help reduce traffic speeds in residential neighborhoods which, in turn, improve pedestrian safety.

Local public works, police and fire departments might object to narrower streets. Referring to the documents in the Additional Resources section can help identify how to address some of their concerns.

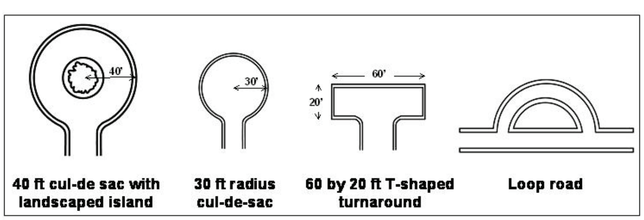
Slimmer sidewalks
Many communities require sidewalks that are excessively wide or are located adjacent to the street where the pedestrians are at risk from vehicles. A better site design technique modifies the width and location of sidewalks to promote safer pedestrian mobility. Impervious cover is reduced when sidewalks are reduced in width and located away from the street. Sidewalks can also be disconnected so they drain to lawns or landscaping instead of the gutter and storm drain system, or they can be constructed with permeable concrete, asphalt or blocks.

Sidewalk that drains to adjacent vegetation and provides common walkways linking pedestrian areas.

Smaller cul-de-sacs
Impervious cover can be reduced by minimizing the diameter of residential street cul-de-sacs and/or incorporating landscaped islands. Many communities require cul-de-sacs that have a greater diameter than needed to allow emergency and large vehicles to adequately turn around. Alternatives to the traditional 80 foot diameter cul-de-sac include 60 foot diameter cul-de-sacs, hammerhead turnarounds and loop roads. The Northwest Area zoning ordinance requires an outside roadway radius of 35 feet and a street property line (right-of-way) of 50 feet.

In addition, the inside of the turnaround can be landscaped as a bioretention area to further reduce impervious cover and improve stormwater treatment. Trees and vegetation planted in landscaped islands can be used to intercept rain water and treat stormwater runoff from surrounding pavement. Each of these alternative turnaround options produces a more attractive and safe environment for residents.

Image Adapted from Center for Watershed Protection. 1997.



Turnaround options for residential streets.

Smaller parking lots
In many communities, parking lots are over-sized and under-designed. Local parking and landscaping codes can be modified to allow the following techniques to be applied within parking lots:

- Minimize standard stall dimensions for regular spaces
- Provide compact car spaces
- Use pervious pavement (asphalt, concrete, pavers, sand amendments, vegetation) particularly for light-use or overflow parking
- Incorporate efficient, narrow parking lanes
- Reduce minimum parking demand ratios for certain land uses
- Treat the parking demand ratio as a maximum limit
- Create hydraulically designed stormwater "islands" or landscaping areas to treat runoff using bioretention, filter strips or other practices
- Encourage shared parking arrangements with adjacent land uses
- Enable owners/developers to provide proof of parking for required number of parking spaces while constructing only those that the owner/developer demonstrates are necessary

The Inver Grove Heights Northwest Area ordinance encourages joint parking arrangements and requires multi-family and mixed-use development to provide 50 percent of total parking underground, under the principal structure or as tuck-under parking. In addition, the ordinance includes incentives for pervious parking if more than the minimum parking requirement is desired.

Parking lot landscaping makes the lot more attractive to customers, and promotes safety for both vehicles and pedestrians. In addition, trees and other landscaping help screen adjacent land uses, shade people and cars, reduce summertime temperatures, improve air quality and bird habitat, reduce runoff volume and improve water quality.

Shorter Driveways
Most local codes contain front yard setback requirements that dictate driveway length. In many communities, front yard setbacks for certain residential zoning categories may extend 50 or 100 feet or even longer, which increases driveway length well beyond what is needed for adequate parking and access to the garage. Shorter setbacks reduce the length and impervious cover for individual driveways. The Northwest Area of Inver Grove Heights, MN, allows a 20 foot setback. In addition, driveway widths can be reduced and more permeable driveway surfaces can be allowed such as porous pavers, porous asphalt or porous concrete. Another way to reduce impervious cover is to allow shared driveways that provide street access for more than a single home. The Northwest Area zoning ordinance allows and encourages shared driveways.

Reduced Imperviousness Development Rules

Development rules are frequently in conflict with alternate design standards that limit the amount of impervious surface associated with a development. Development rules can refer to subdivision codes, zoning regulations, parking and street standards and other local ordinances that regulate development. Section 515.80 Subd. 39 of the City of Inver Grove Heights City Code is a good example of an ordinance facilitating reduced imperviousness (see Additional Resources).

The Center for Watershed Protection (see Additional Resources) recommends the following four step process to adapt local development rules to more closely conform to reduced imperviousness principles and related conservation design principles.

Step 1
Identify the development rules in your MS4. Locate all MS4 rules that have a potential impact on the way land is developed. Consider zoning ordinances, subdivision codes, street standards, covenants, fire codes and standards, parking requirements, building regulations/standards, stormwater management ordinances, buffer or floodplain regulations and environmental regulations.

Step 2
See how the rules stack up to the development principles of interest. Rate development rules on a scale of 1 to 10 (or similar) for how favorably they compare with the reduced imperviousness techniques giving a higher score for more favorable comparisons. If out of the maximum points possible, 80 percent or less are received, consider a systematic reform of imperviousness development rules.

Step 3
Consider which development rules might be changed. Given the difficulty and effort in changing development rules, prioritize proposed changes. Consider all the factors that contribute to established development rules. A low rate from Step 2 does not necessarily imply the rule should be or can be changed. In prioritizing, consider how changes will impact development costs, liability, property values, public safety and any other elements.

Step 4
Start a local roundtable process. Utilize a consensus process such as a local site planning roundtable to proceed with the desired development rule changes. The process allows for systematic review of existing rules and determination of whether or not changes can or should be made. Ultimately, the roundtable will come to agreement on the changes to be made to codes, engineering standards, guidelines, regulations and ordinances. Include key players in the roundtable, especially those agencies or personnel with authority for development review. Consider planning agencies/commissions, public works department, road/highway department, developers, fire officials, health department, land use lawyers, real estate brokers, chamber of commerce, elected officials, residents/land owners, stormwater management authority and any other potential stakeholders. In addition, consider utilizing an outside facilitator to guide and structure the roundtable process.

Maintenance Considerations

Narrower roads, sidewalks and cul-de-sacs, smaller parking lots and shorter driveways reduce maintenance needs, but the nature of the maintenance requirements is no different than that for existing features. Among others, these will include repair of failed structure or surface, periodic sweeping to remove accumulated debris, cleanout of sump manholes, and inspection of drainage paths to make sure structures are operable. There are a variety of pervious pavements with respective maintenance needs that compare to those of impervious pavements but may require annual vacuum cleaning. Pervious pavements can reduce winter maintenance needs including less salting, plowing and sanding due to the textured and porous nature of the pavement.

Typical Cost

Reducing imperviousness surfaces reduce maintenance and construction costs. In addition, reduced imperviousness reduces the size and cost of both the stormwater conveyance system and stormwater management practices. Additional resources may be required at the planning stages until familiarity with the design concepts and standards are established. The adoption of new ordinances requires an investment in training for the plan reviewer, the consultant, and possibly the public. MS4s must also consider the cost of enforcement, including staff and equipment requirements.

LOW IMPACT DEVELOPMENT SITE DESIGN STRATEGIES

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

PRESERVING IMPORTANT HYDROLOGIC FEATURES AND FUNCTION

There are many features in the natural landscape that provide the important hydrologic functions of retention, detention, infiltration, and filtering of stormwater. These features include, but are not limited to; highly permeable soils, pocket wetlands, significant small (headwater) drainage features, riparian buffers, floodplains, undisturbed natural vegetation, and tree clusters. All areas of hydrologic importance should be delineated at the earliest stage in the development planning process.

STRATEGIES

1. ***Buffers provide filtration, infiltration, flood management, and bank stability benefits.*** Unlike stormwater ponds and other structural infrastructure, buffers are essentially a no capital cost and low maintenance form of "green" infrastructure. The benefits of buffers diminish when slopes are greater than 25%; therefore steep slopes should not be counted as buffer.
2. ***Preserve areas of undisturbed soil and vegetation cover.*** Typical construction practices, such as topsoil stripping and stockpiling, and site grading and compaction by construction equipment, can considerably reduce the infiltration capacity (and treatment capacity) of soils. During construction, natural heritage features and locations where stormwater infiltration practices will be constructed should be delineated and not subject to construction equipment or other vehicular traffic, nor stockpiling of topsoil.
3. ***Avoid development on permeable soils.*** Highly permeable soils (i.e., hydrologic soil groups A and B) function as important groundwater recharge areas. To the greatest extent possible, these areas should be preserved in an undisturbed condition or set aside for stormwater infiltration practices. Where avoiding development on permeable soils is not possible, stormwater management should focus on mitigation of reduced groundwater recharge through application of stormwater infiltration practices.
4. ***Preserve existing trees and, where possible, tree clusters.*** Mature stands of deciduous trees will intercept 10 to 20% of annual precipitation falling on them, and a stand of evergreens will intercept 15 to 40%. Preserving mature trees will provide immediate benefits in new developments, whereas newly planted trees will take 10 years or more to provide equivalent benefits. Tree clusters can be incorporated into parking lot interiors or perimeters, private lawns, open space areas, road buffers, and median strips. An uncompacted soil volume of 15 to 28 m3 is recommended to achieve a healthy mature tree with a long lifespan.

SITING AND LAYOUT OF DEVELOPMENT

The location and configuration of elements, such as streets, sidewalks, driveways, and buildings, within the framework of the natural heritage system provides many opportunities to reduce stormwater runoff.

STRATEGIES

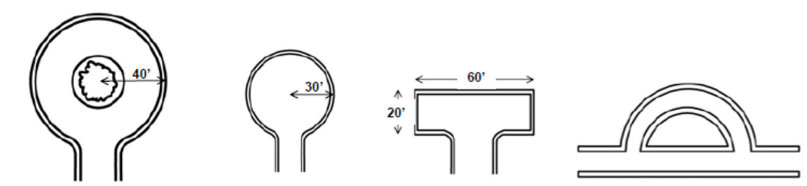
5. ***Fit the design to the terrain.*** Using the terrain and natural drainage as a design element will reduce the amount of clearing and grading required and the extent of necessary underground drainage infrastructure. This helps to preserve predevelopment drainage boundaries.
6. ***Use open space or clustered development.*** Clustering development increases the development density in less sensitive areas of the site while leaving the rest of the site as protected community open space. Some features of open space or clustered development are smaller lots, shared driveways, and shared parking. Clustered development also reduces the amount of impervious surfaces and stormwater runoff to be managed, reduces pressure on buffer areas, reduces the construction footprint, and provides more area and options for stormwater controls.
7. ***Use innovative street network designs.*** Certain roadway network designs (e.g., loops, cul-de-sacs, fused grids) create less impervious area than others. These layouts by themselves may not achieve the many goals of urban design. However, used in a hybrid form together or with other street patterns, they can meet multiple urban design objectives and reduce the necessary street area, thereby reducing the amount of impervious surfaces and stormwater runoff to be managed.
8. ***Reduce roadway setbacks and lot frontages.*** The lengths of setbacks and frontages are a determinant for the area of pavement, street, driveways, and walkways, needed to service a development. Municipal zoning regulations for setbacks and frontages have been found to be a significant influence on the production of stormwater runoff.

REDUCING IMPERVIOUS AREA

Many of the strategies described previously are primarily for the purpose of reducing impervious area on a macro scale. The following strategies provide examples of how to reduce impervious area on a micro or lot level scale.

STRATEGIES

9. ***Reduce street width.*** Streets constitute the largest percentage of impervious area and contribute proportionally to the urban runoff. Streets widths are sized for the free flow of traffic and movements of large emergency vehicles. In many cases, such as low density residential, these widths are oversized for the typical function of the street. Amending urban design standards to allow alternative, narrower street widths might be appropriate in some situations. There are a variety of ways to accommodate emergency vehicle movements and traffic flow on narrower streets, including alternative street parking configurations, vehicle pullout space, connected street networks, prohibiting parking near intersections, and reinforced turf or gravel edges.
10. ***Reduce building footprints.*** Reduce the building footprint by using taller multi-story buildings and taking advantage of opportunities to consolidate services into the same space.
11. ***Reduce parking footprints.*** Excess parking not only results in greater stormwater impacts and greater stormwater management costs but also adds unnecessary construction and maintenance costs and uses space that could be used for a revenue generating purpose.
    - Keep the number of parking spaces to the minimum required. Parking ratio requirements are often set to meet the highest hourly parking demand during the peak season. The parking space requirement should instead consider an average parking demand and other factors influencing demand like access to mass transit.
    - Take advantage of opportunities for shared parking. For example, businesses with daytime parking peaks can be paired with evening parking peaks, such as offices and a theatre, or land uses with weekday peak demand can be paired with weekend peak demand land uses, such as a school and church.
    - Reductions in impervious surface can also be found in the geometry of the parking lot. One way aisles when paired with angled parking will require less space than a two way aisle. Other reductions can be found in using unpaved end-of-stall overhangs, setting aside smaller stalls for compact vehicles, and configuring or overlapping common areas like fire lanes, collectors, loading, and drop off areas.
    - More costly approaches to reducing the parking footprint include parking structures or underground parking.
12. ***Consider alternative cul-de-sac designs.*** Using alternatives to the standard 15 metre radius cul-de-sac can further reduce the impervious area required to service each dwelling. Ways to reduce the impervious areas of cul-de-sacs include a landscaped or bioretention centre island, T-shaped turnaround, or by using a loop road instead.
13. ***Eliminate unnecessary sidewalks and driveways.*** A flexible design standard for sidewalks is recommended to allow for unnecessary sidewalks to be eliminated. Sidewalks that are not needed for pedestrian circulation or connectivity should be removed. Often sidewalks are only necessary on one side of the street. Driveway impervious area can be reduced through the use of shared driveways or alley accessed garages



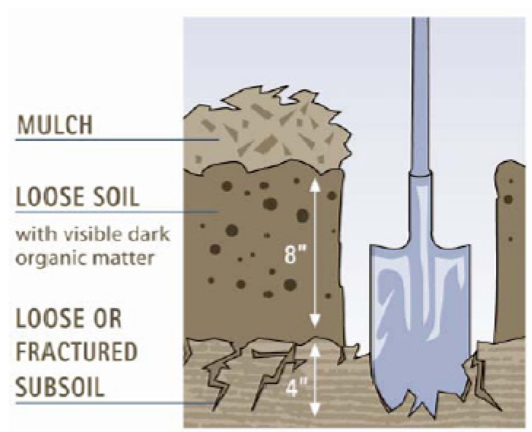
40 ft cul-de sac with landscaped island | 30 ft radius cul-de-sac | 60 by 20 ft T-shaped turnaround | Loop road

Source: CWP, 1998

	Square grid (Miletus, Houston, Portland, etc.)	Oblong grid (most cities with a grid)	Oblong grid 2 (some cities or in certain areas)	Loops (Subdivisions – 1950 to now)	Culs-de-sac (Radburn – 1932 to now)
Percentage of area for streets	36.0%	35.0%	31.4%	27.4%	23.7%
Percentage of buildable area	64.0%	65.0%	68.6%	72.6%	76.3%

Source: CMHC, 2002

Soil Amendment Guidelines



Soil amendment sizing criteria:

impervious area / soil area = 1
- use 100 mm compost, till to 300 - 450 mm depth

impervious area / soil area = 2
- use 200 mm compost, till to 300 - 450 mm depth

impervious area / soil area = 3
- use 300 mm compost, till to 450 - 600 mm depth

Compost should consist of well-aged (at least one year) leaf compost. Amended soil should have an organic content of 8-15% by weight or 30-40% by volume.

Source: Soils for Salmon, 2005

Open Drainage Applied in a Medium Density Neighbourhood

Source: U.S. EPA

USING NATURAL DRAINAGE SYSTEMS

Rather than collect and move stormwater rapidly to a centralized location for detention and treatment, the goal of these strategies is to take advantage of undisturbed vegetated areas and natural drainage patterns (e.g., small headwater drainage features). These strategies will extend runoff flow paths and slow down flow to allow soils and vegetation to treat and retain it. Using natural systems or green infrastructure is often more cost effective than traditional drainage systems, and they provide more ancillary benefits.

STRATEGIES

14. ***"Disconnect" impervious areas.*** Roof leaders or downspouts, parking lots, driveways, sidewalks, and patios should be disconnected from the storm sewer and directed towards stabilized pervious areas as sheet flow where possible. In cases of concentrated flow, the flow can be broken up with level spreaders or flow dissipating riprap. With the proper treatment, the landscaped areas of a site can accept runoff from impervious areas. Deep tilling or soil aeration is recommended for topsoil that has been replaced or compacted by construction equipment. Soil amendments can be applied to hydrologic soil group C and D soils to encourage runoff absorption. Use deep rooting vegetation in landscaped areas when possible which will maintain and possibly improve soil infiltration rate over time:
    - ***Undisturbed densely vegetated areas and buffers*** - A hydrologist and/or ecologist should be consulted before designing a site to drain to sensitive natural heritage features like pocket wetlands.
    - ***Landscaped and disturbed areas*** - With the proper treatment, the landscaped areas of the site can accept runoff from impervious areas. Deep tilling or soil aeration is recommended for topsoil that has been replaced or compacted by construction equipment. Soil amendments can be applied to hydrologic soil group C and D soils to encourage runoff absorption. Use deep rooting vegetation in landscaped areas when possible which will maintain and possibly improve the infiltration rates over time.
15. ***Preserve or create micro-topography.*** Undisturbed lands have a micro-topography of dips, hummocks and mounds which slow and retain runoff. Site grading smoothes out these topographic features. Micro-topography can be restored in areas of ornamental landscaping or naturalization.
16. ***Extend drainage flow paths.*** Slowing down flows and lengthening flow paths allow more opportunities for stormwater to be filtered and infiltrated. Extending the travel time can also delay and lower peak flows. Where suitable, flows should be conveyed using vegetated open channels (e.g., enhanced grass swales).

TORONTO AND REGION Conservation for The Living City

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FOR FURTHER DETAILS SEE SECTION 3.2 OF THE CVC/TRCA LID SWM GUIDE

Volume Control Using Compost Materials / Soil Amendments

Soil amendment techniques, standards and ordinances

Land development including landscaping practices damage soil structure and function by removing or compacting topsoil. These practices can impact water resources by decreasing infiltration, increasing erosion, impairing fish habitat, and increasing the need for permanent stormwater management.

These practices also create chemically dependent landscapes which are difficult and expensive to maintain and contribute to polluted runoff. Soil compaction also reduces the water retention capacity of soil which requires additional irrigation and increased public water supply demand. This fact sheet provides guidance on soil amendment practices and implementation of soil amendment standards and ordinances.

Benefits / Pollution Reduction

Compost, an organic material, absorbs and infiltrates rainwater, reduces flooding and soil erosion and filters out pollutants typically associated with stormwater runoff. Compost also stores water and nutrients for plants to use during drought conditions, promoting healthy plants and better looking lawns that require less irrigation, pesticides and fertilizers. In addition, healthy amended soils that require less irrigation reduce municipal water demand.

Program Development & Implementation

Programs developed to provide volume control through soil amendments may include MS4 standards and/or ordinances. Soil amendment guidelines as well as guidelines for standards and ordinance development are identified below. The program is ultimately dependent upon several factors including the MS4's available resources, extent of development and/or redevelopment opportunities, and character of its soil and stormwater runoff.

Awareness Campaigns

Awareness campaigns inform the public, public employees, businesses, property owners, and elected officials of the negative effects of soil compaction and the benefits of soil amendments. Efforts can also contribute to generating acceptance of a new ordinance and encouraging individuals and organizations to implement soil amendments on a voluntary basis.

Brochures
Develop informative brochures, and guidance for specific audiences such as developers, businesses, homeowners and local development permitting authorities.

Signage at MS4 installations
Locate signage at parks and government buildings identifying compost-amended sites and the associated functions and benefits.

Workshops and seminars
Workshops and seminars can be used to provide the technical assistance that developers, city staff and consultants will need in order to meet a new soil amendment ordinance.

Unrestricted flickr® Image

Compost delivery to a project site.

Soil Amendment Application Guidelines

Design variants are summarized below to provide guidance appropriate for implementing soil amendments within various site constraints and conditions. A good design approach will likely apply a combination of techniques at a single site based on the local conditions. There are soil and compost calculator worksheets in the Additional Resources section.

General guidance

Unless soils are native and can be left undisturbed, the following guidance applies to techniques implemented:

- Minimum final soil depth of 8 inches
- Avoiding plowing or tilling within drip line of trees
- Soil pH testing, and if necessary, adjusting proposed suite of plants

Undisturbed native soil

Areas of the site that do not need to be disturbed should be identified to protect areas of native vegetation. Fence off these areas to protect them from compaction during the construction phase.

Amend existing soil in-place

Where the soil has been compacted or the organic layer (e.g. forest duff or upper soil horizon) removed, the simplest way to restore soil quality is to rototill compost into the existing soil. Apply a 2.5-inch deep layer of compost to the existing soil. Rototill compost into the soil to a depth of at least 8 inches. Tilling to this depth will require repeated passes with a large machine, such as a tractor-mounted or heavy rear-tine rototiller.


Unrestricted flickr ® Image

Rototilling compost into the soil.

Import topsoil mix

Where subsoil is too rocky, compacted or poorly drained to amend effectively, a topsoil mix with 8-13 percent soil organic matter can be imported and placed on the surface. The topsoil mix should contain 30-40 percent compost by volume and clean sand or sandy soil to promote adequate drainage. The soil depth should be 8 inches and the pH suitable for proposed plants. Ask topsoil suppliers for test results of their product to verify the material contains the desired organic matter content and pH. For best results, plow or till compacted subsoil at least 2 inches deep before applying topsoil mix and/or rototill some of the newly applied topsoil into the subsoil.

Native soil

Sites that contain original, undisturbed native soils (most often applicable to forested land) may be stockpiled and reapplied without compost amendments after grading or other construction disturbances are completed. Remove forest duff layer and topsoil and stockpile separately prior to grading. Cover soil and duff piles with woven weed barrier (available from nursery supply stores) that sheds moisture yet allows air flow. Reapply topsoil to landscape areas to a minimum 8-inch depth after grading and other disturbances are completed. For best results, plow or till compacted subsoil at least 2 inches deep before replacing stockpiled topsoil, and/or rototill some of the replaced topsoil into the subsoil. Apply a 2-inch layer of stockpiled duff as mulch after planting.

Disturbed soil

Stockpile topsoil, reapply and amend in place. This design variant is only applicable to sites where the soil is not the original, undisturbed native soil. Topsoil and forest duff excavated for structures and paved areas or removed before site grading can be stockpiled and reapplied after grading and amended.

Remove soil and stockpile prior to grading. Cover soil with woven weed barrier (available from nursery supply stores) that sheds moisture yet allows air flow. Reapply stockpiled soil to landscape areas to a minimum 8-inch depth after grading and other disturbances are completed. In some cases, purchasing additional topsoil will be needed to achieve the 8-inch depth. Plow or till compacted subsoil at least 2 inches deep before replacing stockpiled soil, and/or rototill some of the replaced soil into the subsoil. Apply a layer of compost to the reapplied soil at a depth of 2.5 inches. Rototill compost into the soil to a depth of at least 8 inches. Tilling to this depth will require repeated passes with a large machine, such as a tractor or heavy rear-tine rototiller.

Scarification

The Minnesota Stormwater Manual recommends plowing or tilling (scarifying) compacted subsoil more than the 2 inches recommended in the above applications. For high-traffic areas, the recommended depth of scarification is 10 inches. For all other areas within the construction limits, the recommended depth of scarification is four inches.

Planting areas vs. turf areas

The Minnesota Stormwater Manual recommends a greater depth of compost, 3 inches, for planting areas than for turf areas which may be adequately amended with only 1.75 inches of compost. In all cases, the recommended minimum depth of the resulting topsoil layer with the incorporated compost is 8 inches.

Compost Specifications

When purchasing compost to be incorporated into the soil as a volume control soil amendment, look for specifications presented in the following table, adapted from Table 1 of Chapter 12-3 Runoff Volume Minimization of the Minnesota Stormwater Manual.

Parameter	Parameter Definition	Range
Source material/ Nutrient content	Typically biosolids/animal manure, source separated compostable materials or sorted yard wastes	Nitrogen: 0.5 – 3 Phosphorus: 0.5 – 1.5 Potassium: 0.5 – 1
Maturity	Level of completeness of the composting process	Seed emergence and seed vigor = minimum 80% relative to positive control
Stability	Biological activity in the composted material	CO_2 evolution rate: < 8 milligrams CO_2-C per grams organic matter per day
pH	Acidity/alkalinity	5.5 – 8.5
Soluble salts	The amount of soluble ions in a solution of compost and water	Varies widely according to source materials for compost, but should be < 10 deciSiemen per meter (millimhos per centimeter)
Organic matter	The amount of carbon-based materials	30-65% dry weight basis
Particle size	Size of particles	Pass through 1-inch screen or less
Biological contaminants	Pathogens (disease causing organisms) and weed seeds	Meet or exceed US EPA Class A standards, 40 CFR Section 503.32(2) levels
Physical contaminants	Man-made materials (like pieces of plastic or glass) that do not compose, also called 'inerts'	< 1% dry weight basis
Trace metals	Elements that can be toxic to humans, animals or plants	Meet or exceed standards for Class I compost set in Minn.R. 7035.2836, Subp. 6, (A)

Soil Amendment Ordinances

Introduce regulations whereby property owners and developers are required to provide soil amendments to any development or redevelopment site. King County, Washington, may have been the first local government to institute a clearing and grading ordinance that includes soil amendment requirements. The ordinance was first introduced in 2005 and was updated in December 2008. It serves as a good starting point for an MS4 ordinance.

"The topsoil layer shall be a minimum of eight inches thick, unless the applicant demonstrates that a different thickness will provide conditions equivalent to the soil moisture-holding capacity native to the site. The topsoil layer shall have an organic matter content of between five to ten percent dry weight and a pH suitable for the proposed landscape plants. When feasible, subsoils below the topsoil layer should be scarified at least four inches with some incorporation of the upper material to avoid stratified layers. Compost used to achieve the required soil organic matter content must meet the definition of "composted materials" in WAC 173-350-220."

Rice Creek Watershed District water quality and volume control rules are designed to account for loss of infiltration due to soil compaction during construction. As an incentive for soil amendments, the water quality and volume control benefits of compost amended soils are given credit in the rules. The District provides a corresponding soil amendment guidelines worksheet for permit applicants.

Monitoring and Assessment

The MS4 could engage in documenting the effectiveness of its soil amendment standards by conducting monitoring to see what water quality and other benefits are accomplished. Findings could provide feedback for standards/ordinance revisions.

Maintenance Considerations

Compost amended sites are maintained no differently than sites that have not been amended. However, less watering and fertilizer may be required, as well as less runoff management.

Typical Cost

Amending with compost is often the most economical way to uncompact and bring soils up to the desired soil organic matter content. On sites with the original, undisturbed, native soil and where space permits, stockpiling and reapplying topsoil may be less costly. Importing topsoil usually costs more than amending existing soil, although it may be easier where subsoil conditions make cultivation difficult. Reductions in the need for irrigation and fertilizer can provide payback for up front costs in the range of 2 to 7 years. Implementation of amended soils can also result in a cost savings due to reduced detention ponding requirements.

The adoption of a soil amendment ordinance requires an investment in training for the plan reviewer, the consultant, and possibly the public. MS4s must also consider the cost of enforcement, including staff and equipment requirements. Awareness campaign costs are determined by the type of materials produced and the method of distribution selected. Signs at city buffer installations may initially have a higher cost than printed materials, but can serve as a more effective tool for increasing public understanding.

PERMEABLE PAVEMENT

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Permeable pavements, an alternative to traditional impervious pavement, allow stormwater to drain through them and into a stone reservoir where it is infiltrated into the underlying native soil or temporarily detained. They can be used for low traffic roads, parking lots, driveways, pedestrian plazas and walkways. Permeable pavement is ideal for sites with limited space for other surface stormwater BMPs. Examples of permeable pavement types include:

- permeable interlocking concrete pavers (i.e., block pavers);
- plastic or concrete grid systems (i.e., grid pavers);
- pervious concrete; and
- porous asphalt.

Depending on the native soils and physical constraints, the system may be designed with no underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for a no infiltration or detention and filtration only practice.

DESIGN GUIDANCE

GEOMETRY & SITE LAYOUT

Permeable pavement systems can be used for entire parking lot areas or driveways or can be designed to receive runoff from adjacent impervious pavement. For example, the parking spaces of a parking lot or road can be permeable pavers while the drive lanes are impervious asphalt. In general, the impervious area should not exceed 1.2 times the area of the permeable pavement which receives the runoff (GVRD, 2005).

PRE-TREATMENT

In most permeable pavement designs, the pavement bedding layer acts as pretreatment to the stone reservoir below. Periodic vacuum sweeping and preventative measures like not storing snow or other materials on the pavement are critical to prevent clogging. An optional pretreatment element can be a pea gravel choking layer above the coarse gravel storage reservoir.

CONVEYANCE AND OVERFLOW

All designs require an overflow outlet connected to a storm sewer with capacity to convey larger storms. One option is to set storm drain inlets slightly above the surface elevation of the pavement, which allows for temporary shallow ponding above the surface. Another design option is an overflow edge, which is a gravel trench along the downgradient edge of the pavement surface that drains to the stone reservoir below.

Pavements designed for full infiltration, where native soil infiltration rate is 15 mm/hr or greater, do not require incorporation of a perforated pipe underdrain. Pavements designed for partial infiltration, where native soil infiltration rate is less than 15 mm/hr, should incorporate a perforated pipe underdrain placed near the top of the granular stone reservoir. Partial infiltration designs can also include a flow restrictor assembly on the underdrain to optimize infiltration with desired drawdown time between storm events.

MONITORING WELLS

A capped vertical standpipe consisting of an anchored 100 to 150 mm diameter perforated pipe with a lockable cap installed to the bottom of the facility is recommended for monitoring the length of time required to fully drain the facility between storms.

STONE RESERVOIR

The stone reservoir must be designed to meet both runoff storage and structural support requirements. Clean washed stone is recommended as any fines in the aggregate material will migrate to the bottom and may prematurely clog the native soil. The bottom of the reservoir should be flat so that runoff will be able to infiltrate evenly through the entire surface. If the system is not designed for infiltration, the bottom should be sloped at 1 to 5% toward the underdrain.

GEOTEXTILE

A non-woven needle punched, or woven monofilament geotextile fabric should be installed between the stone reservoir and native soil to maintain separation.

EDGE RESTRAINTS

Pavers must abut tightly against the restraints to prevent rotation under load and any consequent spreading of joints. The restraints must be able to withstand the impact of temperature changes, vehicular traffic and snow removal equipment. Metal or plastic stripping is acceptable in some cases, but concrete edges are preferred. Concrete edge restraints should be supported on a minimum base of 150 mm of aggregate.

LANDSCAPING

Adjacent landscaping areas should drain away from permeable pavement to prevent sediments from running onto the surface. Urban trees also benefit from being surrounded by permeable pavement rather than impervious cover, because their roots receive more air and water.

OPERATION AND MAINTENANCE

Annual inspections of permeable pavement should be conducted in the spring to ensure continued infiltration performance. Check for deterioration and whether water is draining between storms. The pavement reservoir should drain completely within 72 hours of the end of the storm event. The following maintenance procedures and preventative measures should be incorporated into a maintenance plan:

Surface Sweeping: Sweeping should occur once or twice a year with a commercial vacuum sweeping unit. Permeable pavement should not be washed with high pressure water systems or compressed air units.

Inlet Structures: Drainage pipes and structures within or draining to the subsurface bedding beneath permeable pavement should be cleaned out on regular intervals.

Heavy Vehicles: Trucks and other heavy vehicles should be prevented from tracking or spilling dirt onto the permeable pavement.

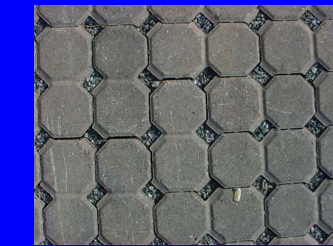
Construction and Hazardous Materials: Due to the potential for groundwater contamination, all construction or hazardous material carriers should be prohibited from entering a permeable pavement site.

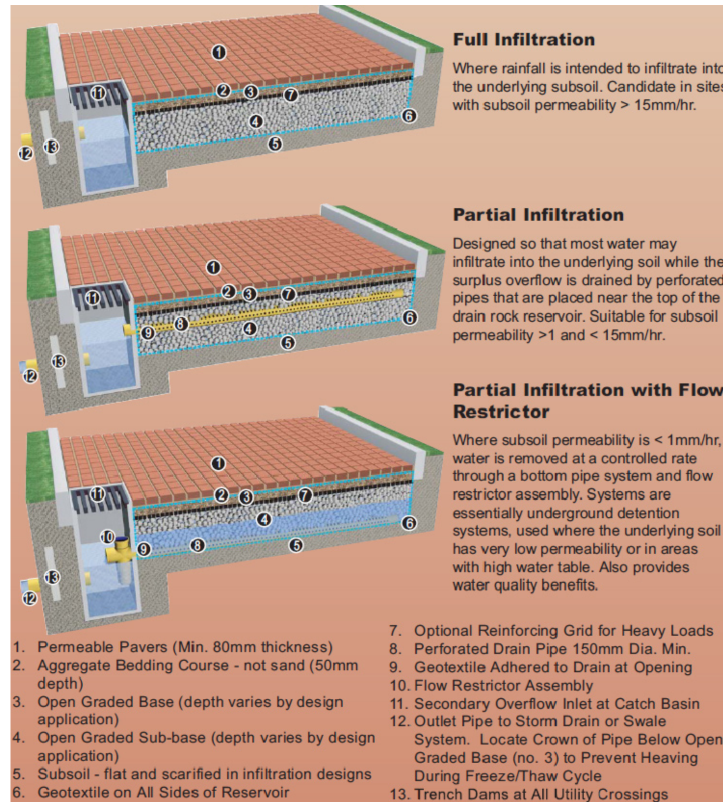
Drainage Areas: Impervious areas contributing to the permeable pavement should be regularly swept and kept clear of litter and debris. Flows from any landscaped areas should be diverted away from thepavement or be well stabilized with vegetation.

Grid Pavers: Grid paver systems that have been planted with grass should be mowed regularly with the clippings removed. Grassed grid pavers may require periodic watering and fertilization to establish and maintain healthy vegetation.

Winter Maintenance: Sand should not be spread on permeable pavement as it can quickly lead to clogging. Deicers should only be used in moderation and only when needed. Pilot studies have found that permeable pavement requires 75% less de-icing salt than conventional pavement over the course of a typical winter season. Permeable pavement is plowed for snow removal like any other pavement. Plowed snow piles should not be stored on permeable pavement systems.



Source: GVRD

ABILTY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Permeable pavement with no underdrain	Yes	Yes - size for water quality storage requirement	Partial - based on available storage volume and soil infiltration rate
Permeable pavement with underdrain	Moderate - based on native soil infiltration rates and storage beneath the underdrain	Yes - size for water quality storage requirement	Partial - based on available storage volume and soil infiltration rate
Permeable pavement with underdrain and liner	No - some volume reduction occurs through evapotranspiration	Moderate - limited filtering and settling of sediments	Partial - based on available storage volume and soil infiltration rate

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Pervious Concrete	• NO4-RG-S7 mix with air entrainment proven to have the best freeze-thaw durability after 300 freeze-thaw cycles. • 28 day compressive strength = 5.5 to 20 MPa • Void ratio = 14% - 31% • Permeability = 900 to 21,500 mm/hr	Thickness will range from 100mm - 150 mm depending on the expected loads
Porous Asphalt	• Open-graded asphalt mix with a minimum of 16% air voids • Polymers can be added to provide additional strength for heavy loads • The University of New Hampshire Stormwater Center has detailed design specifications for porous asphalt on their web-page: http://www.unh.edu/erg/cstev/pubs_specs_info	Thickness will range from 50 mm to 100 mm depending on the expected loads.
Permeable Pavers	• Permeable pavers should conform to manufacturer specifications. • ASTM No. 8 (5 mm dia.) crushed aggregate is recommended for fill material in the paver openings. For narrow joints between interlocking shapes, a smaller sized aggregate may be used (Smith, 2006). • Pavers shall meet the minimum material and physical properties set forth in CAN 3-A231.2, Standard Specification for Precast Concrete Pavers. • Pigment in concrete pavers shall conform to ASTM C 979. • Maximum allowable breakage of product is 5%.	For vehicular applications, the minimum paver thickness is 80 mm and for pedestrian applications is 60 mm. Joint widths should be no greater than 15 mm for pedestrian applications.
Stone Reservoir	All aggregates should meet the following criteria: • Maximum wash loss of 0.5% • Minimum durability index of 35 • Maximum abrasion of 10% for 100 revolutions and maximum of 50% for 500 revolutions Granular Subbase The granular subbase material shall consist of granular material graded in accordance with ASTM D 2940. Material should be clear crushed 50 mm diameter stone with void space ratio of 0.4. Granular Base The granular base material shall be crushed stone conforming to ASTM C 33 No 57. Material should be clear crushed 20 mm diameter stone. Bedding The granular bedding material shall be graded in accordance with the requirements of ASTM C 33 No 8. The typical bedding thickness is between 40 mm and 75 mm. Material should be 5 mm diameter stone or as determined by the Design Engineer (Smith, 2006).	See BMP Sizing section for aggregate bed depth and multiply by application are to get total volume.
Geotextile	Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. Primary considerations are: • Suitable apparent opening size (AOS) for non-woven fabrics, or percent open area (POA) for woven fabrics, to maintain water flow even with sediment and microbial film build-up; • Maximum forces that will be exerted on the fabric (i.e., what tensile, tear and puncture strength ratings are required?); • Load bearing ratio of the underlying native soil (i.e., is geotextile needed to prevent downward migration of aggregate into the native soil?); • Texture (i.e., grain size distribution) of the overlying aggregate material; and • Permeability of the native soil. For further guidance see CVC/TRCA LID SWM Planning and Design Guide, Table 4.7.3.	Between stone reservoir and native soil.
Underdrain (optional)	• HDPE or equivalent material, continuously perforated with smooth interior and a minimum inside diameter of 100 mm. • Perforations in pipes should be 10 mm in diameter. • A standpipe from the underdrain to the pavement surface can be used for monitoring and maintenance of the underdrain. The top of the standpipe should be covered with a screw cap and a vandal-proof lock.	Pipes should terminate 0.3 m short from the sides of the base.

SITE CONSIDERATIONS

Wellhead Protection

Permeable pavement should not be used for road or parking surfaces within two (2) year time-of-travel wellhead protection areas.

Site Topography

Permeable pavement surface should be at least 1% and no greater than 5%.

Water Table

The base of permeable pavement stone reservoir should be at least one (1) metre above the seasonally high water table or top of bedrock elevation.

Soil

Systems located in native soils with an infiltration rate of less than 15 mm/hr (i.e., hydraulic conductivity of less than 1x10-6 cm/s) require a perforated pipe underdrain. Native soil infiltration rate at the proposed location and depth should be confirmed through measurement of hydraulic conductivity under field saturated conditions.

Drainage Area & Runoff Volume

In general, the impervious area treated should not exceed 1.2 times the area of permeable pavement which receives the runoff.

Setback from Buildings

Should be located downslope from building foundations. If the pavement does not receive runoff from other surfaces, no setback is required. If the pavement receives runoff from other surfaces a minimum setback of four (4) metres downgradient is recommended.

Pollution Hot Spot Runoff

To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated by permeable pavement.

CONSTRUCTION CONSIDERATIONS

SEDIMENT CONTROL

The treatment area should be fully protected during construction so that no sediment reaches the permeable pavement system. Construction traffic should be blocked from the permeable pavement and its drainage areas once the pavement has been installed.

BASE CONSTRUCTION

In parking lots, the stone aggregate should be placed in 100 mm to 150 mm lifts and compacted with a minimum 9,070 kg (10 ton) steel drum roller.

WEATHER

Porous asphalt and pervious concrete will not properly pour and set in extremely high and low temperatures.

PAVEMENT PLACEMENT

Properly installed permeable pavement requires trained and experienced producers and construction contractors.

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FOR FURTHER DETAILS SEE SECTION 4.7 OF THE CVC/TRCA LID SWM GUIDE

DOWNSPOUT DISCONNECTION

CVC/TRCA LOW IMPACT DEVELOPMENT
PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Simple downspout disconnection involves directing flow from roof downspouts to a pervious area that drains away from the building. This prevents stormwater from directly entering the storm sewer system or flowing across a "connected" impervious surface, such as a driveway, that drains to a storm sewer. Simple downspout disconnection requires a minimum flow path length across the pervious area of 5 metres.

DESIGN GUIDANCE

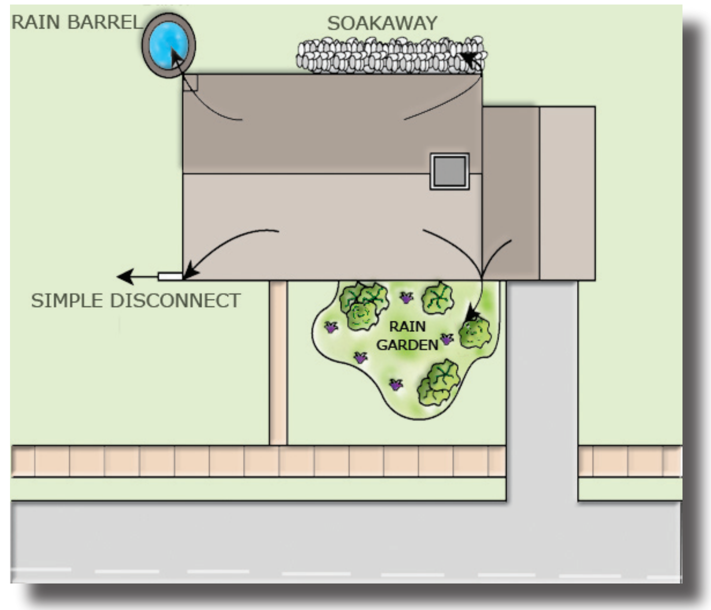
Roof downspout disconnections should meet the following criteria:

- Pervious areas used for downspout disconnection should be graded to have a slope of between 1 to 5%;
- Pervious areas should slope away from the building;
- The flow path length across the pervious area should be 5 metres or greater;
- The infiltration rate of soils in the pervious area should be 15 mm/hr or greater (i.e., hydraulic conductivity of 1x10-6 cm/s or greater);
- If infiltration rate of the soil in the pervious area is less than 15 mm/hr, it should be tilled to a depth of 300 mm and amended with compost to achieve a ratio of 8 to 15% organic content by weight or 30 to 40% by volume;
- If the flow path length across the pervious area is less than 5 metres and the soils are hydrologic soil group C or D, roof runoff should be directed to another LID practice (e.g., rainwater harvesting system, bioretention area, swale, soakaway, perforated pipe system);
- The total roof area contributing drainage to any single downspout discharge location should not exceed 100 square metres; and,
- A level spreading device (e.g., pea gravel diaphragm) or energy dissipating device (e.g., splash pad) should be placed at the downspout discharge location to distribute runoff as evenly as possible over the pervious area.

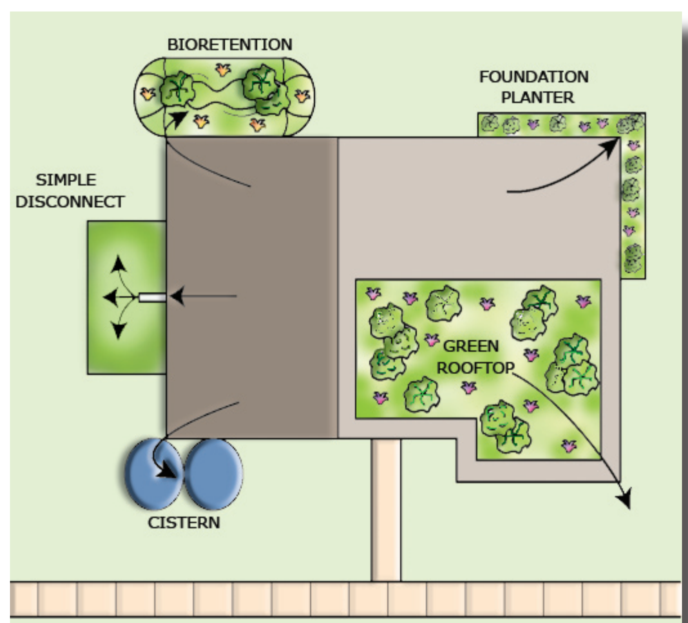
APPLICATIONS

There are many options for keeping roof runoff out of the storm sewer system. Some of the options are as follows:

- Simple roof downspout disconnection to a pervious area or vegetated filter strip, where sufficient flow path length across the pervious area and suitable soil conditions exist;
- Roof downspout disconnection to a pervious area or vegetated filter strip that has been tilled and amended with compost to improve soil infiltration rate and moisture storage capacity;
- Directing roof runoff to an enhanced grass swale, dry swale, bioretention area, soakaway or perforated pipe system;
- Directing roof runoff to a rainwater harvesting system (e.g., rain barrel or cistern) with overflow to a pervious area, vegetated filter strip, swale, bioretention area, soakaway or permeable pavement.



RESIDENTIAL



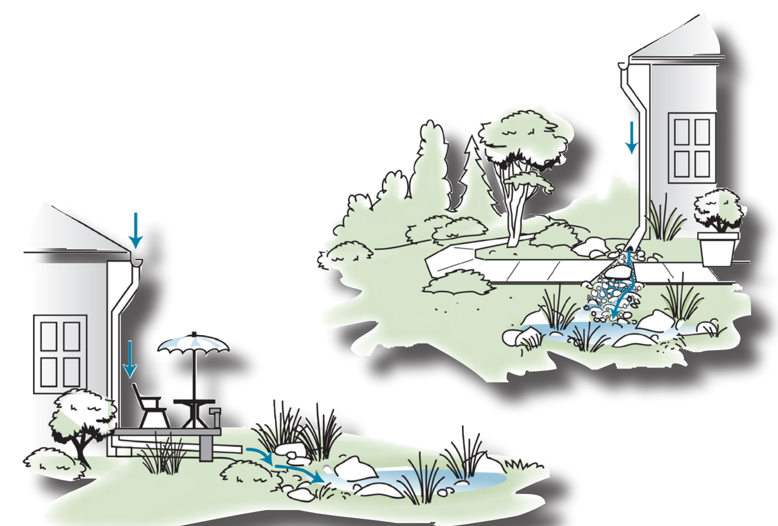
COMMERCIAL

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benfit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Downspout Disconnection	Partial - depends on soil infiltration rate and length of flow path over the pervious area	Partial - depends on soil infiltration rate and length of flow path over the pervious area	Partial - depends on combination with other practices

Downspout disconnection is primarily a practice used to help achieve water balance benefits, although it can also contribute to water quality improvement. Very limited research has been conducted on the runoff reduction benefits of downspout disconnection, so initial estimates are drawn from research on filter strips, which operate in a similar manner. The research indicates that runoff reduction is a function of soil type, slope, vegetative cover and filtering distance. A conservative runoff reduction rate is 25% for hydrologic soil group (HSG) C and D soils and 50% for HSG A and B soils.* These values apply to disconnections that meet the feasibility criteria outlined in this section, and do not include any further runoff reduction due to the use of compost amendments along the filter path.

*Hydrologic soil group (HSG) classifications are based on the ability of the soil to transmit water. Soil groups are ranked from A to D. Group A soils are sandy, loamy sand, or sandy loam types. Group B soils are silt loam or loam types, Group C soils are sandy clay loam types. Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay types



OVERVIEW

SITE CONSIDERATIONS

Site Topography
Disconnected downspouts should discharge to a gradual slope that conveys runoff away from the building. The slope should be between 1% and 5%. Grading should discourage flow from reconnecting with adjacent impervious surfaces.

Water Table
Roof downspouts should only be disconnected where the minimum depth to the seasonally high water table is at least one (1) metre below the surface.

Pollution Hot Spot Runoff
Downspout disconnection can be used where land uses or activities at ground-level have the potential to generate highly contaminated runoff (e.g., vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites) as long as the roof runoff is kept separate from runoff from ground-level impervious surfaces.

COMMON CONCERNS

- ON PRIVATE PROPERTY
  Property owners or managers will need to be educated on its function and maintenance needs, and may be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer user fee based on the area of impervious cover on a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain existing practices.
- STANDING WATER AND PONDING
  Downspout disconnection is not intended to pond water, so any standing water should be infiltrated or evaporated within 24 hours of the end of each runoff event. If ponding for longer than 24 hours occurs, mitigation actions noted under Operation and Maintenance should be undertaken.

CONSTRUCTION CONSIDERATIONS

SOIL DISTURBANCE AND COMPACTION
Only vehicular traffic necessary for construction should be allowed on the pervious areas to which roof downspouts will be discharged. If vehicle traffic is unavoidable, then the pervious area should be tilled to a depth of 300 mm to loosen the compacted soil.

EROSION AND SEDIMENT CONTROL
If possible, construction runoff should be directed away from the proposed downspout discharge location. After the contributing drainage area and the downspout discharge location are stabilized and vegetated, erosion and sediment control structures can be removed.

OPERATION AND MAINTENANCE

Maintenance of disconnected downspouts will generally be no different than for lawns or landscaped areas. A maintenance agreement with property owners or managers may be required to ensure that downspouts remain disconnected and the pervious area remains pervious. For long-term efficacy, the pervious area should be protected from compaction. One method is to plant shrubs or trees along the perimeter of the pervious area to prevent traffic. On commercial sites, the pervious area should not be an area with high foot traffic. If ponding of water for longer than 24 hours occurs, the pervious area should be dethatched and aerated. If ponding persists, regrading or tilling to reverse compaction and/or addition of compost to improve soil moisture retention may be required.

TORONTO AND REGION Conservation for The Living City
CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.3 OF THE CVC/TRCA LID SWM GUIDE

GENERAL DESCRIPTION

Green roofs, also known as "living roofs" or "rooftop gardens", consist of a thin layer of vegetation and growing medium installed on top of a conventional flat or sloped roof. Green roofs are touted for their benefits to cities, as they improve energy efficiency, reduce urban heat island effects, and create greenspace for passive recreation or aesthetic enjoyment. They are also attractive for their water quality, water balance, and peak flow control benefits. The green roof acts like a lawn or meadow by storing rainwater in the growing medium and ponding areas. Excess rainfall enters underdrains and overflow points and is conveyed in the building drainage system. After the storm, a large portion of the stored water is evapotranspired by the plants, evaporates or slowly drains away.

There are two types of green roofs: intensive and extensive. Intensive green roofs contain greater than 15 cm depth of growing medium, can be planted with deeply rooted plants and are designed to handle pedestrian traffic. Extensive green roofs consist of a thinner growing medium layer (15 cm depth or less) with herbaceous vegetative cover. Guidance here focuses on extensive green roofs.

DESIGN GUIDANCE

ROOF STRUCTURE

The load bearing capacity of the roof structure must be sufficient to support the soil and plants of the green roof assembly, as well as the live load associated with maintenance staff accessing the roof. A green roof assembly weighing more than 80 kg per square metre, when saturated, requires consultation with a structural engineer. Green roofs may be installed on roofs with slopes up to 10%. As a fire resistance measure, non-vegetative materials, such as stone or pavers should be installed around all roof openings and at the base of all walls that contain openings.

WATERPROOFING SYSTEM

The first layer above the roof surface is a waterproofing membrane. Two common waterproofing techniques are monolithic and thermoplastic sheet membranes. Another option is a liquid-applied inverted roofing membrane assembly system in which the insulation is placed over the waterproofing, which adheres to the roof structure. An additional protective layer is generally placed on top of the membrane followed by a physical or chemical root barrier. Once the waterproofing system has been installed it should be fully tested prior to construction of the drainage system. Electronic leak detection systems should also be installed at this time if desired.

DRAINAGE LAYER

The drainage system includes a porous drainage layer and a geosynthetic filter mat to prevent fine growing medium particles from clogging the porous media. The drainage layer can be made up of gravels or recycled-polyethylene materials that are capable of water retention and efficient drainage. The depth of the drainage layer depends on the load bearing capacity of the roof structure and the stormwater retention requirements. The porosity of the drainage layer should be greater than or equal to 25%.

CONVEYANCE AND OVERFLOW

Once the porous media is saturated, all runoff (infiltrate or overland flow) should be directed to a traditional roof storm drain system. Landscaping style catch basins should be installed with the elevation raised to the desired ponding elevation. Alternately, roof drain flow restrictors can be used. Excess runoff can be directed through roof leaders to another stormwater BMP such as a rain barrel, soakaway, bioretention area, swale or simply drain to a pervious area.

GROWING MEDIUM

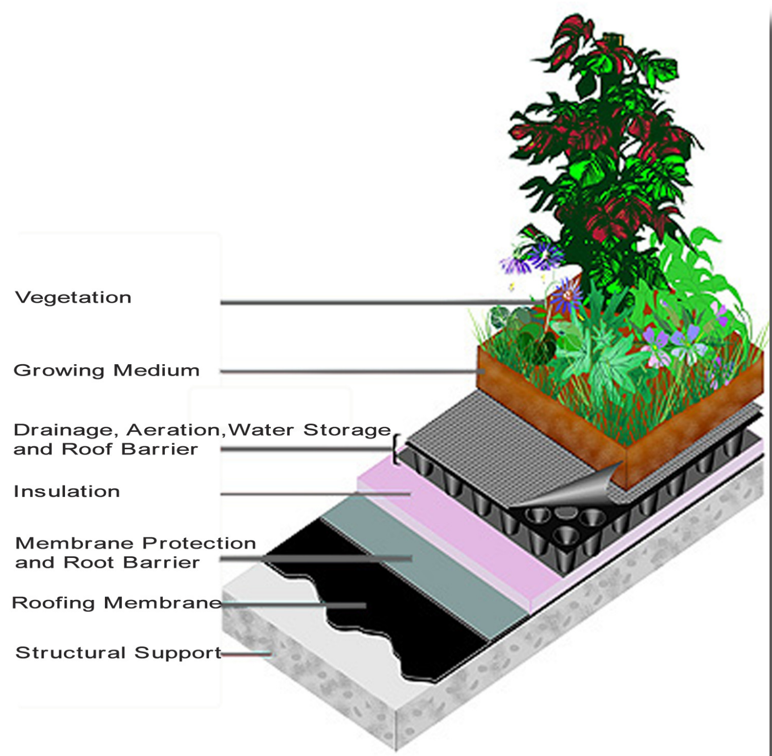
The growing medium is usually a mixture of sand, gravel, crushed brick, compost, or organic matter combined with soil. The medium ranges between 40 and 150 mm in depth and increases the roof load by 80 to 170 kg per square metre when fully saturated. The sensitivity of the receiving water to which the green roof ultimately drains should be taken into consideration when selecting the growing medium mix. Green roof growing media with less compost in the mix will leach less nitrogen and phosphorus. Low nutrient growing media also promotes the dominance of stress-tolerant native plants. Fertilizer applied to the growing medium during production and the period during which vegetation is becoming established should be coated controlled release fertilizer to reduce the risk of damage to vegetation and leaching of nutrients into overflowing runoff. Fertilizer applications should not exceed 5 g of nitrogen per square metre.

MODULAR SYSTEMS

Modular systems are trays of vegetation in a growing medium that are prepared and grown off-site and placed on the roof for complete coverage. There are also pre-cultivated vegetation blankets that are grown in flexible growing media structures, allowing them to be rolled out onto the green roof assembly. The advantage of these systems is that they can be removed for maintenance.

Green Rooftops are composed of:

- A roof structure capable of supporting the weight of a green roof system;
- A waterproofing system designed to protect the building and roof structure;
- A drainage layer that consists of a porous medium capable of water storage for plant uptake;
- A geosynthetic layer to prevent fine soil media from clogging the porous media;
- Soil with appropriate characteristics to support selected green roof plants;
- Plants with appropriate tolerance for harsh rooftop conditions and shallow rooting depths.



GREEN ROOF LAYERS
(Source: Great Lakes Water Institute)

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Green Rooftops	Yes	Yes	Yes

GENERAL SPECIFICATIONS

ASTM International released the following Green Roof standards in 2005:

- E2396-05 Standard Test Method for Saturated Water Permeability of Granular Drainage Media;
- E2397-05 Standard Determination of Dead Loads and Live Loads associated with Green Roof Systems;
- E2398-05 Standard test method for water capture and media retention of geocomposite drain layers for green roof systems;
- E2399-05 Standard Test Method for Maximum Media Density for Dead Load Analysis of Green Roof Systems; and
- E2400-06 Standard Guide for Selection, Installation, and Maintenance of Plants for Green Roof Systems.

Although the Ontario Building Code (2006) does not specifically address the construction of green roofs, requirements from the Building Code Act and Division B may apply to components of the construction. Further requirements from sections 2.4 and 2.11 of the 1997 Ontario Fire Code also require consideration.

COMMON CONCERNS

WATER DAMAGE TO ROOF

While failure of waterproofing elements may present a risk of water damage, a warranty can ensure that any damage to the waterproofing system will be repaired. Leak detection systems can also be installed to minimize or prevent water damage.

VEGETATION MAINTENANCE

Extreme weather conditions can have an impact on plant survival. Appropriate plant selection will help to ensure plant survival during weather extremes. Irrigation during the first year may be necessary in order to establish vegetation. Vegetation maintenance costs decrease substantially after the first two years.

COLD CLIMATE

Green roofs are a feasible BMP for cold climates. Snow can protect the vegetation layer and once thawed, will percolate into the growing medium and is either absorbed or drained away just as it would during a rain event. No seasonal adjustments in operation are needed.

COST

An analysis to determine cost effectiveness for a given site should include the roof lifespan, energy savings, stormwater management requirements, aesthetics, market value, tax and other municipal incentives. It is estimated that green roofs can extend the life of a roof structure by as long as 20 years by reducing exposure of the materials to sun and precipitation. They can also reduce energy demand by as much as 75% .

ON PRIVATE PROPERTY

Property owners or managers will need to be educated on their routine operation and maintenance needs, understand the long-term maintenance plan, and may be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer user fee based on the area of impervious cover on a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain existing practices.

CONSTRUCTION CONSIDERATIONS

An experienced professional green roof installer should install the green roof. The installer must work with the construction contractor to ensure that the waterproofing membrane installed is appropriate for use under a green roof assembly. Conventional green roof assemblies should be constructed in sections for easier inspection and maintenance access to the membrane and roof drains. Green roofs can be purchased as complete systems from specialized suppliers who distribute all the assembly components, including the waterproofing membrane. Alternatively, a green roof designer can design a customized green roof and specify suppliers for each component of the system.

OPERATION AND MAINTENANCE

- Green roof maintenance is typically greatest in the first two years as plants are becoming established. Vegetation should be monitored to ensure dense coverage. A warranty on the vegetation should be included in the construction contract.
- Regular operation of a green roof includes irrigation and leak detection. Watering should be based on actual soil moisture conditions as plants are designed to be drought tolerant. Electronic leak detection is recommended. This system, also used with traditional roofs, must be installed prior to the green roof.
- Ongoing maintenance should occur at least twice per year and should include weeding to remove volunteer seedlings of trees and shrubs and debris removal. In particular, the overflow conveyance system should be kept clear.

SITE CONSIDERATIONS

Roof Slope
Green roofs may be installed on roofs with slopes up to 10%.

Drainage Area & Runoff Volume
Green roofs are designed to capture precipitation falling directly onto the roof surface. They are not designed to receive runoff diverted from other source areas.

Structural Requirements
Load bearing capacity of the building structure and selected roof deck need to be sufficient to support the weight of the soil, vegetation and accumulated water or snow, and may also need to support pedestrians, concrete pavers, etc.

GREEN ROOFS

CVC/TRCA LOW IMPACT DEVELOPMENT
PLANNING AND DESIGN GUIDE - FACT SHEET

TORONTO AND REGION Conservation for The Living City

CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.2 OF THE CVC/TRCA LID SWM GUIDE

VEGETATED FILTER STRIPS

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Vegetated filter strips (a.k.a. buffer strips and grassed filter strips) are gently sloping, densely vegetated areas that treat runoff as sheet flow from adjacent impervious areas. They slow runoff velocity and filter out suspended sediment and associated pollutants, and provide some infiltration into underlying soils. Originally used as an agricultural treatment practice, filter strips have evolved into an urban SWM practice. Vegetation may be comprised of a variety of trees, shrubs and native plants to add aesthetic value as well as water quality benefits. With proper design and maintenance, filter strips can provide relatively high pollutant removal benefits. Maintaining sheet flow into the filter strip through the use of a level spreading device (e.g., pea gravel diaphragm) is essential. Using vegetated filter strips as pretreatment practices to other best management practices is highly recommended. They also provide a convenient area for snow storage and treatment, and are particularly valuable due to their capacity for snowmelt infiltration.

DESIGN GUIDANCE

GEOMETRY AND SITE LAYOUT

The maximum contributing flow path length across adjacent impervious surfaces should not exceed 25 metres. The impervious surfaces draining to a filter strip should not have slopes greater than 3%.

The filter strip should have a flow path length of at least five (5) metres to provide substantial water quality benefits; however, some pollutant removal benefits are realized with three (3) metres of flow path length.

PRETREATMENT

A pea gravel diaphragm at the top of the slope is recommended to act as a pretreatment device and level spreader to maintain sheet flow into the filter strip.

CONVEYANCE AND OVERFLOW

Level spreaders are recommended to ensure runoff draining into the filter strip does so as sheet flow (e.g., pea gravel diaphragms, concrete curbs with cutouts). When filter strip slopes are greater than 5%, a series of level spreaders should be used to help maintain sheet flow.

When designed as a stand alone water quality BMP (i.e., not pretreatment to another BMP) the vegetated filter strip should be designed with a pervious berm at the toe of the slope for shallow ponding of runoff. The berm should be 150 to 300 millimetres in height above the bottom of the depression and should contain a perforated pipe underdrain connected to the storm sewer. The volume ponded behind the berm should be equal to the water quality storage requirement. During larger storms, runoff overtops the berm and flows directly into a storm sewer inlet.

SOIL AMENDMENTS

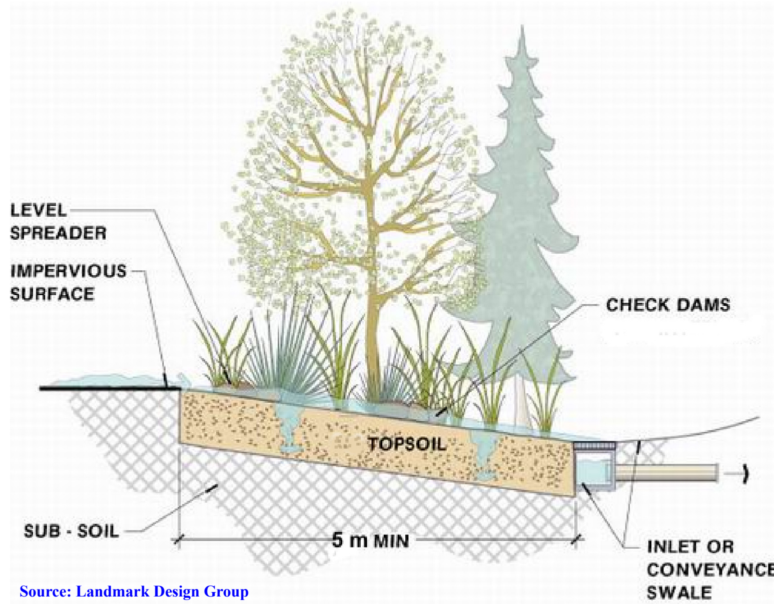
If soils on the filter strip site are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume.

OPERATION AND MAINTENANCE

Generally, routine maintenance will be the same as for any other landscaped area; weeding, pruning, and litter removal. Regular watering may be required during the first two years until vegetation is established. Routine inspection is very important to ensure that dense vegetation cover is maintained and inflowing runoff does not become concentrated and short circuit the practice. Vehicles should not be parked or driven on filter strips. For routine mowing of grassed filter strips, the lightest possible mowing equipment should be used to prevent soil compaction.

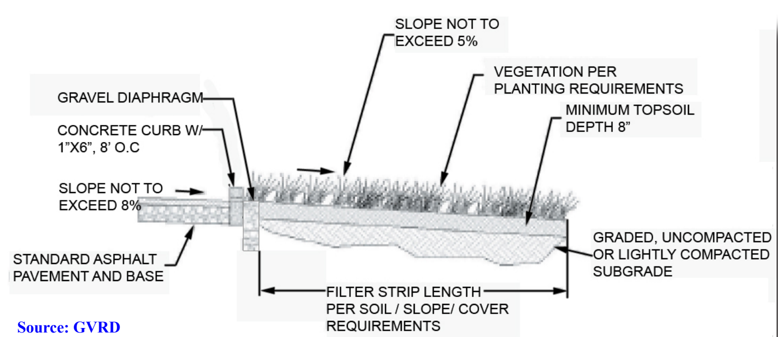
For the first two years following construction the filter strip should be inspected at least quarterly and after every major storm event (> 25 mm). Subsequently, inspections should be conducted in the spring and fall of each year and after major storm events. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, channelization, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices and the filter strip surface at least twice annually. Other maintenance activities include weeding, replacing dead vegetation, repairing eroded areas, dethatching and aerating as needed. Remove accumulated sediment on the filter strip surface when dry and exceeding 25 mm depth

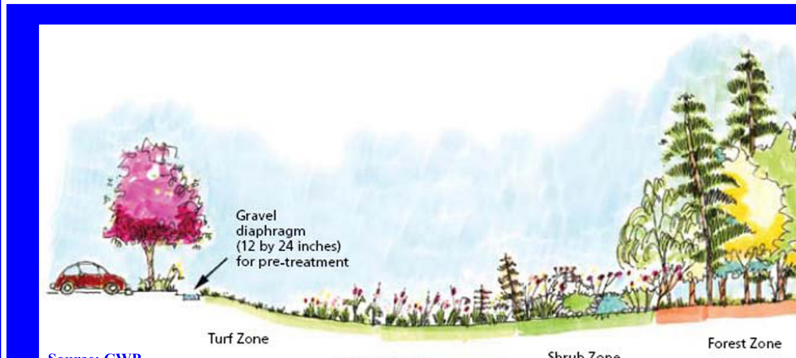


Source: Landmark Design Group

VEGETATED FILTER STRIPS



Source: GVRD



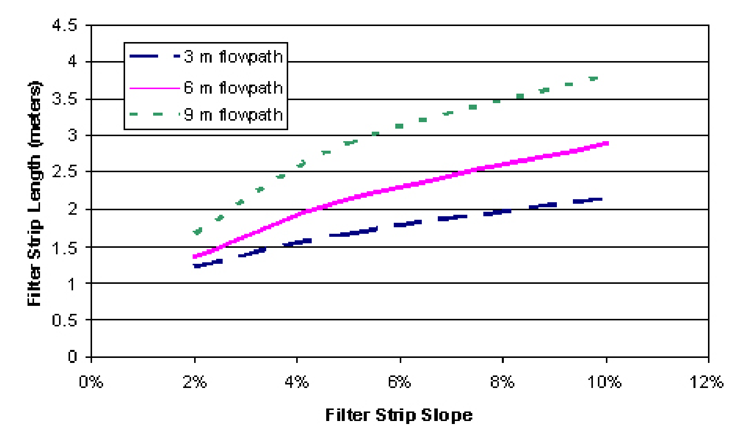
Source: CWP

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Vegetated Filter Strips	Partial - depends on soil infiltration rate	Partial - depends on soil infiltration rate and flow path length	Partial - depends on soil infiltration rate

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Gravel Diaphragm	Washed 3 to 10 mm diameter stone	Diaphragm should be a minimum of 300 mm wide and 600 mm deep (MDE, 2000).
Gravel/ Earthen Berm	Berm should be composed of sand (35 to 60%), silt (30 to 55%), and gravel (10 to 25%) (MDE, 2000) Gravel should be 15 to 25 mm in diameter.	N/A



Source: Pennsylvania Department of Environmental Protection

CONSTRUCTION CONSIDERATIONS

Soil Disturbance and Compaction

The limits of disturbance should be clearly shown on all construction drawings. Before site work begins, areas for filter strips should be clearly marked and protected by acceptable signage and silt fencing. Only vehicular traffic used for construction should be allowed within three metres of the filter strip.

Erosion and Sediment Control

Construction runoff should be directed away from the proposed filter strip site. If used for sediment control during construction, it should be regraded and revegetated after construction is finished.

SITE CONSIDERATIONS

Available Space

The flow path length across the vegetated filter strip should be at least 5 metres to provide substantial water quality benefits. Vegetated filter strips incorporated as pretreatment to another BMP may be designed with shorter flow path lengths.

Site Topography

Filter strips are best used to treat runoff from ground-level impervious surfaces that generate sheet flow (e.g., roads and parking areas). The recommended filter strip slope is between 1 to 5%.

Flow Path Length Across Impermeable Surface

The maximum flow path length across the contributing impermeable surface should be less than 25 metres.

Soil

Filter strips are a suitable practice on all soil types. If soils are highly compacted, or of such low fertility that vegetation cannot become established, they should be tilled to a depth of 300 mm and amended with compost to achieve an organic content of 8 to 15% by weight or 30 to 40% by volume.

Pollution Hot Spot Runoff

To protect groundwater from possible contamination, source areas where land uses or human activities have the potential to generate highly contaminated runoff (e.g., vehicle fueling, servicing and demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites) should not be treated by vegetated filter strips.

Water table

Filter strips should only be used where depth to the seasonally high water table is at least one (1) metre below the ground surface.

Toronto and Region Conservation for The Living City
CVC Credit Valley Conservation

FOR FURTHER DETAILS SEE SECTION 4.6 OF THE CVC/TRCA LID SWM GUIDE

DRY SWALES

CVC/TRCA LOW IMPACT DEVELOPMENT
PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

A dry swale can be thought of as an enhanced grass swale that incorporates an engineered filter media bed and optional perforated pipe underdrain or a bioretention cell configured as a linear open channel. They can also be referred to as infiltration swales or bio-swales. Dry swales are similar to enhanced grass swales in terms of the design of their surface geometry, slope, check dams and pretreatment devices. They are similar to bioretention cells in terms of the design of the filter media bed, gravel storage layer and optional underdrain. In general, they are open channels designed to convey, treat and attenuate stormwater runoff. Vegetation or aggregate material on the surface of the swale slows the runoff water to allow sedimentation, filtration through the root zone and engineered soil bed, evapotranspiration, and infiltration into the underlying native soil.


Source: TRCA


Source: Seattle Public Utilities


Source: City of Portland


Source: Lynn Richards


Source: Portland Public Schools


Source: Lake County, Illinois

DESIGN GUIDANCE

GEOMETRY AND SITE LAYOUT

- SHAPE: A parabolic shape is preferable for aesthetic, maintenance and hydraulic reasons. However, design may be simplified with a trapezoidal cross-section as long as the engineered soil (filter media) bed boundaries lay in the flat bottom areas. Swale length between culverts should be 5 metres or greater.
- BOTTOM WIDTH: For the trapezoidal cross section, the bottom width should be between 0.75 and 2 metres. When greater widths are desired, bioretention cell designs should be used.
- SIDE SLOPES: Should be no steeper than 3:1 for maintenance considerations (mowing). Flatter slopes are encouraged where adequate space is available to provide pretreatment for sheet flows entering the swale.
- LONGITUDINAL SLOPE: Should be as gradual as possible to permit the temporary ponding of the water quality storage requirement. Should be designed with longitudinal slopes generally ranging from 0.5 to 4%, and no greater than 6%. On slopes steeper than 3%, check dams should be used. Check dam spacing should be based on the slope and desired ponding volume. They should be spaced far enough apart to allow access for maintenance equipment (e.g., mowers).

PRE-TREATMENT

Pretreatment prevents premature clogging by capturing coarse sediments before they reach the filter bed. Where runoff source areas produce little sediment, such as roofs, dry swales can function effectively without pretreatment. To treat parking area or road runoff, a two-cell design that incorporates a forebay is recommended. Pretreatment practices that may be feasible, depending on conveyance method and availability of space include:

- SEDIMENTATION FOREBAY (TWO-CELL DESIGN): Forebay ponding volume should account for 25% of the water quality storage requirement and be designed with a 2:1 length to width ratio.
- VEGETATED FILTER STRIP (SHEET FLOW): Should ideally be a minimum of three (3) metres in width. If smaller strips are used, more frequent maintenance of the filter bed can be anticipated.
- GRAVEL DIAPHRAGM (SHEET FLOW): A small trench filled with pea gravel, which is perpendicular to the flow path between the edge of the pavement and the dry swale will promote settling out of sediment and maintain sheet flow into the facility. A drop of 50-150 mm into the gravel diaphragm can be used to dissipate energy and promote settling.
- RIP RAP AND/OR DENSE VEGETATION (CHANNEL FLOW): Suitable for small dry swales with drainage areas less than 100 square metres.

GRAVEL STORAGE LAYER

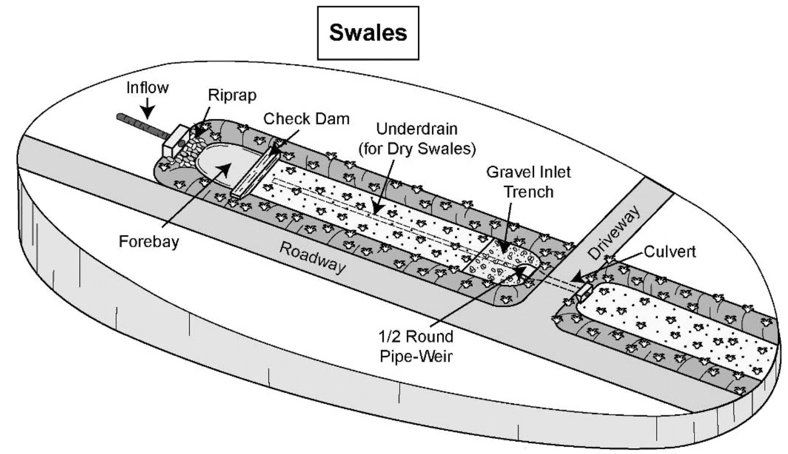
- DEPTH: Should be a minimum of 300 mm deep and sized to provide the required storage volume. Granular material should be 50 mm diameter clear stone.
- PEA GRAVEL CHOKING LAYER: A 100 mm deep layer of pea gravel (3 to 10 mm diameter clear stone) should be placed on top of the coarse gravel storage layer as a choking layer separating it from the overlying filter media bed.

FILTER MEDIA

- COMPOSITION: To ensure a consistent and homogeneous bed, filter media should come pre-mixed from an approved vendor.
- DEPTH: Recommended depth is between 1.0 and 1.25 m. However in constrained applications, pollutant removal benefits may be achieved in beds as shallow as 500 mm. If trees are to be included in the design, bed depth must be at least 1.0 m.
- MULCH: A 75 mm layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth and pretreats runoff before it reaches the filter bed.

UNDERDRAIN

- Only needed where native soil infiltration rate is less than 15 mm/hr (hydraulic conductivity of less than 1x10-6 cm/s).
- Should consist of a perforated pipe embedded in the coarse gravel storage layer at least 100 mm above the bottom.
- A strip of geotextile filter fabric placed between the filter media and pea gravel choking layer over the perforated pipe is optional to help prevent fine soil particles from entering the underdrain.
- A vertical standpipe connected to the underdrain at the furthest downstream end of the swale can be used as a cleanout and monitoring well.



ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Dry swale with no underdrain or full infiltration	Yes	Yes - size for water quality storage requirement	Partial - based on available storage volume and soil infiltration rate
Dry swale with underdrain or partial infiltration	Partial - based on available storage volume beneath the underdrain and soil infiltration rate	Yes - size for water quality storage requirement	Partial - based on available storage volume beneath the underdrain and soil infiltration rate
Dry swale with underdrain and impermeable liner or no infiltration	Partial - some volume reduction through evapotranspiration	Yes - size for water quality storage requirement	Partial - some volume reduction through evapotranspiration

OPERATION AND MAINTENANCE

Dry swales require routine inspection and maintenance of the landscaping as well as periodic inspection for less frequent maintenance needs or remedial maintenance. Generally, routine maintenance will be the same as for any other landscaped area; weeding, pruning, and litter removal. Regular watering may be required during the first two years until vegetation is established.

For the first two years following construction the facility should be inspected at least quarterly and after every major storm event (> 25 mm). Subsequently, inspections should be conducted in the spring and fall of each year and after major storm events. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, channelization, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices, the dry swale surface and inlet and outlets at least twice annually. Other maintenance activities include reapplying mulch, pruning, weeding replacing dead vegetation and repairing eroded areas as needed. Remove accumulated sediment on the dry swale surface when dry and exceeding 25 mm depth.

CONVEYANCE AND OVERFLOW

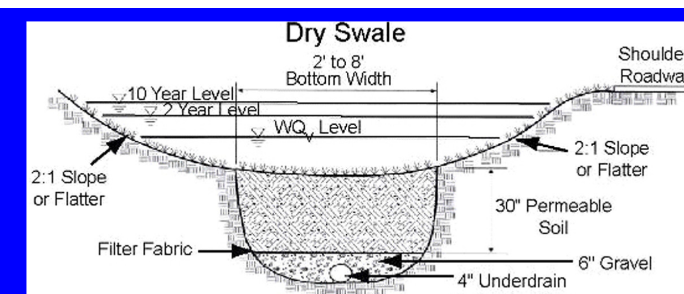
Should be designed for a maximum velocity of 0.5 m/s or less for a 4 hour 25 mm Chicago storm event. The swale should also convey the locally required design storm (usually the 10 year storm) at non-erosive velocities with freeboard provided above the required design storm water level.

MONITORING WELLS

A capped vertical standpipe consisting of an anchored 100 to 150 millimetre diameter perforated pipe with a lockable cap installed to the bottom of the facility at the furthest downgradient end is recommended for monitoring the length of time required to fully drain the facility between storms.

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Filter Media Composition	Filter Media Soil Mixture to contain: • 85 to 88% sand • 8 to 12% soil fines • 3 to 5% organic matter (leaf compost) Other Criteria: • Phosphorus soil test index (P-Index) value between 10 to 30 ppm • Cationic exchange capacity (CEC) greater than 10 meq/100 g • Free of stones, stumps, roots and other large debris • pH between 5.5 to 7.5 • Infiltration rate greater than 25 mm/hr.	Volumetric computation based on surface area and depth used in design computations
Geotextile	Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. For further guidance see CVC/TRCA LID SWM Planning and Design Guide, Table 4.9.4.	Strip over the perforated pipe underdrain (if present) between the filter media bed and gravel storage layer (stone reservoir).
Gravel	Washed 50 mm diameter clear stone with void space ratio of 0.4 should be used to surround the underdrain.	Volumetric computation based on depth.
Underdrain (optional)	Perforated HDPE or equivalent material, minimum 100 mm dia., 200 mm dia. recommended. Set pipe invert at least 100 mm above bottom of the gravel layer.	• Perforated pipe for length of dry swale. • Non-perforated pipe to connect with storm drain system. • One or more caps. • T's for underdrain
Check Dams	• Should be constructed of a non-erosive material such as wood, gabions, riprap, or concrete and underlain with filter fabric. • Wood used should consist of pressure treated logs or timbers, or water-resistant tree species such as cedar, hemlock, swamp oak or locust.	Computation of check dam material needed based on surface area and depth used in design computations
Mulch or Matting	• Shredded hardwood bark mulch • Where flow velocities dictate, use erosion and sediment control matting - coconut fiber or equivalent.	Mulch - A 75 mm layer on the surface of the filter bed. Matting - based on filter bed area.



SITE CONSIDERATIONS

Available Space
Footprints are 5 to 15% of their contributing drainage area. Swale length between culverts should be 5m or greater.

Site Topography
Longitudinal slopes ranging from 0.5 to 4%. On slopes steeper than 3%, check dams should be used.

Drainage Area and Runoff Volume to Site
Typically treat drainage areas of two hectares or less. Typical ratios of impervious drainage area to treatment facility area range from 5:1 to 15:1.

Soil
Dry swales can be located over any soil type, but hydrologic soil group A and B soils are best for achieving water balance benefits. Facilities should be located in portions of the site with the highest native soil infiltration rates. Where infiltration rates are less than 15 mm/hr (hydraulic conductivity less than 1x10-6 cm/s) an underdrain is required. Native soil infiltration rate at the proposed facility location and depth should be confirmed through measurement of hydraulic conductivity under field saturated conditions.

Wellhead Protection
Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.

Water Table
The bottom of the swale should be separated from the seasonally high water table or top of bedrock elevation by at least one (1) metre to prevent groundwater contamination.

Pollution Hot Spot Runoff
To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated dry swales designed for full or partial infiltration. Facilities designed with an impermeable liner (filtration only facilities) can be used to treat runoff from pollution hot spots.

Setback from Buildings
Should be set back four (4) metres from building foundations unless an impermeable liner and underdrain system is used.

Proximity to Underground Utilities
Designers should consult local utility design guidance for the horizontal and vertical clearance between storm drains, ditches, and surface water bodies.

CONSTRUCTION CONSIDERATIONS

Ideally, dry swale sites should remain outside the limit of disturbance until construction of the swale begins to prevent soil compaction by heavy equipment. Dry swale locations should never be used as the site of sediment basins during construction, as the concentration of fines will prevent post-construction infiltration. To prevent clogging, stormwater should be diverted away from the practice until the drainage area is fully stabilized.

TORONTO AND REGION Conservation for The Living City

CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.9 OF THE CVC/TRCA LID SWM GUIDE

BIORETENTION

CVC/TRCA LOW IMPACT DEVELOPMENT
PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

As a stormwater filter and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff. Depending on native soil infiltration rate and physical constraints, the system may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only (i.e., a biofilter). The primary component of the practice is the filter bed which is a mixture of sand, fines and organic material. Other elements include a mulch ground cover and plants adapted to the conditions of a stormwater practice. Bioretention is designed to capture small storm events or the water quality storage requirement. An overflow or bypass is necessary to pass large storm event flows. Bioretention can be adapted to fit into many different development contexts and provide a convenient area for snow storage and treatment.

Source: Minnesota Businesses for Clean Water

Source: City of Portland

DESIGN GUIDANCE

SOIL CHARACTERISTICS

Bioretention can be constructed over any soil type, but hydrologic soil group A and B are best for achieving water balance goals. If possible, bioretention should be sited in the areas of the development with the highest native soil infiltration rates. Bioretention in soils with infiltration rates less than 15 mm/hr will require an underdrain. Designers should verify the native soil infiltration rate at the proposed location and depth through measurement of hydraulic conductivity under field saturated conditions.

GEOMETRY & SITE LAYOUT

Key geometry and site layout factors include:

- The minimum footprint of the filter bed area is based on the drainage area. Typical drainage areas to bioretention are between 100 m2 to 0.5 hectares. The maximum recommended drainage area is 0.8 hectares. Typical ratios of impervious drainage area to treatment facility area range from 5:1 to 15:1.
- Bioretention can be configured to fit into many locations and shapes. However, cells that are narrow may concentrate flow as it spreads throughout the cell and result in erosion.
- The filter bed surface should be level to encourage stormwater to spread out evenly over the surface.

PRE-TREATMENT

Pretreatment prevents premature clogging by capturing coarse sediment particles before they reach the filter bed. Where the runoff source area produces little sediment, such as roofs, bioretention can function effectively without pretreatment. To treat parking area or road runoff, a two-cell design that incorporates a forebay is recommended. Pretreatment practices that may be feasible, depending on the method of conveyance and the availability of space include:

- *Two-cell design (channel flow):* Forebay ponding volume should account for 25% of the water quality storage requirement and be designed with a 2:1 length to width ratio.
- *Vegetated filter strip (sheet flow):* Should be a minimum of three (3) metres in width. If smaller strips are used, more frequent maintenance of the filter bed can be anticipated.
- *Gravel diaphragm (sheet flow):* A small trench filled with pea gravel, which is perpendicular to the flow path between the edge of the pavement and the bioretention practice will promote settling out of sediment and maintain sheet flow into the facility. A drop of 50-150 mm into the gravel diaphragm can be used to dissipate energy and promote settling.
- *Rip rap and/or dense vegetation (channel flow):* Suitable for small bioretention cells with drainage areas less than 100 square metres.

GRAVEL STORAGE LAYER

- DEPTH: Should be a minimum of 300 mm deep and sized to provide the required storage volume. Granular material should be 50 mm diameter clear stone.
- PEA GRAVEL CHOKING LAYER: A 100 mm deep layer of pea gravel (3 to 10 mm diameter clear stone) should be placed on top of the coarse gravel storage layer as a choking layer separating it from the overlying filter media bed.

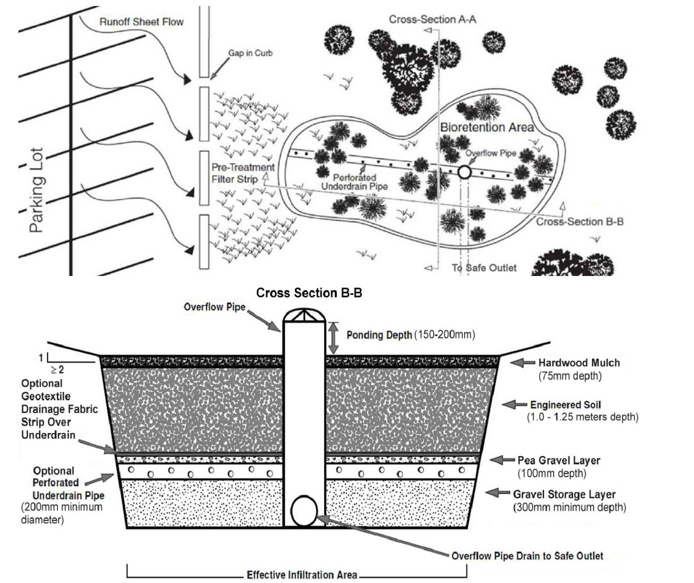
FILTER MEDIA

- COMPOSITION: To ensure a consistent and homogeneous bed, filter media should come pre-mixed from an approved vendor.
- DEPTH: Recommended depth is between 1.0 and 1.25 m. However in constrained applications, pollutant removal benefits may be achieved in beds as shallow as 500 mm. If trees are to be included in the design, bed depth must be at least 1.0 m.
- MULCH: A 75 mm layer of mulch on the surface of the filter bed enhances plant survival, suppresses weed growth and pretreats runoff before it reaches the filter bed.

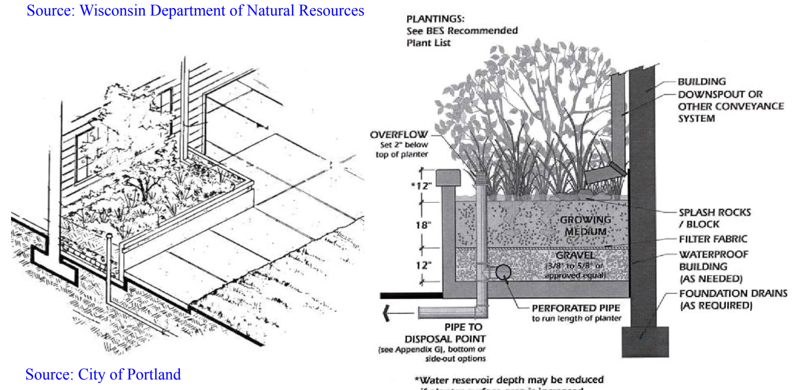
CONVEYANCE AND OVERFLOW

Bioretention can be designed to be inline or offline from the drainage system. Inline bioretention accepts all flow from a drainage area and conveys larger event flows through an overflow outlet. Overflow structures must be sized to safely convey larger storm events out of the facility. The invert of the overflow should be placed at the maximum water surface elevation of the bioretention area, which is typically 150-250 mm above the filter bed surface.

Offline bioretention practices use flow splitters or bypass channels that only allow the required water quality storage volume to enter the facility. This may be achieved with a pipe, weir, or curb opening sized for the target flow, but in conjunction, create a bypass channel so that higher flows do not pass over the surface of the filter bed. Using a weir or curb opening minimizes clogging and reduces maintenance frequency.



Source: Wisconsin Department of Natural Resources



Source: City of Portland

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefits
Bioretention with no underdrain	Yes	Yes - size for water quality storage requirement	Partial - based on available storage volume and infiltration rates
Bioretention with underdrain	Partial - based on available storage volume beneath the underdrain and soil infiltration rate	Yes - size for water quality storage requirement	Partial - based on available storage volume beneath the underdrain and soil infiltration rate
Bioretention with underdrain and impermeable liner	Partial - some volume reduction through evapotranspiration	Yes - size for water quality storage requirement	Partial - some volume reduction through evapotranspiration

UNDERDRAIN

- Only needed where native soil infiltration rate is less than 15 mm/hr (hydraulic conductivity of less than 1x10-6 cm/s).
- Should consist of a perforated pipe embedded in the coarse gravel storage layer at least 100 mm above the bottom.
- A strip of geotextile filter fabric placed between the filter media and pea gravel choking layer over the perforated pipe is optional to help prevent fine soil particles from entering the underdrain.
- A vertical standpipe connected to the underdrain can be used as a cleanout and monitoring well.

MONITORING WELLS

A capped vertical stand pipe consisting of an anchored 100 to 150 mm diameter perforated pipe with a lockable cap installed to the bottom of the facility is recommended for monitoring drainage time between storms.

GENERAL SPECIFICATIONS

Material	Specification	Quantity
Filter Media Composition	Filter Media Soil Mixture to contain: • 85 to 88% sand • 8 to 12% soil fines • 3 to 5% organic matter (leaf compost) Other Criteria: • Phosphorus soil test index (P-Index) value between 10 to 30 ppm • Cationic exchange capacity (CEC) greater than 10 meq/100 g • Free of stones, stumps, roots and other large debris • pH between 5.5 to 7.5 • Infiltration rate greater than 25 mm/hr	Recommended depth is between 1.0 and 1.25 metres.
Mulch Layer	Shredded hardwood bark mulch	A 75 mm layer on the surface of the filter bed
Geotextile	Material specifications should conform to Ontario Provincial Standard Specification (OPSS) 1860 for Class II geotextile fabrics. Should be woven monofilament or non-woven needle punched fabrics. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. For further guidance see CVC/TRCA LID SWM Planning and Design Guide, Table 4.5.5.	Strip over the perforated pipe underdrain (if present) between the filter media bed and gravel storage layer (stone reservoir)
Gravel	Washed 50 mm diameter clear stone should be used to surround the underdrain and for the gravel storage layer Washed 3 to 10 mm diameter clear stone should be used for pea gravel choking layer.	Volume based on dimensions, assuming a void space ratio of 0.4.
Underdrain	Perforated HDPE or equivalent, minimum 100 mm diameter, 200 mm recommended.	• Perforated pipe for length of cell. • Non-perforated pipe as needed to connect with storm drain system. • One or more caps. • T's for underdrain configuration

CONSTRUCTION CONSIDERATIONS

Ideally, bioretention sites should remain outside the limit of disturbance until construction of the bioretention begins to prevent soil compaction by heavy equipment. Locations should not be used as sediment basins during construction, as the concentration of fines will prevent post-construction infiltration. To prevent sediment from clogging the surface of a bioretention cell, stormwater should be diverted away from the bioretention until the drainage area is fully stabilized.

For further guidance regarding key steps during construction, see the CVC/TRCA LID SWM Planning and Design Guide, Section 4.5.2 - Construction Considerations)

OPERATION AND MAINTENANCE

Bioretention requires routine inspection and maintenance of the landscaping as well as periodic inspection for less frequent maintenance needs or remedial maintenance. Generally, routine maintenance will be the same as for any other landscaped area; weeding, pruning, and litter removal. Regular watering may be required during the first two years until vegetation is established.

For the first two years following construction the facility should be inspected at least quarterly and after every major storm event (> 25 mm). Subsequently, inspections should be conducted in the spring and fall of each year and after major storm events. Inspect for vegetation density (at least 80% coverage), damage by foot or vehicular traffic, channelization, accumulation of debris, trash and sediment, and structural damage to pretreatment devices.

Trash and debris should be removed from pretreatment devices, the bioretention area surface and inlet and outlets at least twice annually. Other maintenance activities include reapplying mulch, pruning, weeding replacing dead vegetation and repairing eroded areas as needed. Remove accumulated sediment on the bioretention area surface when dry and exceeding 25 mm depth.

SITE CONSIDERATIONS

Wellhead Protection

Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.

Available Space

Reserve open areas of about 10 to 20% of the size of the contributing drainage area.

Site Topography

Contributing slopes should be between 1 to 5%. The surface of the filter bed should be flat to allow flow to spread out. A stepped multi-cell design can also be used.

Available Head

If an underdrain is used, then 1 to 1.5 metres elevation difference is needed between the inflow point and the downstream storm drain invert.

Water Table

A minimum of one (1) metre separating the seasonally high water table or top of bedrock elevation and the bottom of the practice is necessary.

Soils

Bioretention can be located over any soil type, but hydrologic soil group A and B soils are best for achieving water balance benefits. Facilities should be located in portions of the site with the highest native soil infiltration rates. Where infiltration rates are less than 15 mm/hr (hydraulic conductivity less than 1x10-6 cm/s) an underdrain is required. Native soil infiltration rate at the proposed facility location and depth should be confirmed through measurement of hydraulic conductivity under field saturated conditions.

Drainage Area & Runoff Volume

Typical contributing drainage areas are between 100 m2 to 0.5 hectares. The maximum recommended contributing drainage area is 0.8 hectares. Typical ratios of impervious drainage area to treatment facility area range from 5:1 to 15:1.

Pollution Hot Spot Runoff

To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated by bioretention facilities designed for full or partial infiltration. Facilities designed with an impermeable liner (filtration only facilities) can be used to treat runoff from pollution hot spots.

Proximity to Underground Utilities

Designers should consult local utility design guidance for the horizontal and vertical clearances required between storm drains, ditches, and surface water bodies.

Overhead Wires

Check whether the future tree canopy height in the bioretention area will interfere with existing overhead phone and power lines.

Setback from Buildings

If an impermeable liner is used, no setback is needed. If not, a four (4) metre setback from building foundations should be applied.

TORONTO AND REGION Conservation for The Living City

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FOR FURTHER DETAILS SEE SECTION 4.5 OF THE CVC/TRCA LID SWM GUIDE

Stormwater Tree Pit

Alternative Names: Tree Box, Tree Box Filter, Street Tree Well

BENEFITS

Overall

- Reduces stormwater runoff volume, flow rate and temperature
- Increases groundwater infiltration and recharge
- Provides some local flood control
- Treats stormwater runoff
- Improves quality of local surface waterways
- Improves aesthetic appeal of streets and neighborhoods
- Provides wildlife habitat
- Provides shade to nearby buildings to reduce energy costs
- Requires limited space
- Simple to install
- Available in multiple sizes

Volume Attenuation/Flow Reduction

Stormwater tree pits generally capture and treat stormwater runoff from small, frequently-occurring storms but are not designed to capture runoff from large storms or extended periods of rainfall.

Pollutant Removal

Stormwater tree pits have proven to be effective at reducing some of the pollutants of most concern in the Charles River watershed:

- Total Suspended Solids: 85%
- Total Phosphorus: 74%
- Total Nitrogen: 68%
- Metals: 82%[4]

INSTALLATION COST

$8,000 – $10,000, to purchase one prefabricated system including filter material, plants and possibly some maintenance

$1500 – $6000 installation[3, 4, 6]

DESCRIPTION

Stormwater tree pits consist of an underground structure and above ground plantings which collect and treat stormwater using bioretention. Bioretention systems collect and filter stormwater through layers of mulch, soil and plant root systems, where pollutants such as bacteria, nitrogen, phosphorus, heavy metals, oil and grease are retained, degraded and absorbed. Treated stormwater is then infiltrated into the ground or, if infiltration is not appropriate, discharged into a traditional stormwater drainage system. Numerous prefabricated tree pit structures are commercially available. These typically include a ready-made concrete box containing an appropriate soil mixture and may also include plantings, usually one tree or a few small shrubs. Although underground they differ, above ground stormwater tree pits closely resemble traditional street trees and are perfect for urban streets where space is limited. Ideally, stormwater tree pits are employed in conjunction with other stormwater best management practices.

MAINTENANCE

Needs and Frequency

- Periodic inspection of plants and structural components
- Periodic cleaning of inflow and outflow mechanisms
- Periodic testing of mulch and soil for build-up of pollutants that may be harmful to the vegetation
- Biannual replacement of mulch

Cost

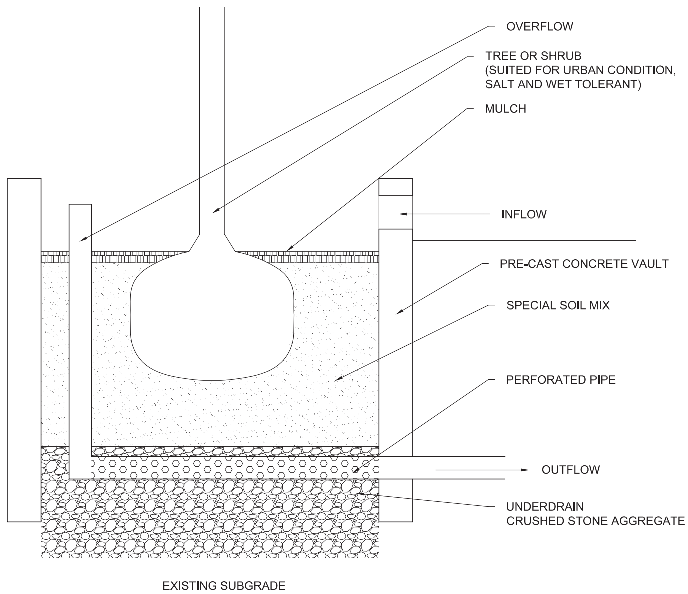
$100 – $500 annually/stormwater tree pit

Many proprietors of prefabricated systems will offer annual maintenance plans which can cost up to $500/year, however, if maintenance is performed by the stormwater tree pit owner it can usually be done more economically.[4]

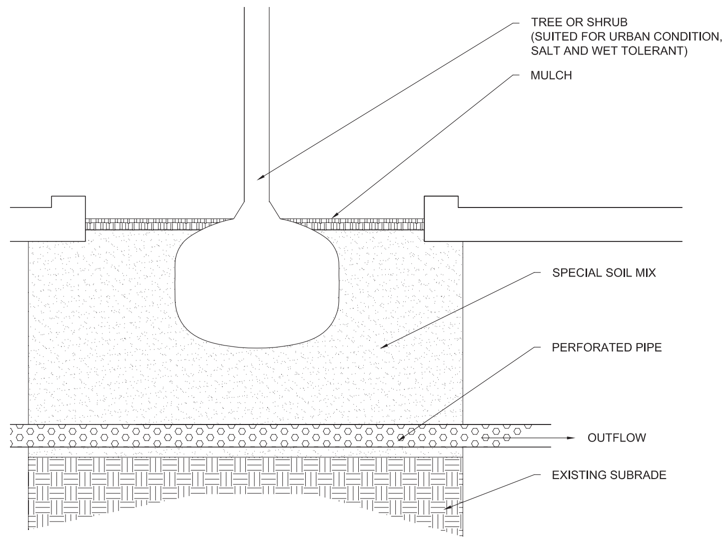
Other

Stormwater tree pits have an average lifespan of 25 years, although vegetation may need to be replaced more frequently.[4]

SCHEMATICS



Adapted from:
Low Impact Development Technologies
for Stormwater Management
http://www.unh.edu/erg/cstev/Presentations/index.htm
Accessed 01/22/2008



Adapted from:
Urban Horticultural Institute, New York
http://www.hort.cornell.edu/uhi/outreach/csc/article.html
Accessed 06/16/08

EXAMPLE PROJECTS

Town of Milton
Milton, MA
Tree pits are being installed upgradient of traditional stormwater catch basins to capture and treat stormwater runoff before it enters the stormwater drainage system.[5]

City of Portland
Portland, OR
Stormwater tree pits are being utilized in retrofits of narrow city streets to collect and treat stormwater.

ADDITIONAL CONCERNS OR UNKNOWNS

- Stormwater tree pits should not be placed at a low point as they are not designed to collected large volumes of runoff.
- Stormwater tree pits should be used in conjunction with other systems, such as upgradient of a traditional catch basin or other stormwater best management practice (BMP).

SOURCES

[1]Center for Watershed Protection. (2007, August). Urban Stormwater Retrofit Practices Appendices. Urban Subwatershed Restoration Manual Series.

[2]Coffman, L. and T. Siviter. Filterra® by Americast. An Advanced Sustainable Stormwater Treatment System.

[3]Cooke, I. (2007). Neponset River Watershed Association. Personal Communication.

[4]Low Impact Development Center (LIDC). (2005, November). Tree Box Filters. Low Impact Development for Big Box Retailers. Available at: http://www.lowimpactdevelopment.org/bigbox/lid%20articles/bigbox_final_doc.pdf.

[5]The Neponset River Watershed Association. (2007). NepRWA's Current Projects. Neponset.org. http://www.neponset.org/CurrentProjects.htm.

[6]Roy, S. (2007). GeoSyntec. Personal Communication. 2007.

SOAKAWAYS, INFILTRATION TRENCHES AND CHAMBERS

CVC/TRCA LOW IMPACT DEVELOPMENT
PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Soakaways are rectangular or circular excavations lined with geotextile fabric and filled with clean granular stone or other void forming material that receive runoff from a perforated pipe inlet and allow it to infiltrate into the native soil. They typically service individual lots and receive only roof and walkway runoff but can also be designed to receive overflows from rainwater harvesting systems. Soakaways can also be referred to as infiltration galleries, dry wells or soakaway pits.

Infiltration trenches are rectangular trenches lined with geotextile fabric and filled with clean granular stone or other void forming material. Like soakaways, they typically service an individual lot and receive only roof and walkway runoff. This design variation on soakaways is well suited to sites where available space for infiltration is limited to narrow strips of land between buildings or properties, or along road rights-of-way. They can also be referred to as infiltration galleries or linear soakaways.

Infiltration chambers are another design variation on soakaways. They include a range of proprietary manufactured modular structures installed underground, typically under parking or landscaped areas that create large void spaces for temporary storage of stormwater, allowing it to infiltrate into the underlying native soil. Structures typically have open bottoms, perforated side walls and optional underlying granular stone reservoirs. They can be installed individually or in series in trench or bed configurations. They can infiltrate roof, walkway, parking lot and road runoff with adequate pretreatment. Due to the large volume of underground void space they create in comparison to a soakaway of the same dimensions, and the modular nature of their design, they are well suited to sites where available space for other types of BMPs is limited, or where it is desirable for the facility to have little or no surface footprint (e.g., high density development contexts). They can also be referred to as infiltration tanks.

DESIGN GUIDANCE

MONITORING WELLS

Capped vertical non-perforated pipes connected to the inlet and outlet pipes are recommended to provide a means of inspecting and flushing them out as part of routine maintenance. A capped vertical standpipe consisting of an anchored 100 to 150 mm diameter perforated pipe with a lockable cap installed to the bottom of the facility is also recommended for monitoring the length of time required to fully drain the facility between storms. Manholes and inspection ports should be installed in infiltration chambers to provide access for monitoring and maintenance activities.

PRE-TREATMENT

It is important to prevent sediment and debris from entering infiltration facilities because they could contribute to clogging and failure of the system. The following pretreatment devices are options:

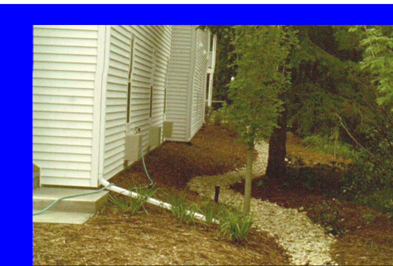
- Leaf screens: Leaf screens are mesh screens installed either on the building eavestroughs or roof downspouts and are used to remove leaves and other large debris from roof runoff.
- In-ground devices: Devices placed between a conveyance pipe and the facility (e.g., oil and grit separators, sedimentation chamber or goss traps), that can be designed to remove both large and fine particulate from runoff. A number of proprietary stormwater filter designs are available
- Vegetated filter strips or grass swales: Road and parking lot runoff can be pretreated with vegetated filter strips or grass swales prior to entering the infiltration practice

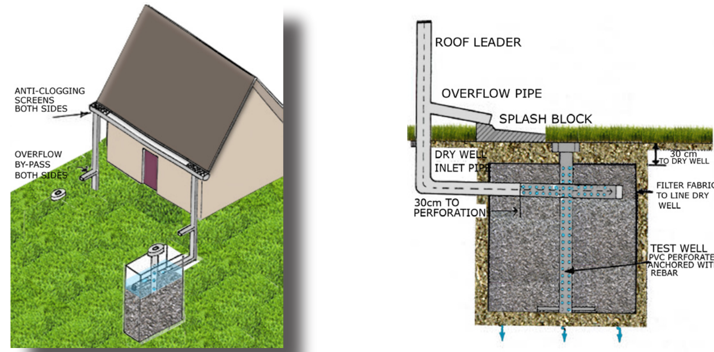
FILTER MEDIA

- Stone reservoir: Soakaways and infiltration trenches should be filled with uniformly-graded, washed stone that provides 30 to 40% void space. Granular material should be 50 mm clear stone
- Geotextile: A non-woven needle punched, or woven monofilament geotextile fabric should be installed around the stone reservoir of soakaways and infiltration trenches with a minimum overlap at the top of 300 mm. Woven slit film and non-woven heat bonded fabrics should not be used as they are prone to clogging. Specification of geotextile fabrics should consider the apparent opening size (AOS) for non-woven fabrics, or percent open area (POA) for woven fabrics, which affect the long term ability to maintain water flow. Other factors that need consideration include maximum forces to be exerted on the fabric, and the load bearing ratio, texture (i.e., grain size distribution) and permeability of the native soil in which they will be installed.

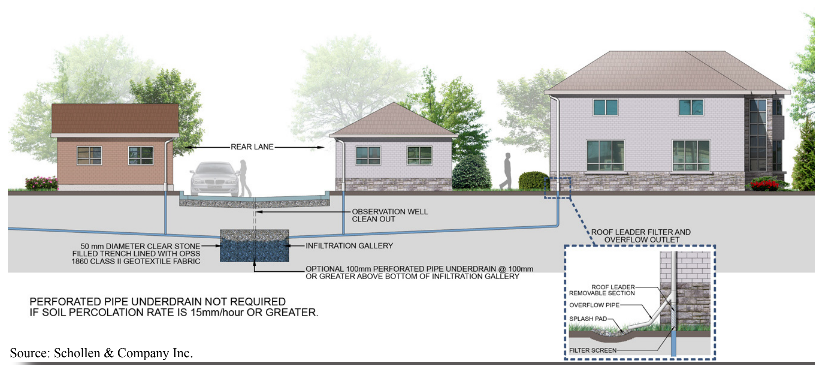

Source: Lanark Consultants Ltd


Source: Pennsylvania Department of Environmental Protection





DRY WELL SYSTEM



INFILTRATION TRENCH BELOW A LANEWAY

INFILTRATION CHAMBER SYSTEM UNDER A PARKING LOT

GEOMETRY AND SITE LAYOUT

Soakaways and infiltration chambers can be designed in a variety of shapes, while infiltration trenches are typically rectangular excavations with a bottom width generally between 600 and 2400 mm. Facilities should have level or nearly level bed bottoms.

CONVEYANCE AND OVERFLOW

Inlet pipes to soakaways and infiltration trenches are typically perforated pipe connected to a standard non-perforated pipe or eavestrough that conveys runoff from the source area to the facility. The inlet and overflow outlet to the facility should be installed below the maximum frost penetration depth to prevent freezing. The overflow outlet can simply be the perforated pipe inlet that backs up when the facility is at capacity and discharges to a splash pad and pervious area at grade or can be a pipe that is at the top of the gravel layer and is connected to a storm sewer. Outlet pipes must have capacity equal to or greater than the inlet.

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Soakaways, Infiltration Trenches and Chambers	Yes	Yes	Partial, depends on soil infiltration rate

CONSTRUCTION CONSIDERATIONS

SOIL DISTURBANCE AND COMPACTION: Before site work begins, locations of facilities should be clearly marked. Only vehicular traffic used for construction of the infiltration facility should be allowed close to the facility location.

EROSION AND SEDIMENT CONTROL: Infiltration practices should never serve as a sediment control device during construction. Construction runoff should be directed away from the proposed facility location. After the site is vegetated, erosion and sediment control structures can be removed.

COMMON CONCERNS

RISK OF GROUNDWATER CONTAMINATION

Most pollutants in urban runoff are well retained by infiltration practices and soils and therefore, have a low to moderate potential for groundwater contamination. To minimize risk of groundwater contamination the following management approaches are recommended:

- infiltration practices should not receive runoff from high traffic areas where large amounts of de-icing salts are applied (e.g., busy highways), nor from pollution hot spots;
- prioritize infiltration of runoff from source areas that are comparatively less contaminated such as roofs, low traffic roads and parking areas; and,
- apply sedimentation pretreatment practices (e.g., oil and grit separators) before infiltration of road or parking area runoff.

RISK OF SOIL CONTAMINATION

Available evidence from monitoring studies indicates that small distributed stormwater infiltration practices do not contaminate underlying soils, even after 10 years of operation.

ON PRIVATE PROPERTY

Property owners or managers will need to be educated on their routine maintenance needs, understand the long-term maintenance plan, and be subject to a legally binding maintenance agreement. An incentive program such as a storm sewer user fee based on the area of impervious cover on a property that is directly connected to a storm sewer could be used to encourage property owners or managers to maintain existing practices. Alternatively, infiltration practices could be located in an expanded road right-of-way or "stormwater easement" so that municipal staff can access the facility in the event it fails to function properly.

WINTER OPERATION

Soakaways, infiltration trenches and chambers will continue to function during winter months if the inlet pipe and top of the facility is located below the local maximum frost penetration depth.

OPERATION AND MAINTENANCE

Maintenance typically consists of cleaning out leaves, debris and accumulated sediment caught in pretreatment devices, inlets and outlets annually or as needed. Inspection via an monitoring well should be performed to ensure the facility drains within the maximum acceptable length of time (typically 72 hours) at least annually and following every major storm event (>25 mm). If the time required to fully drain exceeds 72 hours, drain via pumping and clean out the perforated pipe underdrain, if present. If slow drainage persists, the system may need removal and replacement of granular material and/or geotextile fabric.

SITE CONSIDERATIONS

Wellhead Protection

Facilities receiving road or parking lot runoff should not be located within two (2) year time-of-travel wellhead protection areas.

Site Topography

Facilities cannot be located on natural slopes greater than 15%.

Water Table

The bottom of the facility should be vertically separated by one (1) metre from the seasonally high water table or top of bedrock elevation.

Soil

Soakaways, infiltration trenches and chambers can be constructed over any soil type, but hydrologic soil group A or B soils are best for achieving water balance and channel erosion control objectives. If possible, facilities should be located in portions of the site with the highest native soil infiltration rates. Designers should verify the soil infiltration rate at the proposed location and depth through field measurement of hydraulic conductivity under field saturated conditions.

Drainage Area

Typically are designed with an impervious drainage area to treatment facility area ratio of between 5:1 and 20:1. A maximum ratio of 10:1 is recommended for facilities receiving road or parking lot runoff.

Pollution Hot Spot Runoff

To protect groundwater from possible contamination, runoff from pollution hot spots should not be treated by soakaways, infiltration trenches or chambers.

Setback from Buildings

Facilities should be setback a minimum of four (4) metres from building foundations.

Proximity to Underground Utilities

Local utility design guidance should be consulted to define the horizontal and vertical offsets. Generally, requirements for underground utilities passing near the practice will be no different than for utilities in other pervious areas. However, the designer should consider the need for long term maintenance when locating infiltration facilities near other underground utilities.

TORONTO AND REGION Conservation for The Living City
CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.4 OF THE CVC/TRCA LID SWM GUIDE

RAINWATER HARVESTING

CVC/TRCA LOW IMPACT DEVELOPMENT PLANNING AND DESIGN GUIDE - FACT SHEET

GENERAL DESCRIPTION

Rainwater harvesting is the process of intercepting, conveying and storing rainfall for future use. The rain that falls upon a catchment surface, such as a roof, is collected and conveyed into a storage tank. Storage tanks range in size from rain barrels for residential land uses (typically 190 to 400 litres in size), to large cisterns for industrial, commercial and institutional land uses. A typical pre-fabricated cistern can range from 750 to 40,000 litres in size.

With minimal pretreatment (e.g., gravity filtration or first-flush diversion), the captured rainwater can be used for outdoor non-potable water uses such as irrigation and pressure washing, or in the building to flush toilets or urinals. It is estimated that these applications alone can reduce household municipal water consumption by up to 55%. The capture and use of rainwater can, in turn, significantly reduce stormwater runoff volume and pollutant load. By providing a reliable and renewable source of water to end users, rainwater harvesting systems can also help reduce demand on municipal treated water supplies. This helps to delay expansion of treatment and distribution systems, conserve energy used for pumping and treating water and lower consumer water bills.

DESIGN GUIDANCE

CATCHMENT AREA

The catchment area is simply the surface from which rainfall is collected. Generally, roofs are the catchment area, although rainwater from low traffic parking lots and walkways, may be suitable for some non-potable uses (e.g., outdoor washing). The quality of the harvested water will vary according to the type of catchment area and material from which it is constructed. Water harvested from parking lots, walkways and certain types of roofs, such as asphalt shingle, tar and gravel, and wood shingle roofs, should only be used for irrigation or toilet flushing due to potential for contamination with toxic compounds.

COLLECTION AND CONVEYANCE SYSTEM

The collection and conveyance system consists of the eavestroughs, downspouts and pipes that channel runoff into the storage tank. Eavestroughs and downspouts should be designed with screens to prevent large debris from entering the storage tank. For dual use cisterns (used year-round for both outdoor and indoor uses), the conveyance pipe leading to the cistern should be buried at a depth no less than the local maximum frost penetration depth and have a minimum 1% slope. If this is not possible, conveyance pipes should either be located in a heated indoor environment (e.g., garage, basement) or be insulated or equipped with heat tracing to prevent freezing. All connections between downspouts, conveyance pipes and the storage tank must prevent entry of small animals or insects into the storage tank.

PRE-TREATMENT

Pretreatment is needed to remove debris, dust, leaves, and other debris that accumulates on roofs and prevents clogging within the rainwater harvesting system. For dual use cisterns that supply water for irrigation and toilet flushing only, filtration or first-flush diversion pretreatment is recommended. To prevent ice accumulation and damage during winter, first-flush diverters or in-ground filters should be in a temperature controlled environment, buried below the local frost penetration depth, insulated or equipped with heat tracing.

STORAGE TANKS

The storage tank is the most important and typically the most expensive component of a rainwater harvesting system. The required size of storage tank is dictated by several variables: rainfall and snowfall frequencies and totals, the intended use of the harvested water, the catchment surface area, aesthetics, and budget. In the Greater Toronto Area, an initial target for sizing the storage tank could be the predicted rainwater usage over a 10 to 12 day period.

DISTRIBUTION SYSTEM

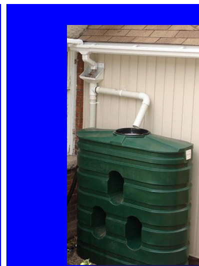
Most distribution systems are gravity fed or operated using pumps to convey harvested rainwater from the storage tank to its final destination. Typical outdoor systems use gravity to feed hoses via a tap and spigot. For underground cisterns, a water pump is needed. Indoor systems usually require a pump, pressure tank, back-up water supply line and backflow preventer. The typical pump and pressure tank arrangement consists of a multistage centrifugal pump, which draws water out of the storage tank into the pressure tank, where it is stored for distribution.

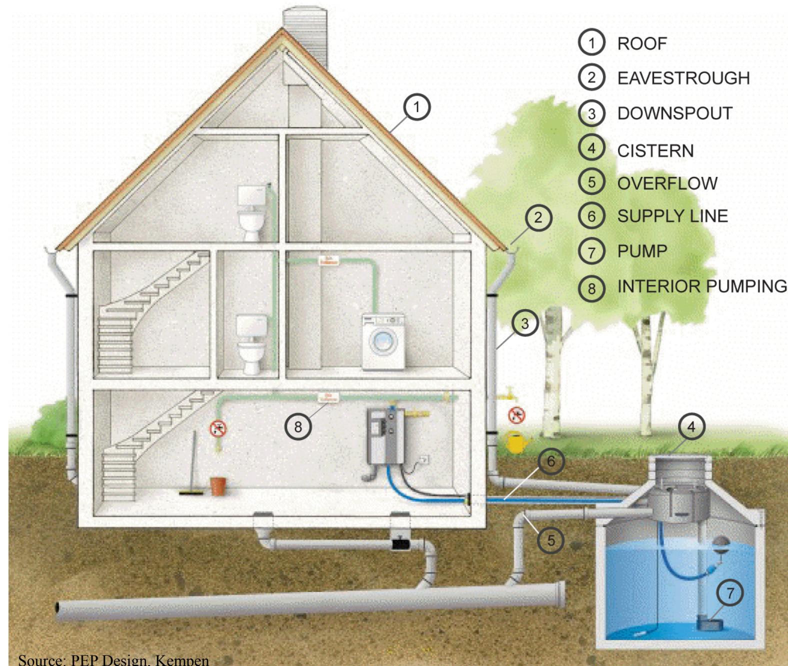
OVERFLOW SYSTEM

An overflow system must be included in the design. Overflow pipes should have a capacity equal to or greater than the inflow pipe(s). The overflow system may consist of a conveyance pipe from the top of the cistern to a pervious area down gradient of the storage tank, where suitable grading exists. The overflow discharge location should be designed as simple downspout disconnection to a pervious area, vegetated filter strip, or grass swale. The overflow conveyance pipe should be screened to prevent small animals and insects from entering. Where site grading does not permit overflow discharge to a pervious area, the conveyance pipe may either be indirectly connected to a storm sewer (discharge to an impervious area connected to a storm sewer inlet) or directly connected to a storm sewer with incorporation of a backflow preventer.

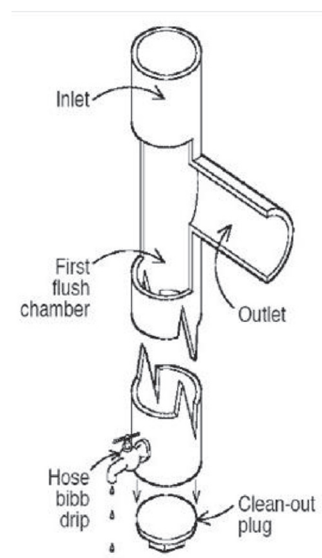
ACCESS AND MAINTENANCE

For underground cisterns, a standard size manhole opening should be provided for maintenance purposes. This access point should be secured with a lock to prevent unwanted access.

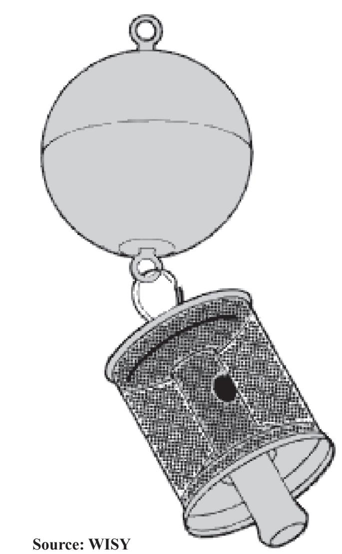




OVERVIEW



FIRST FLUSH DIVERTER



FLOATING SUCTION FILTER

ABILITY TO MEET SWM OBJECTIVES

BMP	Water Balance Benefit	Water Quality Improvement	Stream Channel Erosion Control Benefit
Rainwater Harvesting	Yes - magnitude depends on water usage	Yes - size for the water quality storage requirement	Partial - can be used in series with other practices

GENERAL SPECIFICATIONS

Component	Specification	Quantity
Eavestroughs and Downspouts	Materials commonly used for eavestroughs and downspouts include polyvinylchloride (PVC) pipe, vinyl, aluminum and galvanized steel. Lead should not be used as solder as rainwater can dissolve the lead and contaminate the water supply.	Length of eavestroughs and downspouts is determined by the size and layout of the catchment and the location of the storage tanks.
Pretreatment	At least one of the following: • leaf and mosquito screens (1 mm mesh size); • first-flush diverter; • in-ground filter; • in-tank filter. Large tanks (10 m3 or larger) should have a settling compartment for removal of sediments.	1 per inlet to the collection system
Storage Tanks	• Materials used to construct storage tanks should be structurally sound. • Tanks should be installed in locations where native soils or building structures can support the load associated with the volume of stored water. • Storage tanks should be water tight and sealed using a water safe, non-toxic substance. • Tanks should be opaque to prevent the growth of algae • Previously used containers to be converted to rainwater storage tanks should be fit for potable water or food-grade products. • Cisterns above- or below ground must have a lockable opening of at least 450 mm diameter.	The size of the cistern(s) is determined during the design calculations.

Note: This table does not address indoor systems or pumps.

SITE CONSIDERATIONS

Available Space
Storage tanks can be placed underground, indoors, on roofs, or adjacent to buildings depending on intended uses of the rainwater.

Site Topography
Influences the placement of the storage tank and design of the distribution and overflow systems.

Soil
Underground cisterns should be placed on or in native, rather than fill soil.

Head
Rain barrels or above ground cisterns with gravity distribution systems should be sited up-gradient from landscaping areas to which rainwater is to be applied.

Pollution Hot Spot Runoff
Can be an effective BMP for roof runoff from sites where land uses or activities at ground level have the potential to generate highly contaminated runoff.

Winter Operation
Can be used throughout the winter if tanks are located below the local frost penetration depth or indoors.

Underground Utilities
Presence of underground utilities may constrain the location of underground storage tanks.

Plumbing Code
Code allows the use of harvested rainwater for toilet and urinal flushing, but systems require installation of backflow prevention devices.

Standing Water and Mosquitoes
If improperly managed, tanks can create habitat suitable for mosquito breeding, so screens should be placed on inlets and outlets to prevent entry.

Child Safety
Above and below ground cisterns with openings large enough for children to enter must have lockable covers.

Setback
Tanks should be water tight to avoid ponding or saturation of soils within 4 metres of building foundations.

Vehicle Loading
Underground tanks should be sited in areas without vehicular traffic.

Drawdown Between Storms
A suggested target for sizing the storage tank to ensure drawdown between storms is the predicted rainwater demand over a 10 to 12 day period.

OPERATION AND MAINTENANCE

Maintenance requirements for rainwater harvesting systems vary according to use. Systems that are used to provide supplemental irrigation water have relatively low maintenance requirements, while systems designed for indoor uses have much higher maintenance requirements. All rainwater harvesting system components should undergo regular inspections every six months during the spring and fall seasons to keep leaf screens, eavestroughs and downspouts free of leaves and other debris; check screens and patch holes or gaps; clean and maintain first flush diverters and filters, especially those on drip irrigation systems; inspect and clean storage tank lids, paying special attention to vents and screens on inflow and outflow spigots; and replace damaged system components as needed.

MOSQUITO CONTROL
If screening is not sufficient to deter mosquitoes, vegetable oil can be used to smother larvae. Alternatively mosquito dunks or pellets containing larvicide can be used.

WINTER OPERATION
Rainwater harvesting systems have a number of components that can be affected by freezing winter temperatures. For above-ground systems, winter-time operation may not be possible. Prior to the onset of freezing temperatures, above-ground systems should be disconnected and drained. For below-ground and indoor systems, downspouts and overflow components should be checked for ice blockages during snowmelt events.

TORONTO AND REGION Conservation for The Living City

CVC CREDIT VALLEY CONSERVATION

FOR FURTHER DETAILS SEE SECTION 4.1 OF THE CVC/TRCA LID SWM GUIDE

Appendix C:

Modeling Input Summary Tables

Appendix C: Modeling Input Summary Table

Input Type	Parameter	Model							
		XP-SWMM		P8		RECARGA		Hantush	
		Pre-Development	Post-Development	Pre-Development	Post-Development	Pre-Development	Post-Development	Pre-Development	Post-Development
Base Model	**File Name**	Ex_Full_Watershed.xp	Ex_Full_Watershed.xp	McGaw_All.p8c	McGaw_All.p8c	RECARGA_FINAL.xls	RECARGA_FINAL.xls	NA	Hantush_USGS_SIR_2010-5102-1110.xlsm
Hydrology	**Pervious Area**	Previously Defined (modified based on representative block location)	Measured in GIS	Previously Defined (modified based on representative block location)	Measured in GIS	Previously Defined (modified based on representative block location)	Measured in GIS		
	Impervious Area	Previously Defined (modified based on representative block location)	Measured in GIS	Previously Defined (modified based on representative block location)	Measured in GIS	Previously Defined (modified based on representative block location)	Measured in GIS		
	CN	NR 151 (Table 2)	NRCS Guidance	NR 151 (Table 2)	NRCS Guidance	NR 151 (Table 2)	NRCS Guidance		
	TC	Previously Defined (modified based on representative block location)	Calculated from GIS	Previously Defined (modified based on representative block location)	Not Used	Not Used	Not Used		
Hydraulics	**Routing**	Previously Defined (modified based on representative block location)	Designed for representative blocks	Previously Defined (modified based on representative block location)	Designed for representative blocks	Not Used	Not Used		
	Storage	Previously Defined (modified based on representative block location)	Designed for representative blocks	Previously Defined (modified based on representative block location)	Designed for representative blocks	Not Used	Not Used		
	Infiltration	Previously Defined (modified based on representative block location)	WisDNR Conservation Practice Standards 1002 (Table 2). 24-hour Drawdown. Sandy Loam = 0.5"/hr, Loamy Sand = 1.63"/hr.	Previously Defined (modified based on representative block location)	WisDNR Conservation Practice Standards 1002 (Table 2). 24-hour Drawdown. Sandy Loam = 0.5"/hr, Loamy Sand = 1.63"/hr.	Not Used	Not Used		
Climatology	**Precipitation**	Previously Defined (Design Storms)	Previously Defined (Design Storms)	Mdsn6095.pcp (1-year average, 3/12/1981-12/2/1981, from McGaw_All.p8c) (5-year average, 1/1/1980-12/31/1984,)	Mdsn6095.pcp (1-year average, 3/12/1981-12/2/1981, from McGaw_All.p8c) (5-year average, 1/1/1980-12/31/1984,)	28.81 inches / year	28.81 inches / year		
	Temperature	Not Used	Not Used	Mdsn6095.tmp (P8 standard file)	Mdsn6095.tmp (P8 standard file)	Not Used	Not Used		
Output Used		1, 2, 10, 100-year design storm flow rates		80% TSS post-development met		Recharge rate 9.5 inches (9-10 inches / Year)		Groundwater Mounding	
				No increase in post-development runoff volumes					

Appendix D:

Soil Test Pit Logs

NRC
Natural Resources Consulting, Inc.

P.O. Box 128
Cottage Grove, WI 53527-0128
608-839-1998 • Fax 608-839-1995
www.nrc-inc.net

Project Name: North McGaw Park Neighborhood
Client: Teska Associates, Inc.
NRC Project #: 008-0106-01

Date: 12/31/08
Conditions: 7º, sunny, cold

Soil Pit #: Pit 4
Vegetation (or crop): Corn
Slope: Facing 290º downslope; 7% slope
Elevation:

Soil Map Unit: RnC2, Ringwood silt loam, 6-12% slopes, eroded
Classification: Typic Argiudoll
Parent Material: Loess over sandy loam till
Position: Backslope

Drainage Class: Well-drained
Groundwater:

Additional notes:
Frozen 0-3"

*** Design infiltration rate (without measurement)as per Table 2 of the Wisconsin Department of Natural Resources "Site Evaluation for Stormwater Infiltration" (Design Standard 1002)**

Depth (inches)	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size / Qty	Structure Gr / Size / Type	Consistence (moist)	Mottles / Redox Color / Size / Abund / Contrast	Infiltration Rate* (In/hr)	Other Features
0-13	Ap	CS	10YR3/2	SIL	---	2 M SBK / 2 M GR	FR	---	0.13	---
13-23	Bt1	CS	10YR4/3	SICL	---	2 M SBK	FR	---	0.04	10YR3/2 organic streaking
23-36	Bt2	CS	10YR4/3	SIL	---	2 M SBK	FR	---	0.13	---
36-51	Bt3	CS	10YR4/4	SIL	---	2 M SBK	FR	---	0.13	---
51-57	2Bt4	CS	10YR4/4	SCL/SL	3% G	1 M SBK / 1 M GR	VFR	---	0.11 to 0.50	very moist to wet
57-120	2C	---	10YR5/4	LS/SL	10% G; 2% CB; 2% ST	MA	VFR	---	1.63 to 0.50	SL inclusions approximately 25% of matrix

NRC
Natural Resources Consulting, Inc.
P.O. Box 128
Cottage Grove, WI 53527-0128
608-839-1998 • Fax 608-839-1995
www.nrc-inc.net

Project Name: North McGaw Park Neighborhood
Client: Teska Associates, Inc.
NRC Project #: 008-0106-01

Date: 12/31/08
Conditions: 12º, sunny

Soil Pit #: Pit 7
Vegetation (or crop): Corn
Slope: Facing 40º downslope; 5% slope
Elevation:
Additional notes:
Frozen 0-3"

Soil Map Unit: RnB, Ringwood silt loam, 2-6% slopes
Classification: Typic Argiudoll
Parent Material: Loess over sandy loam till
Position: Lower mid-slope to toeslope

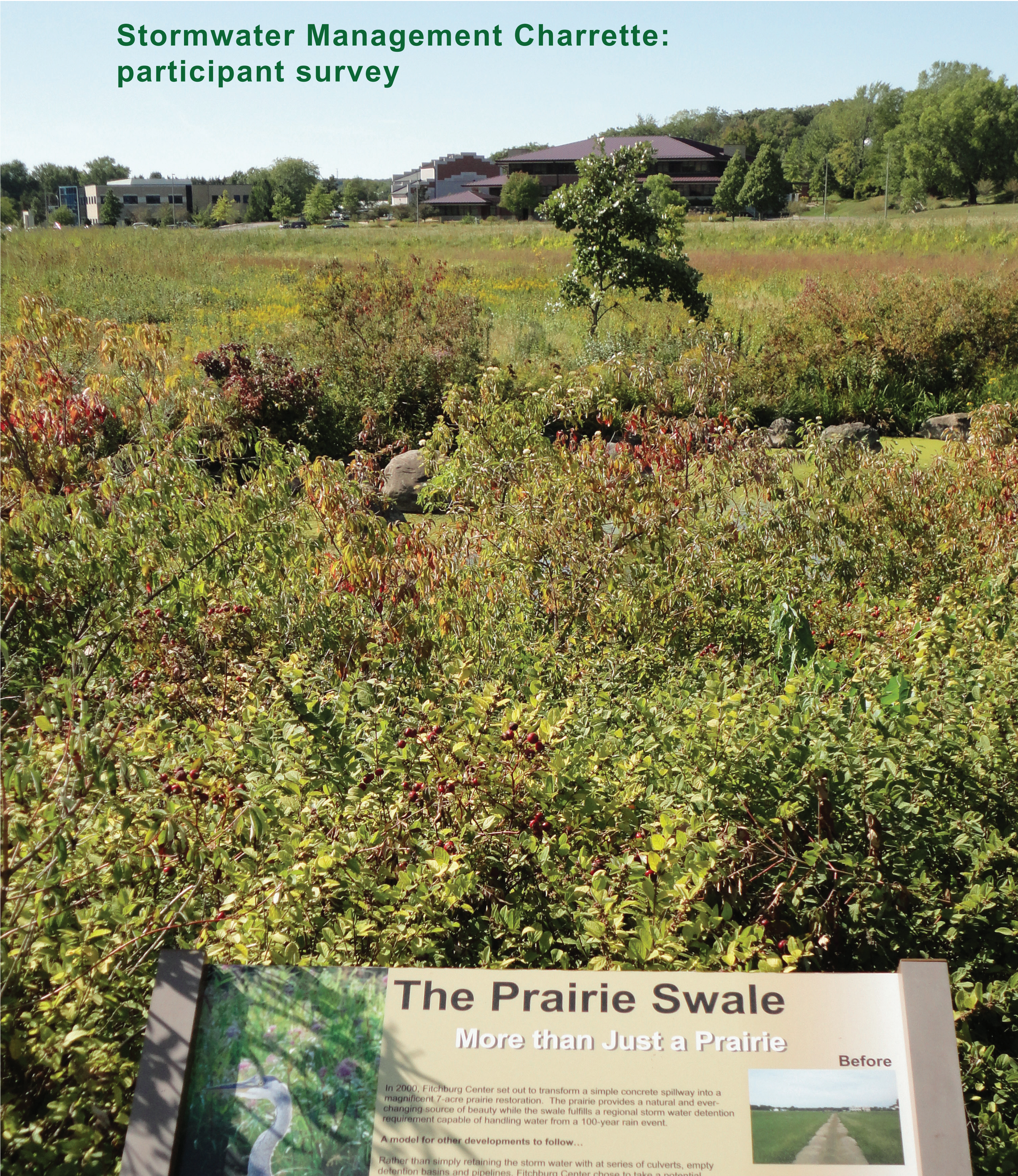
Drainage Class: Well-drained
Groundwater:

* Design infiltration rate (without measurement)as per Table 2 of the Wisconsin Department of Natural Resources "Site Evaluation for Stormwater Infiltration" (Design Standard 1002)

Depth (inches)	Horizon	Bnd	Matrix Color	Texture	Rock Frag Size / Qty	Structure Gr / Size / Type	Consistence (moist)	Mottles / Redox Color / Size / Abund / Contrast	Infiltration Rate* (In/hr)	Other Features
0-12	Ap	CS	10YR3/2	SIL	---	2 F SBK / 2 M GR	FR	---	0.13	---
12-22	Bt1	CS	10YR4/4	SICL	---	2 M SBK	FR	---	0.04	10YR3/2 organic streaking
22-31	Bt2	CS	10YR4/2 / 10YR4/3	SICL	2% G	2 F SBK	FR	---	0.04	---
31-39	2BC	GS	7.5YR4/4	SL	10% G; 2% CB	2 F SBK / MA	VFR	---	0.50	scattered rotten rock
39-120	2C	---	7.5YR5/4	GRLS	15% G; 3% CB; 3% ST	MA	VFR	---	1.63 to 3.60	---

Appendix E:

Stormwater Management Charrette: participant survey



11/12/12

City of Fitchburg Catalytic Project – No Increase in Post development Runoff Volume
Stormwater Management Charrette: Participant Survey

Now that you have listened to the presentation of the draft stormwater management plans developed for R2 and TOD hypothetical blocks, please consider the following questions. Please note that the information provided in the Participant Surveys will be used to generate a revised stormwater management plan for the Hypothetical Blocks.

1. Which of the volume control Best Management Practices (VCBMPs) have you had experience using on new development or redevelopment projects? Do you have a preference for some of these BMPs over others? If so, please indicate in last column.

Volume Control BMP	Experience Using BMP			Preferred BMP
	Yes	No	Not Sure	
Soil Amendments/Decompaction	X		MINIMALLY USEFUL	
Pervious Pavement Systems				
Downspout Disconnection	X		SITUATIONAL	
Green Roofs				
Vegetated Swales	X		TAKES UP SPACE	
Bioretention Devices/Raingardens	X		←	#1 – BEST
Tree Trenches				
Infiltration Basins	X		←	#2
Below-ground Recharge Systems				
Rainwater Harvesting	CISTERN		PLUMBING CODE ISSUES	
Other				

2. What ideas or elements of the draft design concepts are the most exciting to you? Please describe them below. GETTING THE ZONING & CODES TO ALLOW MORE TOOLS.

R2	TOD

3. Is there anything you would change about the draft design concept? Please describe your suggestions below or design your own stormwater management plan on the drawing(s) below.

R2	TOD

NEED TO ADDRESS STORMWATER SWALES TOOLS

Design-Your-Own Stormwater Management Plan – Medium-Density Residential (R2)

INSTRUCTIONS:
According to the results of the modeling analysis, the R2 site meets the volume control standard if 6% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

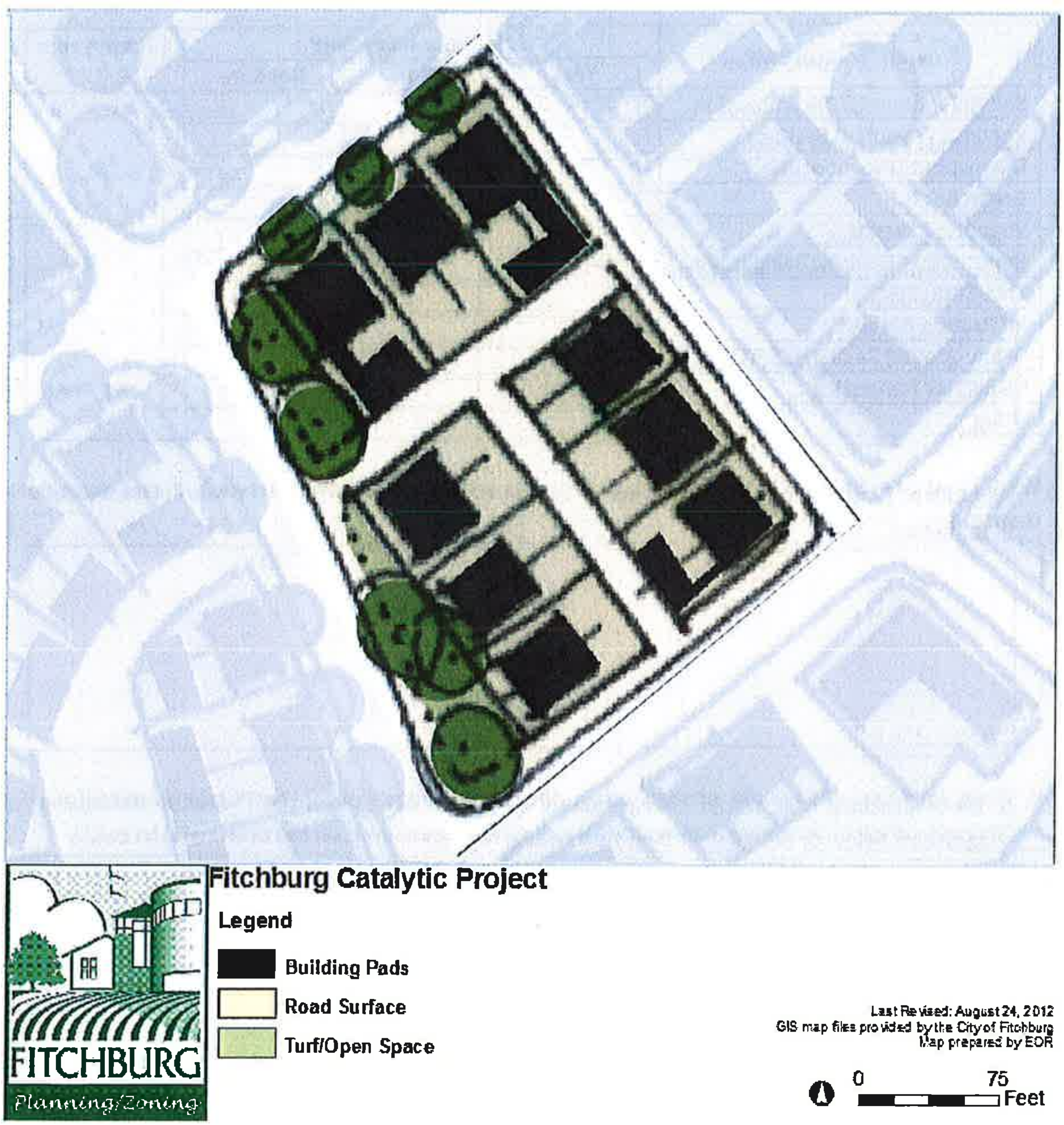
AREA APPROXIMATION:

1% of site (need 6 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



Design-Your-Own Stormwater Management Plan – Transit-Oriented Development (TOD)

INSTRUCTIONS:
According to the results of the modeling analysis, the TOD site meets the volume control standard if 8% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

0.5% of site (need 16 of these)

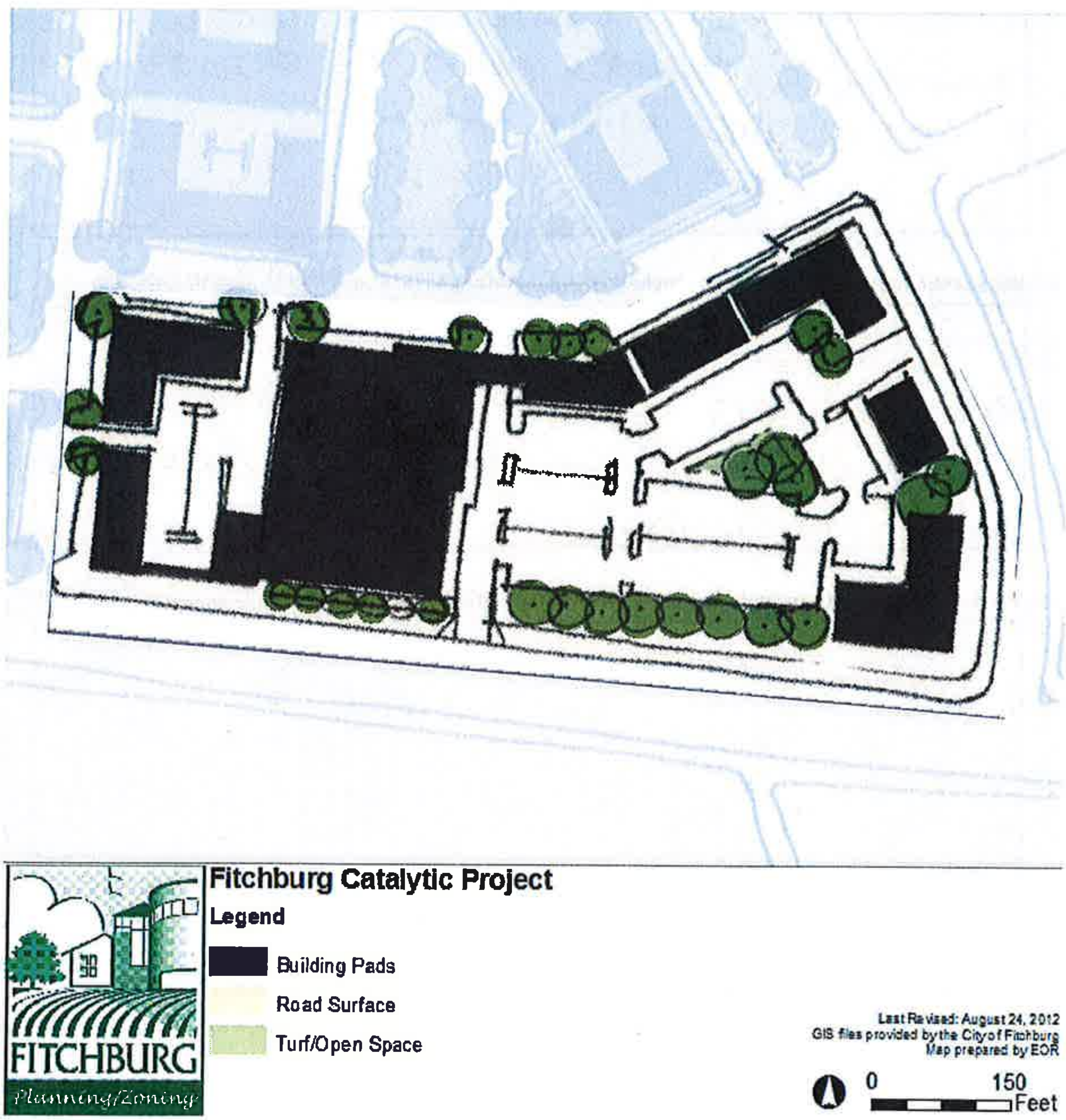
or this

1% of site (need 8 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



4. Are some of these volume control BMPs better suited for a particular application (land use) than others? If so, please describe. HIGHER COST TREATMENTS REQUIRE HIGHER DENSITY.

Yes	No/Avoid
RAIN GARDENS EVERYWHERE!	INFILTRATION BASINS DO NOT ADD QUALITY — (ESTHETICS)

5. What multi-use functions can be combined with stormwater BMPs (e.g. Parking)? Please describe.

PERVIOUS PAVEMENT IS INTERESTING, BUT WE NEED STANDARDS & PERHAPS MORE RESILIENT MATERIALS TO MAKE THIS WORK WELL.

6. What are the biggest obstacles to including stormwater BMPs on a project? Please describe.

WATERWAYS NOT ADDRESSED. MOST DEVELOPMENTS OF ANY ACREAGE REQUIRE HANDLING THESE — WE NEED BMPS FOR THESE IN ADDITION TO PRAIRIE & ACREAGE.

7. Please use this space to provide feedback on the charrette process or offer other general comments.

Do you have additional questions or comments?
Please check the project website at
http://www.city.fitchburg.wi.us/departments/cityHall/planning/OngoingPlansStudies.php
or contact Wade Thompson at wade.thompson@city.fitchburg.wi.us or 608.270.4258

City of Fitchburg Catalytic Project – No Increase in Post development Runoff Volume

Stormwater Management Charrette: Participant Survey

Now that you have listened to the presentation of the draft stormwater management plans developed for R2 and TOD hypothetical blocks, please consider the following questions. Please note that the information provided in the Participant Surveys will be used to generate a revised stormwater management plan for the Hypothetical Blocks.

1. Which of the volume control Best Management Practices (VCBMPs) have you had experience using on new development or redevelopment projects? Do you have a preference for some of these BMPs over others? If so, please indicate in last column.

Volume Control BMP	Experience Using BMP			Preferred BMP
	Yes	No	Not Sure	
Soil Amendments/Decompaction	✓			YES
Pervious Pavement Systems	✓			YES
Downspout Disconnection	✓			YES
Green Roofs	✓			NO (HIGH COST)
Vegetated Swales	✓			YES
Bioretention Devices/Raingardens	✓			YES
Tree Trenches	✓			YES
Infiltration Basins	✓			NO
Below-ground Recharge Systems		✓		YES
Rainwater Harvesting	✓			NO
Other				

2. What ideas or elements of the draft design concepts are the most exciting to you? Please describe them below.

R2	TOD
TREE TRENCHES	TREE TRENCHES BELOW GROUND RECHARGE

3. Is there anything you would change about the draft design concept? Please describe your suggestions below or design your own stormwater management plan on the drawing(s) below.

R2	TOD
I WOULD LIKE TO SEE IF IT IS FEASIBLE TO PUT ALL OF THE PRACTICES IN THE PUBLIC R-O-W.	IS IT POSSIBLE TO PUT ALL OF THE PRACTICES IN THE PUBLIC R.O.W.?

Design-Your-Own Stormwater Management Plan – Medium-Density Residential (R2)

INSTRUCTIONS:
According to the results of the modeling analysis, the R2 site meets the volume control standard if 6% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

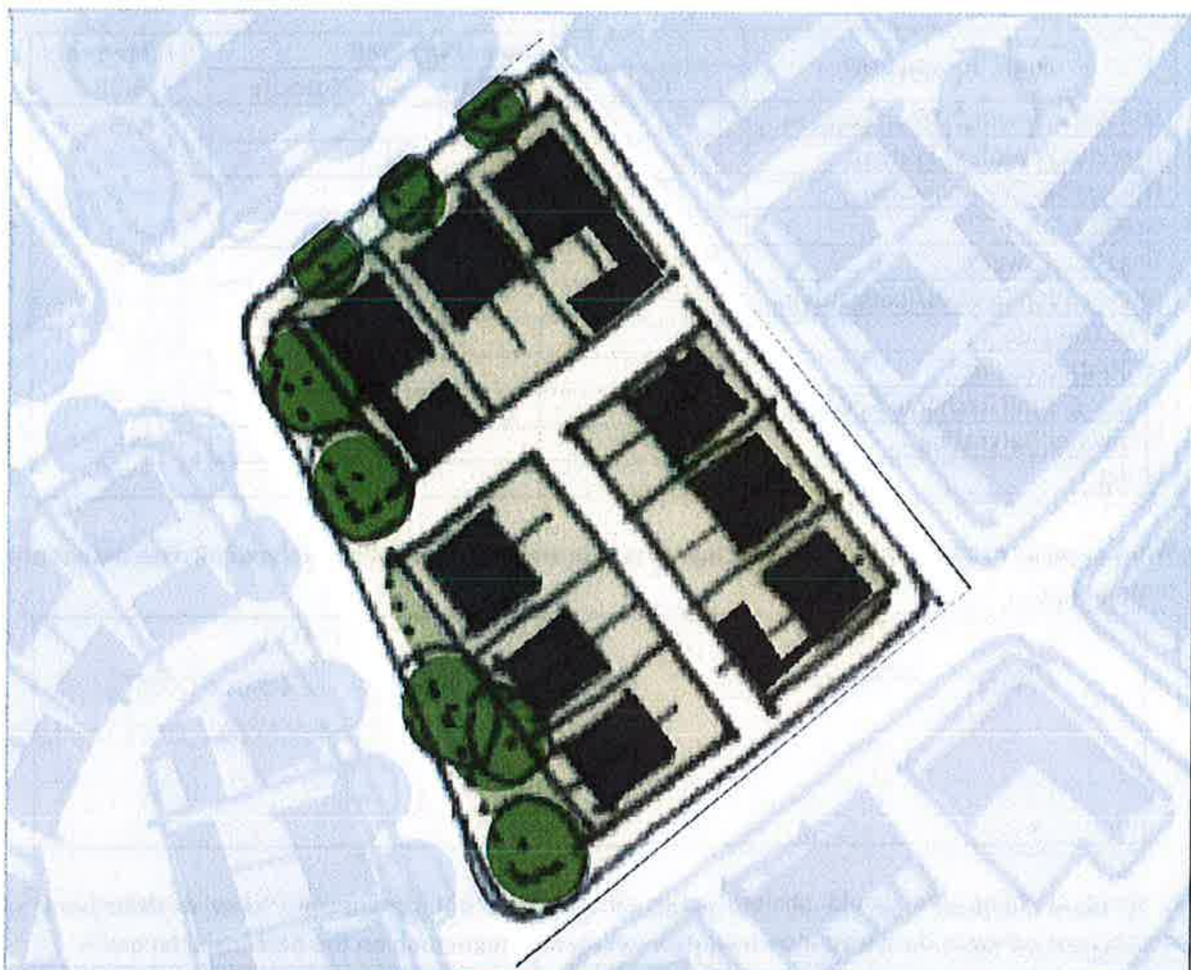
AREA APPROXIMATION:

1% of site (need 6 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



Fitchburg Catalytic Project

Legend

- Building Pads
- Road Surface
- Turf/Open Space

Last Revised: August 24, 2012
GIS map files provided by the City of Fitchburg
Map prepared by EOR

0 75 Feet

Design-Your-Own Stormwater Management Plan – Transit-Oriented Development (TOD)

INSTRUCTIONS:
According to the results of the modeling analysis, the TOD site meets the volume control standard if 8% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

0.5% of site (need 16 of these)

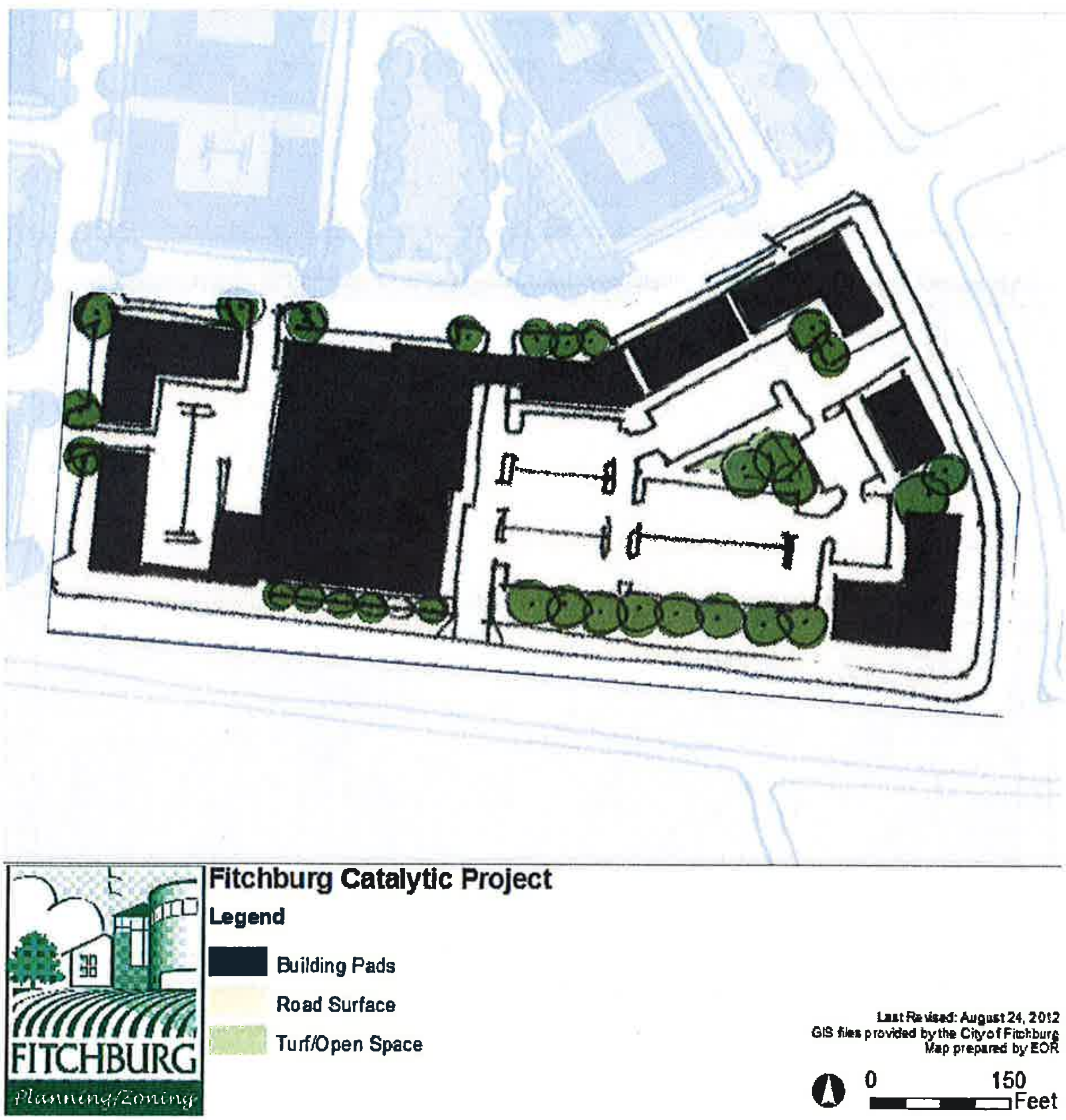
or this

1% of site (need 8 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



4. Are some of these volume control BMPs better suited for a particular application (land use) than others? If so, please describe.

Yes	No/Avoid
TREE TRENCHES IN R-O-W. BELOW GROUND SYSTEMS IN LAWN/ PARKING LOTS BIO-RETENTION	RAINWATER HARVESTING (DIFFICULT TO DETERMINE HOW MUCH CREDIT TO GIVE)

5. What multi-use functions can be combined with stormwater BMPs (e.g. Parking)? Please describe.

AMENITIES THAT ADD DESIGN ELEMENTS & AESTHETICS TO THE DEVELOPMENT.

6. What are the biggest obstacles to including stormwater BMPs on a project? Please describe.

COST.

7. Please use this space to provide feedback on the charrette process or offer other general comments.

GREAT JOB!

Do you have additional questions or comments?
Please check the project website at
http://www.city.fitchburg.wi.us/departments/cityHall/planning/OngoingPlansStudies.php
or contact Wade Thompson at wade.thompson@city.fitchburg.wi.us or 608.270.4258

City of Fitchburg Catalytic Project – No Increase in Post development Runoff Volume
Stormwater Management Charrette: Participant Survey

Now that you have listened to the presentation of the draft stormwater management plans developed for R2 and TOD hypothetical blocks, please consider the following questions. Please note that the information provided in the Participant Surveys will be used to generate a revised stormwater management plan for the Hypothetical Blocks.

1. Which of the volume control Best Management Practices (VCBMPs) have you had experience using on new development or redevelopment projects? Do you have a preference for some of these BMPs over others? If so, please indicate in last column.

Volume Control BMP	Experience Using BMP			Preferred BMP
	Yes	No	Not Sure	
Soil Amendments/Decompaction		✓		
Pervious Pavement Systems	✓			
Downspout Disconnection	✓			←
Green Roofs		✓		
Vegetated Swales	✓			
Bioretention Devices/Raingardens	✓			
Tree Trenches		✓		←
Infiltration Basins		✓		
Below-ground Recharge Systems		✓		←
Rainwater Harvesting	✓			←
Other				

2. What ideas or elements of the draft design concepts are the most exciting to you? Please describe them below.

R2	TOD
I appreciate the pervious alleys. I'd like to see much heavier use of bioretention in terraces.	I'm concerned about dependence on surface parking area for BMPs. I'd like to be more confident we can meet standards in a 4-6 story block with central parking structure.

3. Is there anything you would change about the draft design concept? Please describe your suggestions below or design your own stormwater management plan on the drawing(s) below.

R2	TOD
Add intersection bumpouts with sidewalk ramps to calm traffic, fill remaining no-parking area by stop signs & bus stops with bio-retent. BMPs.	

Why not tree trenches completely around block?

Design-Your-Own Stormwater Management Plan – Medium-Density Residential (R2)

INSTRUCTIONS:
According to the results of the modeling analysis, the R2 site meets the volume control standard if 6% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

1% of site (need 6 of these)

[hatched box] or this [hatched box]

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
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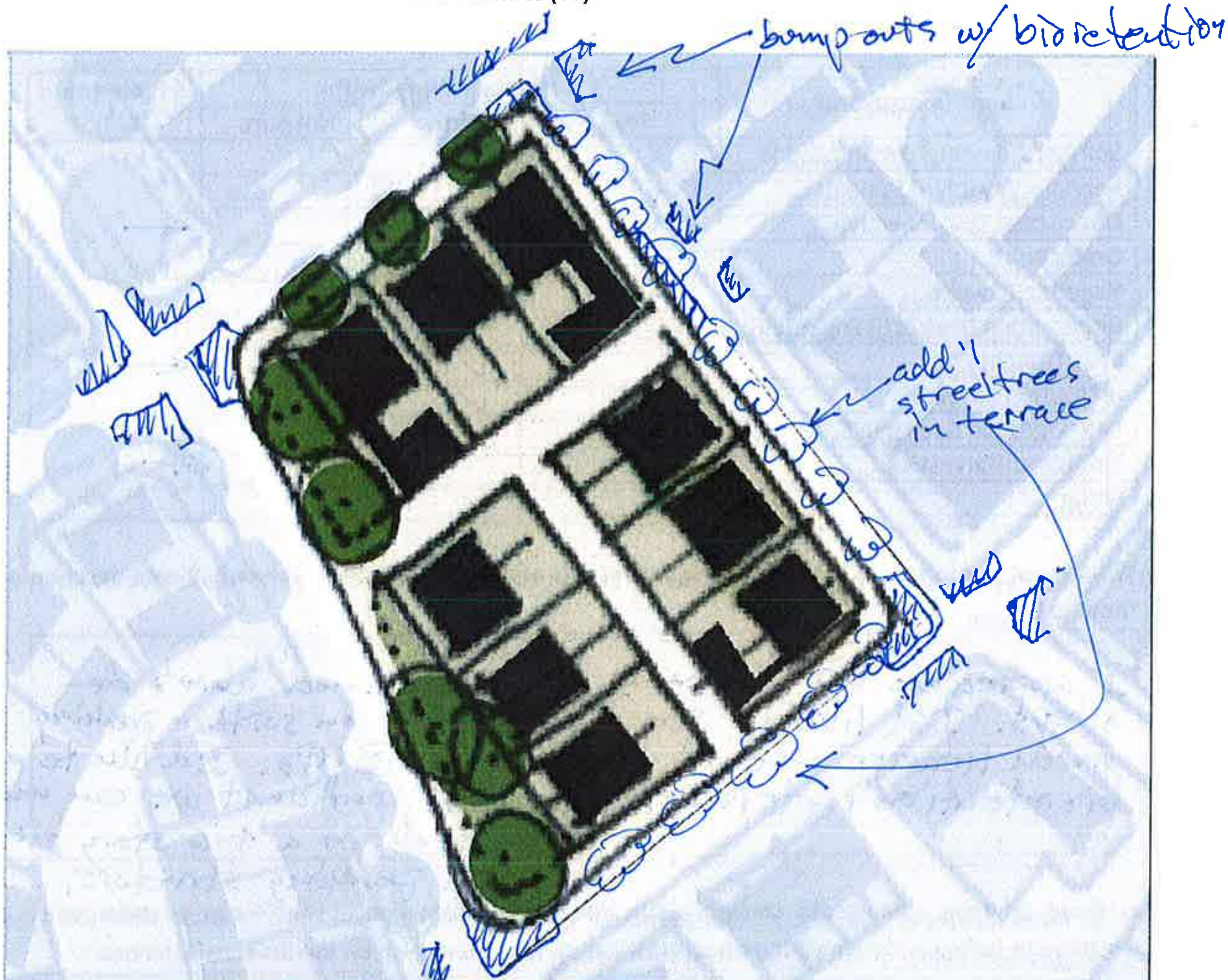
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



Fitchburg Catalytic Project

Legend

- Building Pads
- Road Surface
- Turf/Open Space

FITCHBURG
Planning/Zoning

Last Revised: August 24, 2012
GIS map files provided by the City of Fitchburg
Map prepared by EOR

0 75 Feet

Design-Your-Own Stormwater Management Plan – Transit-Oriented Development (TOD)

INSTRUCTIONS:
According to the results of the modeling analysis, the TOD site meets the volume control standard if 8% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

0.5% of site (need 16 of these)

or this

1% of site (need 8 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
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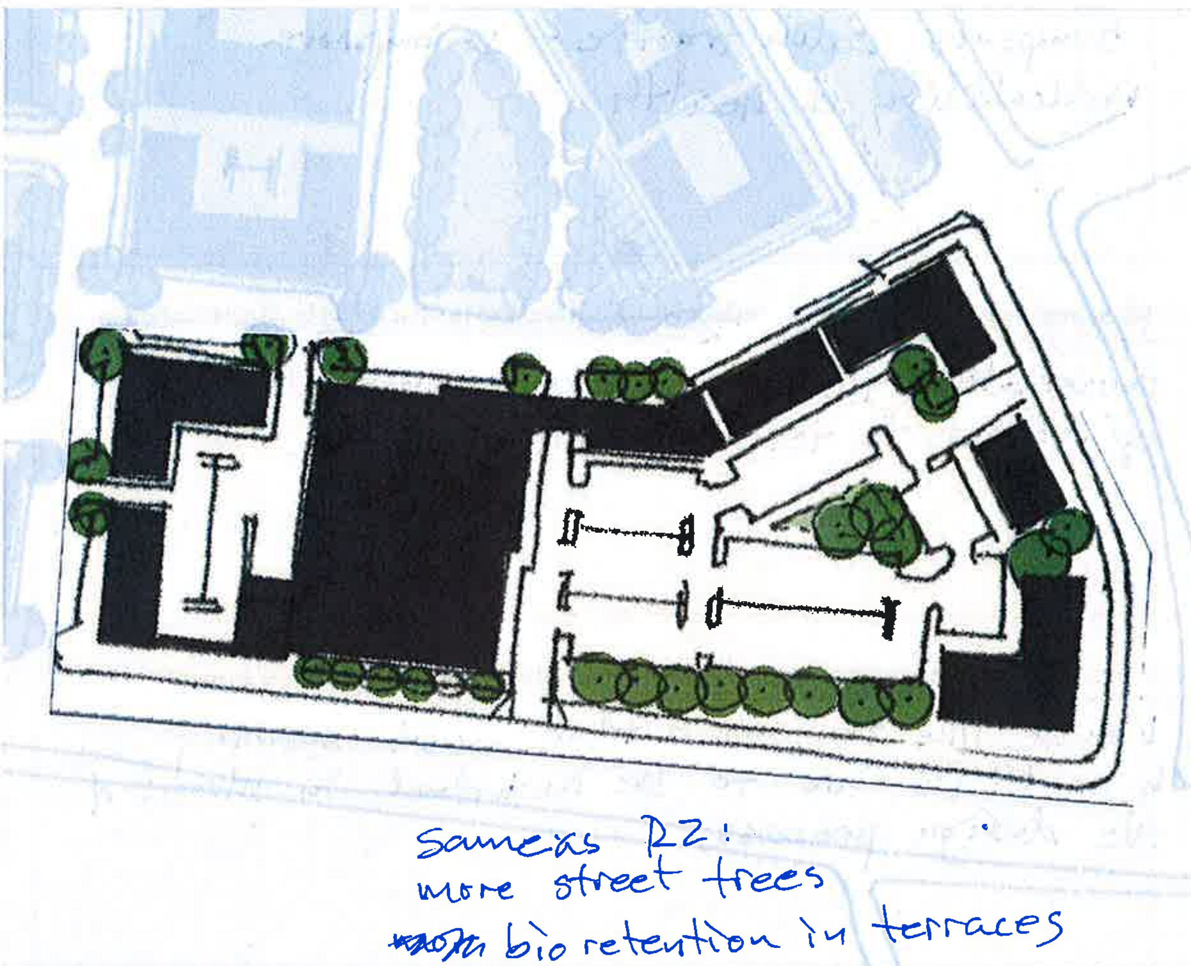

Fitchburg Catalytic Project

Legend

Building Pads

Road Surface

Turf/Open Space

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GIS files provided by the City of Fitchburg
Map prepared by EOR

0 150 Feet

4. Are some of these volume control BMPs better suited for a particular application (land use) than others? If so, please describe.

Yes	No/Avoid

5. What multi-use functions can be combined with stormwater BMPs (e.g. Parking)? Please describe.

bumpouts calm traffic – so improve walkability & health

6. What are the biggest obstacles to including stormwater BMPs on a project? Please describe.

Conservative thinking in public works depts. w/ respect to terraces & alleys.

7. Please use this space to provide feedback on the charrette process or offer other general comments.

Would like to see a flow chart showing how BMPs are to be included in street & site design process.

Do you have additional questions or comments?
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City of Fitchburg Catalytic Project – No Increase in Post development Runoff Volume

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Volume Control BMP	Experience Using BMP			Preferred BMP
	Yes	No	Not Sure	
Soil Amendments/Decompaction	X			✓
Pervious Pavement Systems	X			✓
Downspout Disconnection	X			✓
Green Roofs	X			✓
Vegetated Swales	X			✓
Bioretention Devices/Raingardens	X			✓
Tree Trenches		X		✓
Infiltration Basins	X			✓
Below-ground Recharge Systems	X			✓
Rainwater Harvesting	X			✓
Other				

2. What ideas or elements of the draft design concepts are the most exciting to you? Please describe them below.

R2	TOD
tree trenches	tree trenches

3. Is there anything you would change about the draft design concept? Please describe your suggestions below or design your own stormwater management plan on the drawing(s) below.

R2	TOD

Design-Your-Own Stormwater Management Plan – Medium-Density Residential (R2)

INSTRUCTIONS:
According to the results of the modeling analysis, the R2 site meets the volume control standard if 6% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

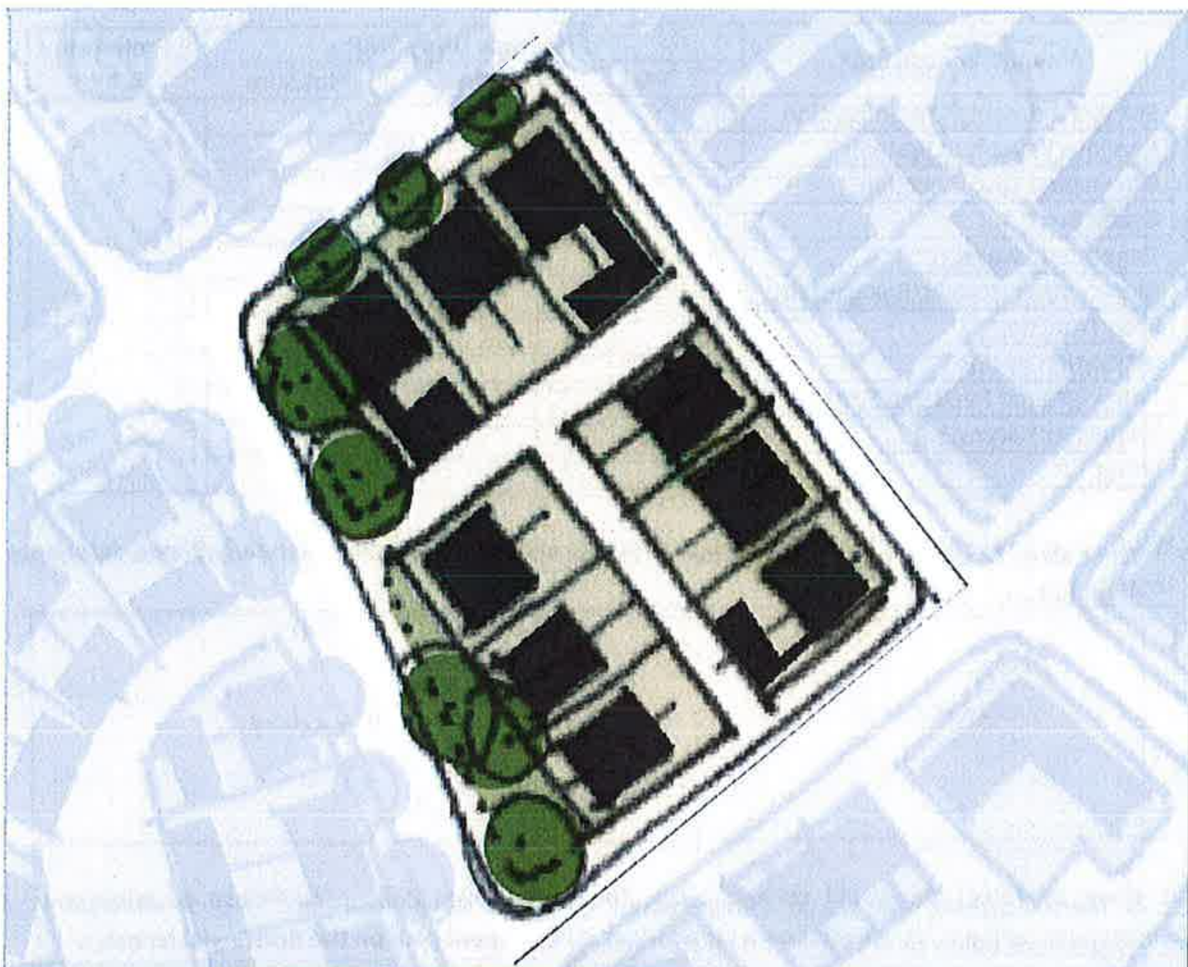
AREA APPROXIMATION:

1% of site (need 6 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



Fitchburg Catalytic Project

Legend

- Building Pads
- Road Surface
- Turf/Open Space

Last Revised: August 24, 2012
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Map prepared by EOR

0 75 Feet

Design-Your-Own Stormwater Management Plan – Transit-Oriented Development (TOD)

INSTRUCTIONS:
According to the results of the modeling analysis, the TOD site meets the volume control standard if 8% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

0.5% of site (need 16 of these)

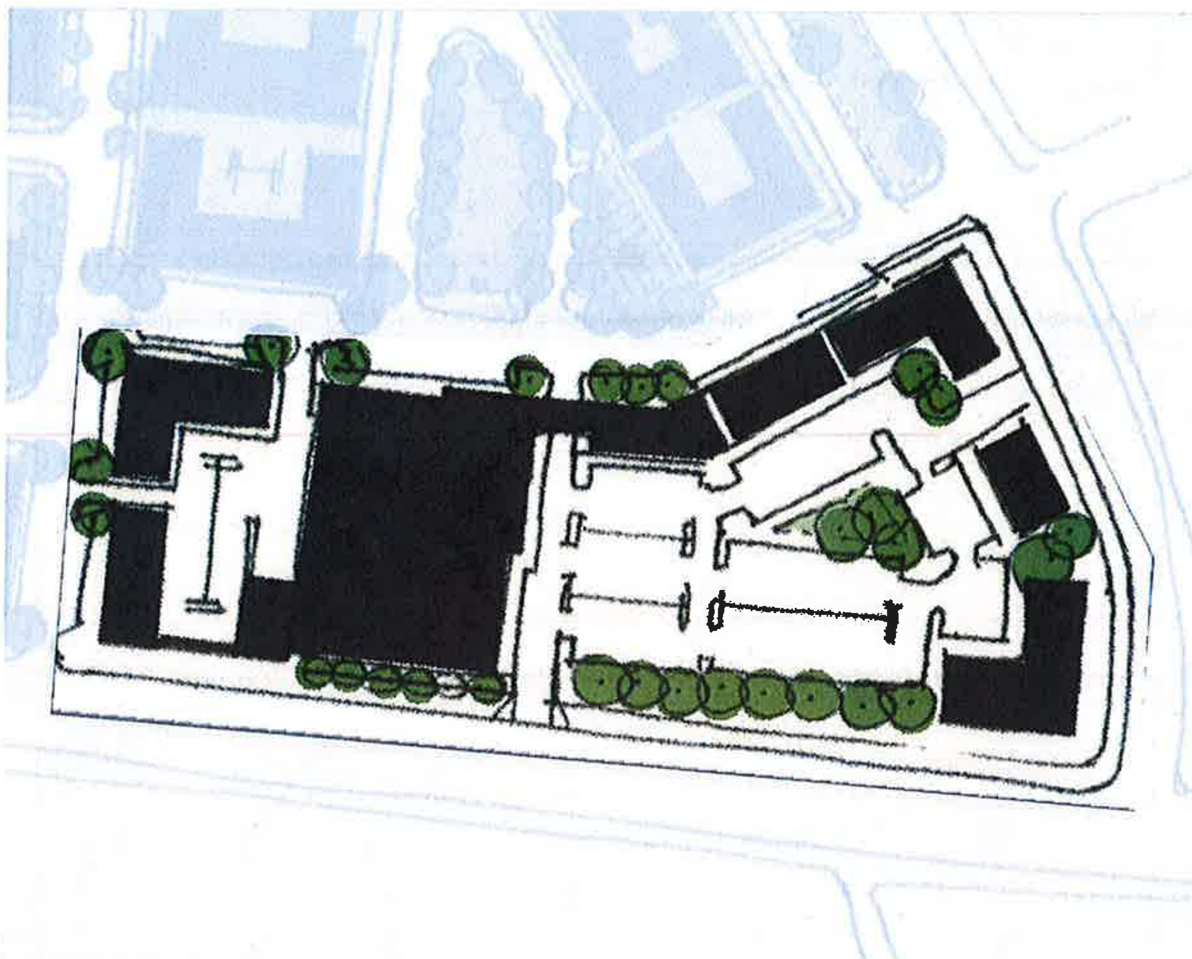
or this

1% of site (need 8 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



Fitchburg Catalytic Project

Legend

Building Pads

Road Surface

Turf/Open Space

FITCHBURG
Planning/Zoning

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0 150 Feet

4. Are some of these volume control BMPs better suited for a particular application (land use) than others? If so, please describe.

Yes	No/Avoid
bioretention devices work well for downstream of parking areas since they provide pretreatment	

5. What multi-use functions can be combined with stormwater BMPs (e.g. Parking)? Please describe.

Green roofs
pervious pavement systems

6. What are the biggest obstacles to including stormwater BMPs on a project? Please describe.

determining needs for pretreatment and designing pretreatment into the scenario

7. Please use this space to provide feedback on the charrette process or offer other general comments.

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City of Fitchburg Catalytic Project – No Increase in Post development Runoff Volume
Stormwater Management Charrette: Participant Survey

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Volume Control BMP	Experience Using BMP			Preferred BMP
	Yes	No	Not Sure	
Soil Amendments/Decompaction				
Pervious Pavement Systems				
Downspout Disconnection	X			
Green Roofs				
Vegetated Swales	X			
Bioretention Devices/Raingardens				
Tree Trenches				
Infiltration Basins	X			
Below-ground Recharge Systems				
Rainwater Harvesting				
Other				

2. What ideas or elements of the draft design concepts are the most exciting to you? Please describe them below.

R2	TOD
Rain Gardens	

3. Is there anything you would change about the draft design concept? Please describe your suggestions below or design your own stormwater management plan on the drawing(s) below.

R2	TOD

Design-Your-Own Stormwater Management Plan – Medium-Density Residential (R2)

INSTRUCTIONS:
According to the results of the modeling analysis, the R2 site meets the volume control standard if 6% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

1% of site (need 6 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
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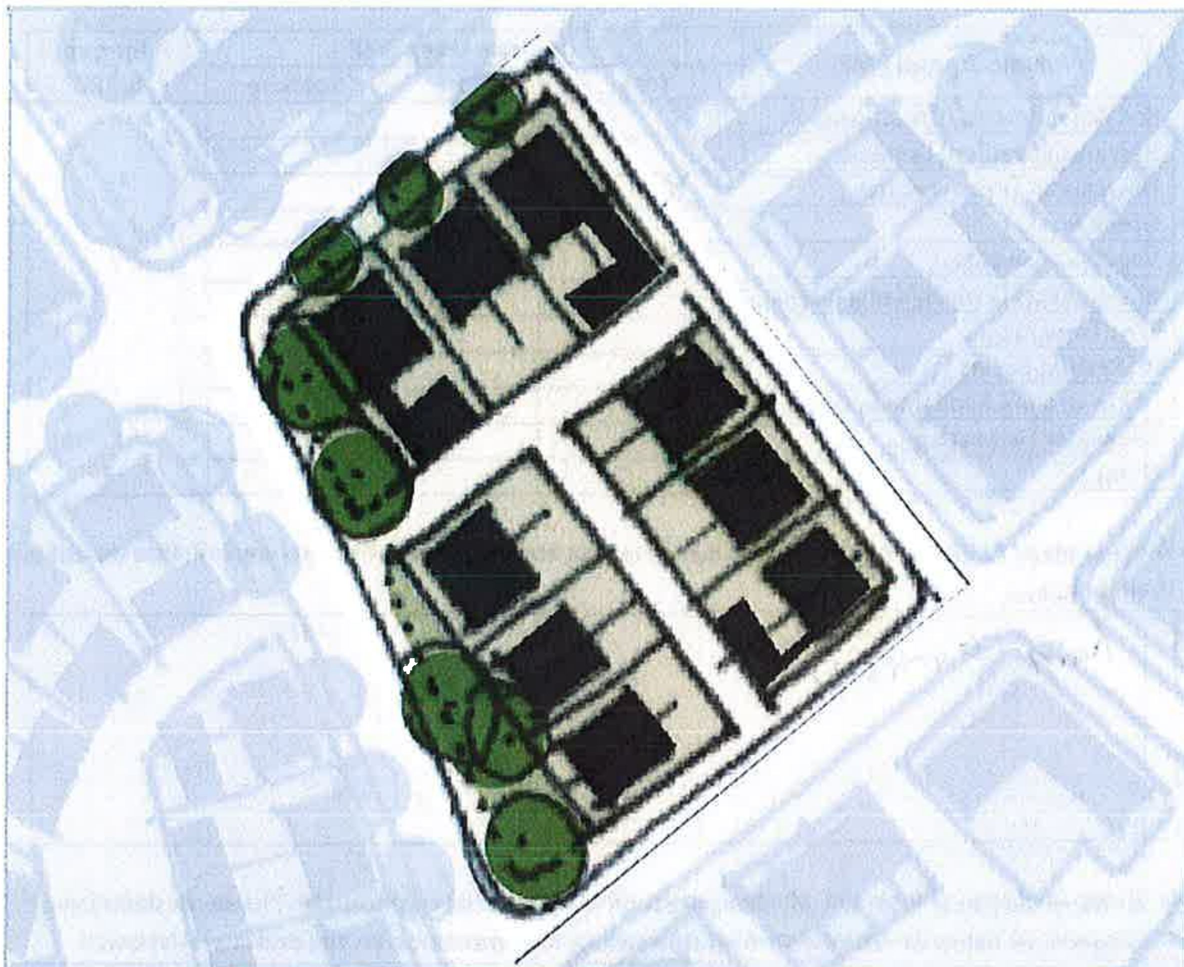


FITCHBURG Planning/Zoning

Fitchburg Catalytic Project

Legend

- Building Pads
- Road Surface
- Turf/Open Space

Last Revised: August 24, 2012
GIS map files provided by the City of Fitchburg
Map prepared by EOR

0 75 Feet

Design-Your-Own Stormwater Management Plan – Transit-Oriented Development (TOD)

INSTRUCTIONS:
According to the results of the modeling analysis, the TOD site meets the volume control standard if **8%** of the entire site is dedicated to stormwater management. Using the area approximations for **0.5%** and **1%** of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

0.5% of site (need 16 of these)

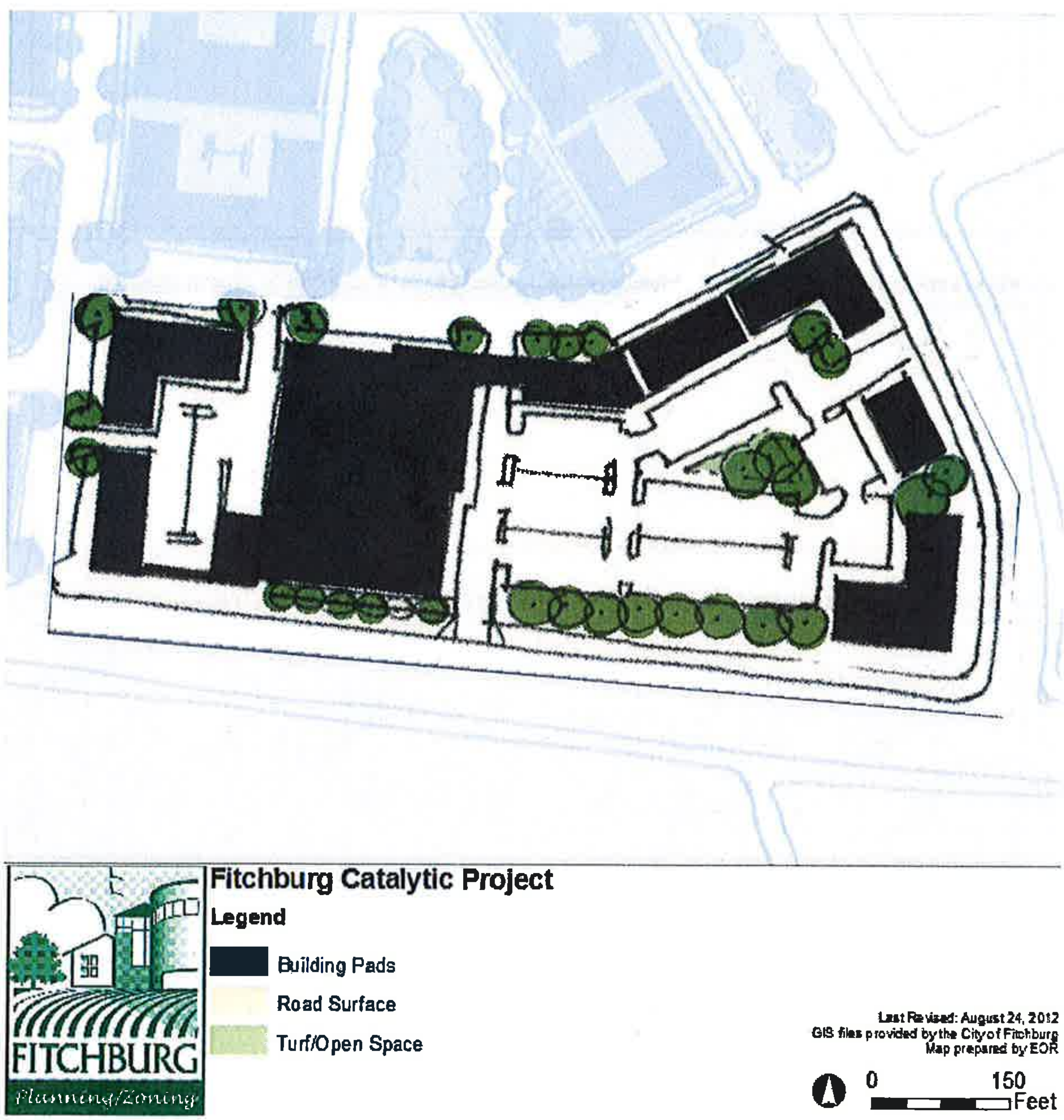
or this

1% of site (need 8 of these)

or this

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



4. Are some of these volume control BMPs better suited for a particular application (land use) than others? If so, please describe.

Yes	No/Avoid
Rain Gardens	

5. What multi-use functions can be combined with stormwater BMPs (e.g. Parking)? Please describe.

6. What are the biggest obstacles to including stormwater BMPs on a project? Please describe.

Cost

7. Please use this space to provide feedback on the charrette process or offer other general comments.

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	Yes	No	Not Sure	
Soil Amendments/Decompaction	X			
Pervious Pavement Systems		X		
Downspout Disconnection	X			
Green Roofs		X		
Vegetated Swales	X			
Bioretention Devices/Raingardens	X			
Tree Trenches		X		
Infiltration Basins	X			
Below-ground Recharge Systems		X		
Rainwater Harvesting		X		
Other				

2. What ideas or elements of the draft design concepts are the most exciting to you? Please describe them below.

R2	TOD
	All uses have applications that may be beneficial. The BMP must be cost effective and fit with the development layout

3. Is there anything you would change about the draft design concept? Please describe your suggestions below or design your own stormwater management plan on the drawing(s) below.

R2	TOD
	- Additional information as applicable for costs: initial implementation, ongoing maintenance, replacement (if necessary) training of maintenance personnel

Design-Your-Own Stormwater Management Plan – Medium-Density Residential (R2)

INSTRUCTIONS:

According to the results of the modeling analysis, the R2 site meets the volume control standard if 6% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

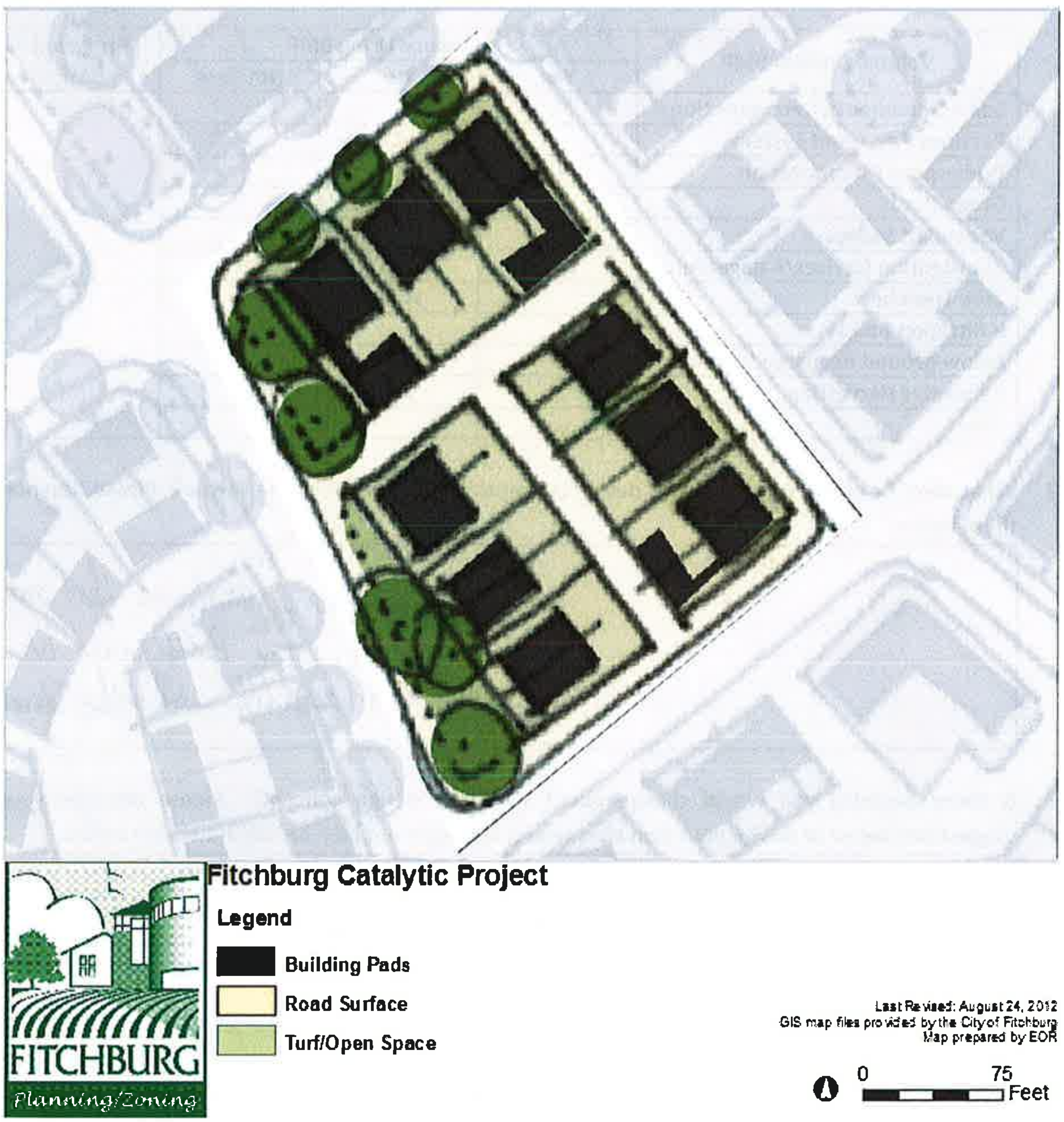
AREA APPROXIMATION:

1% of site (need 6 of these)

[hatched box] or this [hatched box]

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
- Tree Trenches (TT)
- Infiltration Basins (IB)
- Below-ground Recharge Systems (BGRS)
- Rainwater Harvesting (RH)



Design-Your-Own Stormwater Management Plan – Transit-Oriented Development (TOD)

INSTRUCTIONS:

According to the results of the modeling analysis, the TOD site meets the volume control standard if 8% of the entire site is dedicated to stormwater management. Using the area approximations for 0.5% and 1% of the site provided below, indicate where you would install stormwater BMPs and identify the type(s) of BMP(s) in the margins.

AREA APPROXIMATION:

0.5% of site (need 16 of these)

▨ or this ▨

1% of site (need 8 of these)

▨ or this ▨

SELECT FROM FOLLOWING BMPS:

- Pervious Pavement Systems (PPS)
- Green Roofs (GR)
- Bioretention Devices/Raingardens (BD/R)
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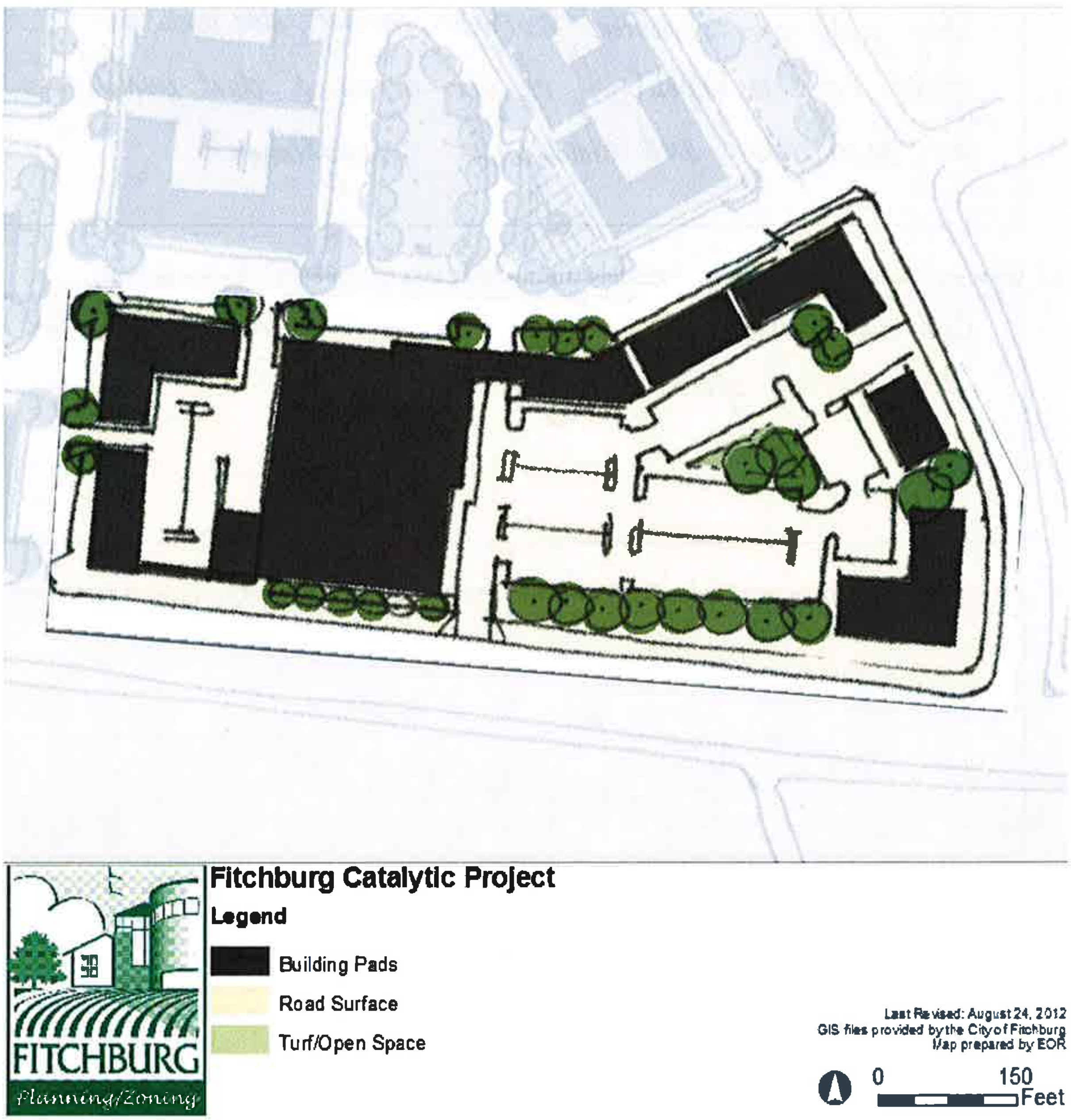

4. Are some of these volume control BMPs better suited for a particular application (land use) than others? If so, please describe.

Yes	No/Avoid

5. What multi-use functions can be combined with stormwater BMPs (e.g. Parking)? Please describe.

Any multi-use function such as parking, side walk, or green roof is helpful if it can serve a dual usefulness for development and stormwater management

6. What are the biggest obstacles to including stormwater BMPs on a project? Please describe.

Cost and Maintenance. Must fit within the development budget and ongoing operating budget

7. Please use this space to provide feedback on the charrette process or offer other general comments.

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Appendix F:

Better Site Design Techniques

Better Site Design Techniques

Contents

I. Introduction

This document provides an overview for designers of the Better Site Design (BSD) techniques and how to plan and apply them at new development sites. Better site design includes a series of techniques that reduce impervious cover, conserve natural areas, use pervious areas to more effectively treat stormwater runoff (Center for Watershed Protection, 1998a) and promote a treatment train approach to runoff management. The goal of better site design is to reduce runoff volume and mitigate site impacts when decisions are being made about proposed layout of a development site. These techniques are known by many different names, such as low impact development, design with nature, sustainable development and conservation design.

When applied early in the design and layout process, better site design techniques can sharply reduce stormwater runoff and pollutants generated at a development site, and also reduce the size and cost of both the stormwater conveyance system and stormwater management practices (Center for Watershed Protection, 1998b).

More than a dozen better site design techniques can be applied early in the design process at development sites. While not all of the better site design techniques will apply to every development site, the goal is to apply as many of them as possible to maximize stormwater reduction benefits, as shown below.

Preserving Natural Areas

- Natural Area Conservation
- Site Reforestation or Restoration
- Shoreline Buffers
- Open Space Design

Disconnecting and Distributing Runoff

- Soil Compost Amendments and/or Soil Tilling
- Disconnection of Impervious Surfaces
- Rooftop Disconnection
- Grass Channels
- Stormwater Landscaping

Reducing Impervious Cover in Site Design

- Narrower Streets
- Slimmer Sidewalks
- Smaller Cul-de-sacs
- Shorter Driveways
- Smaller Parking Lots

II. Preserving Natural Areas

From a stormwater standpoint, it is desirable to maintain as much natural vegetative cover such as forest, prairie or wetland as possible. Natural areas generate the least amount of stormwater runoff and pollutant loads and establish and maintain the desired pre-development hydrology for the site. One of the first steps in the site planning involves identifying, conserving and restoring natural areas present at the development site. The overall strategy is to maximize natural area conservation beyond what is required under local or state resource requirements. Normally, an inventory of natural areas is conducted at the site, along with an assessment of potential areas for reforestation or restoration. Next, designers modify the layout of the development project to take advantage of natural features, preserve the most sensitive areas, and mitigate any stormwater impacts. Open space design is one of the most effective better site design techniques for preserving natural areas at residential sites without losing developable lots.

Natural Area Conservation

Natural area conservation protects natural resources and environmental features that help maintain the pre-development hydrology of a site by reducing runoff and promoting infiltration (Figure 1). Examples include any undisturbed vegetation preserved at the development site, such as forests, prairies, and riparian areas; ridge tops and steep slopes, and stream, wetland and shoreline buffers. Designers should also place a particular priority on preserving natural drainage pathways, intermittent and perennial streams, and floodplains and their associated wetlands. Buildings and roads should be located around the natural topography and drainage so as to avoid unnecessary disturbance of vegetation, soils and natural drainage ways.

Figure 1. Residential Subdivision Preservation of Natural Area. Source: Arendt, 1997

The undisturbed soils and vegetation of natural areas promote infiltration, runoff filtering and direct uptake of pollutants. Forested areas intercept rainfall in their canopy, reducing the amount of rain that reaches the ground. Vegetation also transpires water back into the atmosphere which increases storage available in the soil. Native vegetation also prevents erosion by stabilizing soil, filters sediment and pollutants from runoff, and provides nutrient uptake. Preserving natural areas creates many economic benefits including decreased heating and cooling costs, higher property values and improved habitat (Cappiella, 2005). While a grassland of five acres or larger and a forested site in the range of 20-40 acres might actually approach full ecological function (MN/DNR written correspondence, 2005), successful natural resource preservation and restoration at any scale provides a variety of the benefits described.

Site Reforestation or Restoration

Site reforestation involves planting trees on existing turf or barren ground at a development site with the goal of establishing a mature forest canopy that can intercept rainfall, maximize infiltration and increase evapotranspiration (Figure 2).

Reforestation is accomplished through active replanting or natural regeneration of forest cover. Cappiella (2005) reviewed a range of research that demonstrated the runoff reduction benefits associated with forest cover compared to turf cover. The benefits include reduced annual runoff volumes, higher rates of infiltration, reduced soil erosion, and greater uptake removal of stormwater pollutants. Forest soils actively promote greater infiltration rates due to surface organic matter and macro pores created by tree roots. Forests also intercept rainfall in their canopy, reducing the amount of rain that reaches the ground and increasing potential water storage in forest environments.

Figure 2. . Potential Planting Areas at a Development Site. Source: Cappiella et. al. 2005.

Shoreline Buffers

DNR lake setback requirements and Wetland Conservation Act (WCA) requirements provide a vegetative buffer between developments and lakes or wetlands, respectively. The portions of a site reserved for buffers can present an excellent opportunity to practice better site design. Grassed channels and stormwater conveyance routes can also be managed to realize buffer benefits. The primary function of buffers is to physically protect a water course, lake or wetland from future disturbance or encroachment; however, with careful design they can also be used to capture and filter stormwater runoff from upland areas of the site. To optimize stormwater treatment, the outer boundary of the buffer (Figure 3) should have a stormwater depression area and a grass filter strip. Runoff captured within the stormwater depression is spread across a grass filter designed for sheet flow conditions, and discharges to a wider forest or shrub buffer in the middle or riparian zones that can fully infiltrate and/or further treat storm flows.

Buffers can provide many different environmental and economic benefits, including:

- ✓ Reduced drainage problems and complaints
- ✓ Reduced risk of flood damage
- ✓ Reduced shoreline erosion
- ✓ Increased adjacent property values
- ✓ Enhanced pollutant removal
- ✓ Locations for greenways and trails
- ✓ Sustained integrity of ecosystems and habitat
- ✓ Protection of wetlands associated with the corridor
- ✓ Prevention of disturbance of steep slopes
- ✓ Mitigation of thermal impacts
- ✓ Protection of habitat for wildlife

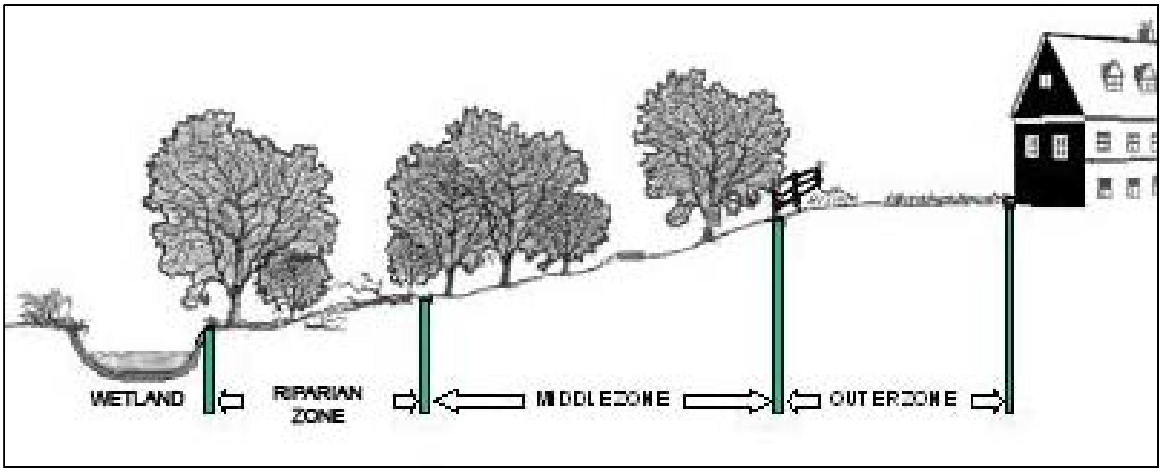

Figure 3. Three-Zone Stream Buffer System. Source: Adapted from Schueler, 1995.

Open Space Design

Open space design is a form of residential development that concentrates lots in a compact area of the site to allow for greater conservation of natural areas (Figure 4). Minimum lot sizes, setbacks and frontage distances are relaxed so as to maintain the same number of dwelling units at the site. This form of development may also be called cluster design or conservation design.

Research has shown that open space designs can reduce overall site impervious cover compared to conventional subdivisions, and command higher prices and more rapid sales, as well (Zielinski, 2001). Other benefits include lower costs for grading, erosion control, stormwater and site infrastructure, as well as greater land conservation, without the loss of developable lots.

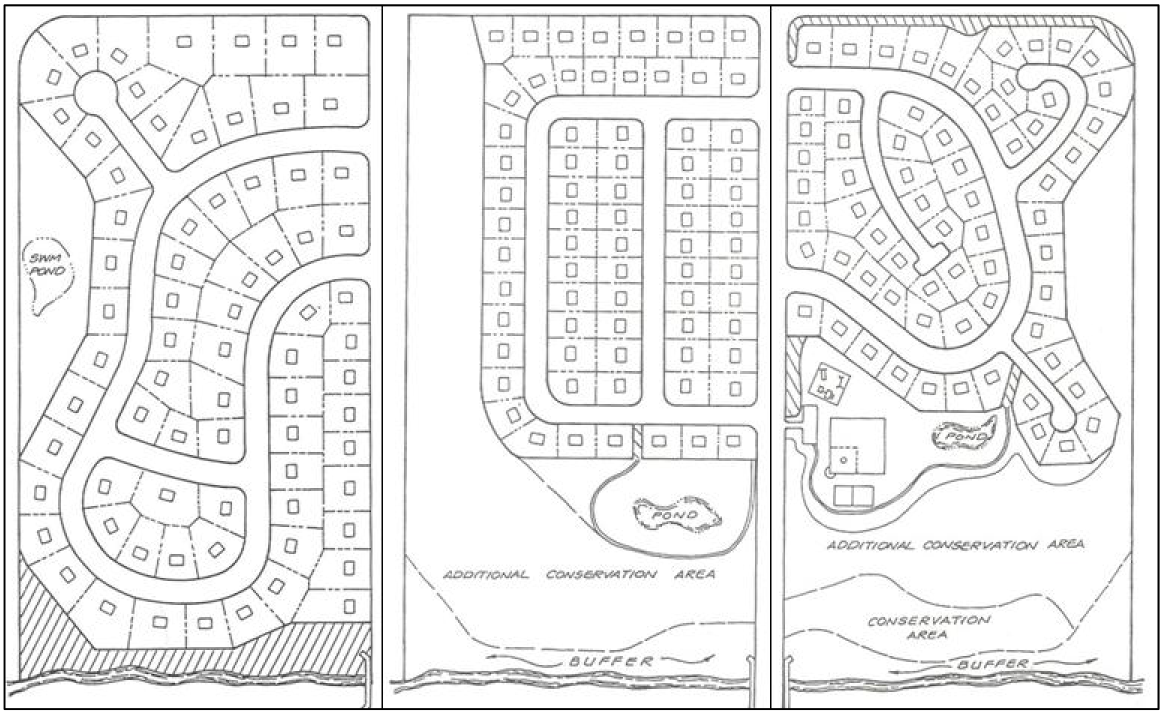

Figure 4. Conventional Subdivision (left) with 72 Lots, and Alternative Layout (center) Using Open Space Design with the same number of Lots, and Another Alternative Layout (right) Using Open Space Design with 66 Lots. Source: Schueler, 1995.

III. Disconnecting and Distributing Stormwater

Another Better Site Design strategy seeks to maximize the use of pervious areas at the site to help filter and infiltrate runoff generated from impervious areas and to spread excess runoff over pervious areas. Most development sites have extensive areas of grass or landscaping where runoff can be treated close to the source where it is generated. Designers should carefully look at the site for pervious areas that might be used to disconnect or distribute runoff. The benefits of this strategy include systematic reductions in runoff volumes, reductions in runoff velocities that can lead to flooding and improved water quality by filtering.

Compost and Amended Soils

Compost amended soils are used to recover soil porosity lost due to compaction as a result of past construction, soil disturbance and ongoing human traffic. The amendment process seeks to recover the porosity and bulk density of soils by incorporating soil amendments or conditioners into the lawn, such as compost, topsoil, lime and gypsum (McDonald, 1999).

Soils can also be amended through the addition of fibers for structural support to prevent compaction, as well as the simple addition of sand to improve permeability or organic material other than compost (e.g. peat).

Soils are the foundation for successful planting, and the water holding capacity of soils can significantly reduce the volume of runoff from a site. What constitutes a "good" soil depends on the purpose it is to serve. For example, if you are planting prairie plants a high organic content in the soil is required. However, if you are planting Kentucky Bluegrass a lower organic content soil can be used.

- In addition to successful plant growth, soils can be engineered to improve water holding capacity. The humus materials or compost created from the compost process has a water holding capacity of up to 80 percent by weight. This quality is very significant when trying to decrease runoff and increase filtration. Higher organic content in the soil also improves the filtering and binding capacity of soils for capturing pollutants.
- On-site soils can be amended by incorporating compost into the soils or by laying a one to three inch "blanket" of compost on top of the soils. Fiber amendments can assist in maintaining soil structure even with heavy surface loads. The method chosen depends on site characteristics and the purpose it is intended to serve, such as promoting infiltration or reducing nutrient and sediment loading to surface waters.

Disconnection of Surface Impervious Cover

Surface disconnection spreads runoff from small parking lots, courtyards, driveways and sidewalks into adjacent pervious areas where it is filtered or infiltrated into the soil. Designers look for areas of the site where flow can be diverted onto turf, lawns or a vegetated filter strip. When many small areas of impervious cover are disconnected from the storm drain system, the total volume and rate of stormwater runoff can be sharply reduced. Disconnections may be restricted based on the length, slope, and soil infiltration rate of the pervious area in order to prevent any reconnection of runoff with the storm drain system. In some cases, minor grading of the site may be needed to promote overland flow and vegetative filtering.

Rooftop Disconnection

Disconnection of rooftops offers an excellent opportunity to spread runoff over lawns and other pervious areas where it can be filtered and infiltrated. Downspout disconnection can infiltrate runoff, reduce runoff velocity, and remove pollutants. Alternately, downspouts can be directed to a dry well, rain garden or surface depression. The stormwater benefits associated with rooftop disconnection can be significant, particularly when residential lot size is large and soils are relatively permeable. Note that building sub-drains generally intercept water from entering a building and do not lend themselves to the impervious disconnection category.

Grass Channels

Curbs, gutters and storm drains are all designed to be hydraulically efficient in removing stormwater from a site. However, they also increase peak runoff discharge, flow velocity, and pollutant delivery to downstream waters. From a better site design perspective, grass channels are preferable to curb and gutters as a conveyance system, where development density, topography, soils and slopes permit their use. Grass channels provide on-site runoff storage, lower peak flows, reduce runoff velocities, and filter or infiltrate some portion of storm flows. While research has indicated that grass channels cannot remove pollutants reliably enough to qualify as a BMP (Winer, 2000), they have been shown to reduce runoff volumes during smaller storms when compared to curbs and gutters.

Stormwater Landscaping

Traditionally, landscaping and stormwater management have been treated separately in site planning. In recent years, engineers and landscape architects have discovered that integrating stormwater into landscaping features can improve the function and quality of both. The basic concept is to adjust the planting area to accept stormwater runoff from adjacent impervious areas and utilize plant species adapted to the modified runoff regime (Table 1). Excellent guidance on how to match plant species to stormwater conditions can be found in the MPCA publication Plants for Stormwater Design: Species Selection for the Upper Midwest (Shaw and Schmidt, 2003) and in Cappiella et al. (2005).

Table 1. Environmental Factors to Consider When Integrating Stormwater and Landscaping

Factor	Problem Addressed
Duration and depth of inundation	Increased duration and depth of water changes the physical and chemical environment in ways that may favor invasive plants
Frequency of inundation	Increased frequency of inundation can carry increased levels of pollutants and toxins
Available moisture during dry weather	Soil compaction can affect plant species success at a site and also the ability of the soil to infiltrate stormwater efficiently
Sediment loading	Susceptibility to erosion and sedimentation from stormwater affects placement of stormwater management BMP as well as selection of plant material
Salt exposure	Browsers (deer and beaver) may be attracted by increased levels of salt in areas that treat roadway and parking lot runoff
Nutrient loading	Increased slopes increase ability to transport nutrients in stormwater

A landscaping area may provide full or partial stormwater treatment, depending on site conditions. An excellent example of the use of landscaping for full stormwater treatment is bioretention (Figure 5). In other cases, landscaping can provide supplemental treatment such as green rooftops and stormwater planters. Even small areas of impervious cover should be directed into landscaping areas since stormwater or melt water help to reduce irrigation needs.

IV. Reducing Impervious Cover in Site Design

This strategy relies on several techniques to reduce the total area of rooftops, parking lots, streets, sidewalks and other types of impervious cover created at a development site. The basic approach is to reduce each type of impervious cover by downsizing the required minimum geometry specified in current local codes, keeping in mind that there are minimum requirements that must be met for fire, snowplow and school bus operation. Less impervious cover directly translates into less stormwater runoff and pollutant loads generated at the site.

Narrower Streets

Many communities require residential streets that are much wider than needed to support travel lanes, on-street parking, and emergency access. Some communities currently require residential streets as wide as 32 to 40 feet and which provide two parking lanes and two moving lanes (Figure 6). Local experience has shown that residential streets can have pavement widths as narrow as 22 to 26 feet, and still accommodate all access and parking needs (ITE, 1997). Even narrower access streets or shared driveways can be used when only a handful of homes are served. Narrower streets help reduce impervious cover and associated runoff and pollutant generation.

Significant cost savings occur in both road construction and maintenance. Narrower streets also help reduce traffic speeds in residential neighborhoods which, in turn, improve pedestrian safety. Snow stockpiles on narrow streets can be accommodated if parking is restricted to one side of the street or alternated between the sides. Alternatively, the right-of-way may be used for snow storage. Narrow snowplows are available. Snowplows with 8' width, mounted on a pick-up truck are common. Some companies manufacture alternative plows on small bobcat-type machines.

Slimmer Sidewalks

Many communities require sidewalks that are excessively wide or are located adjacent to the street where the pedestrians are at risk from vehicles. A better site design technique modifies the width and location of sidewalks to promote safer pedestrian mobility (Figure 7). Impervious cover is reduced when sidewalks are required on only one side of the street, reduced in width and are located away from the street. Sidewalks can also be disconnected so they drain to lawns or landscaping instead of the gutter and storm drain system. Slimmer sidewalks reduce and/or disconnect impervious cover and thus reduce the generation of runoff. Other benefits include greater pedestrian safety, lower construction and maintenance costs, and reduced individual homeowner responsibility for snow clearance.

Figure 5. Examples of the Use of Landscape Islands for Stormwater Treatment in a Suburban Parking Lot (left), the Parking Lot of a Government Office Building (top right), and a Highly Urban Parking Lot (bottom right). Source: Minnesota Stormwater Manual, 2005.

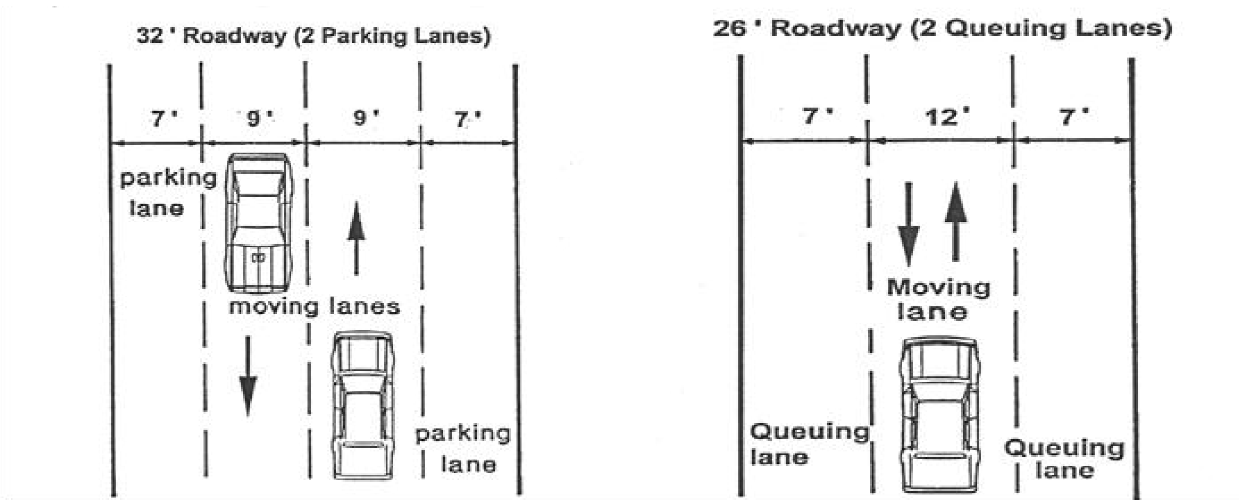

Figure 6. Example of a Traditional Road Design (left) and a Road that was Narrowed Through the Use of "Queuing" lanes (right) Source: Minnesota Stormwater Manual, 2005.

Figure 7. Sidewalk that Drains to Adjacent Vegetation and Provides Common Walkways Linking Pedestrian Areas. Source: Minnesota Stormwater Manual, 2005.

Smaller Cul-De-Sacs

The large cul-de-sacs that enable vehicles to turn around at the end of a residential street provide a great opportunity for better site design. Impervious cover can be reduced by minimizing the diameter of residential street cul-de-sacs and/or incorporating landscaped islands. Many communities require cul-de-sacs that have a greater diameter than needed to allow emergency and large vehicles to adequately turn around. Alternatives to the traditional 80 foot diameter cul-de-sac include 60 foot diameter cul-de-sacs, hammerhead turnarounds and loop roads (Figure 8).

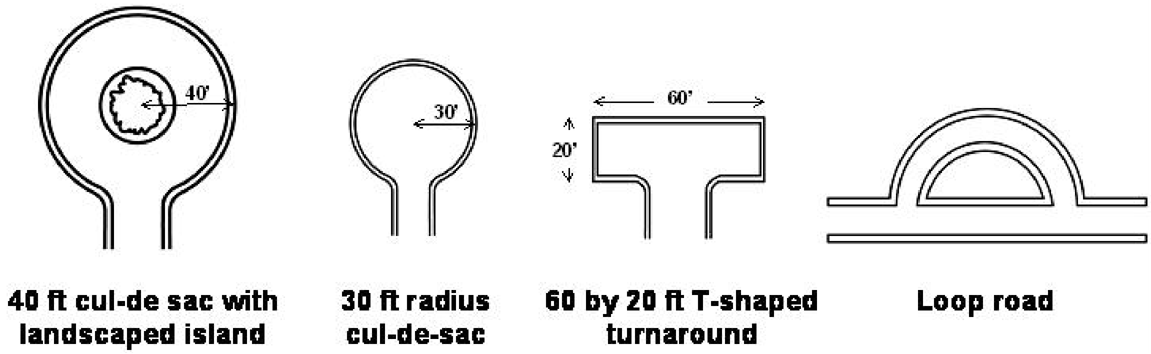

Figure 8. Turnaround Options for Residential Streets. Source: Adapted from Schueler, 1995.

In addition, the inside of the turnaround can be landscaped as a bioretention area to further reduce impervious cover and improve stormwater treatment. Trees and vegetation planted in landscaped islands can be used to intercept rain water and treat stormwater runoff from surrounding pavement (Figure 9). Each of these alternative turnaround options produces a more attractive and safe environment for residents.

Figure 9. Trees and vegetation in the landscape of a Cul-De-Sac (left) and a Loop Road (Right). Source: Minnesota Stormwater Manual, 2005.

Smaller Parking Lots

The parking lot is an excellent place to apply better site design. In many communities, parking lots are over-sized and under-designed. Local parking and landscaping codes can be modified to allow the following better site design techniques to be applied within parking lots:

- ✓ Minimize standard stall dimensions for regular spaces
- ✓ Provide compact car spaces
- ✓ Use of pervious pavement (asphalt, concrete, pavers, sand amendments)
- ✓ Incorporate efficient parking lanes
- ✓ Reduce minimum parking demand ratios for certain land uses
- ✓ Treat the parking demand ratio as a maximum limit
- ✓ Create stormwater “islands” in traffic islands or landscaping areas to treat runoff using bioretention, filter strips or other practices
- ✓ Encourage shared parking arrangements
- ✓ Proof of Parking

Smaller parking lots can sharply reduce impervious cover and provide more effective treatment of stormwater pollutants. In addition, smaller parking lots reduce both up front construction costs and long term operation and maintenance costs, as well as the size and cost of stormwater practices. Parking lot landscaping makes the lot more attractive to customers, and promotes safety for both vehicles and pedestrians. In addition, trees and other landscaping help screen adjacent land uses, shade people and cars, reduce summertime temperatures and improve air quality and bird habitat.

Shorter Driveways

Driveways present another opportunity to practice better site design. Most local codes contain front yard setback requirements that dictate driveway length. In many communities, front yard setbacks for certain residential zoning categories may extend 50 or 100 feet or even longer, which increases driveway length well beyond what is needed for adequate parking and access to the garage. Shorter setbacks reduce the length and impervious cover for individual driveways (Figure 10). In addition, driveway width can be reduced, and more permeable driveway surfaces allowed. Another way to reduce impervious cover is to allow shared driveways that provide street access for up to six homes. Shorter driveways help reduce infrastructure costs for developers since they reduce the amount of paving or concrete needed.

Figure 10. Example of a Shorter Driveway. Source: Minnesota Stormwater Manual, 2005**.**

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Appendix G:

Better Site Design Checklist

Better Site Design Techniques

WORKSHEET

Project Name ____________________________ **Date** _________ **Permit Number** ____________________

This worksheet (3 pages in total) is offered as a means to facilitate the incorporation of Better Site Design techniques early in the Plan development process. Use a ✓ to indicate BSD techniques incorporated during project design. The right hand column should describe BSD techniques incorporated, or for those BSD techniques deemed infeasible, the reasoning for this determination.

RESIDENTIAL STREETS AND PARKING LOTS (1 of 3)

☐	**Residential Street Pavement Width**	Design residential streets for the minimum required pavement width needed to support travel lanes, on-street parking, and emergency, maintenance and service vehicle access	
☐	**Number and Radius of Residential Cul-de-sacs**	Minimize the number of residential street cul-de-sacs and replace with landscaped areas to reduce impervious cover. Consider alternative turnarounds.	
☐	**Residential Street ROW Widths**	Reduce residential street ROW widths to the minimum required to accommodate the travel-way and the sidewalk allowing space for vegetated areas. Locate utilities and storm drains outside of the BMP section of the ROW.	
☐	**Stormwater Conveyance (e.g. swale vs pipe)**	Where density, topography, soils and slope allow, use vegetated open channels in the street ROW to convey and treat stormwater runoff.	
☐	**Parking Ratio and Stall Dimensions**	Where local ordinance permits, use or reduce the minimum required parking ratio. Consider pervious applications in spillover parking stalls.	
☐	**Functional Required Landscaping Imperviousness**	Wherever possible, utilize required landscaping areas and traffic islands for bioretention, filter strips, and/or other stormwater treatment practices.	

LOT DEVELOPMENT (2 of 3)

☐	**Alternative Driveway Surfaces**	Reduce overall lot imperviousness by installing alternative driveway surfaces, shorter or narrower driveways, and shared driveways.	
☐	**Alternative Parking Surfaces**	Utilize pervious parking spaces.	
☐	**Routing of Rooftop Runoff**	Direct rooftop runoff to pervious areas such as yards, open channels or vegetated areas rather than to a stormwater conveyance system.	
☐	**Soil Amendments**	Restore the drainage and/or biological capacity of damaged or lost soils through mechanical improvements or soil amendments.	
☐	**Parking Lot Size Reduction**	Consider joint parking arrangements or other methods (underground parking, tuck under parking, etc.) for reducing the size of parking lots.	
☐	**Open Space Design/ Cluster Development**	Consider open space design development incorporating smaller lot sizes to minimize total impervious area, reduce construction costs, conserve natural areas, provide recreational space and promote water quality.	
☐	**Management of Natural and Recreational Open Space**	Specify how community open space will be managed, and designate a sustainable legal entity responsible for managing both natural and recreational open space.	

CONSERVATION OF NATURAL AREAS (3 of 3)

☐	**Preserved Net Developable Areas**	Preserve a % of net developable areas as natural/open space.	
☐	**Wetland Management Standards**	Include wetlands within outlots and consider incorporation of a buffer.	
☐	**Conservation of Existing Trees or Other Vegetation**	Conserve trees and other vegetation by planting additional vegetation, clustering tree areas, and promoting the use of native plants. Manage community open space, street ROWs, parking lot islands, and other landscaped areas.	
☐	**Use of Native Vegetation Throughout the Site**	Utilize native, drought-resistant vegetation for lower management needs, habitat creation and aesthetics.	
☐	**Extension of Easements**	Extend easements beyond required District or local landuse authority requirements for protection of open space.	
☐	**Seeding vs. Planting Plugs**	Vegetate infiltration basins and swales with plugs rather than seed in order to facilitate plant establishment and performance quality.	
☐	**Limit Clearing and Grading**	Limit clearing and grading of trees and native vegetation to the minimum area needed to build lots, allow access and provide fire protection.	

Appendix H:

BMP Cost Estimate Worksheet

BIORETENTION DEVICE
COST ESTIMATE WORKSHEET
2005 Prices

Project Title ______________________

Owner ______________________

Location ______________________

Project Number ______________________

Date ______________________

Description	Units	Quantity	Unit Cost	Total Estimated Price
Site Preparation				
Tree removal - up to 12" diameter	each		$350.00	$0.00
Clear and grub brush	square yard		$1.50	$0.00
Tree protection - temp. fence	lineal foot		$3.00	$0.00
Topsoil - salvage	square yard		$4.50	$0.00
Site Formation				
Excavation - 4' average depth	square yard		$10.00	$0.00
Grading	square yard		$1.50	$0.00
Hauling off-site	square yard		$6.50	$0.00
Structural Components				
Underdrain - with pea gravel and geotextile	lineal foot		$30.00	$0.00
Inlet structure	each		$1,500.00	$0.00
Outlet structure	each		$2,500.00	$0.00
Site Restoration				
Filter strip	square yard			$0.00
Soil preparation	square yard		$30.00	$0.00
Seeding - above outlet elevation	square yard		$0.50	$0.00
Planting - below outlet elevation	square yard		$30.00	$0.00
Mulch	square yard		$5.00	$0.00
			Subtotal	$0.00
			10% Contingencies	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL CONSTRUCTION COST	$0.00

Description	Units	Quantity	Unit Cost	Total Estimated Price
Annual Operation and Maintenance				
Debris removal	per visit		$50.00	$0.00
Weed control	per visit		$50.00	$0.00
Sediment removal	per year		$500.00	$0.00
Replace planting media	square yard		$12.00	$0.00
Replace plants	per plant		$5.00	$0.00
Mow filter strips	per visit		$50.00	$0.00
Erosion repair	square yard		$75.00	$0.00
Inspection	per visit		$125.00	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL ANNUAL O&M COST	$0.00

Minnesota Location Factors	
Bemidji	0.963
Brainerd	1.003
Detroit Lakes	0.962
Duluth	0.991
Mankato	0.990
Minneapolis	1.035
Rochester	0.983
St. Paul	1.000
St. Cloud	1.002
Thief River Falls	1.042
Willmar	0.961
Windom	0.935

Note: Suggested unit costs are based on RSMeans prices for Spring, 2005, then factored into an area basis based on typical design features for Bioretention BMPs. To be used for preliminary cost estimation.

INFILTRATION BASIN
COST ESTIMATE WORKSHEET
2005 Prices

Project Title	
Owner	
Location	
Project Number	
Date	

Description	Units	Quantity	Unit Cost	Total Estimated Price
Site Preparation				
Tree removal - up to 12" diameter	each		$350.00	$0.00
Clear and grub brush	square yard		$1.50	$0.00
Tree protection - temp. fence	lineal foot		$3.00	$0.00
Infiltration area protection - silt fence	lineal foot		$2.00	$0.00
Topsoil - 6" depth, salvage on site	square yard		$4.50	$0.00
Site Formation				
Excavation - 6' depth	square yard		$8.00	$0.00
Grading	square yard		$1.50	$0.00
Hauling off-site - 6' depth	square yard		$10.00	$0.00
Structural Components				
Inlet structure	each		$1,500.00	$0.00
Multi-stage outlet structure	each		$2,500.00	$0.00
Site Restoration				
Sod filter strip	lineal foot		$1.50	$0.00
Soil preparation	square yard		$5.00	$0.00
Seeding	square yard		$0.50	$0.00
Planting - below outlet elevation	square yard		$30.00	$0.00
Mulch	square yard		$2.00	$0.00
			Subtotal	$0.00
			10% Contingencies	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL CONSTRUCTION COST	$0.00

Description	Units	Quantity	Unit Cost	Total Estimated Price
Annual Operation and Maintenance				
Replace planting media	square yard		$12.00	$0.00
Debris removal	per visit		$50.00	$0.00
Mow filter strips	per visit		$50.00	$0.00
Sediment removal	per year		$500.00	$0.00
Replace plants	per plant		$5.00	$0.00
Erosion repair	square yard		$75.00	$0.00
Gate / valve operation	per visit		$125.00	$0.00
Inspection	per visit		$125.00	$0.00
			Subtotal	$0.00
			Apply MN Location Factor	
			TOTAL ANNUAL O&M COST	$0.00

Minnesota Location Factors	
Bemidji	0.963
Brainerd	1.003
Detroit Lakes	0.962
Duluth	0.991
Mankato	0.990
Minneapolis	1.035
Rochester	0.983
St. Paul	1.000
St. Cloud	1.002
Thief River Falls	1.042
Willmar	0.961
Windom	0.935

Note: Suggested unit costs are based on RSMeans prices for Spring, 2005, then factored into an area basis based on typical design features for Infiltration Basin BMPs. To be used for preliminary cost estimation.

Appendix I:

BMP Construction Checklist

BIORETENTION - Construction Inspection Checklist

Project:	
Location:	
Site Status:	
Date:	
Time:	
Inspector:	

Construction Sequence	Satisfactory / Unsatisfactory	Comments
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Facility area cleared		
Soil tested for permeability		
Project benchmark near site		
Facility location staked out		
Temporary erosion and sediment protection properly installed		
2. Excavation		
Lateral slopes completely level		
Soils not compacted during excavation		
Longitudinal slopes within design range		
Stockpile location not adjacent to excavation area and stabilized with vegetation and/or silt fence		
3. Structural Components		
Stone diaphragm installed per plans		
Outlets installed pre plans		
Underdrain installed to grade		
Pretreatment devices installed per plans		
Soil bed composition and texture conforms to specifications		
4. Vegetation		
Complies with planting specs		
Bioretention Construction Inspection Checklist		

Construction Sequence	Satisfactory / Unsatisfactory	Comments
Topsoil complies with specs in composition and placement		
Soil properly stabilized for permanent erosion control		
5. Final Inspection		
Dimensions per plans		
Pretreatment operational		
Inlet/outlet operational		
Soil/ filter bed permeability verified		
Effective stand of vegetation stabilized		
Construction generated sediments removed		
Contributing watershed stabilized before flow is diverted to the practice		

Comments:

Actions to be taken:

Bioretention Construction Inspection Checklist

Infiltration Trench - Construction Inspection Checklist

Project:
Location:
Site Status:
Date:
Time:
Inspector:

Construction Sequence	Satisfactory / Unsatisfactory	Comments
1. Pre-Construction		
Pre-construction meeting		
Runoff diverted		
Soil permeability verified		
Groundwater / bedrock verified		
Project benchmark established		
Facility location staked out		
Temporary erosion and sediment control established		
2. Excavation		
Size and location per plans		
Side slopes stable		
Depth adjusted to soil layer with specified soil type and permeability		
Sub-soil not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
Stockpile location not adjacent to excavation area and stabilized with vegetation and/ or silt fence		
3. Filter Fabric Placement		
Fabric per specifications		
Placed per plan location		
4. Aggregate Material		
Size as specified		
Clean / washed material		
Infiltration Trench Construction Inspection Checklist		

Construction Sequence	Satisfactory / Unsatisfactory	Comments
Placed properly		
5. Observation Well		
Pipe size per plans		
Under-drain installed per plans		
Inlet installed per plans		
Pre-treatment devices installed per plans		
6. Vegetation		
Complies with planting specifications		
Topsoil complies with composition and placement in specifications		
Permanent erosion control measures in place		
7. Final Inspection		
Dimensions per plans		
Check dams operational		
Inlet / outlet operational		
Effective stand of vegetation and stabilization		
Contributing watershed stabilized before flow is routed to the facility		
Comments:		
Actions to be taken:		

Infiltration Trench Construction Inspection Checklist

Appendix J:

BMP Operation & Maintenance Checklist

BIORETENTION - Operation & Maintenance Checklist

Project:	
Location:	
Site Status:	
Date:	
Time:	
Inspector:	

Maintenance Item	**Satisfactory / Unsatisfactory**	**Comments**
1. Debris Cleanout (Monthly)		
Contributing areas clean of litter and vegetative debris		
No dumping of yard wastes into practice		
Bioretention area clean of litter and vegetative debris		
2. Vegetation (Monthly)		
Plant height taller than design water depth		
Fertilized per O&M plan		
Plant composition according to O&M plan		
Undesirable vegetation removed		
Grass height less than 6 inches		
No evidence of erosion		
3. Check Dams/Energy Dissipators/Sumps (Annual, After Major Storms)		
No evidence of sediment buildup		
Sumps should not be more than 50% full of sediment		
No evidence of erosion at downstream toe of drop structure		
4. Dewatering (Monthly)		
Dewaters between storms within 48 hours		
No evidence of standing water		
5. Sediment Deposition (Annual)		
Pretreatment areas clean of sediments		

Bioretention Operation, Maintenance and Management Inspection Checklist

Maintenance Item	Satisfactory / Unsatisfactory	Comments
Contributing drainage area stabilized and clear of erosion		
Winter sand deposition evacuated every spring		
6. Outlet/Overflow Spillway (Annual, After Major Storms)		
Good condition, no need for repair		
No evidence of erosion		
No evidence of any blockages		
7. Integrity of Filter Bed (Annual)		
Filter bed has not been blocked or filled inappropriately		
Comments:		
Actions to be Taken:		

Bioretention Operation, Maintenance and Management Inspection Checklist

Infiltration Trench/ Basin - Operation & Maintenance Checklist

Project:	
Location:	
Site Status:	
Date:	
Time:	
Inspector:	

Maintenance Item	Satisfactory / Unsatisfactory	Comments
1. Debris Cleanout (Monthly)		
Contributing drainage area clear of litter and vegetative debris		
Trench surface clean		
Inflow pipes clear		
Overflow spillway clear		
Inlet area clean		
2. Sediment Traps or Forebays (Annual)		
Obviously trapping sediment		
Greater than 50% of storage volume remaining		
3. Dewatering (Monthly)		
Trench dewaters between storms		
4. Vegetation (Monthly)		
Mowing done per O&M plan		
Minimum mowing depth not exceeded		
Undesirable vegetation removed		
No evidence of erosion		
Fertilized per O&M plan		
5. Sediment Cleanout of Trench (Annual)		
No evidence of sedimentation in gravel filter		
Sediment accumulation doesn't yet require cleanout		
6. Sediment deposition of Basin (Annual)		
Clean of sediment		
Infiltration Trench/ Basin Operation, Maintenance, and Management Inspection Checklist		

Maintenance Item	Satisfactory / Unsatisfactory	Comments
Winter accumulation of sand removed each spring		
Contributing drainage area stabilized and free of erosion		
7. Inlets (Annual)		
Good condition		
No evidence of erosion		
8. Outlet/Overflow Spillway (Annual)		
Good condition, no need for repair		
No evidence of erosion		
9. Aggregate Repairs (Annual)		
Surface of aggregate clean		
Top layer of stone does not need replacement		
Trench does not need rehabilitation		

Comments:

Actions to be Taken:

Infiltration Trench/ Basin Operation, Maintenance, and Management Inspection Checklist

Appendix K:

Report Template for Program Evaluation

Permit 00-063
Lino Lakes State Bank

Description of BMPs Incorporated:
The infiltration practices include a 13 stall proof-of-parking area constructed with Netlon and an infiltration island with depressed storage.

Findings and Assessment:
The Netlon parking area is constructed according to plan but should be considered as a combined infiltration -filtration feature since the design includes a sub-drain capable of conveying runoff downstream. The infiltration island (photo) is not graded according to plan – there is significantly less infiltration area at the 916 contour and no depressional storage at the 915.5 contour. As constructed, runoff would flow over approximately 10 linear feet of sod before discharging to a catch basin. Limited infiltration over this area is expected.

Recommended Follow-up:
Require owner to regrade the island per the approved plans.

Permit 00-064
Meridian Properties

Description of BMPs Incorporated:
Infiltration practices include three rain gardens downstream of parking areas.

Findings and Assessment:
Site construction has been phased and only two of the rain gardens have been excavated. Of these two, the east rain garden is graded according to plan. The north rain garden area along Edgewood Drive (photo) is reduced in size to accommodate a sidewalk and the catch basin overflow is set too low (at the basin bottom instead of being perched).

Recommended Follow-up:
Require owner to modify the Edgewood Drive rain garden to increase depressional storage, provide positive slope from curb cuts to rain garden bottom, and plant with wet tolerant vegetation. In addition, the drainage route from parking lot to the east rain garden and the rain garden itself need to be better stabilized and vegetated. District staff should continue to inspect the project as the second lot (and 3rd rain garden) is constructed.