Carver Lake Subwatershed Infiltration Study

Prepared for
Ramsey-Washington Metro Watershed District

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BARR

4700 West 77th Street
Minneapolis, MN 55435-4803
Phone: (952) 832-2600
Fax: (952) 832-2601

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Executive Summary

The purpose of the Carver Lake Subwatershed Infiltration Study was threefold:

- To identify an annual volume reduction goal for watershed areas tributary to Carver Lake.
- To identify specific infiltration BMP opportunities throughout the Carver Lake Subwatershed that would achieve phosphorus reduction in retrofit projects.
- To suggest potential infiltration opportunities in areas slated for redevelopment in the near future.

As a result of this study, an annual volume reduction goal of 0.56 acre-ft/year (24,293 cubic feet/year) is recommended. In order to meet the Ramsey Washington Metro Watershed District's (District's) water quality goals for Carver Lake and to meet the MPCA's TP criteria for lakes in the North Central Hardwood Forests Ecoregion within 20 years, a minimum of 0.56 acre-feet (24,293 cubic feet) of water quality volume reduction should be implemented each year in the areas tributary to Carver Lake.

Water quality volumes achieved through the implementation of the volume reduction rule in redeveloping areas and through the District's BMP Cost Share Program should be tracked on an annual basis. Where implementation of the volume reduction rule alone does not allow the District to meet the volume reduction goal, additional projects (such as the ones presented in this report) should be implemented.

Results of this study show that there are some good opportunities for implementation of additional infiltration and other volume reduction BMPs in the Carver Lake Subwatershed. In particular, it is recommended that the District pursue projects that have been grouped into specific neighborhood areas where focused education and volume reduction initiatives can be launched on an as-needed basis.

The types of infiltration and volume reduction BMPs presented in this study are:

- Impervious surface reduction
- Infiltration basins
- Biofiltration basins
- Boulevard bump-outs with infiltration and biofiltration basins
- Permeable pavement
- Tree planting

1.0 Introduction

1.1 Purpose

Carver Lake is currently listed on the Minnesota Pollution Control Agency's (MPCA's) 2008 Draft 303(d) Impaired Waters List for excessive nutrients. Table 1 shows the lake's past water quality in comparison to the MPCA's listing criteria for deep lakes. The District's current water quality goals for the lake are the same as the MPCA listing criteria for deep lakes.

Table 1: Carver Lake's historical water quality in comparison to the MPCA's Impaired Waters Listing criteria for water quality parameters

Water Quality Parameter	MPCA's Deep Lake Standard and RWMWD Goal for the Lake	1977 to 2006 Growing Season (June through September) Average	1997 to 2006 Growing Season (June through September) Average
Total Phosphorus	40 μg/L	54 μg/L	58 μg/L
Secchi Disk	1.2 m (3.9 ft)	1.5 m (5.0 ft)	1.6 m (5.4 ft)
Chlorophyll *a*	15 μg/L	20.0 μg/L	13.7 μg/L

As shown in Table 1, reduction of the lake's growing season phosphorus concentration is warranted.

The purpose of the Carver Lake Subwatershed Infiltration Study was threefold:

1. To identify an annual volume reduction goal, in terms of cubic feet of water quality volume, in the Carver Lake Subwatershed that, if achieved, can be expected to improve the water quality in Carver Lake to meet a 40 μg/L growing season average (June through September) within 20 years.
2. To identify specific infiltration opportunities throughout the Carver Lake Subwatershed that would achieve phosphorus reduction in retrofit projects. These projects would offer additional infiltration when implementation of the volume reduction rule (Rule C, Number 3(c), RWMWD Rules, 2006) is not enough to meet the annual volume reduction goal. Projects that are not associated with redevelopment will be limited, as implementation will be limited by existing structures, etc. It is the intent of this report to recommend the types of retrofit infiltration projects that will likely be most effective in these areas. It is important to note that not all of the projects mentioned here would have to be implemented to meet the water quality goal for the lake. Rather, this report contains a number of options from which the District or others can choose as needed when implementation of the volume reduction rule is not enough to meet the annual volume reduction goal.

3. To suggest potential infiltration opportunities in areas slated for redevelopment in the near future (road reconstruction projects are currently the only areas with scheduled plans for reconstruction). It is important to note that in future redeveloping areas that are subject to the District's volume reduction rule slated for redevelopment, there may be other types of infiltration projects that would be better suited to the site, depending on what type of redevelopment is planned. In these areas, developers will likely have a number of infiltration/filtration options available to them. However, this report does provide ideas for the types of infiltration projects that may be well-suited to these sites, given existing soil and land use conditions.

The extent of the Carver Lake Subwatershed boundary is shown in Figure 1.

1.2 Background

1.2.1 Carver Lake Strategic Lake Management Plan (SLMP)

In 2000, the District completed a Strategic Lake Management Plan (SLMP) for Carver Lake. The SLMP concluded that a significant portion of soluble phosphorus must be removed from stormwater runoff in order to improve Carver Lake water quality.

1.2.2 Supplemental Infiltration Modeling Study

Shortly after the SLMP was completed, a supplemental study was conducted to evaluate how implementation of infiltration practices in the Carver Lake watershed would influence the in-lake water quality, under ultimate land use conditions. The results of this study indicated that infiltration practices designed to capture the first 0.25 inches of runoff from the directly connected impervious areas in the Carver Lake Subwatershed would greatly improve the water quality of Carver Lake. A memo dated October, 2000 describes this study and its results in detail, and is included in Appendix A of this report. Figure 2 shows the predicted (modeled) summer average phosphorus concentrations in Carver Lake, resulting from a range of management scenarios, including infiltration (shown in Figure 2 as Scenarios 6 and 7). It should be noted that the recommendation from the study assumed that the 0.25 inches of infiltration would be implemented evenly over the entire Subwatershed.

1.2.3 Exploring Retro-fit Opportunities in the Carver Lake South Subwatershed- 2003 Study

Based on the results of the supplemental infiltration study, the District decided to explore the feasibility of implementing retro-fit infiltration practices throughout the Carver Lake South Subwatershed in order to meet the lake's water quality goals. In 2003, a feasibility study was conducted to identify several specific sites that were suitable for installation of stormwater infiltration systems that could be installed and then monitored. Ultimately, the goal of installing

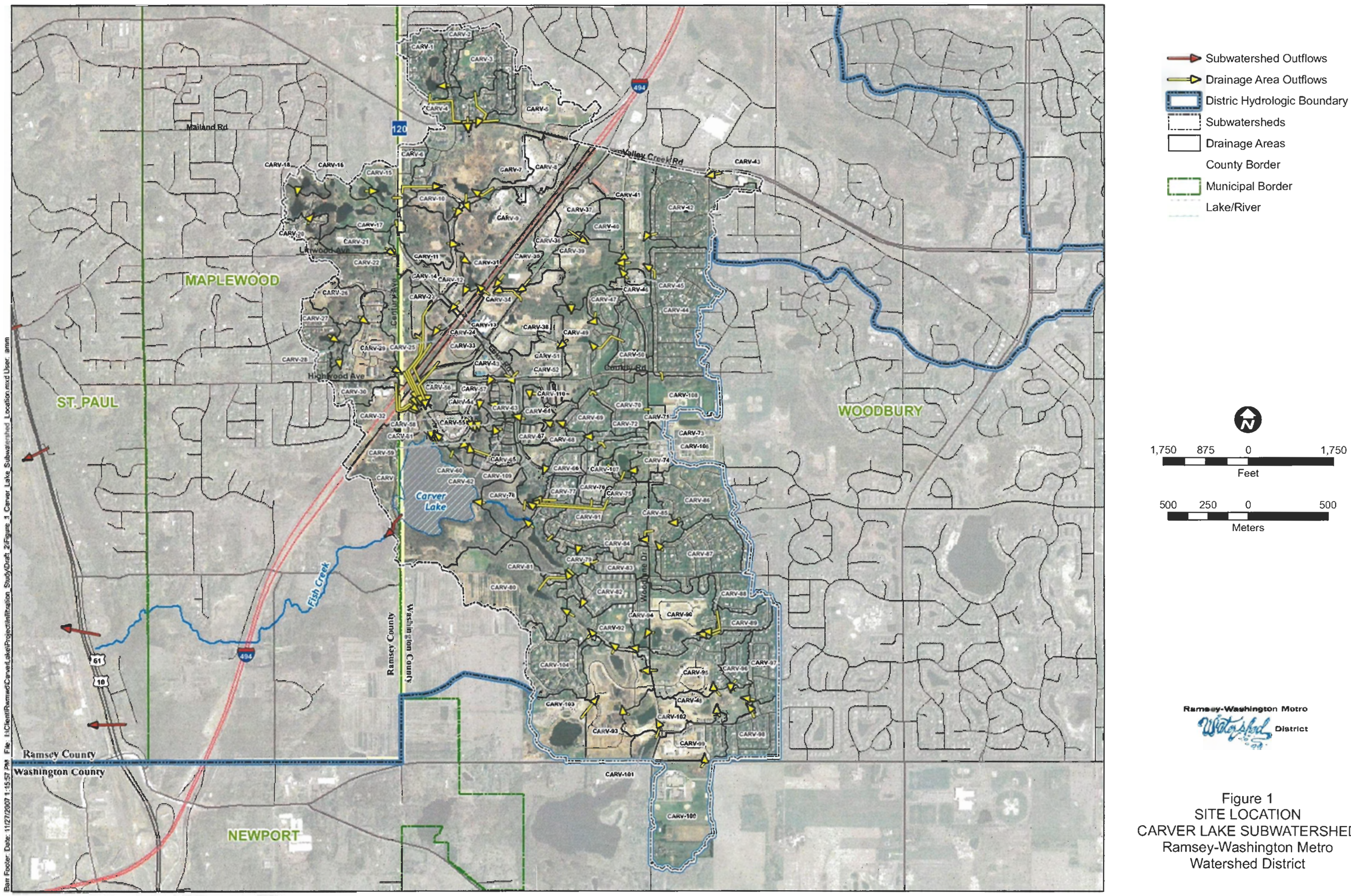
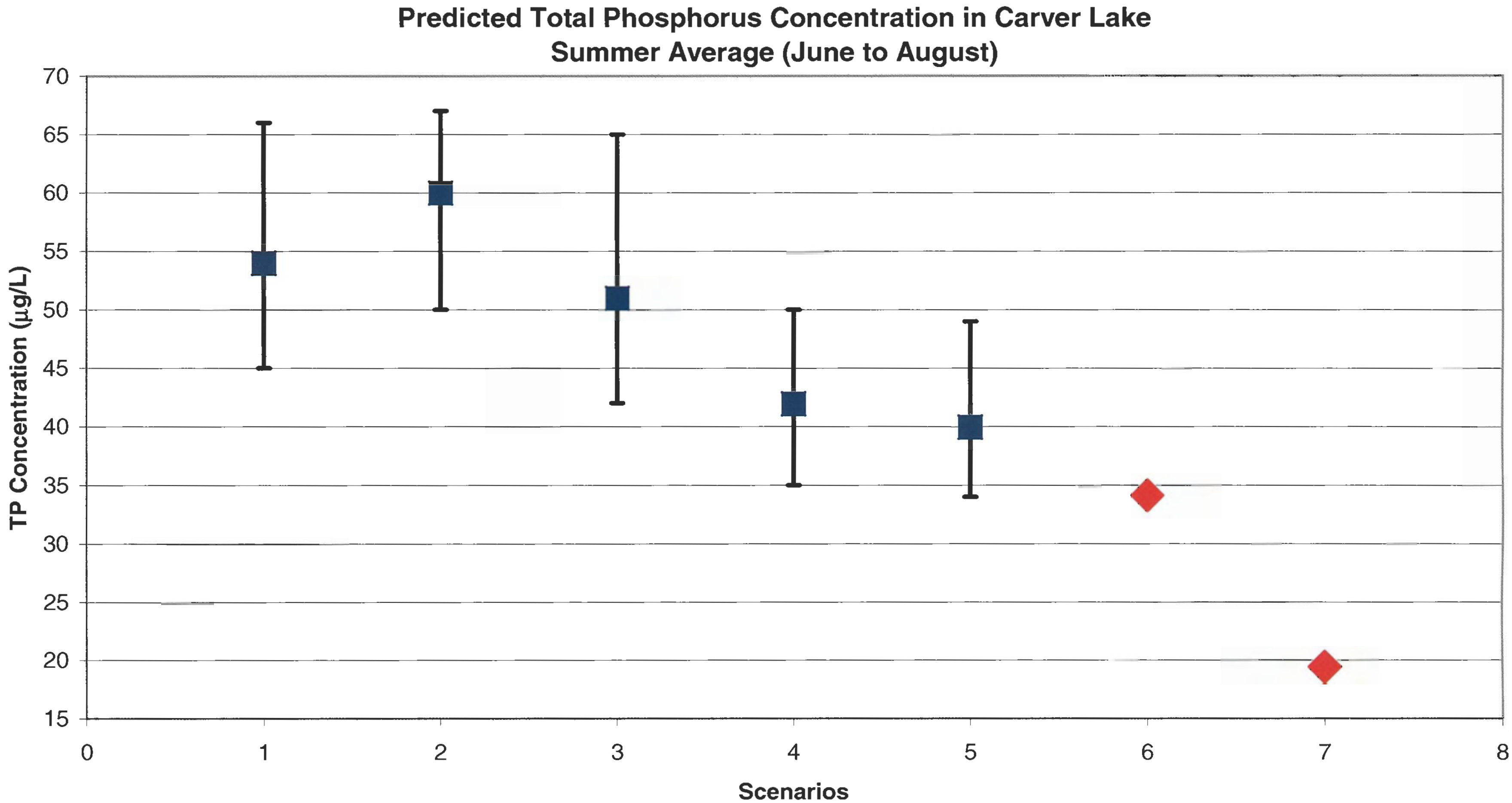


Figure 1
SITE LOCATION
CARVER LAKE SUBWATERSHED
Ramsey-Washington Metro
Watershed District

Figure 2



Note: The error bars indicate the range of possible TP concentrations predicted for each scenario, based on a range of climatic conditions (dry to wet).

The diamonds and square points between the bars represents the TP concentration predicted for the average climatic year.

Scenario 1: Existing land use conditions

Scenario 2: Ultimate land use conditions (with no control of increased loads due to newly developed areas in the watershed).

Scenario 3: Increased detention for the ponds in CARV-22 and CARV-60, mainenance for ponds CARV-78 and CARV-66.

Scenario 4: Alum treatment of flows in CARV-79

Scenario 5: Alum treatment of flows in CARV-79, increased detention for the ponds in CARV-22 and CARV-60.

Scenario 6: Infiltration Storage Volume Equivalent to 0.25" Over All Directly Connected Impervious Areas in the Watershed.

Scenario 7: Infiltration Storage Volume Equivalent to 0.50" Over All Directly Connected Impervious Areas in the Watershed.

these case study infiltration systems was to assess the feasibility of retrofitting the entire Carver Lake Subwatershed with stormwater infiltration systems to improve the water quality in Carver Lake.

The South Subwatershed was selected for the focus of the study. Initially, the focus was on locating sites that were suitable for infiltration basins, either on-lot basins, or rain gardens, or larger area infiltration basins. Initial site locations were chosen based on several physical criteria; the three most important physical considerations were as follows:

1. Average slope less than 5 to 6 percent—this was mostly an aesthetic consideration related to the requirement for deeper depressions and larger sized infiltration basins in areas with steeper slopes.
2. Sub-surficial soils with percolation rates of at least 9 inches/day.
3. Surficial soils with infiltration capacities of at least 5.5 inches/day.

Other physical criteria were also considered:

- The depth of the seasonal high water table and depth to bedrock.
- The distance of the basin from houses or important infrastructure features.
- The location of underground utilities or surface features that would be difficult or expensive to relocate.

In addition, only areas with less than 30% impervious area were thought to be suitable for aesthetically pleasing projects. Non-physical criteria were related to public acceptance and cooperative city or homeowners at locations where infiltration basins would be located.

Using GIS software, a soils map was superimposed on an aerial photo in order to identify areas with suitable soils characteristics. This map was used to facilitate a field investigation in which areas with suitable soil characteristics were visited to identify potential sites for infiltration basins.

The conclusion of the 2003 field investigation was that the South Subwatershed did not contain good sites for infiltration basins for the following reasons:

- The slope of the ground and streets within much of the area with suitable soil characteristics exceeded 5 percent to 6 percent.

- The vast majority of the area with suitable soil characteristics is developed with multiple-family residential neighborhoods with a high percentage of directly connected impervious areas.
- These multiple-family residential neighborhoods have small yards that would limit the area of infiltration basins.
- There is very limited open space area with suitable soil characteristics, elevations, and slopes within the Subwatershed.

Because the South Subwatershed was deemed unfavorable for infiltration basins, alternative storm water infiltration systems were recommended:

- Two trench infiltration systems which would be use to infiltrate large quantities of runoff under existing roadways.

- Porous pavement installed in two cul-de-sacs (Macbeth Court and Juliet Drive). It was recommended that porous pavement be monitored in these cul-de-sacs. The cul-de-sac projects were subsequently installed in 2005 and are currently being monitored for their effectiveness.

1.3 Differences Between the 2003 and 2007 Carver Lake Subwatershed Infiltration Studies

The 2007 Carver Lake Subwatershed Infiltration Study presented in this report builds on the 2003 study and expands it to the entire watershed. There are differences, however, in this study that stem from new knowledge in the quickly growing field of stormwater infiltration. These include:

a. This study includes the entire Carver Lake Subwatershed (Northeast, Northwest and South) and includes numerous other land uses.

b. Slopes greater than 5 percent were considered in slopes perpendicular to streets that extend into rights-of-way. Here boulevard bump-outs could be constructed. Slopes greater than 5 percent along a street longitudinally were not considered. Also, the use of retaining walls can allow for infiltration basin installation in areas where slopes exceed 5 percent.

c. No maximum percent impervious was set to rule out infiltration basins. In the 2003 study nothing over 30 percent imperviousness was considered due to aesthetic considerations. In this study it is assumed that basins can be designed to be attractive in any area.

d. Multiple family residential areas were not ruled out for BMPs. Small yards were considered as possible locations.

1.4 Infiltration BMPs—a Responsible Reaction to Climate Change

Climate change is an impending force that will affect Carver Lake and its watershed. Predictions for the Midwest states indicate that we will experience more days over 90 degrees Fahrenheit, increased wind, more intense but less frequent storm events, and less snow cover with higher average winter temperatures, among other affects (Seeley, 2007). This means changes for the watershed—increased drying of soils and lower water levels in lakes, wetlands and streams, stressed vegetation, frequent drought, intense but infrequent storm events, and many other effects. The challenges presented by climate change will likely become more evident in the coming years.

Preparation for these changes should begin now. It is important to capture stormwater where it falls and store it in the ground for use by trees and to recharge groundwater, rather than treating it as a waste product to be discharged downstream. Runoff that still travels downstream after infiltration limits are reached will arrive at the receiving water body with lower concentrations of sediment and phosphorous, and at a slower rate of flow and cooler temperatures.

By pursuing infiltration BMPs in the areas tributary to Carver Lake, the District is working to counter the effects of climate change by both improving the water quality of Carver Lake as well as recharging groundwater levels and putting water to use where it falls in the watershed. This report suggests ways to capture valuable stormwater and keep it in the Carver Lake Subwatershed's hydrologic cycle and groundwater tables rather than letting it escape unused downstream.

2.0 Process

The process of creating recommendations for alternative stormwater practices in the Carver Lake watershed involved the following steps:

1. A GIS analysis of watershed characteristics including:
   - Hydrologic soil groups classification; (United States Department of Agriculture, or USDA, soils groups C and D were eliminated for consideration for infiltration basins. Areas with these soil types may be considered for biofiltration basins instead.
   - Well head locations; a setback of 50 feet was created for infiltration basins.
   - Depth to bedrock less than 12 feet.
   - Depth to water table less than 10 feet.
   - Streets scheduled for reconstruction.

2. The watershed was then inspected to survey suitable locations for implementation of best management practices (BMPs). Locations were mapped. Visual selection criteria used to identify best locations were areas that:
   - Are relatively flat.
   - Have few existing trees, or trees that would tolerate some root pruning.
   - Appear to have abundant parking; some of which might be eliminated.

3. The GIS analysis maps and the on-site watershed survey were synthesized through additional GIS mapping to determine suitable sites for BMP implementation. From this, priorities for implementation were identified. Also, street construction schedules were examined for the county and cities within the watershed and were mapped along with the BMP suggestions as this information may be helpful in deciding how to proceed with particular projects. For example, a retrofit project should not be launched in an area that will soon be redeveloped. However, the District could use these areas as opportunities to create treatment over and above what the volume reduction rule requires by partnering with cities, counties or other parties involved in reconstruction activities.

4. The runoff volume that would be reduced through the infiltration of 0.25 inches of runoff from all of the directly connected impervious areas in the Carver Lake Subwatershed was estimated. This volume was divided by 20 years to calculate an annual average. This annual average can be considered an annual volume reduction target for infiltration projects. If this target is met, it is expected that Carver Lake could meet its water quality goal of 40 µg/L after 20 years of implementation.

5. The increase in volume reduction achieved by additional infiltration projects presented in this report were estimated as a total (the total water quality volume provided by all of the presented projects), as well as by drainage area and for individual targeted neighborhood projects.

6. Several neighborhoods were identified as the first round of candidates for an annual targeted volume reduction and public education/involvement programs that could be used to supplement the total volume reduction achieved each year. These areas were chosen because they are fairly flat, have space available in the street right-of-way or within the street, appear to have excessive impervious surface, and have soil types of hydrologic groups A or B which readily infiltrate. Each of these areas have roughly the same volume reduction potential.

7. Preliminary discussions with City of Woodbury staff (Steve Kernik, Assistant City Engineer) were conducted to discuss the possibility of implementing these projects in the future, and to understand what challenges the implementation of these projects (particularly the bump-out options) would face. This discussion dealt with design on a conceptual level, and were not targeted at specific project areas.

3.0 Results and Recommendations

Results of this study show many opportunities to implement BMPs in order to work toward the volume reduction goal. The most suitable options for the Carver Lake Subwatershed include:

- Impervious surface reduction
- Infiltration basins
- Biofiltration basins
- Boulevard bump-outs with infiltration basins
- Permeable pavement
- Tree planting

Each is discussed below. Figure 3 shows the road reconstruction projects that are currently scheduled in the Carver Lake Subwatershed. No County road reconstruction projects are planned at present for the area. These areas are shown for two reasons: (1) they are areas in the near future that may be subject to the volume reduction rule through the permitting process, and (2) because some infiltration projects may be required of these areas, these areas may provide good opportunities to cost–effectively go over and above the volume reduction rule by using cost-sharing projects to enhance what is already required.

Figure 4 shows the potential volume reduction BMP implementation locations in the Carver Lake Subwatershed. Opportunities for tree planting and pervious pavement implementation are too numerous to map. Creation of programs to promote implementation of these BMPs wherever possible is recommended. The following sections describe each of these BMP options in detail.

3.1 Impervious Surface Reduction

Reducing impervious surface results in decreased runoff, and increased infiltration. Both are positives for Carver Lake. Roads, driveways and parking lots are often designed for a worst case (high use) scenario to most fully accommodate extreme events for automobile movement and parking. This approach ignores the impervious surface impact on natural resources and stormwater management in particular. New development in the watershed should restrict impervious surfaces to that needed for every day use through revisions to city ordinances. In the future, ordinances should be evaluated for reasonable changes that would reduce impervious surfaces without greatly impacting the functionality of roads, driveways and parking lots.

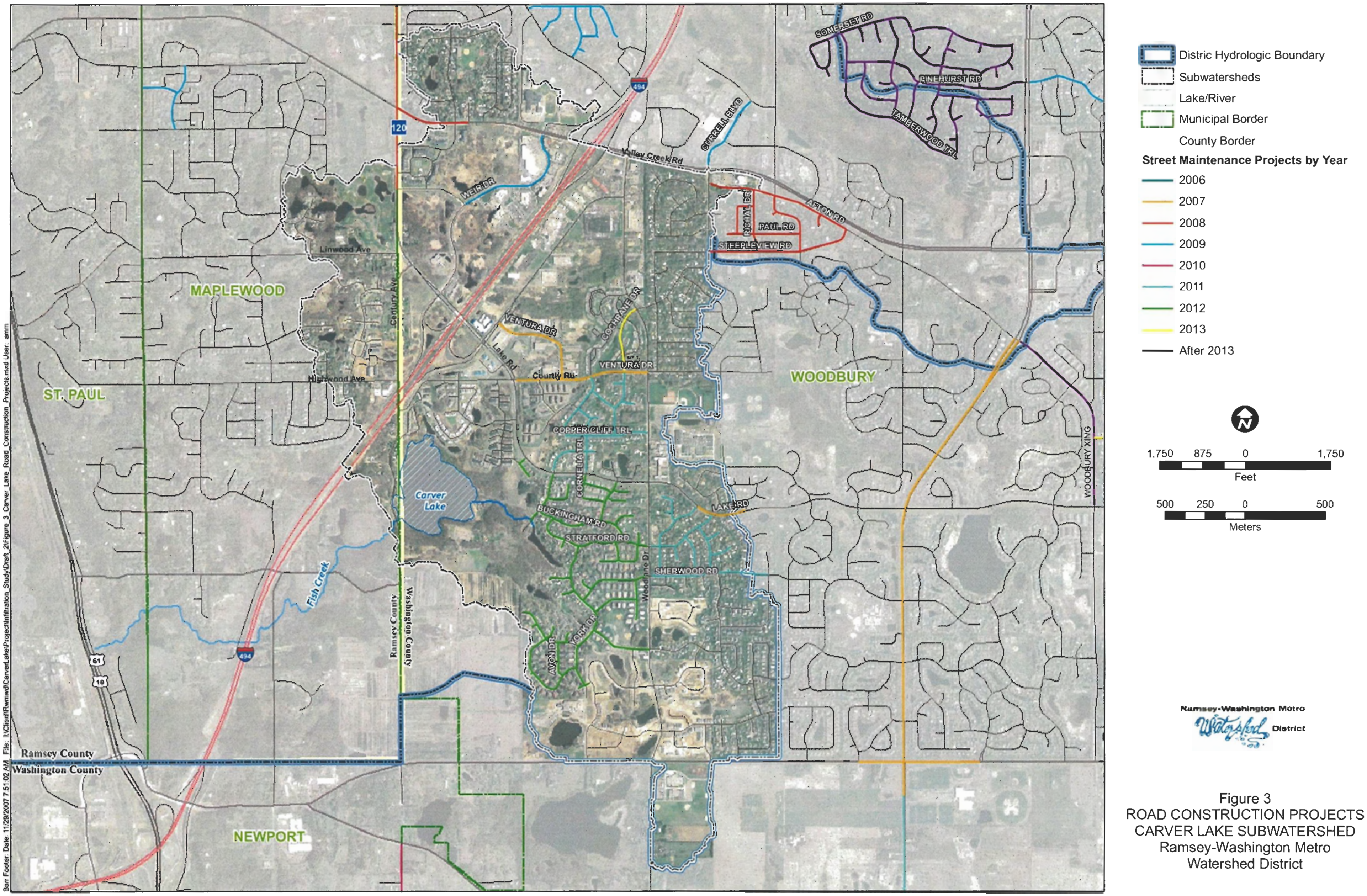


Figure 3
ROAD CONSTRUCTION PROJECTS
CARVER LAKE SUBWATERSHED
Ramsey-Washington Metro
Watershed District

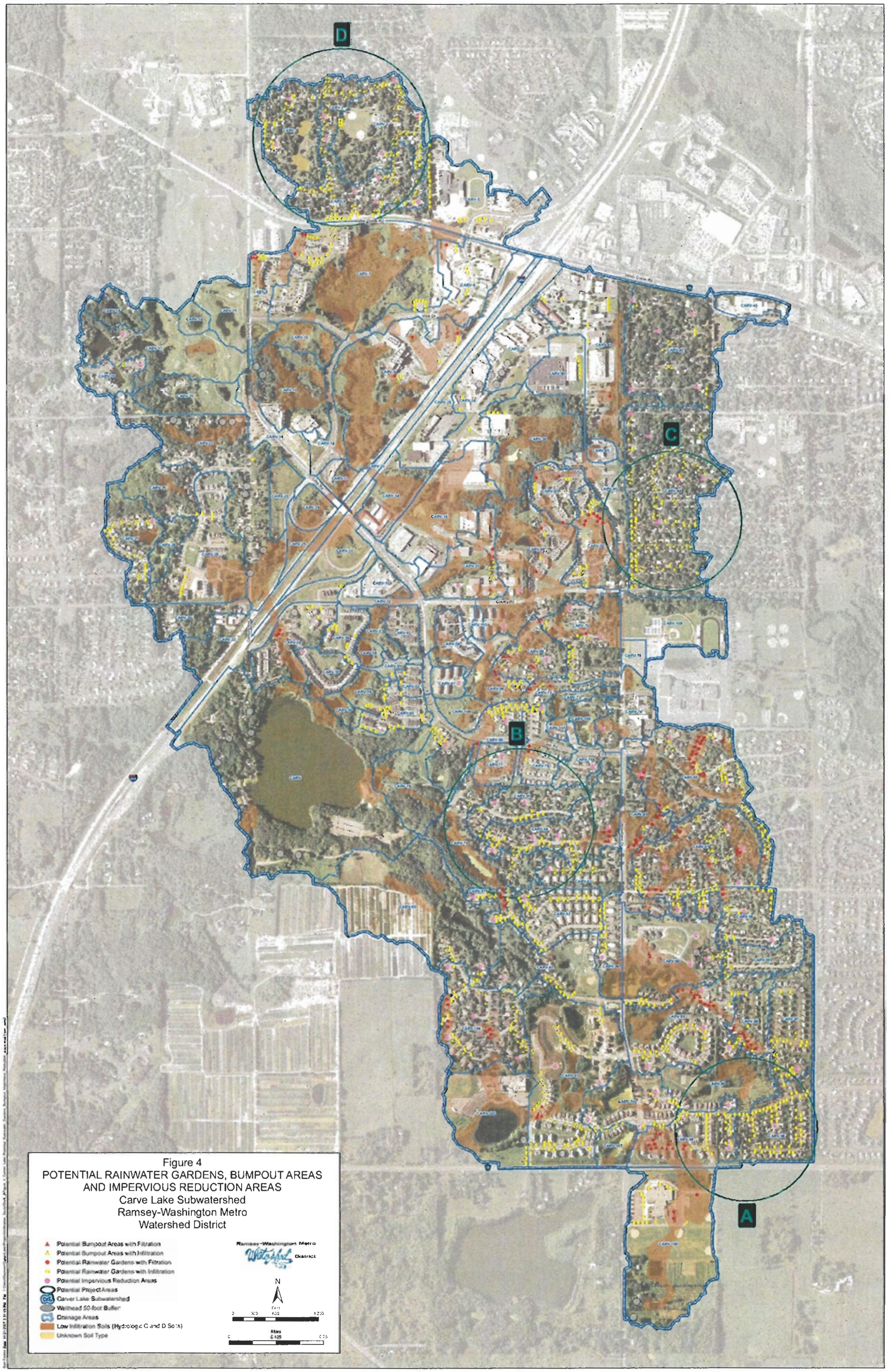


Figure 4
POTENTIAL RAINWATER GARDENS, BUMPOUT AREAS AND IMPERVIOUS REDUCTION AREAS
Carve Lake Subwatershed
Ramsey-Washington Metro
Watershed District

Impervious surface in Carver Lake Subwatershed can be reduced in the following ways:

Roads: Situations exist in the Carver Lake Subwatershed where roads can be narrowed. Often parking lanes are built that are never or rarely used. One parking lane, as opposed to two, may accommodate the parking needs for many neighborhoods. The most economical opportunity for reducing road widths is when they are scheduled for reconstruction. Figure 3 shows locations where roads in the watershed are scheduled for reconstruction.

Driveways: There are two ways to limit driveway impervious surface: reduce length and reduce width. The only opportunity to reduce length is during new construction. In residential situations, reducing house setbacks reduces driveway length and is achieved through changes to city subdivision ordinances. Narrowing is the second way to reduce driveway imperviousness; achieved through necking down long driveways to one lane, creating "two track" driveways, or using pervious pavers in all or part of the driveway—especially in front of the third garage of a residence.

Parking Lots: Parking lots were not specifically evaluated for impervious surface reduction in this project, but through quick inspection it appears that some parking lots are over-sized; designed for the 'extreme event', rather than every day parking use. Parking lots in the watershed should be further evaluated for surface reduction and creation of infiltration basins. Also, city parking ordinances should be evaluated to consider reducing the number of required parking stalls.

Roofs: Roofs in industrial and retail facilities are a major source of stormwater runoff. The most practical solutions in these tight urban situations are implementation of extensive green roofs that hold as much as a 1 inch storm event which then evaporates. Green roofs should be considered in new 'big box' developments. Two or more story buildings also reduce the foot print of a building.

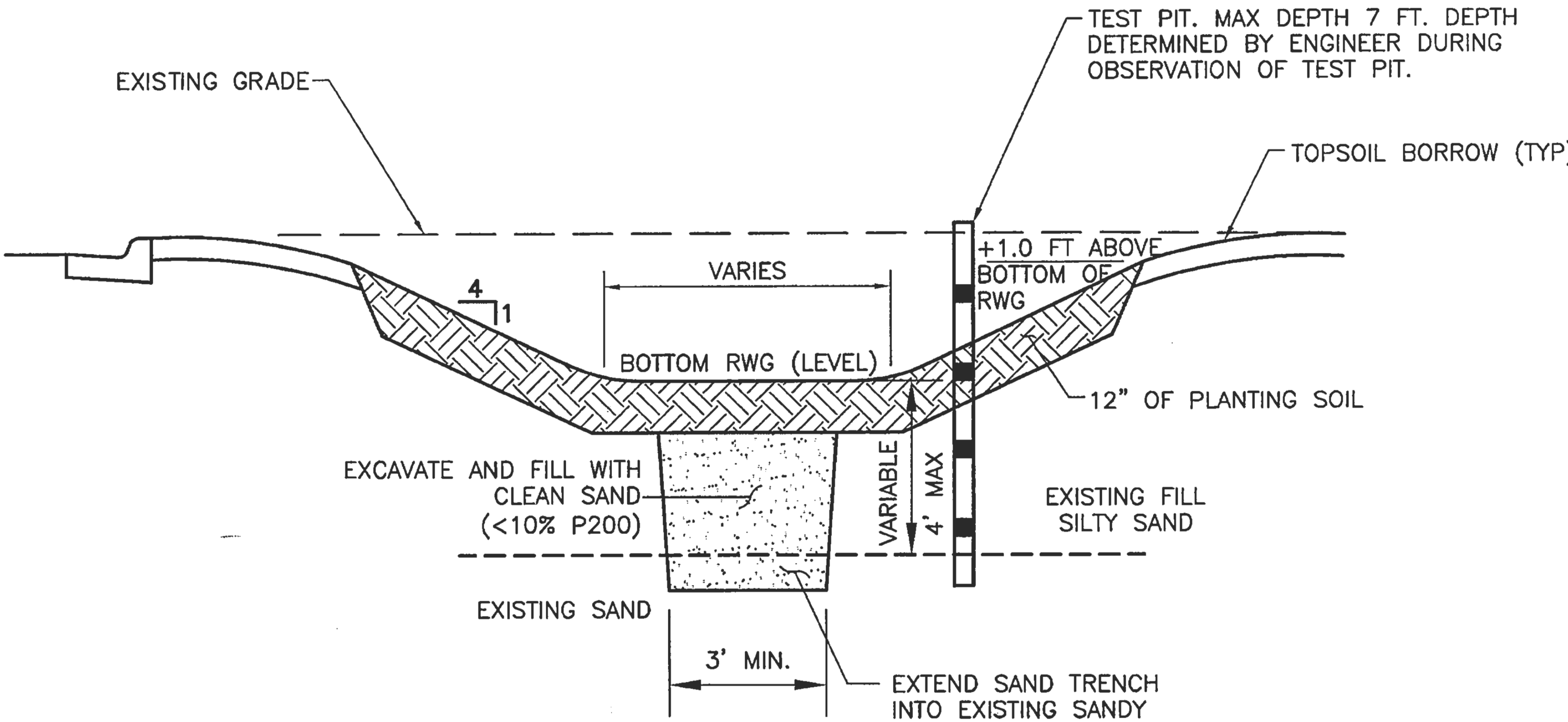
3.2 Infiltration Basins

The Carver Lake Subwatershed has been evaluated for the potential to construct infiltration basins. In the Carver Lake Subwatershed, soils are mostly of United States Department of Agriculture (USDA) hydrologic group B, which is appropriate for infiltration basins. Infiltration basins are the most effective BMP presented in this document because they eliminate (or at least slow) water from the runoff system and thus eliminate (or at least reduce) phosphorus from the system. To be effective, they must be built to intercept runoff as close to its source as possible. Also, they are most effective when distributed throughout the watershed, not concentrated in regional treatment facilities. The survey of the watershed shows many locations for potential infiltration basins (as rainwater gardens) as shown on Figure 4.

In residential situations, the basins should be constructed to accept runoff from the street along with roof and lawn runoff. Figure 5 shows a standard detail of an infiltration basin design for a rainwater garden. The estimated cost of a typical rainwater garden is shown in Table 2, below. Costs are based on a $10 per square foot cost for construction (estimated from Burnsville's Rushmore Drive rainwater garden retro-fit project). The basin size is assumed to be eight feet by thirty feet. No use of volunteers was figured into the cost.

Table 2: Estimated Cost of a Rainwater Garden Construction in a Retro-Fit Situation

Rainwater Garden Retro-Fit Construction Activity	Estimated Cost (2007 Dollars) Per Rainwater Garden
Site Survey	$500
Soil Investigation	$500
Engineering Design	$1,500
Construction	$2,500
Construction Observation	$500
Total	$5,500



NOTE:

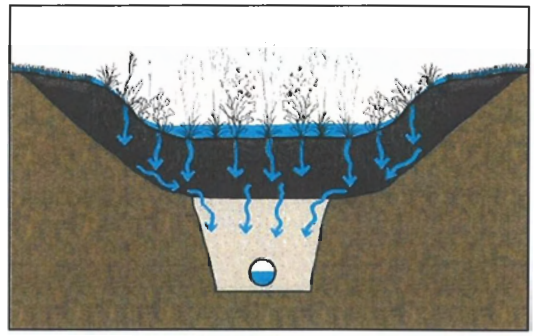
ALL SUBCUT AND PLACEMENT OF SAND BACKFILL AND PLANTING SOIL SHALL OCCUR AFTER THE EXTERIOR OF THE BLDG IS FINISHED TO AVOID COMPACTION OF THE SOIL DURING CONSTRUCTION.

SECTION: RAINWATER GARDEN EXCAVATION (TYP.)

NOT TO SCALE

FIGURE 5

3.3 Biofiltration Basins



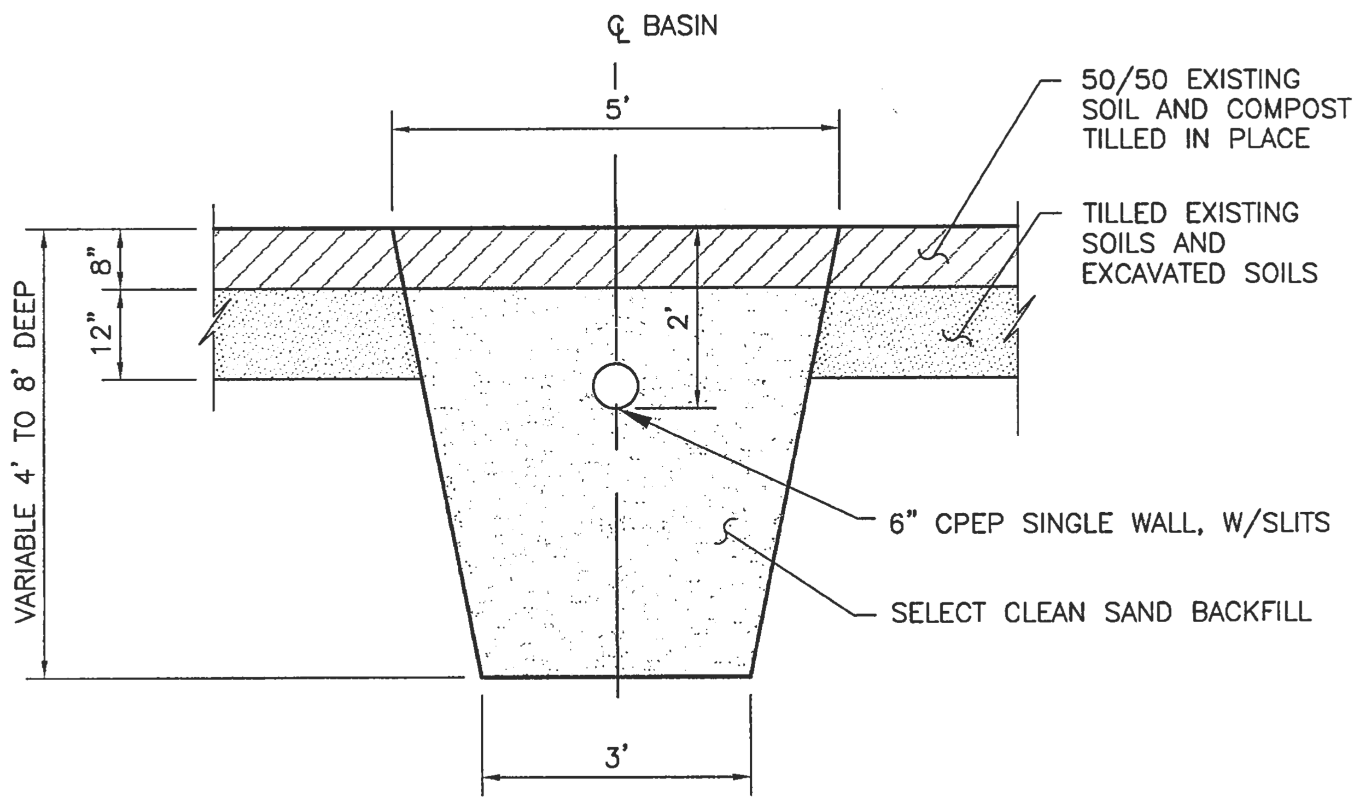
Biofiltration basins are constructed in the same manner as infiltration basins except that they have a drain tile installed in the subsoil below the basin. They function to filter stormwater and release it slowly downstream, rather than infiltrate stormwater and eliminate it from the drainage system. Biofiltration basins are constructed in areas where soils are too heavy to infiltrate stormwater rapidly; hydrologic group C and D soils. Locations for biofiltration basins are also shown on Figure 4. Figure 6 shows a standard detail of an infiltration basin design for a biofiltration basin. The estimated cost of a typical biofiltration garden is shown in Table 3 below. The cost increase from the infiltration basin stems from construction of the trench which contains a drain tile and is filled with sand. The basin size is assumed to be eight feet by thirty feet. No use of volunteers was figured into the cost.

Table 3: Estimated Cost of a Biofiltration Garden Construction in a Retro-Fit Situation

Biofiltration Garden Retro-Fit Construction Activity	Estimated Cost (2007 Dollars) Biofiltration Garden
Site Survey	$500
Soil Investigation	$500
Engineering Design	$1,500
Construction	$3,500
Construction Observation	$500
Total	$6,500

3.4 Boulevard Bump-Outs With Infiltration Basins

Boulevard bump-outs are a method of creating space for infiltration basins in neighborhoods where space is limited due to topography, trees or other obstacles limit the ability to place them within the street right-of-way. Bump-outs create a



SECTION: FILTRATION BASIN
1"=2'-0"

0 2 4
SCALE IN FEET

FIGURE 6

double stormwater management advantage by eliminating pavement and creating space to construct infiltration basins. Possible locations of bump outs are shown on Figures 4a and 4b.

Bump-outs are shown only in areas where parking space can most likely be eliminated, based on an initial visual inspection. In many neighborhoods parking on both sides of the street (along with two driving lanes) is not necessary due to adequate driveway parking or low-density housing. Bump-outs are also used for slowing traffic, and can be particularly effective at slowing traffic at intersections. Figure 7 shows a standard detail of a street modification that would include a bump-out. The estimated cost of construction of a bump-out is shown in Table 4 below. Costs are based on a $10 per square foot cost for construction of the rainwater garden (estimated from Burnsville's Rushmore Drive rainwater garden retro-fit project). The basin size is assumed to be eight feet by thirty feet. No use of volunteers was figured into the cost.

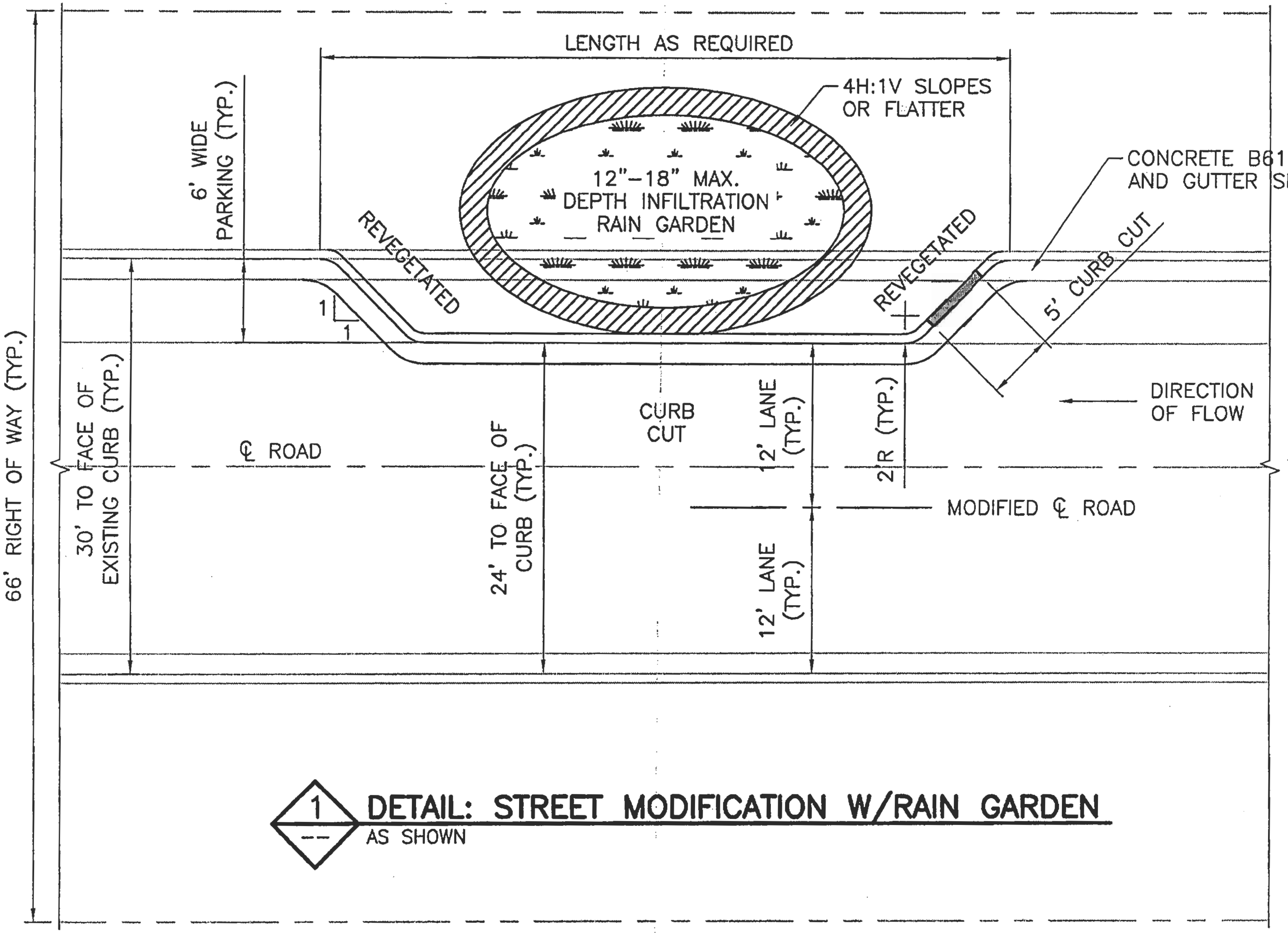
Table 4: Estimated Cost of a Bump-out with a Rainwater Garden Construction in a Retro-Fit Situation

Bump-out with Rainwater Garden Retro-Fit Construction Activity	Estimated Cost (2007 Dollars) Per Bump-out with a Rainwater Garden
Estimated Cost of a Rainwater Garden Construction in a Retro-Fit Situation	$5,500
Bump-out Engineering and Design	$500
Pavement Removal	$500
New Curb	$1,000
Construction Observation	$1,000
Total	$8,500

3.5 Permeable Pavement

Some of the negative effects of pavement can be eliminated by replacing existing pavement with permeable pavement. Various permeable pavement types are available including permeable pavers, bituminous, and concrete. They work to infiltrate stormwater where it lands. A mosaic of permeable and impermeable pavement can be implemented in catchment areas where runoff is fairly free of particulate matter that will clog the pores. Permeable pavement is best used as an impervious surface

GGN M:\cad\Client\RWMWD\Street Impervious Reduction.dwg Plot at 1 11/16/2007 15:42:53



NOTE:

EXISTING STREET WIDTH ASSUMED. MODIFICATIONS TO WIDTH SUBJECT TO LOCAL MINIMUM WIDTH REGULATIONS FOR TRAFFIC DESIGN.

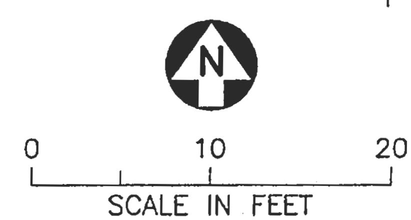


FIGURE 7

reduction technique where permeable pavement completely replaces the impervious pavement. It is estimated, however, that permeable pavement can accept runoff from adjacent impervious pavement at about a ratio of 5:1, impermeable to permeable.

Whenever permeable pavements are planned, an adequate budget for their maintenance is necessary. Vacuuming of the pavement at least twice each year is essential to their success. For winter maintenance, sand applications to permeable pavement should be avoided. If de-icing is necessary, some salt may be applied. However, it is possible that permeable pavement may require a much lower rate of application than impervious pavement, given its ability to infiltrate water on the surface whenever snow and ice intermittently melts during the winter months.

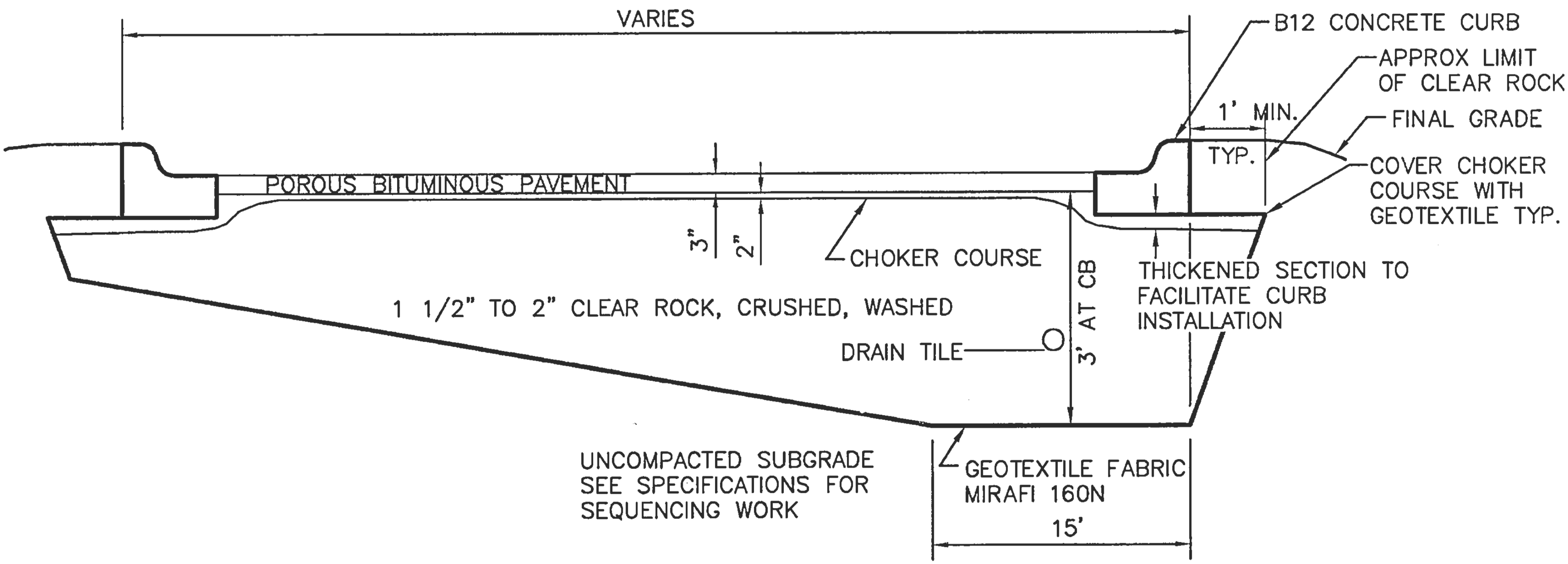
In this report, specific locations for permeable pavement are not specified, since they are too numerous and require a greater level of analysis. Cul du sacs, however, are identified for potential sites for permeable pavement. They are shown on Figure 4. Figure 8 shows a standard detail of cross section of porous bituminous pavement. The estimated cost of a 1 ft^2 section of permeable pavement is shown in Table 5 below.

Table 5: Estimated Cost of a 1 ft^2 Permeable Pavement Section Construction in a Retro-Fit Situation

Permeable Pavement Construction Activity	Estimated Cost (2007 Dollars) Per ft^2 of permeable pavement
Total cost per sf of Permeable Pavement (construction only)	$8*
Total cost per sf of Permeable Pavers	$9*

*This includes a one foot crushed rock subgrade, geotextile, and installation. This does not include the excavation and disposal of the subgrade (highly variable).

In 2005, the asphalt in two Carver Lake Subwatershed cul-de-sacs, Macbeth Court and Juliet Drive (both in Woodbury), was replaced with porous pavement. These cul-de-sacs receive drainage from upstream areas, including lawns, buildings, driveways and streets. Prior to project implementation, all of this runoff entered storm sewers and flowed untreated into Carver Lake. This project is a test to monitor the benefits achieved by porous pavement as a method of infiltration and volume



SECTION: POROUS BITUMINOUS PAVEMENT

NOT TO SCALE

FIGURE 8

reduction. District staff began monitoring this project in 2005. Monitoring results are shown in Table 6.

3.6 Estimated Phosphorus Reductions

3.6.1 Phosphorus Reduction from Infiltrating 0.25 Inches of Runoff from Directly Connected Impervious Areas

The conclusion of the 2000 Supplemental Infiltration Modeling Study was that if 0.25 inches of runoff were infiltrated from the Carver Lake Subwatershed's directly connected impervious areas, the lake's phosphorus concentration could be lowered to meet the MPCA's Deep Lake Criteria for Total Phosphorus (40 μg/L), thereby allowing the lake to be removed from the Impaired Waters List.

It is important to note that in modeling the estimated effect of infiltrating 0.25 inches of runoff from all of the Carver Lake Subwatershed's directly connected impervious areas over the next 20 years, it was assumed that only impervious areas that were directly connected to the storm sewer system (impervious areas that did not first pass over pervious areas before entering the storm sewer system) would be captured in the infiltration area. This was considered to be a more realistic, and conservative, assumption. Also, in the past, the uncertainty in whether or not the infiltrated water actually reached the lake has been shown in modeling results. For the purposes of this report, only the more conservative assumption (that the infiltrated water does not reach the lake, thereby not providing a dilution benefit) was used. Lastly, it was assumed that infiltration projects would be spread evenly over the entire Subwatershed, providing 0.25 inches of infiltration in each drainage area (as opposed to an average over all drainage areas). This should be considered during implementation to the extent possible (infiltrating more runoff in some areas and less in others is discouraged).

It is possible that implementation of the District's volume reduction rule could provide most of the volume reduction needed in any given year. However, given the uncertain nature of these required infiltration projects and their implementation, it is likely that additional, retrofit projects will need to be implemented (or that projects with their water quality volume equivalent be implemented) over the next 20 years on an as-needed basis, whenever implementation of the volume reduction rule alone does not meet the annual volume reduction goal.

Table 6: Water quality volume achieved by proposed projects in each individual Carver Lake drainage area.

Drainage Area	Total Area (acres)	Directly Connected Impervious Area (acres)	Reduction if 0.25 inches are infiltrated from Directly Connected Impervious Areas (AF)	Water Quality Volume Achieved by Proposed Projects (Including Bump-Outs) TOTAL (ac-ft)	Volume Captured by Proposed Projects (Including Bump-outs) INFILTRATION ONLY	Volume Captured by Proposed Projects (Including Bump-outs) FILTRATION ONLY	Volume Achieved by Proposed Projects (NOT Including Bump-Outs) TOTAL (ac-ft)	Volume Achieved by Proposed Projects (NOT Including Bump-Outs) INFILTRATION ONLY (ac-ft)	Water Quality Volume Captured by Proposed Projects (NOT including Bump-Outs) FILTRATION ONLY (ac-ft)
CARV	83	5.0	0.104	0.00	0.00	0.00	0.00	0.00	0.00
CARV-1	24.6	2.2	0.046	0.11	0.11	0.00	0.06	0.06	0.00
CARV-10	8.9	4.1	0.085	0.00	0.00	0.00	0.00	0.00	0.00
CARV-100	56.8	8.5	0.178	0.18	0.15	0.03	0.18	0.15	0.03
CARV-101	6.7	0.9	0.018	0.01	0.01	0.00	0.00	0.00	0.00
CARV-102	20	2.2	0.046	0.06	0.06	0.00	0.03	0.03	0.00
CARV-103	32.6	3.3	0.068	0.00	0.00	0.00	0.00	0.00	0.00
CARV-104	34.4	10.7	0.222	0.44	0.37	0.08	0.25	0.19	0.06
CARV-106	5.7	0.3	0.007	0.00	0.00	0.00	0.00	0.00	0.00
CARV-107	1.9	0.3	0.007	0.00	0.00	0.00	0.00	0.00	0.00
CARV-108	24.8	1.2	0.026	0.00	0.00	0.00	0.00	0.00	0.00
CARV-109	5.6	0.2	0.004	0.00	0.00	0.00	0.00	0.00	0.00
CARV-11	24.5	14.7	0.306	0.00	0.00	0.00	0.00	0.00	0.00
CARV-110	1.5	0.5	0.009	0.00	0.00	0.00	0.00	0.00	0.00
CARV-12	10	5.6	0.117	0.00	0.00	0.00	0.00	0.00	0.00
CARV-13	5.5	2.6	0.054	0.00	0.00	0.00	0.00	0.00	0.00
CARV-14	15.1	7.7	0.160	0.00	0.00	0.00	0.00	0.00	0.00
CARV-15	12.7	0.4	0.008	0.00	0.00	0.00	0.00	0.00	0.00
CARV-16	3.8	0.0	0.000	0.00	0.00	0.00	0.00	0.00	0.00
CARV-17	35.5	1.4	0.030	0.00	0.00	0.00	0.00	0.00	0.00
CARV-18	7.3	0.6	0.012	0.00	0.00	0.00	0.00	0.00	0.00
CARV-2	10.1	1.8	0.038	0.09	0.09	0.00	0.02	0.02	0.00
CARV-20	8	1.4	0.030	0.00	0.00	0.00	0.00	0.00	0.00
CARV-21	15.3	0.5	0.010	0.00	0.00	0.00	0.00	0.00	0.00
CARV-22	52	12.0	0.249	0.00	0.00	0.00	0.00	0.00	0.00
CARV-23	7.4	4.7	0.099	0.00	0.00	0.00	0.00	0.00	0.00
CARV-24	6.7	1.5	0.032	0.00	0.00	0.00	0.00	0.00	0.00
CARV-25	4.5	0.9	0.020	0.00	0.00	0.00	0.00	0.00	0.00
CARV-26	16.2	2.1	0.044	0.00	0.00	0.00	0.00	0.00	0.00
CARV-27	18.1	2.5	0.053	0.11	0.11	0.00	0.04	0.04	0.00
CARV-28	6.4	0.9	0.019	0.00	0.00	0.00	0.00	0.00	0.00
CARV-29	33.5	6.7	0.140	0.28	0.28	0.00	0.28	0.28	0.00
CARV-3	29.8	3.0	0.082	0.12	0.12	0.00	0.05	0.05	0.00
CARV-30	11.1	2.2	0.046	0.00	0.00	0.00	0.00	0.00	0.00
CARV-31	17.1	0.0	0.000	0.00	0.00	0.00	0.00	0.00	0.00
CARV-32	27.6	3.6	0.075	0.00	0.00	0.00	0.00	0.00	0.00
CARV-33	14.6	3.4	0.070	0.00	0.00	0.00	0.00	0.00	0.00
CARV-34	14.3	7.2	0.149	0.00	0.00	0.00	0.00	0.00	0.00
CARV-35	22.4	7.4	0.154	0.00	0.00	0.00	0.00	0.00	0.00
CARV-36	14.7	10.0	0.208	0.04	0.04	0.00	0.04	0.04	0.00
CARV-37	17.3	11.4	0.238	0.00	0.00	0.00	0.00	0.00	0.00
CARV-38	33.7	14.5	0.302	0.00	0.00	0.00	0.00	0.00	0.00
CARV-39	31.9	17.2	0.359	0.29	0.29	0.00	0.29	0.29	0.00
CARV-4	25.6	5.1	0.107	0.21	0.21	0.00	0.09	0.09	0.00
CARV-40	14.7	10.1	0.211	0.08	0.08	0.00	0.08	0.08	0.00
CARV-41	44.5	25.4	0.528	0.21	0.19	0.02	0.21	0.19	0.02
CARV-42	49.7	11.9	0.249	0.20	0.20	0.00	0.07	0.07	0.00
CARV-43	8	4.6	0.096	0.00	0.00	0.00	0.00	0.00	0.00
CARV-44	68.7	12.4	0.258	0.62	0.62	0.00	0.18	0.18	0.00
CARV-45	2.8	1.9	0.039	0.00	0.00	0.00	0.00	0.00	0.00
CARV-46	12.6	6.2	0.129	0.00	0.00	0.00	0.00	0.00	0.00
CARV-47	10.9	2.2	0.045	0.02	0.01	0.01	0.02	0.01	0.01
CARV-48	21.6	1.1	0.023	0.00	0.00	0.00	0.00	0.00	0.00
CARV-49	44.5	11.6	0.241	0.48	0.24	0.24	0.48	0.24	0.24
CARV-5	34.7	14.9	0.311	0.12	0.12	0.00	0.12	0.12	0.00
CARV-50	18	4.0	0.083	0.07	0.04	0.02	0.04	0.02	0.02
CARV-51	20.9	13.4	0.279	0.22	0.14	0.09	0.02	0.00	0.02
CARV-52	17	9.0	0.188	0.00	0.00	0.00	0.00	0.00	0.00
CARV-53	5.5	3.5	0.072	0.00	0.00	0.00	0.00	0.00	0.00
CARV-54	7.9	2.2	0.046	0.04	0.04	0.00	0.04	0.04	0.00
CARV-55	9.2	2.0	0.042	0.00	0.00	0.00	0.00	0.00	0.00
CARV-56	18.9	3.4	0.071	0.03	0.02	0.01	0.03	0.02	0.01
CARV-57	5.1	0.6	0.013	0.00	0.00	0.00	0.00	0.00	0.00
CARV-58	3.1	0.2	0.004	0.00	0.00	0.00	0.00	0.00	0.00
CARV-59	7	0.7	0.015	0.06	0.06	0.00	0.06	0.06	0.00
CARV-6	12.1	3.4	0.071	0.03	0.02	0.01	0.01	0.01	0.01
CARV-60	3.5	0.1	0.002	0.00	0.00	0.00	0.00	0.00	0.00
CARV-61	2.7	0.9	0.020	0.00	0.00	0.00	0.00	0.00	0.00
CARV-62	3.4	0.7	0.014	0.00	0.00	0.00	0.00	0.00	0.00
CARV-63	7.8	1.6	0.037	0.00	0.00	0.00	0.00	0.00	0.00
CARV-64	9.2	2.3	0.046	0.00	0.00	0.00	0.00	0.00	0.00
CARV-65	9.1	1.7	0.036	0.03	0.03	0.00	0.03	0.03	0.00
CARV-66	20.1	4.0	0.084	0.17	0.17	0.00	0.15	0.15	0.00
CARV-67	4.7	1.1	0.024	0.00	0.00	0.00	0.00	0.00	0.00
CARV-68	11.2	1.9	0.040	0.06	0.05	0.02	0.04	0.04	0.00
CARV-69	13.5	2.7	0.056	0.09	0.06	0.03	0.03	0.02	0.01
CARV-7	69	15.2	0.316	0.38	0.34	0.04	0.33	0.29	0.04
CARV-70	22.3	3.6	0.079	0.06	0.05	0.01	0.03	0.03	0.00
CARV-71	3.6	0.3	0.007	0.00	0.00	0.00	0.00	0.00	0.00
CARV-72	5.3	1.1	0.022	0.02	0.01	0.01	0.00	0.00	0.00
CARV-73	4.7	0.1	0.003	0.00	0.00	0.00	0.00	0.00	0.00
CARV-74	15.9	8.1	0.169	0.00	0.00	0.00	0.00	0.00	0.00
CARV-75	7.3	2.4	0.050	0.00	0.00	0.00	0.00	0.00	0.00
CARV-76	12.5	3.5	0.073	0.03	0.02	0.01	0.03	0.02	0.01
CARV-77	7.3	1.2	0.024	0.00	0.00	0.00	0.00	0.00	0.00
CARV-78	19.6	0.2	0.004	0.00	0.00	0.00	0.00	0.00	0.00
CARV-79	28.5	2.6	0.053	0.11	0.08	0.02	0.02	0.00	0.02
CARV-8	24.8	16.9	0.351	0.07	0.08	0.01	0.07	0.06	0.01
CARV-80	63.3	17.1	0.356	0.71	0.71	0.00	0.26	0.26	0.00
CARV-81	6.3	1.4	0.030	0.12	0.10	0.02	0.07	0.06	0.01
CARV-82	19.2	5.6	0.116	0.23	0.23	0.00	0.15	0.15	0.00
CARV-83	12	3.5	0.073	0.09	0.09	0.00	0.01	0.01	0.00
CARV-84	29.5	6.5	0.135	0.22	0.19	0.03	0.14	0.12	0.02
CARV-85	19.4	4.5	0.093	0.19	0.03	0.15	0.09	0.00	0.09
CARV-86	41.8	10.9	0.226	0.27	0.18	0.09	0.13	0.06	0.07
CARV-87	41.6	7.1	0.147	0.29	0.23	0.07	0.09	0.07	0.02
CARV-88	17.6	3.2	0.067	0.11	0.10	0.01	0.08	0.07	0.01
CARV-89	11.9	2.0	0.042	0.02	0.02	0.00	0.00	0.00	0.00
CARV-9	58.8	27.5	0.574	0.11	0.07	0.04	0.11	0.07	0.04
CARV-90	38.2	5.0	0.103	0.04	0.04	0.00	0.03	0.03	0.00
CARV-91	18.2	4.2	0.087	0.09	0.09	0.00	0.06	0.06	0.00
CARV-92	27.7	4.2	0.087	0.17	0.17	0.00	0.13	0.13	0.00
CARV-93	57.8	4.6	0.096	0.19	0.18	0.01	0.07	0.07	0.00
CARV-94	10.4	2.8	0.059	0.14	0.14	0.00	0.09	0.09	0.00
CARV-95	39	4.3	0.089	0.18	0.14	0.04	0.08	0.07	0.02
CARV-96	10.2	1.6	0.034	0.03	0.01	0.02	0.02	0.01	0.01
CARV-97	22.4	3.4	0.070	0.07	0.07	0.00	0.05	0.05	0.00
CARV-98	25	3.8	0.078	0.31	0.31	0.00	0.31	0.31	0.00
CARV-99	23.4	2.8	0.059	0.12	0.08	0.03	0.09	0.07	0.02
	Total Water Quality Volume (AF):		11.15	8.84	7.67	1.17	5.49	4.68	0.81

Note: "TOTAL" and "FILTRATION ONLY" columns are shaded because filtration projects, while providing some sediment and phosphorus reduction, do not truly result in a volume reduction of stormwater. As a result, those projects would not be counted toward the volume reduction goal if implemented.

3.6.2 Water Quality Volume Achieved in Additional Projects-With and Without Bump-Outs

The retro-fit projects shown on Figure 4 could provide an estimated total of up to 7.7[1] acre-feet of water quality volume to intercept and infiltrate runoff from impervious areas during each storm event, over the entire Carver Lake Subwatershed[2]. Figure 9 shows the estimated water quality volume (in acre-feet) that could be infiltrated from impervious areas as a result of infiltration projects in each drainage area throughout the Carver Lake Subwatershed. As shown on the figure, water quality volumes achieved as a result of these projects range from zero to 0.7 acre-feet. It is important to note that Figure 9 does not include the water quality volume that would be provided as a result of the implementation of the volume reduction rule. These projects would provide water quality volume over and above the levels shown on Figure 9.

Construction of bump-outs may pose significant challenges to the District, Cities, Counties and neighborhoods in which they are planned. These changes to neighborhood streets will involve a higher level of communication with residents and corresponding governmental agencies.

Brief discussions with City officials in Woodbury (and other cities in other lakes' watersheds) revealed the following concerns:

- Designs for bump-outs would have to take snow plowing and street sweeping into consideration, perhaps incorporating gradual curbs on which plows and sweepers could partially drive while negotiating turns.
- Fire department officials in the cities will need to be consulted so that requirements for fire truck traffic are met after bump-outs are constructed.
- Early public involvement and education in neighborhood projects will be critical to gain acceptance. Past projects (for traffic control purposes) have been met with resistance in some cases.

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[1] Only water quality volumes from infiltration projects (as opposed to filtration projects) are referred to in this text and on Figure 9. While filtration projects would provide some sediment and phosphorus reduction, they do not provide a reduction of stormwater volume.

[2] If tree plantings and permeable pavement were also implemented throughout the watershed, even more interception would occur.

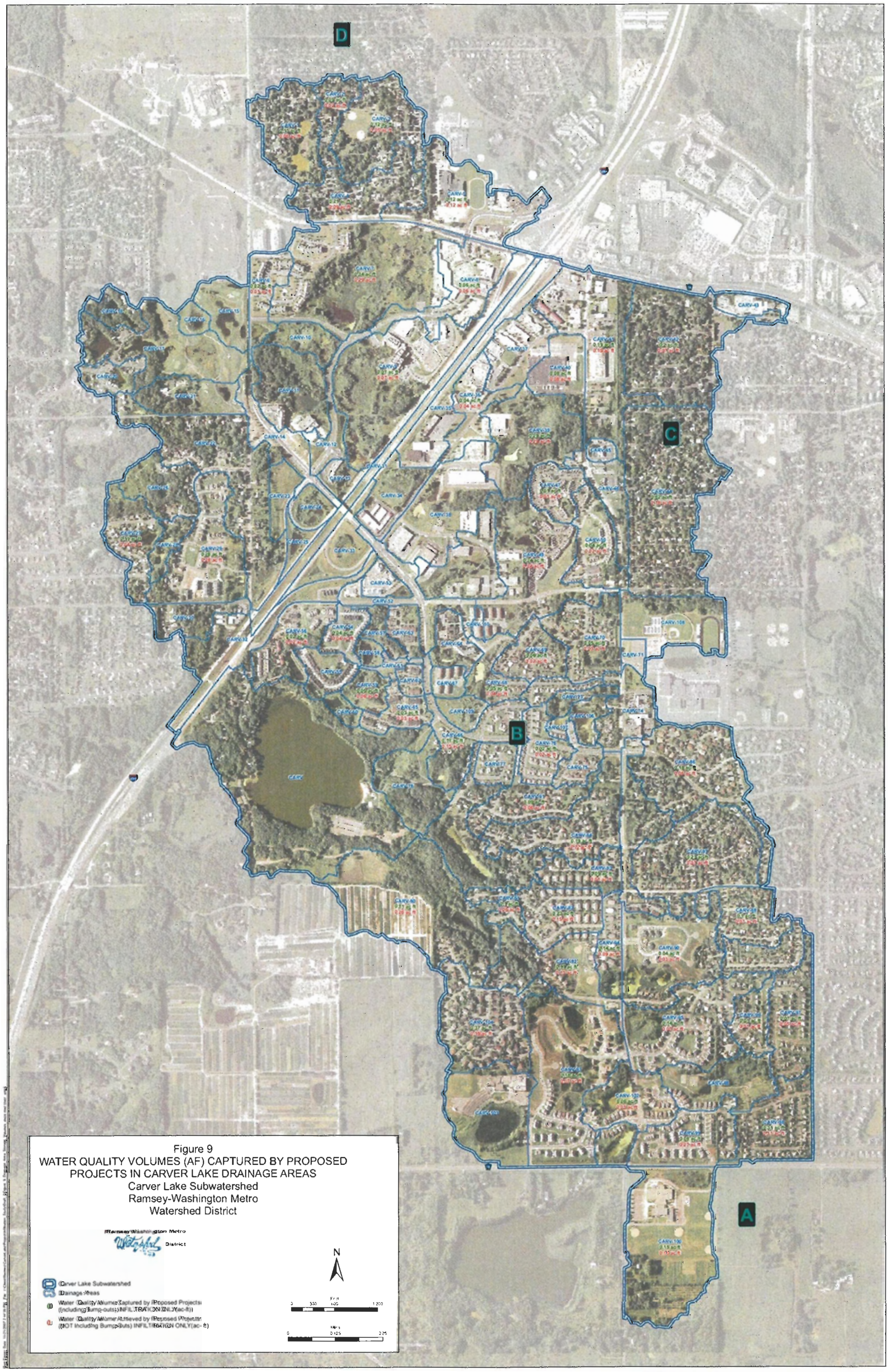

Figure 9
WATER QUALITY VOLUMES (AF) CAPTURED BY PROPOSED PROJECTS IN CARVER LAKE DRAINAGE AREAS
Carver Lake Subwatershed
Ramsey-Washington Metro
Watershed District

Despite these concerns, City officials in Woodbury seemed optimistic that these types of collaborative projects with the District would be possible. It should be noted that the City already has a volume reduction requirement of its own, indicating the City's openness to volume reduction projects in the future.

However, depending on the level of challenge that implementation of bump-outs could face, it may be necessary for the District to pursue more traditional infiltration/volume reduction methods first in some areas (i.e., rainwater gardens) and coming back to bump-outs at a later date, once the process for implementing bump-outs has been streamlined. Figure 9 shows the water quality volume that would be achieved in each drainage area both with (in green) and without (in red) the bump-outs suggested for each drainage area. The total water quality volume that could be provided by the projects shown on Figure 9, if the effect of bump-outs is excluded, is 4.7 acre-feet[3].

Table 6 shows the water quality volume achieved by the proposed projects for each individual drainage area in the Carver Lake Subwatershed. This water quality volume is shown in both with and without bump-outs. Also, included in this table is the runoff volume that would be infiltrated if 0.25 inches of runoff off of the directly connected impervious areas in the drainage area were infiltrated.

3.6.3 Annual Water Quality Volume Goal

It is recommended that an annual water quality goal be created so that the success of infiltration project implementation can be tracked. In this way, the District will be able to evaluate whether infiltration projects outside of those required of redeveloping areas should be pursued in any given year, and if so, to what degree.

In order to meet the 40 μg/L phosphorus goal, a 20-year timeline is recommended. Based on the target of 0.25 inches of runoff infiltrated from each drainage area over 20 years (11.2 acre-feet), an annual infiltration volume goal can be defined as:

11.2 acre-feet / 20 years = 0.56 acre-feet per year.

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[3] Only water quality volumes from infiltration projects (as opposed to filtration projects) are referred to in this text and on Figure 9. While filtration projects would provide some sediment and phosphorus reduction, they do not provide a reduction of stormwater volume.

Therefore, 0.56 acre-feet can be considered the target water quality volume of infiltration projects to be implemented each year, either as a result of the District's volume reduction rule, or other retrofit projects pursued by the District or other organizations or individuals. It should be noted that this target volume is specifically for infiltration of runoff from ***impervious areas***, and ideally, impervious areas that are directly connected to the conveyance system (usually a storm sewer) that delivers them to Carver Lake.

In order to put this goal into perspective, it is useful to consider the actual volume reduction that has been achieved in the Subwatersheds tributary to Carver Lake through implementation of the volume reduction rule since its inception on October 1, 2006. To date, there have been no permits in the Carver Lake Subwatershed that have resulted in volume reduction requirements, nor have there been any Cost Share Program projects. Whether this is indicative of future activities in the area is currently unknown.

3.7 Potential Challenges in Implementing Retro-Fit Infiltration Projects in Neighborhoods

Preliminary discussions with City of Woodbury staff indicate an openness to pursue some of these projects cooperatively, including implementation of bump-outs. In fact, City staffs are already exploring the use of these concepts in their road reconstruction projects as a way to retrofit treatment technologies in older neighborhoods (Steve Kernik, personal communication). Past implementation of bump-outs for traffic control in other cities have, at times, been met with resistance by residents who don't like having the bump-outs on their streets or commuting routes. Starting bump-out implementation on wider roads with greater resident education and involvement early in the process may result in greater community acceptance of these projects. Another important consideration is designing bump-outs with snow plowing and street sweeping in mind.

4.0 Implementation Recommendations

In order to meet the District's water quality goal and the MPCA total phosphorus criteria (40 µg/L) for Carver Lake, a minimum of 0.56 acre-feet (24,293 cubic feet) of water quality volume should be implemented each year in the areas tributary to Carver Lake.

Water quality volumes achieved through the implementation of the volume reduction rule in redeveloping areas and through the District's BMP Cost Share Program should be tracked on an annual basis. Where the volume reduction rule alone does not allow the District to meet the water quality volume goal, additional projects (such as the ones presented in this report) should be implemented.

Results of this study show that there are some good opportunities for implementation of additional infiltration and other volume reduction BMPs in the Carver Lake Subwatershed. In particular, it is recommended that the District pursue projects that have been grouped into specific neighborhood areas where focused education and volume reduction initiatives can be launched on an as-needed basis.

4.1 Neighborhood Stormwater Volume Reduction Initiative

Figure 4 shows neighborhoods that, at first look, show excellent potential for BMP implementation. These neighborhoods are labeled A through D in the figure. These areas are shown in greater detail on Figures 10, 11, 12 and 13. These areas have good potential because they are fairly flat, have space available in the street right-of-way or within the street, have excessive impervious surface, and have soil types of hydrologic groups A or B which readily infiltrate. These areas were only chosen as a first round of candidates that may be relatively easy to work with, given site conditions. In these areas, it would likely be possible to construct infiltration basins, bump-outs with infiltration basins, and retrofit with permeable pavers. Also, these are areas that are not currently slated for redevelopment, so they will not already be covered by the District's volume reduction rule.

It is suggested that an annual program be developed that begins by choosing one of the neighborhoods shown on Figures 10 through 13 to implement targeted neighborhood infiltration projects that including educating residents on the importance of stormwater harvest and infiltration, continues with design for specific BMP implementation (design), includes funding for implementation, and provides supervision and direction for construction. Projects should be

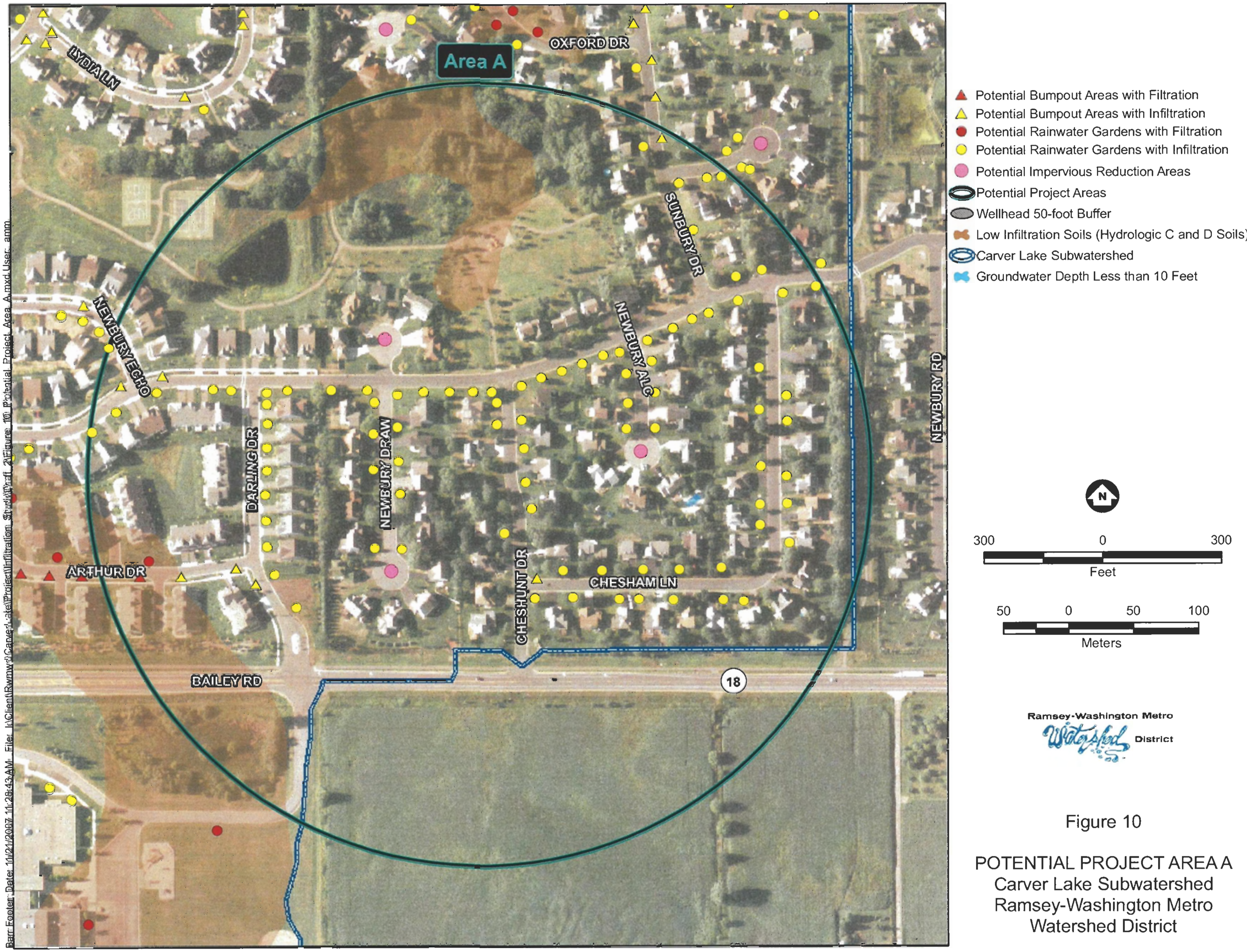
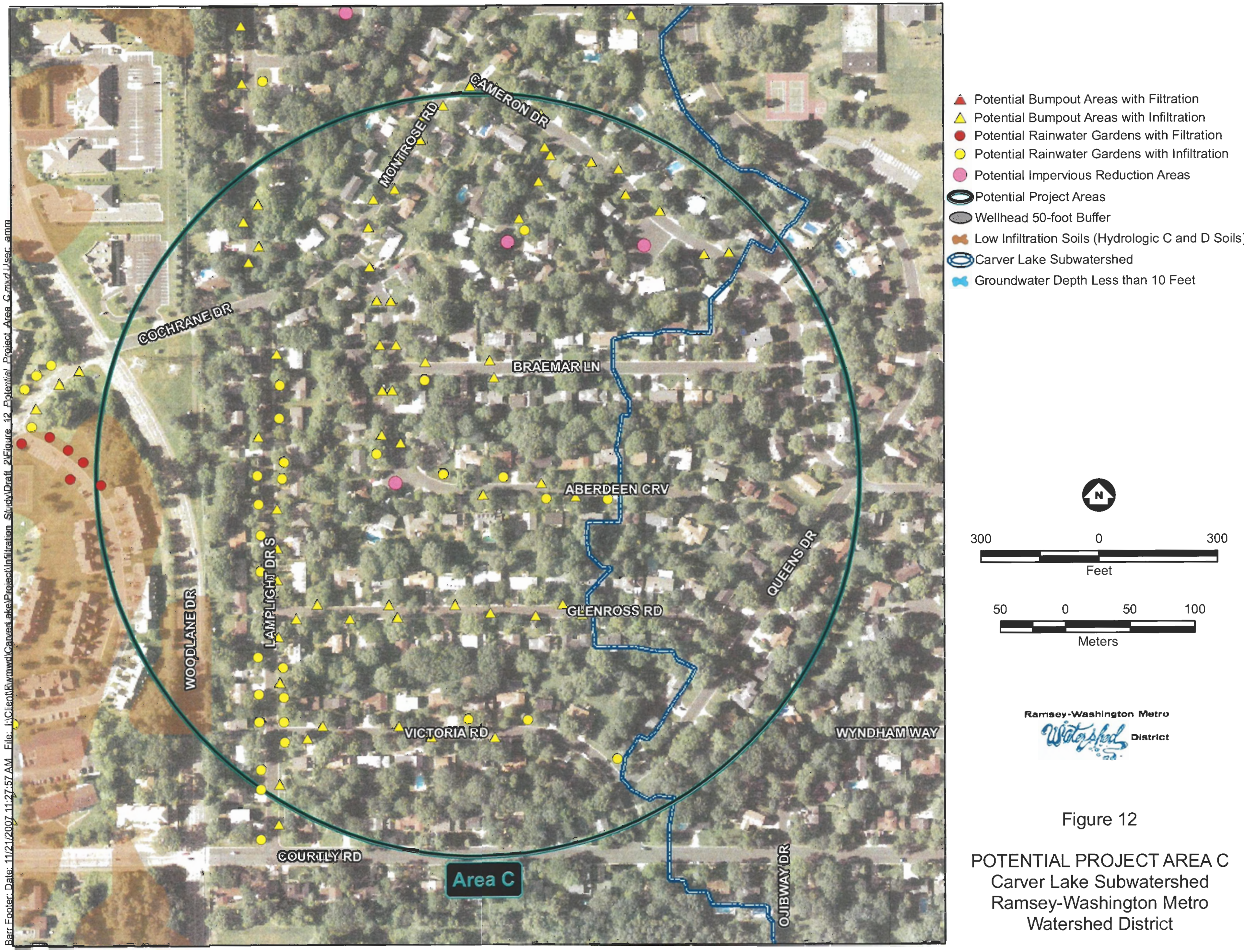


Figure 10

POTENTIAL PROJECT AREA A
Carver Lake Subwatershed
Ramsey-Washington Metro
Watershed District

Figure 11

POTENTIAL PROJECT AREA B
Carver Lake Subwatershed
Ramsey-Washington Metro
Watershed District



Ramsey-Washington Metro Watershed District

Figure 12

POTENTIAL PROJECT AREA C
Carver Lake Subwatershed
Ramsey-Washington Metro
Watershed District

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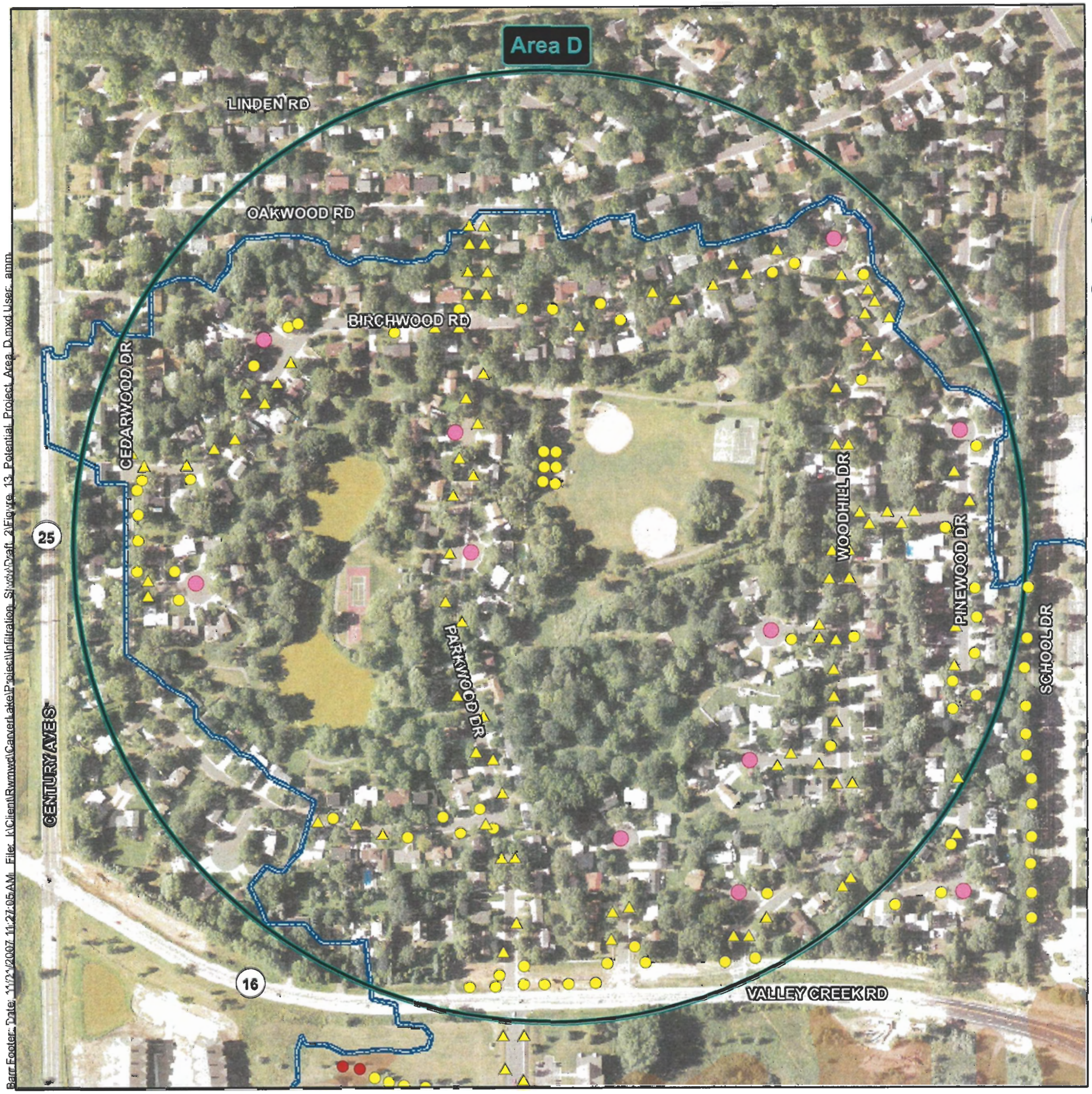

- Potential Bumpout Areas with Filtration
- Potential Bumpout Areas with Infiltration
- Potential Rainwater Gardens with Filtration
- Potential Rainwater Gardens with Infiltration
- Potential Impervious Reduction Areas
- Potential Project Areas
- Wellhead 50-foot Buffer
- Low Infiltration Soils (Hydrologic C and D Soils)
- Carver Lake Subwatershed
- Groundwater Depth Less than 10 Feet

N

350 0 350
Feet

100 0 100
Meters

Ramsey-Washington Metro Watershed District

Figure 13

POTENTIAL PROJECT AREA D
Carver Lake Subwatershed
Ramsey-Washington Metro
Watershed District

Barr Footer: Date: 11/21/2007 11:27:05 AM File: I:\Client\Rwmwd\CarverLake\Project\Infiltration_Study\Draft_2\Figure 13 Potential Project Area D.mxd User: amm constructed with monitoring and maintenance in mind in order to assess the performance of each project and to ensure that each project functions as intended in the years following construction.

The estimated water quality volume that could be achieved (with and without bump-outs) as well as the associated construction maintenance costs for the projects is shown for each neighborhood in Table 7 below.

Table 7: Water Quality Volume Achieved by Proposed Projects in Each Targeted Neighborhoods "A" Through "D"

Neighborhood Area	Total Area (acres)	Water Quality Volume Achieved (Rainwater Gardens and Bump-Outs) (ac-ft)	Water Quality Volume Achieved (Excluding Bump-Outs) (ac-ft)
A	71.6	0.40	0.38
B	78.9	0.40	0.19
C	68.4	0.54	0.16
D	109.3	0.54	0.22

Note: Water quality volumes from filtration BMPs are not included in this table.

Further investigation into specific implementation plans in each neighborhood will be necessary. Underground utilities and easements must be located in order to plan for BMP implementation, and soil borings must be conducted in each proposed infiltration basin location. The need for neighborhood education and involvement and collaboration can not be over-emphasized. When residents understand the benefits of stormwater management projects they are more willing to participate and take ownership of the projects in which they're involved.

The process of defining which projects to pursue will be multi-phased. This is intended to be an annual program that would be conducted as follows:

Year 1: Contact residents to gage support in two or three neighborhoods, determine which one neighborhood is the best candidate.

Conduct soil borings and utility locates in the target neighborhood.

Prepare preliminary design and obtain city approvals.

Obtain City/County agreements to maintain the BMPs planned for construction.

Year 2: Implement projects.

Start the process again (new "Year 1"): Contact residents to gauge support in two or three neighborhoods, determine which neighborhood is the best candidate.

4.2 Role of the City of Woodbury

City support for and involvement in these projects (both those pursued as a part of the District's volume reduction rule as well as those supplemental projects pursued to meet the annual volume reduction goal) will be critical. It is likely that the Carver Lake TMDL report (to be written at some point in the next 10 years) will refer to the 20-year impact of implementing the volume reduction rule as a key factor in meeting the MPCA's deep lake standard. As such, it will be imperative that the cities cooperate in the process of finding locations for project implementation, opportunities for public education and the maintenance of the projects that are ultimately pursued. This is an example of stakeholder involvement in the TMDL process.

4.3 Other Considerations

In moving forward with focused neighborhood projects it may be helpful in the future to consider these additional practices to improve the District's chances in meeting their water quality volume goals.

4.3.1 Ordinance Review

Sometimes city ordinances inhibit the possibility of BMP implementation. For example, ordinances might require wide streets and excessive street parking, parking requirements for businesses might not match the use of the facility, trees might not be allowed to be planted in public right-of-ways, and trees might not be required in parking lots, among others. It is suggested that RWMWD work with the City of Woodbury to make future changes to ordinances to better allow for implementation of BMPs, reduce impervious surface and promote Low Impact Development (LID) practices. Materials from University of Minnesota Extension Service NEMO (Nonpoint Education for Municipal Officials) Program (where appropriate) could be used to educate policy makers about the need for new or improved city policies.

4.3.2 Tree Planting

Trees play a critical role in reducing stormwater runoff volume and peak intensity. Tree canopy intercepts much of the precipitation during a storm event, allowing the rainwater to evaporate, or slowly trickle down to the ground as stem flow where it is more readily infiltrated. Studies have shown that between 10 and 40 percent of all precipitation through the tree canopy is intercepted and removed from stormwater (Xiao, 2000).

Trees also enhance infiltration by loosening soil with their roots and creating natural channels for water infiltration. Trees also change the nature of the ground surface by creating ground clutter and forming natural depressions around the root system, which promotes storage and infiltration, in addition to slowing down runoff rates. There is an added water quality benefit for the rain that falls through the tree canopy and runs off as stormwater. The leaves and stems slow the rain, reducing the intensity of rainwater impact on the ground, reducing erosion, and thereby reducing sediment loading in stormwater runoff.

Because of these benefits, a street and parking lot tree planting program in partnership with cities within the watershed may be beneficial to help achieve the water quality volume annual goal. Multiple other benefits result from tree planting and indirectly benefit the watershed as well. This program proposal would assist cities in tree plantings on public property, while a second educational program would teach private land owners about appropriate tree selection and planting, and potentially provide discounted trees. Together these two tree planting programs would substantially increase the tree canopy in the watershed and restore a hydrologic cycle that more closely mimics presettlement conditions. Trees can also be planted in biofiltration and infiltration basins and added to parking lot infiltration islands.

The addition of tree boxes for stormwater collection and infiltration provides runoff volume reduction and improves tree health. This approach holds particular promise in retrofit situations in highly impervious areas. The photo below was taken at City Hall in Minnetonka and shows young trees planted to improve infiltration in an infiltration strip in the middle of a parking lot.

Figure 14 is a detail of a tree box constructed below an impervious section of sidewalk. A grate constructed around the tree trunk (not shown in the figure) would allow water to pass into the soil around the trees roots. An optional collection drain, below the tree, is shown in the detail.

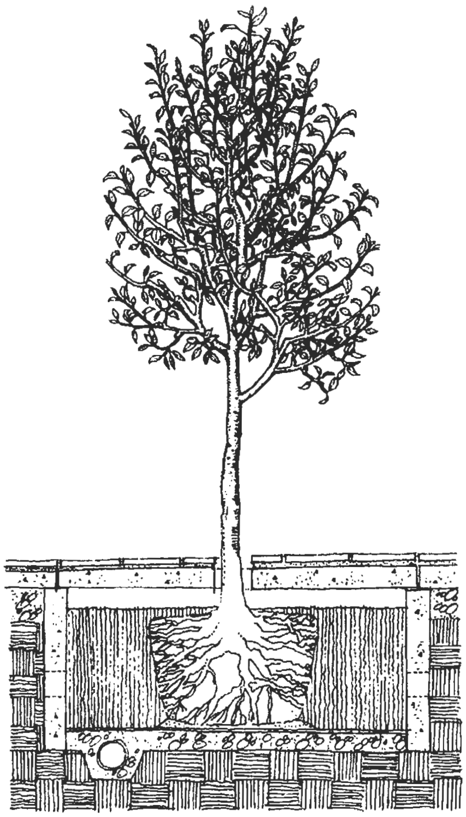

Figure 14: Detail of a tree box under a section of sidewalk.

It should be noted, however, that some studies have also shown that trees growing near directly connected impervious areas may actually increase the *concentration* of sediments and phosphorus in runoff during the fall, as leaves collect on streets (Waschbusch et al., 1999). This finding indicates the importance of street sweeping programs to remove fallen leaves from streets, as they accumulate.

Appendix B contains a discussion of the benefits of trees as cited by the United States Department of Agriculture. Appendix C contains a summary of a recent study by the City of Minneapolis on the stormwater volume reduction benefits of trees.

4.4 Monitoring

It will be important to monitor the long-term effectiveness of all of the different projects being constructed in the Carver Lake Subwatershed. The Macbeth and Juliet Court projects are two examples of how monitoring could be conducted at newly implemented sites. The impact of future infiltration projects will be monitored through the continuation of both individual sites and within the lake itself.

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Appendices

Appendix A

Evaluation of the Water Quality Effects from Implementation of Infiltration Practices in the Carver Lake Subwatershed

BARR

Memorandum

To: Ramsey-Washington Metro Watershed District Infiltration Research Project File

From: Greg Wilson

Subject: Evaluation of Water Quality Effects from Implementation of Infiltration Practices in Carver Lake Watershed

Date: October 20, 2000

Project: 23/62-031 000 020

Cc: Brad Lindaman

This memorandum provides an evaluation of the expected water quality improvement for Carver Lake following implementation of infiltration practices within the watershed. The discussion in this memorandum describes the assumptions made for this water quality analysis, results of the evaluation, and provides recommendations for further study based on the results and limitations of this analysis.

Basis and Assumptions for Water Quality Analysis

Both the P8 Urban Catchment Model (P8) and an in-lake water quality model were calibrated to observed data and used to make predictions about the water quality of Carver Lake for the Draft Carver Lake Strategic Lake Management Plan (Draft Management Plan), prepared by Barr Engineering (August 2000). P8 estimates the water and phosphorus loads entering the lake from its watershed and can be used to evaluate Best Management Practices (BMPs). The goal of this analysis was to evaluate how implementation of infiltration practices in the Carver Lake watershed would influence the in-lake water quality, under ultimate land use conditions. The following water quality scenarios were completed for the Draft Management Plan to predict the summer average total phosphorus concentration in Carver Lake:

- **Scenario 1:** Existing land use conditions
- **Scenario 2:** Ultimate land use conditions (with no control of increased loads due to newly developed areas in the watershed).
- **Scenario 3:** Increased detention for the ponds in CARV-22 and CARV-60, mainenance for ponds CARV-78 and CARV-66.
- **Scenario 4:** Alum treatment of flows in CARV-79
- **Scenario 5:** Alum treatment of flows in CARV-79, increased detention for the ponds in CARV-22 and CARV-60.

Figure 18, based on the corresponding figure from the Draft Management Plan, shows the predicted concentrations for each of these five scenarios. Two additional modeling scenarios were evaluated as part of this analysis:

- **Scenario 6:** Infiltration Storage Volume Equivalent to 0.25" Over All Directly Connected Impervious Areas in the Watershed.
- **Scenario 7:** Infiltration Storage Volume Equivalent to 0.50" Over All Directly Connected Impervious Areas in the Watershed

Scenarios 6 and 7 utilize the P8 models developed for Scenario 2, with the addition of an infiltration basin for each one of the three major watersheds that drain to Carver Lake. Each infiltration basin modeled in P8 was designed to capture and infiltrate an amount of stormwater runoff equal to the volume of either 0.25 inches (Scenario 6) or 0.5 inches (Scenario 7) over the total area of directly connected impervious surfaces in the respective watersheds. Based on this infiltration storage volume, the surface area of each infiltration basin was determined by assuming an average depth of one foot and a maximum depth of 18 inches. An infiltration rate of 0.25 inches per hour was used for each infiltration basin, based on the assumption that the deepest portion of the basin should completely drain within 72 hours after each runoff event (18 inches/72 hours = 0.25 in./hr.). This approach is consistent with the infiltration design guidelines from the draft rules that have been developed by both the Rice Creek and Riley-Purgatory-Bluff Creek Watershed Districts. Finally, each infiltration basin was placed at the furthest downstream point in the P8 model network and it was assumed that all of the infiltrated water from each infiltration basin would not represent a water or phosphorus load to Carver Lake.

Water Quality Effects of Infiltration Practices in Carver Lake Watershed

The results of this analysis indicate that infiltration practices designed to capture between 0.25 inches (Scenario 6) and 0.5 inches (Scenario 7) of volume over the directly connected impervious areas will greatly improve the water quality of Carver Lake. The P8 modeling results of Scenario 6 indicate that the total water and phosphorus loads from the three watersheds will be reduced by 62% and 72%, respectively. The P8 modeling results of Scenario 7 indicate that the total water and phosphorus loads from the three watersheds will be reduced by 81% and 89%, respectively. The load reductions for Scenarios 6 and 7 result in predicted average summer total phosphorus concentrations in Carver Lake of 34 μg/L and 20 μg/L, respectively. Figure 18 (attached) shows how the predicted in-lake phosphorus concentrations for Scenarios 6 and 7 compare with the other BMP modeling scenarios presented in the Draft Management Plan. The Watershed Management Plan (Barr Engineering, 1997) states that the summer average total phosphorus goal for Carver Lake is 30 μg/L. Figure 18 shows that implementation of watershed infiltration practices at a level between that assumed for Scenarios 6 and 7 may provide the only means to meet this water quality goal for Carver Lake during an average year.

Recommendations from this Analysis

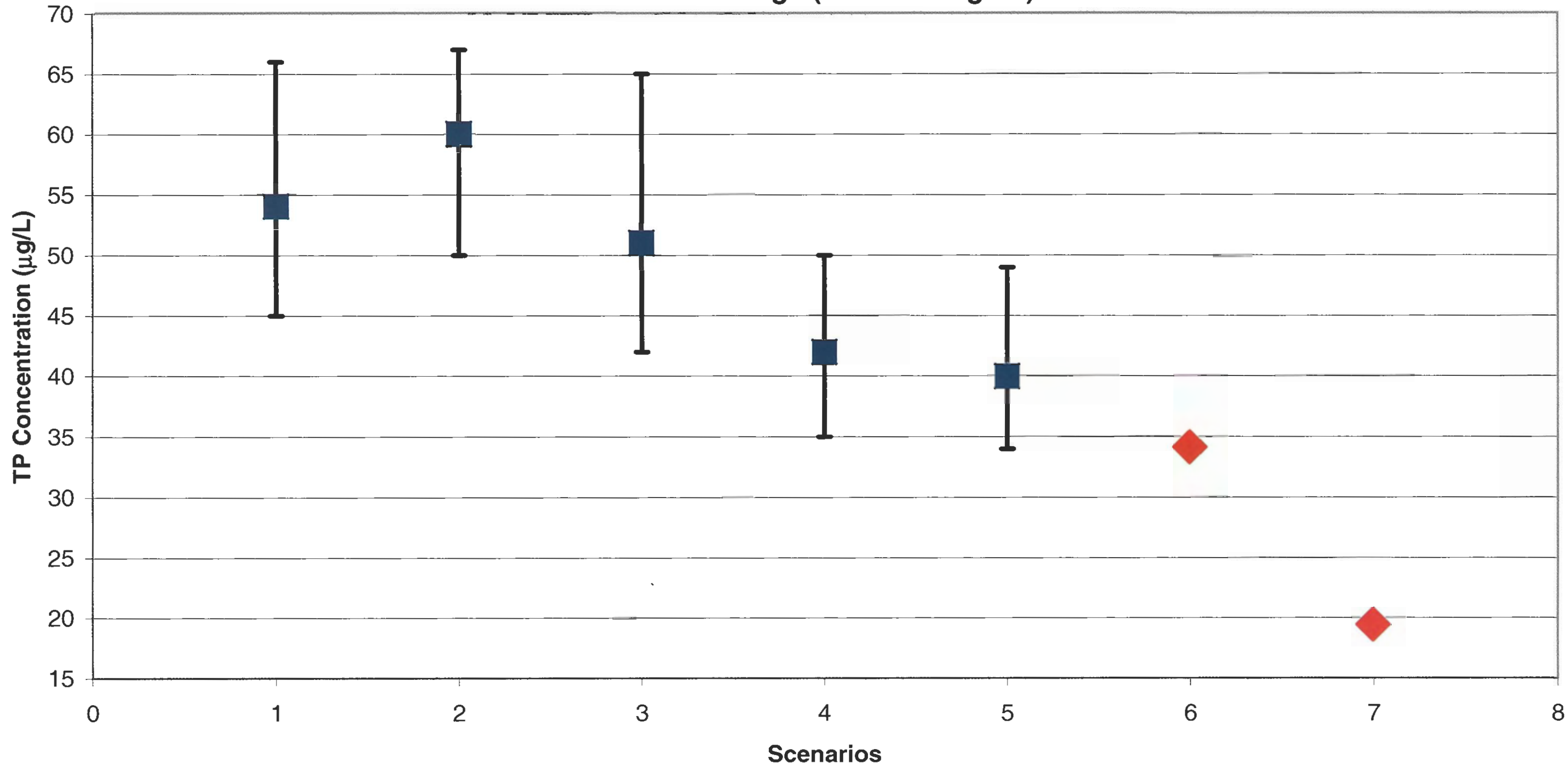
In all likelihood the total phosphorus concentrations predicted for Carver Lake in each infiltration scenario represent the optimistic boundary of what could be attained for the lake following implementation of each infiltration design scenario, given the assumptions that were made for this analysis. This is due to the fact that the main assumption made for this analysis was that the infiltrated water from the infiltration basins would not contribute any water or phosphorus to Carver Lake. Depending upon groundwater flow patterns in the Carver Lake watershed, it is more reasonable to believe that some portion of the infiltrated water (with some of its associated phosphorus) will represent groundwater loading to the lake. The following factors may also limit the conclusions that can be drawn from this analysis:

- Monitoring of infiltration devices has been limited with regard to long-term effectiveness, potential applicability to different site conditions and designs, performance in cold weather climates, documenting the factors associated with their success or failure, and determining the type and frequency of maintenance that is necessary for these areas.

- Few, if any, published studies have been done involving the calibration and verification of P8 to observed data collected on infiltration devices. Modeling based on a detailed monitoring program should be done to evaluate P8 (and other water quality models) uses, limitations, prediction uncertainty, and applicability to various infiltration practices and site conditions.
- A thorough understanding of the site conditions throughout the watershed is necessary to reliably predict the pollutant removal effectiveness and assess the relative cost and potential applicability of the various types of infiltration practices.

The limitations of this analysis notwithstanding, it appears that implementation of infiltration practices within the Carver Lake watershed has the potential to provide significant water quality improvements. Therefore, it is recommended that the feasibility, cost-effectiveness and modeling of infiltration practices be evaluated in more detail to determine its potential benefits for Carver Lake and the remaining water bodies in the District.

Figure 18
Predicted Total Phosphorus Concentration in Carver Lake
Summer Average (June to August)



Note: The error bars indicate the range of possible TP concentrations predicted for each scenario, based on a range of climatic conditions (dry to wet).

The diamonds and square points between the bars represents the TP concentration predicted for the average climatic year.

Scenario 1: Existing land use conditions

Scenario 2: Ultimate land use conditions (with no control of increased loads due to newly developed areas in the watershed).

Scenario 3: Increased detention for the ponds in CARV-22 and CARV-60, mainenance for ponds CARV-78 and CARV-66.

Scenario 4: Alum treatment of flows in CARV-79

Scenario 5: Alum treatment of flows in CARV-79, increased detention for the ponds in CARV-22 and CARV-60.

Scenario 6: Infiltration Storage Volume Equivalent to 0.25" Over All Directly Connected Impervious Areas in the Watershed.

Scenario 7: Infiltration Storage Volume Equivalent to 0.50" Over All Directly Connected Impervious Areas in the Watershed.

Appendix B

The Benefits of Trees

Excerpt from United States Department of Agriculture Brochure on the Benefits of Trees

Appendix B: The Benefits of Trees

Excerpt from United States Department of Agriculture Brochure on the Benefits of Trees

Trees provide many benefits to the environment and community. The past few decades of tree research has documented and quantified the benefits of trees. Early on, researchers were quantifying the amount of greenhouse gases trees remove from the atmosphere (about ½ ton of carbon dioxide per tree per year) and pollutants (about 4.3 pounds of pollutants per tree per year). Since then, researchers have begun to document an ever growing list of benefits that may not be so obvious.

Quick Facts

- Trees remove pollutants and greenhouse gasses
- Trees reduce the cost of electricity for cooling
- Trees improve the flow of water into the groundwater table and reduce the flow of water into the storm water system
- Trees are good for business
- Trees add to a property's value
- Tree benefits are three times their costs

Benefits to the Environment

In addition to the direct removal of greenhouse gases and pollutants, mentioned above, trees:

- Reduce temperatures by shading streets, sidewalks and other hardscapes, resulting in reduced use of electricity for cooling and a corresponding reduction of any non-renewable fuels used to generate that electricity. Furthermore, there is a reduction in the emission of greenhouse gases and pollutants associated with the use of fossil fuels.
- Increase the amount of water that reaches the groundwater table as rainfall follows tree root systems down below the soil surface.
- Intercept rain with leaves and branches reducing the amount of water that reaches the storm sewer system, particularly when properly placed to grow over streets, sidewalks, parking lots and rooftops. This reduces downstream the erosive force of large volumes of runoff to natural water bodies, and flooding.
- Add organic matter to the soil which further improves the water holding capacity of the soil.
- Improve the resiliency of soil to respond to rain events by removing water from the soil which can reduce saturated conditions which exacerbate storm water load. One mature tree can capture over 5,000 gallons of water in a year.
- Reduce soil erosion with dense root systems. Less soil, contaminated or clean, reaches the storm water system, creeks and rivers.

For these reasons, the Environmental Protection Agency recommends an average tree cover of 50 percent for suburbs in our area of the United States.

Benefits to the Community

Trees help promote pride in the community and a sense of place. Other benefits of trees affect us either directly or indirectly in our daily lives, or have direct effects on our roads, utilities and businesses. Here is some of what we know to be true:

- Street trees are an important factor in reducing road maintenance costs. Recently, researchers showed that streets shaded by medium-sized trees required less frequent resealing than streets fully exposed to the sun.
- Tree-filled neighborhoods show lower levels of domestic violence.
- Street trees can calm traffic and lower traffic speed by reducing the perceived width of street. Streets without trees have the opposite effect, appearing "wide open".
- Trees help reduce noise levels.
- Trees are known to shorten hospital stays.
- Trees can reduce workplace stress.
- Trees can be used to screen unsightly views.
- Our trees are part of the legacy from those who came before us.
- Healthy trees in neighborhoods enhance property values.
- The sales price for a home increases by about 1 percent for each large front yard tree.
- But a single, large, specimen tree in a yard can add 10 percent to the property's value.

Trees are also good for business. Surveys of shoppers in commercial districts with tree-lined streets reported that:

- They shop there more frequently.
- They shop for longer periods of time.
- They are more willing to pay for parking.
- They spend, on average, 12 percent more on goods than they do in areas without trees.

Adding it All Up

When the benefits that can be quantified are weighed against the cost of trees (i.e., purchase, planting, pruning, and removal), these **benefits outweigh the cost by a margin of about three to**

one. This doesn't include the benefits we cannot quantify such as community pride or reduction in stress. Communities continue to reap these benefits. These benefits started with proper planting of trees on streets and other public property, and by encouraging appropriate planting on private property. It is important to continue planting trees in the watershed and be sure the urban forest is properly maintained to prevent an erosion of these benefits and an increase in costs associated with neglect.

Appendix C

City of Minneapolis Study on the Benefits of Trees

Appendix C: City of Minneapolis Study on the Benefits of Trees

In June 2005, the City of Minneapolis published a study on the benefit that trees provide to the community (McPherson, 2005). One of the benefits that were analyzed was a reduction in stormwater infrastructure costs due to tree interception. The city first determined how much water is intercepted by each species of tree and found a total reduction in stormwater runoff for each species. The city then calculated a total stormwater infrastructure cost savings of $0.027/gallon based on the 20-year life-cycle cost of a 5-acre pond. This is a more expensive assumption than other studies have used due to the higher costs of land acquisition in an urban area. Approximately half of the cost in the assumption is based on the land acquisition costs.

The study determined that annually Minneapolis's city-managed trees intercept and evaporate 44.75 million cubic feet of rainwater, or 1,685 gallons per tree. The study found that different species of trees saved between $4 (Gingko) and $190 (American elm) each, and the average tree saved $46 per year in stormwater infrastructure costs. The trees that performed best had larger leaves and stem area.

Minneapolis calculated that the total stormwater savings for all the trees under its care is $9,071,809, while the total costs associated with planting, maintaining and removing the trees is $9,209,041 (roughly equal). However, other benefits are not included in this calculation- if savings based on energy demand reduction, reduced CO_2, improved air quality and enhanced aesthetics are included, trees can be worth three times their investment. When these other benefits that can be quantified are weighed against the cost of trees, these benefits outweigh the costs by a margin of about three to one.

Using the methodology in the Minneapolis study, the addition of 774 trees (of varying species) in the Carver Lake watershed would provide the same water quality benefit as a stormwater pond with a storage capacity of 1 acre-foot. Even higher savings would be realized by planting trees with larger leaves. To maximize the stormwater removal, trees should be planted to canopy impervious surfaces. Trees would be most effectively placed along streets, in parking lots, and alongside buildings.