IMPLEMENTING RAINWATER GARDENS IN URBAN STORMWATER MANAGEMENT

LESSONS LEARNED FROM THE CITY OF MAPLEWOOD

CAPSTONE PROJECT
INFRASTRUCTURE SYSTEMS ENGINEERING
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APPENDIX

Implementing Rainwater Gardens in Urban Stormwater Management: Lessons Learned from the City of Maplewood

ABSTRACT:

Based on experience gained by the City of Maplewood, recommendations for ensuring the successful use of rainwater gardens for urban stormwater management are provided.

As redevelopment within urban areas increases, stormwater management becomes a critical problem. Due to their perceived attractiveness, rainwater gardens--small infiltration ponds filled with plants--are a popular best management practice for stormwater management. As a result, many cities are initiating plans to integrate them into their drainage system. Inadequate information about the design and maintenance of rainwater gardens, however, could hinder their successful implementation. By contrast, the City of Maplewood has constructed 350 rainwater gardens in the past eight years, an experience data base that could be used to offset the lack of engineering knowledge.

The history and evolution of rainwater gardens in the City of Maplewood is outlined. Alternative rainwater designs are presented and the advantages and disadvantages of each design are noted. The role of the public in issues related to the construction and maintenance of rainwater gardens in Maplewood is investigated. Based on studies and investigations, recommendations for ensuring the successful use of rainwater gardens for urban runoff are presented.

CHAPTER 1: INTRODUCTION

1.1 PROBLEM:

The City of Maplewood is a community of approximately 30,000 residents. Maplewood is a first ring suburb lying northeast of St. Paul. The entire city is developed except for small pockets of land scattered within the city and 40 acres at the southern tip. The first areas to develop occurred during the late 1800s. For the past eight years the city has vigorously focused its efforts on improving the existing streets and utilities in these older neighborhoods.

The city encountered many challenges when reconstructing streets and utilities in these older neighborhoods. One of the most significant problems has been lack of adequate space to treat storm water runoff along with minimal existing storm sewer in the old neighborhoods. Maplewood has turned to the use of rainwater gardens for storm water treatment in existing neighborhoods.

More and more communities will be looking to incorporate best management practices into their storm sewer system. Increasing redevelopment in urban areas and the need to improve on existing storm sewer systems forces communities to implement innovative storm treatment methods. Rainwater gardens are versatile and work well in existing and new developments.

It is important that agencies using rainwater gardens understand proper design and construction. Maplewood has designed and constructed gardens using methods resulting in attractive, functional rainwater gardens.

1.2 OBJECTIVES

The objective of this study is to present the problems and successes regarding the implementation of rainwater gardens in Maplewood.

Throughout the past eight years, the introduction of rainwater gardens into the city's storm sewer system has affected street and storm sewer design. This report explores the changes made to the storm sewer, street and rain garden design in residential neighborhoods since gardens were first introduced.

The types of vegetation planted in rainwater gardens have also changed throughout the years. The types of plants that have been used in the past and and current recommendations are presented.

Maplewood has realized the important role the public plays when rain gardens are used in neighborhoods. This report discusses the public's reaction to rain water gardens and how the city has overcome residents' resistance to the gardens.

Many mature gardens are maintained in Maplewood. Maintenance of gardens depends on how they were constructed, the soil type, the plants used to vegetate the garden and how much runoff the garden receives. The maintenance required for rainwater gardens is further explored.

The city encourages developers to incorporate best management practices (BMPs) in their developments. The city has worked closely with developers and their contractors to ensure the gardens are designed and constructed properly. The city is currently struggling with the construction of rainwater gardens by contractors. These issues will be reported on.

1.3 METHODS

The methods used to meet the objectives of this study, as defined in the previous section, will be to review the City of Maplewood's past projects. New developments that have incorporated the rainwater garden design into their sewer system will also be evaluated. Maintenance, vegetation and public perception will be examined.

Since 1997 the city has constructed six rainwater garden projects. This report will review each project and how rainwater gardens have evolved and improved. Details on the design, construction, plantings and maintenance of the gardens will be closely reviewed and reported.

Information regarding the above projects will be retrieved through interviews with the city's naturalist to better understand construction and plantings of the gardens. Interviews with the city's maintenance crew chief will be conducted to determine in detail the maintenance issues associated with the rainwater gardens.

The public's reaction to rainwater gardens will be reported through the author's firsthand knowledge of dealing with residents who have had rainwater gardens constructed in boulevards adjacent to their property. Inspectors on these projects have dealt with residents and contractors on a daily basis. Their perspective on the pros and cons of the gardens will be used to better understand the issues encountered. The Wisconsin Department of Natural Resources conducted a study group with Maplewood residents to research homeowners' reaction to rainwater gardens in the city. Findings from this report will be presented to better understand the public's perception of rainwater gardens in their neighborhood.

The city has been challenged in recent years implementing rainwater gardens in new construction. The issues the city has had with developers, their engineers and contractors will be presented.

1.4 OUTCOMES

The expected outcomes reflect positively on the use of rainwater gardens for water treatment in residential and commercial developments. It is anticipated that rainwater gardens will be found to be versatile and may be adapted to varying site conditions with respect to soils, topographies and space constraints.

It is predicted that the health and function of the gardens will be dependent on annual maintenance activities. Proper construction techniques are also anticipated to affect the infiltration characteristics of the garden.

It is expected that the public's acceptance of rainwater gardens is based on several criteria including the type of curb used on the street, existing drainage problems and resident's proximity to a water body.

This report will examine the design changes made throughout the years to improve the function of rainwater gardens to their specific site conditions. It is expected that lessons learned will help other agencies avoid the difficulties Maplewood has experienced regarding use of rain gardens in existing neighborhoods and in developing areas.

This report is expected to provide a better understanding of the advantages and disadvantages of various rainwater garden designs.

1.5 OUTLINE

The outline for the body of the report is to discuss the basic rainwater garden design and construction, along with various outlet designs that have been used in Chapter 2. Chapter 3 presents in-depth information detailing neighborhood reconstruction projects the city has done in the past. Details regarding garden designs will be presented along with the reasoning behind each design. Chapter 4 covers appropriate vegetation used in rainwater gardens. The public's perception of the gardens will be reported in Chapter 5. Chapter 6 discusses the maintenance of gardens. Information will be provided based on the city's experience with the use of rainwater gardens in new developments in Chapter 7. Chapter 8 summarizes the main findings of the report and ends with recommendations for the use of rainwater gardens.

CHAPTER 2: MAPLEWOOD RAINWATER GARDEN BASICS

2.1 OBJECTIVE

It is important to understand the basic design of rainwater gardens in Maplewood. There are two different types of gardens the city currently constructs. The first garden type is constructed in public boulevards in front of residential property. These gardens handle drainage from yards, rooftops, driveways and a small portion of runoff from the street. The second garden type is large, public gardens. These gardens treat runoff from a larger drainage area, typically ten to twenty acres. Storm sewer systems discharge into these larger gardens. The difference in the two garden designs is discussed.

2.2 METHOD

Typical garden designs currently used by the city are presented in detail. Current garden design has evolved from designs used in the past.

2.3 OUTCOMES

Residential gardens vary in size, ranging from 8 by 16 feet to 12 by 24 feet. These gardens are generally 1 to 2 feet deep to the bottom of the finished garden. Eight inches of virgin ground at the bottom of the garden is scarified. This is a key factor in rainwater garden construction and will be discussed further in the report. Eight inches of bedding material is then spread over the scarified soil and topped with 2 to 3 inches of shredded wood mulch. A rock sump with a diameter of 42 inches is constructed in each garden at a depth of 3 to 6 feet. The sumps consist of 1 ½ inch clear crushed rock wrapped in geotextile filter fabric (City of Maplewood, “Engineering Standard Plate No. 115,” 2004). The sump promotes infiltration in the gardens. The gardens are then planted with appropriate vegetation. Most, but not all, of the gardens have a small drain connected to the storm sewer system. The top of the drain is set approximately one half foot above the bottom of the garden. A detail of a garden is shown in **Figure 1**.

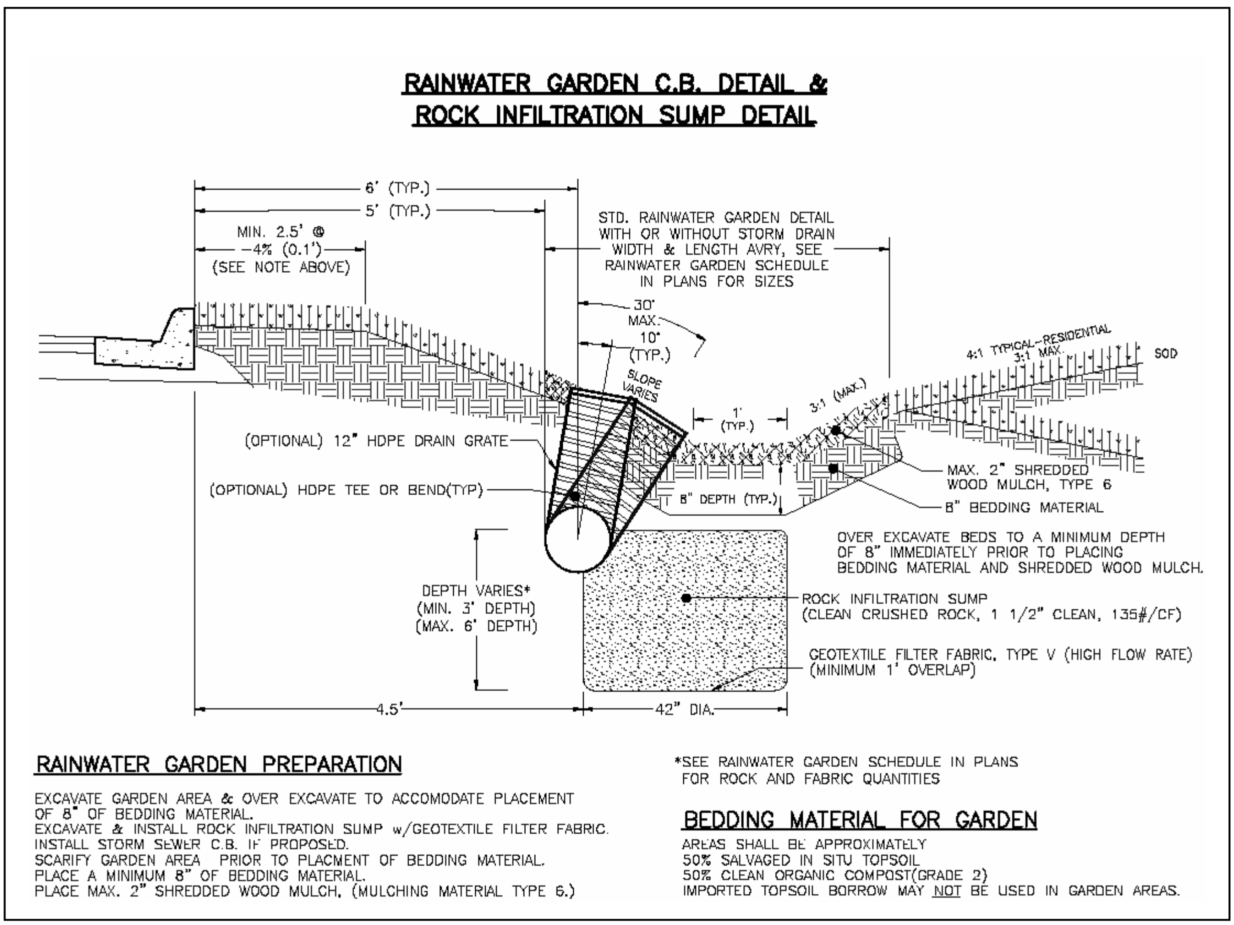


Figure 1. Rainwater Garden Detail (City of Maplewood, Standard Plate 115, 2004)

The type of vegetation is an important factor in the function of a rainwater garden. The plants used in the garden serve an aesthetic purpose, but more importantly they are essential in the infiltration process. The plants uptake nutrients deposited from storm water runoff. Plants also keep soils open and aerated to promote infiltration (City of Maplewood, “Rainwater Garden Facts,” 2004).

Residential rainwater gardens are offered to residents within the project boundaries. Residents may volunteer to have a garden placed in the city’s right of way adjacent to their property. The city constructs the gardens and provides plantings for the gardens. It is the resident’s responsibility to plant the garden and maintain it. Essentially the residents own the garden.

Larger rainwater gardens the city designs for residential reconstruct projects are designed similar to the smaller residential gardens. These gardens are designed to handle a much larger volume of runoff and therefore occupy a greater area and are deeper. Gardens constructed in previous projects have been designed for drainage areas ranging from ten to twenty acres. In residential street reconstruction project areas, gardens are designed to infiltrate a 1.5 inch rainfall event or more. The normal water elevation of the garden is set 1 to 2 feet above the bottom of the garden. It is desirable to design the garden to infiltrate storm water in 24 to 48 hours. Variation in the design of the large gardens occurs when adverse soil conditions exist. This topic will be explored further in the report.

Large rainwater gardens are constructed in city property and are planted and maintained by the city.

2.4 SUMMARY

The basic function of residential gardens is to store and infiltrate runoff from a small drainage area. The larger public gardens are designed to handle runoff from a much larger drainage area. The following chapter reviews past rainwater garden projects in the city. The very first rainwater garden design is discussed along with the progression of rainwater garden design throughout the past eight years.

CHAPTER 3: PAST RAINWATER GARDEN PROJECTS

3.1 OBJECTIVE

Maplewood has implemented rainwater gardens into residential reconstruction projects for the past eight years. The design of rainwater gardens has changed over the years to improve the function and effectiveness of the gardens. The objective of this chapter is to track problems the city encountered with previous designs and explore changes made to improve the gardens.

3.2 METHODS

Six past residential street reconstruction projects utilizing rainwater gardens are reviewed. The problems encountered during each project and changes made are examined.

3.2.1 BIRMINGHAM PILOT PROJECT

"*The Birmingham Pilot Project was a partnership between the City of Maplewood, the University of Minnesota Department of Landscape Architecture, and the Ramsey Washington Metro Watershed District. Maplewood City Engineer Ken Haider, Watershed District Director Cliff Aichinger, and Professor Joan Iverson Nassauer from the University were the visionaries for this work. The project was funded in part by Legislative Commission on Minnesota Resources*". (City of Maplewood, "Rainwater Gardens," 2004) The project was constructed in 1997 and was the first rainwater garden construction project in Maplewood.

The project was constructed within a two-block section of Birmingham Street. The section of street was isolated in the sense that there was no existing storm sewer to connect into on adjacent streets. The management of storm water was designed to be contained within the project area and to handle a 10 year storm event (Priebe, 2004).

Prior to design of the rainwater gardens, the University of Minnesota conducted interviews with residents in the project area to involve them in the design process and to understand their expectations regarding the function and aesthetic design of the gardens. From these interviews, it was discovered that residents were concerned with maintenance, a clean appearing garden edge and quick infiltration. The interviews conducted with the residents helped the city design gardens that met the public's needs and wants (City of Maplewood, Project File 95-12, Nassauer 1995).

The basic residential rainwater garden design was 6 inches of native topsoil with ¾ to 4 inches of wood mulch. The key to infiltrating runoff in these gardens was a French drain. The top of the French drain was set just beneath the topsoil. The French drain consisted of 12" diameter corrugated polyethylene perforated pipe encased in 12 inches of Class C aggregate (pea rock) wrapped in geotextile fabric. The garden and French drain were designed to infiltrate runoff through the first 6 inches of topsoil. Water continues through the geotextile fabric and pea rock. Eventually water is stored in the perforated pipe until it infiltrates into the ground. The vertical length of the French drain constructed was approximately 5 feet deep. A detail of this is shown in **Figure 2**.

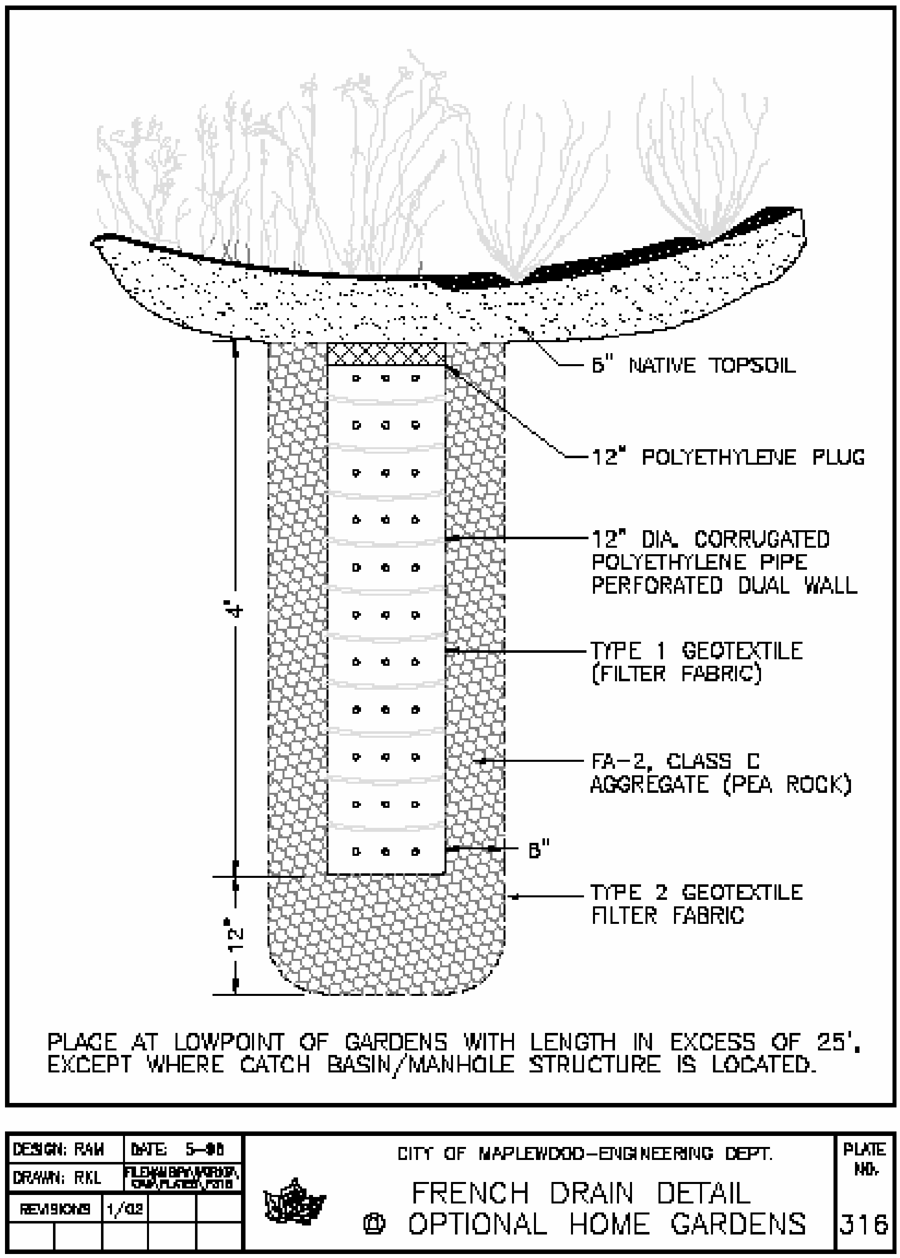


Figure 2. French Drain Detail (City of Maplewood, Standard Plate 316, 2004)

The larger gardens within this project were designed to infiltrate in a similar manner to the residential gardens. A 24” perforated pipe was surrounded by

6 inches of Class C aggregate and approximately 10 feet deep. A standard stool grate was set flush with the bottom of the gardens to direct runoff into the perforated pipe. Runoff is stored in the pipe until it infiltrates through the perforations, past the aggregate and into the ground. Unfortunately, the Minnesota Pollution Control Agency deemed this drain system an illegal type 5 well and this was considered direct discharge of runoff into the ground water system (Priebe, 2004). On the other hand, in 1997 the U.S. Environmental Protection Agency awarded the city with the National 2^{nd} place award for Outstanding Municipal Storm Water Control Program (City of Maplewood, Project File 95-12, Haider, 1995).

The French drain systems in the rainwater gardens were the only outlets designed for the gardens in the Birmingham pilot project. The gardens and French drains were not designed to store the volume of water generated by large storm events. During small rain events, the gardens and the manhole sumps function properly. There is adequate volume in the gardens and French drains to handle smaller events (Priebe, 2004)

Many recent reconstruction projects have utilized some type of concrete curb. It should be noted that Birmingham Street was constructed with no curb. Runoff sheets off the street and into the boulevard. The rainwater gardens were located at the lowest point in the boulevard to capture the runoff. Swales were constructed to direct runoff from the boulevard into the gardens. During large rain events, water overtopped the gardens into the street, around driveways and into the next downstream garden. For this design to work properly it was important to ensure positive driveway grades to prevent water from flowing into private property. For existing negative driveway grades, a hump was constructed near the street edge to contain the runoff. This prevented runoff from flowing down driveways. It is essential in all projects incorporating gardens to ensure emergency overflows are available.

One maintenance problem stemmed from the use of red stem dogwood in the gardens. Red stem dogwood is found in moist conditions, along the edges of streams in nature. The height of dogwood can range from 3 to 15 feet tall (Las Pilitas, 2004). This tall shrub has become a maintenance issue for the city's maintenance department. According to Erick Oswald, storm sewer crew chief at the City of Maplewood, the height of the dogwood becomes a problem when trying to access the French drains to perform maintenance activities such as removing debris from the pipe. He suggested that the smaller shrubbery be planted around the drains to provide for easier access (Oswald, 2004).

The Birmingham Pilot project initiated the city's use of rainwater gardens in residential reconstruction projects. Valuable lessons were learned by everyone involved in the project regarding drain design, emergency overflows, and vegetation of the gardens. The city has since refined the garden design.

3.2.2 Harvester Area Streets Improvements

The Harvester Project is the second street project in Maplewood to utilize rainwater gardens and was constructed in 1999. This project was approximately 1.5 miles of street reconstruction. The majority of this project area was very flat with street grades as flat as 0.39 percent. This neighborhood was an ideal candidate for rainwater gardens.

The garden design was revised from the pilot project design. The project area was larger and there was existing storm sewer available to tie into. The garden design used for this project eliminated the French drain system. Instead, a rock sump was constructed in the gardens as described in Chapter 2.   In some of the residential gardens, plastic drains were installed approximately 0.5 to 1 foot above the bottom of the garden. The drains were connected to a storm sewer system to convey overflow from the smaller gardens to a pond or to nearby Michael Lake. Not all of the gardens were connected to a larger storm sewer system though. The overflow from the gardens without the drains was designed to overflow into the street and continue downstream into catch basins.

Rainwater gardens were offered to residents in the project area on a voluntary basis. A swale was constructed in boulevards adjacent to residents who opted against a rainwater garden. Swales are slight depressions constructed in boulevards to store a small amount of runoff or direct water downstream into a rainwater garden.

There was one short segment of street within the project area on Ferndale Street, approximately 300 feet long, where the street grade exceeded 8 percent.

For this segment of street, an integral bituminous curb was constructed to contain runoff in the street and prevent erosion in the boulevards. Once the street grade flattened out, the integral curb ended and runoff was allowed to sheet off the street and into a large garden. Over time erosion problems started to occur where the curb ended. The steep grade on the street resulted in water flowing at a high velocity. The abrupt end to the integral curb allowed a concentrated flow of runoff to enter the garden at a single point and caused erosion. This was an error in the design and was another lesson learned by the city.

In other areas, the boulevards were quite steep due to house pads elevated higher than the street. In these areas it was very difficult to construct a swale or garden lower than the street. Integral bituminous curb was constructed to contain runoff in the street for short segments where steep boulevards existed. Once the boulevard grades flattened out, it became feasible to end the integral curb and allow runoff to flow off of the street and into a swale or garden. It should be noted that gardens were constructed for residents who requested them regardless of the type of curb that was constructed in the street.

In this project area, a large public rainwater garden was constructed in a residential backyard area. Since Maplewood is mostly developed, it can be difficult to find public parcels that are available for ponding purposes, as was the case in this project. An easement was obtained from residents in the project area to construct a large rainwater garden on their property. This rainwater garden stores and treats runoff from a small drainage area on Ferndale Street. The garden is maintained and cared for by the city.

3.2.3 Bartelmy Acres

The city reconstructed streets in the Bartelmy Acres neighborhood in 2000. The project length was approximately 0.5 miles. The streets in this neighborhood are flat. A fair portion of the streets had less than 0.5 percent grade. The rainwater garden and street design mimicked the design used in the Harvester Project. Residents were offered rainwater gardens. Swales were constructed in the boulevards where residents opted against the gardens. In this project a majority of the residential rainwater gardens were connected to the storm sewer system by an overflow drain. The difference in the storm sewer design occurred in the swaled areas. Drains were introduced at the bottom of the swales to eliminate the standing water and eliminate the potential of flooding nearby homes. Drains were located in the swaled areas between driveways. Additional drains were required in this neighborhood because a great number of homes sat lower than the street. Drains were needed to prevent water from overflowing into the resident's yards or homes since water could not overflow into the street. A detail of a swale with a drain is shown in **Figure 3**.

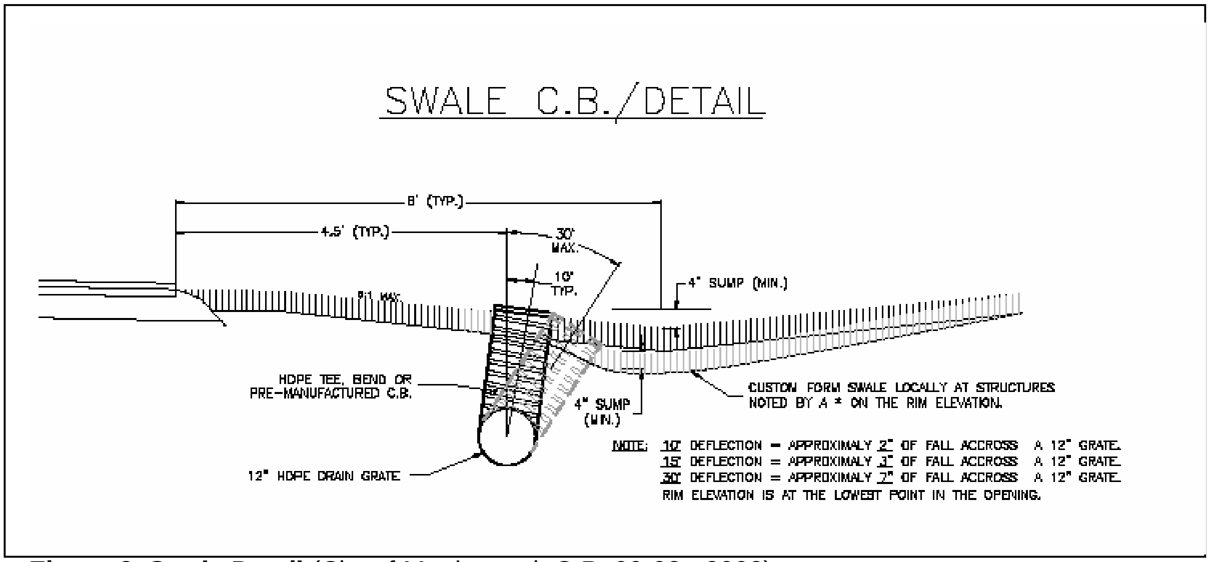


Figure 3. Swale Detail (City of Maplewood, C.P. 00-03 , 2002)

The storm system can be seen in **Figure 4**. The swales and gardens are shown connected to the storm system.

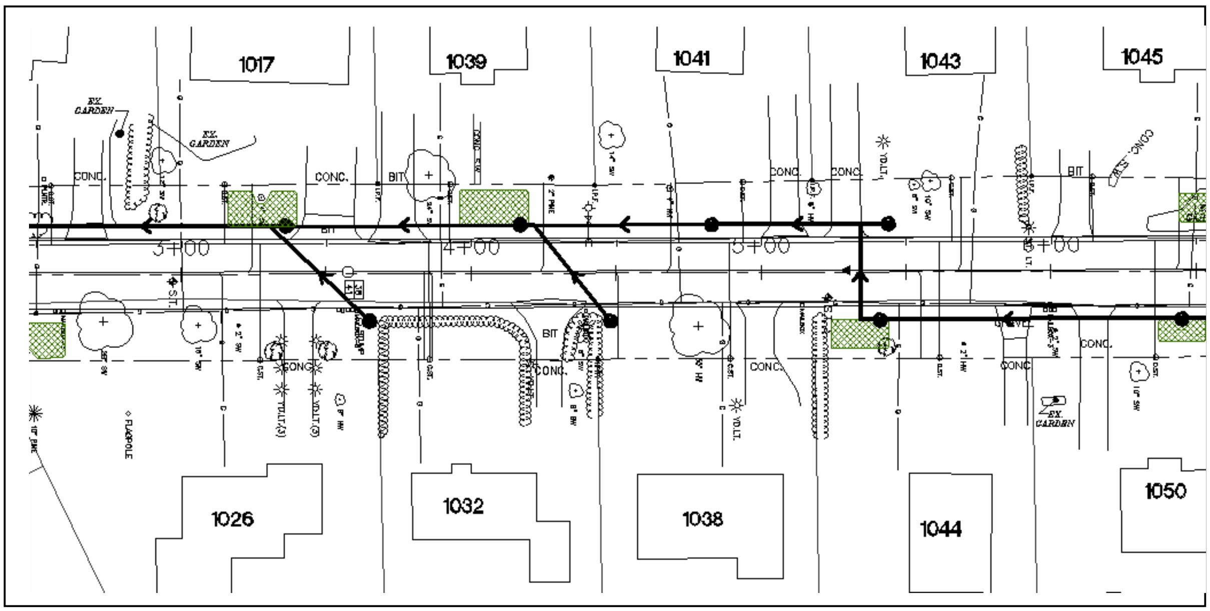


Figure 4. Plan view (City of Maplewood, C.P. 99-13, 2000)

The fact that the homes were lower than the street created some unique challenges during the design process. The city had initially considered lowering the street to create positive drainage in the driveways or at the very least allow a bump to be constructed in the driveway to contain the runoff in the street. The water main under the streets in this neighborhood was shallow and lowering the street even by one half foot may have created freezing problems in the main. To obtain additional ground coverage over the water main, the elevation of the street was raised. This in turn caused problems with the existing driveways since many of them were very flat or had negative grades. To overcome this problem the city created slight dips in the driveway to trap runoff. A slight cross slope was constructed to direct water off of the driveway and into the gardens or swales. A cross section of the driveways is shown in **Figure 5**. While this dip functioned in the warmer months, it created problems in the winter months. When residents would snow plow or shovel their driveways, dams would be created and the runoff would pond and freeze in the dip. This is a continuing problem in the spring during snowmelt.

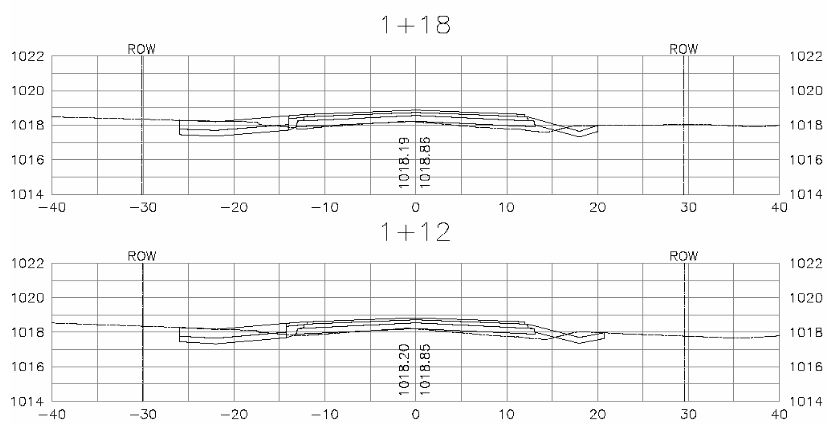


Figure 5. Cross Sections

3.2.4 GLADSTONE WEST

The Gladstone West neighborhood was reconstructed in 2001. This project was slightly less than two miles in length. The neighborhood is located just east of Lake Phalen. Many of the streets in the neighborhood had a considerable grade. For this reason, many of the streets were constructed with a bituminous curb. Runoff on these streets was not allowed to sheet off the road and into a garden or swale; instead runoff flowed directly into the storm sewer system via catch basins and into Lake Phalen.

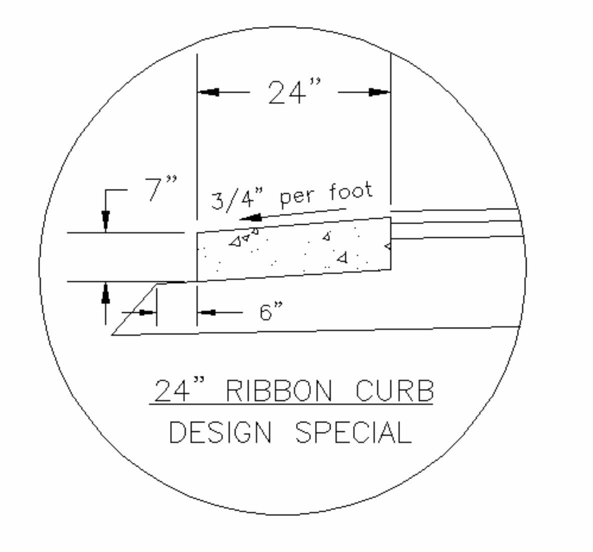
Some street sections in the neighborhood were flat and did utilize a street section without curb. Rain gardens or swales were constructed in the boulevard to treat runoff from this street. Several larger public rainwater gardens were constructed to treat flow from the storm sewer system. Of the 163 homes in the entire project area, 60 homes were located on a street section without curb. Rainwater gardens were offered to residents in these street sections. Twenty-three homes opted for rainwater gardens.

The residents on this project were given the option of the concrete versus bituminous curb. The residents wanted a rural street section, and bituminous curb was constructed on streets where runoff needed to be contained in the street. Otherwise no curb was constructed. The residents were very concerned with the street section on this project and were adamantly opposed to concrete curb. They did not seem as concerned with the incorporation of gardens and swales into their boulevards to treat water. This seems to be a key factor in the acceptance of swales and rainwater gardens by residents. Residents associate concrete curb with an urban setting and connect swales or ditches with a rural setting. Residents seem willing to accept runoff from the street when concrete curb is not constructed. Concrete curb was constructed in the Gladstone South neighborhood and is presented in the next section. Gladstone South incorporated the use of swales, rain gardens and ribbon curb to manage storm water.

3.2.5 GLADSTONE SOUTH

In 2002 the city reconstructed approximately 2.7 miles of street in the Gladstone South neighborhood. Again, rainwater gardens were incorporated into the storm sewer system. The streets in this neighborhood were mostly flat. Wakefield Lake is located directly adjacent to this neighborhood. Discharge from a 60" pipe is directed into Wakefield Lake. The residents in this neighborhood had noted that over time sediment accumulated in the lake. Residents were concerned with the water quality in Wakefield Lake.

This neighborhood was an ideal candidate for rainwater gardens. The majority of the streets in this neighborhood were constructed to allow runoff to sheet off the street. All of the streets in this neighborhood were designed with a concrete curb. A ribbon curb was used on most of the streets to allow water to sheet off. The ribbon curb is approximately 2 feet wide, 7 inches thick with a 3% cross slope. In the few areas that were not suited for a swale or garden, a D412 curb was used. A detail of ribbon curb and D412 curb is shown in **Figure 6**.



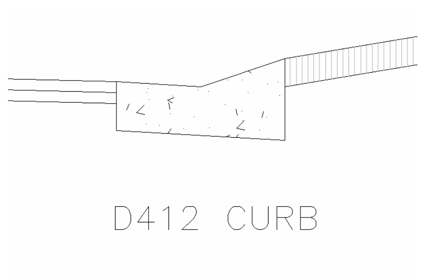


Figure 6. Ribbon Curb Detail on the left and D412 curb on the right

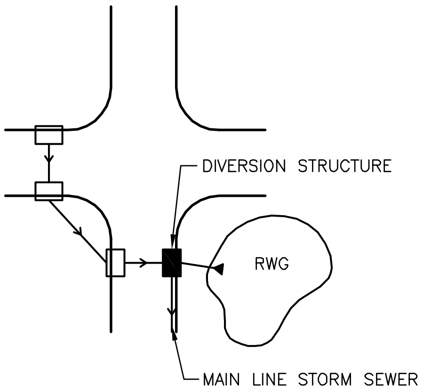
(City of Maplewood, C.P. 00-03 , 2002)

Designing streets and storm sewer systems for this type of project was more challenging than design of streets that use conventional curb and gutter. As with previous projects, drains were not placed in every single rainwater garden or swale, rather they were placed in every other garden or swale. It was important to ensure that an overflow route directed runoff to the street and not towards a resident's yard or home. It was also important to take into consideration the rate and volume of runoff flowing in the street where D412 curb changed to ribbon curb. The amount of runoff flowing in the gutter of the D412 curb discharged at the ribbon curb transition point. This sometimes resulted in erosion of the boulevard and rainwater gardens due a concentrated flow of runoff.

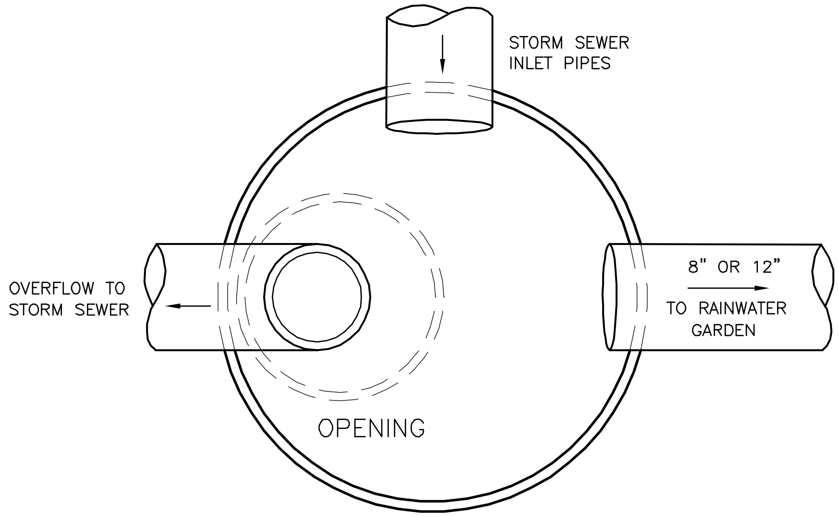
Of the 250 homes in the neighborhood, 127 rainwater gardens were constructed in addition to the 3 large public gardens that were constructed. The storm sewer was sized using the rational method. A lower runoff coefficient was used in drainage areas utilizing ribbon curb, swales and rainwater gardens. A lower runoff coefficient takes into account the infiltration that is occurring in the gardens and the volume of water captured in gardens. The individual rain gardens are not micro designed to hold a certain storm event, rather they are designed to hold a small volume of water and overtop into the storm sewer system. The large public rainwater gardens are designed to store and infiltrate a 1.5” rainfall event. Any additional runoff from the large gardens overflows into the storm sewer system.

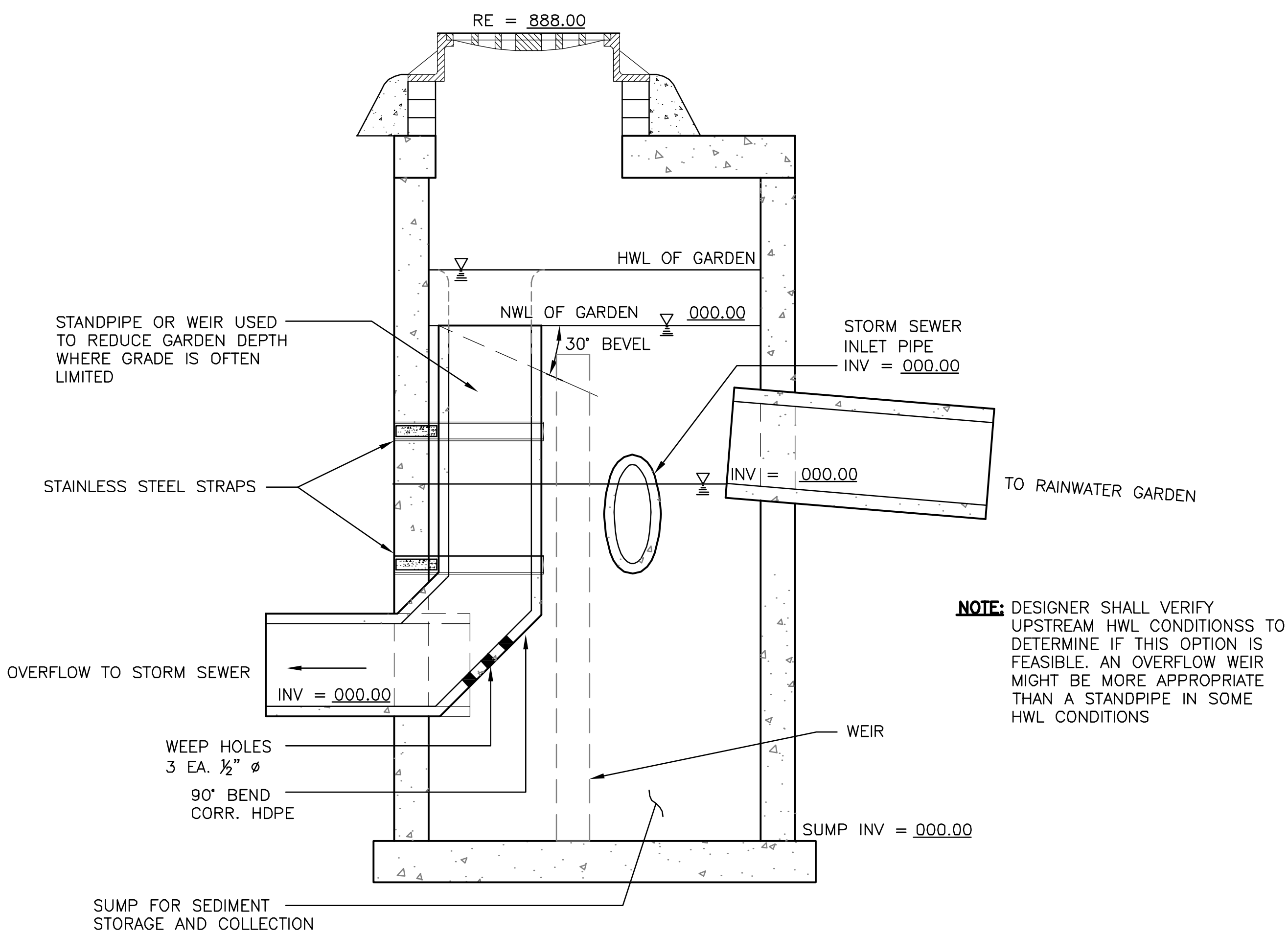
To prevent flow-through in large gardens, a first flush outlet was used and this is shown in **Figure 7** on the next page.

EXAMPLE:



PLAN OF TOP SLAB





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REVISIONS	

CITY OF MAPLEWOOD-ENGINEERING DEPT.

FIRST FLUSH/LOW FLOW RATE DIVERSION STRUCTURE

PLATE NO. S2

This outlet system utilized two outlet pipes; the inlet pipe elevation is the lowest and allows runoff to flow to the garden. The outlet pipe elevation is higher than the inlet and controls the water elevation in the pond. The outlet pipe is connected to a downstream storm sewer system. The purpose of this outlet is to allow water to flow into the garden during small rainfall events. When the water reaches a certain elevation, flow bypasses the inlet pipe to the garden and continues down the storm sewer system. The advantage to this design is that water does not flow through the garden and disrupt the settlement of sediment.

Often times it is difficult to obtain proper cover over pipes when a garden utilizes the first flush outlet system. This problem may be overcome by installing a standpipe or weir in the outlet manhole. This allows the garden to function as a first flush system even when ground cover is at a minimum.

Of all the projects where the city has utilized rainwater gardens, Gladstone South was of the largest scale. In retrospect this project utilized best management practices to the fullest regarding the street and storm sewer design. The majority of the neighborhood had either a rainwater garden or swale in the boulevard. While the actual design of the storm sewer system was challenging, the most difficult part of the project was dealing with residents in the project. The city is very involved with residents within neighborhood project areas. The city hosts two neighborhood meetings prior to any design work occurring for the project. During these neighborhood meetings, the purpose and function of rainwater gardens, swales and ribbon curb are thoroughly covered. After design is completed, prior to construction, the city hosts an open house where residents may come to review the design plans. Again, rainwater gardens, swales and ribbon curb are discussed. Even though the city gives every opportunity to its residents to learn about the project, many do not attend the meetings. To overcome this, the city mails considerable literature regarding rainwater gardens. Despite all these efforts, some residents are surprised by the street section that is being built in front of their home.

One of the most common and frustrating problems the city has encountered is complaints from residents who do not want to see ribbon curb and swales constructed in front of their home. Once the curb is constructed, residents become aware that runoff will be sheeting off of the street into the boulevard. One resident even went as far as to pay the city to remove the new ribbon curb and install D412 curb. Most residents are not willing to go that far to have the design changed once it has been constructed.

Quite often residents do not make any distinction between their property and the city's right of way. After swales have been constructed and the first rain has occurred, some residents call complaining of standing water in their yard. They are unwilling to accept a small amount of standing water. The standing water rarely lasts for more than 48 hours before it infiltrates or evaporates. None the less, residents do not approve of water flowing into their property from the street. The city often uses the example that water must flow somewhere and if every resident's yard can absorb a small portion of runoff and provide treatment, then water flowing out of the neighborhood and into a nearby lake is much cleaner than if a conventional curb and gutter system had been installed.

Sometimes residents do have a legitimate complaint that water stands in swales too long. This can happen when there are poor soils in the area. To fix this problem, the city has installed rock sump in the swales to improve infiltration. Once this has been done, residents seem to be satisfied with the improved infiltration.

3.2.6 KENNARD/FROST AREA STREETS

In 2003 the city reconstructed the Kennard/Frost neighborhood, comprised of 2.5 miles of streets. This neighborhood consisted of 250 small lots. The lots were densely compacted in the neighborhood. The topography of the area was very hilly with street grades ranging from 5 to 8%. This neighborhood was not an ideal candidate for the type of design used in the Gladstone South neighborhood which utilized ribbon curb and swales.

The street design in this neighborhood consisted of barrier curb to contain runoff in the street and direct it into the storm sewer system via catch basins. The street grades in this neighborhood were too steep to direct runoff off the street and into the boulevard. Erosion problems would have occurred if water were to run down an 8% slope in a grassy area.

Rainwater gardens were constructed throughout the neighborhood but did not receive the volume of water as they had in past from street runoff. Rainwater gardens were offered to residents on a voluntary basis. The residential rainwater gardens mainly captured runoff from roofs, driveways and yards. Even though the gardens were not treating runoff from the street, they were still effective at treating the runoff from residential yards.

The storm sewer designed for this neighborhood was a conventional storm sewer system utilizing catch basins for pick ups. Rainwater gardens constructed in the boulevards did not tie into the storm sewer system because they were not receiving runoff from the streets and were not at risk to overflow.

The soil under a majority of the streets in this neighborhood consisted of clay and was not conducive to infiltration. Rock sumps were constructed in all of the residential rainwater gardens. Since the gardens were not receiving much runoff, they did infiltrate the small amount of runoff received due to the rock sumps.

One large rainwater garden was constructed in the project area and treated a drainage area of approximately 20 acres. The garden is approximately 775 square yards. The soils where the rainwater garden was constructed were poor clay type soils and were not conducive to infiltration. The standard rainwater garden design was altered to effectively infiltrate and treat runoff that was directed into the garden. Two infiltration trenches were constructed beneath the bottom of the garden. The infiltration trenches consisted of a 2 by 2 foot trench lined with geotextile fabric and filled with 1.5 inches of clean river rock. In the center of the trench, 6 inch perforated drain tile was installed. A detail of the pond is shown below. The pond was constructed over an existing 42” storm sewer pipe as shown in the detail. The drain tile was connected to a downstream storm sewer system. The pond functions well and infiltrates water within 48 hours. A detail of under drain is shown in **Figure 8**. The outlet to the pond was designed as a first flush outlet. This is the same type of outlet constructed in the Gladstone South neighborhood.

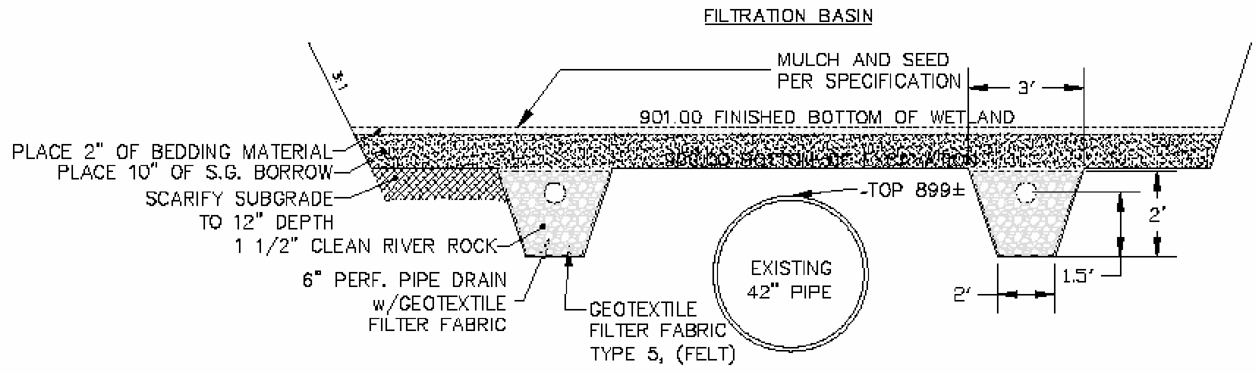

Figure 7. Rainwater Garden Under Drain (City of Maplewood, C.P. 02-10, 2003)

3.3 SUMMARY

Rainwater gardens constructed in the city have evolved over the past eight years. Garden design has been improved after problems with initial garden designs were realized. The design is an important part of how the garden functions. It is also important to realize that the type of vegetation planted in the garden affects the aesthetics and function of the garden. Vegetation in the rainwater gardens is explored in the next chapter.

CHAPTER 4: VEGETATION IN RAINWATER GARDENS

4.1 OBJECTIVE

It is important to understand the type of vegetation suited for rainwater gardens. The garden will be underwater for periods of time but may be dry if drought conditions occur. The aesthetics and function of rainwater gardens is dependent on the type of vegetation planted in the garden and is briefly explored in this chapter.

4.2 OUTCOMES

Vegetation used in the rainwater gardens is divided into two categories, the upland zone and the wetland zone (Figure 8). The upland zone is for the area above the normal water level of the garden or the area of the garden above the outlet. The upland zone utilizes prairie and woodland plants. The prairie plants are an effective resource for infiltrating water in the garden. Their roots establish deeply and soak up a lot of water from the garden (Gaynor, 2004). Deep rooted plants are essential to help keep the soils open and allow for infiltration. Examples of plants appropriate for the upland condition are August Lily Hosta, daylilies, and Johnson's Blue Geranium.

The wet zone is the area below the normal water level. This is the area of the garden that will be inundated with water from time to time and utilizes wetland plants. Examples of wetland plants used in the gardens are flowers, ferns, shrubs, sedges, and grasses. Plants in the wet zone must be able to adapt to both wet and dry conditions (Gaynor, 2004). Examples of wetland plants include Marsh Milkweed, Blue Flag Iris, Great Blue Lobelia and the Ostrich Fern.

Figure 8. Rainwater Garden Planting Zones

The city offers homeowners a choice of 7 different types of gardens. The different garden types are Minnesota Prairie, Easy Shrub, Sunny Border, Sunny Garden, Butterflies and Friends, Easy Day Lily and Shady Garden. In conjunction with the engineering consulting firm Bonestroo Rosene Anderlik and Associates, the city has pamphlets for each type of garden. These pamphlets provide a garden layout design along with maintenance tips for the specific type of garden. All seven different garden pamphlets are included in the Appendix A.

4.3 SUMMARY

The type of vegetation used in rainwater gardens will enhance the aesthetic characteristics of the garden and improve the infiltration capabilities of the garden if planned properly. It is important to have a general understanding of the types of plants suited for rainwater gardens to ensure their success.

Rainwater gardens can be a very attractive element in a neighborhood. Despite their attractive appearance, the public often is very opinionated regarding the incorporation of gardens and swales into their neighborhood storm sewer system. The public’s perception of rainwater gardens is further explored in Chapter 5.

CHAPTER 5: PUBLIC PERCEPTION

5.1 OBJECTIVE

The public's perception regarding rainwater gardens in their boulevards is important to understand when promoting the use of gardens within an existing neighborhood. This chapter identifies the public's reaction to the incorporation of rainwater gardens and also discusses the problems they associate with rainwater gardens, such as West Nile Virus.

5.2 METHODS

To better understand the public's perception of rainwater gardens, a focus group was interviewed by the Wisconsin Department of Natural Resources. The findings of the interviews are reported. The public also has many misconceptions about rainwater gardens and these issues are discussed. West Nile Virus is often a topic associated with ponding water. Facts about West Nile Virus are discussed.

5.3 RESIDENTIAL GARDENS

Even the best street and boulevard designs with regard to water treatment often result in confused and frustrated residents. Many residents do not understand the importance of treating runoff and how rainwater gardens and swales accomplish this. Communication with the public is very important and helps to convey the importance of water treatment and the utilization of rainwater gardens. It is very difficult to reach every single resident within a project. This creates a problem for the uninformed resident and eventually creates problems for the city.

In May of 2002 the Wisconsin Department of Natural Resources investigated two focus groups in the City of Maplewood. The purpose of these focus groups was to allow the Wisconsin DNR to research how homeowners respond to rainwater gardens in their boulevards. The Wisconsin DNR chose the City of Maplewood for this investigation due to the fact that no comparable groups existed in Wisconsin. The Wisconsin DNR interviewed residents from past neighborhoods where rainwater gardens were incorporated in reconstruction projects. One focus group was comprised of homeowners who opted for rainwater gardens, and the second group was made up of residents who did not choose to have a rainwater garden.

The report discussed what type of resident would opt for a garden and discovered that three factors influence whether or not residents would choose a garden: age, attitudes towards gardens and experience with water problems. It is important to note that residents with past water problems were more apt to choose a rainwater garden to try to minimize or eliminate their problem.

Another topic that was explored was the indication that accepting a rainwater garden would help eliminate standing water in other neighbors' property. The focus group review by the Wisconsin DNR reported:

"*Those without water problems indicated being unaware of how water leaving their property affected others. In short, a neighborly spirit-even if present- is of little effect unless residents understand how their decisions have consequences for their neighbor*."

In old, unimproved residential neighborhoods, water often migrates across streets and through private property. The lack of crown on the road and lack of adequate drainage systems in old neighborhoods often creates problems for some unlucky homeowners. Upstream residents who do not experience water problems often do not understand that runoff from their property is creating a problem for a downstream resident. It is important that homeowners understand that a small amount of ponding water on their property results in improved drainage and water quality downstream (City of Maplewood, Focus Review Group of Rainwater Gardens, 2004).

The swales that are constructed in the boulevards of homeowners who did not opt for a rainwater garden are often viewed as nuisances since the water is not contained in a garden or does not infiltrate as fast as a garden. Another quote from the Wisconsin DNR study stated,

"These ditches are apparently not draining as well as the rainwater gardens; only the non-gardeners complained of standing water as a problem persisting even after the project was complete."

Rainwater gardens serve a dual purpose: they treat runoff and create continuity and a sense of unity throughout the neighborhoods. The city does receive complaints about gardens that are not maintained. The city does not try to convince residents to opt for a rainwater garden if the resident does not plan to maintain the garden. Unkempt gardens create eyesores in the neighborhood. Gardens that are maintained and cared for are aesthetically pleasing.

One question the city often answers is what happens to the rainwater gardens once the homeowner who opted for the garden moves. The rainwater gardens are essentially owned by the homeowner, even though they are constructed on city property. The rainwater garden should be treated like any other garden within private property. Rainwater gardens that are properly cared for tend to be a selling point rather than a detriment to prospective home owners.

5.4 WEST NILE VIRUS

One concern that residents have regarding the implementation of rainwater gardens in close proximity to their home is the danger of West Nile Virus. Residents are concerned that the standing water in the rainwater gardens will attract mosquitoes and therefore increase their chances of contracting West Nile Virus. In July of 2003, the Ramsey Washington Metro Watershed District (RWMWD) published an article discussing West Nile Virus and stormwater management.

Mosquitoes are dependent on standing water to breed. "*Mosquitoes start out as an egg laid by females in standing water. In water, this egg then develops into several larval and pupal stages before emerging as an adult mosquito. They can go from egg to adult in 7-14 days. Most adult mosquitoes live for only a few weeks. However, some mosquitoes can overwinter (several months) in an adult stage."* (City of Charlotte, 2004) Rainwater gardens are designed to hold water for less than 48 hours. If the gardens are constructed properly, they will not hold water for longer than 48 hours and will not become mosquito breeding grounds.

Rainwater gardens are not mosquito breeding grounds. "*According to current research, ideal water conditions for mosquito development are found at the edges of semi-permanent wetlands or in wet meadows. These ideal environments consist of very shallow water conditions (1"-24"), thick vegetative cover, high levels of organic debris and fluctuating water levels, most of which contribute to bacterial growth through rotting vegetation. This bacteria acts as an important food source for the mosquito larvae."* (Ramsey Washington Metro Watershed District, 2004). If gardens are properly maintained and maintain their infiltration capabilities, they do not provide a desirable habitat for mosquitoes.

In the summertime residents in Minnesota experience outdoor conditions where they encounter many mosquitoes. The RMWD reports "*Out of some 2500 or more different mosquito species worldwide, approximately 50 can be found locally and only a few species are suspected as potential carriers of WNV, with research focusing on one primary carrier. It is believed that the two most* *common Minnesota mosquitoes, the vexans mosquito and common cattail mosquito, are not effective transmitters of WNV. The targeted Culex spp. of mosquitoes compose a very small percentage of the local population. They are a primary suspect because of their feeding preferences and ability to carry similar encephalitis diseases. Research indicates that less than 1% of all mosquitoes actually carry the WNV."* (Ramsey Washington Metro Watershed District, 2004). The chances of being bit by a mosquito with West Nile virus are slim and of all people bit by an infected mosquito, less than 1% of those people become seriously ill. (Ramsey Washington Metro Watershed District, 2004).

5.5 SUMMARY

Residents often have concerns about the implementation of rainwater gardens near their homes. They are most concerned with the standing water associated with gardens, the look of the gardens, whether or not they are maintained and West Nile Virus. If residents are educated about the facts of rainwater gardens they can make an educated decision about rainwater gardens.

The maintenance aspect of rainwater gardens is very important to the health and function of the garden. There are several key maintenance activities that must take place to ensure a healthy garden. These maintenance activities are discussed in Chapter 6.

CHAPTER 6: MAINTENANCE

6.1 OBJECTIVE

Maintenance activities performed on an annual basis are essential for a healthy, vibrant garden. The function of gardens also depends on regular maintenance activities. Recommended maintenance activities are discussed.

6.2 METHODS

Ginny Gaynor, the city's naturalist, has outlined several key maintenance activities for rainwater gardens. These key activities are discussed. The city's storm sewer crew chief has encountered problems associated with the gardens. These problems are examined.

6.3 OUTCOMES

Rainwater garden maintenance is an ongoing, continuous process. It is recommended that in the first year the rainwater gardens are vegetated, that weeds be removed and also the plants receive an adequate amount of water. Ongoing maintenance for the life of the garden includes replenishing the mulch in the garden every year for the first few years. The gardens must receive rain to keep the plants alive. If a severe drought does occur, it is recommended to water the gardens during these periods. The dead material should be cut back every spring or fall to maintain a healthy and vibrant looking garden. To prevent overgrowth in the garden, the plants should be split or divided every 4 to 5 years (Gaynor, 2004).

Since the gardens are designed to take runoff directly off the street, it is important to know how much sediment is accumulating in the garden. This has not presented a problem for Maplewood. The main sediment washing into the gardens is sand, which allows for infiltration. Also, the vegetation in the gardens keeps the soils open and maintains the infiltration capabilities of the garden. The problem that may result is the volume of the garden is reduced by additional sediment accumulating in the garden. Any significant sediment build up should be removed to maintain storage capabilities of gardens.

To minimize sediment deposits in large rainwater gardens, a sump is constructed in the last downstream manhole prior to the garden. This sump allows sediment to deposit in the manhole prior to discharging into the gardens. The sump manholes must be cleaned on a regular basis to perform properly. Figure 6 on page 27 illustrates the sump designed into the manhole.

The city constructs gardens approximately 4 to 5 feet behind the edge of curb to provide a buffer zone. The buffer zone minimizes the sand and salt that washes into the garden. Sand accumulation and salt kill have not been a problem in the city's gardens due to the buffer that is allowed for.

On residential street projects, the city must resolve any problems residents may have with their gardens. Erick Oswald, the city's storm sewer crew chief, stated several problems he has encountered with gardens. The wood chips used in the bottom of the gardens plug the weep holes that are constructed in the larger garden outlets (see Figure 7.) This can become a headache requiring ongoing maintenance to unplug the weep holes. Erosion becomes a maintenance problem when there are areas of concentrated flow going into the gardens. This occurs when the barrier style curb transitions to the ribbon curb. These areas are prone to washouts and must be stabilized with an erosion control blanket. The last maintenance concern is gardens that do not infiltrate due to compacted soils. These gardens require the maintenance department to auger holes and re-scarify the garden bottom to allow water to infiltrate into the ground (Oswald, 2004).

6.4 SUMMARY

Maintaining rainwater gardens is critical to the longevity and attractiveness of the gardens. Vegetation in the gardens requires a lot of maintenance to ensure the garden is not overrun with weeds. The garden plants are a key component of infiltration characteristics and are essential to a healthy rainwater garden.

CHAPTER 7: DEVELOPERS & CONTRACTORS

7.1 OBJECTIVES

Developers are encouraged to implement best management practices such as rainwater gardens into their developments. Rainwater gardens are an excellent resource for developers. The implementation of rainwater gardens in new developments is increasing in Maplewood. The advantages and problems encountered by developers and contractors when gardens are implemented are discussed.

7.2 OUTCOMES

The City of Maplewood encourages developers to incorporate rainwater gardens into their storm system design. Developers often view the incorporation of rainwater gardens as an advantage to their developments. In Maplewood developers must meet certain criteria regarding storm water. The first criterion is that post development runoff rates must be equal to or less than pre development rates off site. Generally, developers design National Urban Runoff Program (NURP) ponds to remove sediments and pollutants and meet the city's storage and discharge requirements. The disadvantage to NURP ponds is they require a 10 foot safety bench and sometimes an additional 10 foot maintenance bench depending on the layout of the site. The benches take up a lot of space and may result in the loss of a sellable lot. When rainwater gardens are incorporated, it is possible for developers to regain a lot that may have been used for a NURP pond. The city requires developers using rainwater gardens to store and infiltrate a 2” rainfall event. Rainwater gardens may be constructed in boulevards and can also wind through common spaces or along trails. Rainwater gardens are much more versatile than a conventional NURP pond. An example of rainwater gardens incorporated into a new development is shown in **Figure 8**. For these reasons, developers often incorporate rainwater gardens into their design.

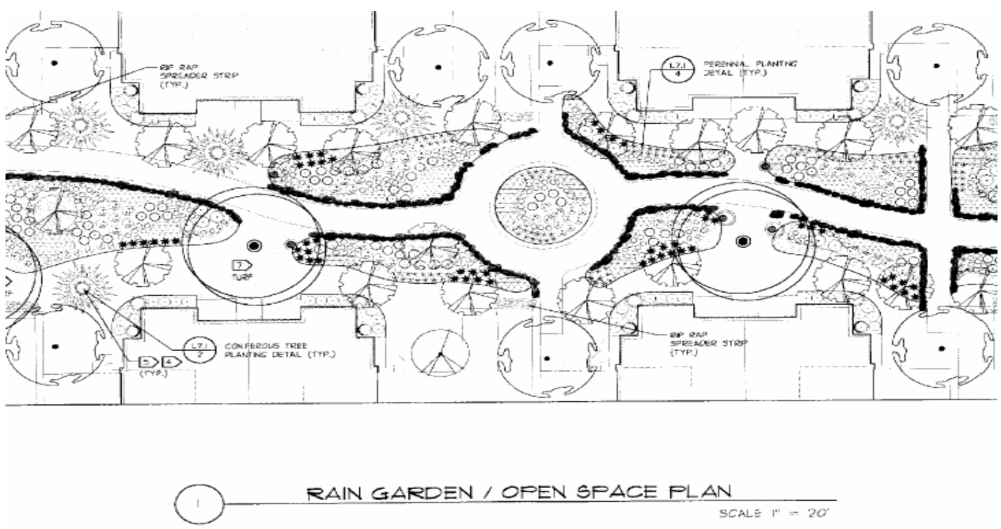

Figure 8. Rain gardens in new developments. (Cavett, 2004)

The disadvantage to developers using rainwater gardens in their site is that the gardens are more difficult to design and construct. The design of rainwater gardens is new for the developer. A development using gardens to treat runoff requires a micro design effort to ensure the city’s requirements are met. Instead of designing one large NURP pond, engineers are often designing several smaller rainwater gardens. This requires more time and effort.

Once developers do have an approved rainwater garden design, the next challenge is getting the contractor to construct them correctly. Even though gardens may be designed correctly, the city has struggled with contractors and the construction phase. The single biggest mistake that contractors make is compacting the soils. After the rock sump is constructed beneath the garden, any soil that is used to cover the rock sump or any of the virgin ground at the bottom of the garden must be scarified to help infiltrate water. Contractors may either fail to scarify the bottom, or, if they do, the scarified ground is re-compacted by equipment running through the gardens. Even having too many people walking through the gardens and compressing the soil with their feet can hinder the infiltration process. The city often requires a construction schedule from contractors that outlines the rainwater garden construction. It is very important that the gardens are one of the last items completed on site to avoid equipment running through the gardens and compacting the soils. If the soils are compacted during construction, the city may require the contractors to re-scarify the soils. This may become difficult if the gardens have been seeded and planted.

The city also requires developers to submit a detailed landscape plan for the rainwater gardens. It is essential that the gardens be vegetated with deep rooted plants to promote infiltration. The city must work closely with the developers to ensure that the landscape design is appropriate for the gardens.

7.3 SUMMARY

Rainwater gardens are an excellent way for developers to meet the requirements of the city and retain more sellable property. Developers along with their engineers and contractors must put more work upfront to produce a design that works on paper and functions in the field.

CHAPTER 8: CLOSING

8.1 SUMMARY OF METHODS

The evolution of the rainwater garden design has been discussed in detail by outlining the past six projects the city has constructed. Rainwater garden designs and outlets have been reviewed. Vegetation of the gardens has been discussed through information provided by the city's naturalist, Ginny Gaynor. Maintenance activities and problems associated with the gardens were reviewed. The incorporation of rainwater gardens into new developments, and advantages to using gardens, was explored. The problems encountered regarding the construction of the gardens by contractors were detailed.

8.2 MAIN FINDINGS

Rainwater gardens are a useful tool when designed and constructed properly. The gardens are versatile and may be adapted to poor soil conditions, varying topographies and space constraints. Rain garden design must be innovative. A "cookie cutter" approach should not be taken when designing rain gardens. Maplewood has experimented with the design of rain gardens. This has resulted in a successful, practical design for rainwater garden implementation in urban environments. The street design directly impacts the effectiveness of rain gardens and should be considered carefully for existing neighborhoods.

Rainwater gardens require ongoing maintenance to ensure they function properly and are aesthetically pleasing. Care must be taken during the design and construction process to ensure that erosion and compaction issues do not become an ongoing maintenance problem. Healthy vegetation is vital to the success of rainwater gardens.

Agencies must be committed to educating residents about the importance of water treatment and the function of rainwater gardens. Residents must be willing to take an active role in the maintenance and upkeep of the gardens if they are to be an attractive amenity in neighborhoods.   Public education is important to gain the support of the neighborhood where rainwater gardens projects are proposed. Facts about West Nile Virus should be presented to the public to respond to and ease resident concerns about the virus.

Native plants that withstand wet and dry conditions are best for rain gardens. The vegetation in the garden plays an important role in the infiltration process of the garden. Deep rooted native plants are ideal for rainwater gardens as they keep the soils open and soak up water from the basins. Care must be taken to ensure that the appropriate plants are put in the upland and wetland zones of the gardens.

Developers are implementing rainwater gardens into new developments. Developers, their engineers and city staff must all work together to ensure the successful implementation of rainwater gardens. Agencies should encourage the implementation of rainwater gardens in private developments to meet water treatment requirements. Agencies need to guide proper design and construction of the gardens when private entities are implementing them.

8.3 FURTHER WORK

Further work that needs to be completed regarding the use of rainwater gardens, in lieu of conventional treatment methods such as NURP ponds, is to gather information quantifying the pollutant and sediment load removals accomplished by rainwater gardens. The effect that rainwater gardens have on downstream water bodies also needs to be studied to determine how effective the gardens are at treating runoff.

8.4 RECOMMENDATIONS

It is recommended that other agencies wishing to incorporate rainwater gardens into their communities begin by adopting a rainwater garden design and retro fitting the design to their specific needs. The City of Maplewood's standard rainwater garden design may be used as a starting point. Requirements regarding the storage and infiltration characteristics of rain gardens should eventually be determined and a guideline established in agencies allowing the use of rain gardens. It will take time for engineers, landscape architects, developers and contractors to become comfortable with rain garden design and construction. The use of rain gardens in commercial and residential sites is growing as storm water treatment restrictions become tighter. Rain gardens are an excellent way to fulfill storm water treatment requirements.

It is recommended that Maplewood continue the use of rainwater gardens in all of their reconstruction projects and continue to encourage the use of rainwater gardens in new developments. The city does not currently have any requirements regarding the use of rainwater gardens or the use of best management practices in new developments. The city should incorporate requirements into their engineering guidelines detailing the use of rainwater gardens or other best management practices.

References

1. Cavett, Chris, Assistant City Engineer, Power Point Presentation, May 4, 2004.

2. City of Charlotte, Mecklenburg County, http://www.charmeck.org/Departments/Health+Department/Programs+and+Services/Environmental+Health/Pest+Management/Mosquito/mfaq.htm, November 08th, 2004.

3. City of Maplewood, "Engineering Standard Plates,." http:// www.ci.maplewood.mn.us, accessed November 20, 2004.

4. City of Maplewood, C.P. 00-03, Construction Plans, Sheet 11, April 8, 2002

5. City of Maplewood, C.P. 02-10, Construction Plans, Sheet 19, March 31, 2003

6. City of Maplewood, C.P. 99-13, Construction Plans, Sheet 11, April 24, 2000

7. City of Maplewood, "Focus Review Group of Rainwater Gardens," http:// www.ci.maplewood.mn.us, accessed November 20, 2004.

8. City of Maplewood, Project file 95-12, Folder 2, Letter from Joan Nassauer, October 6, 1995.

9. City of Maplewood, Project file 95-12, Folder 2, Letter from Ken Haider, November 5, 1997.

10. City of Maplewood, "Rainwater Gardens," http:// www.ci.maplewood.mn.us, accessed October 12th, 2004.

11. City of Maplewood, "Rainwater Garden Facts." http:// www.ci.maplewood.mn.us, accessed October 14th, 2004.

12. Gaynor, Ginny, City of Maplewood Naturalist, Landscape Wetland Plants Power Point, March 2004.

13. Las Pilitas, "Cornus stolonifera," http://www.laspilitas.com/plants/222.htm, accessed October 14, 2004.

14. Oswald, Erick, Interview with Storm Sewer Crew Chief, City of Maplewood, October 16th, 2004.

15. Priebe, Bill, Interview with Senior Engineering Technician, City of Maplewood, October 14, 2004.

16. Ramsey Washington Metro Watershed District, "West Nile Virus and Stormwater Management," www.rwmwd.org November 08, 2004

APPENDIX A

CITY OF MAPLEWOOD'S
7 RAINWATER GARDEN DESIGNS