Crosby Lake Management Plan

Capitol Region Watershed District
Saint Paul, MN

Prepared in partnership with City of Saint Paul and other agencies

Prepared by Wenck Associates, Inc.

October 2012

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BY CAPITOL REGION WATERSHED DISTRICT

Prepared in partnership with:

City of Saint Paul
MN Pollution Control Agency
Metropolitan Council
MN Department of Natural Resources
MN Department of Transportation
National Park Service
Ramsey County
Friends of the Mississippi River
The Friends of the Parks and Trails of Saint Paul and Ramsey County
The Crosby Lake Management Plan Citizen Advisory Committee

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Saint Paul, Minnesota
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1.0 Introduction

1.1 PURPOSE

Capitol Region Watershed District (CRWD) received a grant in late 2009 from the MN Clean Water Partnership Program, which is administered by MN Pollution Control Agency, for the development of a management plan for Crosby Lake, one of four lakes located in CRWD. Although Crosby Lake currently meets water quality standards, it has not been immune to the effects of urbanization. Water quality has declined since 2005, which warrants the need for developing a framework for the protection and improvement of Crosby Lake.

The goal of the plan is to protect the water quality and natural hydrologic regime of Crosby Lake by applying science-based lake management implementation activities. The objectives of the plan are:

- to assess the current conditions of the lake;
- to identify the issues of concern and the priority watershed areas for management;
- to develop management goals and objectives; and
- to determine the implementation opportunities and activities for protecting and improving the water quality, ecological, aesthetic and recreational benefits of the lake.

1.2 THE STRATEGIC PLANNING PROCESS

CRWD's first generation 10-Year Watershed Management Plan, adopted in 2000, identified the need to prepare lake management plans for CRWD's lakes. The purpose of these plans is to address resource concerns and future management of each lake and ensure protection and improvement of lake health. Management plans have been developed and are being implemented for Como Lake in Saint Paul (CRWD, 2002), Loeb Lake in Saint Paul (CRWD, 2009) and Lake McCarrons in Roseville (CRWD, 2003).

Essential in developing a comprehensive lake management plan that defines all lake-related issues and explores all opportunities for management is broad stakeholder participation and input during the development process. Whereas CRWD is the lead or project sponsor for the Crosby Lake Management Plan, the City of Saint Paul, which owns and maintains the park surrounding Crosby Lake—Crosby Farm Regional Park—is a key partner. Additional support for the project is being provided by other federal, state and local government agencies, non-profit organizations, and the public. Two advisory groups, technical and citizen based, were convened to bring all partners and stakeholders to the table in developing the management plan.

1.2.1 Technical Advisory Group

The technical advisory group comprised staff from government agencies and non-profit groups including the City of Saint Paul, National Park Service (NPS), Ramsey County, MN Pollution Control Agency (MPCA), Minnesota Department of Natural Resources (MN DNR), Metropolitan Council, MN Department of Transportation (MnDOT) and the Friends of the Mississippi River (FMR). The technical advisory group assisted in determining and prioritizing the issues of most concern in Crosby Lake and in developing lake management goals and actions to address the issues. The technical advisory group met three times over the course of the project.

In October 2010, CRWD kicked off the project by presenting background information about CRWD and Crosby Lake and the goals, objectives, elements and timeline for developing the management plan. A second meeting was held in December 2010 to discuss and receive feedback on preliminary water quality goals and management projects and activities. A third meeting was held in summer 2011 to present the draft management plan and receive comments.

1.2.2 Citizen Advisory Group

CRWD convened a second advisory group consisting of citizens interested in protecting and improving Crosby Lake. This citizen advisory group included members of CRWD's Citizen Advisory Committee, CRWD residents, frequent visitors to the park and other interested citizens. CRWD received assistance in engaging the citizen advisory group from Minnesota Waters, a non-profit group dedicated to engaging and training citizens in protection of MN water resources.

Similar to the technical advisory group, three meetings were held with the citizen advisory group. In late September 2010, the first meeting focused on "getting to know CRWD" and the management plan development process. Information on CRWD and Crosby Lake and the process for developing the management plan was presented.

The purpose of the second meeting held in December 2010 was to obtain citizen input on their priorities and concerns for Crosby Lake and the activities and projects to address these concerns and priorities. Small group discussions were held to identify the top three concerns, challenges or issues pertaining to Crosby Lake and the ideas for addressing them. The top public concerns included protecting water quality, minimizing trash to the lake and river, maintaining Crosby Farm Regional Park as a natural, passive park and increasing public awareness about the issues facing the lake and river. All public input was reviewed and considered for inclusion into the management plan by CRWD. See Appendix C for the second citizen advisory group meeting minutes.

At the third meeting in summer 2011, CRWD presented the draft management plan to the citizens and described how the public's ideas were incorporated into it. The citizens also provided comments on the draft management plan.

2.0 Watershed and Lake Characterization

2.1 WATERSHED DESCRIPTION

CRWD is a 41-square mile watershed located in Saint Paul, Roseville, Maplewood, Falcon Heights and Lauderdale that drains to the Mississippi River.

The Crosby Subwatershed, one of 15 major subwatersheds in CRWD, is located in the southwestern portion of the watershed district (Figure 2-1). The watershed is fully developed except for two parks, Crosby Farm Regional Park and Highland Park, which includes Highland National Golf Course. It includes 35E Freeway running from north to south on its eastern side. The watershed has two major flow patterns with 234 acres draining to Crosby Lake and the remaining 1,291 acres draining directly to the Mississippi River (Figure 2-2). Subwatersheds CRO1, CRO7, and CRO3 flow to CRO5 which then discharges directly to the Mississippi River via a ditch along Interstate 35E (Figure 2-2). CRO2 also discharges to the Mississippi River mostly as overland flow. Subwatersheds CRO4 and CRO6 flow to Little Crosby and Crosby Lake.

2.1.1 Land Use

Land use is primarily single-family, residential in the northern portion of the Crosby Subwatershed with commercial and industrial land uses in the southern and eastern portions along Shepard Road and West Seventh Street (Table 2-1, Figure 2-3).

Table 2-1. Land Use in the Crosby Subwatershed

Land Use	Subwatershed							Total Area (acres)	Percent
	CR01	CR02	CR03	CR04	CR05	CR06	CR07		
	Area (acres)								
Commercial	6	12	3	--	7	5	2	35	2%
Highway	1	23	1	--	50	--	--	75	5%
Industrial		23	14	--	5	41	5	88	6%
Institutional	25	--	--	--	0.5	--	10	35.5	2%
Multi-Family Residential	19	3	1	5	13	12	1	54	4%
Open Water		9	--	8		71		88	6%
Parks and Recreation	18	316	--	21	10	66	239	670	44%
Single Family Residential	253	0.4	0.5	4	26	1	110	394.9	26%
Undeveloped	2	68	3		11	1		85	6%
Total	324	455	23	37	123	197	366	1,525	100%

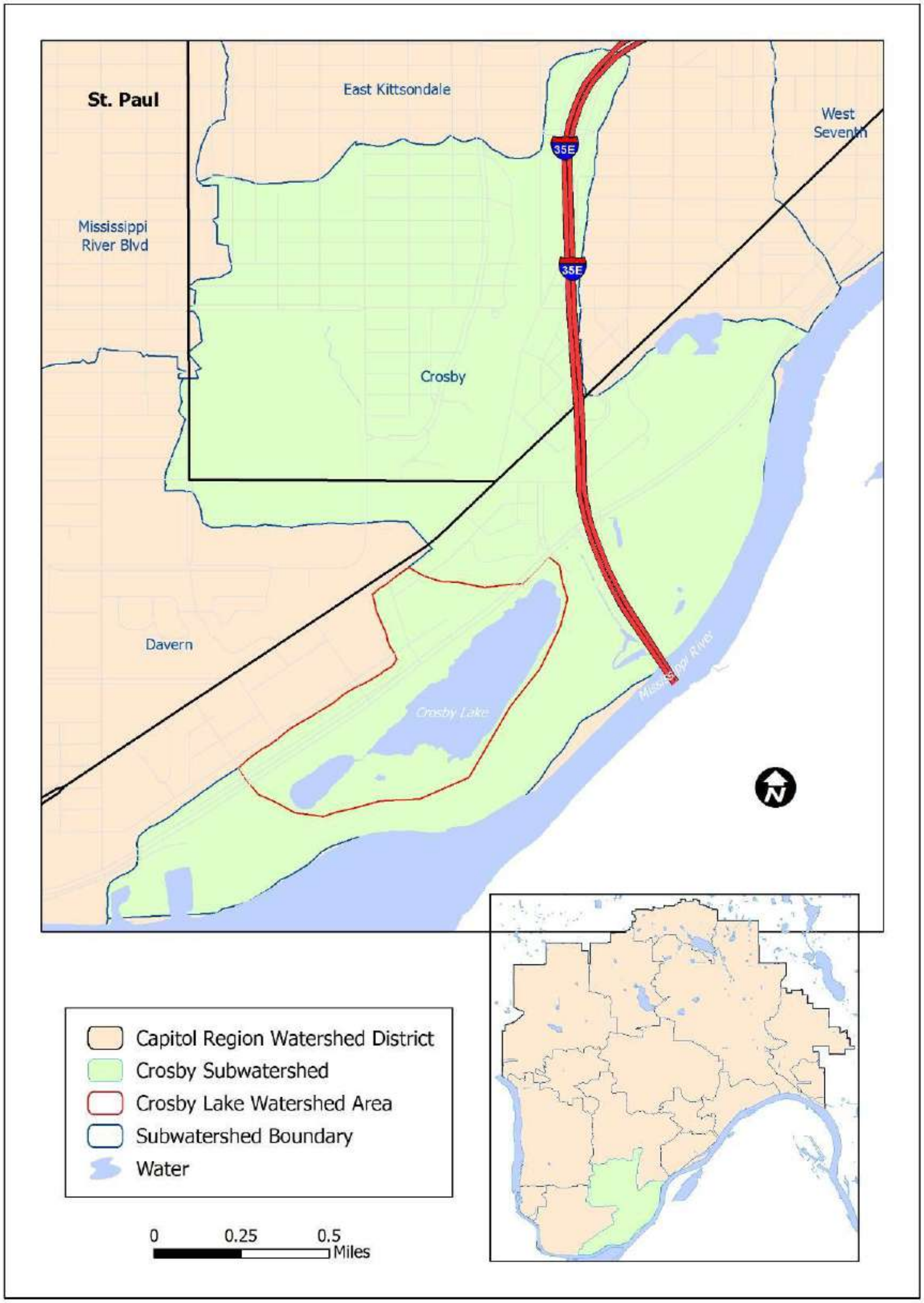

Figure 2-1. The Crosby Lake Watershed and Crosby Subwatershed (Drains to Mississippi River)

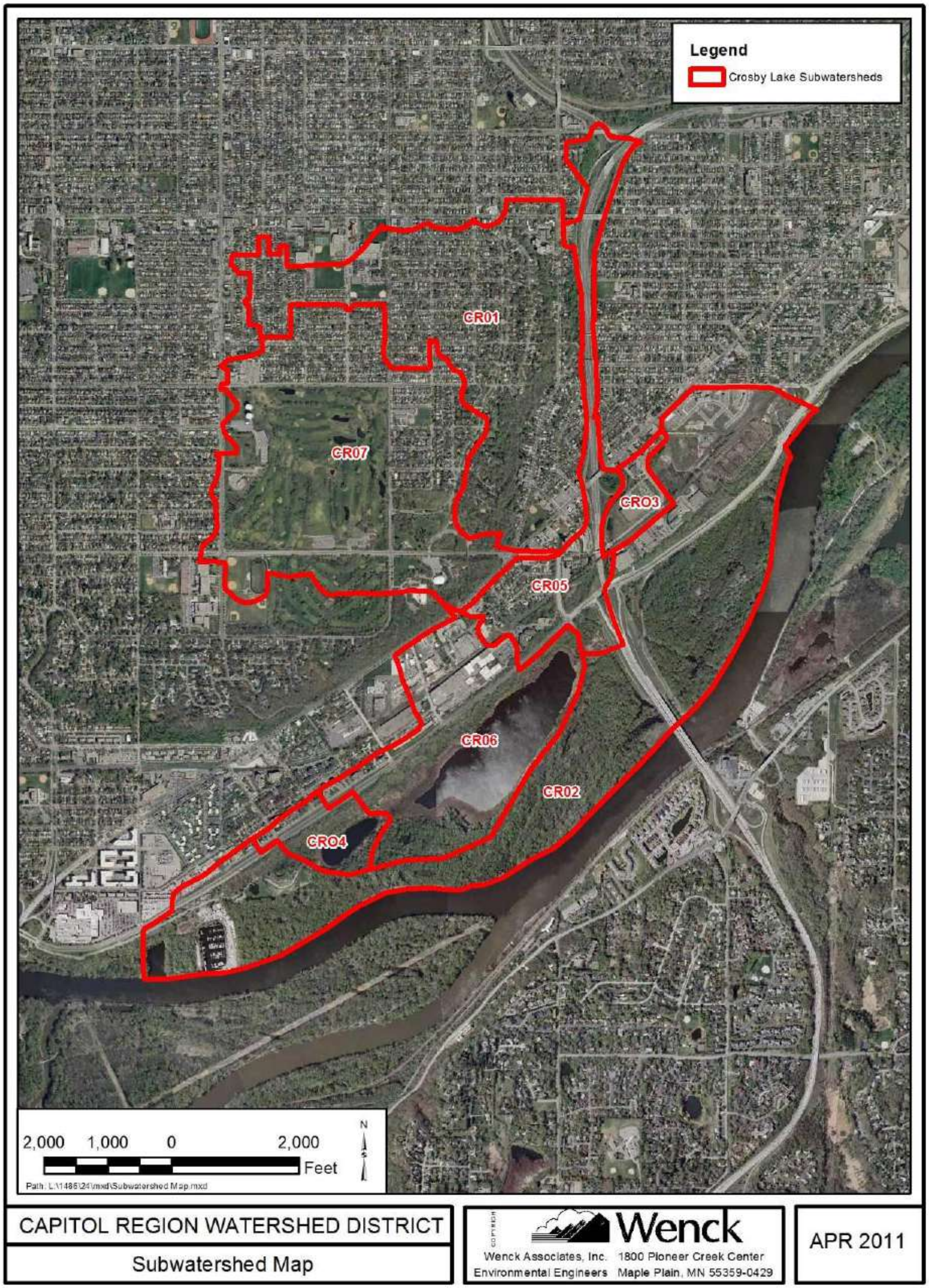

Figure 2-2. Crosby Subwatersheds

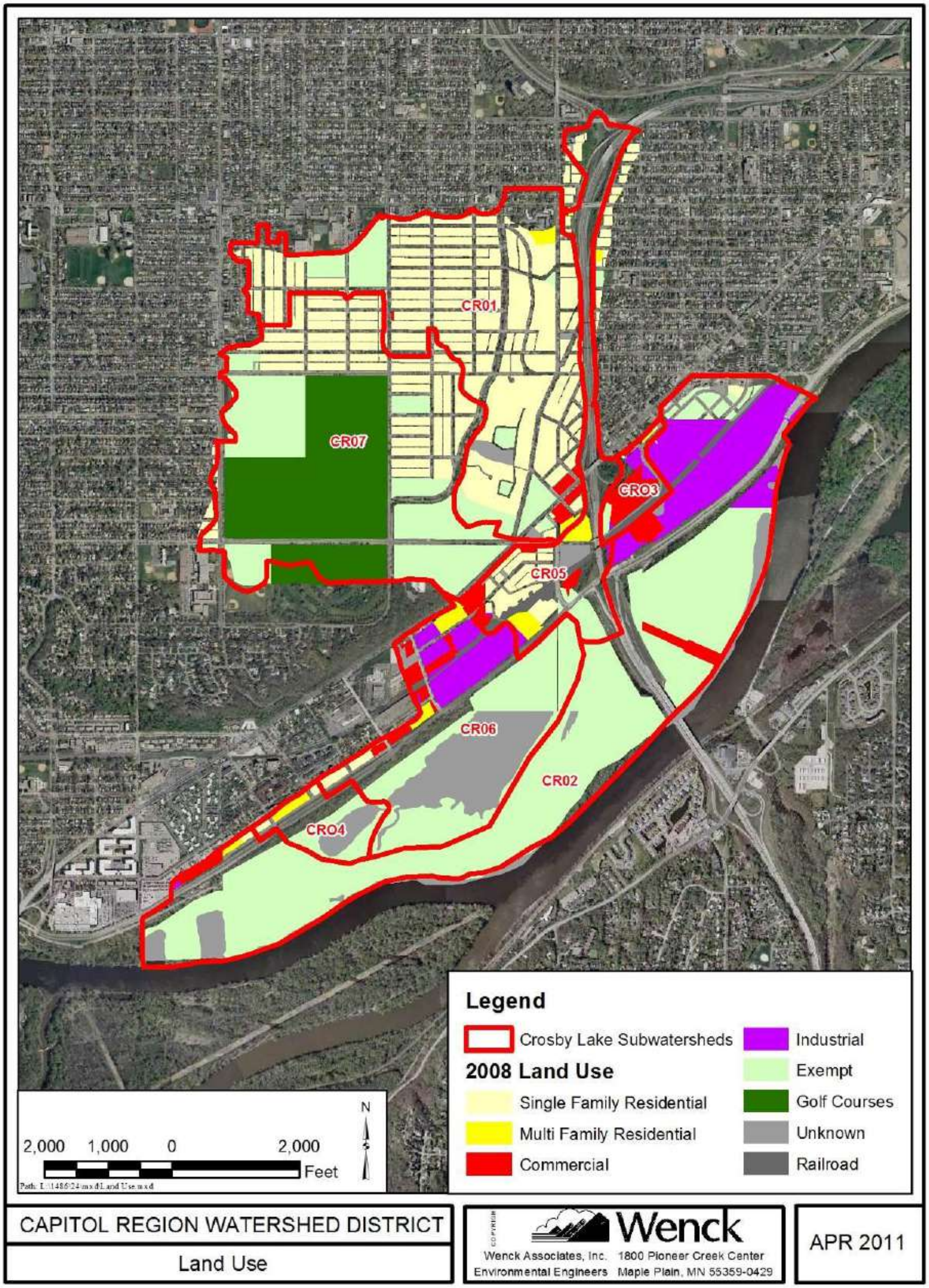

Figure 2-3. Land Use in the Crosby Subwatersheds

2.1.2 Soils

Hydrologic soil groups in the Crosby Subwatershed are presented in Figure 2-4. It is important to note that many areas in the watershed are not characterized and are likely dominated by fill brought in during urbanization and development of Saint Paul. The majority of identified soils demonstrate a moderate potential for infiltration. However, most of the areas where rain gardens may be implemented are currently uncharacterized and need to be evaluated at the site level to determine the effectiveness of a rain garden.

2.1.3 Watershed Water Quality

Stormwater quality monitoring is not currently conducted in the Crosby Subwatershed. Stormwater quality was estimated by updating a previously developed P8 model for the Capitol Region Watershed District. The Crosby Lake P8 model was updated with the new watershed boundaries for the Crosby Subwatershed and executed for the 2000 through 2009 period using a Minneapolis-Saint Paul Airport precipitation file. Average annual output from the model was compiled for the model period (Table 2-2).

Table 2-2. Average Annual Flow, TSS and TP for the Crosby Subwatershed and Crosby Lake Subwatershed from 2000 through 2009

	Watershed	Flow	Total Suspended Solids		Total Phosphorus	
		(acre-feet)	pounds/year	mg/L	pounds/year	µg/L
Crosby Subwatershed (Direct River Discharge)	CRO1	261	41,450	58	179	250
	CRO2	201	17,124	31	82	159
	CRO3	29	2,980	37	19	233
	CRO5	141	27,098	70	104	269
	CRO7	174	57,983	123	167	342
	Total to River	806	146,635	67	551	251
Crosby Lake Subwatershed	CRO4	14	5,275	134	15	361
	CRO6	102	20,991	76	77	276
	Total to Crosby Lake	116	26,266	83	92	292

Because water quality in the Crosby Subwatershed has not been monitored, the P8 model output represents the current best estimate of water quality discharging to the Mississippi River and Crosby Lake. Output concentrations are generally consistent with monitored data in other subwatersheds in the District. Estimated water quality of stormwater discharging from the Crosby Subwatershed had an annual average concentration of 134 milligrams per Liter (mg/L) of TSS and 361 micrograms per Liter (µg/L) of TP for Little Crosby Lake (CRO4) and 76 milligrams per Liter (mg/L) of TSS and 276 micrograms per Liter (µg/L) of TP for Crosby Lake (CRO6).

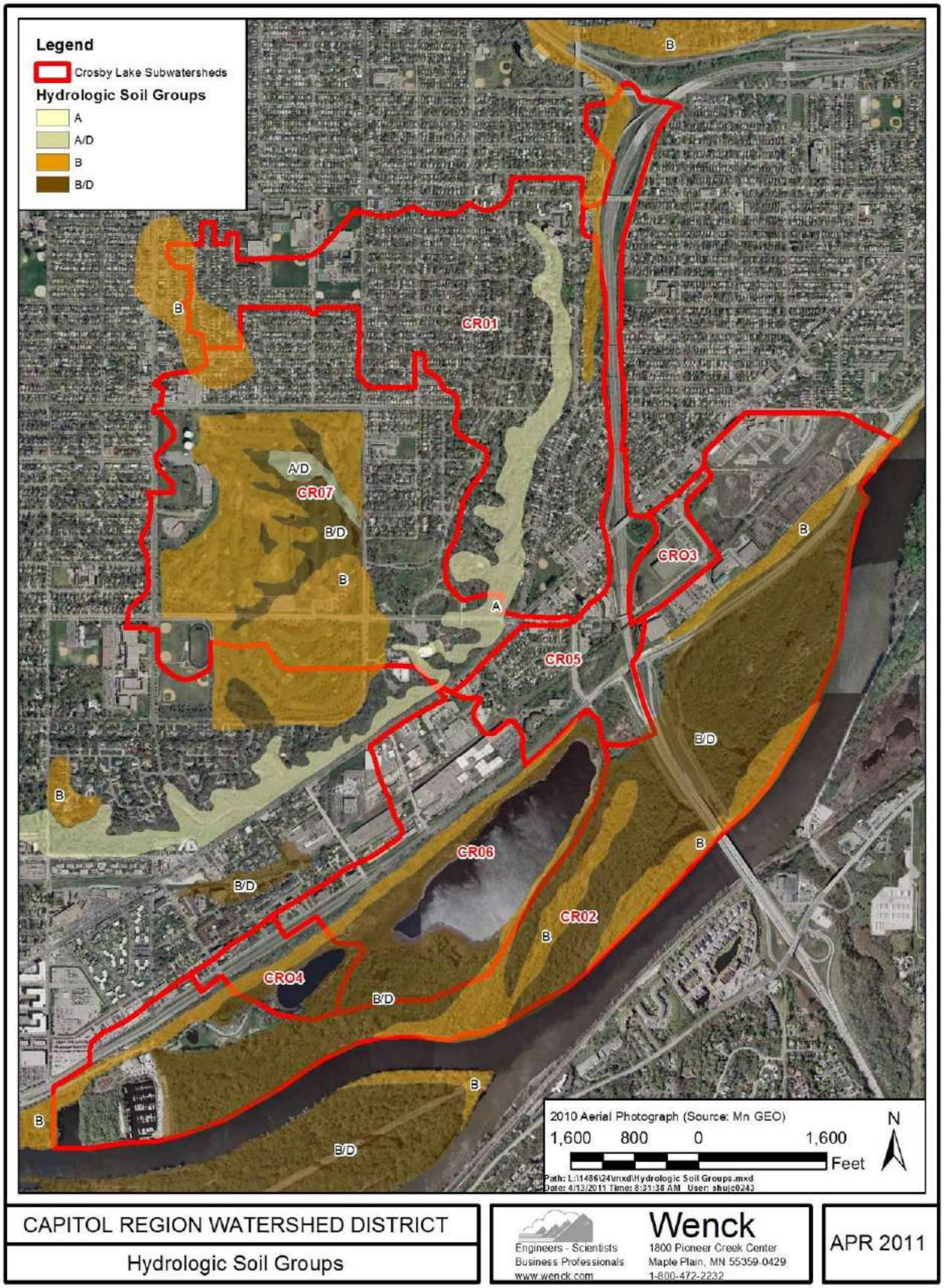

Figure 2-4. Soil Groups in the Crosby Subwatersheds

2.2 CROSBY LAKE

2.2.1 Crosby Farm Park

History

Minnesota is the homeland of the Dakota Oyate (Nation), Minnesota's oldest indigenous people. Crosby Farm Regional Park is located within *Bdote*, a culturally and historically significant site of the Dakota Nation. *Bdote* is sacred land at the confluence of the Mississippi River (*HaHa Tanka*), the Minnesota River (*Mnisota Wakpa*), and Minnehaha Creek, and includes Crosby Lake and Crosby Farm Regional Park.

In 1805, the Dakota Nation and the US government signed a landmark treaty at *Bdote* on *Wita Tanka* (Pike Island). In the treaty, the Dakota sold a portion of the *Bdote,* which included the land for present-day Saint Paul and gave the US permission to establish a military post at Fort Snelling. In return for the lands that created Fort Snelling and Saint Paul, the treaty guaranteed the Dakota ongoing use of the land and waters in and around *Bdote.* This information as well as additional details about the Dakota Nation History related to Crosby Farm Regional Park was provided by residents of the Crosby Lake Subwatershed, citizen advisory group members and members of the Dakota Nation. It can be found in Appendix A.

In 1858, Thomas Crosby purchased 160 acres for a farm in present-day Crosby Farm Regional Park and farmed it until his death in 1886. Crosby's farm was the largest and longest-running farm in the West End/Highland Park area. Cattle, dairy cows, horses, pigs, and chickens were raised on the farm, along with crops including potatoes and apples. The farm continued to be farmed by a succession of other families until the early 1960s, when it was obtained by the Saint Paul Port Authority who leases two-thirds of the property to the City of Saint Paul as a park (NPS website, http://www.nps.gov/miss/planyourvisit/crosfarm.htm).

Present

The land surrounding Crosby Lake, collectively known as the Crosby Farm Regional Park, is a City of Saint Paul park and a part of the National Park Service's Mississippi National River and Recreation Area. The Park provides opportunities for fishing, canoeing, walking, hiking, and cross country skiing.

The 736-acre park consists of a large area of floodplain and valley side slopes (bluffs). The area contains a complex system of diverse wetland and forest habitats that offer refuge for a broad diversity of native wildlife species. The highlights of a 2004 vegetation survey by Great River Greening include areas of intact sedge meadow, black ash seepage swamps, areas of diverse spring ephemeral wildflowers, a colony of Kentucky coffee trees and large tracts of intact floodplain forest. Over 300 plant species have been identified in the Park (Great River Greening, 2005).

Crosby Lake provides various recreational opportunities for the region including a respite from the built, urban environment and essential environmental functions including floodplain for the Mississippi River and aquatic and wildlife habitat.

2.2.2 Hydrogeology and Surrounding Land Use

Crosby Lake (Lake) sits on the floodplain between an 80-foot bluff and the main channel of the Mississippi River (River). It is periodically inundated during floods and may temporarily become part of the River channel during these periods. As such, lake topography may reflect the effects of erosion and scouring during floods. The landscape between the Lake and River bears evidence of recent flooding (recent sand deposits).

A small stream bed is visible exiting the south end of the lake, however, during a field inspection in September 2010, there were areas of ponded water in the stream bed but no active flow. A portion of the stream was blocked by a large sand bar deposited during a recent flood. Based on this inspection and a review of the topographic information, the Lake does not flow directly to the Mississippi during normal conditions. Culverts connect the lake to peripheral wetlands to the east. Wetlands on the north end of the lake were lower than the lake during the inspection and there was no flow in the culverts. It appears that during high water periods the wetlands fill and flow into the Lake. Topography also suggests an ancestral stream channel entered the Lake basin/flood plain from the north just south of the I-35 E Bridge. The sediments in this channel may also supply groundwater to the Lake.

The bluffs bounding the Lake to the northwest are outcrops of the St. Peter Sandstone. The St. Peter is soft, friable sandstone that is easily eroded by the River. Above the St. Peter is the Platteville limestone, which is visible along the river as a thinly bedded limestone forming resistant cap over the St. Peter. Based on topography and geologic mapping of the area, it is reasonable to conclude that the St. Peter is completely eroded under the floodplain and Crosby Lake. The next deeper geologic formation is the Prairie du Chien limestone, which is approximately 50 feet below the floodplain at an elevation of approximately 650 feet. There are likely seeps or springs entering the Lake from the base of the bluff and from seeps out of the Platteville. These seeps may not be visible due to soil covering the slopes of the bluff. Fractures in the bedrock are also preferential flow paths to the floodplain areas.

Figure 2-5 is a conceptual cross section showing the likely hydrogeologic relationship of the Lake to the aquifers and the River. The cross section is based on digital topography information but is vertically exaggerated for illustration purposes, so angles and flow lines are distorted. Figure 2-5 shows some typical groundwater flow lines that were inferred from topography, regional geologic data, and visual observations. These represent a best-judgment estimate of the flow system meant as guide to understanding the likely hydrogeologic setting and to provide insight into the mechanisms affecting the water balance of the system.

The normal or ordinary water level (OWL) in Crosby Lake is about 694 feet. The normal pool elevation for the River is about 687 feet. This normal 7-foot head difference indicates that groundwater flow is from the Lake to the River under non-flood conditions. Under normal conditions, the Lake level reflects equilibrium between surface and groundwater flow into the Lake, evapotranspiration, and groundwater flow out of the Lake to the River. The major groundwater input is from the St. Peter aquifer to the west. The Lake also interacts locally with the wetlands in the floodplain but groundwater flow between the wetlands and the Lake is a minor part of the budget.

Groundwater flow from St. Peter is intercepted by Crosby Lake. It is also hypothesized that some of the deeper flow passes beneath the Lake and enters the river directly. Groundwater also flows out of the eastern side of the Lake and to the River. The base of the St. Peter has a lower permeability mudstone that can act as a partial aquitard, which reduces infiltration to the Prairie du Chien layer and helps direct flow to the River. Under the River, the St. Peter is absent allowing good upward flow from the Prairie du Chien.

There is likely minor localized shallow groundwater flow from the intermediate river bank to both the River and the Lake. This is shown as a minor groundwater divide on Figure 2-5. Since the River is the lowest elevation it likely dominates the control of shallow groundwater flow, especially during periods of little precipitation.

2.2.3 Geomorphometry

Situated in the floodplain of the Mississippi River in Saint Paul, Crosby Lake is divided into two separate waterbodies by a bog trail, forming Crosby Lake and Little (or Upper) Crosby Lake (Figure 2-6). Little Crosby Lake is a small, deep basin with a small direct watershed (Table 2-3). Although the basin is quite deep, the majority of the area is littoral (<15 feet in depth) and supports a robust submerged aquatic vegetation (SAV) community. Crosby Lake is quite shallow with an average depth of 3 feet and a maximum depth of 17 feet. Both of these basins are considered shallow lakes.

Table 2-3. Physical Characteristics of Crosby Lake

Parameter	Crosby Lake	Little Crosby Lake
Surface Area (ac)	45	8
Average Depth (ft)	3	7
Maximum Depth (ft)	17	34
Volume (ac-ft)	130	59
Residence Time (years)	2	2.8
Littoral Area (ac)	51 (100%)	7 (88%)
Watershed (ac)	152	29

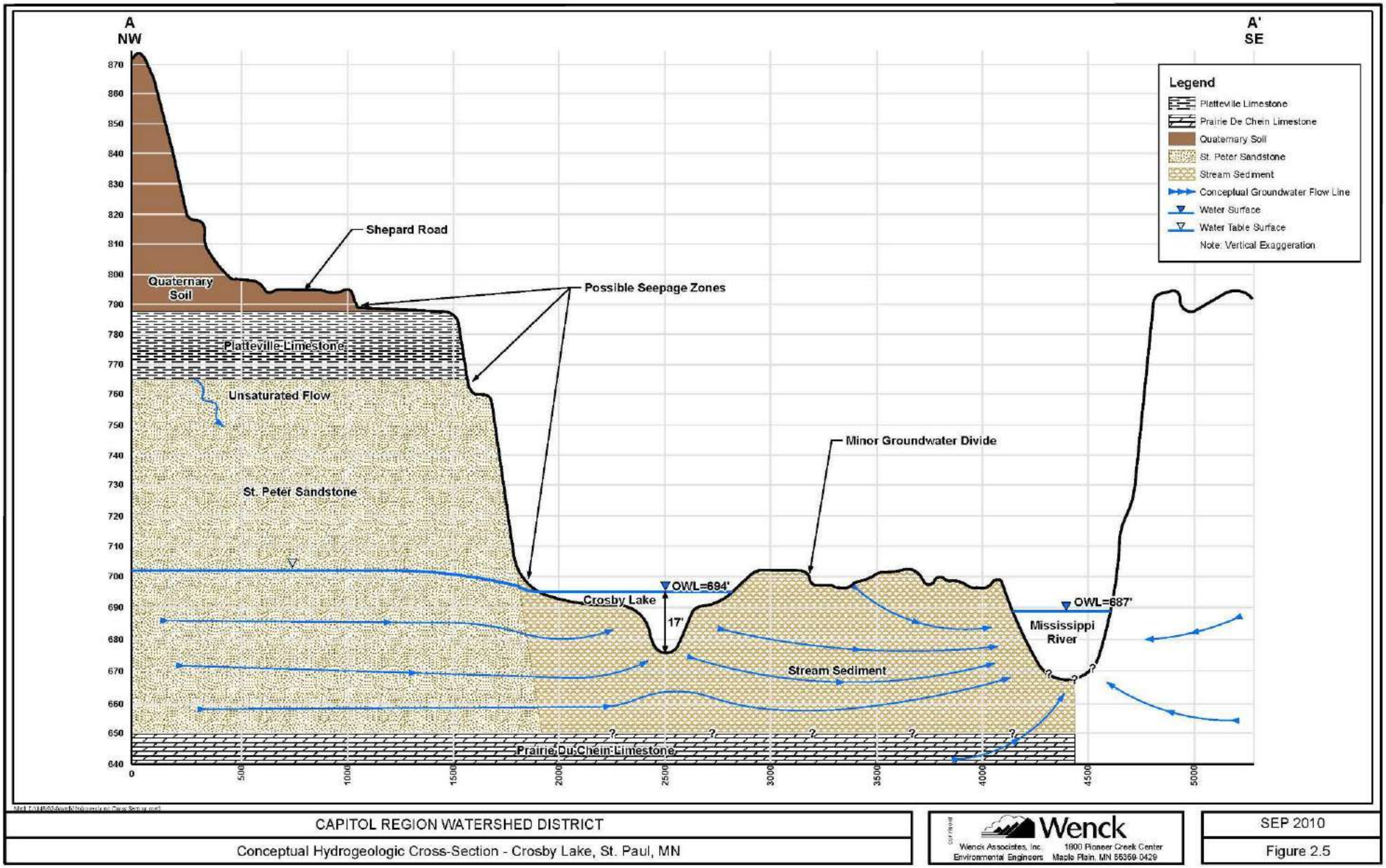

Figure 2-5. Conceptual Hydrogeologic Cross-Section for Crosby Lake

Figure 2-6. Location of Crosby Lake Relative to the Mississippi and Minnesota Rivers

2.2.4 Shallow Lake Ecology

<u>General Description</u>

Shallow lakes are ecologically different from deep lakes due to a greater interaction with lake sediment and a greater influence by the biology of the lake. In shallow lakes, there is a greater area of sediment-water interface allowing for potentially larger sediment contributions to nutrient loads as well as sediment resuspension that can decrease water clarity. Biological organisms also play a greater role in maintaining water quality. Rough fish, especially carp, can uproot submerged aquatic vegetation and stir up sediment contributing to sediment nutrient loading and sediment resuspension. Submerged aquatic vegetation stabilizes the sediment reducing the amount that can be resuspended which protects water clarity. Submerged aquatic vegetation also provides refugia for zooplankton, a group of small crustaceans that can reduce algae populations through grazing.

All of these interactions result in the lake residing in two alternative stable states: a clear-water state and a turbid water state. The clear water state is characterized by clear water, a robust and diverse submerged aquatic vegetation community, balanced fish community and large daphnia (a zooplankton that is very effective at algal grazing). Alternatively, the turbid water state typically lacks submerged aquatic vegetation, is dominated by rough fish, and is characterized by turbid water from both sediment resuspension and algal productivity. Which state the lake persists in is dependent upon the biological community as well as the nutrient conditions in the lake. Therefore lake management must focus on the biological community as well as the water quality of the lake.

A five step process has been developed for restoring shallow lakes in Europe which is also applicable here in the United States. The steps established for restoring shallow lakes includes:

- Forward switch detection and removal
- External and internal nutrient control
- Biomanipulation (reverse switch)
- Plant establishment
- Stabilizing and managing restored system

The first step refers to identifying and eliminating those factors that are driving the lake into a turbid water state (also known as switches). These can include high nutrient loads, invasive species such as carp and Curly-leaf pondweed, altered hydrology, and direct physical impacts such as plant removal. Once the switches have been eliminated, an acceptable nutrient load must be established for the lake. After the first two steps, the lake is likely to remain in the turbid water state even though conditions have improved. The lake must be forced back into the clear lake state by manipulating the biology of the lake also known as biomanipulation. Biomanipulation typically includes whole lake drawdown and fish removal. Once the submerged aquatic vegetation has been established, management will focus on stabilizing the lake in the clear lake state (steps 4 and 5).

Crosby Lake Shallow Lake Ecology

Crosby Lake is in a clear lake state; however the lake is showing signs of pressure from several potential forward switches including sediment phosphorus release, filamentous algae and the presence of Curly-leaf pondweed. This plan will focus on managing the potential forward switches to protect Crosby Lake.

Water level management can be an important aspect of shallow lake management. While raising or lowering the water level in Crosby Lake will not impact current water quality in the lake, long term stabilization of lake water levels in shallow lakes can lead to stabilizing the turbid water state. Shallow lakes typically go through wet and dry periods under natural conditions, providing for sediment consolidation and nutrient (primarily nitrogen through denitrification) loss that promotes a healthy native plant community. Loss of this process can lead to unconsolidated nutrient rich sediments that promote more tolerant native species such as Coontail and can grow to nuisance abundance levels. Consequently, long term water level stabilization can lead to a turbid water state, which needs to be considered with lake management.

2.2.5 Mississippi River Interaction

One of the unique features of Crosby Lake is that the lake resides in the floodplain of the Mississippi River (Figure 2-6). Because Crosby Lake is in the floodplain of the Mississippi River, the two water bodies will exchange water under high flow conditions potentially exchanging nutrients and biological organisms. This interaction must be considered when developing management actions for Crosby Lake.

A review of Mississippi River flow and stage data was conducted to develop an understanding of the magnitude and frequency of flood water interaction with Crosby Lake (Appendix B). Using 2-foot contours provided by the City of St. Paul, it appears that the river and lake are "connected" at approximately elevation 697. The connection occurs at the southeast corner of the lake where there is a break in the 698 contour (Figure 2-7). There appears to be a flow path from this point and southeast to the river.

Figure 2-7. Crosby Lake Connection to the Mississippi River

Based on this assessment, it was determined that a flow of 49,000 cubic feet per second (cfs) would initiate exchange of water between the Mississippi River and Crosby Lake which is approximately equal to the flow for a 3-year storm event (33% chance of occurrence each year). A flow of 49,000 cfs or greater occurs approximately 2.5% of average daily flows going back to 1892. In other words, only 2.5% of all the recorded flows would be high enough for exchange between the Mississippi River and Crosby Lake.

2.2.6 Crosby Lake Water Quality

Lake water quality is typically measured by assessing the amount of algal growth and water clarity in a lake during the summer growing season. When too much algae grow in a lake, water clarity is reduced and noxious smells can emit from the lake. This process is known as eutrophication. When lakes become hyper-eutrophic, the entire food web is affected by changes in the algal community and water quality including dissolved oxygen depletion and decreased water clarity. A healthy lake has a balanced growth of algae providing support for the base of the food chain without causing harm to water quality or biological organisms. Algal growth (measured as total chlorophyll-*a*) is typically limited by the amount of phosphorus available for uptake by algae in the water column. Therefore, total phosphorus is measured as the causative factor for algal growth. Water clarity is limited by the amount of algae as well as suspended particles in the water column.

Crosby Lake demonstrates reasonably good water quality with total phosphorus concentrations below the state standard for shallow lakes (based on the North Central Hardwood Forest Ecoregion Standard of <60 µg/L TP as a summer average) in six of the eight years monitored between 1999 and 2009 (Figure 2-8). Little Crosby Lake has not been monitored to date. The two years that exceeded the state standard for shallow lakes were only slightly higher.

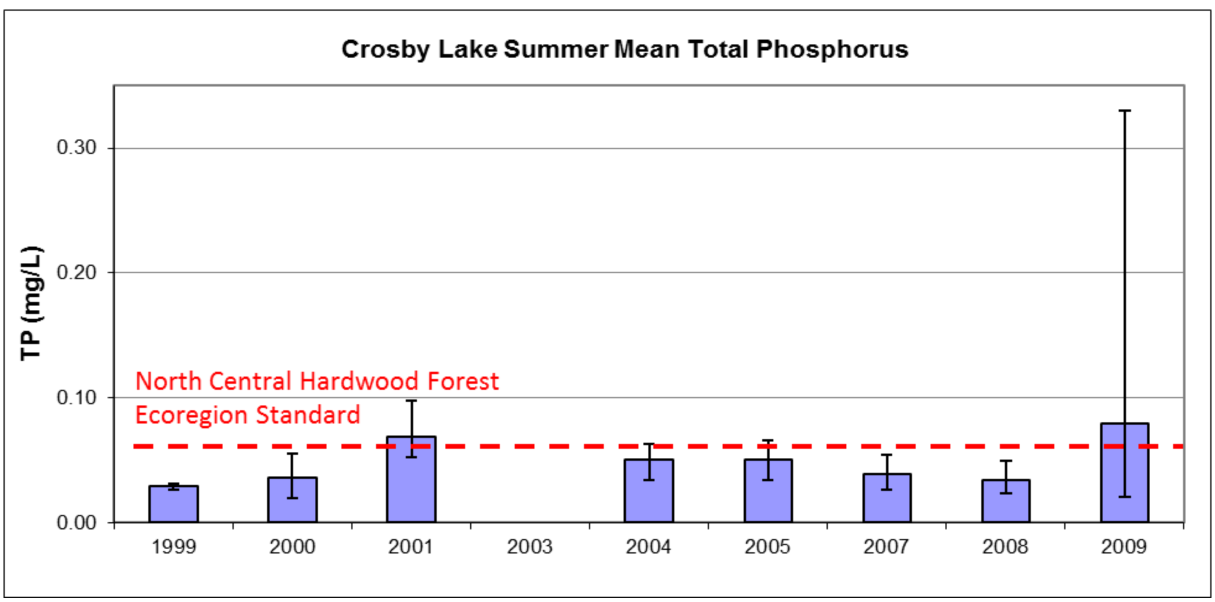

Figure 2-8. Surface Summer Average Total Phosphorus Concentrations for Crosby Lake

Although surface water total phosphorus concentrations are typically below the state standard for shallow lakes, there are signs of eutrophication in Crosby Lake. Bottom water samples collected just above the sediments contained very high concentrations of total phosphorus reaching well over 3,000 µg/L (3 mg/L) and typically reaching over 1,000 µg/L (Figure 2-9). These data suggest that the sediments in Crosby Lake are high in total phosphorus and are releasing total phosphorus into the water column. This process can increase algal growth in two ways. First, because Crosby Lake is shallow and does not stratify, this phosphorus can be easily mixed up into the water column and increase algal growth. Secondly, the release of phosphorus from the sediments can lead to large filamentous algae blooms, which start their life cycle on the sediments. The filamentous algae can then form large mats on the surface of the lake reducing the aesthetic appeal of the water body as well as shading out submerged aquatic vegetation.

Lake response modeling (see Section 2.3) suggests that internal nutrient loading is not an important source for pelagic (open water) algae. Pelagic algae have a life cycle that occurs completely in open water and therefore uses open water nutrients as their primary source. However, visual observation of Crosby Lake suggests that there may be a significant filamentous algae issue that could possibly have long term impacts on the overall health of Crosby Lake. Current sampling on Crosby Lake only quantifies open water (pelagic) algae and does not account for filamentous algae. Because filamentous algae are benthic (bottom dwelling) early in their life cycle, much of their nutrients are from the sediments which have shown high release. To prevent filamentous algae blooms, the most effective strategy is to reduce internal loading through chemical addition such as alum. It is important to note that filamentous algae growth has not been quantified to data and should be assessed prior to any actions.

One of the likely sources of the high nutrient concentrations in sediment is likely the episodic flooding from the Mississippi River. However, flooding would be very difficult if not impossible to control. Rather, if filamentous algae are truly at nuisance levels, management will likely have to focus on periodic applications of alum to reduce the impacts of the phosphorus rich sediment influx. Long term controls will be accomplished through reductions in Mississippi and Minnesota River nutrients and sediment.

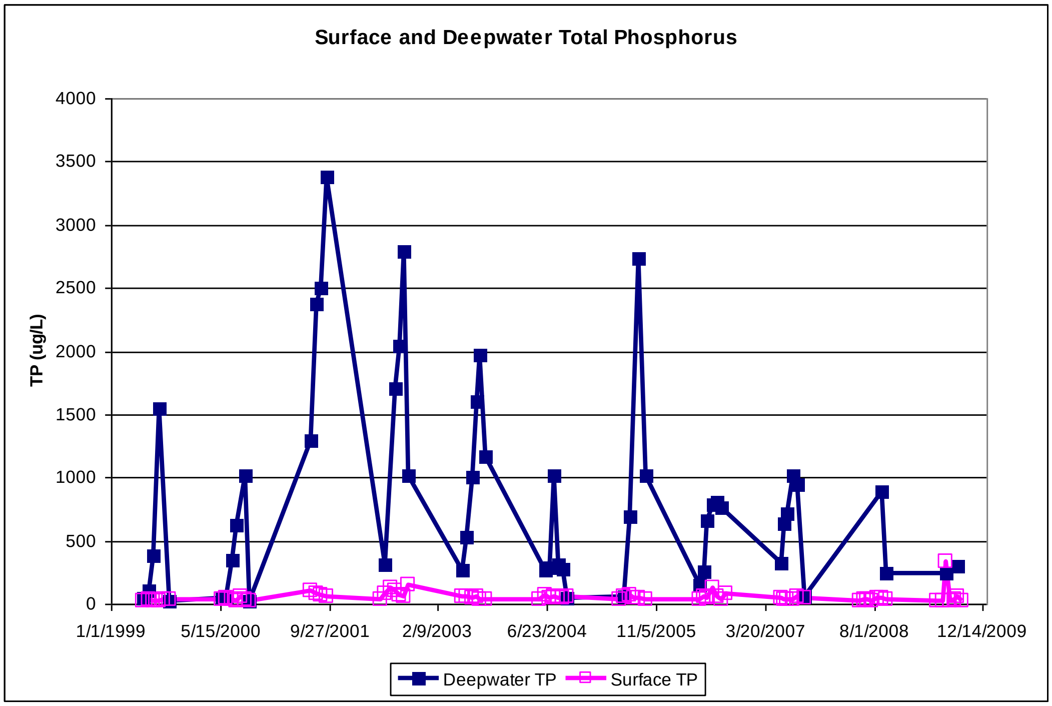

Figure 2-9. Surface and Bottom Total Phosphorus Concentrations in Crosby Lake

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Algal growth in Crosby Lake is typically below the state standard for shallow lakes (<20 µg/L chlorophyll-*a* as a summer average) suggesting that the bottom water phosphorus is not currently driving surface water algae blooms (Figure 2-10). Although Crosby Lake exceeds the state standard for total phosphorus in two of the monitoring years, Crosby Lake does not demonstrate the expected nuisance algae levels. This is fairly common in shallow lakes in the clear water state because there are feedback mechanisms that offset the lakes response to nutrients including zooplankton grazing. Consequently, Crosby Lake is demonstrating healthy, clear water even with some signs of eutrophication.

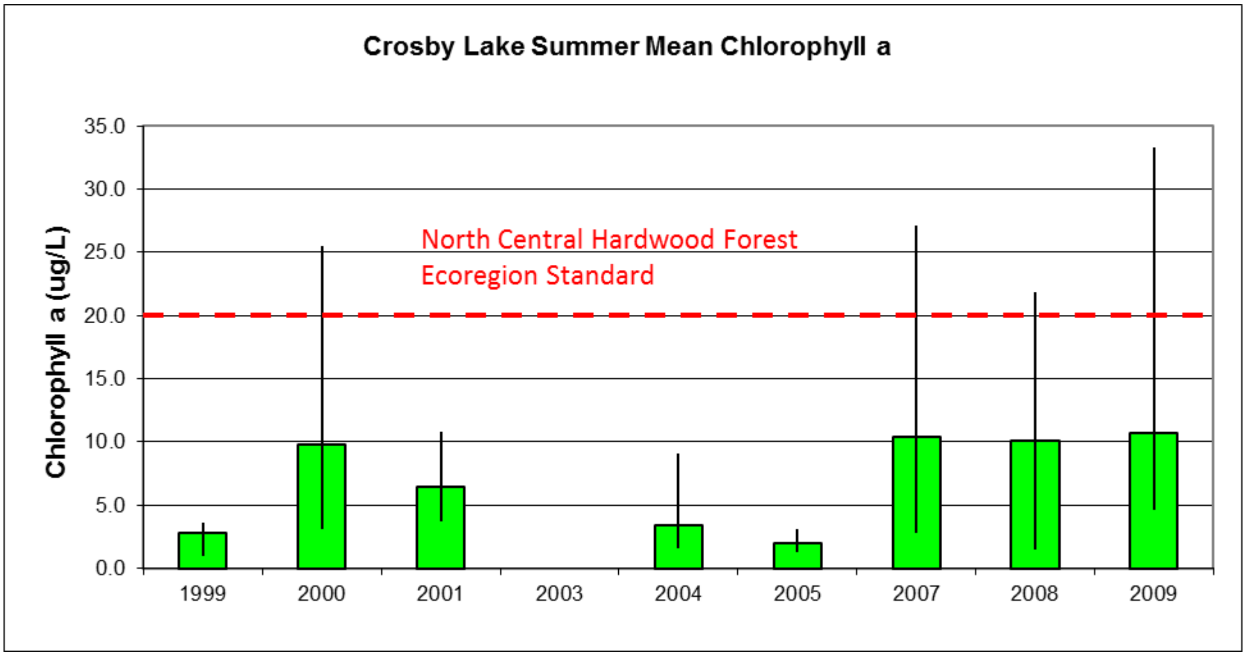

Figure 2-10. Surface Water Summer Average Chlorophyll-*a* Concentrations in Crosby Lake

Water clarity is also very good in Crosby Lake with Secchi disk transparencies typically exceeding the state standard for shallow lakes (>1 meter) and exceeding 2 meters in most years (Figure 2-11). The good water clarity is a result of low algal productivity and a robust submerged aquatic vegetation community that stabilizes the sediments preventing wind resuspension.

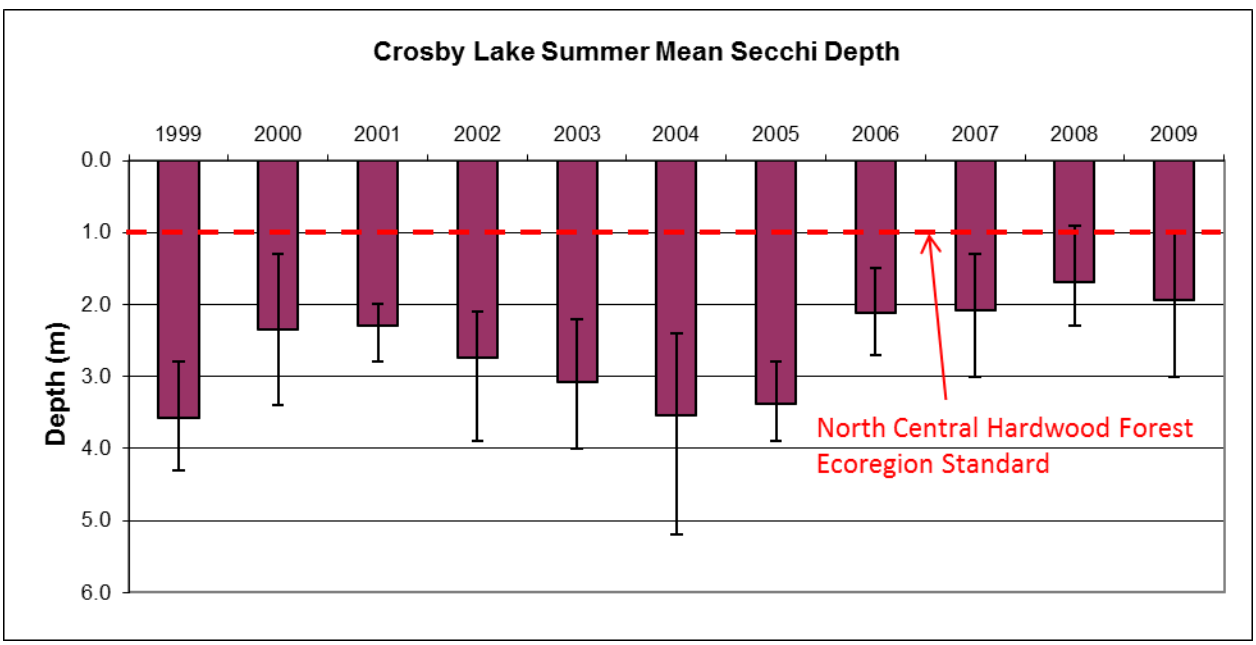

Figure 2-11. Summer Average Water Clarity as Measured by Secchi Depth in Crosby Lake

2.2.7 Fisheries

Fisheries surveys have been periodically conducted in Crosby Lake by the MN DNR since 1968. The data have been grouped into functional feeding groups to assess their potential impact on water quality. Both the total biomass and number of individuals have been presented for each functional group. The four groups include:

1. Top predators. This group includes those fish that are piscivorous (fish that eat other fish) and include such species as walleye and northern pike.
2. Pan fish. This group includes the small pan fish population and includes such species as blue gills and crappie. These fish tend to eat zooplankton early in their life cycle and then macroinvertebrates later in their life cycle.
3. Forage species. This group includes species such as yellow perch. These fish tend to forage for macroinvertebrates.
4. Rough fish. This group includes bottom foragers such as common carp, yellow and black bullhead and buffalo. These fish tend to have a destructive feeding pattern, rooting through sediment and submerged vegetation to find food. Note that carp have been separated out due to their increased significance for water quality in shallow lakes.

Prior to 1983, the lake demonstrated a rough fish dominated fish community although the top predators were present in decent numbers and size (Figure 2-12). Most notable during this period was the presence of large carp although low in abundance. A hard winterkill occurred in 1978 after a MN DNR survey had been conducted. In response to the winterkill, the MN DNR repeated the survey in the following year to assess the potential impact of a hard winterkill on the fish community. After the winterkill, the carp population increases substantially. This is likely a result of loss of predation on carp eggs following the reduction of pan fish which typically eat carp eggs. It is important to note that pan fish population recovered very quickly, typically within a year or two.

After 1983, the rough fish community has diminished in size and abundance. Crosby Lake now demonstrates a much more balanced fishery with a healthy pan fish population and small numbers of rough fish. It is not clear what has spurred this change in the fish community. However, it does represent a healthy fish population.

2.2.8 Aquatic Vegetation

Vegetation data was compiled from MN DNR fish surveys and Ramsey County to develop a general history of vegetative conditions in Crosby Lake (Figure 2-13). MN DNR surveys were conducted as far back as 1968 and then in 1978, 1988, and 1999. The most recent survey was conducted by Ramsey County in 2009. In general, submerged aquatic vegetation has been dominated by coontail since 1968. Coontail is typically found in more eutrophic shallow lakes and can develop nuisance abundances that choke out other native species. However, Coontail does not appear to have reached these conditions in Crosby Lake. Other species such as muskgrass, native milfoil, and Canada waterweed are also common in Crosby Lake. The 2009 survey, however did find a greater dominance by coontail suggesting that the lake is becoming more eutrophic. It is also important to note that the 2009 survey was a point intercept survey that does a better job of describing the entire submerged vegetation community. Previous surveys were conducted using a simple transect method.

Curly-leaf pondweed is one of the species lake managers are most interested in. Curly-leaf pondweed has a unique life cycle that begins growing under ice cover in low light conditions giving it a competitive advantage over other native species. Curly-leaf pondweed then senesces (dies back) in the middle of the growing season releasing phosphorus back into the water column and often spurring algal blooms.

Curly-leaf pondweed can have a large and lasting impact on shallow lakes. Its presence is somewhat uncertain in Crosby Lake. It was identified in previous surveys conducted by the MN DNR; however, it is not having a large impact in Crosby Lake because the most recent point intercept survey by Ramsey County did not identify any Curly-leaf pondweed in the lake. Curly-leaf pondweed does not do well in all shallow lakes; however, the reasons for it dominating some shallow lakes and not others are unclear. If it is present in Crosby Lake, there may be other factors limiting its growth including sediment chemistry and competition from other native species such as coontail. Long term monitoring of Curly-leaf pondweed should be conducted to ensure it’s not having an impact on Crosby Lake and determine the limiting factors of its growth.

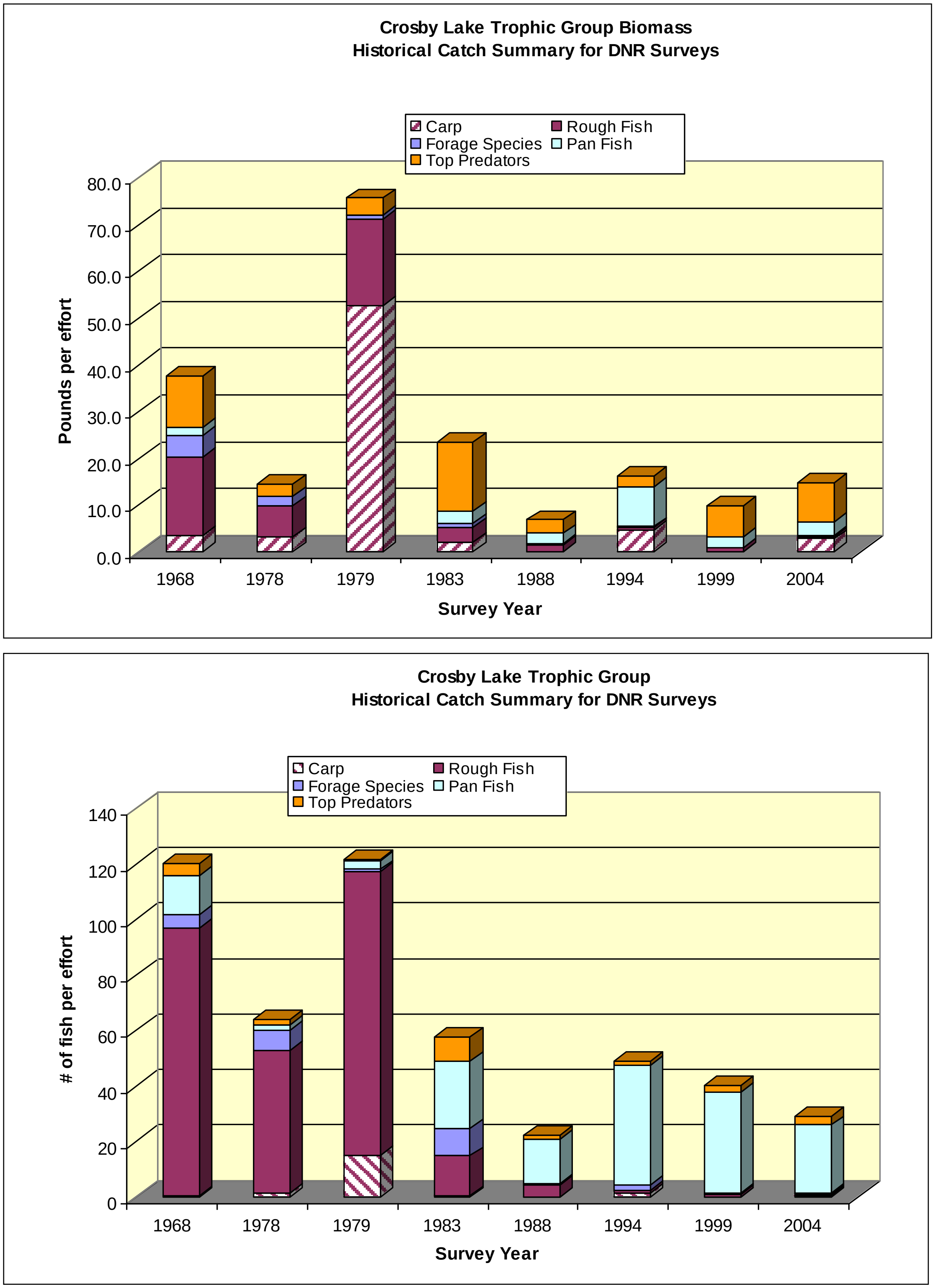

Figure 2-12. Fisheries Data for Crosby Lake Broken Down into Functional Feeding Groups (The top graph shows total biomass per effort and the bottom graph shows total individuals caught per effort.)

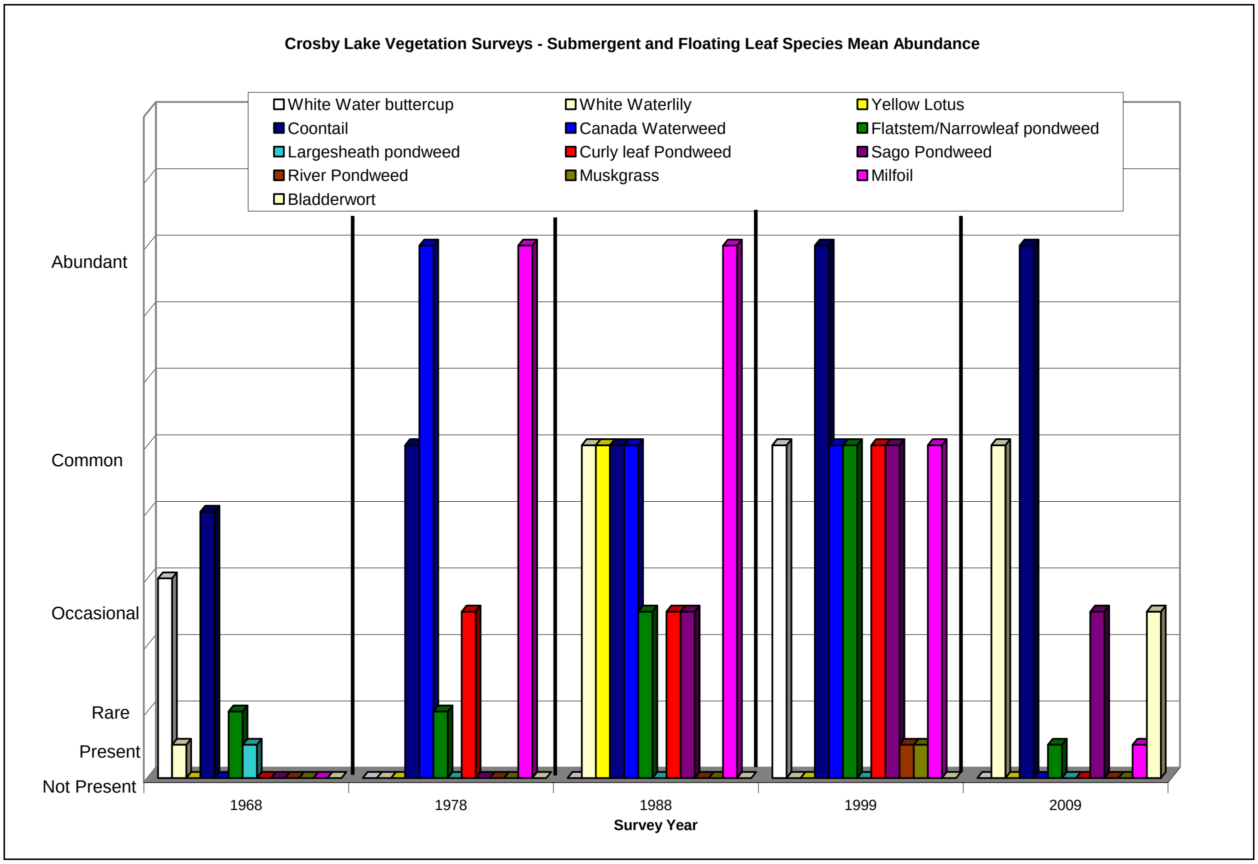

Figure 2-13. Submerged Aquatic Vegetation in Crosby Lake

2.3 CROSBY LAKE RESPONSE MODEL

A BATHTUB lake response model was developed for Crosby Lake to assess the impacts of various water quality improvement projects on in-lake water quality. The purpose of the model was to develop a phosphorus budget for the lake, identify the major driving factors for current and future water quality, and to provide an understanding of the level and magnitude of improvement project implementation required to meet identified water quality goals. A publicly available model, BATHTUB was developed by William W. Walker for the U.S. Army Corps of Engineers (Walker 1999). BATHTUB has been used successfully in many lake studies in Minnesota and throughout the United States. BATHTUB is a steady-state annual or seasonal model that predicts a lake's summer (June – September) mean surface water quality. BATHTUB's time-scales are appropriate because watershed P loads are determined on an annual or seasonal basis, and the summer season is critical for lake use and ecological health. BATHTUB has built-in statistical calculations that account for data variability and provide a means for estimating confidence in model predictions. The heart of BATHTUB is a mass-balance P model that accounts for water and P inputs from tributaries, watershed runoff, the atmosphere, sources internal to the lake, and (if appropriate) groundwater; and outputs through the lake outlet, groundwater (if appropriate), water loss via evaporation, and P sedimentation and retention in the lake sediments. BATHTUB allows choice among several different mass-balance

P models. For deep lakes in Minnesota, the option of the Canfield-Bachmann lake formulation has proven to be appropriate in most cases. For shallow Minnesota lakes, other options have often been more useful. BATHTUB's in-lake water quality predictions include two response variables, chlorophyll-*a* concentration and Secchi depth, in addition to total phosphorus concentration. Empirical relationships between in-lake total phosphorus, chlorophyll-*a*, and Secchi depth form the basis for predicting the two response variables.

The BATHTUB model was built for the average of the eight monitoring years available for Crosby Lake (Appendix D). A second order decay model was selected for Crosby Lake as this model fit was the best of all the available models. Watershed loading was estimated using the results of the updated P8 model for the watershed. Internal loading was estimated using an assumed release rate of 2 mg/m^2/day and an average anoxic factor of 10 days. The model fit observed monitored data reasonably well (Figure 2-14).

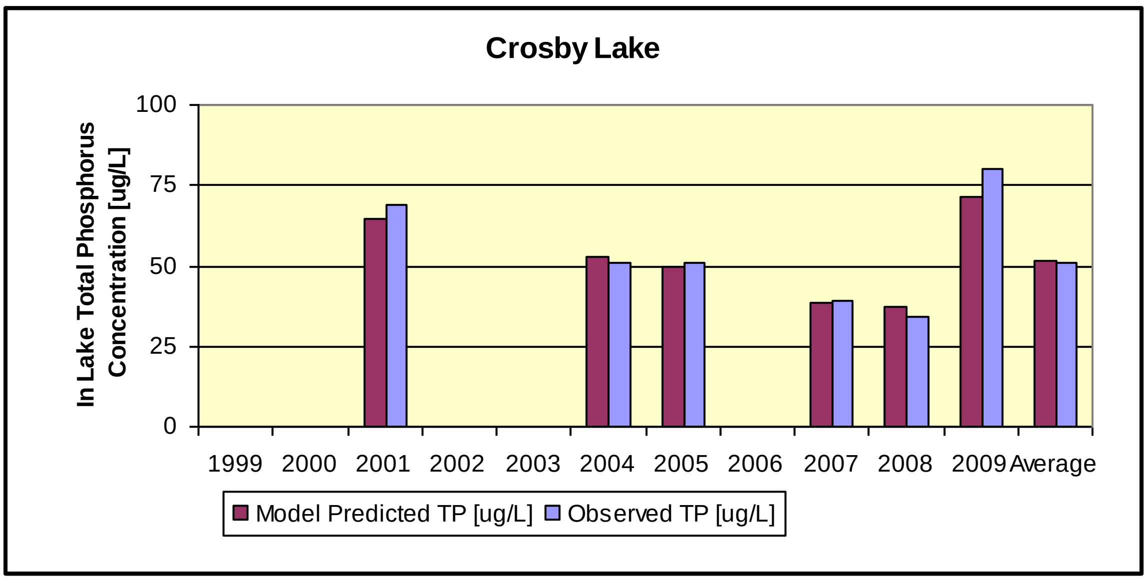

Figure 2-14. Predicted and Observed Concentrations for Crosby Lake Using BATHTUB

A BATHTUB model of the average of all monitoring years was used to determine the current total phosphorus budget for Crosby Lake and identify necessary reductions to meet goals identified in Section 3.3. Phosphorus sources are dominated by watershed runoff (drainage areas) accounting for 76% of the phosphorus entering Crosby Lake (Figure 2-15). Internal loading was determined to be a small percentage (11%) of the phosphorus budget although high concentrations of phosphorus were measured in the bottom waters. Because there is such a small deep hole that goes anoxic, this source represents a relatively small proportion of the overall budget. Consequently, watershed sources of phosphorus are the primary driving force for water quality in Crosby Lake. High phosphorus release by sediments should not be ignored however as this can lead to other problems such as filamentous algae blooms.

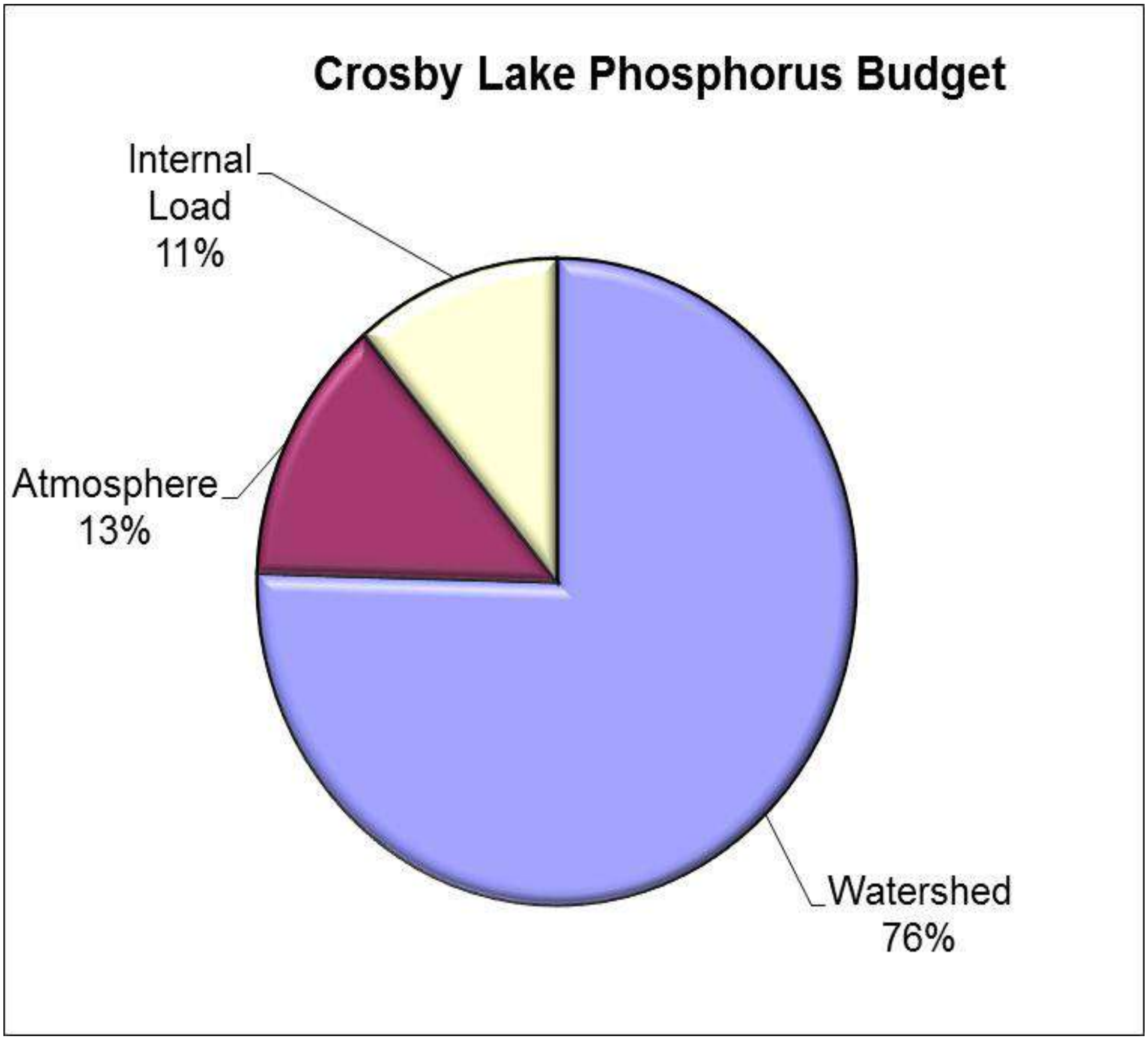

Figure 2-15. Total Phosphorus Budget for Crosby Lake

3.0 Identification of Issues and Goals

3.1 GOAL IDENTIFICATION

An important step in developing a management plan for Crosby Lake and the Crosby Lake subwatershed is to identify appropriate goals or endpoints to guide management actions and the magnitude of implementation activities. To that end, current standards for the Mississippi River, Minnesota River, and Minnesota lakes were reviewed to provide regulatory context to potential goals for runoff to the river and for Crosby Lake.

3.2 STAKEHOLDER PRIORITIES

3.2.1 Citizen Advisory Group Priority Issues

As a part of the Citizen Advisory Group process, participants were asked to identify their issues for Crosby Lake. Following is a summary of the identified issues.

Water Quality

Understanding how water flows into Crosby Lake and the potential that runoff has for carrying pollutants and sediment to the water body was an important common concern. Citizens largely identified this as an issue of managing water quality. Some specific thoughts and ideas include:

- Need to identify all the inlets and potential sources for pollution;
- Both point and non-point source pollution have to be studied;
- Old printing plant outlet near Crosby Lake needs to be eliminated;
- Evaluate threat to lake from nearby marina – during flooding there is potential for gasoline pollution;
- Drainage from Shepard Road to the lake is an issue;
- Evaluate negative impacts from bluff erosion; and
- Need to address the salt in runoff and its effect on the lake.

Other ideas included:

- Addressing water quality is fundamental to utilizing Crosby Lake as an example to the nation for progressive conservation.
    - It should be made a natural, clean lake with pre-industrial conditions.
    - Growing wild rice, which is an indicator that high water quality standards are met.
- Maintain Crosby Lake as a lake; avoid the natural process of filling in from sedimentation to form a marsh.
- Need to have long term protection of the lake

Watershed Land Use Management

Flooding
- Need to establish a consistent flood management plan
- There is a need for improved outlet flow between lake and river

Litter/trash
- Trash comes down from the bluff top – Shepard Road
- Run-off from the 35E bridge dumps trash (plastic bottles) near the lake

Erosion
- Incorporate Highland Ravine study into management plan. It is part of the watershed and has erosion issues.

Park Use and Management

Development
- This is a unique, national park in St. Paul and should be maintained in its natural state – no more paved paths.
- Create a more stable and safe path between the two lakes (marsh boardwalk)

Erosion
- Trails and bluffs need to be managed to reduce sediment flow to lake.

Education and Outreach

- There is a lack of public awareness about issues involving Crosby Lake.
- It is necessary to have an educated community in order to have positive change.
- Work with local Dakota tribe representatives who have an historical and cultural tie to the area.

Plants, Fishery and Wildlife Management

While these were presented as three separate areas for action, there was common recognition that they are interrelated and often are affected by and/or directly impact water quality.

- Need to eliminate and manage exotic plants, both aquatic and terrestrial (shoreline)
- Re-establish and promote native vegetation in and out of lake
- Algal growth has negative impact on aesthetics, both in lake and along outlet channels
- Healthy fish means a healthy lake
- Ensure safe nesting for birds and habitat for wildlife
- The wildlife value of the lake is important
- Deer hunting should not be allowed in the park

3.3 POTENTIAL WATER QUALITY GOALS FOR CROSBY LAKE

Crosby Lake has met the state shallow lake standard of 60 µg/L for total phosphorus (as a summer average) in six of the last eight years. However, during this period, Crosby Lake has easily met the chlorophyll-*a* and Secchi depth standards in all of the years which is enough to determine the lake is not impaired using State impairment assessment criteria.

Three primary approaches for developing water quality goals for Crosby Lake were considered:

1. <u>Set a goal to maintain the current water quality conditions in the lake</u>. Establishing current water quality as the baseline will provide long term protection of current conditions. However, this approach does not address some of the signs of eutrophication that are occurring in the lake.

2. <u>Focus on phosphorus to meet state water quality standards in all years.</u> A more aggressive approach would be to target watershed phosphorus loading so that all years meet the total phosphorus target. This approach may offset any long term inputs from the Mississippi River that will be difficult to control. Lake Response modeling suggests this approach would require a 47% reduction in watershed loading to Crosby Lake.

3. <u>Develop alternative goals for Crosby Lake.</u> A third option for establishing goals for Crosby Lake would be to develop more non-traditional goals such as floristic quality. Floristic quality is a measure of the diversity and water quality sensitivity of aquatic species in the Lake. These data can be used in an index to measure the quality of the vegetation community. Other goals could include the use of lake based indices of biotic integrity, species richness, wildlife use, or other non-traditional metrics. These goals would be aimed at maintaining a healthy submerged aquatic vegetation community in Crosby Lake. It is important to note that application of many of these techniques would require data collection to fill data gaps.

3.4 POTENTIAL WATER QUALITY GOALS FOR DIRECT RIVER DISCHARGE

For management and target selection purposes, it is useful to consider current and proposed water quality goals. There are several water quality goals proposed for the Mississippi River including proposed nutrient standards that are currently under review (Table 3-1). These proposed goals can serve as a guide for selecting water quality goals for discharge directly to the Mississippi River. Because both the phosphorus and TSS goals are concentration based standards, it is likely that discharges will be held to the same standard assuming no attenuation in the receiving water. However, large rivers will offer some nutrient attenuation similar to lakes, meaning pollutant inputs can be higher than the standard and still meet water quality goals. A relatively conservative approach would be to apply the standards directly to discharges. TSS standards are typically applied to dischargers assuming no receiving water attenuation.

Table 3-1. Minnesota Water Quality Targets for the Mississippi and Minnesota Rivers

	Total Phosphorus[1]	Total Suspended Solids
Proposed Minnesota Stream and River Nutrient Standards	100 µg/L (includes Pool 1 Miss R)	NA
Proposed Lake Pepin Nutrient Standards	100 µg/L 50% reduction in MN River 150 µg/L @ Jordan for MN River 20% reduction in Miss. River 100 µg/L Pool 1 Miss. River	40 mg/L Mississippi River[1] 32 mg/L Lake Pepin[1]
Lower Minnesota Turbidity TMDL Target	NA	100 mg/L
South Metro Mississippi River Turbidity TMDL	NA	32 mg/L median 44 mg/L 90th percentile

[1]Applied as a summer average

An aggressive approach for a total phosphorus goal would be to adopt the nutrient standard of 100 µg/L as a summer average. This could also be applied as the flow-weighted average of all of the outfalls to allow flexibility in achieving the standard in one watershed where projects may be more feasible to implement. This would be consistent with the proposed Minnesota stream and river nutrient standards as well as the nutrient standards to protect Lake Pepin. This would require approximately a 66% reduction in current phosphorus discharges from the Crosby Subwatershed.

Establishing a TSS goal is less clear in light of the various targets identified for the Minnesota and Mississippi Rivers. However, the South Metro Mississippi River proposed site specific standard would likely apply and require TSS concentrations of 32 mg/L as a summer median. This goal would also require an approximately 66% reduction in TSS loads from the Crosby Subwatershed.

3.5 SELECTED WATER QUALITY GOALS

The following water quality goals were selected for management of Crosby Lake, the Crosby Lake Subwatershed, and the Crosby Subwatershed.

Crosby Lake

1. Meet state water quality standards (TP $\leq$ 60 µg/L as summer average) in all years for total phosphorus. This target requires an approximately 47% reduction in watershed phosphorus loading.

2. Develop long term targets for plant and fish diversity as surveys and data are collected. Target an excellent rating for the submerged aquatic vegetation population using the Floristic Quality Index (Nichols, 1999). Target a good Index of Biotic Integrity score once the IBI has been completed by the Minnesota DNR.

Direct Discharge to the Mississippi River

1. Achieve a median total suspended solids concentration of 32 mg/L annually (MPCA, 2010). This requires an approximately 66% reduction in TSS loading from the watershed.

2. Achieve a mean summer total phosphorus concentration of 100 µg/L. This requires an approximately 66% reduction in total phosphorus loading from the watershed.

3.6 ADAPTIVE MANAGEMENT

It is important to note that the goals established in this plan represent aggressive goals for nutrient reductions and are highly dependent on the achievement of reductions in the watershed. Consequently, implementation will be conducted using adaptive management principles (Figure 3-1). Adaptive management is essentially a phased approach where a strategy is identified and implemented in the first cycle. After implementation of that phase has been completed, progress toward meeting the goals is assessed. A new strategy is then formed to continue making progress toward meeting the goals. These steps are continually repeated until the established goals are met. This process allows for future technological advances that may alter the course of actions detailed here. Continued monitoring and "course corrections" responding to monitoring results are the most appropriate strategy for attaining the water quality goals established in this management plan.

Adaptive management will be applied using the 10 year planning cycle for watersheds. The first five years will be used to implement projects that are ready to go, develop feasibility studies and designs for other projects, and continue monitoring and outreach activities. The second five years will be used to continue implementing projects on the ground as well as monitoring to assess effectiveness of the selected practices. At the end of the 10 year cycle, a determination of progress and next steps can be developed along with "next generation" CRWD planning.

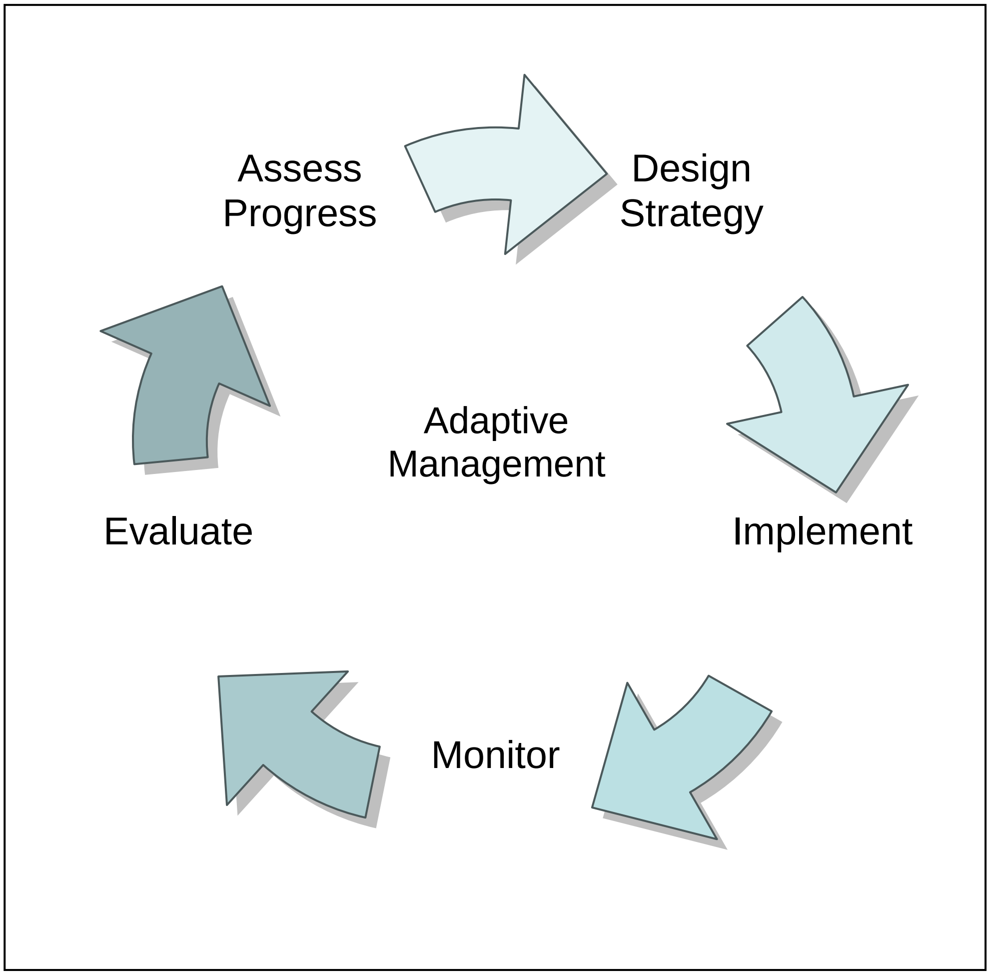

Figure 3-1. The Adaptive Management Cycle

4.0 Implementation Plan

4.1 MANAGEMENT ACTIVITY SELECTION

The purpose of this plan is to identify water quality goals for management of Crosby Lake and the Crosby Subwatershed and to identify projects necessary to reach those goals. To that end, CRWD, the Technical Advisory Group, and the Citizens Advisory Group (CAG) identified a list of projects to address water quality in the watershed and Crosby Lake. Almost 30 potential projects were identified; however, some were eliminated due to poor site conditions. The remaining projects have been evaluated and included in this plan (Figure 4-1). Following is a discussion of the potential projects for the watershed.

4.2 CITIZEN INPUT ON SOLUTIONS

Following each participant's identification of top concerns and ideas at the second CAG meeting, small groups discussed possible solutions for the lake issues and challenges they identified. While participants did not always explicitly state which action area their solution addressed, they have been categorized appropriately below.

Some of the identified activities were outside the scope of this lake management plan. Those activities are summarized in Appendix E and are not explicitly addressed in this plan. Following is a summary of the activities identified by the CAG that are addressed in this plan.

The CAG identified the following actions to address water quality:

- Identify all point and non-point source pollution and address each individually through appropriate BMPs
- Track sources of pollution through monitoring data.
- Conduct an erosion study of bluff areas

These actions are addressed as a part of this study through the assessment of water quality and identification of BMPs to address the sources. However, it is important to note that this plan focuses on sediment and nutrients and no other non-traditional pollutants. After an initial review of the data, other pollutants did not appear to be an issue. No monitoring data other than the lake monitoring data was available; however monitoring stormwater runoff/discharges is part of the recommended actions. An erosion study had already been completed for the bluff areas by Ramsey County and those recommendations are included in this plan.

Another significant issue for the CAG is trash in Crosby Farm Regional Park including trash that makes its way down the bluff from Shepard Road. Some of the recommendations included:

- Install fence at top of bluff to avoid litter coming down into lake area

- Conduct trash clean-ups
- Establish park as a model for community clean-up efforts
- Revive an anti-litter campaign

Trash is not explicitly addressed in this lake management plan; however, several partners including the Friends of the Mississippi River and the City of Saint Paul conduct clean ups to remove trash in the park. Consequently, these were included in the plan.

The following plant and fishery goals were identified by the CAG:

- Restore native vegetation throughout park
- Ask fisherman what they have been catching
- Analyze fish for pollution/contaminants

These actions are included in the lake management plan through partner agencies (Minnesota DNR; Ramsey County; St. Paul Parks and Recreation).

In early 2011, CRWD received recommended management plan language related to the Dakota Nation that was submitted by members of the Dakota Nation, members of the CAG, and residents of the Crosby Lake subwatershed. See Appendix A for the full text. The language included historical text about the relationship of the Dakota Nation with Crosby Lake and recommended implementation steps. Out of the eight implementation steps, only one was pertinent to the lake management plan as it is similar to the defined purpose of the management plan which is to guide protection and improvement of the water quality of Crosby Lake and the Mississippi River. The remaining recommendations, which are primarily directed to the City of Saint Paul's Parks and Recreation Department and deal with park management, use and activities, were not included in the Crosby Lake Management Plan.

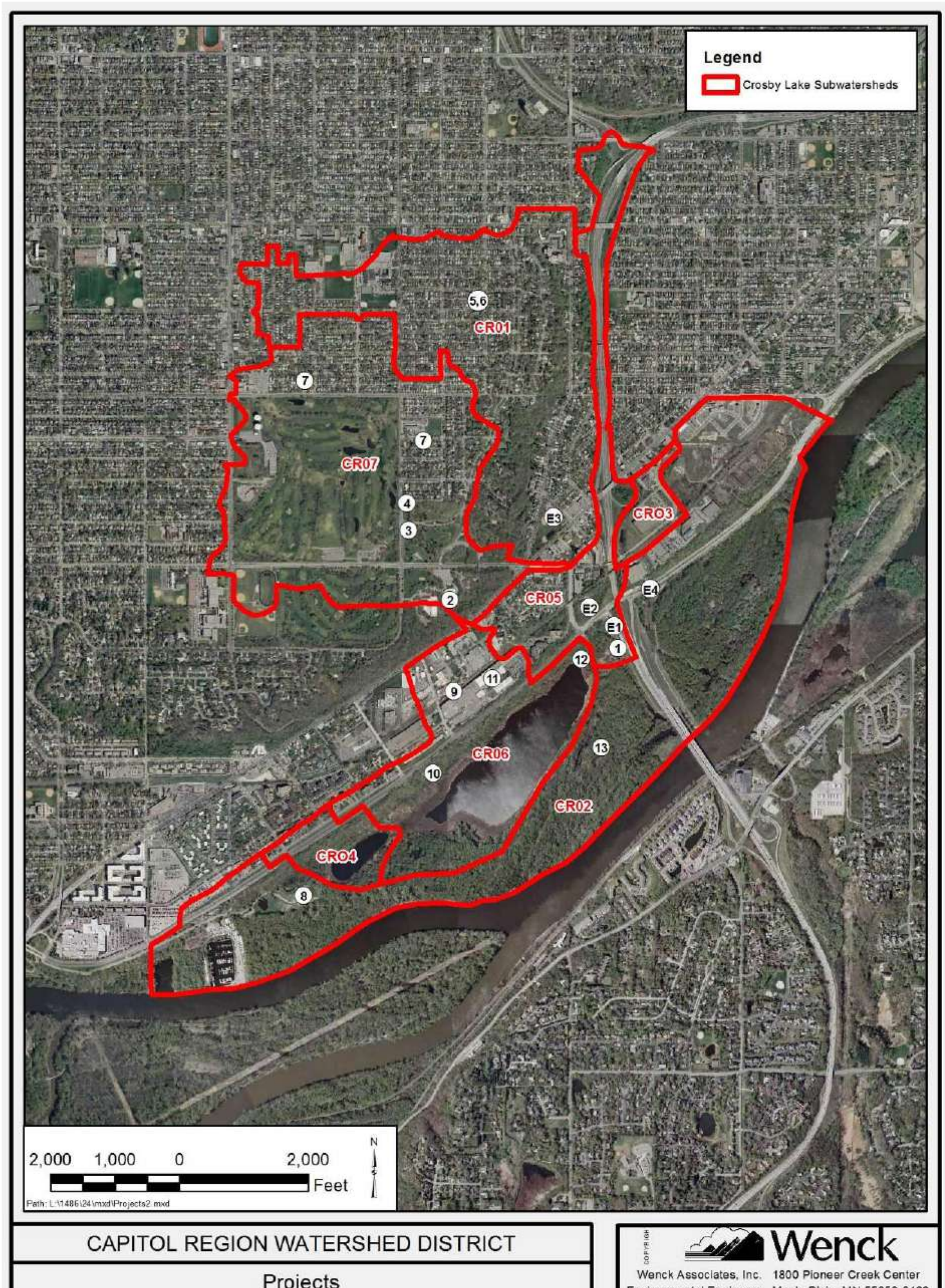

Figure 4-1. Location of Projects to Address Water Quality in Crosby Lake and Runoff to the Mississippi River

4.3 DIRECT RIVER DRAINAGE

Following is a list of potential projects identified to address stormwater runoff discharging directly to the Mississippi River. See Figure 4-1 and Table 4-1 for the corresponding project numbers and locations. Some projects may not appear on Figure 4-1 because they are broad in scope. Potential studies and monitoring projects are listed in Table 4-2. In the tables, responsible party is the agency or organization that is responsible for initiating and leading the project or activity. This is determined by the group's ownership or purview of the property where the proposed project or activity will take place.

4.3.1 35E Regional Stormwater Pond

This site is adjacent to the 35E ditch that conveys approximately 836 acres of the Crosby Lake Watershed to the Mississippi (Project #1). It is feasible to build a stormwater detention pond with an approximate surface area of 1.75 acres and an average depth of 4 feet. Tree removal, significant grading and construction of an access road for maintenance would be required. Due to the location of the project, on the bluff and in St. Paul, both the State Archeologist's Office and the MN DNR Natural Heritage and Nongame Research would require a review. Any significant findings or concerns could minimize the pond treatment area or eliminate the project entirely.

4.3.2 Infiltration Basin Expansion along 7th Street

Currently a small depression at this site collects a small amount of stormwater runoff from the 367-acre subwatershed before discharging to an existing storm sewer (Project #2). Expansion of the basin, creating a 1 to 2 foot deep infiltration basin of approximate size 0.9 acres, would have significant water quality benefits. Tree removal and grading would be required.

4.3.3 Highland Ravine Stabilization/Restoration Project

In fall 2010, CRWD, with assistance from the City of Saint Paul, commissioned a ravine stabilization and restoration feasibility study in Highland Ravine in Saint Paul. Bounded on the west and east by Edgcumbe Road and Lexington Parkway and on the north and south by Highland Parkway and Montreal Avenue, Highland Ravine is composed of wooded, steep ravines with two ravines highly eroded, which has contributed to downstream flooding, sedimentation and poor water quality.

The purpose of the study was to better understand local hydrology and identify the locations and causes of erosion, sedimentation and flooding in the Highland Ravine. In addition, planning level solutions and their costs were proposed. The study recommends options for stabilizing and restoring the ravines as well as best management practices, such as rain gardens and pervious pavement, to reduce stormwater runoff and improve water quality from upstream areas. See Appendix F for the Highland Ravine Stabilization/Restoration Feasibility Study.

4.3.3.1 Highland Creek Bank Stabilization - Site 1

Highland Creek is a small stream that runs from the Highland Golf Course to the Mississippi River. Stream bank restoration and the potential construction of eyebrow wetlands would reduce the amount of sediment that high flows currently wash downstream, and increase infiltration (Project #3). Bank restoration could include channel reshaping, live stakes, brush bundles, boulders and rip rap. Eyebrow wetlands are shallow basins constructed above the bank full height of the channel. When the banks overtop during high flows the eyebrow wetlands fill and promote infiltration. The costs associated with this project are based on recent bids of similar projects (see Section 4.8). The total length of stream bank restoration is estimated to be 300 feet.

4.3.3.2 Highland Creek Bank Stabilization - Site 2

As in Highland Creek Site 1, stream bank restoration would reduce the amount of sediment that high flows currently wash downstream (Project #4A-K). Bank restoration could include channel reshaping, live stakes, brush bundles, boulders and rip rap.

4.3.4 Stream Corridor Restoration Feasibility Study for Highland Creek

The 2010 CRWD Watershed Management Plan identifies the development of a stream restoration feasibility study for Highland Creek from Highland Golf Course to the Mississippi River. (See Table 4-2.) Completion of this study could identify further opportunities to provide infiltration as well as filtration of stormwater.

4.3.5 Griggs / Scheffer Residential Street Vitality Program

During street reconstruction, green infrastructure practices, such as rain gardens, stormwater vaults, and infiltration practices, could be implemented to meet CRWD Rules for redevelopment projects equal to or greater than one acre and protect the water quality of the river (Project #5). Approximately 8.5 impervious acres could receive water quality treatment. A map produced by the City of Saint Paul Department of Public Works is shown below (Figure 4-2). The highlighted segments are proposed to be reconstructed in 2012.

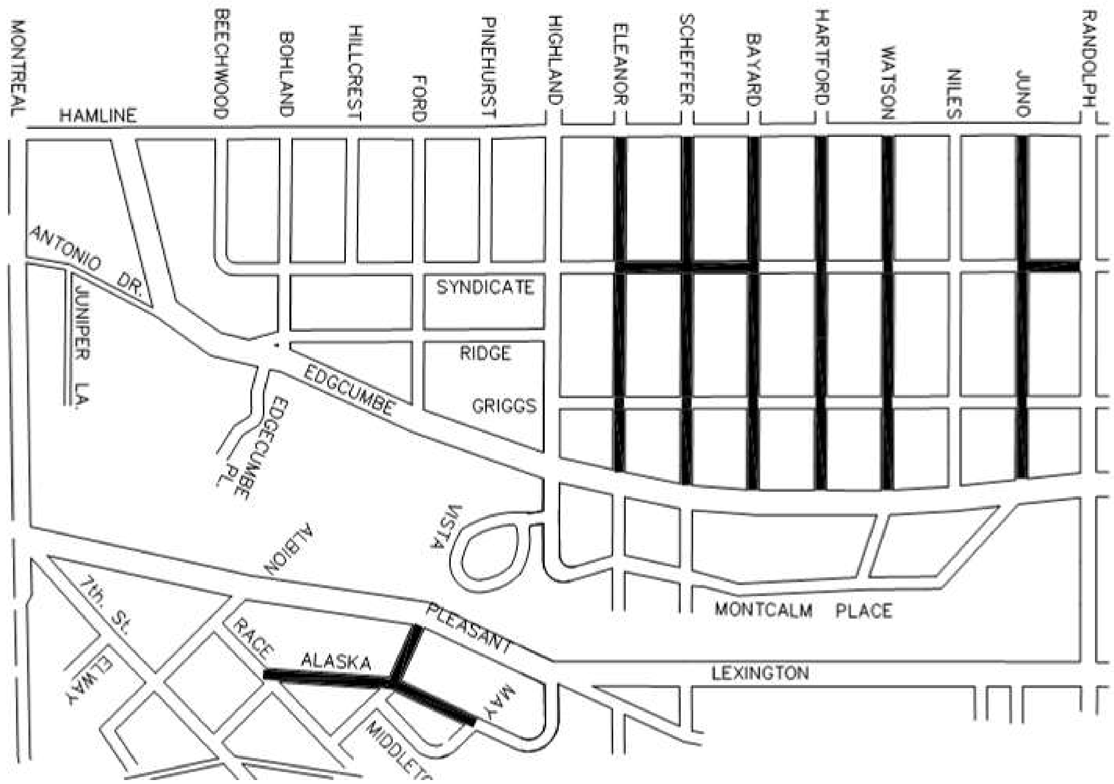

Figure 4-2. Griggs/Scheffer Residential Street Vitality Program

CRWD has established a cost cap for linear projects of $30,000 per acre of impervious surface. It was assumed that this cap would be reached in determining the cost estimate of the project (See Section 4.5).

4.3.6 Implement Rain Gardens throughout the Watershed

CRWD will promote the installation of rain gardens through the watershed where soils are appropriate (Project #6 and #7). It was assumed that 5% of the impervious area in watershed CR01and CR07 would be treated by a rain garden. However, rain gardens can be implemented through the watershed. Figure 2-4 shows soils in the Crosby Subwatershed.

4.3.7 Saint Paul Parking Lot Reconstruction West of Crosby Lake

This project is currently being considered by the City of Saint Paul Parks and Recreation Department and if constructed the project would likely have to meet CRWD Rules (Project #8). If stormwater BMPs such as porous pavement and rain gardens were installed, 1.5 impervious acres that are currently not treated would receive water quality treatment.

4.3.8 Sump Manholes and Grit Chambers

Construction of water quality treatment options are limited in highly developed areas due to the lack of open space. However, inline storm sewer practices can effectively reduce the amount of solids delivered to surface waters. St. Anthony Falls Laboratory at the University of Minnesota has developed baffled weirs to improve the performance of sump manholes. In addition, swirl separators can improve solids removal from stormwater. The City of Saint Paul should consider the used of sump manholes during redevelopment to improve solids removal from stormwater. This project is not included on Figure 4-1 because it is broad in scope.

4.3.9 Street Sweeping

Recent studies by the Wisconsin DNR and the City of Madison have concluded that vacuum street sweepers can remove approximately 1 pound of TP per lane mile per year if sweeping occurs at least once per month during all available months, typically April through November. The City of Saint Paul should consider the use of vacuum street sweepers on a monthly basis in high priority areas. This project is not included on Figure 4-1 because it is broad in scope.

4.3.10 Golf Course Stormwater and Fertilizer Management

The City of Saint Paul Parks and Recreation Department manages the Highland Golf Course located in the western part of the watershed. It is currently believed that the golf course rarely discharges to the conveyance system due to pond storage and water reuse throughout the course. Therefore, the area likely has little impact on nutrient loading downstream. Management will continue to focus on minimizing fertilizer use and promoting water reuse to keep nutrients on the golf course. CRWD and the City of Saint Paul will consider assessing the frequency and magnitude of discharge from the golf course to ensure limited nutrient loading to downstream waters . (See Table 4-2.)

4.3.11 Monitoring

Water quantity and quality data are not currently collected in the Crosby Subwatershed for either stormwater discharged directly to the Mississippi River or to Little Crosby and Crosby Lake. Water quality and quantity data should be collected in the Crosby Lake watershed to validate models, assess the effectiveness of BMP implementation, and develop a long term baseline to measure changes in water quality against. (See Table 4-2.)

4.4 CROSBY LAKE WATERSHED

Following is a list of projects identified to address stormwater runoff discharging to Crosby Lake. See Figure 4-1 and Table 4-3 for the corresponding project numbers and locations. Some projects may not appear on Figure 4-1 because they are broad in scope.

4.4.1 Madison / Benson Residential Street Vitality Program

During street reconstruction green infrastructure practices could be implemented to meet the District's Rules (Project #9). Approximately 1.1 impervious acres that are currently not treated could receive water quality treatment. A map produced by the City of Saint Paul Department of Public Works is shown below (Figure 4-3). The highlighted segments are proposed to be reconstructed in 2012.

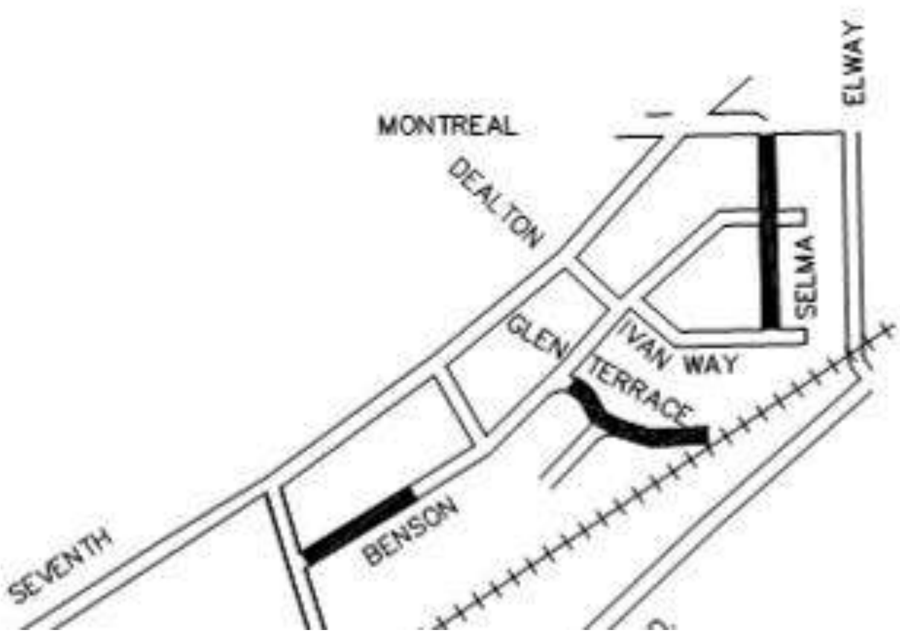

Figure 4-3. Madison/Benson Residential Street Vitality Program

4.4.2 Stormwater Diversion along Shepard Road

As outlined in the Crosby Farm Park Bluff Stabilization /Restoration Feasibility Report (Appendix G), this project includes regarding of the ditch along Youngman Ave to convey overland flow to the deep storm sewer tunnel under Stewart Street and abandoning the storm sewer outfalls to the bluff (Project #10A-C). If completed this project would divert a total of 68 highly developed acres to the Mississippi River and reduce bluff erosion from entering Crosby Lake. The 68 acres is spread over three subwatersheds as defined in the report and is broken down as follows: 9 acres from subwatershed CR02, 4 acres from CR04 and 55 acres from CR06. Although diversion of stormwater away from Crosby Lake protects lake water quality, it will also increase loading to the Mississippi River. Therefore, green infrastructure practices were identified to treat stormwater prior to diversion to the river (Project #11). Also, a groundwater analysis should be completed prior to implementing the diversion to make sure Crosby Lake water levels are not adversely affected. However, due to the position of Crosby Lake in the floodplain, it is unlikely that water levels will be affected.

The areas diverted by the stormwater diversion are shown below in Figures 4-4, 4-5, and 4-6 from the Crosby Farm Park Bluff Stabilization/Restoration Feasibility Report, followed by the specific areas diverted from subwatersheds CR02, CR04 and CR06.

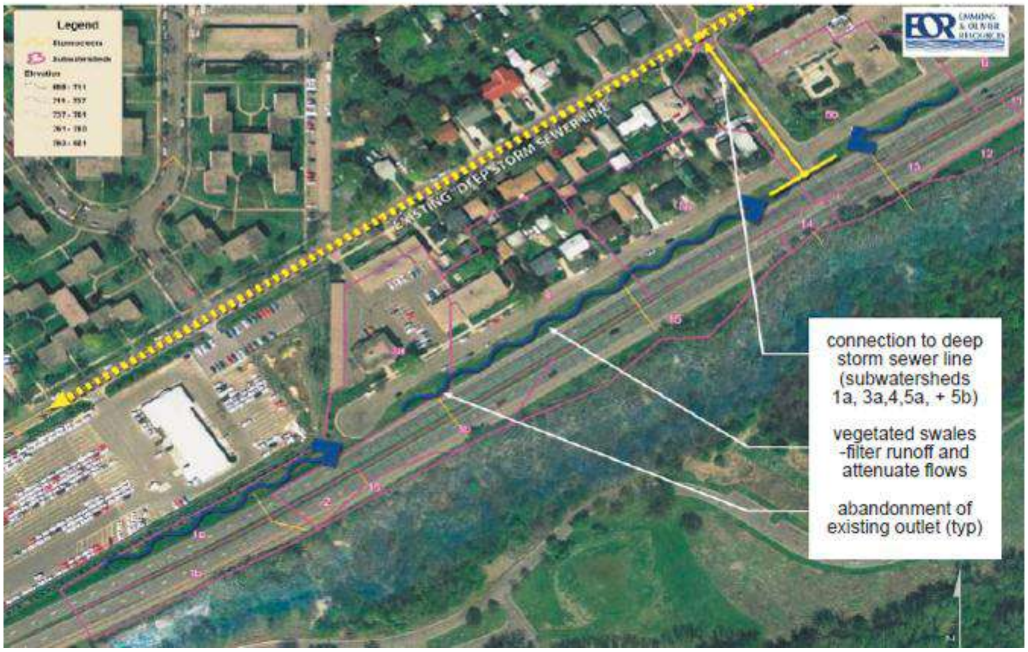

Figure 4-4. Subwatershed CR02 Stormwater Diversion

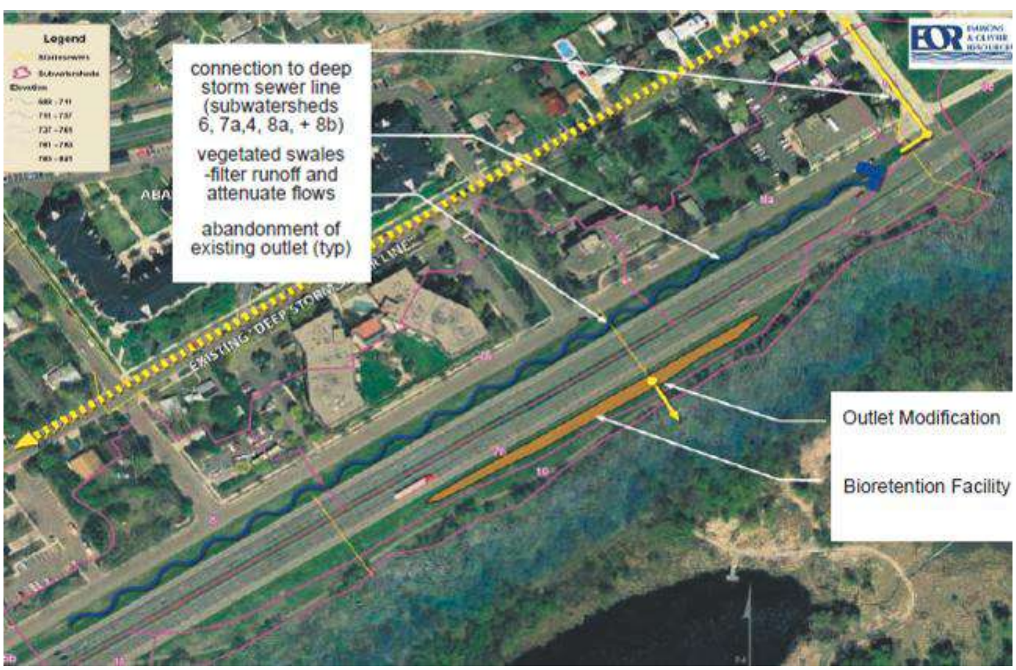

Figure 4-5. Subwatershed CR04 Stormwater Diversion

Figure 4-6. Subwatershed CR06 Stormwater Diversion

To estimate the load reduction due to the stormwater diversion of each subwatershed the P8 model was run for the same time period used to predict the overall runoff of the Crosby Lake watershed. Because all 68 acres is diverted from Crosby Lake the entire amount of TSS and TP estimated by the P8 model is the reduction. However, this load was added to the Mississippi River loading.

4.4.3 Saint Paul Parking Lot East of Crosby Lake

This project is currently being designed by the City of Saint Paul Parks and Recreation Department (Project #12). The City is exploring stormwater management opportunities but there is very little potential for additional water quality benefits for the Crosby Lake Subwatershed because it would convert open space to a parking lot.

4.4.4 Management of Natural Areas

The City of Saint Paul Parks and Recreation Department is responsible for the management of Crosby Farm Regional Park including the natural areas throughout the park. Management actions will consider water quality by protecting mature forest areas, limiting impervious area, and managing for a healthy, diverse floodplain forest.

One critical aspect to long term protection of water quality in Crosby Lake and the Mississippi River is protection of the forested areas within Crosby Farm Regional Park (Project #13). Natural forested areas protect water quality by reducing the amount of surface runoff and associated pollutants. Old growth forest also decreases stormwater runoff by holding more water in soils and on vegetation further reducing runoff.

4.4.5 Manage Trash along the Bluff and in Crosby Farm Regional Park

CRWD will partner with the City of Saint Paul and the Friends of the Mississippi River to reduce trash along Shepard Road and in Crosby Farm Regional Park. Activities may include clean up events, education and awareness, or addition of trash receptacles. This project is not included on Figure 4-1 because it is broad in scope.

FMR will conduct 1-2 litter clean-up events in the watershed with organized student or volunteer groups. The likely locations for these events are parks along the river or lakeshore. The events will include an educational component about preventing stormwater pollution. FMR will coordinate the events with the City.

4.4.6 Crosby Farm Park and Hidden Falls Park - Prairie and Woodland Restoration

Restoration work by FMR and the City of Saint Paul includes ongoing invasive species removal to maintain the floodplain prairie, prepping sites for volunteer events and expanding habitat improvement projects to adjacent floodplain forest and woodland areas of the parks. (This ongoing project is not included among the numbered projects in Figure 4-1 or Table 4-3.)

4.4.7 Gorge Leadership Team

FMR's trained a group of 20 volunteers will participate in two team outings in Crosby Park and Hidden Falls Park to provide ongoing care and management at high quality natural areas in the parks. (This ongoing project is not included among the numbered projects in Figure 4-1 or Table 4-3.)

4.4.8 Bluff Stabilization

Once the majority of stormwater is diverted away from the bluff, the remaining impacts to the bluff will need to be addressed including bare soils and vegetation loss. Bluff areas, including informal paths, are being used more frequently by cyclists, runners and general nature enthusiasts who are impacting sensitive, unstable areas and causing erosion of the bluffs. The Bluff Erosion study offers a plan to educate users and revegetate areas that may deter use of the sensitive bluff areas. (This educational program is not included among the numbered projects in Figure 4-1 or Table 4-3.)

4.5 ELIMINATED PROJECTS

Several projects were evaluated and determined to be infeasible based on physical conditions at the site. Following is a brief description of the evaluated options. See Figure 4-1 for project locations.

4.5.1 Expansion of Depression west of 35E and South of Shepard Road

This area is a NWI category 7 (wooded swamp) wetland (Project E1). It is the watershed district's policy not to disturb a natural wetland. Excavation to form a water quality feature at the site is not recommended. However, because of the existing stormwater issues in this watershed, future regulatory pollutant load reduction requirements, and the lack of space available for BMPs, this eliminated project could be reevaluated during plan implementation.

4.5.2 Infiltration Basin at the NE Corner of Elway and Shepard

This property is owned by the City of St. Paul and an investigation was completed to determine the site's feasibility for stormwater management (Project E2). Because the large, deep storm sewer pipes do not allow for diverting stormwater to ground level and the shallow bedrock does not allow for infiltration, this site is not feasible for an infiltration basin.

4.5.3 Storm Sewer Diversion to Underground Infiltration

Analysis of this site found that underground infiltration was not feasible due to deep storm sewer and shallow bedrock (Project E3).

4.5.4 Shepard Road Green Infrastructure Practices East of Interstate 35E

During street reconstruction, green infrastructure practices could be implemented to meet the District's Rules (Project E4). However, green space currently is not available along the road or bike trail for infiltration practices.

4.6 IN-LAKE MANAGEMENT

Following is a list of in-lake projects and management practices identified to address water quality in Crosby Lake.

4.6.1 Assess and Manage Filamentous Algae

Based on anecdotal evidence, Crosby Lake likely demonstrates large filamentous algae blooms that form mats on the lake surface throughout the summer. Filamentous algae start their life cycle on the sediments and are typically driven by internal phosphorus release.

Filamentous algae blooms should be monitored and assessed for nuisance bloom levels. If filamentous algae are determined to be a nuisance, control should focus first on internal phosphorus release from the sediments of Crosby Lake.

If filamentous algae are determined problematic during the assessment, internal nutrient controls should be evaluated. Internal nutrient control in Crosby Lake includes the evaluation and dosing of alum (aluminum sulfate) to the sediments. Although the Mississippi River is a likely source of nutrient rich sediment to Crosby Lake, controlling flooding of Crosby Lake would be difficult and expensive. Furthermore, the Mississippi River relies on the floodplain in which Crosby Lake is situated and reducing the flood storage would create more flooding downstream.

4.6.2 Integrated Carp Management

There is a carp population in Crosby Lake that has historically reached nuisance levels and likely negatively impacted lake water quality. However, current data suggests that the carp population is fairly small and not likely impacting water quality. Carp movement in and out of Crosby Lake will be difficult to control because of river flooding, however it doesn't appear that significant carp recruitment (new individuals born into the carp population) is occurring in Crosby Lake.

Because carp have been historically abundant in Crosby Lake, it is worthwhile to consider developing an action plan to maintain small enough carp populations that do not negatively affect water quality. One approach is the development of an integrated carp management plan to ensure that carp are controlled to sustainable levels in Crosby Lake. An integrated carp management plan would address:

1. Preventing recruitment by ensuring a robust panfish population (i.e. preventing fish kills);
2. Identifying potential inflow pathways;
3. Developing an action plan should recruitment occur; and
4. Periodic monitoring to assess carp population.

4.6.3 Curly-leaf Pondweed Control

Curly-leaf pondweed can have negative impacts on lake water quality if the population reaches nuisance levels. Curly-leaf pondweed was identified in 1978, 1988, and 1999 by the Minnesota DNR during their fish surveys with the most recent survey characterizing curly-leaf pondweed as common. CRWD staff also recorded the presence of curly-leaf pondweed during recent monitoring. However, a point intercept survey conducted by the Ramsey County on July 2nd, 2009 did not identify curly-leaf pondweed at any of the sample locations. Consequently, the current extent and abundance of curly-leaf pondweed in Crosby Lake is not well characterized.

A Curly-leaf pondweed management plan would entail monitoring early season pondweed extent and density, determination of problem areas if any occur, and designated control actions such as chemical treatment, physical removal or sediment iron addition. The plan would first focus on identifying the presence and abundance of curly-leaf pondweed. The second step would be to determine if any actions are necessary or if just long term monitoring is required.

4.6.4 Shoreline Restoration

The 2010 CRWD Management Plan identifies the assessment of the Crosby Lake shoreline and restoration planning as a critical activity. Because Crosby Lake sits entirely within the Crosby Farm Regional Park, the shorelines are relatively undeveloped other than trails. An evaluation of shoreline conditions will identify impacts from trail runoff, invasive vegetation, and other impacts that may reduce habitat quality. Impacted areas will be restored using bioengineering and native vegetation.

4.6.5 Crosby (Upper) Lakeshore Restoration

The project will support new and continued restoration work at Crosby Park in coordination with the City of Saint Paul Department of Parks and Recreation. In 2011, FMR and City staff will continue with a shoreline restoration project around the small pond at Crosby (Upper Lake), in order to improve habitat and water quality. Native shrubs and herbaceous plants will be installed with volunteers where invasive species were removed in 2010.

4.6.6 Water Quality Monitoring

Since 2005, Ramsey County has monitored the water quality of Crosby Lake. Each growing season, May through September, Ramsey County collects samples on monthly or bi-weekly basis that are analyzed for nutrients, chlorophyll-*a*, and chloride. Water temperature, clarity, dissolved oxygen, pH and conductivity are also measured in Crosby Lake by Ramsey County.

Future monitoring should consider monitoring both Crosby and Little Crosby Lakes to characterize any water quality differences. TSS should be considered as an additional parameter to evaluate the potential role of non-algal turbidity in the lake. Submerged aquatic vegetation monitoring should also continue including a spring survey to evaluate curly-leaf pondweed.

4.6.7 Install Nesting Boxes

The Minnesota DNR should consider the addition of nesting boxes for Crosby Lake to promote waterfowl habitat and production. The addition of nesting boxes will promote wildlife use at the lake increasing the aesthetic value of the resource.

4.6.8 Fish Monitoring

MN DNR periodically monitors the fish community in Crosby Lake. Monitoring of the fish community will continue to evaluate any changes that may need to be addressed.

4.6.9 Shallow Lake Habitat Assessment

MN DNR and US Fish and Wildlife Service will provide guidance on the assessment of submerged aquatic vegetation as it pertains to waterfowl and wildlife habitat. Assessments may include sensitive species analysis, identification of key food species, and other critical habitat needs. The USFWS will provide input on a regional basis for waterfowl management and protection.

4.6.10 Evaluate an Index of Biotic Integrity for Crosby Lake

MN DNR is currently developing an Index of Biotic Integrity (IBI) for Minnesota lakes. An IBI is a measure of the health of a biological community through the use of an index. The index is based on a comparison of certain metrics to reference conditions to evaluate biological condition. CRWD will encourage the DNR to include Crosby Lake in their assessment and to supply metric calculations once the IBI has been established.

4.7 EDUCATION AND OUTREACH

CRWD's Education and Outreach Program provides those living and recreating in CRWD with knowledge and skills required to assure protection and improvement of local surface water and ground water resources. The two crucial components of the education and outreach program are to build the public's awareness and to effect behavior change that will benefit local water resources.

The Crosby Lake Citizen's Advisory Group identified that there is a lack of public awareness about the issues regarding Crosby Lake and the need for a well-informed community to affect positive change on the lake. The CAG made a number of education and outreach recommendations, which are listed below.

Education and outreach activities for Crosby Lake and its watershed should be developed and implemented by CRWD and its partners, which include:

- Distribute Crosby Lake and other local water quality monitoring data via CRWD's website and other partner websites and directly to the stakeholder advisory groups;
- Install educational kiosk in Crosby Farm Regional Park that would include information on CRWD, the lake's health and public behaviors and activities to protect it;
- Utilize lake and park as an outdoor science classroom to provide hands-on learning about lake water quality and ecology;
- Conduct community clean ups in the Crosby Lake subwatershed to prevent trash, leaf litter and other debris from being carried to Crosby Lake and the Mississippi River; and
- Promote residential water quality improvement projects, such as rain gardens, rain barrels, pervious pavement and small green roofs, and CRWD's Stewardship Grant Program that offers both technical and financial assistance for these projects.

FMR is developing a new educational program focused on the ecology of the plants and animals in and around Crosby Lake and how they affect or are affected by water pollution. The program will be family-friendly and include hands-on aquatic exploration of pond invertebrates, fish and amphibians, learning about wetland plants and how they improve water quality, looking for signs of beavers and other wildlife, and other experience-based learning activities.

4.8 IMPLEMENTATION PLAN COSTS

4.8.1 Watershed Projects

Table 4-1 summarizes the potential capital projects to reduce watershed TP and TSS loading to the Mississippi River. Cost estimates are life cycle costs that include design, construction, and operation and maintenance. Costs were annualized over 30 years using an assumed 3.5% interest rate to determine the cost per pound removal of total suspended solids and total phosphorus. If all of these projects were implemented, the total project costs would reach almost $2.6M. The largest project is the regional 35E stormwater pond to treat a large portion of the watershed prior to draining into the Mississippi River. Although this project has a relatively high cost per pound

TP removal, it represents one of the few opportunities in the watershed to treat a relatively large proportion of stormwater from the watershed. No reductions in TSS and TP were assumed for the stream restoration projects because in-stream sources are not modeled in P8. However, eliminating bank erosion and increasing infiltration will benefit water quality. Additional information regarding the cost estimates for implementation projects and activities is presented in Appendix H.

Table 4-1. Potential Capital Improvement Projects in the Crosby Subwatershed (Drains to River)

Project Number	Project	BMP Type	Estimated Annual Removal of TSS (lbs/yr)	Estimated Annual Removal of TP (lbs/yr)	Estimated Total Project Cost[3]	Annual Life Cycle Cost per pound of TSS removal	Annual Life Cycle Cost per pound of TP removal	Responsible Party
1	Regional 35E Stormwater Pond	Sedimentation Pond	65,443	63	$405,410	$0.34	$351	City of Saint Paul; CRWD
2	Highland Infiltration Basin	Infiltration / Sedimentation	33,950	64	$150,300	$0.24	$127	City of Saint Paul; CRWD
3	Highland Creek Stabilization	Bank stabilization, potential eyebrow wetlands	NA[3]	NA[3]	$67,000	NA	NA	CRWD
4A	Highland Creek Stabilization	Bank stabilization, potential eyebrow wetlands	NA[3]	NA[3]	$71,350	NA	NA	CRWD
4B (Catch ment #2)	Highland Ravine Stabilization[1]	Slope Stabilization	3,000	12	$35,000	$0.09	$2,250	City of Saint Paul; CRWD
4C (Catch ment #2)	Private Road Porous Pavement[1]	Green Infrastructure Practices	12,000	47	$179,000	$0.04	$3,445	City of Saint Paul; CRWD
4D (Catch ment #2)	Rain Gardens[2]	Green Infrastructure Practices	1,200	5	$74,000	$1	$10,080	City of Saint Paul; CRWD
4E (Catch ment #3)	Storm sewer improvements[1]	Sediment removal	15,000	59	$116,600	$0.01	$705	City of Saint Paul; CRWD

Table 4-1, cont. Potential Capital Improvement Projects in the Crosby Subwatershed (Drains to River)

Project Number	Project	BMP Type	Estimated Annual Removal of TSS (lbs/yr)	Estimated Annual Removal of TP (lbs/yr)	Estimated Total Project Cost3	Annual Life Cycle Cost per pound of TSS removal	Annual Life Cycle Cost per pound of TP removal	Responsible Party
4F (Catchment #3)	Private Road Porous Pavement[1]	Green Infrastructure Practices	5,000	20	$156,060	$0.17	$6,903	City of Saint Paul; CRWD
4G (Catchment #3)	Highland Ravine Stabilization[1]	Slope Stabilization	20,000	79	$37,400	$0.01	$372	City of Saint Paul; CRWD
4H (Catchment #3)	Rain Gardens[2]	Green Infrastructure Practices	2,000	8	$61,880	$0.30	$4,860	City of Saint Paul; CRWD
4I (Catchment #2)	Highland Ravine Stabilization[1]	Slope Stabilization	3,000	12	$35,000	$0.09	$2,250	City of Saint Paul; CRWD
4J (Catchment #2)	Private Road Porous Pavement[1]	Green Infrastructure Practices	12,000	47	$179,000	$0.04	$3,445	City of Saint Paul; CRWD
4K (Catchment #2)	Rain Gardens[2]	Green Infrastructure Practices	1,200	5	$74,000	$1	$10,080	City of Saint Paul; CRWD
5	Griggs/Scheffer RSVP	Green Infrastructure Practices	1,787	7	$353,700	$11	$2,666	City of Saint Paul; CRWD
6	Rain Gardens	Green Infrastructure Practices	2,073	9	$189,540	$5	$1,144	CRWD

Table 4-1, cont. Potential Capital Improvement Projects in the Crosby Subwatershed (Drains to River)

Project Number	Project	BMP Type	Estimated Annual Removal of TSS (lbs/yr)	Estimated Annual Removal of TP (lbs/yr)	Estimated Total Project Cost3	Annual Life Cycle Cost per pound of TSS removal	Annual Life Cycle Cost per pound of TP removal	Responsible Party
7	Rain Gardens	Green Infrastructure Practices	2,073	9	$189,540	$5	$1,144	CRWD
8	Crosby Farm Regional Park Parking Lot Reconstruction (West)	Infiltration or Filtration	306	1	$177,400	$31	$7,815	City of Saint Paul
11[4]	Diverted Stormwater Bioinfiltration	Bioinfiltration Areas	4,516	23	$73,626	$1	$178	City of Saint Paul; CRWD
NA[5]	Catch basin and sump manhole cleaning	Maintenance			$6 /manhole	--	--	City of Saint Paul
NA[5]	Street Sweeping	Maintenance	15,852	66	Street Sweeping	Maintenance	Street Sweeping	City of Saint Paul
NA[5]	Implement District Rules	Green Infrastructure Practices			Staff Time	--	--	CRWD

[1]These projects were not included in the overall reduction estimates because these processes are not modeled in P8.
[2] Reductions for these projects were taken directly from their associated reports and may over estimate removals.
[3]Total project costs are present value including design, construction, operation, and maintenance.
[4]This is part of the stormwater diversion project called out in section 4.4.2. Projects 9 and 10 are included in Table 4-3.
[5]This project is not included on Figure 4-1 because it is broad in scope.

Several studies are also identified in the plan as outlined in Table 4-2.

Table 4-2. Potential Studies and Monitoring for the Crosby Subwatershed

Project	Activities	Cost	Goal	Responsible Party
Studies	Highland Creek Restoration Feasibility Study	$50,000	Identify restoration opportunities and costs for Highland Creek	CRWD
	Highland Golf Course Stormwater and Fertilizer Management Study	$10,000	Determine if Highland Golf Course discharges and identify potential management options	City of Saint Paul
Monitoring	Water quantity and quality monitoring	$20,000/ annually	Monitor water quality to validate models and measure progress	CRWD

Capital projects for the areas draining to Crosby Lake include stormwater diversion away from the bluffs and to the Mississippi River as recommended in the Ramsey County Bluff study (Table 4-3). There were three distinct areas that could be diverted, so each of these areas was maintained as an individual project. These projects also include water quality treatment prior to discharging to the river so as not to trade one water quality problem for another. Diverting the stormwater away from Crosby Lake protects the bluffs and protects lake water quality relatively inexpensively. It is also unlikely that lake water levels will be adversely impacted, however this should be verified prior to implementation of the project.

Once the stormwater is diverted, the remaining impacts to the bluff will need to be addressed. Wenck estimates a bluff stabilization cost of $10/SY (includes $3/SY compost blanket; $3/SY seed in compost blanket; $4/SY turf reinforcement mat). Because the feasibility study did not identify a total area that needs stabilization, a total project cost was not identified.

The total cost for implementing all of these projects is roughly $335,000.

Table 4-3. Potential Capital Improvement Projects in the Crosby Lake Subwatershed (Drains to Lake)

Project Number	Project	BMP Type	Estimated Removal of TSS (lbs/yr)	Estimated Removal of TP (lbs/yr)	Estimated Cost[3]	Annual Life Cycle Cost per pound of TSS removal	Annual Life Cycle Cost per pound of TP removal	Responsible Party
9	Madison/Benson RSVP (2012)	Green Infrastructure Practices	225	1	$68,600	$17	$4120	City of Saint Paul; CRWD
10A	Bluff Stormwater Diversion[1]	Stormwater Diversion	1,167	6	$104,800	$5	$913	CRWD; City of Saint Paul
10B	Bluff Stormwater Diversion[1]	Stormwater Diversion	3,250	18	$110,180	$2	$338	CRWD; City of Saint Paul
10C	Bluff Stormwater Diversion[1]	Stormwater Diversion	10,720	61	$51,980	$0.26	$46	CRWD; City of Saint Paul
12[4]	Crosby Farm Regional Park Parking Lot Construction (East)	Infiltration or Filtration	NA[2]	NA	Cost of Construction	NA	NA	St. Paul Parks and Recreation
13	Open Space and Forest Protection	Protection	NA	NA	NA	NA	NA	St. Paul Parks and Recreation; Friends of the Mississippi River
NA[5]	Manage Trash	--	--	--	In-kind	--	--	Friends of the Mississippi River; CRWD
NA5	Street Sweeping	Maintenance	2,627	11	$25 / curb mile	$0.12	$50 to $150	City of Saint Paul
NA5	Catch basin and sump manhole cleaning	Maintenance			$6 / manhole	--	--	City of Saint Paul
NA5	Implement District Rules	Green Infrastructure Practices			Staff Time	--	--	CRWD

[1]There are three separate stormwater diversion areas. Each was established as an individual project. Costs were updated to include O&M costs.
[2]Projects with an NA represent protection from additional loading rather reductions in current loading.
[3]Total project costs are present value including design, construction, operation, and maintenance.
[4]Project #11 is included in Table 4-1.
[5]This project is not included on Figure 4-1 because it is broad in scope.

To evaluate the potential for reaching the established goals, estimated load reductions were compared to current loading and target load reductions (Table 4-4). For total phosphorus draining to the river, current projects can reduce 248 pounds draining to the river or almost 50% of the established goal. Although these projects alone cannot reach the established goal, they represent a good start toward the goal. As new projects arise and technology advances, further progress can be made toward reaching the goals. For Crosby Lake, diversion of stormwater away from the lake exceeds the total phosphorus target reductions for the Lake. Implementation of these projects would shift the focus for Crosby Lake from watershed management to in-lake management.

Table 4-4. Estimated Total Phosphorus Loading and Load Reductions from BMPs for Each Subwatershed

Watershed	Total Phosphorus Load (pounds/year)	Estimated Load Reduction from Capital Projects (pounds/year)	Estimated Load Reduction from Good Housekeeping and Redevelopment[1] (pounds/year)	Total Load after BMPs (pounds/year)	Target Load (pounds/year)
Mississippi River					
CR01-CR03-CR05-CRO7	469	165	47	257	159
CR02	82	1	8	73	28
Diverted Stormwater	113	23	11	79	38
Total to River	664	189	66	409	226
Crosby Lake					
CRO4	15	6	3	6	8
CRO6	77	61	8	8	41
Total to Lake	92	67	11	14	49

[1]An estimated 10% load reduction was assumed for good housekeeping (increased street sweeping, sump manholes, etc.) and redevelopment under CRWD rules.

For total suspended solids, implementation of the identified projects would exceed the target load reduction for drainage to the river and exceed the target load reduction for the Crosby Lake Subwatershed (Table 4-5).

Table 4-5. Estimated Total Suspended Solids Loading and Load Reductions from BMPs for Each Subwatershed

Watershed	Total Suspended Solids Load (pounds/year)	Estimated Load Reduction from Capital Projects (pounds/year)	Estimated Load Reduction from Good Housekeeping and Redevelopment[1] (pounds/year)	Total Load after BMPs (pounds/year)	Target Load (pounds/year)
Mississippi River					
CR01-CR03-CR05-CRO7	129,511	108,526	12,951	8,034	44,034
CRO2	17,124	306	1,712	15,105	5,822
Diverted Stormwater	11,888	4,516	1,189	6,186	4,042
Total to River	158,523	113,348	15,852	29,322	53,898
Crosby Lake					
CRO4	5,275	1,167	528	3,580	2,796
CRO6	20,991	10,720	2,099	8,172	11,125
Total to Lake	26,266	11,888	2,627	11,752	13,921

[1]An estimated 10% load reduction was assumed for good housekeeping (increased street sweeping, sump manholes, etc.) and redevelopment under CRWD rules.

4.8.2 In-lake Management

Crosby Lake is currently in a clear-lake state with relatively good water quality. Consequently, management should focus on stabilizing the lake in the clear-lake state and on increased biological health including a healthy fish and submerged aquatic vegetation community. There are four focus areas for in-lake management including shorelines, fisheries, aquatic vegetation, and filamentous algae. Table 4-6 outlines the proposed activities along with estimated costs.

Table 4-6. In-lake Management Actions, Costs and Goals for Crosby Lake

Project	Activities	Cost	Goal	Responsible Party
Shoreline Restoration	Assess Shoreline Condition	$10,000	Identify impacted areas including invasive species	CRWD; Ramsey County; St. Paul Parks and Recreation
	Shoreline Restoration	$20/linear foot	Improve natural shorelines	CRWD; St. Paul Parks and Recreation; Friends of the Mississippi River
Filamentous Algae Control/Internal Nutrient Load Control	Assess Filamentous Algae Blooms	$5,000	Determine the extent and severity of filamentous algae blooms	Ramsey County
	Reduce Internal Loading – Alum Addition	$50,000	Reduce or eliminate nutrient source for filamentous algae if necessary	CRWD; St. Paul Parks and Recreation
Fisheries Management	Monitor Fisheries	In-kind	Minnesota DNR monitors fish community for health	Minnesota DNR
	Rough Fish Management Plan	$5,000	Develop action plan if carp or rough were to become over abundant	Minnesota DNR; CRWD
	Fisheries Management Plan	In-kind	Work with Minnesota DNR to maintain balanced fish community through stocking or aeration	Minnesota DNR; CRWD
Submerged Aquatic Vegetation Management	Monitor Submerged Aquatic Vegetation Community in Spring and Late Summer	$5,000 biannually	Maintain long term record of SAV community	Ramsey County
	Control Curly-leaf pondweed if necessary	$10,000 annually	Minimize impacts of Curly-leaf pondweed if present	Ramsey County; CRWD; St. Paul Parks and Recreation
	Increase Plant Diversity	In-kind	Work with Minnesota DNR and USFWS to develop actions to improve SAV diversity	CRWD; Minnesota DNR; USFWS; St. Paul Parks and Recreation
Water Quality Monitoring	Monitor water quality in Upper Crosby and Crosby Lake	$5,000 annually	Continue to track progress of water quality in the lake.	Ramsey County
Wildlife	Install nesting boxes	In-kind	Improve wildlife habitat	Minnesota DNR; USFWS
Studies	Shallow lake habitat assessment	In-kind	Improve wildlife habitat	Minnesota DNR; USFWS
	Evaluate an Index of Biotic Integrity for Crosby Lake	In-kind	Improve fisheries	Minnesota DNR; USFWS

4.9 IMPLEMENTATION SCHEDULE

An important aspect of any implementation plan is the sequence in which activities are undertaken. Typically, watershed activities are the initial focus before any internal loading projects are completed to protect the long term benefits on any internal load reduction practice. Assuming that implementation of this management plan will require 15 years, Table 4-7 outlines the appropriate sequence for protecting and restoring Crosby Lake and the Crosby Subwatershed.

Table 4-7. Management Plan Implementation Schedule

Cycle	Ongoing Activities	Capital Projects and Studies
0-5 years	• Coordination and education • Water quality monitoring • Monitor fisheries • Monitor submerged aquatic vegetation • Catch basin and sump manhole cleaning • Street sweeping • Implement CRWD rules • Open Space and Forest Protection • Manage Trash	• Highland Infiltration Basin • Griggs/Scheffer RSVP • Madison/Benson RSVP • Crosby Farm Regional Parking Lot (East) • Rain Gardens • Highland Creek Restoration Feasibility Study • Highland Golf Course Stormwater and Fertilizer Management Study • Assess and Restore Shoreline • Assess Filamentous Algae Blooms • Rough Fish Management Plan • Fisheries Management Plan • Shallow Lake Habitat Assessment • Install Nesting Boxes
5-10 years	• Coordination and education • Water quality monitoring • Monitor fisheries • Monitor submerged aquatic vegetation • Catch basin and sump manhole cleaning • Street sweeping • Implement CRWD rules • Open Space and Forest Protection • Manage Trash	• Regional 35E Stormwater Pond • Highland Ravine Improvements • Rain Gardens • Bluff Stormwater Diversion • Diverted Stormwater Bioinfiltration • Crosby Farm Regional Parking Lot (West) • Internal Load Control • Curly-leaf Pondweed Control • IBI Development

Finally because many of the implementation projects involve monitoring, CRWD has presented the monitoring activities and schedules in a separate table, Table 4-8.

Table 4-8. Crosby Lake Management Plan Monitoring/Assessment Activities

Monitoring Activity	Description	Responsible Party	Schedule
Lake Water Quality Monitoring	Collect water quality data from Crosby and Little Crosby Lakes	Ramsey County	Ongoing
Stormwater Monitoring	Collect stormwater water quality and quantity data from the Crosby Lake subwatershed and the Crosby subwatershed that drains directly to the Mississippi River	CRWD	2013
Filamentous Algae Survey	Monitor Crosby Lake for filamentous algae, which can become invasive and a nuisance	Ramsey County; CRWD	2012 - Plan; 2013 - Implement
Curly Leaf Pondweed Survey	Monitor Crosby Lake for curlyleaf pondweed in the late winter/early spring, which can become invasive and a nuisance	Ramsey County; CRWD	2012 - Plan; 2013 - Implement
Shoreline Survey	Assess existing conditions of shoreline	CRWD; Ramsey County; City of Saint Paul	2012
Fisheries Assessment	Monitor the fish community in Crosby Lake	MN DNR	2014
Shallow Lake Habitat Assessment	Assess submerged aquatic vegetation as it pertains to waterfowl and wildlife habitat	MN DNR/ US FWS	TBD

5.0 References

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6.0 Glossary

Aeration Any active or passive process by which intimate contact between air and liquid is assured, generally by spraying liquid in the air, bubbling air through water, or mechanical agitation of the liquid to promote surface absorption of air.

Algae Microscopic organisms/aquatic plants that use sunlight as an energy source (e.g., diatoms, kelp, seaweed). One- celled (phytoplankton) or multicellular plants either suspended in water (Plankton) or attached to rocks and other substrates (periphyton). Their abundance, as measured by the amount of chlorophyll-*a* (green pigment) in an open water sample, is commonly used to classify the trophic status of a lake. Numerous species occur. Algae are an essential part of the lake ecosystem and provide the food base for most lake organisms, including fish. Phytoplankton populations vary widely from day to day, as life cycles are short.

Algal Bloom Population explosion of algae in surface waters due to an increase in plant nutrients such as nitrates and phosphates.

Alkalinity The ability of water, or other substances, to absorb high concentrations of hydrogen ions. Substances with a pH greater than 7.0 are considered alkaline. A measure of the amount of carbonates, bicarbonates, and hydroxide present in water. Low alkalinity is the main indicator of susceptibility to acid rain. Increasing alkalinity is often related to increased algae productivity. Expressed as milligrams per liter (mg/1) of calcium carbonate (CaCO3), or as microequivalents per liter (ueq/1). 20 ueq/1 = 1 mg/l of CaCO3.

Alum Common name for commercial-grade Aluminum Sulfate. Its chemical formula is generally denoted by $Al_2(SO^4)_3$ X $12H_2O$. Most often used in lakes as a way to precipitate a floc that settles through the water column removing fine particles to the sediment and building up a barrier layer to contain soluble phosphorus in the bottom sediments.

Anoxic Without oxygen.

Aquatic Organisms that live in or frequent water.

Aquatic Invertebrates Aquatic animals without an internal skeletal structure such as insects, mollusks, and crayfish.

Aquifer A saturated permeable geologic unit that can transmit significant quantities of water.

Banks and Shorelines Those areas along streams, lakes, ponds, rivers, wetlands, and estuaries where water meets land. The topography of banks and shorelines can range from very steep to very gradual.

Benthic Zone The bottom zone of a lake.

Biomass The total quantity of plants and animals in a lake. Measured as organisms or dry matter per cubic meter, biomass indicates the degree of a lake system's eutrophication or productivity.

Chloride (Cl^-) Chlorine in the chloride ion (Cl^-) form has very different properties from chlorine gas (Cl_2), which is used for disinfecting. The chloride ion (Cl^-) in lake water is commonly considered an indicator of human activity. Agricultural chemicals, human and animal wastes, and road salt are the major sources of chloride in lake water.

Chlorophyll-*a* Green pigment present in all plant life and necessary for photosynthesis. The amount present in lake water depends on the amount of algae and is therefore used as a common indicator of water quality.

Clarity The transparency of a water column. Measured with a Secchi disc.

Concentration Expresses the amount of a chemical dissolved in water. The most common units are milligrams per liter (mg/1) and micrograms per liter (ug/1). One milligram per liter is equal to one part per million (ppm). To convert micrograms per liter (ug/1) to milligrams per liter (mg/1), divide by 1000 (e.g. 30 ug/l = 0.03 mg/1). To convert milligrams per liter (mg/1) to micrograms per liter (ug/1), multiply by 1000 (e.g. 0.5 mg/l = 500 ug/1). Microequivalents per liter (ueq/1) is also sometimes used, especially for alkalinity; it is calculated by dividing the weight of the compound by 1000 and then dividing that number into the milligrams per liter.

Conductivity (specific conductance) Measures water's ability to conduct an electric current. Conductivity is reported in micromhos per centimeter (umhos/cm) and is directly related to the total dissolved inorganic chemicals in the water. Values are commonly two times the water hardness unless the water is receiving high concentrations of contaminants introduced by humans.

Daphnia Small crustacean (zooplankton) found in lakes. Prey for many fish species.

Dissolved Oxygen (DO) The amount of free oxygen absorbed by the water and available to aquatic organisms for respiration; amount of oxygen dissolved in a certain amount of water at a particular temperature and pressure, often expressed as a concentration in parts of oxygen per million parts of water.

Diversity Number of species in a particular community or habitat.

Ecosystem A system formed by the interaction of a community of organisms with each other and with the chemical and physical factors making up their environment.

Erosion The wearing away and removal of materials of the earth's crust by natural means.

Eutrophic Pertaining to a lake or other body of water characterized by large nutrient concentrations such as nitrogen and phosphorous and resulting high productivity. Such waters are often shallow, with algal blooms and periods of oxygen deficiency. Slightly or moderately eutrophic water can be healthful and support a complex web of plant and animal life. However, such waters are generally undesirable for drinking water and other needs.

Eutrophication The process by which lakes and streams are enriched by nutrients, and the resulting increase in plant and algae growth. This process includes physical, chemical, and biological changes that take place after a lake receives inputs for plant nutrients--mostly nitrates and phosphates--from natural erosion and runoff from the surrounding land basin. The extent to which this process has occurred is reflected in a lake's trophic classification: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile), hypereutrophic (extremely productive and fertile). *Cultural eutrophication* is the accelerated eutrophication that occurs as a result of human activities in the watershed that increase nutrient loads in runoff water that drains into lakes

Exotic A non-native species of plant or animal that has been introduced.

Filamentous Algae Algae that forms filaments or mats attached to sediment, weeds, piers, etc.

Food Chain The transfer of food energy from plants through herbivores to carnivores. An example: insect-fish-bear or the sequence of algae being eaten by small aquatic animals (zooplankton) which in turn are eaten by small fish which are then eaten by larger fish and eventually by people or predators.

Groundwater Water contained in or flowing through the ground. Amounts and flows of groundwater depend on the permeability, size, and hydraulic gradient of the aquifer. G*roundwater discharge areas* are areas where groundwater exits to the surface. Depending on local topography, these may create continuously saturated areas on slopes or in shallow depressions that support unusual plant communities, or may interact with surface water runoff to create ponds and deep-water wetlands. *Groundwater recharge areas* are areas on the earth's surface where surface water can percolate down to the water table. A g*roundwater drainage lakes*, often referred to as a spring-fed lake, has a large amount of groundwater as its source, and a surface outlet. Areas of high groundwater inflow may be visible as springs or sand boils. Groundwater drainage lakes often have intermediate retention times with water quality dependent on groundwater quality.

Habitat The place where an organism lives that provides an organism's needs for water, food, and shelter. It includes all living and non-living components with which the organism interacts.

Hydrologic (water) Cycle The process by which the earth's water is recycled. Atmospheric water vapor condenses into the liquid or solid form and falls as precipitation to the ground surface. This water moves along or into the ground surface and finally returns to the atmosphere through transpiration and evaporation.

Hydrologic Soil Groups The classification of soils by their reference to the intake rate of infiltration of water, which is influenced by texture, organic matter content, stability of the soil aggregates, and soil horizon development.

Hydrology The study of water, especially its natural occurrence, characteristics, control and conservation.

Impervious A term denoting the resistance to penetration by water or plant roots; incapable of being penetrated by water; non-porous.

Limiting factor The nutrient or condition in shortest supply relative to plant growth requirements. Plants will grow until stopped by this limitation; for example, phosphorus in summer, temperature or light in fall or winter.

Littoral The near shore shallow water zone of a lake, where aquatic plants grow.

Nitrate (NO3-) An inorganic form of nitrogen important for plant growth. Nitrogen is in this stable form when oxygen is present. Nitrate often contaminates groundwater when water originates from manure pits, fertilized fields, lawns or septic systems. High levels of nitrate-nitrogen (over 10 mg/1) are dangerous to infants and expectant mothers. A concentration of nitrate-nitrogen (NO3-N) plus ammonium-nitrogen (NH4-N) of 0.3 mg/l in spring will support summer algae blooms if enough phosphorus is present.

Non-Point Source A source of pollution that comes from no single identifiable point of discharge. Example: topsoil erosion into a lake or stream.

Nutrients Elements or substances such as nitrogen and phosphorus that are necessary for plant growth. Large amounts of these substances can become a nuisance by promoting excessive aquatic plant growth.

Organic Matter Elements or material containing carbon, a basic component of all living matter.

Permeability The ability of a substance, such as rock or soil, to allow a liquid to pass or soak through it.

pH The numerical value used to indicate how acid or alkaline a solution is. The number refers to the number of hydrogen ions in the solution. The pH scale ranges from 1 to 14 with 7.0 being neutral. Acid ranges from 0 to 6. Alkaline ranges from 8 to 14.

Phosphorus Key nutrient influencing plant growth in freshwater lakes. Soluble reactive phosphorus is the amount of phosphorus in solution that is available to plants. Total phosphorus includes the amount of phosphorus in solution (reactive) and in particulate form.

Photosynthesis The process by which green plants convert carbon dioxide (CO2) dissolved in water to sugar and oxygen using sunlight for energy. Photosynthesis is essential in producing a lake's food base, and is an important source of oxygen for many lakes.

Phytoplankton Microscopic floating plants, mainly algae, that live suspended in bodies of water and that drift about because they cannot move by themselves or because they are too small or too weak to swim effectively against a current.

Plankton Small plant organisms (phytoplankton and nanoplankton) and animal organisms (zooplankton) that float or swim weakly though the water.

Pollution The contamination of water and other natural resources by the release of harmful substances into the environment.

Precipitation Rain, snow, hail, or sleet falling to the ground.

Predator An animal that hunts and kills other animals for food.

Prey An animal that is hunted or killed by another for food.

P8 Program for Predicting Polluting Particle Passage thru Pits, Puddles, & Ponds. A model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds.

Retention Time (turnover rate or flushing rate) The average length of time water resides in a lake, ranging from several days in small impoundments to many years in large seepage lakes. Retention time is important in determining the impact of nutrient inputs. Long retention times result in recycling and greater nutrient retention in most lakes. Calculate retention time by dividing the volume of water passing through the lake per year by the lake volume.

Runoff Water that flows over the surface of the land because the ground surface is impermeable or unable to absorb the water.

Secchi Disc An 8-inch diameter plate with alternating quadrants painted black and white that is used to measure water clarity (light penetration). The disc is lowered into water until it disappears from view. It is then raised until just visible. An average of the two depths, taken from the shaded side of the boat, is recorded as the Secchi disc reading. For best results, the readings should be taken on sunny, calm days.

Sedimentation The removal, transport, and deposition of detached soil particles by flowing water or wind. Accumulated organic and inorganic matter on the lake bottom. Sediment includes decaying algae and weeds, marl, and soil and organic matter eroded from the lake's watershed.

Soluble Capable of being dissolved.

Species A group of animals or plants that share similar characteristics such as can reproduce.

Stormwater Runoff Water falling as rain during a storm and entering a surface water body like a stream by flowing over the land. Stormwater runoff picks up heat and pollutants from developed surfaces such as parking lots.

Submerged Aquatic Vegetation (SAV) See *macrophytes*

Subwatershed A smaller geographic section of a larger watershed unit with a drainage area of between 2 and 15 square miles and whose boundaries include all the land area draining to a point where two second order streams combine to form a third order stream.

Sulfate (SO^4--) The most common form of sulfur in natural waters. The amounts relate primarily to soil minerals in the watershed. Sulfate (SO4) can be reduced to sulfide (S--) and hydrogen sulfide (H2S) under low or zero oxygen conditions. Hydrogen sulfide smells like rotten eggs and harms fish. Sulfate (SO4--) input from acid rain is a major indicator of sulfur dioxide (SO2) air pollution. Sulfate concentration is used as a chemical fingerprint to distinguish acid lakes acidified by acid rain from those acidified by organic acids from bogs.

Suspended Solids A measure of the particulate matter in a water sample, expressed in milligrams per liter. When measured on inflowing streams, it can be used to estimate the sedimentation rate of lakes or impoundments.

Trophic Status or Classification Eutrophication is the process by which lakes are enriched with nutrients, increasing the production of rooted aquatic plants and algae. The extent to which this process has occurred is reflected in a lake's trophic classification or state: oligotrophic (nutrient poor), mesotrophic (moderately productive), and eutrophic (very productive and fertile).

Turbidity Degree to which light is blocked because water is muddy or cloudy.

Turnover Fall cooling and spring warming of surface water increases density, and gradually makes temperature and density uniform from top to bottom. This allows wind and wave action to mix the entire lake. Mixing allows bottom waters to contact the atmosphere, raising the water's oxygen content. However, warming may occur too rapidly in the spring for mixing to be effective, especially in small sheltered kettle lakes.

Water Table The top or “surface” of groundwater. The water table level changes in response to amounts of groundwater recharge flowing in, and amounts of water leaving the ground through seeps, springs, and wells.

Watershed The geographic region within which water drains into a particular river, stream, or body of water.

Wetland Habitats where the soil is saturated or covered with water for part of the year.

Zooplankton Microscopic or barely visible animals that eat algae. These suspended plankton are an important component of the lake food chain and ecosystem. For many fish, they are the primary source of food.

APPENDIX A – Dakota Nation History Related to Crosby Farm Regional Park

Draft Text for Crosby Lake Water Management Plan Background & Action Steps

drafted by residents of the Crosby Lake Watershed, Crosby Lake Citizen Committee members, and members of the Dakota Nation

January 6, 2011

I. HISTORICAL SIGNIFICANCE: Dakota Nation and Crosby Lake

Minnesota is the homeland of the Dakota, Minnesota's oldest indigenous people. Crosby Park sits within *Bdote*, a culturally and historically significant site of the Dakota Oyate (Nation). A plan to manage Crosby Lake provides an opportunity to acknowledge and honor this unique site. The Dakota Nation, Minnesota's first environmental advocates, is a strong partner for protecting Crosby Lake and all natural resources in Crosby Park.

The confluence of the Mississippi River *(HaHa Tanka)*, the Minnesota River (*Mnisota Wakpa*), and Minnehaha Creek is named *Bdote*.[1] In the origin stories of the *Bdewakantunwan* (Dwellers by the Mystic Lake) Dakota, *Bdote* is the area of the Dakota creation. This makes the confluence of the waterways a Dakota sacred site. *Bdote* encompasses the area surrounding the confluence including Pike Island (*Wita Tanka*) and St. Paul's Crosby Park and its lake.

Bdote is also of historic significance to non-Native people who make their home in St. Paul. Since the 1500s, the Dakota have greeted the explorers, fur traders, government officials,

[1] This definition of *Bdote* is compiled from interviews from Santee Dakota tribal members and from the *Bdote* Memory website, an educational deep mapping tool developed by Dakota media artist Mona Smith in partnership with the Minnesota Humanities Center and Dakota historians, such as Dave Larsen, elder of the Lower Sioux Community and Dr. Chris Mato Nunpa, retired professor and member of Upper Sioux Community. Additional testimony to the significance of this area is available from the Mendota Dakota people who are charged with protecting *Bdote* from their traditional home in Mendota, just across the river from Pike Island and Crosby Park.

soldiers, and settlers who arrived in Minnesota. In 1805, the Dakota (Sioux[2]) Nation and the U.S. Government signed a landmark treaty at *Bdote* on *Wita Tanka*, (Pike Island). This was the first treaty ever signed in Minnesota between an indigenous nation and the U.S. federal government. Thus this treaty marks another beginning--the creation of our city and our state.

In the ground-breaking 1805 U.S.-Dakota treaty, the Dakota gave the United States permission to establish military posts in the region of *Bdote*. The purchased land also included a corridor running nine miles on both the east and west side of the Mississippi River. As a result, the 1805 federal treaty formed the land base for Fort Snelling, which was later completed in 1825. With the fort in place, the City of Saint Paul grew up in the *Bdote* region. In fact, all of Saint Paul was originally Dakota land sold to the U.S Government.

In return for the lands that created Fort Snelling and St. Paul, the 1805 U.S. Treaty guaranteed the Dakota ongoing use of the land and waters in and around *Bdote*. The United States promised on their part to "permit the Dakota to pass, repass, hunt or make other uses of the said districts, as they have formerly done, without any other exception, but those specified in the first article of the treaty where the Dakota Nation grants to the United States, the full sovereignty and power over said districts forever, without any let or hindrance whatsoever." This government-to-government provision, enacted by the U.S. Congress, reveals that the Dakota Nation has a unique relationship to the management and use of Crosby Lake and Park.

[2] Sioux is a derogatory term that no longer is in common usage among the Dakota people. It means 'snake' in the Ojibwe/Anishinabe language. However, the 1805 U.S.-Sioux Treaty with the Dakota Nation uses the term and thus it is included here.

II. ACTION STEPS that could be included in the Management Actions section of the report.

While members of the Dakota Oyate now live throughout Minnesota, the Dakotas, Nebraska, Montana, Canada, and right here in St. Paul, *Bdote* is still a sacred site for *all* Dakota people. Given the cultural and historical significance of *Bdote*, as well as the federally guaranteed treaty provisions, the Dakota Nation and its representatives make the following requests.

1) The Capital Region Watershed District protect and improve water quality and aquatic life in Crosby Lake, and protect native plant species in order to enhance lake quality.

2) The Capital Region Watershed District and St. Paul Parks and Recreation Department involve Dakota Nation representation in all future management and planning of Crosby Park and Lake, as they are legitimate stakeholders, per the Treaty of 1805.

3) The St. Paul Parks and Recreation Department oppose or minimize additional development in Crosby Park to maximize traditional green space that honors this significant sacred site.

4) The St. Paul Parks and Recreation Department install Dakota history interpretive signs along the river trails in Crosby Park where people can view and honor the cultural and historic significance of *Bdote*.

5) The St. Paul Parks and Recreation Department include Dakota culture and history in

all other public information on Crosby Park and Lake, including the city's website, as an additional strategy to educate people about the unique significance of this region.

6) The St. Paul Parks and Recreation Department invite Dakota band members to participate, for free, in the annual bow and arrow culling of deer in Crosby Park.

7) The St. Paul Parks and Recreation Department recognize Dakota Nation fishing rights in Crosby Lake and the Mississippi River.

8) The St. Paul Parks and Recreation Department consider renaming Crosby Park to reflect the significance of Dakota Nation land in establishing the City of Saint Paul.

APPENDIX B – Mississippi River Interaction with Crosby Lake

Wenck Engineers • Scientists

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MEMORANDUM

TO: Joe Bischoff

FROM: Todd Shoemaker, P.E., C.F.M.

DATE: September 23, 2010

SUBJECT: Crosby Lake hydraulic connection to the Mississippi River

CC:

This memorandum summarizes my review and analysis of Mississippi River data to determine how frequently the river inundates Crosby Lake. Data reviewed included stage and discharge information from the USGS gage in St. Paul between Wabasha and Robert Streets and the *2003 Flow Frequency Study* performed by the Corps of Engineers.

The USGS has recorded stage and discharge for the Mississippi River in downtown St. Paul since 1892. Using this data, they have developed a rating curve for flood flows above elevation 690 (Figure 1). (Establishing a rating curve below elevation 690 is problematic because of backwater effects due to the dam at Hastings.)

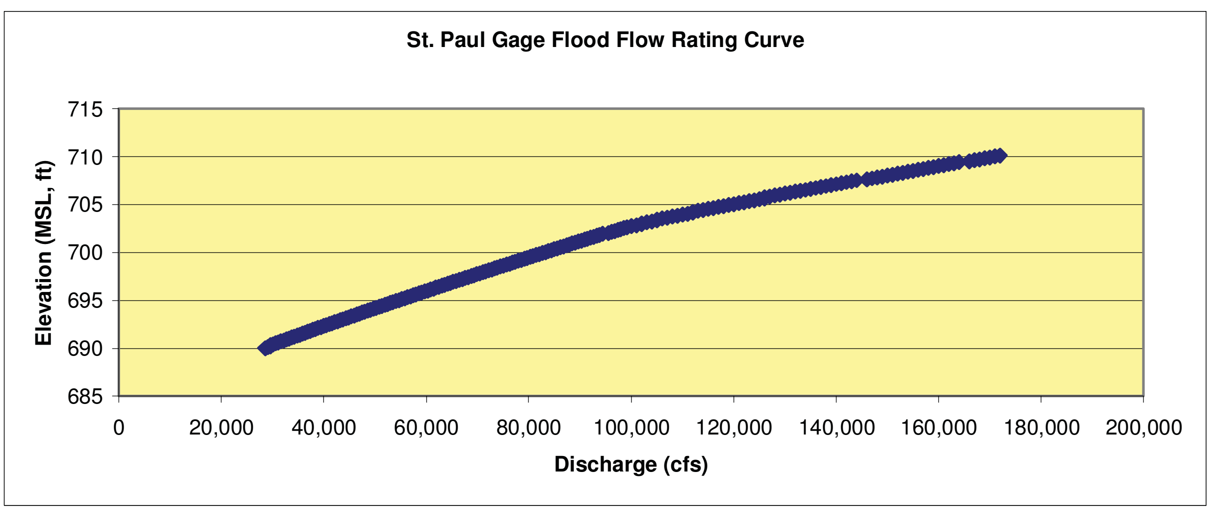

Figure 1. Flood flow rating curve for USGS St. Paul gage (courtesy USGS).

The USGS gage in downtown St. Paul is approximately 4 miles downstream of Crosby Lake. Because of this distance, the rating curve in downtown St. Paul must be translated upstream to correlate with the topography surrounding Crosby Lake.

The *2003 Flow Frequency Study* calculated flood elevations for the Crosby Lake to St. Paul reach of the Mississippi River for 5-, 10-, 50-, 100-, and 500-year recurrence intervals. Using these five recurrence intervals, I calculated the difference in elevation between the St. Paul gage and river mile 843.4 (approximate location of Crosby Lake). I then plotted the elevation difference versus flow for the five recurrence intervals and fit the data to a 2nd order polynomial trendline to establish an equation for the difference in river elevation based on flow (Figure 2).

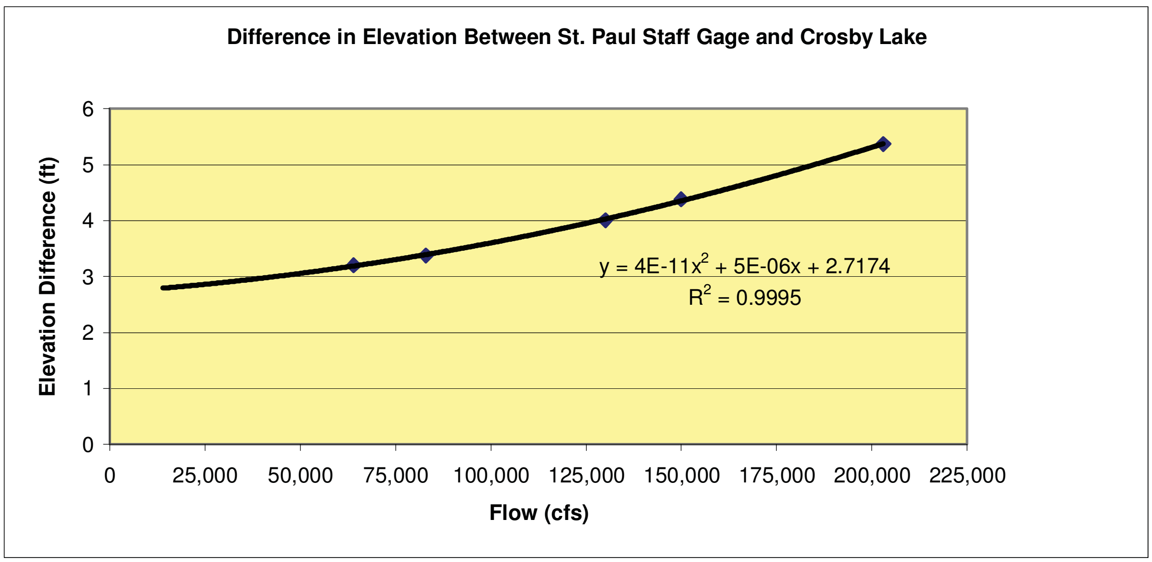

Figure 2. Relationship between Mississippi River elevation between Crosby Lake and downtown St. Paul.

The equation from Figure 2 was used to create a rating curve for the Mississippi River at Crosby Lake (River Mile 843.4, Figure 3). Flows from the USGS rating curve were substituted for "x" and the result was added to the elevation at the St. Paul gage.

The next step was to evaluate topography around Crosby Lake to determine at what elevation the Mississippi River overtops its banks and inundates the lake. Using 2-foot contours provided by the City of St. Paul, it appears that the river and lake are "connected" at approximately elevation 697. The connection occurs at the southeast corner of the lake where there is a break in the 698 contour. There appears to be a flow path from this point and southeast to the river. During our field visit in August, we noticed a swale or ditch that appeared to be man-made southwest of the lake. This feature is shown on the 2-foot contours but has a low elevation of approximately 699.

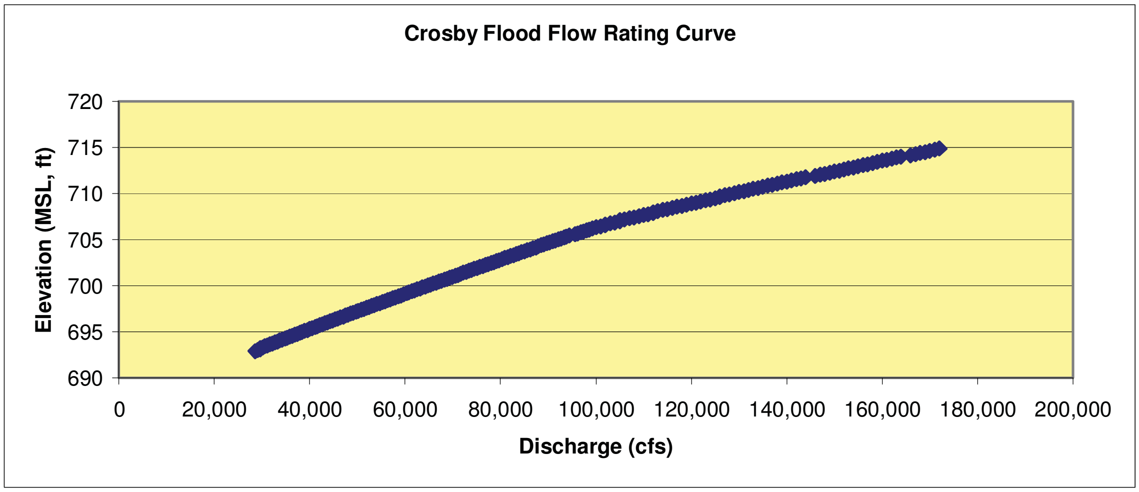

Figure 3. Mississippi River rating curve at River Mile 843.4 (Crosby Lake).

Based on an overflow elevation of 697, I used a portion of Figure 3 to determine what flow event would cause the river to inundate Crosby Lake (Figure 4).

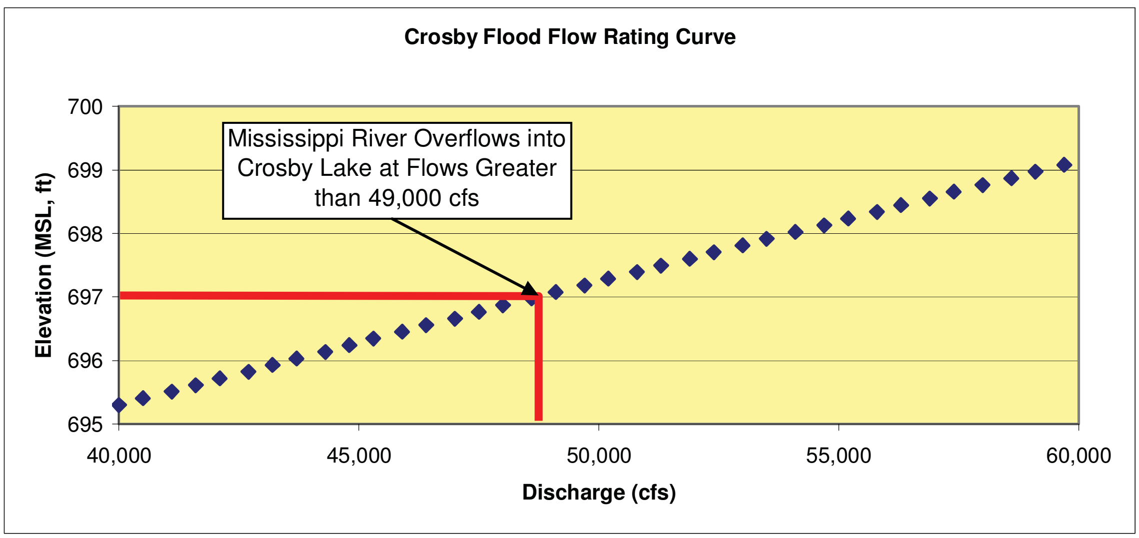

Figure 4. Portion of Mississippi Rating curve at River Mile 843.4 (Crosby Lake).

A flow of 49,000 cfs is approximately equal to the flow for a 3-year storm event (33% chance of occurrence each year). This was determined by plotting the flows for the 5-, 10-, 50-, 100-, and 500-year recurrence intervals on a log scale (Figure 5).

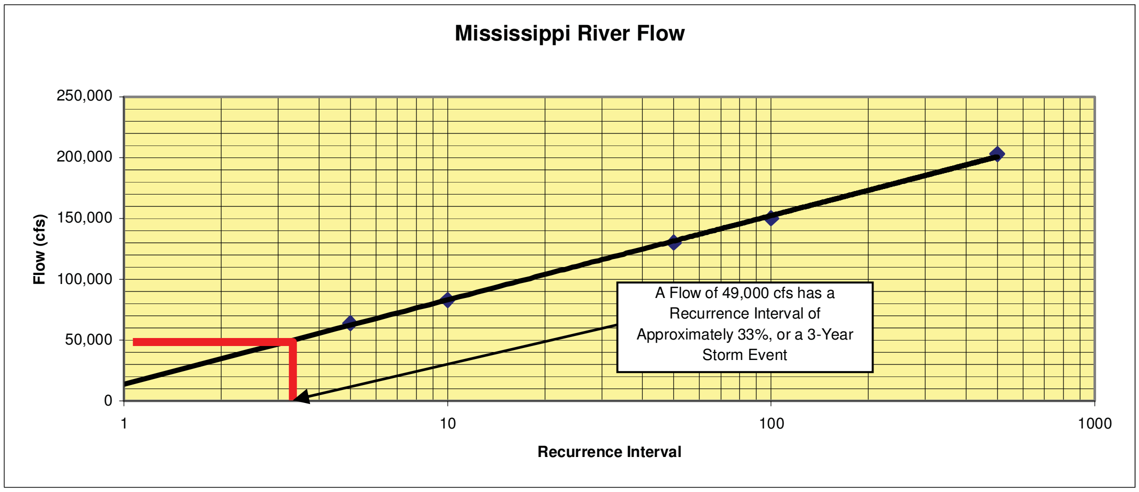

Figure 5. Recurrence interval determination for Mississippi River flow of 49,000 cfs.

The final step was to develop a flow duration curve for the Mississippi River using recorded data from the St. Paul gage. Figure 6 shows that a flow of 49,000 cfs or greater occurs approximately 2.5% of average daily flows going back to 1892.

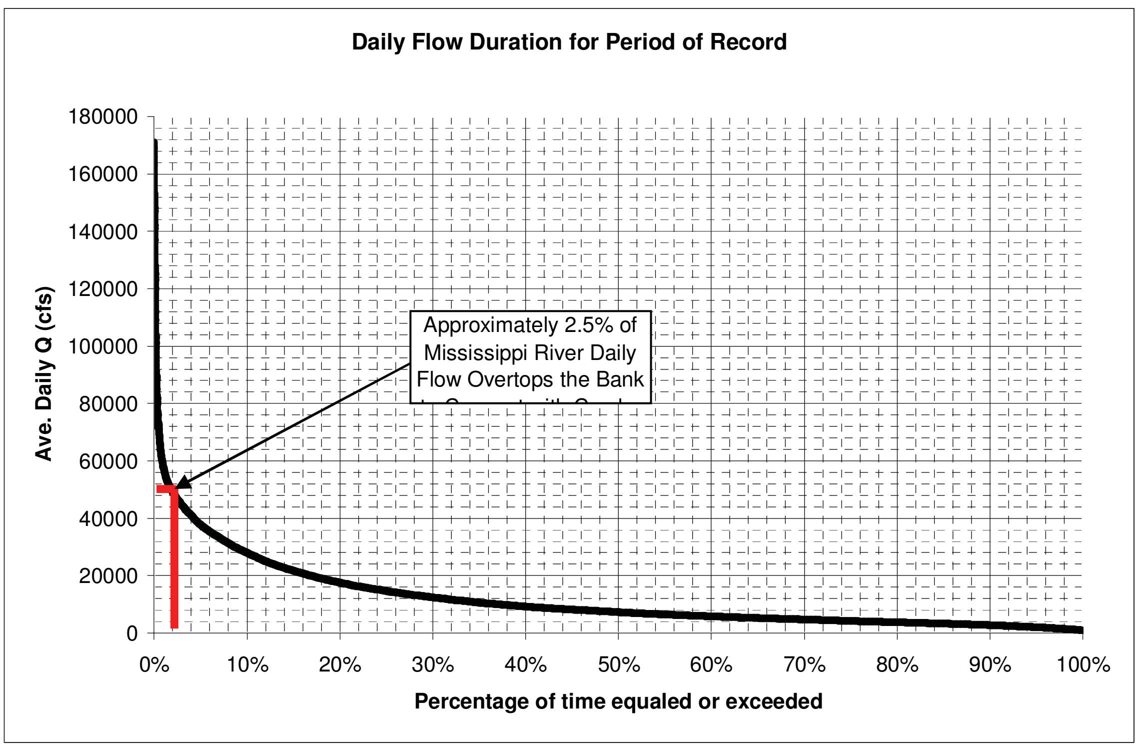

Figure 6. Mississippi River average daily flow duration curve for St. Paul.

The figures below show the average annual flow between 1892 and 2009. Figure 7 shows that the 30-year moving average is generally trending upward. This is likely due to development and greater impervious surface generating additional runoff. Figure 8 shows the same data but with a 10-year moving average. The 10-year moving average shows an upward trend between 1940 and 2000, but there has been a sharp decrease in flow during the 2000's. This may be due to several years of below-average precipitation in the decade. Note that the 30-year moving average in Figure 6 levels off in the 2000's – again likely due to precipitation trends.

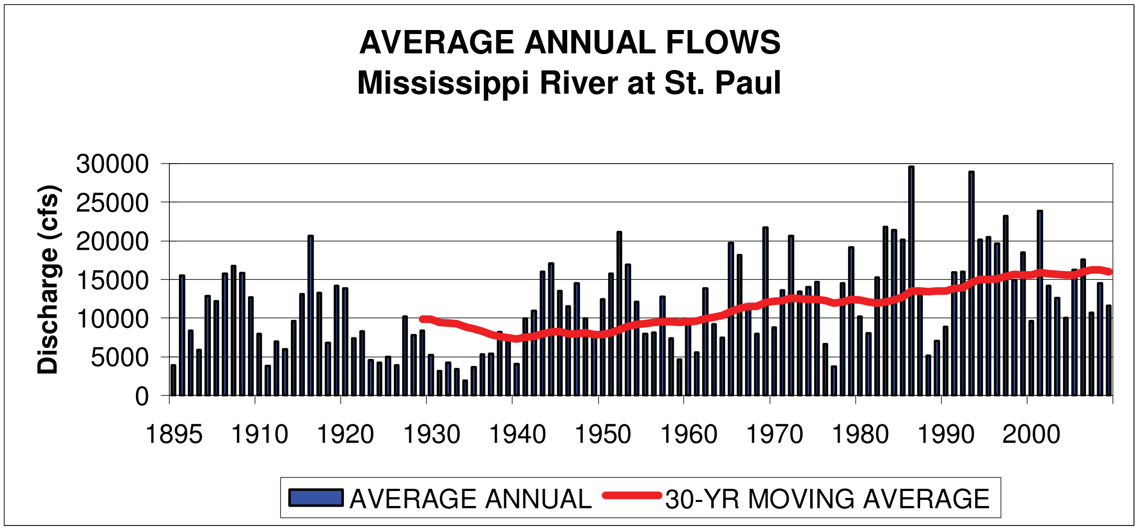

Figure 7. Mississippi River average annual flows at St. Paul with the 30-year moving average.

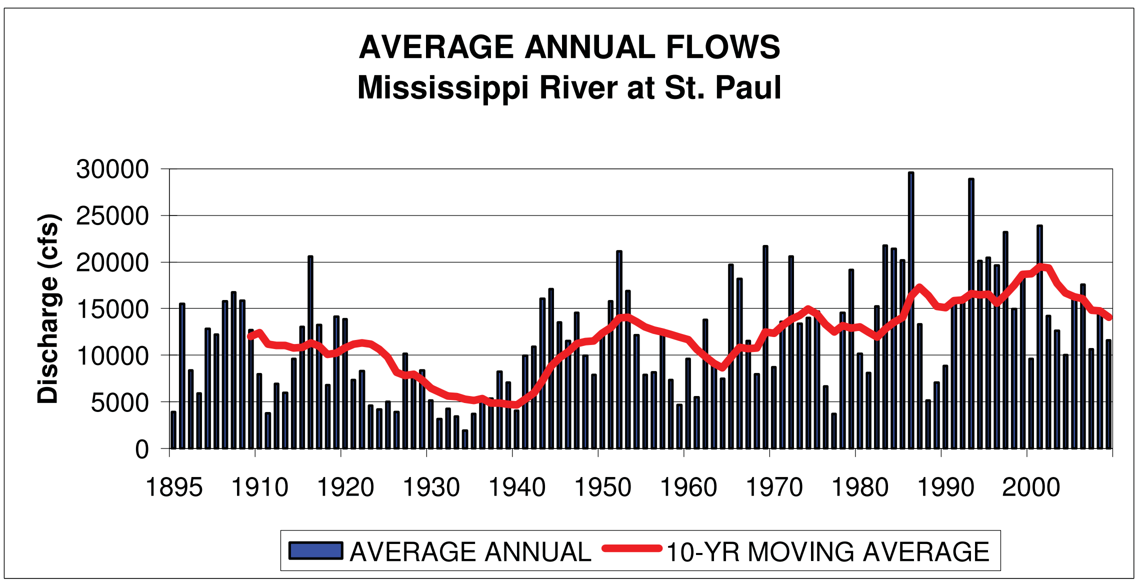

Figure 8. Mississippi River average annual flows at St. Paul with the 10-year moving average.

APPENDIX C – Advisory Group Members and Meeting Minutes

Crosby Lake Management Plan
Technical Advisory Group Members

Name	Organization
Wes Saunders-Pearce	City of Saint Paul
Anne Weber	City of Saint Paul Public Works Department
Brian Tourtelotte	City of Saint Paul Parks and Recreation Department
Mike Kimble	Saint Paul Parks and Recreation Department
Terry Noonan	Ramsey County Public Works
Anne White-Eagle	Ramsey Conservation District
Jim Levitt	MN DNR Fisheries
Craig Wills	DNR Waters
Beth Neuendorf	MN Department of Transportation
Jack Frost	Metropolitan Council
Brooke Asleson	MN Pollution Control Agency
Lark Weller	Mississippi National River and Recreation Area (MNRRA) National Park Service
Irene Jones	Friends of Mississippi River
Steve Hauser	The Friends of the Parks and Trails of St. Paul and Ramsey County
Mark Doneux	Capitol Region Watershed District
Anna Eleria	Capitol Region Watershed District

Crosby Lake Management Plan
Citizen Advisory Group Members

Juliet Branca	Pat Lindgren	Jarett Lettner
Gregory Blees	Dennis Rosemark	Michael Kaluzniak
Shirley Reider	Bryan Mulligan	Andrew Hine
Pat Harris	Afton Martens	Kelly and Marty Hicks
Dave Thune	Ed Johnson	Peggy Lynch
Kathy Carruth	Jim Hamilton	Rev. Mr. Jim and Judy Clasen
Steve Hauser	Steve Moravec	Charles Breer
Ed Heimel	Leslie Stewart and Carolyn Sparks	Gerry Frisch
Bill Barton	Mei-Ling Anderson	Duane Radawke
Nicholas A. Peterson	Tim Boonstra	Julie Kiyono
Ginny and Richard Stockwell	Tonya Nicholie	Bob Leonetti
Jeff Marcolina and Jean Murtaugh	Nick Peterson	Christine Campbell
Julian Sellers	Colbey Sullivan	Nora Murphy
Karen Sutherland	Christine Treanor	Steve Gorg
Katie Sterns	Betty Moran	Jane McClure
Ben Shardlow	Steve Murray	Roxanne Jorgenson/Ted Hanson
Nicholas Mancini	Kent Patterson	Patrick Bettenburg
Jeff Evans	Jim Brewer	Michael Hallman

Crosby Lake Management Plan
Citizens Advisory Group, Meeting #1
September 29, 2009

Meeting Attendees
See meeting sign in sheet.

Anna's Introduction

Is the management plan looking two years out? Ten years?

- It will be adaptive, planning for 10 years.

Is the plan for the upper and lower lakes?

- Yes, plus the drainage to the Mississippi River that bypasses the lake watershed.

How expensive will the plan be? Will it include developing the park more?

- The plan is for the lake only.

Will zoning for the Mississippi River (as a critical area) affect the plan? Does the National Park Service have a role in this?

- The NPS will have one member on our advisory board. Ideally, our management plan will align with the critical area needs.

Brian with city of St. Paul

Where does the water in the lake come from?

- Groundwater and storm sewers mostly. It is also part of the Mississippi River floodplain.

The Sam Morgan's Paths have blocked and entrance to the park from Alton Road. There was no community input before the construction of the paths.

- True, because it was a stimulus project. The construction has incorporated stormwater BMPs to prevent stormwater overflow from Sheppard Road.

Why don't they put the new parking lot further down the road and make it bigger (rather than the small proposed parking lot midway up on a steep slope)?

- The lower area is a less disturbed, more natural area that we want to remain in tact. Also there was a safety issue with the cars being so far away from the main road.

Joe Bishoff's Shallow Lakes

Other than flooding, does the water level fluctuate?

- Probably not, because the groundwater levels keep it stable. There are a few outlets to relieve high water levels. Plus the lake has a relatively small watershed.

How does the Minnesota River interact with the lake?

- During a flood event, there is a big mixing zone that allows sediment from the Minnesota River to overflow into Crosby Lake.

Will you comment on how climate change may affect shallow lakes?

- Changing precipitation (both more and less) will have a big effect. However, city lakes are highly managed, so they will adjust for the changes.

Lilydale Lake has been cleaned up recently – does this have a connection to Crosby Lake.

- Not sure, it is not within the scope of this project.

How is the water quality in Crosby Lake? Is there a mercury issue in the fish?

- There is a fish advisory for mercury consumption. The lake is connected to the Mississippi River that carries a lot of pollutants. Overall, the water quality is good for a shallow lake.

Will you comment on particulate in the water – what is the distribution of them, and how do they interact?

- Fine organic particles settle. Silica particles are the first to grow in a lake. When they die, the settle and fossilize. They are not active with other nutrients.

What happens when the lake goes away (dries up).

- The flood plain still exists. Sediment flows downstream.

Is water from Sheppard Road piped to the Marina?

- Yes, fortunately the drainage is outside of the lake watershed.

This used to be a farming area. Could there be heavy metals in the soil? Do you test just the water or do you test the sediments and soils too?

- We only test the water. Sediments will drop, and heavy metals are not expected to be a big problem.

Has the Department of Natural Resources been stocking the lake with fish?

- Not sure.

How much of an impact does Sheppard Road have on the lake?

- Lead and other car debris exist and are washed away with storm water. If there is a flooding event, the water can overflow down the cliff and into the lake.

I often see muskrats and beavers, even eagles by the lake. What can we imply from the mammals living near the lake? Does that mean the water is of good quality?

- Yes, that means there is a good food base and good water quality. If no animals wanted to live near the lake, that would indicate the water quality is poor.

Is the short end of the lake spring fed? It doesn't seem to freeze in the winter?

- Yes there is lots of groundwater flow as well. There are some springs. Lakes are formed in many different ways: river changes, glaciers, springs, etc.

Crosby Lake Management Plan
Citizens Advisory Group, Meeting #2
December 7, 2010

Meeting Attendees

See meeting sign-in sheet

Meeting Goal and Structure

Following the first informational meeting held in September on the Lake Management Plan process for Crosby Lake, Minnesota Waters planned and facilitated the second meeting to gain input from community members on their priorities and concerns for the future of Crosby Lake. The 20 participants were broken down into three small groups and asked to write their three top concerns, challenges or issues pertaining to the management and future of Crosby Lake on separate post-it notes. They were then asked to place each of these ideas under one of eight action areas identified by CRWD as relevant to the scope of a lake management plan, and give a short explanation of their idea to provide more detail. The small groups then discussed and identified their highest priorities and reported back to the large group. Notes were taken by several facilitators throughout the meeting and the following report was compiled by Alex Gehrig of Minnesota Waters.

Priority Issues within Action Areas

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- Addressing water quality is fundamental to utilizing Crosby Lake as an example to the nation for progressive conservation.

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- Maintain Crosby Lake as a lake; avoid the natural process of filling in from sedimentation to form a marsh.
- Need to have long term protection of the lake

Watershed Land Use Management

Flooding
- Need to establish a consistent flood plan
- There is a need for improved outlet flow between lake and river

Litter/trash
- Trash comes down from the bluff top – Shepard road
- Run-off from the 35E bridge dumps trash (plastic bottles) near the lake

Erosion
- Incorporate Highland Ravine study into management plan. It is part of the watershed and has erosion issues.

Park Use and Management

Development
- This is a unique, national park in St. Paul and should be maintained in its natural state – no more paved paths
- Create a more stable and safe path between the two lakes (marsh boardwalk)

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- Trails and bluffs need to be managed to reduce sediment flow to lake

Education and Outreach

- There is a lack of public awareness about issues involving Crosby Lake
- It is necessary to have an educated community in order to have positive change
- Work with local Dakota tribe representatives who have an historical and cultural tie to the area.

Plant Fishery and Wildlife Management

While these were presented as three separate areas for action, there was common recognition that they are interrelated and often are affected by and/or directly impact water quality.

- Need to eliminate and manage exotic plants, both aquatic and terrestrial (shoreline)
- Re-establish and promote native vegetation in and out of lake

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- Healthy fish means a healthy lake
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Following each participant's identification of top concerns and ideas, small groups discussed possible solutions for the challenges they identified. While participants did not always explicitly state which action area their solution addressed, they have been categorized appropriately below.

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- Identify all point and non-point source pollution and address each individually through appropriate BMPs
- Track sources of pollution through monitoring data.
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- Ask fisherman what they have been catching
- Analyze fish for pollution/contaminants

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Is there value in deepening the lake?
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What is already in the lake in terms of pollution and nutrient loading?
Is bluff erosion worse in particular areas? It seems worse on the west side.
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How can we restore a wild rice population?
Is submerged aquatic vegetation a concern?
How will Highland Ravine study be incorporated into this plan?
*What is the goal for Crosby Lake – restore to pristine conditions, or just improve?
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Next Steps

Upon review of the Citizen Input Summary, CRWD staff will incorporate concerns and ideas from participants into the lake management plan that fit within the framework of the District's rules and priorities. It was explained at the beginning of the meeting that CRWD highly values the input of citizens and considers it important to incorporate it into plans for Crosby Lake, but that not all input could be feasibly addressed through the District's planning process.

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Crosby Lake Management Plan
Citizens Advisory Group, Meeting #3
August 8, 2011

Meeting Attendees

See meeting sign-in sheet

Question and Answers

Could Sphagnum moss be used as a filter – specifically in the proposed 35E improvement?

Joe – that particular site has a large amount of flow and would require an expensive and large structure and a lot of maintenance, the moss is more effective in smaller flow situations.

Anna – CRWD is looking into the possibility of its use on Como Golf course as a demonstration.

Greg Blees – River Flooding

- Starting with the concept that a watershed cleans water and controls flooding, Parks and Rec controls development of Crosby Park – the watershed district should make suggestions concerning development. Specifically:
- Many (or most) parks have a passive use; people come and go during operational hours
- There are only two parks in the area (along the river) that are passive use but are also nature reserves – Crosby and Pig's Eye
- Given the trend that there is less land available for flood relief overall – the watershed district should make recommendations that development be minimized within the park. This would be similar to the Willow recommendations made on the Loeb Lake plan
- The Great River Project calls for more campsites and restaurant development; this should be prevented in parks like Crosby.

Parks rep (Brian Tourtelotte?) – How will the outcome of the plan be affected by the monitoring that is planned or will be planned in the district?

Anna – the process of implementation is to prioritize as new information is found – it may turn out that parts of the plan are unnecessary or impractical as we find out more. Monitoring is being planned right now for the 2012 budget

Joe – implementation utilizes adaptive management

Gentleman standing in the back of the room (most likely Mark Baldwin – the last to sign in)

Concerning the 35E pond project – most folks would be okay with it – is it necessary to cut and remove trees? Is it possible to direct flow somewhere else upstream to reduce flow at the outlet?

Anna – It's necessary to remove trees to create a basin.
Difficult and probably not feasible to re-direct flow upstream given where it comes from.

Mark - How long would the projects take – 35E project?
Anna – looking at a span of 10 years, there are a lot of partners that need to be a included in the process

Greg – at the last board meeting there was a suggestion to put forward a double digit tax increase?
Board rep – No. that is not the case

Greg – We support a tax increase. If the district believes that the public should comment at board meetings they should inform us.

Brian – Did you consider the effects of salt in this plan?
Joe – was not a part of the study (or was not a major part of the study). There could be impacts; the stormwater diversion project will help. It would also be easy to add conductivity profiles to the monitoring program.

Brian – What are the implications for the lake's health with lake level management? Are there benefits with allowing levels to rise through control measures?
Joe – given the level differentiation that you could consider with Crosby, the impacts on lake health would be negligible.

APPENDIX D – Crosby Lake Response Models

10 yr Avg. Loading Summary for Crosby Lake

Water Budgets				Phosphorus Loading		

Inflow from Drainage Areas

Name	Drainage Area [acre]	Runoff Depth [in/yr]	Discharge [ac-ft/yr]	Phosphorus Concentration [ug/L]	Loading Calibration Factor (CF)[1] [--]	Load [lb/yr]
1 CRO4	37.00	3.6	11	268	1.0	8
2 CRO6	197.00	5.4	88	230.2	1.0	55
3						
4						
5						
Summation	*234*	*9*	*99*	*249.1*		*63.0*

Failing Septic Systems

Name	Area [ac]	# of Systems	Failure [%]	Load / System	[lb/ac]	[lb/yr]
1 CRO4	37	#N/A	#N/A	#N/A	#N/A	#N/A
2 CRO6	197		#N/A	#N/A	#N/A	#N/A
3						
4						
5						
Summation	*234*	*#N/A*	*#N/A*		*#N/A*	*#N/A*

Inflow from Upstream Lakes

Name	Discharge [ac-ft/yr]	Estimated P Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
1		-	1.0	
2		-	1.0	
3		-	1.0	
Summation	*0*	-		*0*

Atmosphere

Lake Area [acre]	Precipitation [in/yr]	Evaporation [in/yr]	Net Inflow [ac-ft/yr]	Aerial Loading Rate [lb/ac-yr]	Calibration Factor [--]	Load [lb/yr]
45	22.0	22.0	0.00	0.22	1.0	10.0
			Dry-year total P deposition =	0.222		
			Average-year total P deposition =	0.239		
			Wet-year total P deposition =	0.259		
			(Barr Engineering 2004)			

Groundwater

Lake Area [acre]	Groundwater Flux [m/yr]	Net Inflow [ac-ft/yr]	Phosphorus Concentration [ug/L]	Calibration Factor [--]	Load [lb/yr]
45	0.0	0.00	0	1.0	0

Internal

Lake Area [acre]	Anoxic Factor [days]	Release Rate [mg/m^2-day]	Calibration Factor [--]	Load [lb/yr]
	10.0	0.0	1.0	0
45	0.0	0.00	1.0	0

Net Discharge [ac-ft/yr] =	**99**	**Net Load [lb/yr] =**	**73**

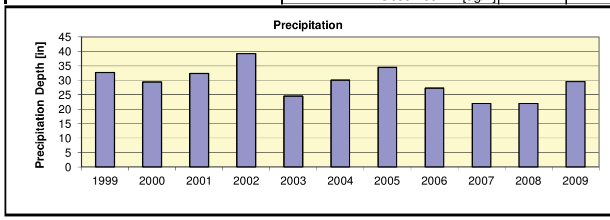
NOTES

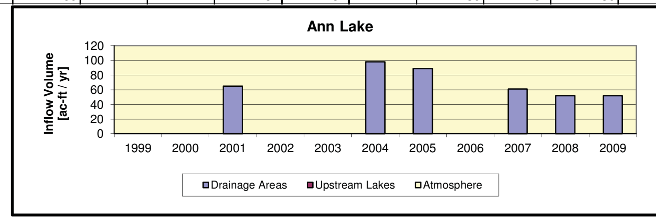
[1] Loading calibration factor used to account for special circumstances such as wetland systems, fertilizer use, or animal waste, among others, that might apply to specific loading sources.

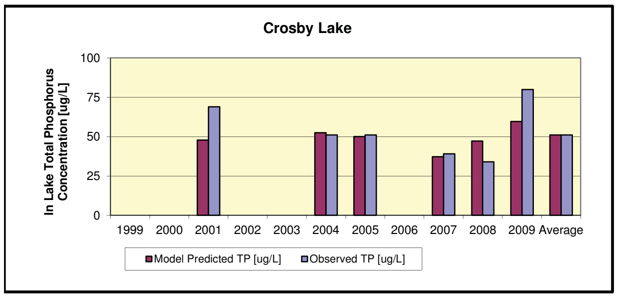
10 yr Avg. Lake Response Modeling for Crosby Lake

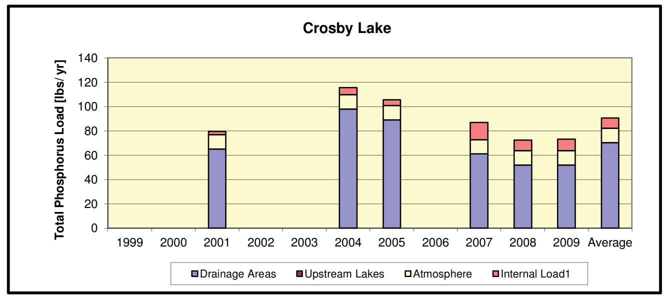
Modeled Parameter	Equation	Parameters	Value [Units]
TOTAL IN-LAKE PHOSPHORUS CONCENTRATION			
		as f(W,Q,V) from Canfield & Bachmann (1981)	
$P = \left[-1+(1+4KA1P_iT)^{-5}\right] / (2KA1T)$		C_P =	1.00 [--]
		C_{CB} =	0.162 [--]
$A1 = 0.056 Fot^{-1} Qs / (Qs + 13.3)$		b =	0.458 [--]
		W (total P load = inflow + atm.) =	73 [lb/yr]
		Q (lake outflow) =	99 [ac-ft/yr]
$Qs = Max(Z/T, 4)$		V (modeled lake volume) =	189 [ac-ft]
		Fot=	0.37 [--]
		Qs=	5.5 [m/yr]
		T = V/Q =	1.91 [yr]
		P_i = W/Q =	272 [ug/l]
Model Predicted In-Lake [TP]			**51.0 [ug/l]**
Observed In-Lake [TP]			**51.0 [ug/l]**
CHLOROPHYLL-A CONCENTRATION			
	$[\mathrm{Chl}a] = CB \times 0.28 \times [TP]$	as f(TP), Walker 1999, Model 4	
		CB (Calibration factor) =	1.00 [--]
Model Predicted In-Lake [Chl-a]			**19.0 [ug/l]**
	$[\mathrm{Chl}a] = \dfrac{CB \times B_x}{[(1+0.025 \times B_x \times G)(1+G \times \mathrm{a})]}$	as f(TP, N, Flushing), Walker 1999, Model 1	
		CB (Calibration factor) =	0.30
$B_x = \dfrac{X_{pn}^{1.33}}{4.31}$		P (Total Phosphorus) =	80 [ug/l]
		N (Total Nitrogen) =	1670 [ug/l]
		B_x (Nutrient-Potential Chl-a conc.) =	43.1 [ug/l]
$X_{pn} = \left[P^{-2} + \left(\dfrac{N-150}{12}\right)^{-2}\right]^{-0.5}$		X_{pn} (Composite nutrient conc.)=	50.8 [ug/l]
		G (Kinematic factor) =	0.71 [--]
		F_s (Flushing Rate) =	0.52 [$year^{-1}$]
$G = Z_{mix}(0.14 + 0.0039 F_s)$		Z_{mix} (Mixing Depth) =	16.40 [ft]
		C_a (non-algal turbity coefficient) =	0.015 [-]
$F_s = \dfrac{Q}{V}$; $a = \dfrac{1}{SD} - C_a \times [\mathrm{Chl}a]$		a (Non algal turbidity) =	0.29 [m^{-1}]
		S (Secchi Depth) =	8.27 [ft]
		Maximum lake depth =	34.54 [ft]
Model Predicted In-Lake [Chl-a]			**7.3 [ug/l]**
Observed In-Lake [Chl-a]			**7.1 [ug/l]**
SECCHI DEPTH			
	$SD = \dfrac{CS}{(\mathrm{a} + C_a \times [\mathrm{Chl}\ a])}$	as f(Chla), Walker (1999)	
		CS (Calibration factor) =	1.00 [--]
		a (Non algal turbidity) =	0.29 [m^{-1}]
Model Predicted In-Lake SD			**2.50 [m]**
Observed In-Lake SD			**2.52 [m]**
PHOSPHORUS SEDIMENTATION RATE			
	$P_{sed} = C_P \times C_{CB} \times \left(\dfrac{W_P}{V}\right)^b \times [TP] \times V$		
		P_{sed} (phosphorus sedimentation) =	**55 [lb/yr]**
PHOSPHORUS OUTFLOW LOAD			
	W-P_{sed} =		**18 [lb/yr]**

Crosby Lake	**Source**	***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***Average***
Precipitation Depth [in]		30.02	32.68	29.42	32.4	39.22	24.52	30.12	34.44	27.31	22.02	22.02	29.5
	Residence Time [yr]			1.8			1.4	1.4		2.1	2.5	2.5	2.0
Inflow Volume [ac-ft / yr]	Drainage Areas			107.0			137.0	136.0		90.0	77.0	75.0	103
	Upstream Lakes			0.0			0.0	0.0		0.0	0.0	0.0	0
	Atmosphere			0.0			0.0	0.0		0.0	0.0	0.0	0
	TOTAL =			**107.0**			**137.0**	**136.0**		**90.0**	**77.0**	**75.0**	103
Total Phosphorus Load [lbs/ yr]	Drainage Areas			65			98	89		61	52	52	70
	Septic Systems			0			0	0		0	0	0	0
	Upstream Lakes			0			0	0		0	0	0	0
	Atmosphere			12			12	12		12	12	12	12
	Internal Load[1]			3			6	5		14	9	9	9
	TOTAL =			**80**			**116**	**106**		**87**	**72**	**73**	**91**
Model Results	Model Predicted TP [ug/L]			48			52	50		37	47	60	51
	Observed TP [ug/L]			69			51	51		39	34	80	51

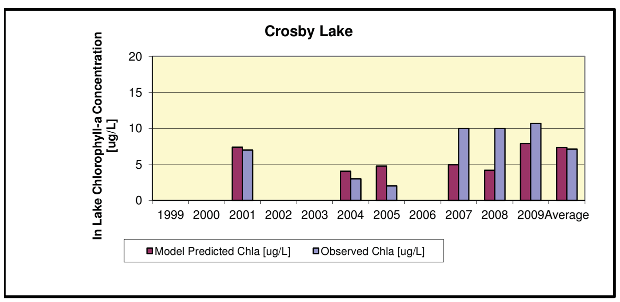


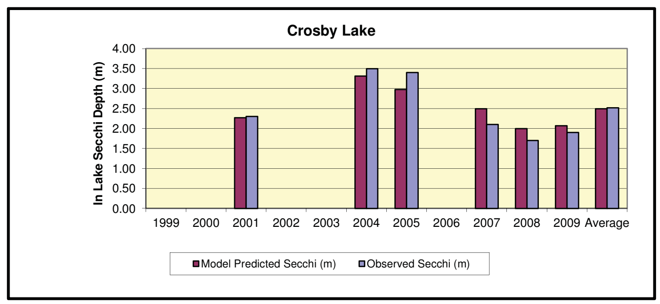






Crosby Lake		***1999***	***2000***	***2001***	***2002***	***2003***	***2004***	***2005***	***2006***	***2007***	***2008***	***2009***	***Average***
Model Results	Model Predicted Chla [ug/L]			7			4	5		5	4	8	7
	Observed Chla [ug/L]			7			3	2		10	10	11	7
Model Results	Model Predicted Secchi (m)			2.27			3.31	2.98		2.50	2.00	2.07	2.50
	Observed Secchi (m)			2.30			3.50	3.40		2.10	1.70	1.90	2.52





APPENDIX E – Citizen Activities Outside Scope of the Management Plan

Capitol Region Watershed District

minnesota waters

Citizen Input Summary
Citizens Advisory Group, Meeting #2
December 7, 2010

Meeting Attendees
See meeting sign-in sheet

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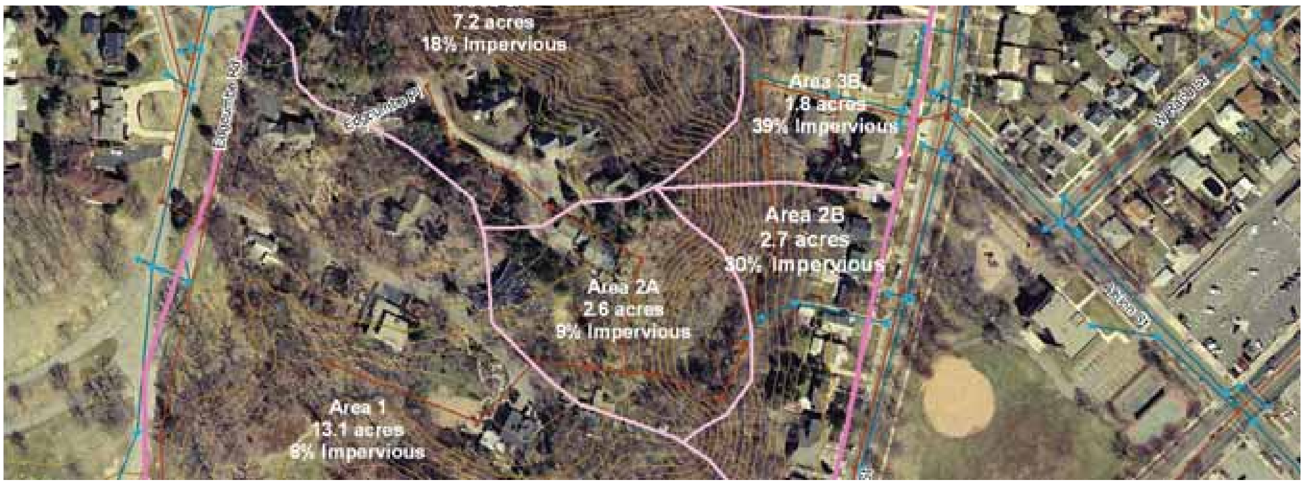
APPENDIX F – Highland Ravine Stabilization/Restoration Feasibility Study

Prepared by:
Emmons & Olivier Resources, Inc.
for the Capitol Region Watershed District

Highland Ravine Stabilization/Restoration Feasibility Study



February 9, 2011 DRAFT
March 21, 2011 FINAL

Document Component Specs

Text: Staples • multipurpose paper, 24 lb. text – 50% post-consumer fibers, FSC Certified.

Back Cover: Neenah Paper • Esse • Texture, Sapphire • 100 lb. cover • 30% post-consumer fibers, Green Seal® Certified

Wire Binding: Manufactured using recycled high carbon steel

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I. INTRODUCTION

Background

The Highland Ravine Stabilization/Restoration Feasibility Study was commissioned by Capitol Region Watershed District (CRWD) with support from the City of Saint Paul in response to claims of flooding and erosion by a number of local residents over the past four years.

In 2007, the Saint Paul Parks and Recreation Department completed a flood mitigation and ravine stabilization project in the southern portion of the study area (Catchment #1) to alleviate flooding onto private property and minimize erosion in the ravine. Further information about this issue and the City's work to resolve it can be found in Section II.

The area referred to as *Highland Ravine* is roughly bound by Edgcumbe Road and Lexington Parkway on the west and east boundaries with Highland Parkway as the northern boundary and Montreal Avenue as the southern boundary. This roughly fifty acre project area is illustrated in Figure-1 below.

Project Goals

The goals of the study were to identify and quantify flooding, erosion and water quality concerns; determine causes of the problem(s) identified; recommend solutions for addressing the problem(s); and provide a cost/benefit analysis of the proposed solutions.

Figure-1 General Limits of Project Investigation

II. EXISTING CONDITIONS

Project Area

The project area is composed of steep, wooded ravines with several springs found at discrete elevations. Several of these groundwater discharge location are routed to storm drains or only found during wet years. Landuse is primarily single-family residential properties, which are located at the top and at the base of the ravine. Impervious areas (roofs, driveways, roads) are relatively low to average (8-39%) as compared to other areas in the watershed district.

Utilizing existing infrastructure and topographic data, the project area was delineated into separate catchments (depicted in Figure 2). This delineation was verified and corrected via onsite reconnaissance. The project area was divided into six primary drainage or catchment areas as shown in Figure-2. Of these six catchment areas, four of the catchments, (2, 4, 5, and 6) were determined by EOR and CRWD staff to not have significant issues of concern either observed during the site visit or expressed by local residents. To provide a more detailed assessment of the areas of concern, Catchments #1 and #3 were further evaluated during a detailed survey completed by EOR staff on December 3, 2010.

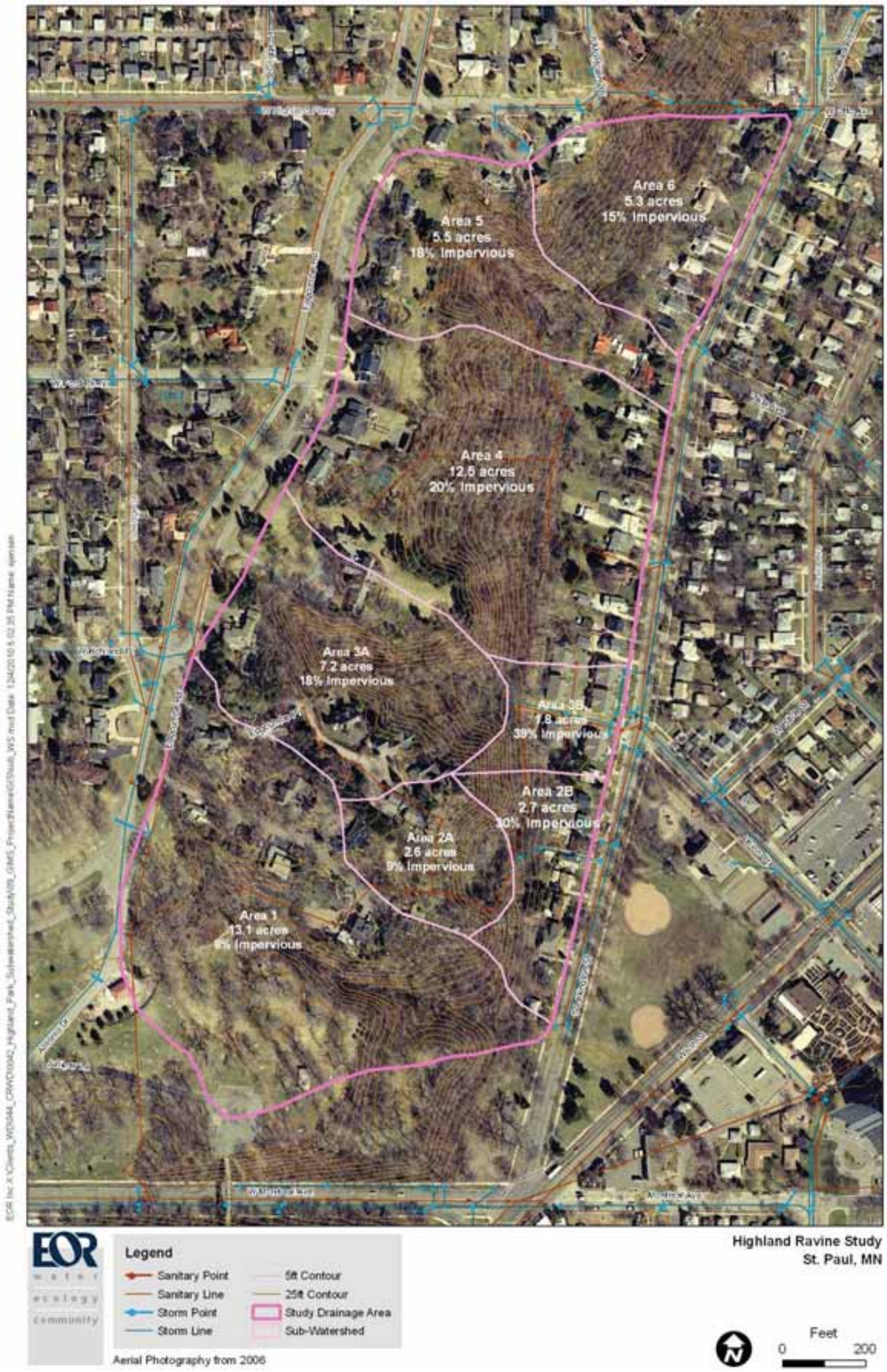

Figure-2 Highland Ravine Catchments

Catchment #1

<u>*Setting & History*</u>
Catchment #1 conveys drainage from a subwatershed of 13.1 acres with low imperviousness (roughly 8%). This area drains to a 10-foot wide ravine approximately 1,110-feet in length with a slope averaging near 10% (from EOR topographic survey) (Figure-3). The ravine runs west to east and towards its end flows just south of residential properties. Runoff then flows over the boulevard sidewalk, and onto Lexington Parkway where it flows north along the curb line to a nearby catch basin.

The house located immediately adjacent to the base of the ravine on the north (909 Lexington Parkway S) has experienced flooding during large rainfall events. To alleviate flooding onto this property, the Saint Paul Parks and Recreation Department in 2007 redefined and stabilized the ravine channel by removing sediment and creating a berm on the north edge of the channel. The City also removed the mounded soil on the boulevard to allow runoff from the ravine to enter the City's storm sewer system on Lexington Parkway. According to verbal reports from neighbors, gathered during onsite surveying and reconnaissance by EOR staff in late 2010, the City's efforts reduced flooding, but it still occurs during larger precipitation events.

There has been no significant increase in drainage area or impervious area since this work was completed in 2007.

The ravine is heavily shaded, primary by a mature canopy with some understory native and invasive woody species. Due in part to the limited about of sunlight, the groundcover layer is sparse.

Figure-3 Catchment Area #1

Modeling

In order to assess the volume and rate of runoff, a HydroCAD model was constructed to quantify ravine flows for both small and large rainfall events. Flows were estimated for the 1-inch, 2-inch, 10-year, 24 hour (4.2 inches) and 100-year, 24 hour (5.9 inches) storms. Flows in excess of 40 cubic feet per second (cfs) for the 100-year rain event were estimated. Runoff volume for the same event exceeded 2.1 acre-feet or 720,000 gallons. See Table-1 for specific results. Sizing and capacity assessment of the storm sewer beneath Lexington Parkway was not performed as part of this analysis.

Problems

The primary concerns of Catchment #1 are localized flooding and water quality impacts. Although flooding onto private property has been reduced by the ravine work completed by the Parks and Recreation Department in 2007, flooding is still being reported and untreated runoff laden with sediment and nutrients flows through the ravine and discharges into the Lexington Parkway storm sewer that eventually discharges to the Mississippi River.

Causes

Visual observations and limited surveying indicate that ravine storm flows could bypass and/or over-top the berm created to alleviate flooding. There is also some evidence to suggest that the channel has aggraded (increase in land elevation due to the deposition of sediment) in this lower reach, resulting in reduced separation between the residence of concern and the ravine. To further determine the cause(s) of continued localized flooding, a detailed hydraulic model of this ravine would need to be completed.

Also of note, landscaping activities and practices upstream of the ravine are exacerbating the flooding and ravine stability issues. Roof leaders and other stormwater conveyances directly discharge into the ravine and in some instances, at unstable locations. Additionally, EOR and CRWD staff observed disposal of yard trimmings in the ravine. This practice adds nutrients to the ravine runoff and impedes vegetation growth that is critical to for stabilizing the bluff and preventing erosion.

Catchment #3

<u>*Setting & History*</u>

As seen in Figure-4, Catchment #3A collects surface runoff from Edgcumbe Place and surrounding properties, as well as a large estate off of Edgcumbe Road. Runoff collects in a steep, confined ravine and flows to Catchment #3B, which includes the 12-unit Deer Park Condominiums, where it is intended to be captured and conveyed via an existing 18-inch diameter HDPE (plastic) pipe. This pipe also collects additional flow from the condominiums and connects to twin 36-inch HDPE storage pipes located underneath the front yards of the Deer Park Condominiums on Lexington Parkway. These pipes, which are intended to provide rate control for the Deer Park Condominiums, outlet to the main storm sewer underneath Lexington Parkway via a 12-inch ductile iron pipe (DIP).

The Deer Park Condominiums were constructed in 2002. Prior to this, runoff was conveyed overland along a single family lot line to Lexington Parkway.

The ravine is heavily shaded, primary by a mature canopy with some understory native and invasive woody species. Due in part to the limited about of sunlight, the groundcover layer is sparse.

Figure-4 Catchment Area #3A & #3B

Modeling

In order to assess the volume and rate of water runoff flowing through the ravine, a HydroCAD model was constructed to quantify the runoff. Modeling results show that localized flooding occurs between the 2-inch and 10-year storm events. See Table-3 for specific results.

Problems

Significant erosion is occurring in the ravine creating gullies and deposition of coarse and fine grained sediment within the ravine. In addition, Deer Park Condominiums located down gradient of the ravine experiences flooding and sedimentation during large storm events. Figure 5 is an aerial photo of the condominium property taken in 2006 that shows flooding and sedimentation. Both temporary (silt fences) and permanent (berm) structures have been installed to direct runoff away from the condominiums and prevent flooding and sedimentation onto their properties, however, according to condominium residents these have been ineffective.

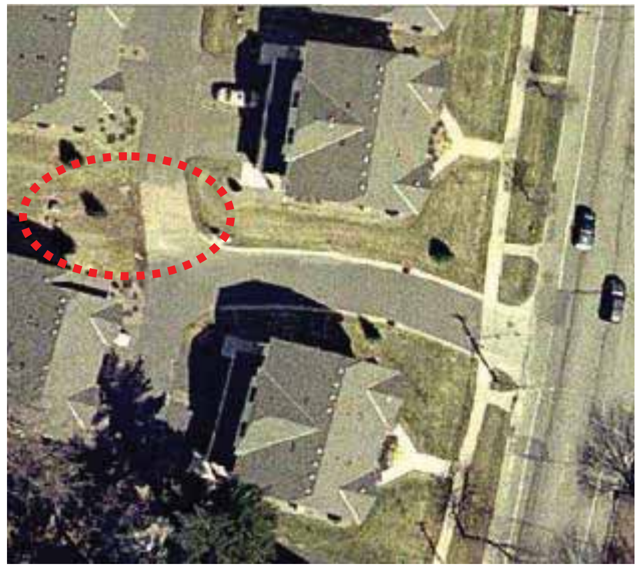

Figure-5 Flooding and Sedimentation of Deer Park Development – Spring of 2006

Causes

The problems in this catchment are the result of compounding causes that can be deduced to some level of certainty; however there are a number of other minor changes that have impacted the stability of the ravine and the functionality of the storm sewer system over time. The following are the three main causes for ravine erosion and sedimentation and the subsequent flooding, sedimentation and poor stormwater quality downstream.

Deer Park Development – The 2002 design and construction of the 12-unit Deer Park Condominium development concentrated ravine flows and attempts to collect the flows into an 18-inch HDPE flared end inlet section (Figure 6). A rip-rap emergency overflow (EOF) is located immediately south of the 18-inch HDPE inlet. However, the EOF was improperly constructed. The EOF elevation, as surveyed in December 2010, was 8" below the top of the flared end section (FES) inlet pipe, which allows bypass before inlet capacity is exceeded. Additional conveyance exists between the rip rap voids, allowing water to bypass the flared end inlet section at elevations similar to the FES invert. Assuming that water is not able to pass beneath the top of rip rap, flows still bypass the system regularly. The model estimates that bypass occurs between the 2-inch and 4.2-inch (10-year, 24 hour) events. See Table-3 for a summary of bypass frequency.

Deer Park Development Rate Control -- In addition to the issues with the flared end inlet section, the lower portion of this private storm sewer is not functioning properly. The problematic lower section consists of 18-inch HDPE pipe draining into flat, twin 36-inch HDPE pipes which were installed for rate control. The 36-inch pipes run north-south from the catch basins near the condominium driveway entrance and through the front yards of the condominiums facing Lexington Parkway, then connect to the main storm sewer beneath Lexington (Figure 6). See Appendix for detail of this configuration.

The final outlet (12" DIP) invert is the same invert as the 36" rate control pipes. This system would ideally have been constructed with the final invert above that of the 36" pipe, so sedimentation can occur within the 36" pipes when velocities slow down (as they do in larger, flatter pipes) and sediment would not block the outlet pipe. Additionally, the flat 36" pipes need to be maintained (cleaned out) at a minimum on an annual basis or more frequently if it is determined the volume of sediment generated by the ravine and condominium development warrants it. Cleanout manholes are indicated on construction plans, but could not be located during the December 2010 survey. The cleanout manholes may have been covered by final grading or more recent landscaping activities. No records of maintenance have been located.

Edgcumbe Place – There has been no significant increase in drainage area, but there has been an increase in impervious area (0.2± acre) since the condominium redevelopment. An additional home was constructed on Edgcumbe Place in 2007. As evident by the 2006 date of the aerial photograph in Figure-5, by-pass of the Condominium inlet was occurring prior to this construction. Exacerbating the problem is that a number of roof drains are routed directly to the ravine via rain leaders and piping.

Also of note, landscaping activities and practices upstream of the ravine are exacerbating the flooding and ravine stability issues. Roof leaders and other stormwater conveyances directly discharge into the ravine and in some instances, at unstable locations. Additionally, EOR and CRWD staff observed disposal of yard trimmings in the ravine. This practice adds nutrients to the ravine runoff and impedes vegetation growth that is critical to for stabilizing the bluff and preventing erosion.

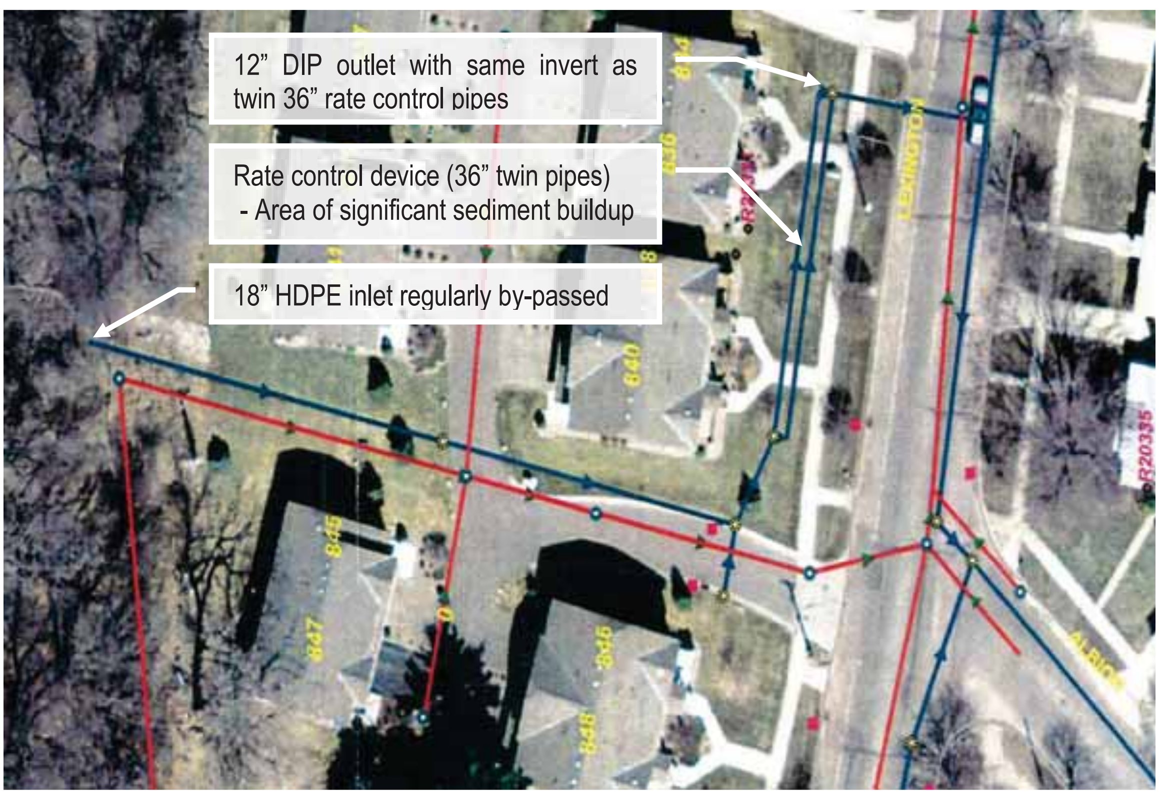

Figure-6 Deer Park Development Stormwater (blue) and Sanitary Sewers (red)

III. IDENTIFICATION OF SOLUTIONS FOR CATCHMENTS #1 AND #3

Identification of Solutions for Catchment #1

Base - Flood Reduction Solution

Runoff in Catchment #1 posed a major flood risk to private property as well as contributed pollutants including sediment to the storm sewer system on Lexington Parkway that eventually discharges to the Mississippi River. The City in 2007 created a deeper and more confined, stable channel with a northern berm to keep runoff away from private property and to limit sediment conveyance to the downstream storm sewer. As mentioned previously, flooding remains an issue on the adjacent private property during very large storm events and spring snowmelt because the capacity of the channel to convey flows has likely reduced since the work in 2007.

Further work to enhance the capacity and stabilize the ravine should be conducted to alleviate future flooding on private property and minimize pollution to the Mississippi River. While this solution provides an improved flow setting for protecting private property, it does not substantively reduce flows and volumes or improve water quality.

Since the lot line between Highland Park and private residences following the ravine centerline this solution would likely be constructed on public and private property.

Additional Water Quality and Quantity Options

Stormwater best management practices (BMPs) including raingardens and porous pavement were considered and analyzed for their effectiveness in reducing stormwater runoff and improving water quality. Raingardens (specific locations were not identified, but a total area of 3,500 sf and volume of 2,919 cf was assumed to be feasible) and porous pavement for the private road were selected to limit the impact of the upstream impervious surfaces on the ravine (see Figure 7). Due to the slope of the watershed, only 6" of storage depth was assumed in the porous pavement. Each of these features can fully capture a storm of ~1.5".

Since the associated drive is privately owned these options would be constructed on private property.

Areas considered for infiltration and/or filtration have well-drained soils (Urban land-Waukegan Complex), with greater than 5 feet of separation from the seasonally high water table.

Augmentation of groundwater seepage by infiltrated stormwater may pose some problems (i.e. ravine instability due to soil cohesion) and should be further considered, but ravine stability gains from stormwater rate and volume reductions likely out weigh any hazards.

Table-1 summarizes the hydrologic improvements (flow and volume reductions) for each of the proposed options.

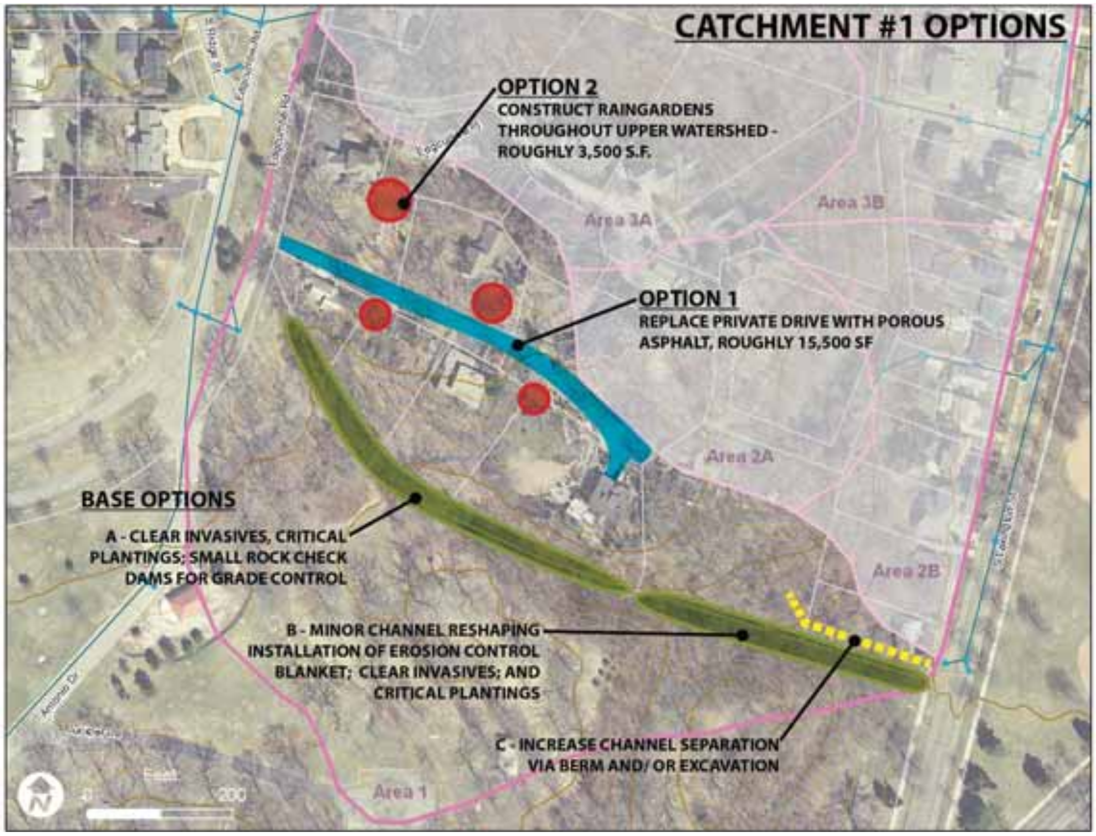

Figure-7 Catchment #1 Schematic Design

		Option:	*Base*	*Additional Water Quality & Quantity Options*					
Storm Event	**Hydraulic Parameter**	**Existing Conditions**	**Ravine Stabilization**	**(1) Porous Pavement**		**(2) Rain Gardens**		**(3) Base + Options 1 & 2**	
				Flow / Volume	**Reduction (%)**	**Flow / Volume**	**Reduction (%)**	**Flow / Volume**	**Reduction (%)**
1-inch	Flow [cfs]	1.3	insig.	0.4	72%	0.4	72%	0.4	72%
	Volume [AF]	0.07	none	0.02	68%	0.02	68%	0.02	68%
2-inch	Flow [cfs]	2.7	none	0.8	69%	0.8	69%	0.8	69%
	Volume [AF]	0.21	none	0.10	50%	0.11	49%	0.10	50%
10-yr	Flow [cfs]	19.0	none	16.6	12%	18.5	2%	16.0	16%
	Volume [AF]	1.14	none	0.97	14%	1.03	10%	0.91	20%
100-yr	Flow [cfs]	40.1	none	37.5	7%	39.0	3%	35.8	11%
	Volume [AF]	2.21	none	2.03	8%	2.10	5%	1.94	12%

Table-1 Catchment #1 Hydrologic Model Results Summary

Water Quality Benefits

Many different approaches can be used to quantify erosion and/or stormwater pollutant loading. Although study areas #1 and #3 occur within a major metropolitan area, this site is not a typical urban setting. The steep slopes, observed highly eroding soils and low impervious cover make the study area more representative of a rural/agricultural setting. Additionally, sedimentation rates in downstream infrastructure indicate that upstream erosion is occurring orders of magnitude greater than those typically assumed for urban areas.

Keeping this unique urban setting in mind, a simple analysis utilizing the Revised Universal Soil Loss Equation (RUSLE) was completed to determine the water quality benefits of the base option and additional options for each catchment. See Appendix C for results. For Catchment #1, the highly erodible area was estimated at 5.3 acres using aerial photography and topographic survey to delineate the ravine. This erodible area was multiplied by the annual sediment loading results of the RUSLE analysis to calculate the total soil loss for the site under existing and proposed conditions. RUSLE parameters were defined based on literature values with the site conditions assumed to be similar to a disturbed woodlot. (USDA 2008, Haan et al 1994)

Given the high rates of observed erosion, it was assumed that contributions of sediment-bound phosphorus from eroding soils is the predominant source of total phosphorus loading in the watershed. To calculate the annual export of phosphorus under existing and proposed scenarios, the phosphorus content (7.9 lbs TP/ton sediment) of typically eroded urban soils within Capital Region Watershed District (Barr 2000) was multiplied by the calculated erosion. As shown in the table below, the existing conditions are compared and contrasted to the potential conditions for each option considered.

	Options:	*Base*	*Additional Water Quality & Quantity Options*		
Parameter	**Existing Conditions**	**Ravine Stabilization**	**(1) Porous Pavement**	**(2) Rain Gardens**	**(3) Base + Options 1 & 2**
P. Load [lb/yr]	237	225	190	232	164
Sed. Load [ton/yr]	30.0	28.5	24.0	29.4	20.7
Pollutant Load Reduction [%]	-	5%	20%	2%	31%

Table-2 Catchment #1 Water Quality Estimates

Minor Maintenance and Landscape Improvements

Certain landscaping and land use activities practiced in this catchment are exacerbating the flooding and ravine stability problems. Roof leaders and other stormwater conveyances are directly discharging to the ravine and in some instances, at unstable locations. Additionally it is common practice in this catchment to dispose of yard trimmings in the ravine. This practice is adding nutrients to the ravine and eliminating any vegetation growth, which is critical for ravine stability. Direct stormwater connection to the ravine should be disconnected and treated (i.e. raingarden) if possible.

Identification of Solutions for Catchment #3:

Base - Flood Reduction Solution

In order to alleviate the recurring Deer Park Condominium flooding, the flared end storm sewer inlet at the base of the ravine needs to be modified. A drop structure inlet should replace the flared end inlet in conjunction with creation of a depressional basin via excavation and raising the existing berm. This solution will provide a storage area for water to temporarily pond and outlet through the existing system. A drop outlet structure will provide higher capacity stormwater conveyance. The berm elevation will be significantly increased and the area upstream of the berm will be excavated to provide additional treatment and stormwater storage. Note that this solution may not fit entirely on the Condominium property and may require an easement from the landowner(s) to the west. The project would primarily be constructed on private property with some use of the public utility easement.

Due to the steep nature of the area downstream of the storm sewer inlet and the high number of utilities, it would be very costly to construct a controlled emergency overflow. Instead, a secondary, high capacity inlet is proposed to provide another connection to the storm sewer system in case the primary inlet becomes clogged, requires maintenance, or does not have sufficient capacity.

The flat 36" pipes located in the downstream north-south storm sewer section should be cleaned out as part of the storm sewer improvements to reduce flooding. The observable pipes and catch basins were almost completely full of sediment. Model results indicate that a high portion of the flow that was intended to flow through this section is actually bubbling out the catch basin manholes and entering Lexington Parkway due to the pipe constriction.

Table 3 summarizes the benefits of the flood reduction solution (primarily storm sewer improvements) on flows bypassing the designed inlet pipe. The Base improvements would safely convey the 100-year. Note that the flood reduction results of the other water quality and quantity options, which are described below, are also presented in the table. For comparative purposes Options 1-3 assume that the flood reduction solution (Base option) is not made. Any of these options alone would not eliminate flows from bypassing the storm sewer system during the 10-year and 100-year, 24 hour storms.

	Option:	*Base*		*Additional Water Quality & Quantity Options*							
Event	**Existing Condition**	**Stormsewer Infrastructure**		**(1) Porous Pavement**		**(2) Ravine Stabilization**		**(3) Rain Gardens**		**(4) Base + Options 1-4**	
		Flow (cfs)	**Reduc-tion (%)**	**Flow (cfs)**	**Reduc-tion (%)**	**Flow (cfs)**	**Reduc-tion (%)**	**Flow (cfs)**	**Reduc-tion (%)**	**Flow (cfs)**	**Reduc-tion (%)**
1-inch	0.0	0.0	0%	0.0	0%	insig	0%	0.0	0%	0.0	0%
2-inch	0.0	0.0	0%	0.0	0%	none	0%	0.0	0%	0.0	0%
10-yr	3.7	0.0	100%	2.6	31%	none	0%	3.7	1%	0.0	100%
100-yr	14.1	0.0	100%	12.5	11%	none	0%	14.1	0%	0.0	100%

Table-3 Catchment #3 Deer Park Development Bypass Flow (cfs) Model Results

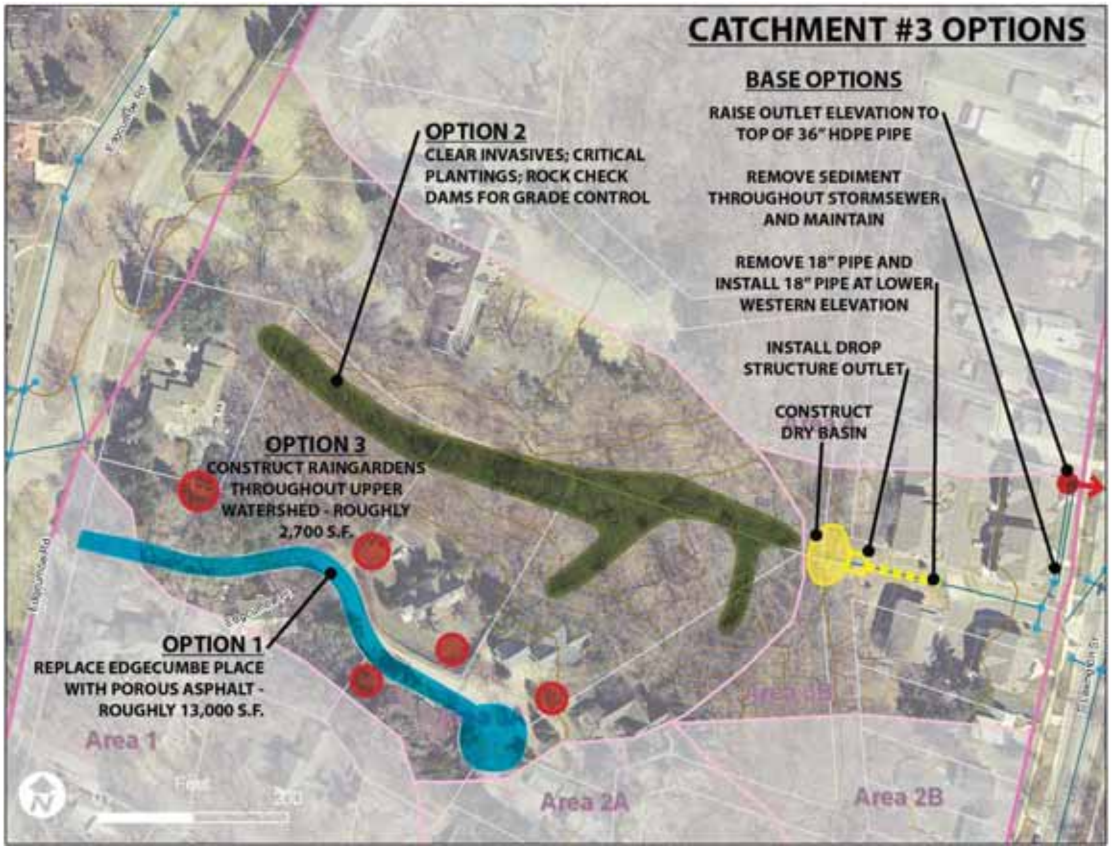

Figure-8 Catchment #3 Schematic Design

Additional Water Quality and Quantity Options

The proposed storm sewer improvements provide additional flooding protection for the Deer Park Condominium residents. However, it does little to improve water quality. If left unchanged, conditions in the ravine will continue to contribute and transport sediment to the condominiums and the City's storm sewer system. This ravine should be stabilized and BMPs, such as raingardens and porous pavement, should be considered in the upper catchment area to improve water quality as well as runoff volume. Raingardens (specific locations were not identified, but a total area of 2,700 sf and 2,221 cf of volume was assumed to be feasible) and porous pavement for Edgcumbe Place were selected to limit the impact of the upstream impervious surfaces on the ravine (Figure 8). Due to the slope of the watershed, only 6" of storage depth was assumed in the porous pavement. Each of these features can fully capture a storm of ~1.5". These improvements would also help lengthen the maintenance cycle for the storm sewer infrastructure. The hydrologic modeling results for these additional options and the base option can be seen in Table 4. These facilities would be constructed with the public right-of-way

Areas considered for infiltration and/or filtration have well-drained soils (Urban land-Waukegan Complex), with greater than 5 feet of separation from the seasonally high water table.

Augmentation of groundwater seepage by infiltrated stormwater may pose some problems (i.e. ravine instability due to soil cohesion) and should be further considered, but ravine stability gains from stormwater rate and volume reductions likely out weigh any hazards.

Water Quality Benefits

The same RUSLE analysis used for Catchment #1 was employed for Catchment #3. An estimated erosion yield from the observed volume of sediment captured within the private stormsewer (including rate control storage) over the life of the system was comparable to the RUSLE analysis. See Appendix C for results. Reports of silt fence filling within 1 month of installation and sediment flows as see in Figure-5 further substantiate this rate. This rate of erosion is not considered typical, but currently accelerated. As shown in Table 5, the existing conditions are compared and contrasted to the potential conditions for each option considered.

Minor Maintenance and Landscape Improvements

Certain landscaping and land use activities practiced in this catchment are exacerbating the flooding and ravine stability problems. Roof leaders and other stormwater conveyances are directly discharging to the ravine and in some cases, at unstable locations. Additionally, it is common practice in this catchment to dispose of yard trimmings in the ravine. This practice is adding nutrients to the ravine and eliminating vegetation growth, which is critical for ravine stability. Direct stormwater connection to the ravine should be disconnected and treated (i.e. raingarden) if possible.

		Option:	*Base*		*Additional Water Quality & Quantity Options*							
Storm Event	**Hydraulic Parameter**	**Existing Condition**	**Storm Sewer**		**(1) Porous Pavement**		**(2) Ravine Stabilization**		**(3) Rain Gardens**		**(4) Base + Options 1-3**	
			Flow / Volume	**Reduction (%)**	**Flow / Volume**	**Reduction (%)**	**Flow / Volume**	**Reduction (%)**	**Flow / Volume**	**Reduction (%)**	**Flow / Volume**	**Reduction (%)**
1-inch	Flow [cfs]	1.4	0.0	100%	0.8	45%	insig.	0%	0.8	45%	0.0	100%
	Volume [AF]	0.08	0.00	100%	0.04	45%	none	0%	0.04	45%	0.00	100%
2-inch	Flow [cfs]	3.1	0.4	87%	1.7	45%	none	0%	1.7	45%	0.0	100%
	Volume [AF]	0.20	0.07	65%	0.13	38%	none	0%	0.13	38%	0.00	99%
10-yr	Flow [cfs]	13.0	8.1	38%	11.4	13%	none	0%	12.9	1%	6.1	53%
	Volume [AF]	0.79	0.64	19%	0.66	16%	none	0%	0.70	11%	0.48	40%
100-yr	Flow [cfs]	25.1	12.7	49%	23.3	7%	none	0%	24.7	1%	11.4	55%
	Volume [AF]	1.41	1.26	11%	1.27	10%	none	0%	1.33	6%	1.06	25%

Table-4 Catchment #3 Hydrologic Model Results Summary

	Option:	*Base*	*Additional Water Quality & Quantity Options*			
Parameter	**Existing**	**Storm Sewer**	**(1) Porous Pavement**	**(2) Ravine Stabilization**	**(3) Rain Gardens**	**(4) Base + Options 1-3**
P. Load [lb/yr]	395	336	375	316	387	213
Sed. Load [ton/yr]	50.0	42.5	47.5	40.0	49.0	27.0
Pollutant Load Reduction [%]	-	15%	5%	20%	2%	46%

Table-5 Catchment #3 Water Quality Estimates

IV. ESTIMATED COST

Implementation (engineering and construction) as well as maintenance costs were estimated for the solutions considered. Since maintenance is essential to the function of all solution options, a 30-year projection of cost (in 2011 dollars) is included because the life spans of storm sewer infrastructure and BMPs are estimated at 30 years.

The estimates below reflect single, independent projects. A 5%-15% reduction in cost would be expected if multiple options were designed and constructed concurrently.

Comparative projects were utilized for estimating the cost of the ravine stabilization and stormsewer infrastructure options. An average cost of $13 per square foot was utilized for the raingardens. This is a median installation cost for a moderately complex raingarden, including engineered soils, under-drains and pretreatment [source Metro Conservation Districts Average BMP Cost Estimates, among others]. An average cost of $9.00 per square foot estimate was used for porous pavement. This is a median installation cost for porous asphalt drives with a granite storage base [source Metro Conservation Districts Average BMP Cost Estimates, among others].

The following typical maintenance activities are reflected in the estimated 30-Year Maintenance cost:

Porous Pavement
- 38 vacuum sweepings over 30 year period
- 2 high pressure spray cleanings over 30 year period
- Minor patch/replacement

Ravine Stabilization (Catchment #1 Base and Option for Catchment #3)
- Repair of minor erosion instabilities – annually or as needed
- Weeding – annually first 5 years
- Vegetation maintenance – every 5 years for remaining 25 years

Rain Gardens
- Weeding, minor sediment removal, garbage remove and mulch dressing – twice annually first 5 years; annually next 25 years.

Storm Sewer (Catchment #3 Base)
- Sediment removal from dry basin – annually
- Sediment removal from stormsewer – every 2-3 years
- Removal debris from outlet – as needed

Catchment #1

The implementation cost for the Base option (flood reduction solution) is $27,000 and the projected maintenance costs for this option over 30 years is $8,000. The associated costs for the additional water quality and quantity options are in addition to the Base option costs.

	Option:	*Base*	*Additional Water Quality & Quantity Options*	
Location	**Item**	**Ravine Stabilization**	**(1) Porous Pavement***	**(2) Rain Gardens**
Catchment #1	Engineering & Admin	$7,000	$24,699	$8,400
	Construction	$20,000	$137,214	$42,000
	Implementation Cost:	**$27,000**	$161,913	$50,400
	30-Year Maintenance	$8,000	$18,000	$23,800
	Total 30-Year Cost:	**$35,000**	$179,913	$74,200

Table-6 Catchment #1 Cost Estimates
*Note – recommendation for private road

Option:	*Base*	*Additional Water Quality & Quantity Options*	
Catchment #1 - Parameters	**Ravine Stabilization**	**(1) Porous Pavement**	**(2) Rain Gardens**
Implementation Cost [$]	$27,000	$161,913	$50,400
P load removal [lb/yr]	12	47	5
P load removal [$/lb]	$2,250	$3,445	$10,080
Sed Load removal [ton/yr]	1.5	6	0.6
Sed Load removal [$/ton]	$188	$73	$2,016

Table-7 Catchment #1 Cost:Benefit Analysis Summary

Catchment #3

The implementation cost for base option (storm sewer improvements) is $41,600. The projected maintenance costs for this option over 30 years is $75,000. The associated costs for the additional water quality and quantity options are in addition to the Base option costs.

	Option:	*Base*	*Additional Water Quality & Quantity Options*		
Location	**Item**	**Storm Sewer**	**(1) Porous Pavement**	**(2) Ravine Stabiliz.**	**(3) Rain Gardens**
Catchment #3	Engineering & Admin	$9,600	$21,060	$8,400	$6,480
	Construction	$32,000	$117,000	$21,000	$32,400
	Implementation Cost:	**$41,600**	$138,060	$29,400	$38,880
	30-Year Maintenance	$75,000	$18,000	$8,000	$23,000
	Total 30-Year Cost:	**$116,600**	$156,060	$37,400	$61,880

Table-8 Catchment #3 Cost Estimates

Option:	*Base*	*Additional Water Quality & Quantity Options*		
Catchment #3 - Parameters	**Storm Sewer**	**(1) Porous Pavement**	**(2) Ravine Stabiliz.**	**(3) Rain Gardens**
Implementation Cost [$]	$41,600	$138,060	$29,400	$38,880
P load removal [lb/yr]	59	20	79	8
P load removal [$/lb]	$705	$6,903	$372	$4,860
Sed Load removal [ton/yr]	7.5	2.5	10	1
Sed Load removal [$/ton]	$12	$345	$5	$608

Table-9 Catchment #3 Cost:Benefit Analysis Summary

Ghost Parks

The project area contains two isolated public parcels referred to as *Ghost Parks* and a network of utility corridors traversing the bluff (Figure 9). "The association between ghost parks and springs is hardly accidental, because these frequently rugged little lots were donated to the city by individuals who found them useless for building purposes and the city probably did not formally develop them for the same reason. But that happens to be exactly the sort of hillside situation in which the drift-Decorah spring is lurking." (excerpt from Brick, G., 2007c. St. Paul's Diamond Necklace. Minnesota Ground Water Association Newsletter 26 (September): 15-17)

Groundwater Drainage

Catchment #2A contains a groundwater fed wetland approximately a third of an acre in size, located on the Western Edge of Walsh Park (Figure 9). This wetland is being actively drained by a french-drain type pipe, which is tied to the City storm sewer. The formal drainage is presumably intended to minimize basement flooding and dampness for homes along Lexington Parkway.

Figure-9 Public Property within Study Area.

V. CONCLUSIONS & RECOMMENDATIONS

Catchment #1

Conclusion
Due to the aggradation (increase in land elevation due to the deposition of sediment) of the lower end of the ravine and possible inadequate berm height and extent meant to protect private property, reports of some flooding are still being made.

Recommendations
The *Base* option for flood reduction, as outlined in Section III, should be implemented as soon as possible. This improvement will significantly reduce the risk of flooding and will provide some water quality benefits.

As funding becomes available and/or infrastructure needs replacing, the additional water quality and quantity options, (as discussed in Section III) should be considered. These improvements will reduce runoff rates and volumes and provide water quality benefits. For example, it may be cost prohibitive to convert the private road to porous pavement at this time, but it is a viable option when the road bed requires replacement.

Landowner education on the sensitivity of ravine landscapes and land stewardship opportunities (i.e., downspout redirection, raingardens, and rain barrels) is strongly recommended.

Catchment #3

Conclusions
The primary cause of the Deer Park Condominium flooding is due to inadequacies of the Condominium's private storm sewer system and the lack of maintenance that has been completed on this system. The flared-end inlet pipe does not adequately capture flow from the ravine, and due to the absence of an adequate emergency overflow, bypass water is not safely conveyed and instead flows towards private property. This problem is compounded by the significant amount of sediment constraining the capacity constrictions of the flat, 36" pipes and other infrastructure pieces.

The land use practices and landscaping activities in the upper watershed play a role in the stability of the ravine and the resulting amount of sediment transported as well as the volume and timing of stormwater runoff. However, it is secondary relative to the Condominium's storm sewer deficiencies for addressing the flooding issues on their property.

Recommendations
The *Base* option for flood reduction, as outlined in Section III, should be implemented as soon as possible. This improvement will significantly reduce the risk of flooding and will provide some water quality benefits. Given it's high water quality return and impact on future stormwater maintenance cost, Additional Water Quality and Quantity Option #2 (Ravine Stabilization), should also be completed in conjunction with the *Base* option.

As funding becomes available and/or infrastructure needs replacing, additional water quality and quantity options #1 and #3, (as discussed in Section III) should be considered. These improvements will reduce runoff rates and volumes and provide water quality benefits. For example it may be cost prohibitive to convert Edgcumbe Place to porous pavement at this time, but it is a viable option when the road bed requires replacement.

Landowner education on the sensitivity of ravine landscapes and land stewardship opportunities (i.e., downspout redirection, raingardens, and rain barrels) is strongly recommended.

VI. REFERENCES

Barr Engineering 2000. Capital Region Watershed District Stormwater Modeling

Haan, C.T., Barfield, B.J., Hayes, J.C. 1994. Design Hydrology and Sedimentology for Small Catchments. Academic Press

United States Department of Agriculture (USDA). 2008. User's Reference Guide – Revised Universal Soil Loss Equation Version 2.

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Deer Park Development
Related Development Correspondence

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March 29, 2002

Randy Hudlund
Hudland Engineering
2005 Pin Oak Drive
Eagan, Minnesota 55122

RE: Deer Park Development

Dear Randy:

Per our phone conversation of March 28, 2002 the comments are:

1. The Sewer Maintenance Crew had performed the video inspection of the existing 10" sanitary sewer that passes through the above site. The report (copy attached) indicates that this sewer is in good condition except there are some tree roots problems. The condition of the sewer does not warrant a replacement of the sewer at this time. However we intend to line this sewer. We have determined to include this sewer on the roots cleaning list until it gets lined.

2. Recently, our staff people brought to my attention that there is a ground water problem in the areas located north and South of the proposed development. Drain tiles systems were installed to correct it. We suggest that you investigate this potential ground water problem at this site and plan to take care of it.

3. I visited this site on March 27,2002. Substantial water (snowmelt) from the west of the site was passing through the site. We have concerned that surface water may create problems for the future homeowners. We would like to see an analysis and determination of what runoff will be moving through this site in 100 year storm event and to demonstrate us that it will pass safely through the proposed development.

Sincerely,

Ila Shah
Sewer Utility

JOHN KRATZ, BUILDER

Fax Transmission

From: John Kratz

To: Ila Shah

Company: City of St. Paul

Fax #: 651-298-5621

Date: April 15, 2002 Time:

# of Pages (including cover): 3

NOTE: Attached is my letter regarding Deer Park water issues.

FAX: 651-690-5360

PHONE: Same

John Kratz, Builder

1424 Edgcumbe Road, St. Paul, MN 55116

Phone/Fax: 651-690-5560
MN License # 20035288

April 15, 2002

Ms. Ila Shah
Sewer Utility
City of St. Paul
700 City Hall Annex
St. Paul, MN 55102

RE: Deer Park Development

Dear Ms. Shah:

This will confirm my representations to you, made as owner/developer of the referenced 12-unit townhome development, regarding your concerns about potential ground water and surface water issues on the site.

Because the neighbors advised me of possible ground water problems even before I purchased the property last summer, I have been looking for evidence of it ever since and have found none. During the demolition of the "existing" houses on the site, both basement excavations were open for more than a week last November and no water seeped into either hole. Additionally, we dug two test holes at the approximate location and footing depth of the proposed rear buildings and encountered only damp soils (sandy clay/clayey sand) and no seeping water.

The townhomes to be built will each have an interior drain tile/sump basket system as a standard feature. But if any ground water sources are encountered, or even suspected, during the construction process, please rest assured that we will take whatever steps are necessary to insure that the future owners will have dry and trouble-free basements. These steps might include upgraded water-proofing, additional exterior drain tile, rock-based drainage systems, and subsurface piping to the onsite storm sewer system if determined to be necessary.

Surface water drainage can be easily accommodated. The tops of building foundations are well above the drives and a deep rear yard offers plenty of room to grade a swale with positive drainage away from the buildings. Even the

Ms. Ila Shah
April 15, 2002
Page Two

basement floors of the lower (eastern) buildings are at least three feet above the curb/spill line of Lexington Parkway out front. A very small amount of grading will direct the storm runoff from the property to the west onto the proposed paved drainage swale and private street, and into the proposed detention structures, thus passing safely through the proposed development. Even without the proposed improvements, I don't believe storm water runoff seriously threatened the previous houses on the site. Although poor maintenance did allow the runoff to leave the Albion right-of-way, run through the rear yard of the house to the south, and with some regularly cause a washout of mud and small rocks onto Lexington at Albion. These problems will be eliminated by our proposed improvements.

Sincerely,

John Kratz

cc: Tom Beach

John Kratz, Builder

1424 Edgcumbe Road, St. Paul, MN 55116

Phone/Fax: 651-690-5360
MN License # 20035288

May 1, 2002

Ms. Ila Shah
Sewer Utility
City of St. Paul
700 City Hall Annex
St. Paul, MN 55102

RE: Deer Park Development – Storm Sewer

Dear Ms. Shah:

It is my understanding that the City is recommending the extension of a storm sewer line through the Deer Park development, in order to handle the run-off from the properties to the west. I acknowledge that it will be my responsibility to construct and maintain this storm sewer system as a private facility.

This maintenance obligation shall "run with the land" and shall be an obligation of any successors in interest (i.e., the future homeowners), to be carried out under the auspices of the homeowners' association to be formed for the benefit of the 12 townhome owners.

Sincerely,

John Kratz

Deer Park Development
Storm and Sanitary Construction Plan Sheets

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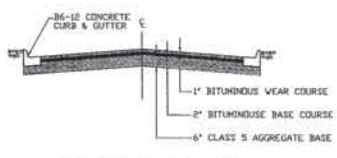
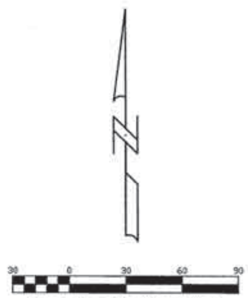
PRIVATE DRIVE



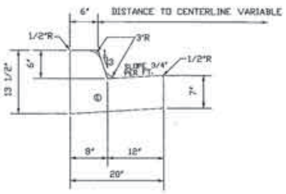
PAVEMENT SECTION



Scale 1" = 30' (Plan View)
Scale 1" = 50' (Profile)

NOTE:

1. ABANDONING EXISTING SEWER SERVICE OR MAKING NEW CONNECTIONS TO CITY SEWER MUST BE DONE TO CITY STANDARDS BY A LICENSED HOUSE DRAIN CONTRACTOR UNDER A PERMIT FROM PUBLIC WORKS SEWER SECTION (651-266-6151)
2. WATERMAIN TO BE CONSTRUCTED TO S.P.R.W. STANDARDS.
3. SANITARY AND STORM SEWER TO BE CONSTRUCTED TO CITY OF ST. PAUL AND C.E.A.M. SPECIFICATIONS.
4. SANITARY SEWER SERVICE WYES TO BE 8"X 4" DUCTILE IRON.
5. SANITARY MANHOLES TYPE 1 PER CITY PLATE # 2101B
6. ALL WORK ON SEWER CONNECTIONS TO PUBLIC SANITARY MAIN IN PUBLIC ROADWAYS OR PUBLIC EASEMENTS MUST BE INSPECTED BY A DEPARTMENT OF PUBICS WORKS SEWER UTILITY INSPECTOR. THE CONTRACTOR MUST REQUEST AN INSPECTION BY CONTACTING SEWER UTILITY (651-266-6234)



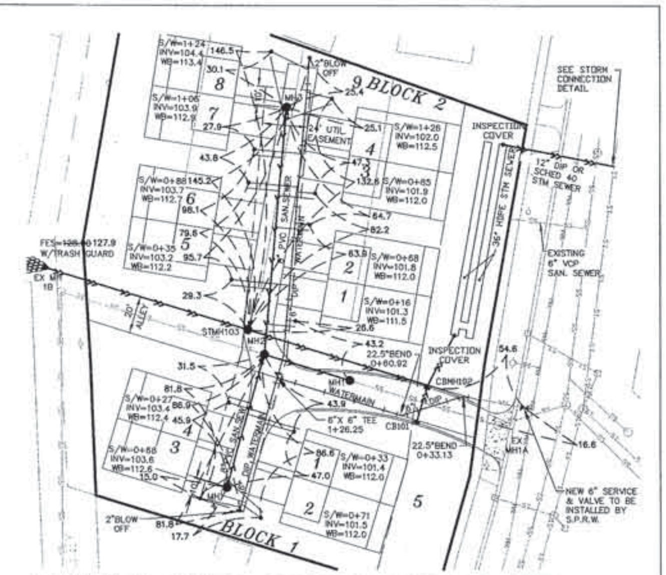
CONCRETE CURB DETAIL

MnDOT B6-12

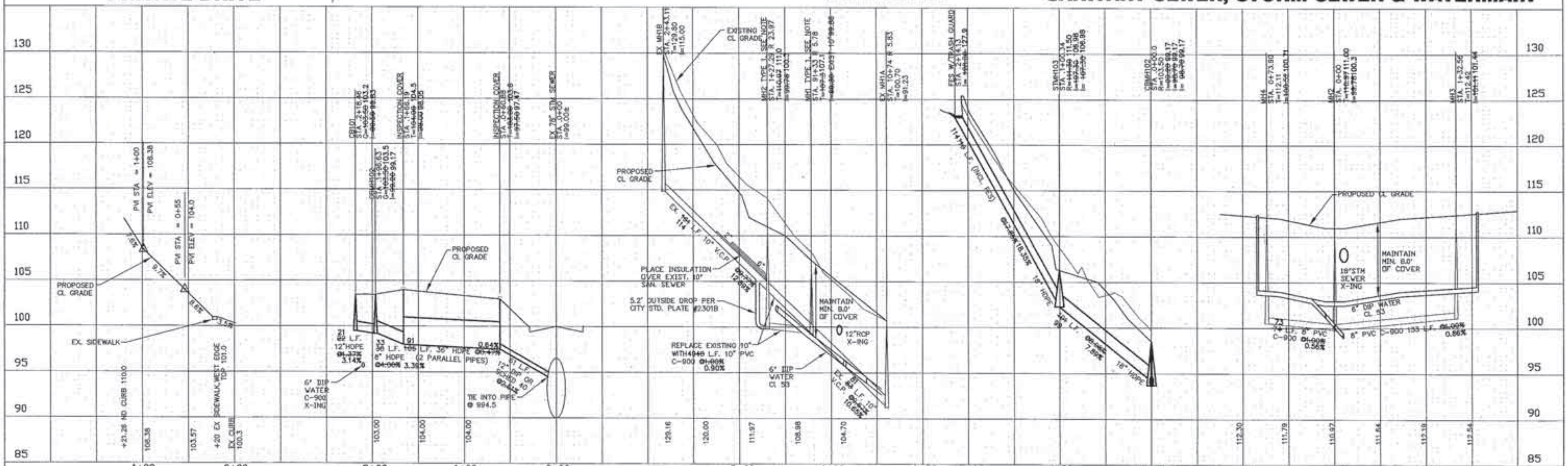
STORM SEWER SCHEDULE

STRUCTURE NUMBER	DIAMETER	LID/GRATE
CB101	2'x3'	R-3067-V
CBMH102	4'	R-3067-V
CBMH103	4'	R-3067-V

ALL STORM SEWER PIPE CLASS 5 UNLESS OTHERWISE NOTED



SANITARY SEWER, STORM SEWER & WATERMAIN



NO.	DATE	BY	REMARKS
4	7/10/03	SLP	UTILITY AS-BUILTS
3	4-22-02	SLP	City Remarks & Final Utilities
2	4-11-02	SLP	City Remarks & Final Utilities
1	2-27-02	SLP	City Remarks & Final Utilities

REVISIONS

DESIGNED BY: RCH
DRAWN BY: SLP
CHECKED: RCH
DATE: 2-20-02

I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA

DATE 2-20-02 REG. NO. 19576

PREPARED BY:

HEDLUND

Planning Engineering Surveying
2005 PIN OAK DRIVE
EAGAN, MINNESOTA 55122
PHONE: (651) 405-6600

DEER PARK

St. Paul, Minnesota

JOHN KRATZ-BUILDER/DEVELOPER

SCALE:
Horiz: 1" = 50'
Vert: 1" = 5'
BOOK: PAGE:
JOB NO. 011021

STREET, SANITARY & STORM SEWER

Private Drive

SHEET C-2.0

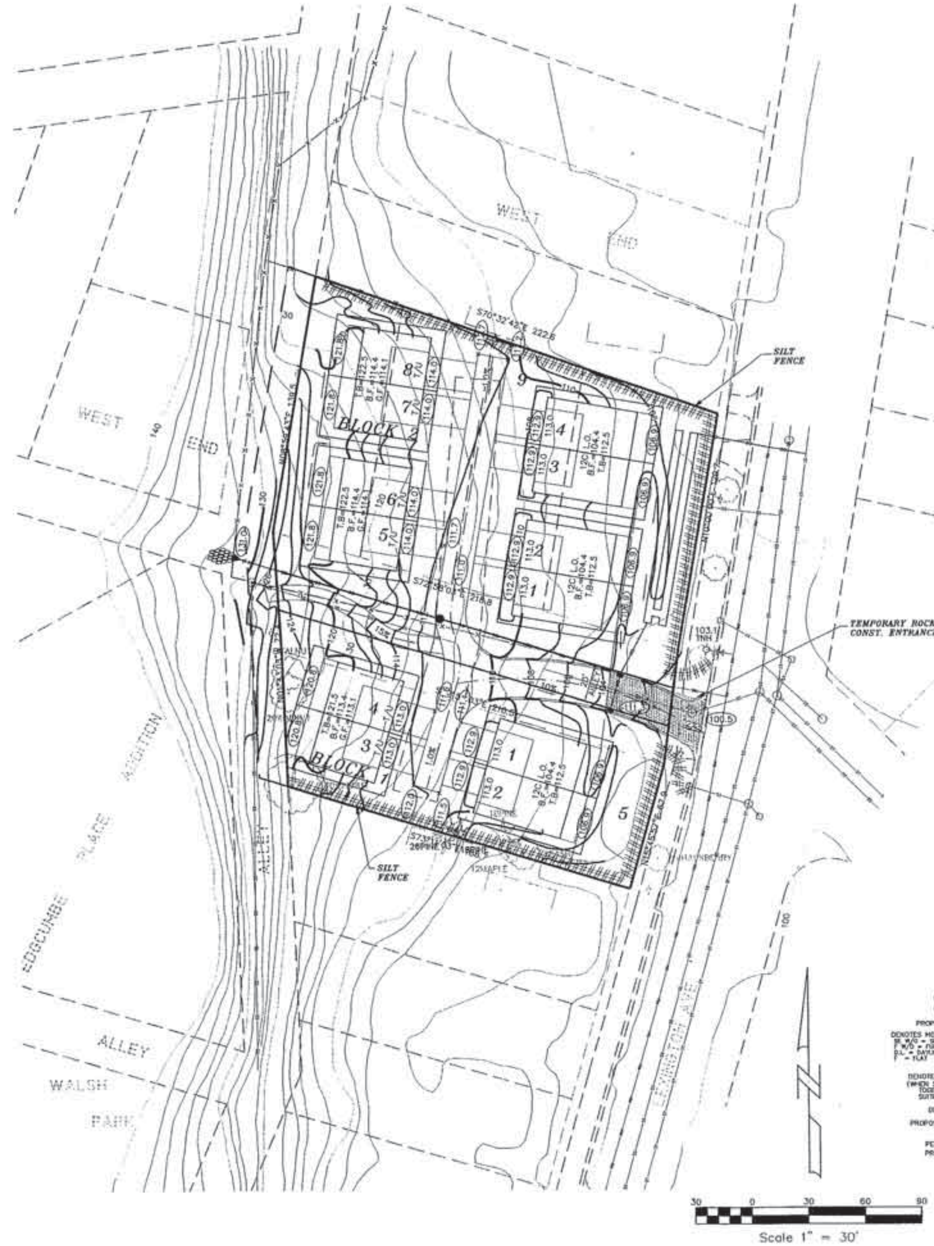
SHEET 6 OF 6

Contractor: CARLSON SEWER & WATER CO. INC.

Asbuilt: 7-03

DEER PARK

City of Saint Paul
Ramsey County, Minnesota



Scale 1" = 30'

LEGEND:

	EXISTING CONTOUR
X = 920.8	EXISTING GRADE ELEVATION
	EXISTING TREE LINE
—SS—SS—	EXISTING SANITARY SEWER
—WM—WM—	EXISTING WATERMAIN
—ST—ST—	EXISTING STORM SEWER
—X—	EXISTING FENCE
	PROPOSED CONTOUR
	PROPOSED SANITARY SEWER
	PROPOSED WATERMAIN
	PROPOSED STORM SEWER
	EROSION CONTROL BARRIER
(920.8)	PROPOSED GRADE
	RETAINING WALL
[920.8]	DENOTES AS-BUILT GRADE
	ROCK CONSTRUCTION ENTRANCE
XXXXXXXXXXXX	TREE PROTECTION

GENERAL GRADING NOTES:

1.) UNDERLYING TOPOGRAPHY FROM CITY PLANS AND FIELD SHOTS BY HEDLUND ENGINEERING.

2.) EXISTING UTILITY LOCATIONS AS-PER PLANS PROVIDED BY CITY ENGINEERING AND FIELD SHOTS BY HEDLUND ENGINEERING.

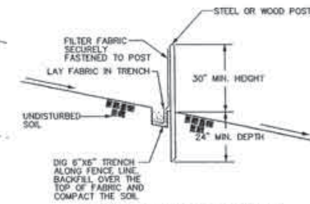
3.) INSTALL, MAINTAIN AND REPAIR SILT FENCING, ROCK CONSTRUCTION ENTRANCE AND SEDIMENT FILTER(S) UNTIL CONSTRUCTION IS COMPLETED. AND NEW VEGETATION AND SURFACING IS ESTABLISHED.

4.) ALL DENUDED AREAS OUTSIDE OF THE STREET RIGHT OR WAY SHALL BE REVEGETATED WITHIN 72 HOURS AFTER FINAL GRADING .
SEED WITH MNDOT 600 (6) SPECIFICATION MIXTURE BY JUNE 15TH. IF PLANTING OCCURS AFTER AUGUST 15TH, SEED WITH A NURSE CROP OF RYE BY OCTOBER 5TH. IF PLANTING HAS NOT OCCURED BY OCTOBER 5TH, THEN DORMANT SEED THE SITE AFTER NOVEMBER 1.
STRAW MULCH SHALL BE SPREAD AT THE RATE OF 1 1/2 TONS PER ACRE AND ANCHORED WITH A STRAIGHT, SERRATED BLADE DISC.
AVAILABLE TOP SOIL SHALL BE SPREAD TO A MINIMUM THICKNESS OF 4 INCHES OUTSIDE HOUSE PAD AREAS AND 2 INCHES WITHIN HOUSE PADS. REFER TO THE GRADING MANUAL FOR CONSTRUCTION SCHEDULE.
ALL AREAS ALTERED BECAUSE OF CONSTRUCTION MUST BE RESTORED WITH SEED AND DISCED MULCH, SOD OR WOOD FIBER BLANKETS.
AREAS ALTERED WITH A SLOPE OF 3:1 OR GREATER MUST BE RESTORED WITH SOD OR FIBER BLANKETS.

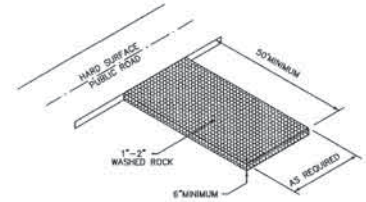
5.) PUT HAY BAILS ACROSS THE SITE ENTRANCE WHEN SITE WILL NOT BE WORKED ON FOR MORE THAN 24 HOURS.

6.) UPON COMPLETION OF STORM SEWER INSTALLATION, STORM SEWER INLETS SHALL BE PROTECTED FROM SEDIMENT BY SILT FENCE, HAY BALES OR EQUIVALENT MEASURES. PROTECTION SHALL REMAIN IN PLACE UNTIL BITUMINOUS AREAS HAVE BEEN PAVED AND LAWN AREAS HAVE BEEN ESTABLISHED.

7.) ADJACENT STREETS AND ALLEYS MUST BE SWEPT TO KEEP THEM FREE OF SEDIMENT. CONTRACTOR MUST MONITOR CONDITIONS AND SWEEP AS NEEDED OR WITHIN 24 HOURS OF NOTICE BY THE CITY.



SILT FENCE TYPICAL
No Scale



ROCK CONSTRUCTION ENTRANCE
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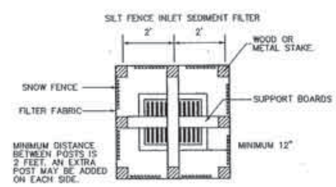

TYPE A SEDIMENT FILTER
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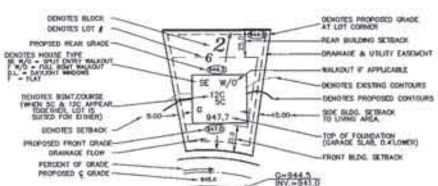

TYPICAL LOT DETAIL
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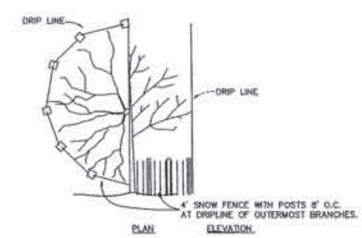

TREE PROTECTION DETAIL
No Scale

PROJECT NUMBER	011021

REVISIONS		
REMARKS	DATE	BY
City Comments & Final Utilities	1-21-02	SLP

CERTIFICATION: I hereby certify that this plan was prepared by me or under my direct supervision and that I am a duly Licensed Professional Engineer under the Laws of the State of Minnesota.

Randall C. Hedlund, Minn. No. 19576

PREPARED BY: **HEDLUND** PLANNING ENGINEERING SURVEYING
2005 PIN OAK DRIVE
EAGAN, MINNESOTA 55122
PHONE: (651) 405-6600
FAX: (651) 405-6606

SHEET TITLE: DEER PARK GRADING PLAN

PREPARED FOR: JOHN KRATZ
1424 EDGECUMBE ROAD
ST. PAUL, MINNESOTA 55116
PHONE: (651) 690-5360

DRAWN	CHECKED	DESIGN
SLP		

SHEET NUMBER: C-1.3

DATE: 12/4/01

RUSLE Analysis for Catchment #1 & #3

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Highly Erodible Soil Area (ac)		5.3	Sample Values			*Options*	*Base*	*Additional Water Quality & Quantity Options*			Notes and Assumptions
Parameter	**Units**	**Description**	**Low**	**Twin Cities Estimate**	**High**	**Existing Conditions**	**Ravine Stabilization**	**(1) Porous Pavement**	**(2) Rain Gardens**	**(3) Base + Options 1 & 2**	
R		rainfall/runoff factor	60	100	150	100	100	100	100	100	Standard Regional Value
K		Soil erodibility factor	0.17	0.24	0.49	0.43	0.43	0.43	0.43	0.43	Outwash Sandy Loam
L		Slope length factor	0.1	1	1	1	1	1	1	1	Standard Regional Value
S		slope steepness factor	0.1	1	1	1	1	1	1	1	Standard Regional Value
C		cover and management factor	0.02	0.65	1	0.36	0.36	0.36	0.36	0.36	Disturbed Woodlot
P		supporting conservation practice factor	0.02	0.5	1.5	0.37	0.35	0.29	0.36	0.25	Estimated based on observed erosion compared to farm field
A	**tons/ ac/year**	**Soil Loss**	**0.0000408**	**7.8**	**110.3**	**30.0**	**28.5**	24.0	**29.4**	**20.7**	**Calculated**

Table-10 RUSLE Analysis Catchment #1

Highly Erodible Soil Area (ac)		2.7	Sample Values			*Options*	*Base*	*Additional Water Quality & Quantity Options*				Notes and Assumptions
Parameter	Units	Description	Low	Twin Cities Estimate	High	Existing Conditions	Storm Sewer	(1) Porous Pavement	(2) Ravine Stabilization	(3) Rain Gardens	(4) Base + Options 1-3	
R		rainfall/runoff factor	60	100	150	100	100	100	100	100	100	Standard Regional Value
K		Soil erodibility factor	0.17	0.24	0.49	0.43	0.43	0.43	0.43	0.43	0.43	Outwash Sandy Loam
L		Slope length factor	0.1	1	1	1	1	1	1	1	1	Standard Regional Value
S		slope steepness factor	0.1	1	1	1	1	1	1	1	1	Standard Regional Value
C		cover and management factor	0.02	0.65	1	0.36	0.36	0.36	0.36	0.36	0.36	Disturbed Woodlot
P		supporting conservation practice factor	0.02	0.5	1.5	1.20	1.00	1.14	0.95	1.18	0.65	Estimated based on observed erosion compared to farm field
A	**tons/ ac/year**	**Soil Loss**	**0.0000408**	**7.8**	**110.3**	**50.2**	**41.8**	**47.6**	**39.7**	**49.3**	**27.2**	**Calculated**

Table-11 RUSLE Analysis Catchment #3

APPENDIX G – Crosby Lake Bluff Feasibility Report

Prepared by:
Mitch Johnson, PE and Kevin Biehn of Emmons & Olivier Resources, Inc.
for the Soil and Water Conservation District of Scott County

Crosby Farm Park: Bluff Stabilization / Restoration Feasibility Study - St. Paul, MN

Feasibility Report 08/07/2007

Emmons & Olivier Resources, Inc.
www.eorinc.com / 651.770.8448

A collaboration of professionals enhancing the value of our natural and cultural resources through science and design

Table of Contents

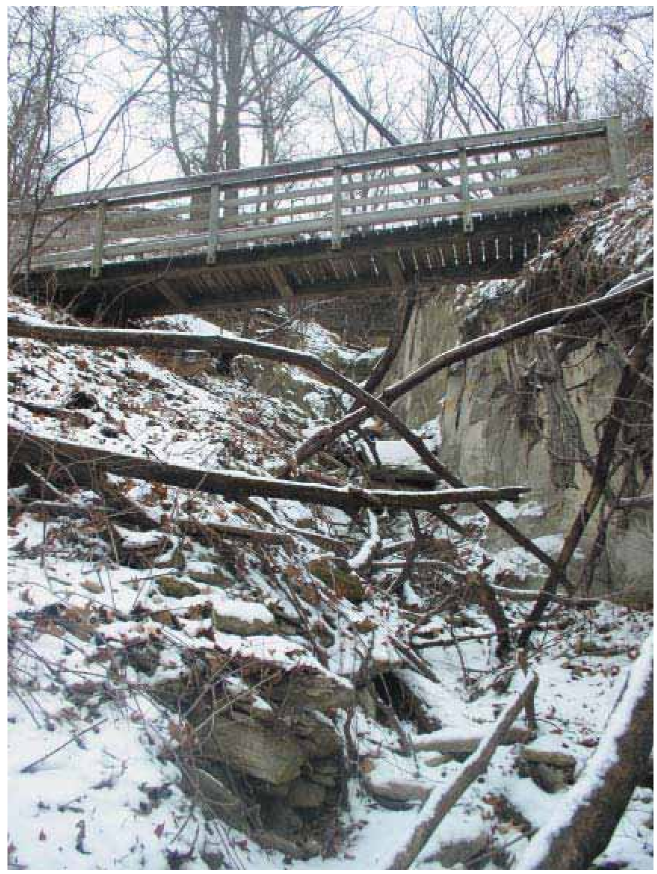
Figures

Tables

I. Introduction

The portion of the Crosby Farm Park bluff on the south side of Shepard R., between the west end of Youngman Ave and Homer Street is a known unstable and actively degrading system. An inventory conducted by the Ramsey Conservation District identified 39 actively eroding points of interest. The majority of the head-cuts found along this bluff are a significant threat to infrastructure and natural resources. The erosion of this bluff has been rapidly accelerated by human influence. At some points, stormwater outfalls, discharging a top the bluff, have carved dramatic gorges through this bluff. Ten of the worst head-cuts have reached or are rapidly approaching the right-of-way of Shepard Road. Many of these ravines have consumed segments of stormsewer with head cuts coming within feet of Shepard Road, potentially leading to structural failure of the RH east bound lane. Down slope, this severe erosion is a serious threat to the water quality of Crosby Lake and the adjacent trail system of the Park.

Applying an appropriate solution to this complex problem will require the input of many effected stakeholders. In addition to Ramsey Conservation District, the St. Paul Parks and Recreation Department (property owner), the State of MN as road authorities for Shepard Rd (MSA road) and the Capital Region Watershed District will have considerable at stake in this project. Additional groups, such as Mississippi National River and Recreation Area, Friends of the Mississippi River and Great River Greening will also be interested stake holders in the project.



The objectives and goals of this study were to determine the best method of controlling or eliminating the bluff degradation in Crosby Farm Park that has been accelerated by man's activities primarily ever since Shepard Rd. was constructed. There were undoubtedly natural drainage paths prior to the development of this area. Evidence still exists where the fragile bedrock had formed ravines and drainage ways for passage of normal runoff down to the Mississippi River floodplain level at Crosby Lake. Subsequent changes in the land use, drainage mechanisms and vehicular and pedestrian traffic have drastically upset the previously established natural drainage patterns and destabilized the slopes along Crosby Farm Park. When reviewing the data points located by the Ramsey Conservation District's 2004 survey, we found three categories of causes to the eroded locations:

1. Stormwater piping discharge points,
2. Surface water runoff discharge points,
3. Pedestrian and recreational activities along the bluff.

The primary culprit causing the most acute damage to the bluff area is the stormsewer outfalls that were terminated at the extreme top of the bluff with no forethought as to the damage the concentrated flows would cause to the fragile bluff ecosystem. This, then, became the primary focus of our analysis and recommendations.

II. Modeling Methodology

General

Modeling for the Crosby Bluff was performed using XP-SWMM version 10. The XP-SWMM model represents state-of-the-art in stormwater modeling. It accurately models backwater conditions, can represent multiple scenarios simultaneously, simulates infiltration, can run real rainfall data, and has the power to run continuous simulations. The model flexibility and sophisticated features allow for the most accurate and realistic representation of real flow conditions and different flow regimes.

Rainfall

A range of synthetic design events following the SCS Type II distribution were simulated to evaluate the systems response to both small and large rainfall events. The magnitude and duration of all events modeled was selected from the Minnesota Hydrology Guide[1].

Rainfall events simulated included:

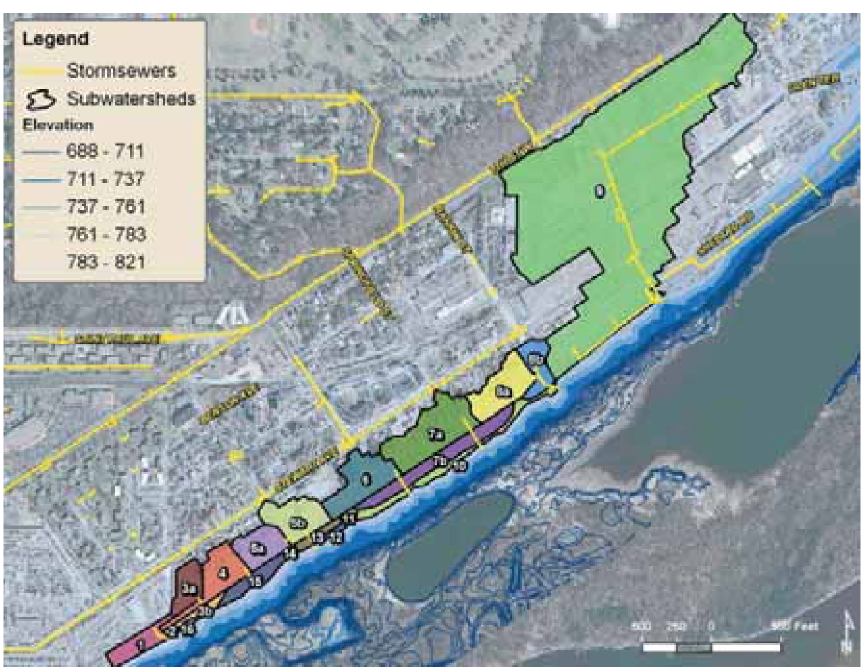
1.5-year	24-hour (2.5 inches)
2-year	24-hour (2.8 inches)
5-year	24-hour (3.6 inches)
10-year	24-hour (4.2 inches)
25-year	24-hour (4.8 inches)
50-year	24-hour (5.4 inches)
100-year	24-hour (6.0 inches)

Although the entire range of storm events were simulated during the analysis, only the 2, 50, and 100-year results are presented for a more concise summary of the model output and system response.

Subwatersheds

The project area contributing to the targeted bluff erosion was delineated into a total of 9 major subwatersheds ranging in size from 0.1 to 44 acres (Figure 1). The average subwatershed size (excluding subwatershed 9) was approximately 1.5 acres.

Figure 1: Subwatersheds



Runoff

Model runoff parameters defining subwatershed hydrology were estimated using the SCS methodology. Input parameters appropriate for the land use, and time of concentration were computed following the methodology and guidance outlined in the Minnesota Hydrology Guide. Model input parameters are summarized below in Table 1.

Table 1: Hydrology Model Input Data

Final Subwatershed Names	Total Acres	% Impervious (Black)	Tc (hrs)	Weighted Area CN
1	1.14	74.6	6.5	95
2	0.15	80.0	5.0	96
3a	1.42	81.0	6.8	96
3b	0.44	68.2	5.0	95
4	2.43	68.7	12.9	95
5a	1.94	64.4	15.0	94
5b	2.51	66.5	18.0	95
6	3.09	53.7	24.9	93
7a	4.47	52.6	15.0	93
7b	2.74	64.6	10.0	94
8a	2.87	68.3	10.5	95
8b	1.45	71.0	10.0	95
9	43.62	75.7	30.9	96
10	1.71	94.2	5.0	97
11	0.21	71.4	5.0	95
12	0.20	65.0	5.0	95
13	0.54	77.8	5.0	96
14	0.13	92.3	5.0	97
15	1.12	74.1	5.0	95
16	0.14	50.0	5.0	93

* *Note that the Curve Number (CN) in Table 1 is a weighted average.*
The applied pervious area CN was 88 and impervious area CN was 98.

Hydraulics

Channel characteristics and flow patters were determined using 1 foot topography and field investigation and verification. Pipe location, size and inverts within the project area were surveyed during the summer of 2006 and entered into the XP-SWMM model to define the project hydraulics.

III. Modeling Results

Existing Conditions

The existing conditions model identifies a rapidly drained, "flashy", storm response which is typical of this type and age of intense development. The lack of BMP's for either water quantity or quality result in minimal flow retention or treatment.

Currently, the system north of Sheppard Road generally handles flows up to the 5-year 24-hour event assuming clean (not clogged) inlet conditions. Events exceeding the 5-year frequency result in surface/ditch flooding.

The small subwatersheds on the south side of Sheppard Road (top of the bluff) drain by surface flow and concentrate at multiple points before dropping over the bluff.

Existing condition hydrology results (defining surface runoff) are summarized for the 2, 50, and 100-year 24-hour rainfall events in Table 2. The existing condition hydraulics (pipe flows and velocities) are summarized and repeated in Tables 3, 4, & 5.

Table 2: Crosby Bluff Hydrology

Subwatershed ID	Area (ac)	Rainfall Event											
		2-yr 24-hr (2.8 inches)				50-yr 24-hr (5.4 inches)				100-yr 24-hr (6.0 inches)			
		Total Runoff Depth (in)	Max Flow (cfs)	Total Runoff Volume (ac-ft)	Total Runoff Volume (cu-ft)	Total Runoff Depth (in)	Max Flow (cfs)	Total Runoff Volume (ac-ft)	Total Runoff Volume (cu-ft)	Total Runoff Depth (in)	Max Flow (cfs)	Total Runoff Volume (ac-ft)	Total Runoff Volume (cu-ft)
1	1.4	2.3	4.5	0.3	11623.7	4.8	9.2	0.6	24598.5	5.4	10.3	0.6	27608.1
2	0.2	2.4	0.5	0.0	1287.2	4.9	1.0	0.1	2694.7	5.5	1.2	0.1	3020.9
3a	1.4	2.4	4.7	0.3	12185.5	4.9	9.3	0.6	25453.4	5.5	10.4	0.7	28530.7
4	2.4	2.2	6.6	0.5	19767.6	4.8	13.6	1.0	42340.3	5.4	15.2	1.1	47588.8
5a	1.9	2.2	3.4	0.4	15549.2	4.8	7.0	0.8	33598.3	5.4	7.8	0.9	37795.5
6	3.1	2.1	6.1	0.5	23768.2	4.7	13.0	1.2	52494.2	5.3	14.5	1.4	59213.0
7a	4.5	2.1	11.0	0.8	34058.6	4.6	23.4	1.7	75402.7	5.2	26.2	2.0	85057.2
8a	2.9	2.2	8.3	0.5	23430.3	4.8	17.0	1.2	50236.1	5.4	19.0	1.3	56466.1
9	43.6	2.3	81.4	8.4	367033.5	4.9	165.8	17.8	775235.6	5.5	185.0	20.0	869923.3
7b	2.7	2.2	8.3	0.5	21931.4	4.8	17.2	1.1	47373.8	5.4	19.2	1.2	53291.7
3b	0.4	2.2	1.5	0.1	3585.7	4.8	3.0	0.2	7688.9	5.4	3.4	0.2	8642.4
5b	2.5	2.2	7.3	0.5	20372.9	4.8	15.1	1.0	43834.5	5.4	16.8	1.1	49292.1
8b	1.5	2.3	4.6	0.3	11858.7	4.8	9.3	0.6	25285.9	5.4	10.4	0.7	28401.8
11	0.2	2.3	0.7	0.0	1720.5	4.8	1.4	0.1	3665.1	5.4	1.5	0.1	4117.2
12	0.2	2.2	0.6	0.0	1592.8	4.7	1.3	0.1	3438.3	5.3	1.4	0.1	3868.1
13	0.5	2.3	1.7	0.1	4549.6	4.9	3.5	0.2	9567.7	5.5	3.9	0.2	10732.1
14	0.1	2.5	0.4	0.0	1167.0	5.0	0.9	0.1	2382.2	5.6	1.0	0.1	2662.9
15	1.1	2.3	3.3	0.2	9399.7	4.9	6.8	0.5	19913.3	5.5	7.6	0.5	22352.7
16	0.1	2.7	0.5	0.0	1356.4	5.3	0.9	0.1	2670.6	5.9	1.0	0.1	2973.5

IV. Bluff Inventory and Evaluation

Map 1 in Appendix V is the compilation of data inventories conducted by Ramsey Conservation District and those gathered as part of this report. The matrix below is organized by subwatersheds in the study area. It is the result of extensive field research and the synthesis and analysis of all available data sets for the Crosby Bluff area.

Table 3: Site Assessment Matrix

	SUBWATERSHED #	1a	1b	2	3a	3b	4	5a	5b	6	7a	7b	8a	8b
	DRAINAGE AREA	0.79	0.63	0.15	1.42	0.44	2.43	1.94	2.51	3.09	4.47	2.47	2.87	1.45
	IMPERVIOUS AREA	0.29	0.46	0.12	1.15	0.30	1.67	1.25	1.67	1.66	2.35	1.77	1.96	1.03
	DISCHARGE OVER BLUFF	Pipe		Pipe	Pipe	Overland	Pipe	Pipe		Pipe	Pipe		Pipe	
	ASSOCIATED EROSION PIONT* Sept 2004 Ramsey Conservation District Erosion Inventory	#11		#10	#8		#4	#13		#26	#32		#36	
QUALITATIVE RANKING	ACTIVE EROSION SEVERITY	High		Medium	High		High	High		High	Very High		Extreme	
	POTENTIAL R.O.W. / STORMSEWER INFRASTRUCTURE LOSS	Low		Low	Medium		Low	Medium		Medium	Low		Medium	
	POTENTIAL PARK INFRASTRUCTURE LOSS	Low		Low	Low		Low	Low		Low	High		Medium	
	POTENTIAL SAFETY LIABILITY	Low		Low	High		Low	Low		Low	High		High	
	PRIORITY (1-Low to 4-High)	2	1	1	2	1	1	2	2	2	3	3	3	3

	SUBWATERSHED #	9a	9b	9c	9d	9e	9f	10	11	12	13	14	15	16
	DRAINAGE AREA	2.80	4.30	4.53	3.69	6.65	21.66	1.71	0.21	0.20	0.54	0.13	1.12	0.14
	IMPERVIOUS AREA	2.21	3.04	2.86	1.11	5.06	20.26	1.61	0.15	0.13	0.42	0.12	0.83	0.07
	DISCHARGE OVER BLUFF	Pipe						Overland	Overland	Overland	Overland	Pipe	Overland	Overland
	ASSOCIATED EROSION PIONT* As Identified by Ramsey Conservation District (Sept 2004)	#39												
QUALITATIVE RANKING	ACTIVE EROSION SEVERITY	Extreme						Medium	Medium	Low	Medium	Medium	Medium	Low
	POTENTIAL R.O.W. / STORMSEWER INFRASTRUCTURE LOSS	High						Low	Low	Low	Low	Low	Low	Low
	POTENTIAL PARK INFRASTRUCTURE LOSS	Medium						Low	Low	Low	Medium	Low	Low	Low
	POTENTIAL SAFETY LIABILITY	Extreme						Low	Low	Low	Low	Low	Low	Low
	PRIORITY (1-Low to 4-High)	4	4	4	4	4	4	1	1	1	1	1	1	1

** Note: erosion inventor points not directly associated with subwater point discharge*

Feasibility Study Recommends Stormwater Improvement Projects:

2 West Improvements (Youngman Ave W.) 3 Central Improvements (Youngman Ave W.) 4 North Improvements (Homer Street)

V. Stormwater Remediation Options

By utilizing the existing conditions model, given that we now know the outfall rates, velocities and volumes that are being generated under current conditions, modifications of the model were made to represent proposed conditions or modifications that could be made to the stormwater system to reduce the erosive effects of the runoff. Multiple scenarios were investigated to determine to what extent and we could reduce the outflows by retrofitting various stormwater management techniques into the system. During this process we started with simpler, less costly, system modifications, changed the model to represent the new conditions, derived the impacts to the runoff rates, velocities and volumes as a result of the stormwater system improvements and moved on to investigate the next logical modification based on the effectiveness of the previous step. In this way, we sought out the most economical solution that would meet the goals of the study.

South-West & Central Section Analysis

Because the composition and logistical positioning of subwatersheds 1 through 8 (excluding the small watersheds that drain directly to the bluff on the south side of Shepard Rd,) was similar and hydrologically related by the linear ditch/boulevard area that is located between Shepard Rd. and Youngman Ave. (refer to Figure 1), it was logical to utilize the 3000 feet of ditch in some fashion to mitigate the peak rates, velocities and volumes leaving this system.

<u>Option 1</u> – (Figure 2)

Existing ditch section along Youngman Ave. would be maintained and the outlets would all be fitted with two-stage or perforated standpipe (height approx. 1.5 feet) control structures. This scenario would utilize the existing pipes to continue discharging over the bluff.

- ► Benefits: Good "small storm" water quality treatment.
- ► Drawbacks: Ditch lacks retention volume to properly meter out "large storms". Peak rates and velocities are not reduced.

Table 4: South-West & Central Section Option 1 Model Results

Rain Event	Subwatershed	Pipe Name	Existing Conditions		Option 1 *	
			Max Flow cfs	Max Velocity ft/s	Max Flow cfs	Max Velocity ft/s
2-Year 24-Hour	1	L1.3	2.8	4.6	1.6	4.0
	3	L3.1	5.1	4.9	2.9	4.0
	4	L4	5.0	5.9	2.4	5.1
	5	L5.2	7.7	7.1	2.7	5.9
	6	L6	2.8	2.5	1.2	1.9
	7	L7.2	9.6	5.5	2.3	3.1
	8	L8.6	8.9	11.0	6.4	10.6
50-Year 24-Hour	1	L1.3	5.2	5.2	5.5	5.2
	3	L3.1	9.5	5.7	5.4	4.8
	4	L4	7.9	6.3	2.9	5.3
	5	L5.2	11.4	9.2	9.8	8.0
	6	L6	4.3	3.6	2.2	2.3
	7	L7.2	10.6	6.1	3.0	3.4
	8	L8.6	18.1	14.9	18.9	11.8
100-Year 24-Hour	1	L1.3	5.5	5.2	5.7	5.2
	3	L3.1	10.1	5.8	5.9	5.0
	4	L4	7.9	6.4	3.1	5.4
	5	L5.2	11.6	9.3	11.3	9.1
	6	L6	4.6	3.8	2.9	2.6
	7	L7.2	10.8	6.1	3.1	3.4
	8	L8.6	18.7	11.8	19.1	11.8

Figure 2: South-West & Central Section Option 1

Section Option 2 - (Figure 3)

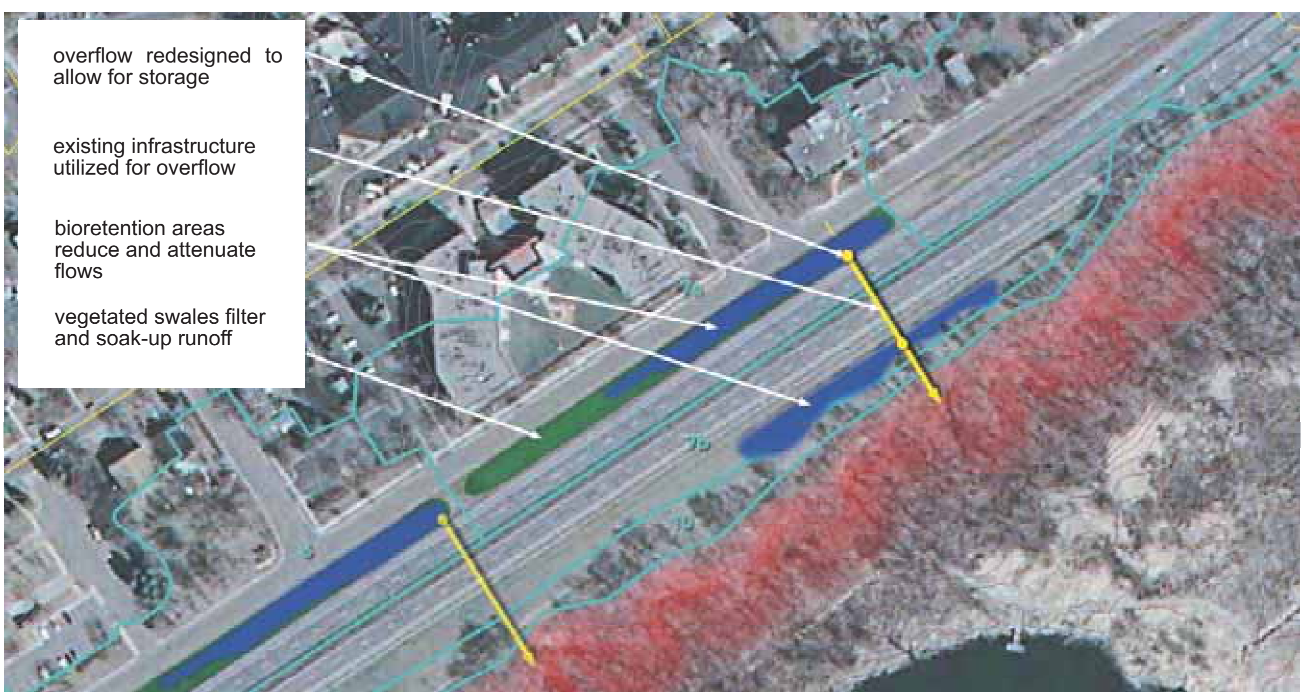
Ditch section along Youngman Ave. is slightly re-graded to bypass the existing outlets and utilize only two of the outlets as illustrated in Figure 2. Existing outlets would be fitted with 2-stage control structures (approx. height 1.5 feet). Secondary flows discharge via existing pipes to bluff.

- Benefits: Good "small storm" water quality treatment.
- Drawbacks: Reconfigured/combined ditch section also lacks retention volume to properly meter out "large storms". Peak rates and velocities are not reduced.

Table 5: South-West & Central Section Option 2 Model Results

Rain Event	Subwatershed	Pipe Name	Existing Conditions		Option 2	
			Max Flow cfs	Max Velocity ft/s	Max Flow cfs	Max Velocity ft/s
2-Year 24-Hour	1	L1.3	2.8	4.6	0.0	0.0
	3	L3.1	5.1	4.9	1.5	3.3
	4	L4	5.0	5.9	0.0	0.0
	5	L5.2	7.7	7.1	0.0	0.0
	6	L6	2.8	2.5	0.0	0.0
	7	L7.2	9.6	5.5	0.0	0.0
	8	L8.6	8.9	11.0	14.0	11.5
50-Year 24-Hour	1	L1.3	5.2	5.2	0.0	0.0
	3	L3.1	9.5	5.7	5.2	4.8
	4	L4	7.9	6.3	1.2	4.3
	5	L5.2	11.4	9.2	0.0	1.2
	6	L6	4.3	3.6	0.0	0.0
	7	L7.2	10.6	6.1	0.1	1.3
	8	L8.6	18.1	14.9	36.4	12.5
100-Year 24-Hour	1	L1.3	5.5	5.2	0.0	0.0
	3	L3.1	10.1	5.8	6.6	5.1
	4	L4	7.9	6.4	1.8	4.8
	5	L5.2	11.6	9.3	0.6	4.0
	6	L6	4.6	3.8	0.1	0.7
	7	L7.2	10.8	6.1	0.9	2.5
	8	L8.6	18.7	11.8	39.9	12.8

Figure 3: South-West & Central Section Option 2



Section Option 3 - (Figure 4)

Ditch section along Youngman Ave. is slightly re-graded to drain as in scenario 2 above. All existing outlet are abandoned and new outlets are installed to redirect overflows to the deep storm sewer tunnel under Stewart St.

- ► Benefits: Good "small storm" water quality treatment. No flows allowed to discharge over the bluff or to Crosby Lake.
- ► Drawbacks: Costly infrastructure improvements required.

Table 6: South-West & Central Section Option 3 Model Results

Rain Event	Subwatersheds	Existing Conditions			Option 3 *	
		Pipe Name	Max Flow cfs	Max Velocity ft/s	Max Flow cfs	Max Velocity ft/s
2-Year 24-Hour	1, 3, 4, 5 & 6	L1.3	2.8	4.6	22.2	7.7
		L3.1	5.1	4.9		
		L4	5.0	5.9		
		L5.2	7.7	7.1		
		L6	2.8	2.5		
	7 & 8	L7.2	9.6	5.5	8.9	6.4
		L8.6	8.9	11.0		
50-Year 24-Hour	1, 3, 4, 5,& 6	L1.3	5.2	5.2	42.6	9.2
		L3.1	9.5	5.7		
		L4	7.9	6.3		
		L5.2	11.4	9.2		
		L6	4.3	3.6		
	7 & 8	L7.2	10.6	6.1	19.2	7.5
		L8.6	18.1	14.9		
100-Year 24-Hour	1, 3, 4, 5,& 6	L1.3	5.5	5.2	45.8	9.4
		L3.1	10.1	5.8		
		L4	7.9	6.4		
		L5.2	11.6	9.3		
		L6	4.6	3.8		
	7 & 8	L7.2	10.8	6.1	20.8	7.5
		L8.6	18.7	11.8		

Figure 4: South-West & Central Section Option 3

North-East Section Analysis

The approach to Subwatershed 9 was slightly different. In this subwatershed, there is no predominant surface drainage feature that could be modified for stormwater mitigation purposes. Within Subwatershed 9, however, are several open green spaces in located within the topography where they could collect runoff if converted into drainage features for stormwater retention and infiltration. In concert with the water quality improvements suggested above, the existing stormsewer system could also be diverted to the deep storm sewer tunnel under Stewart St.

Surface Drainage Areas to Bluff Analysis

Of the several subwatersheds that consist of sections of the eastbound lanes of Shepard Rd. and the boulevard that exists along the south side adjacent to the bluff, only one has any size and consequential runoff, namely 7b. This subwatershed does have enough properly located green area that could be utilized to mitigate runoff by being converted into drainage features for stormwater retention and infiltration. As for the outlet itself, one of two approaches would resolve the point source erosion at the pipe outlet: 1) Modifying or replacing the existing stormsewer piping to drain back to the north side of Shepard Rd. into subwatershed 7a. or 2) Adding an extension on to the outlet piping to the east to provide a safe discharge point lower in the profile of the bluff where erosive velocities could be dissipated in a small basin or stilling pond.

VI. Recommendations

Summary

By referring to Map1 and reviewing the data points located by the Ramsey Conservation District's 2004 survey, we found three categories of causes to the eroded locations:

1. Stormwater piping discharge points,
2. Surface water runoff discharge,
3. Pedestrian and recreational activities along the bluff.

The sections that follow contain our recommendations for resolving these three distinct causes of erosion on the bluff.

Stormwater Piping Discharge Points

South-West Area

Re-grade the ditch section along Youngman Ave. to drain to Alton Ave. Restoration of the new ditch will consist of minor soils amendments and native seeding and plantings. All existing outlets are abandoned and new stormsewer is installed to redirect overflows to the deep storm sewer tunnel under Stewart St. (Figure 6 Below)

Table 7: South-West Cost Estimate

	Item	Unit	Quantity	Cost	Extension
1	Ditch/Swale Improvements (Re-vegetation)	AC	1.030	$15,000.00	$15,450
2	Existing Outlet Standpipe Modifications*	EA	7	$250.00	$1,750
3	Install Deep Sewer Outlet Piping 30” RCP	LF	340	$75.00	$25,500
4	Upgrade Alton Crossing 24” RCP	LF	65	$40.00	$2,600
5	24” Apron & Trash Rack	EA	2	$1,200.00	$2,400
6	Manhole	EA	1	$2,500.00	$2,500
7	Saw cut Pavement	LF	827	$2.50	$2,068
8	Removals	CY	75	$8.00	$600
9	Replace Paving & Base	SY	440	$12.60	$5,544
	** Indicates Optional or Interim Item*				$58,412

South-West Area Description

Utlize island/ditches between west cul-de-sac on Youngman and Alton for storage/bio-infiltration area, install outlet piping in Alton to deep storm sewer at Stewart.

Figure 6: South-West Area Plan

Central Area

Same approach as the South-West area. Re-grade the ditch section along Youngman Ave. to drain to Rankin Ave. Restoration of the new ditch will consist of minor soils amendments and native seeding and plantings. All existing outlet are abandoned and new stormsewer is installed to redirect overflows to the deep storm sewer tunnel under Stewart St. (Figure 7 Below)

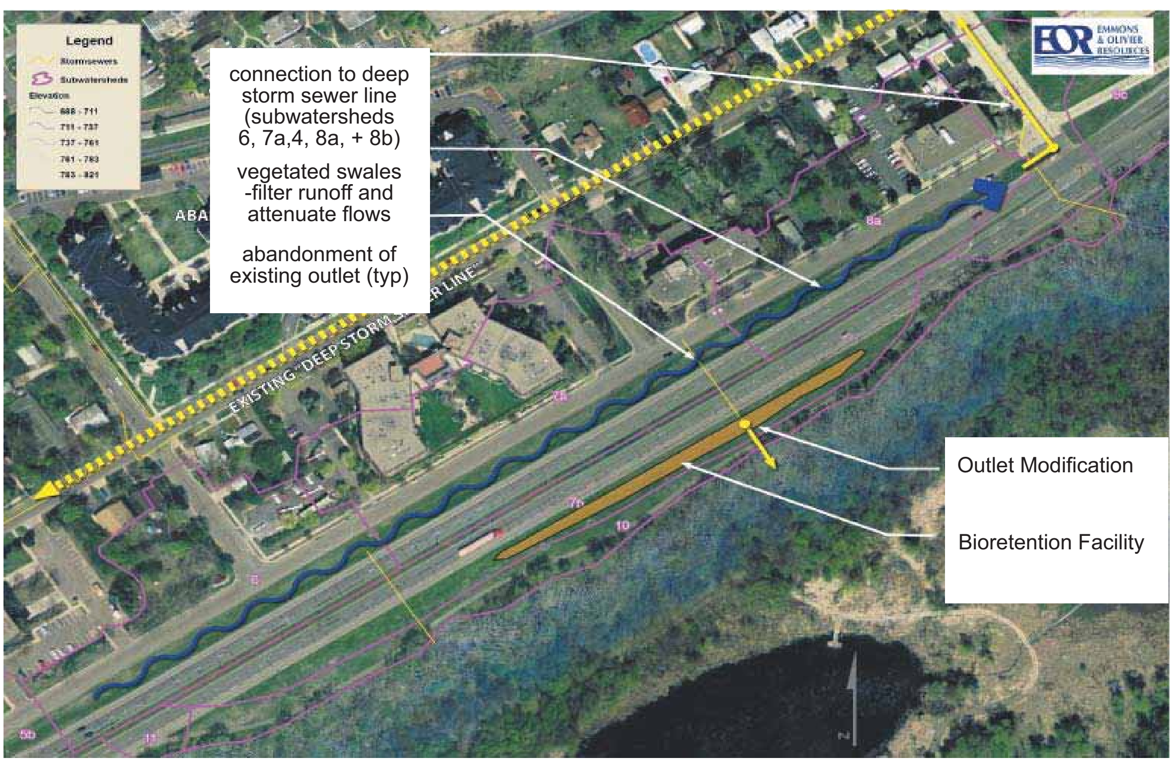
Table 8: Central Area Cost Estimate

	Item	Unit	Quantity	Cost	Extension
1	Ditch/Swale Improvements (Re-vegetation)	AC	1.790	$15,000.00	$26,850
2	Existing Outlet Standpipe Modifications*	EA	7	$250.00	$1,750
3	Install Deep Sewer Outlet Piping 24” RCP	LF	360	$40.00	$14,400
4	Manhole	EA	1	$2,500.00	$2,500
5	24” Apron & Trash Rack	EA	1	$1,200.00	$1,200
6	Saw cut Pavement	LF	754	$2.50	$1,885
7	Removals	CY	70	$8.00	$560
8	Replace Paving & Base	SY	410	$12.60	$5,166
	* Indicates Optional or Interim Item				$54,311

Central Area Descritpion

Utlize island/ditches between Alton and Rankin for storage/bio-infiltration area, install outlet piping north in Rankin to deep sewer at Stewart.

Figure 7: Central Area Plan



North-East Area

Within subwatershed 9, several open green spaces that are located within the topography where they could be used to capture stormwater would be converted into drainage features for stormwater retention and infiltration. New stormwater features are enhanced to provide water quality benefits through minor soil amendments and native seeding and plantings. In concert with the water quality improvements suggested above, the existing stormsewer system could be diverted at Stewart St. to the deep storm sewer tunnel at Stewart St. and Rankin St. (Figure 8 Below)

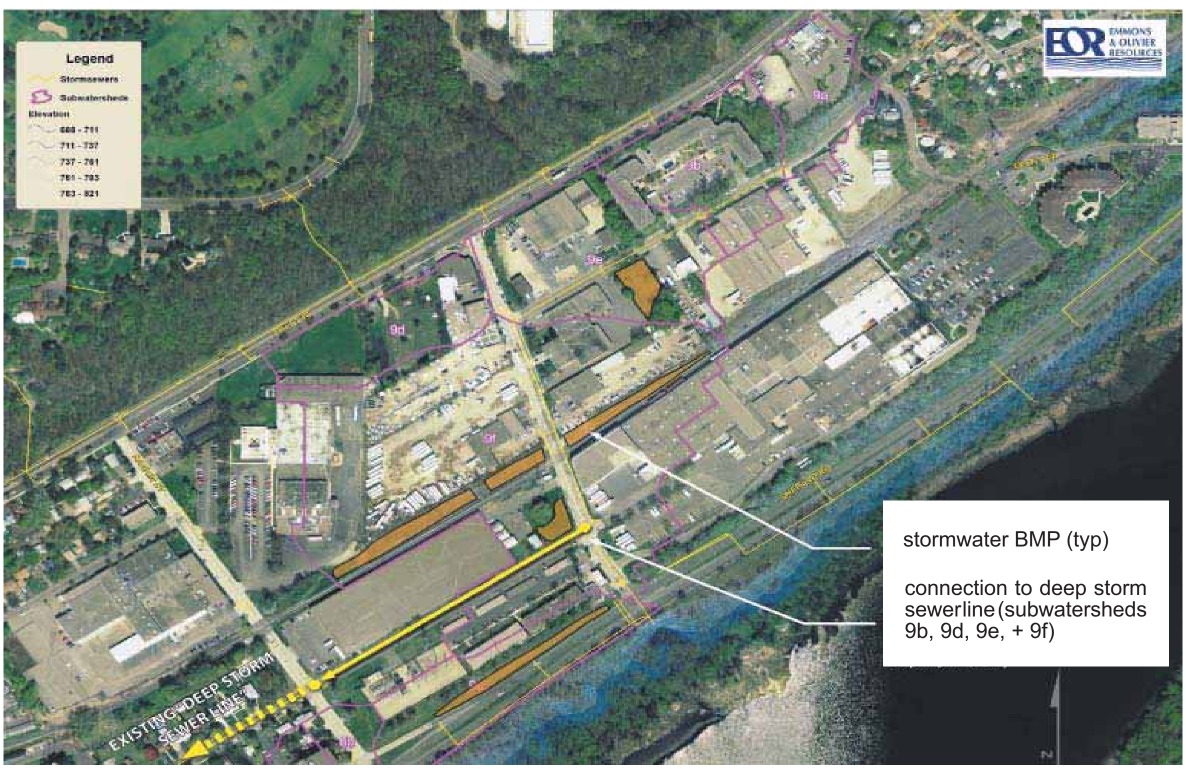
Table 9: North-East Area Cost Estimate

	Item	Unit	No.	Cost	Extension
1	Ditch/Swale Improvements (Re-vegetation)	AC	1.315	$15,000.00	$19,725
2	Existing Outlet Standpipe Modifications	EA	1	$250.00	$250
3	Bio-Infiltration Areas	SY	682.9	$45.00	$30,732
					$50,707

North-East Area Description

Utlize street islands, ditches, available green spaces and retrofitted parking areas for storage/bio-in-filtration areas.

Figure 8: North-East Area Plan



Surface water runoff discharge points:

Referring to Table 3 & Map 1, Subwatersheds (16, 2, 16, 36, 15, 14, 13, 12, 11, 10) have minor influences on the active erosion occurring on the face of the bluff. These areas will be treated as part of the General bluff restoration and re-vegetation efforts (see below).

Table 10: Subwatershed 7b Cost Estimate

	Item	Unit	No.	Cost	Extension
1	Ditch/Swale Improvements (Re-vegetation)	AC	1.315	$15,000.00	$19,725
2	Existing Outlet Standpipe Modifications	EA	1	$250.00	$250
3	Bio-Infiltration Areas	SY	682.9	$45.00	$30,732
					$50,707

Subwatershed 7b Description

Utlilize existing green spaces for storage/bio-infiltration areas. Link to west cul-de-sac on Youngman ditch.

Figure 9: Subwatershed 7b Plan

Surface Water Runoff Discharge Points

General Surface Drainage Problems

Referring to Table 3 & Map 1, Subwatersheds 3b, 10, 11, 12, 13, 15 & 16 have erosion associated with concentration of overland flow. Most of these cases would need to be individually approached with a unique erosion control plan. Through the proper placement and maintenance of bio-rolls, heavy erosion control blanket and plantings of grasses and possibly shrubs these problems could be resolved. In conjunction with treating these “upper” areas, restoration of the bluff zones would ideally coincide to take a holistic approach (see General bluff restoration and re-vegetation section below).

Subwatershed 7b

Referring to Figure 7 and Map 1, Subwatershed 7b has a unique opportunity to utilize the existing topography and infrastructure to retrofit a water quality treatment or rain garden feature. Through the modification of the existing surface drain and minor soils amendments and seeding/plantings to the proposed rain garden area the existing mowed sod will provide more pleasing sights and

Pedestrian and recreational activities along the bluff:

The Crosby Farm Park bluff areas are becoming used more and more by cyclists, runners and general nature enthusiasts. Traffic on the aging trail system is taking its toll. Many of the timber shoring and cribbing walls, as well as multiple bridges, are decayed and disintegrating in many locations. The reconstruction of these structures will improve the erosion associated with the trial itself, however, there is innumerable evidence of cliff climbing, and slope scrambling off of the trails that continually degrades the vegetation that meagerly tries to establish itself. A comprehensive approach outlined in the section below may begin to deter off trail activities. In addition, signing along the paths to inform and encourage park users to take and active roll in the restoration during the revegetation process may peak peoples interest in helping preserve the new growth and have long term affects for those who experienced the process (signing example: Please Stay on Trails - Native Plant Restoration in Progress).

General Bluff Restoration and Re-vegetation:

Referring to the Ramsey Conservation Districts erosion points survey, points 1, 2, 3, 5, 6, 7, 9, 12, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 27, 28, 29, 30, 31, 33, 34, & 35 are primarily associated with pedestrian traffic on the trails and bluff areas. The combined efforts of trial improvements and overall bluff restoration will address these erosion problems.

For the bluff itself and any associated upland areas, a recommended approach might be as follows:

1. Cut buckthorn, Siberian pea shrub, black locust and Siberian elm trees and shrubs. Within 24 hours of cutting, apply basal application of garlon- herbicide to cut stumps. Pile and burn all cuttings – any cuttings not burned, place in compact pile outside bluff restoration zone. Native trees and shrubs should be retained, except where the canopy exceeds approximately 40% canopy coverage. Larger trees, rather than being cut and removed, should be girdled and treated with a basal application of Garlon-4.
2. Hand rake and harrow slopes to remove woody debris and trash and to loosen soil surface. All trash should be bagged and properly disposed of. Woody debris may be burned along with invasive shrub removals.
3. Spot spray broadleaf and woody invasive species, not cut under task 3.1 with Garlon, taking care not to kill woodland woody and herbaceous species.
4. Place 1400 LF of 8-inch diameter compost sock as directed by Project Manager. A portion of cover crop seed shall be incorporated into compost in sock. Compost socks shall be placed to take advantage of stumps, rocks and topographic features that will help to provide a firm anchor. Compost socks shall be staked 2-feet on center.
5. Place of compost within gullies and highly erodible areas as directed by the Project Manager

6. Hydroseed grass/cover crop mix as a dormant seeding if work completed in fall season or as soon as conditions permit in the spring season. Seed should be installed evenly over all areas where active rill erosion is occurring, where establishment of native grasses and forbs has failed, or where stocking densities of seedlings are low. Since soil is generally loose on the slope, no further site preparation is required. Seed should be applied with a fan-type nozzle in mixture of 75 pounds of hydromulch per 500 gallons of water for each acre of slope seeded.

7. Hydroseeding – Following seeding, all slopes shall be hydromulched with a bonded fiber matrix (BFM) product such as Soil Guard. The BFM shall be installed by a contractor certified by the manufacturer to be trained in the proper procedures for mixing and application of the product. The BFM shall be mixed according to manufacturer's recommendations and contractor shall demonstrate 'free liquid" test to inspector upon request. Bonded Fiber Matrix shall be spray-applied at a rate of 3,000-4,000 LB/acre, utilizing standard hydraulically seeding equipment in successive layers as to achieve 100% coverage of all exposed soil. The BFM shall not be applied immediately before, during or after rainfall, such that the matrix will have opportunity to dry for up to 24 hours after installation.

8. (Optional) Place heavy duty chain link fence (as approved by St. Paul Parks and Recreation Department) along edge of steep slope as marked by Project Manager to restrict foot travel over steep slopes. Place semi-permanent/permanent informational signs explaining need for restricted use of area on fence posts at approximate intervals of 50 feet and/or where past trails are located.

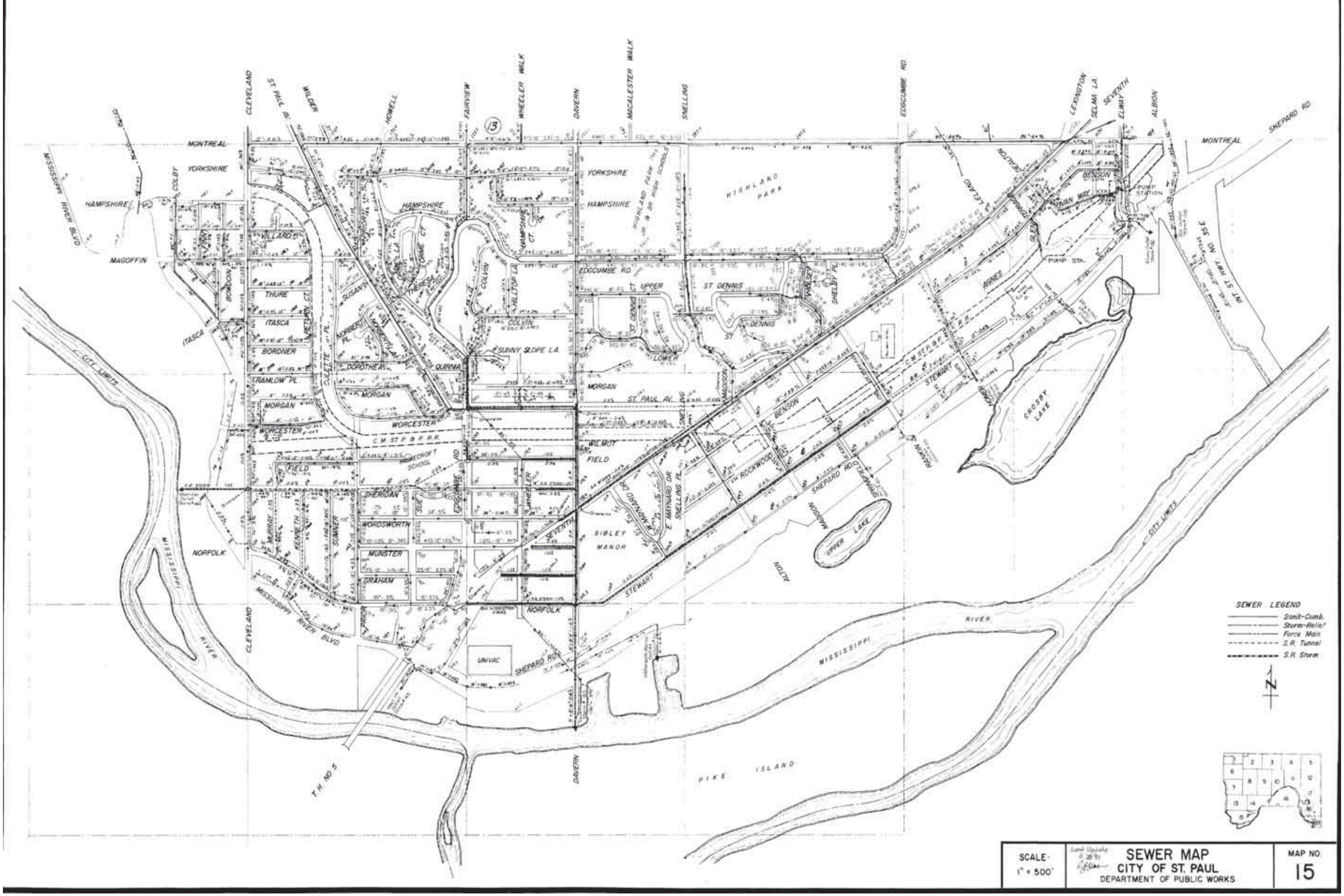
List of Appendices

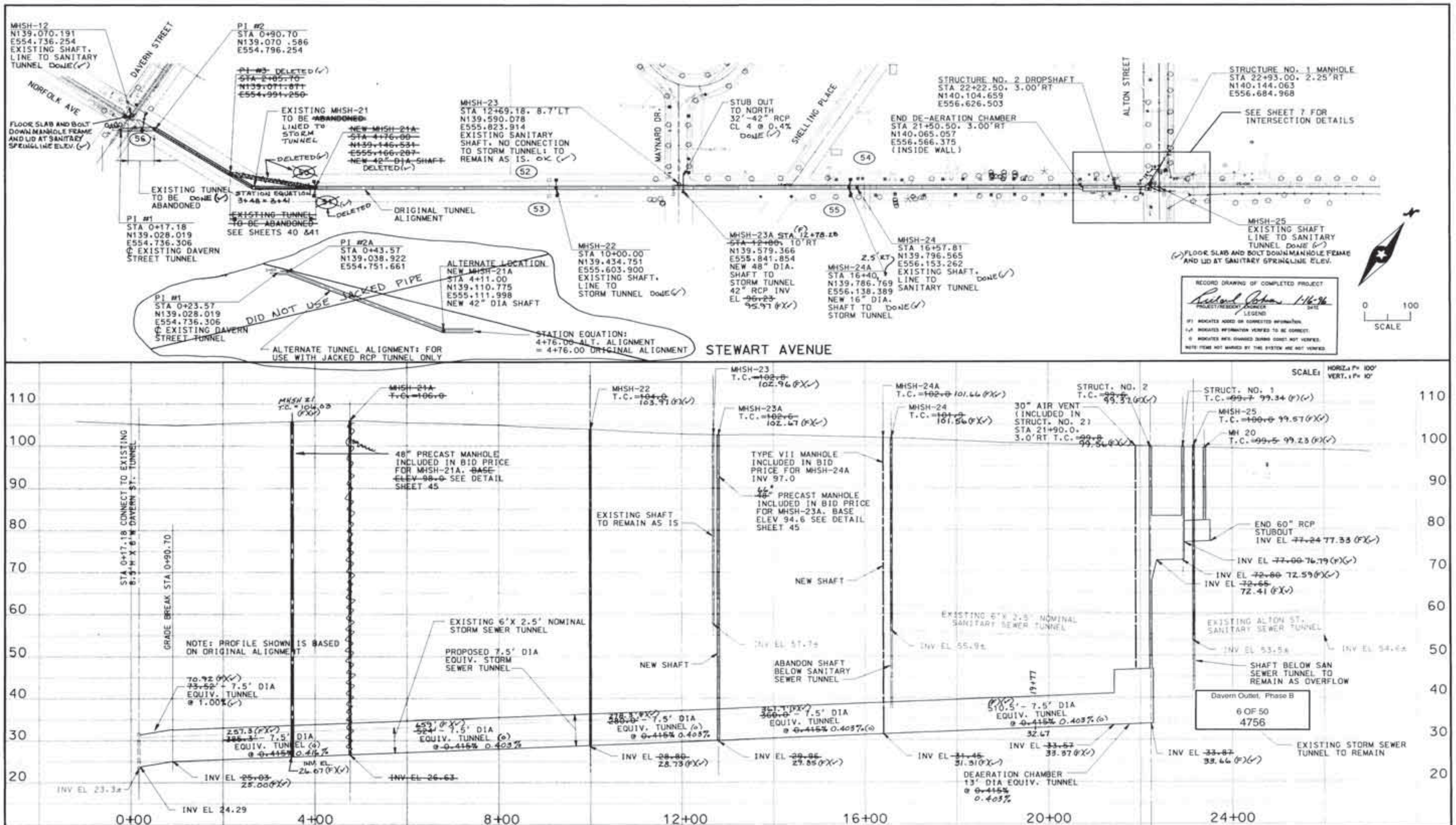
I. **City Storm Sewer Plates**

II. **Excerpt - Crosby Farm Regional Park Ecological Inventory and Restoration Management Plan**

III. **Excerpt Crosby Trail Study - by Great River Greening**

IV. **Figure 1 - Subwatershed Map**


SEWER MAP
CITY OF ST. PAUL
DEPARTMENT OF PUBLIC WORKS
SCALE: 1" = 500'
MAP NO. 15
SEWER LEGEND
Sanit-Comb.
Storm-Relief
Force Main
S.R. Tunnel
S.R. Storm
MONTREAL
YORKSHIRE
HAMPSHIRE
MAGOFFIN
ITASCA
THURE
BORDNER
DOROTHEA
RAMLOW PL.
MORGAN
WORCESTER
C M ST P & R R
FIELD
SHERIDAN
WORDSWORTH
MUNSTER
GRAHAM
NORFOLK
CLEVELAND
ST PAUL AV
WILDER
HOWELL
FAIRVIEW
WHEELER WALK
DAVERN
MACALESTER WALK
SNELLING
EDGCUMBE RD
LEXINGTON
SELMA LA
SEVENTH
ELWAY
ALBION
SHEPARD RD
COLBY
HIGHLAND PARK
EDGCUMBE RD.
ST DENNIS
COLVIN
SUNNY SLOPE LA
HILLTOP LA
SHELBY PL
BENSON
AGNES
VAN WAY
PUMP STATION
PUMP STA.
STEWART
ROCKWOOD
SIBLEY MANOR
UPPER LAKE
CROSBY LAKE
MISSISSIPPI RIVER BLVD
MISSISSIPPI RIVER
CITY LIMITS
PIKE ISLAND
T.H. NO. 5
UNIVAC
HIGHCROFT SCHOOL
WILMOT
MADISON
ALTON
INT ST HWY NO. 35 E
13



DAVERN OUTLET PHASE B 94-S-8085B SEWER DR. NO. 11 DRWG. NO 5355	NO.	DATE	BY	REVISION	VERIFY SCALES: BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY	DSGN PWB / DR DAD / CHK PWB / APVD PWB

I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

Paul W. Blum

DATE 08-11-94 REG. NO. 12779

HNTB

HOWARD NEEDLES TAMMEN & BERGENDOFF

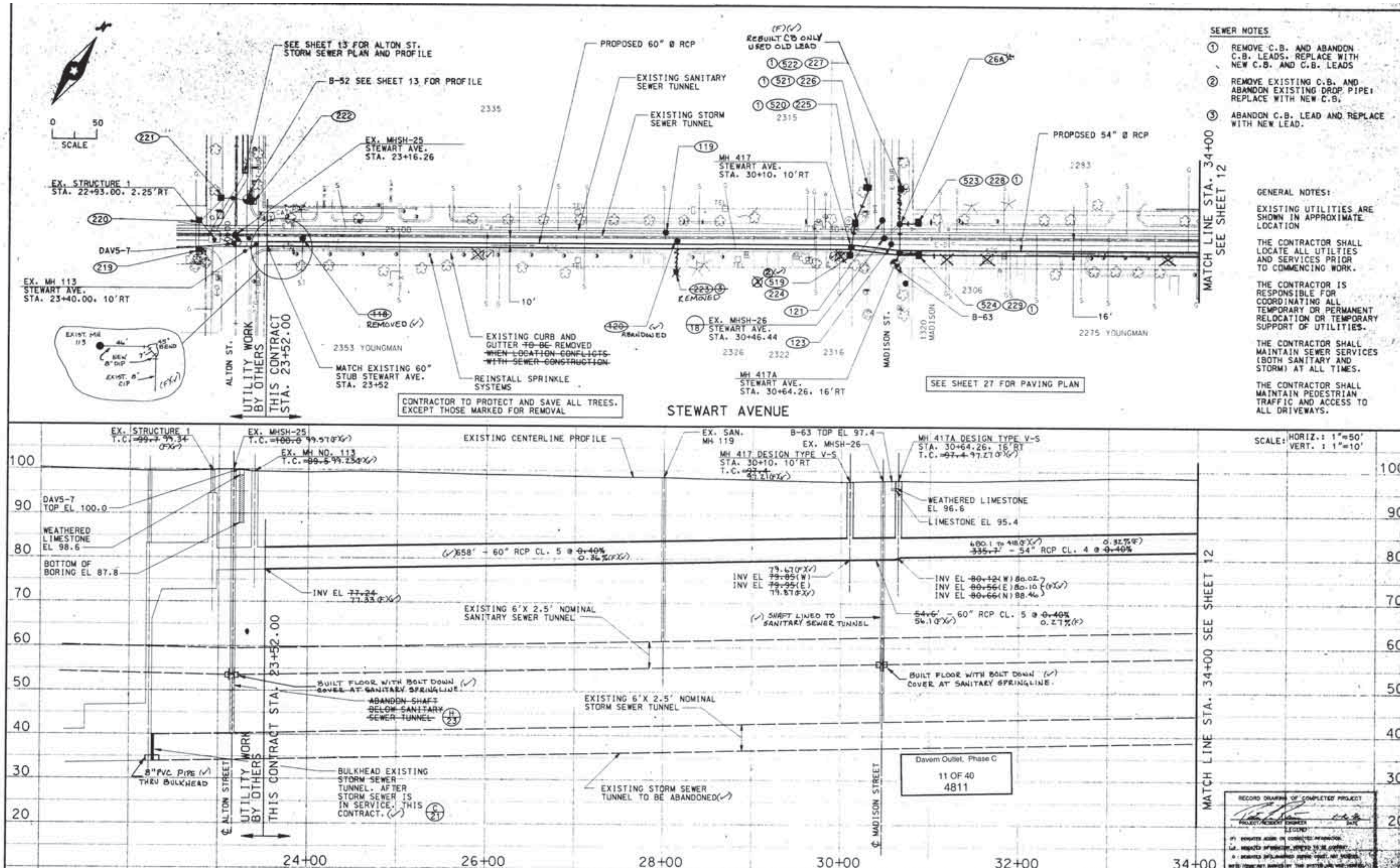
CITY OF SAINT PAUL, MINNESOTA - DEPARTMENT OF PUBLIC WORKS

DAVERN OUTLET PHASE B

TUNNEL PLAN & PROFILE

STEWART AVE. STA. 0+00 TO 24+00

SHEET 6 OF 48
DATE 8-8-94
PROJ ID 15358
FILE DT2TU001



DAVERN OUTLET PHASE C	1	2-14-95	TPM	ADDENDUM NO. 1
95-S-8085C 95-P-8070				
SEWER DR. NO. 11 DRWG. NO 5357	NO.	DATE	BY	REVISION

VERIFY SCALES: BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

DSGN TPM · DR DAD · CHK TPM · APVD WBC

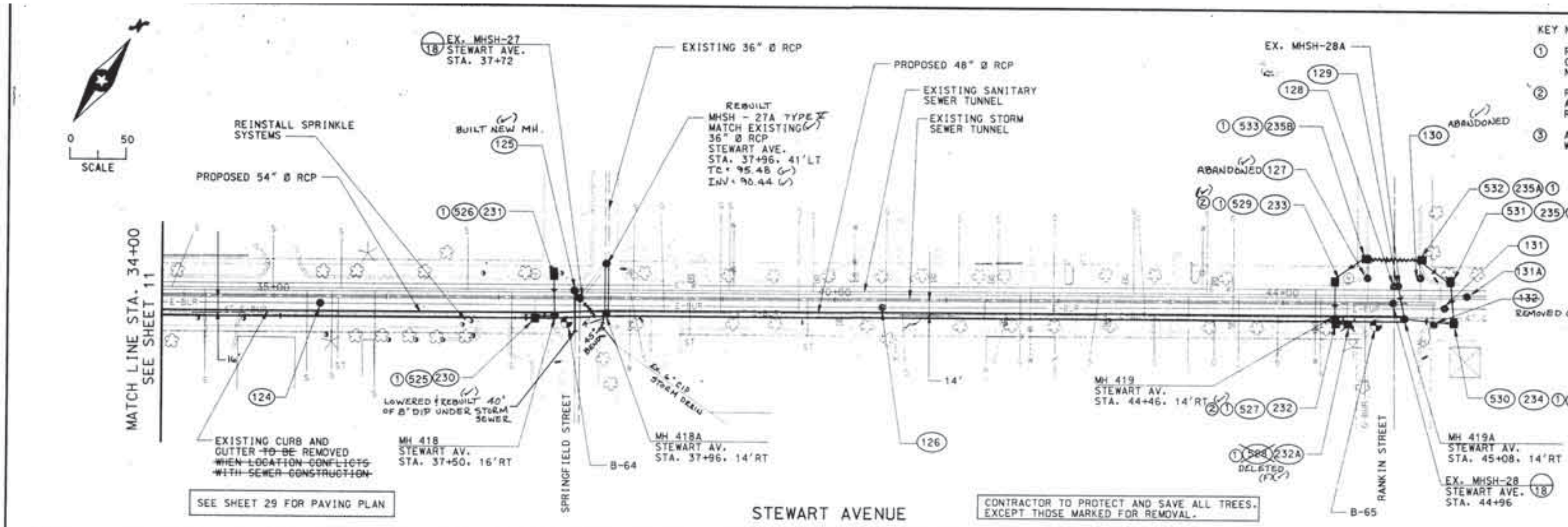
I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

DATE 2-14-95 REG. NO. 19469

HNTB
HOWARD NEEDLES TAMMEN & BERGENDOFF

CITY OF SAINT PAUL, MINNESOTA - DEPARTMENT OF PUBLIC WORKS
DAVERN OUTLET PHASE C
SEWER PLAN AND PROFILE
STEWART AVENUE STA. 23+52 TO STA. 34+00

SHEET 11 OF 40
DATE 1-18-95
PROJ ID 15358
FILE DT35S007



KEY NOTES:

1. REMOVE C.B. AND ABANDON C.B. LEADS. REPLACE WITH NEW C.B. AND C.B. LEADS
2. REMOVE EXISTING C.B. AND ABANDON EXISTING DROP PIPE: REPLACE WITH NEW C.B.
3. ABANDON C.B. LEAD AND REPLACE WITH NEW LEAD.

GENERAL NOTES:

EXISTING UTILITIES ARE SHOWN IN APPROXIMATE LOCATION

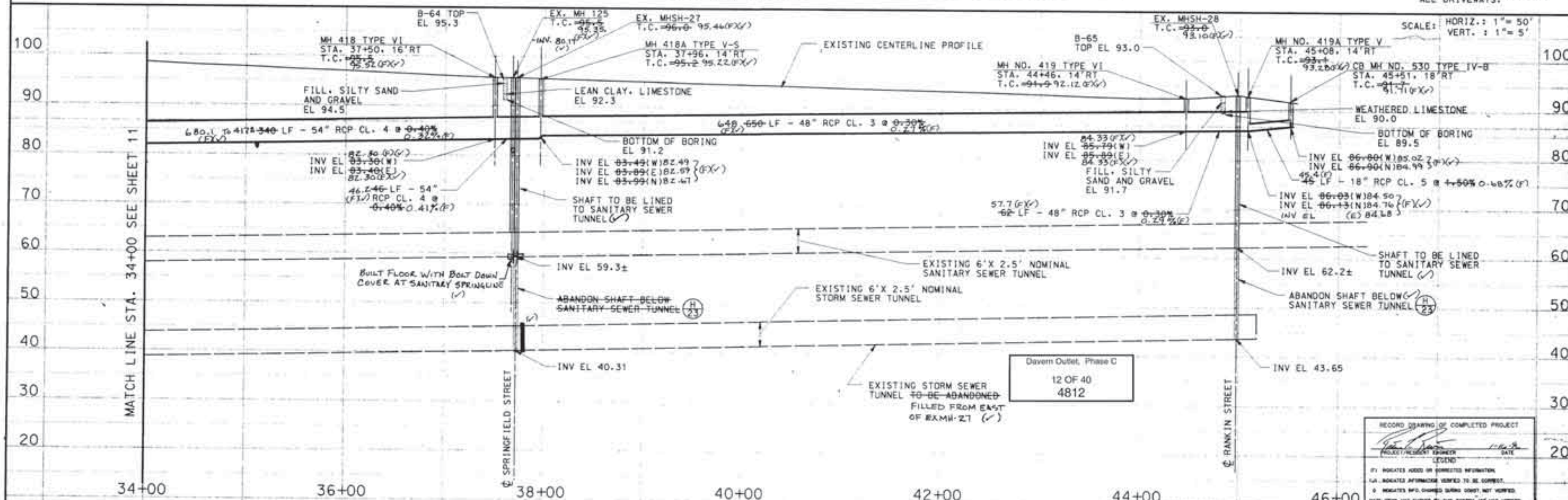
THE CONTRACTOR SHALL LOCATE ALL UTILTIES AND SERVICES PRIOR TO COMMENCING WORK.

THE CONTRACTOR IS RESPONSIBLE FOR COORDINATING ALL TEMPORARY OR PERMANENT RELOCATION OR TEMPORARY SUPPORT OF UTILITIES.

THE CONTRACTOR SHALL MAINTAIN SEWER SERVICES (BOTH SANITARY AND STORM) AT ALL TIMES.

THE CONTRACTOR SHALL MAINTAIN PEDESTRIAN TRAFFIC AND ACCESS TO ALL DRIVEWAYS.

SCALE: HORIZ.: 1" = 50' VERT. : 1" = 5'



Davern Outlet, Phase C
12 OF 40
4812

RECORD DRAWING OF COMPLETED PROJECT

DAVERN OUTLET PHASE C 95-S-8085C 95-P-8070 SEWER DR. NO. 11 DRWG. NO 5357	NO.	DATE	BY	REVISION
	1	2-14-95	TPM	ADDENDUM NO. 1

VERIFY SCALES: BAR IS ONE INCH ON ORIGINAL DRAWING. IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY

DSGN TPM / DR DAD / CHK TPM / APVD WBC

I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA.

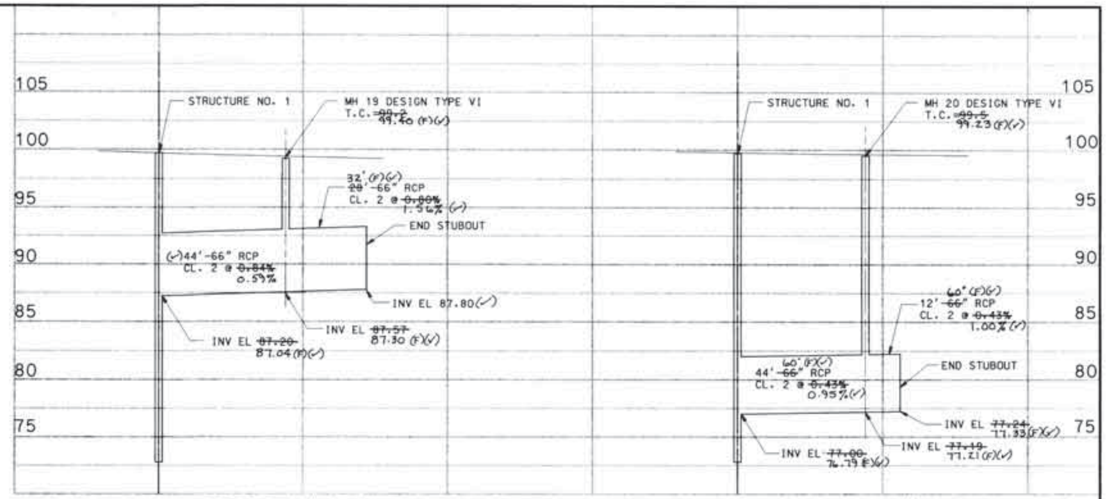
DATE 2-14-95 REG. NO. 19469

HNTB
HOWARD NEEDLES TAMMEN & BERGENDOFF

CITY OF SAINT PAUL, MINNESOTA - DEPARTMENT OF PUBLIC WORKS

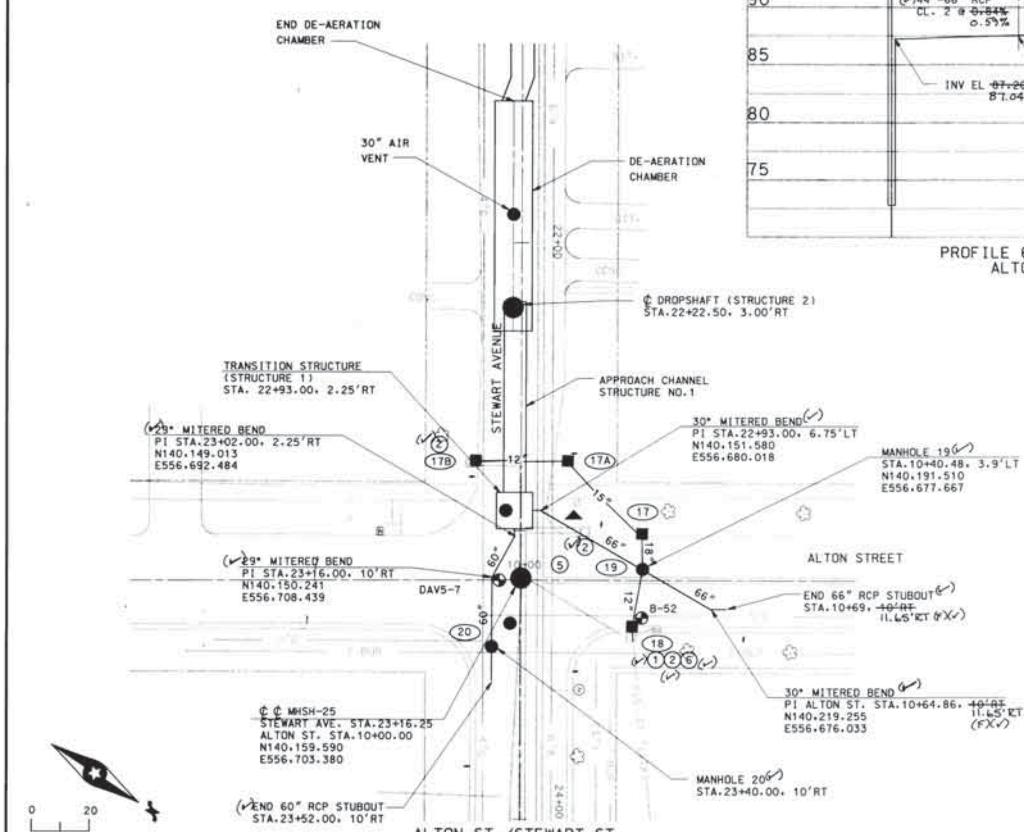
DAVERN OUTLET PHASE C
SEWER PLAN AND PROFILE
STEWART AVENUE STA. 34+00 TO STA. 45+08

SHEET 12 OF 40
DATE 1-16-95
PROJ ID 15358
FILE DT35S008



PROFILE 66" STUBOUT ON ALTON STREET

PROFILE 60" STUBOUT ON STEWART AVENUE



ALTON ST./STEWART ST.

INTERSECTION SEWER PLAN

Davern Outlet, Phase B
7 OF 50
4757

SEWER NOTES:

1. REMOVE EXISTING MH/CB AND ABANDON EXISTING CB LEAD.
2. REMOVE EXISTING CB AND ABANDON EXISTING CB DROP PIPE.
3. REMOVE EXISTING MH ABANDON EXISTING DROP PIPE AND REPLACE WITH MH/CB.
4. REMOVE EXISTING CB AND CB LEAD.
5. EXISTING MANSHAFT TO BE LINED.
6. EXTEND AND RECONNECT EXISTING 10" STORM TO CB 18

▲ CONTRACTOR TO PREFORM TEST EXCAVATION TO DETERMINE DEPTH OF WATER MAIN

NOTES:

EXISTING UTILITIES SHOWN ARE APPROXIMATE.

THE CONTRACTOR SHALL LOCATE ALL UTILITIES AND SERVICES PRIOR TO COMMENCING WORK.

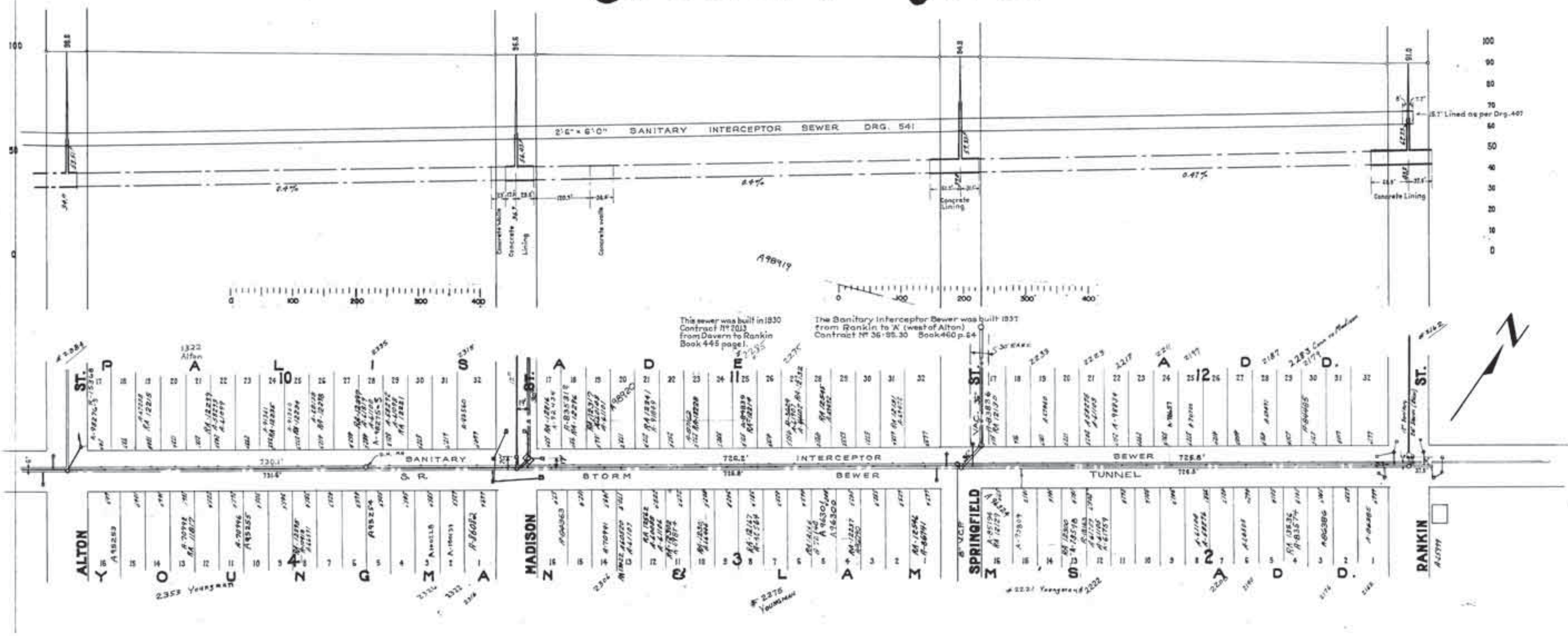
THE CONTRACTOR IS RESPONSIBLE FOR COORDINATING ALL TEMPORARY OR PERMANENT RELOCATION OR TEMPORARY SUPPORT OF UTILITIES.

THE CONTRACTOR SHALL MAINTAIN SEWER SERVICE (BOTH SANITARY AND STORM) AT ALL TIMES.

RECORD DRAWING OF COMPLETED PROJECT
Richard Osborn 1-16-96
PROJECT/RESIDENT ENGINEER DATE
LEGEND
(F) INDICATES ADDED OR CORRECTED INFORMATION.
(✓) INDICATES INFORMATION VERIFIED TO BE CORRECT.
? INDICATES INFO. CHANGED DURING CONST. NOT VERIFIED.
NOTE: ITEMS NOT MARKED BY THIS SYSTEM ARE NOT VERIFIED.

DAVERN OUTLET PHASE B 94-S-8085B SEWER DR. NO. 11 DRWG. NO 5355	NO. / DATE / BY / REVISION	VERIFY SCALES BAR IS ONE INCH ON ORIGINAL DRAWING IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY	DSGN PWB DR DAD CHK PWB APVD PWB	I HEREBY CERTIFY THAT THIS PLAN WAS PREPARED BY ME OR UNDER MY DIRECT SUPERVISION AND THAT I AM A DULY REGISTERED PROFESSIONAL ENGINEER UNDER THE LAWS OF THE STATE OF MINNESOTA. Paul W. Blum DATE 08-11-94 REG.NO. 12779	HNTB HOWARD NEEDLES TAMMEN & BERGENDOFF	CITY OF SAINT PAUL, MINNESOTA - DEPARTMENT OF PUBLIC WORKS DAVERN OUTLET PHASE B ALTON/STEWART INTERSECTION DETAILS	SHEET 7 OF 48 DATE 8-8-94 PROJ ID 15358 FILE DT21P005

Stewart Ave.


2'6" × 6'0" SANITARY INTERCEPTOR SEWER DRG. 541
0.4%
0.47%
Concrete Lining
This sewer was built in 1930
Contract Nº 2013
from Davern to Rankin
Book 445 page 1.
The Sanitary Interceptor Sewer was built 1937
from Rankin to 'A' (west of Alton)
Contract Nº 36-95.30 Book 460 p. 64
ALTON ST.
MADISON ST.
SPRINGFIELD ST.
RANKIN ST.
PAULIS ADD.
YOUNGMAN & LAMM'S ADD.
SANITARY INTERCEPTOR SEWER
S. R. STORM SEWER TUNNEL
730.1'
726.2'
725.8'
N

Crosby Farm Regional Park Ecological Inventory and Restoration Management Plan

GREAT RIVER GREENING

Prepared for the City of St. Paul
Division of Parks and Recreation
by Great River Greening
January 2005

With assistance from the Ramsey
Conservation District

Crosby Farm Regional Park
Ecological Inventory and Restoration Management Plan

Compiled by
Fred Harris
Great River Greening

With assistance from
Tom Petersen, Dave Bauer, Matt Swanson
Ramsey Conservation District

January 2005

Great River Greening (GRG) is a nonprofit organization that restores valuable and endangered natural areas in the greater Twin Cities by engaging individuals and communities in stewardship of the Mississippi, Minnesota and St. Croix river valleys and their watersheds. Greening involves local citizens in hands-on volunteer and training programs on a larger scale than any other Twin Cities organization− 14,000 since inception in 1995. (See Appendix D for more information).

Ramsey Conservation District (RCD) is a special purpose local government agency responsible for promoting the conservation of Ramsey County's natural resources. The district, through its publicly elected board of supervisors and staff, assists private citizens, businesses, and other governmental agencies implement natural resource conservation practices.

Fred Harris, Ph.D. is the Lead Ecologist for Great River Greening. He conducts ecological inventories and writes restoration plans. Previously, he worked for many years with the Minnesota Department of Natural Resources as a plant ecologist with the Minnesota County Biological Survey and as an ecologist for the Minnesota Chapter of The Nature Conservancy.

Tom Petersen, Ramsey Conservation District Manager, is responsible for the administration and management of all district programs. He has 25 years of experience in urban land use conservation programs and has specialized in soil erosion control and landscape restoration technologies and wetland ecology.

Dave Bauer, District Conservation Technology Specialist and Mn Licensed Professional Soil Scientist, is responsible for District GIS technologies and services, applied soil science programs, and soil erosion and sediment control programs. He has nine years of experience in this area.

Matt Swanson, District Groundwater Specialist and Mn Licensed Professional Geologist, is responsible for developing and implementing the District's groundwater quality protection programs and geologic and hydro-geologic science programs. He has 15 years of experience, including consulting and government work.

Executive Summary

Crosby Farm Regional Park is the largest natural park within the City of St. Paul. It is also a significant natural area within the State of Minnesota Mississippi River Critical Area Corridor and the Mississippi National River and Recreation Area (MNRRA). The park consists of a large area of floodplain and valley side slopes, the "bluffs," along the Mississippi River near its confluence with the Minnesota River. The park's forests, wetlands and lakes are important refuges for a broad diversity of native wildlife species. As a natural oasis of oak woods, marshes, lakes, floodplain forests and Mississippi River shoreline in a major metropolitan area, the park attracts tens of thousands of local residents throughout the year.

A detailed vegetation inventory, analysis of management problems, and assessment of bluff trails was conducted in 2004. The bluff trails analysis completed in June focuses on recommendations for ameliorating erosion problems and improving trail design. It was published separately in a companion report entitled *Crosby Park Bluff Trail Project: Design Strategies for an Ecologically Sustainable Bluff Trail* (Shaw et al. 2004) also compiled by Great River Greening.

This report on Crosby Farm Regional Park focuses on the following main objectives: A.) preliminary documentation and assessment of bluff erosion problems; B.) detailed inventory and mapping of terrestrial and wetland native plant communities in the park; C.) identification and analysis of problem areas needing management and restoration work; and D.) identification of strategies for managing and reconstructing native plant communities in the park.

Appendices to this inventory and management plan provide technical information to supplement the recommendations, including a checklist of plants seen in the park in 2004, detailed plant species lists of target native plant communities, and information about controlling exotic species.

Preliminary examinations of the bluffs along the north side of Crosby Park reveal numerous examples of erosion from excess storm water runoff and off-trail traffic, ranging from low levels of sandstone weathering to deep canyons incised into the bluff. This erosion is compromising the integrity of the native vegetation of the bluffs, washing out portions of the park's trail system, and depositing silt and sand into the park's lakes.

Crosby Park has a broad range of terrestrial and wetland native plant communities containing over 300 plant species. Vegetation survey highlights include areas of intact sedge meadow, black ash seepage swamps, areas of diverse spring ephemeral wildflowers, a colony of Kentucky coffee trees, and large tracts of intact floodplain forest.

This project was not intended to inventory the wildlife species, aquatic environments or recreation/environmental education values of the park – subjects that should be addressed in future inventory and management plans.

Acknowledgements

This project was made possible with major funding from the Capitol Region Watershed District, the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources, and the U.S. National Park Service via the Mississippi National River and Recreation Area. Additional financial or in-kind contributions to the project were provided by the Ramsey Conservation District, the City of St. Paul Division of Parks and Recreation, the Carolyn Foundation, and Great River Greening.

This project would not have existed without the leadership of Patricia Freeman, Environmental Resource Specialist for St. Paul Parks and Recreation, who initiated the project, brought a diverse group of resource professionals together for input, and organized funding to make it a reality. Dan Tix assisted air photo interpretations, vegetation surveys, and plant identification. Alan Olson and Richard Peterson, Minnesota DNR Foresters, provided extensive advice on strategies for forest restoration. Michael Varien, Melissa Peterson, Katie Anderson, and Adam DeKeyrel mapped the park's buckthorn concentrations. Dan Shaw, Wiley Buck, Cade Hammerschmidt, Patricia Freeman, Mark Doneaux, Cy Kosel, Nancy Duncan, John Grzybek, and Kelly Osborn reviewed and commented on drafts of the report.

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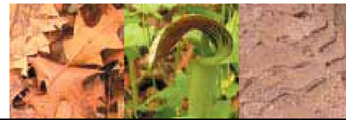
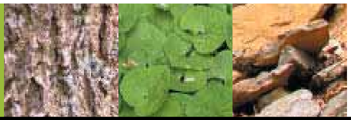


Crosby Park: Bluff Trail Project

Produced for the City of St. Paul, Minnesota
by
Great River Greening

Authors:
Dan Shaw
Carlos Fernandez
Courtney Skybak
Ryan Holdorf

June 2004



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Right and below: Aerial photos of Crosby Park. (Copyright 2003 Regents of the University of Minnesota. All rights reserved. Used with the permission of the Design Center for the American Urban Landscape.)

Introduction

Purpose

This plan provides recommendations for improving the Bluff Trail at Crosby Park in St. Paul, Minnesota. The plan includes a study of current trail conditions and provides a detailed trail plan and constructions details. The plan will help the City of St. Paul manage the site in a way that meets the various needs of local residents and visitors while also being cost-effective and ecologically sustainable. The plan will also act as a model for similar projects in the Twin Cities area. This trail plan is a companion document to a natural resources inventory and ecological restoration plan that is also being developed by Great River Greening and will be completed in the fall of 2004.

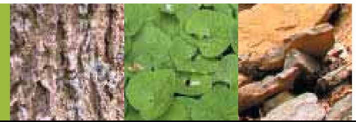
Funding for this project came from the Legislative Commission on Minnesota Resources and project partners included the City of Saint Paul, Great River Greening, and the Ramsey Soil and Water Conservation District.

Crosby Park

Crosby Park is the largest natural park in St. Paul, Minnesota. The park is located on the east side of the Mississippi River as it flows along the western edge of St. Paul. It is very popular regionally, due to its access to the Mississippi River, diversity of plant communities, rock outcroppings, abundant wildlife and extensive trail network. The park is owned by the City of St. Paul, but it is also part of the National Park Service's Mississippi National River and Recreation Area and is an important corridor for migratory birds.

The Trail Network

Trails play an important role within Crosby Park. They provide access to natural features such as the river, bluffs, and wetlands and provide many opportunities for the exploration of nature. The trails are heavily used by a combination of walkers, runners, and bicyclists. The trails in Crosby Park connect with other trails that follow a network of parks that parallel the Mississippi as it flows through the Twin Cities.



Introduction

The Bluff Trail

This plan focuses on the re-construction and restoration of the bluff trail, one of the most unique trails in the park. The bluff trail follows the contours of the bluffs that parallel the Mississippi River. A large section of the trail is situated half way up the bluff in a mesic oak forest, where it meanders in and out of moist ravines. This trail is unique in that it provides hikers with opportunities to observe a variety of natural habitats and the plants and animals that they support. In addition to ravines, hikers also experience dry ridges with mature oak trees, and as the trail drops in elevation it traverses floodplain forest, lowland hardwood forest, and black ash seepage swamps.

Although the bluff trail existed as an undeveloped trail for many years, it was formally designed by Les Blacklock in the early 1970s. The original building materials are still at the site and consist of recycled telephone poles, rail road ties and wooden fence posts. The trail was well constructed, but over the last 30 years it has received a significant amount of use and has degraded due to soil erosion and the decomposition of building materials.

Erosion has resulted from routine use but also from storm sewer outlets at the top of the bluff, the tires of mountain bikes, and runoff from slopes that are bare due to trampling by animals and people and the presence of invasive plant species. As a result of the erosion there is very little organic material on the slopes to help sustain plant growth. Organic matter plays an important role in controlling erosion on the bluffs by slowing the flow of water, absorbing moisture, and providing nutrients for ground-layer woodland plant species. The organic layer also provides a good insulating layer for plants during the winter.

The Trail Plan

The trail plan focuses on the development of sustainable and ecologically sound construction techniques that will retain the character and natural experience of the site while solving erosion issues and structural problems. The plan also investigates areas for interpretation or wildlife viewing. The plan is organized with an analysis of current conditions at the beginning, followed by the plan with proposed trail improvements. The plan references construction details for specific areas along the trail and these details are included at the end of the document. The severity of problems along the trail are defined in the plan to aid in the determination of where construction work should begin.

Trail Use

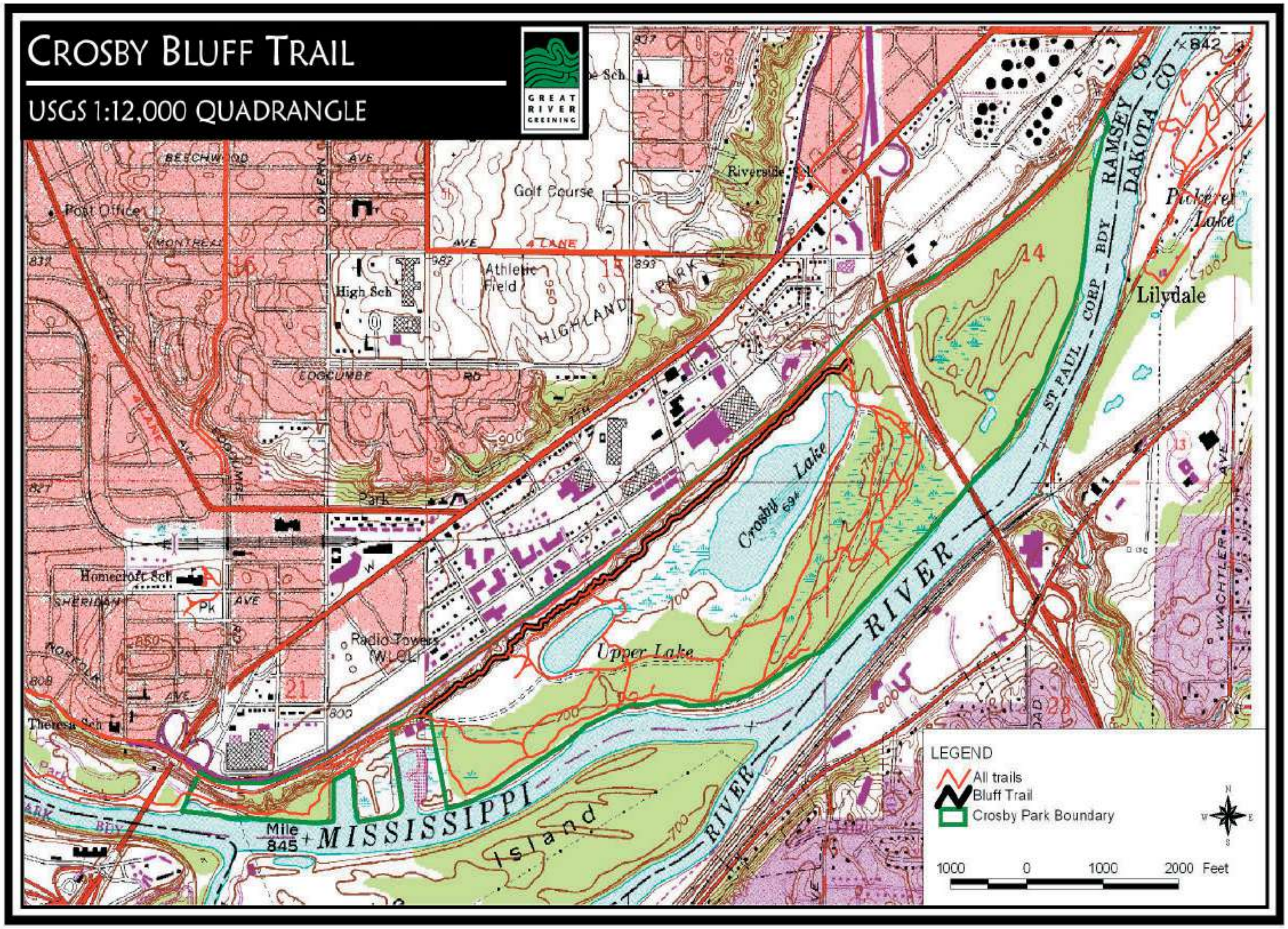
The soils on the bluff are highly erodable and as a result, trail use other than hiking should be discouraged. Mountain biking should be restricted to trails that are less prone to erosion and people and animals should be persuaded to stay on the trail. The trail plan recommends the removal of some unnecessary trails in the park to prevent further erosion problems.

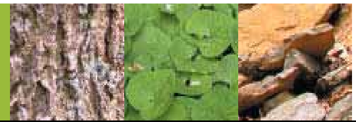
Trail Monitoring

Periodic monitoring of the Bluff Trail will help prevent small problems from becoming more serious. Neighborhood residents can play an important role in monitoring for problems as part of the City of St. Paul's Eco Stewards program. Through this program, volunteers adopt project sites and conduct activities such as monitoring and invasive species control.

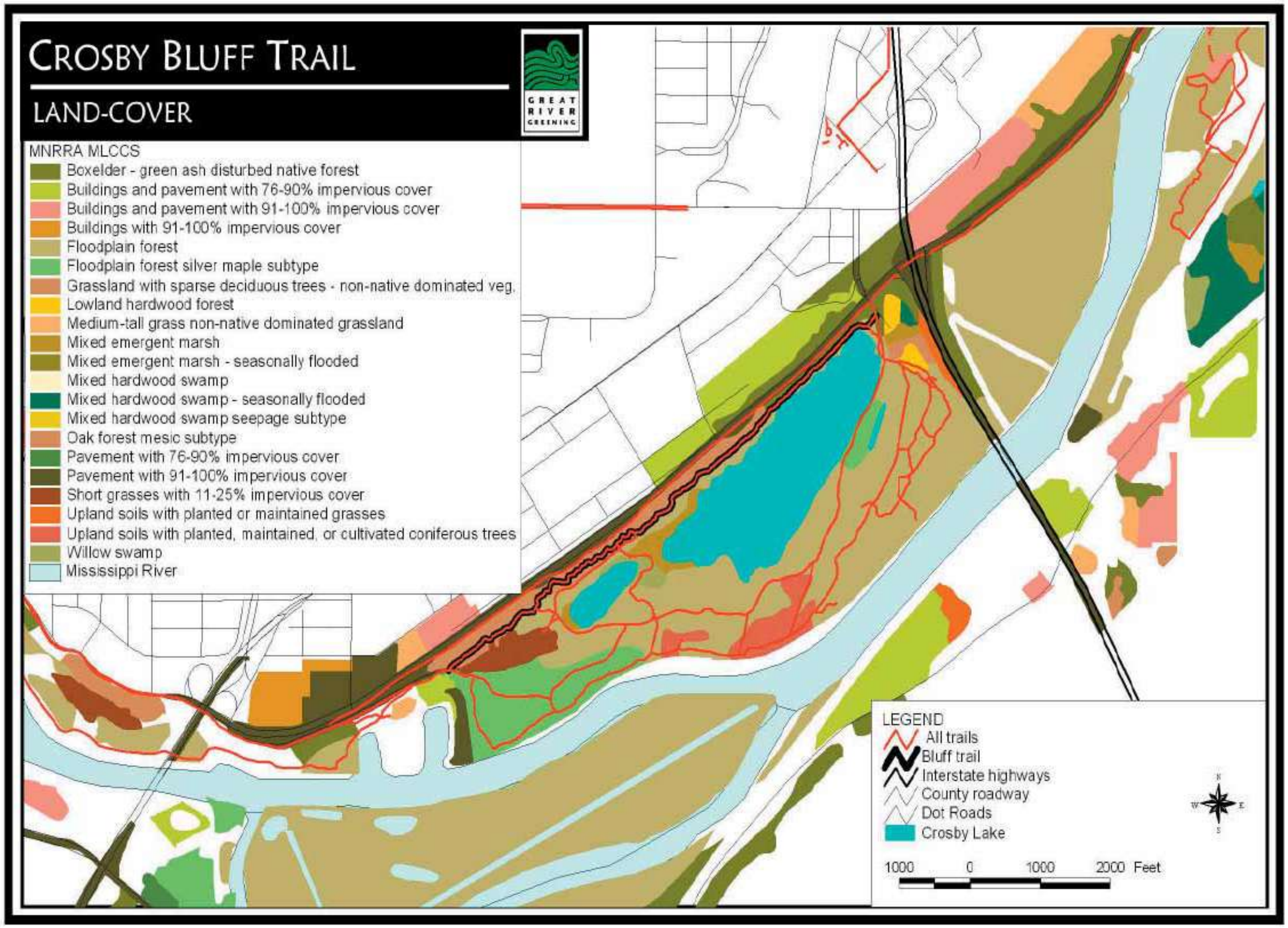
USGS Quadrangle

The USGS map shows constructed elements around Crosby Park such as local roads, county roads, highways, building footprints, political boundaries and parking lots. The park is framed by Shephard Road on the northwest, and by the Mississippi River on the other sides. The area directly north of Shephard Road features a number of light industrial and commercial structures with large parking lots, and is characterized by a large amount of impervious surface. Further north are the residential blocks of the Highland Park neighborhood, as well as the Highland Park Golf Course.





Resource Analysis of Intrinsic Qualities

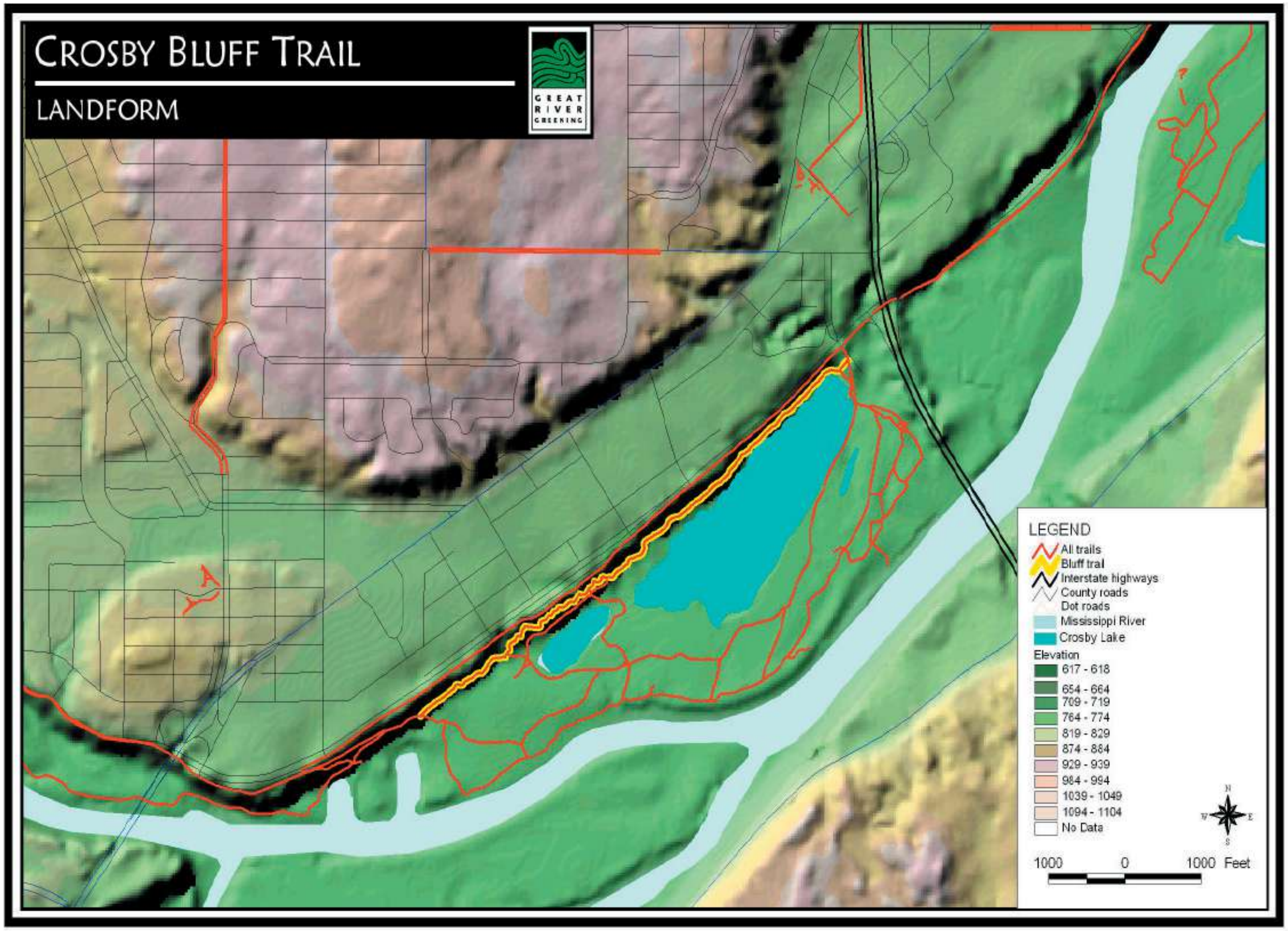


Land-Cover

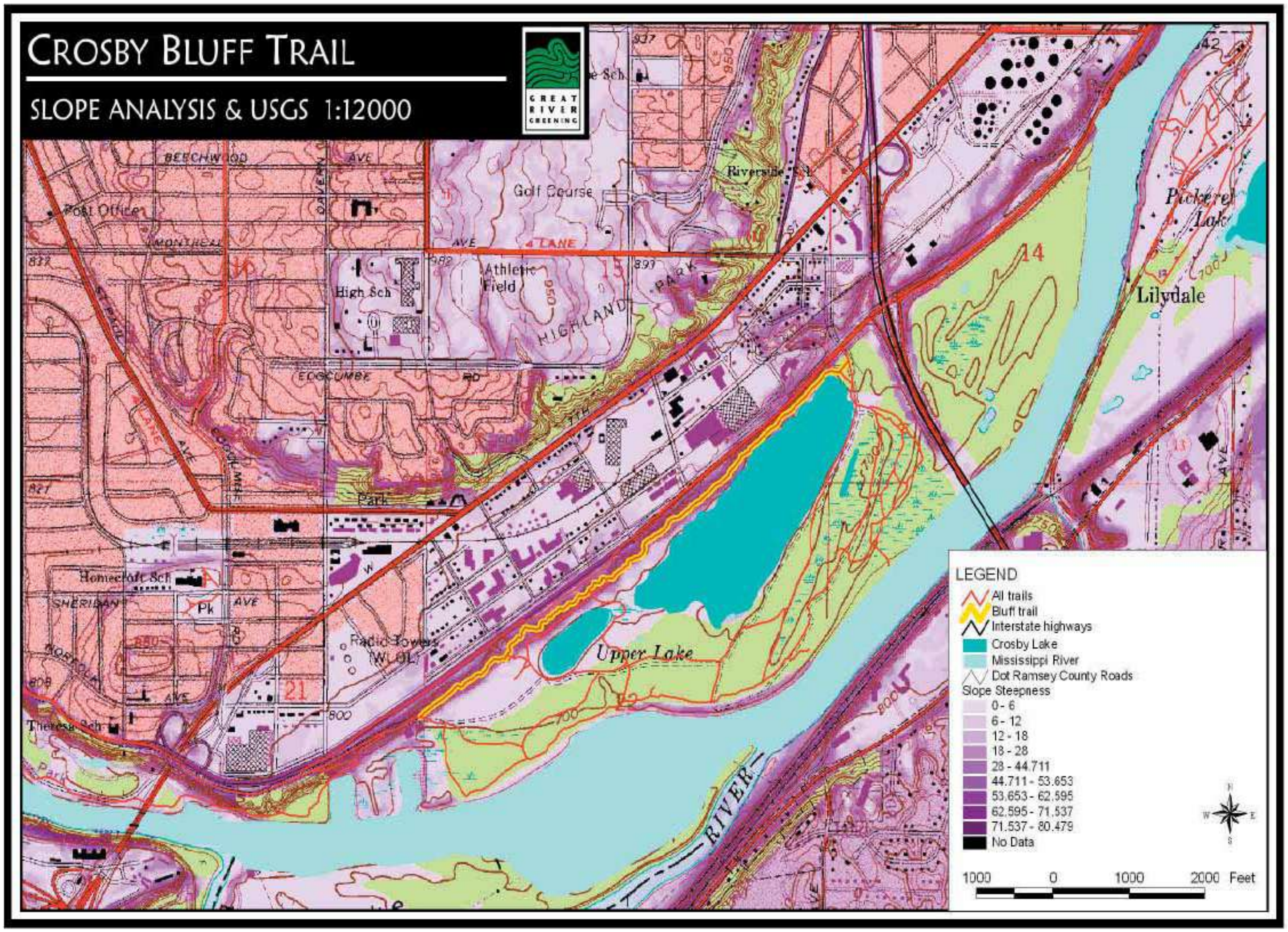
The land-cover map identifies the current biological layers contained within the Crosby Park area. The park is dominated by the Floodplain Forest land-cover type. but the bluff trail moves through mostly Oak Forest Mesic Subtype vegetation, with a portion of Boxelder-Green Ash Disturbed Native Forest at the eastern end. The land-cover map was constructed using MLCCS data from the Minnesota DNR Data Deli.

Landform

The landform map illustrates the physical form of the Crosby Park area in order to 1) identify how water moves through the site, 2) using a 3-dimensional model, locate where steep slopes exist and where shallow slopes exist, 3) identify which direction the slopes face (aspect) and their corresponding access to solar radiation, and 4) give a sense of how physical form can play a role in how one might experience or interpret the bluff trail. The bluff trail is located on or at the base of a steep southeast-facing slope.



Resource Analysis of Intrinsic Qualities

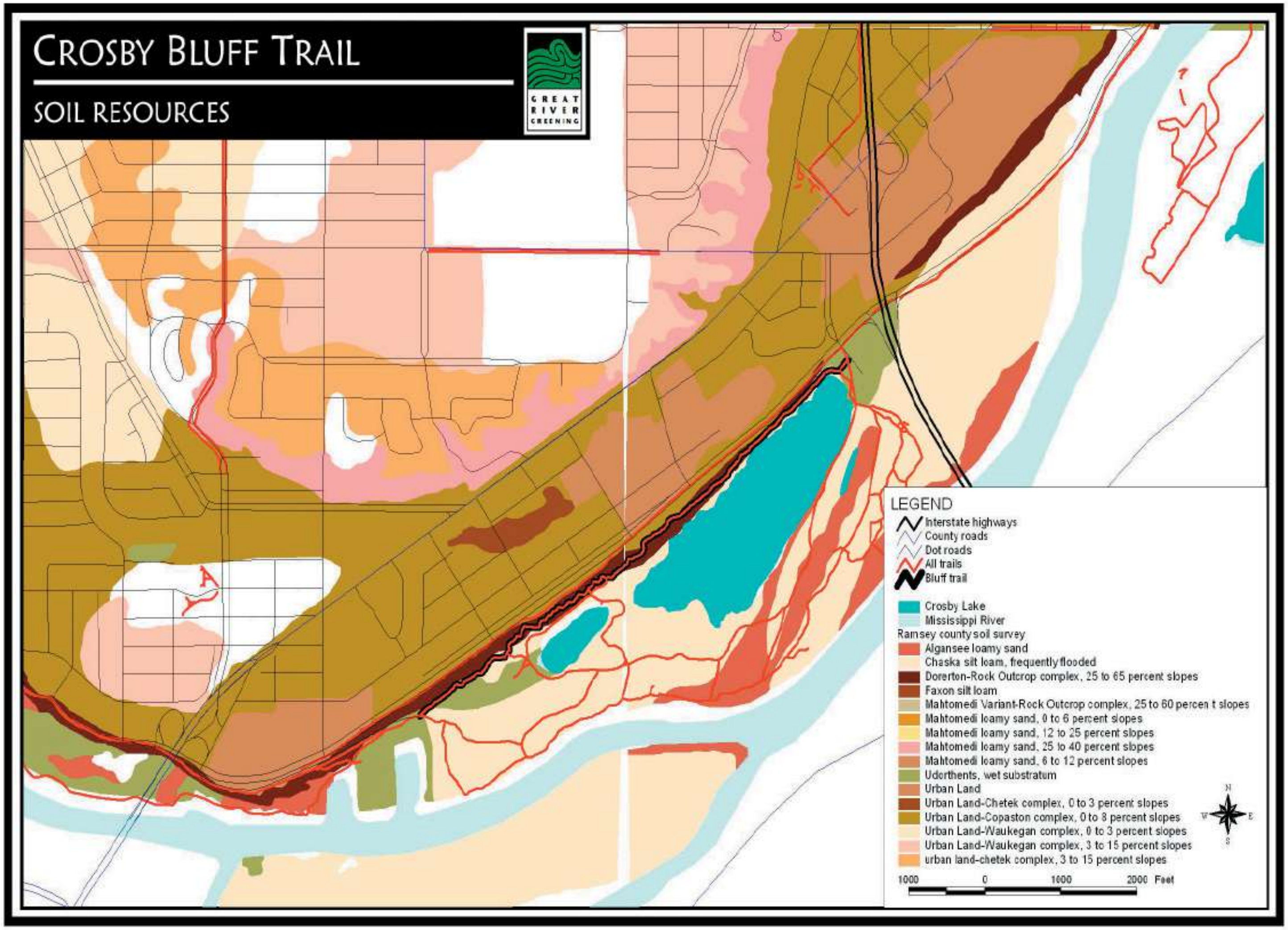


Slope

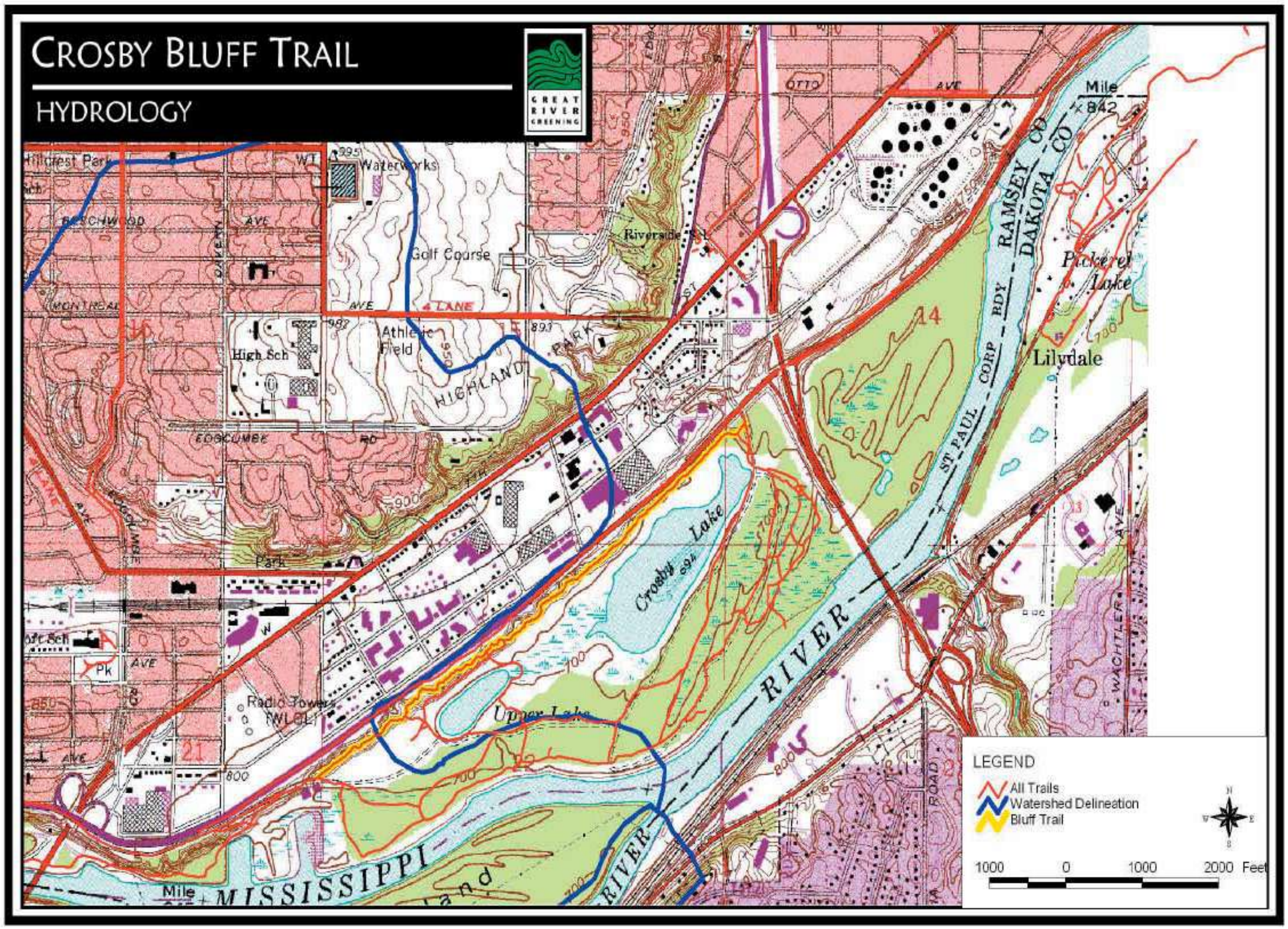
The Slope Analysis overlay on the USGS 1:12000 map identifies the steepness of slopes in and around the site. A measurement of slope steepness is useful in understanding the process of erosion, and the relationship between slope, soil stability, stormwater movement, and vegetation. Vegetation often has difficulty taking hold in steep areas, yet at the same time is essential for the stabilization of soils on the slope. The slope analysis helps to pinpoint areas where the risk of erosion is high and to guide the placement of erosion control elements along the trail. The entire bluff trail runs along areas of steep slopes.

Soils

The Soil Resources map was constructed using the Ramsey County Soil Survey. The key contains those soils found within or around Crosby Park. It is also important to note that a slope percentage is often indicated after each individual soil ID, which is useful when determining the "workability" of a particular soil group. Most of Crosby Park is dominated by Chaska Silt Loam (frequently flooded) and Algansee Loamy Sand. The bluff trail moves through areas of Dorerton-Rock Outcrop Complex, with 25% to 65% slopes.



Resource Analysis of Intrinsic Qualities

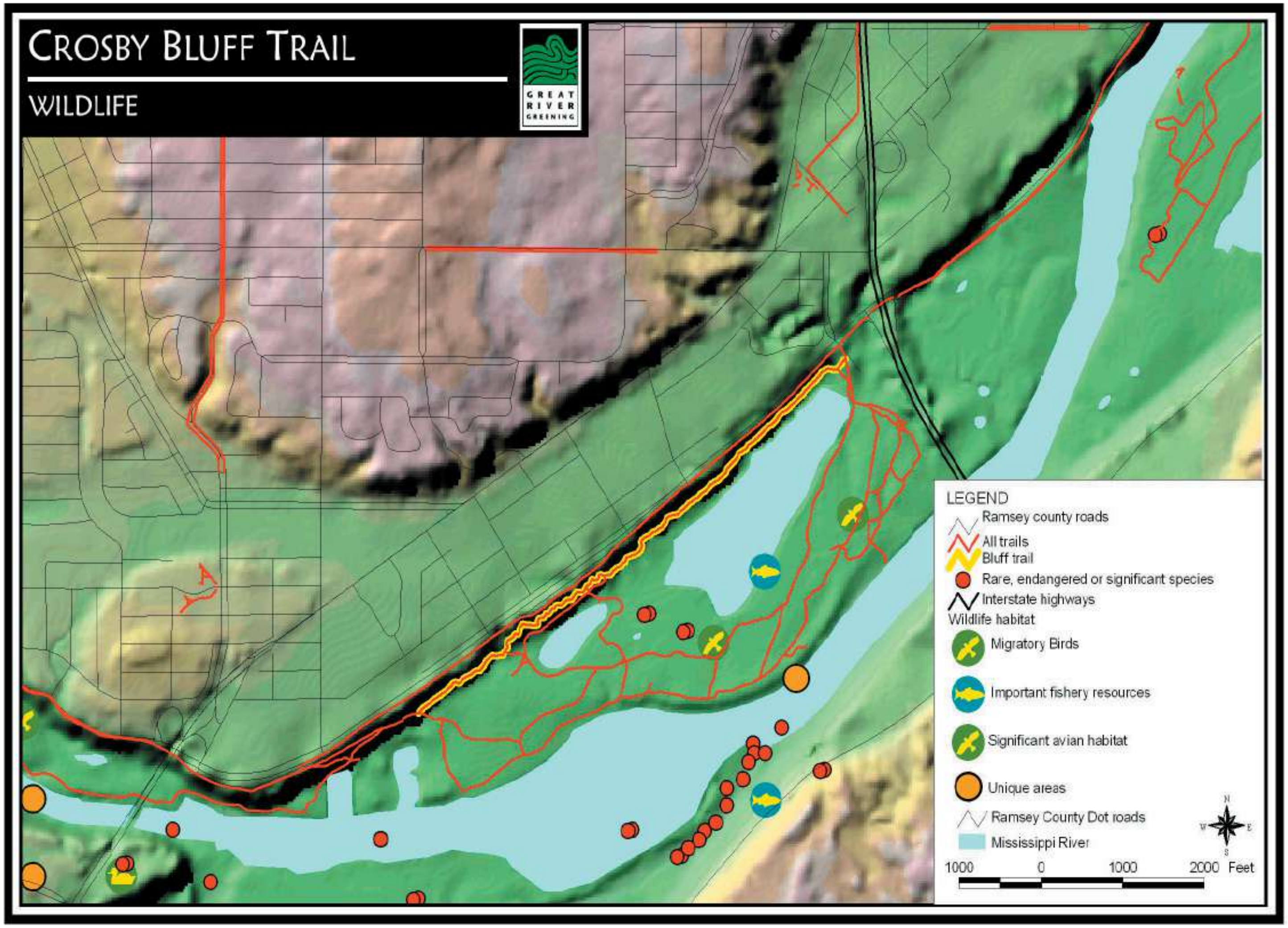


Hydrology

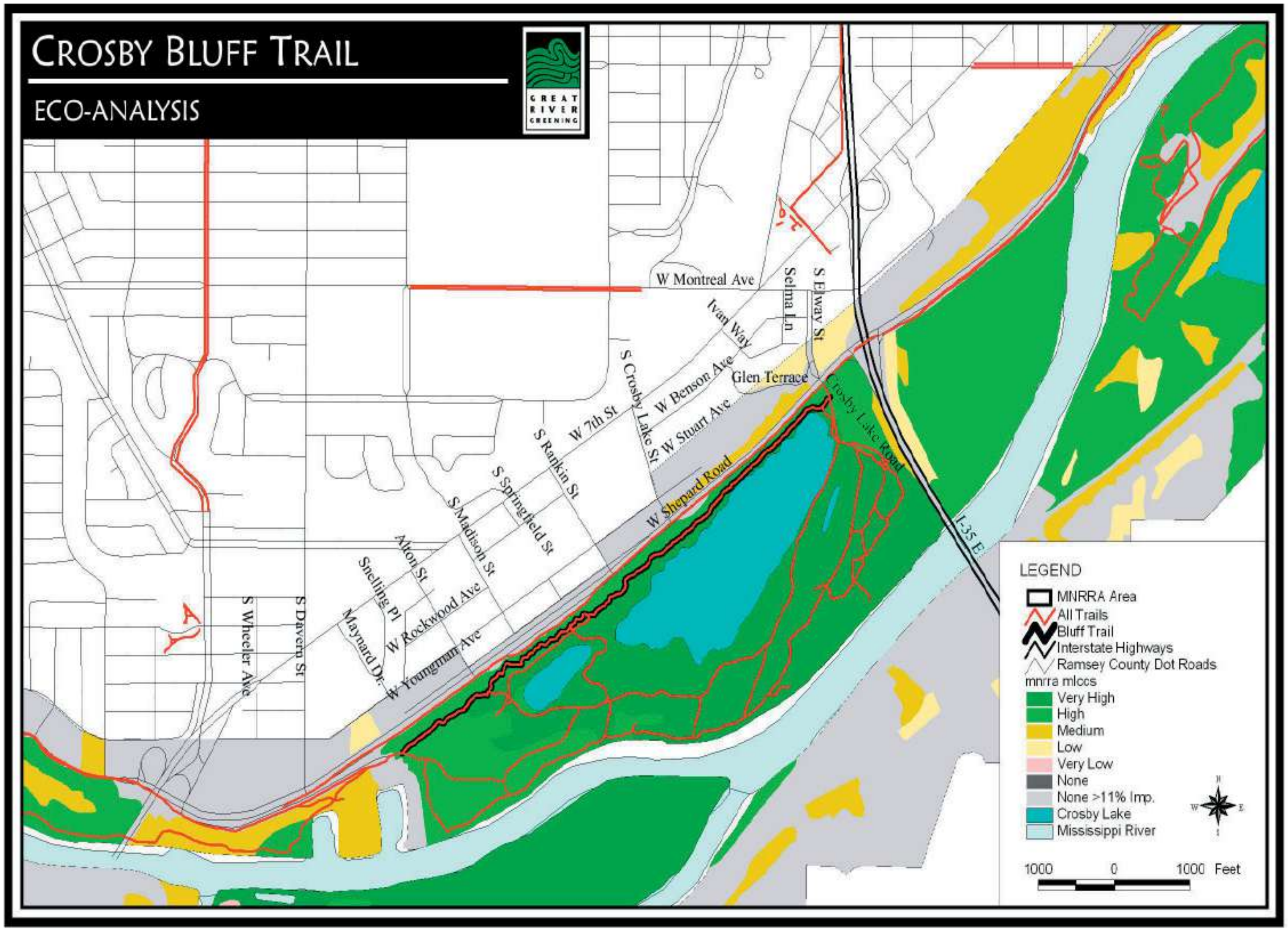
The Hydrology map identifies watershed boundaries in relation to trail location and the extent of Crosby Park. A watershed boundary divides the bluff trail into two portions. Stormwater in the area around the larger portion (to the east) drains into Crosby Lake. Stormwater in the area around the smaller, western portion collects in the black ash seepage swamp at the foot of the slope.

Wildlife

The Wildlife map indicates areas within or near Crosby Park that are ecologically significant to wildlife. Ecological significance is defined in terms of breeding habitat, use as food source, or the location of rare, endangered or ecologically significant species to the Mississippi River Valley Region. Crosby Park contains valuable aquatic and avian habitat, as well as a number of rare, endangered, or significant species.

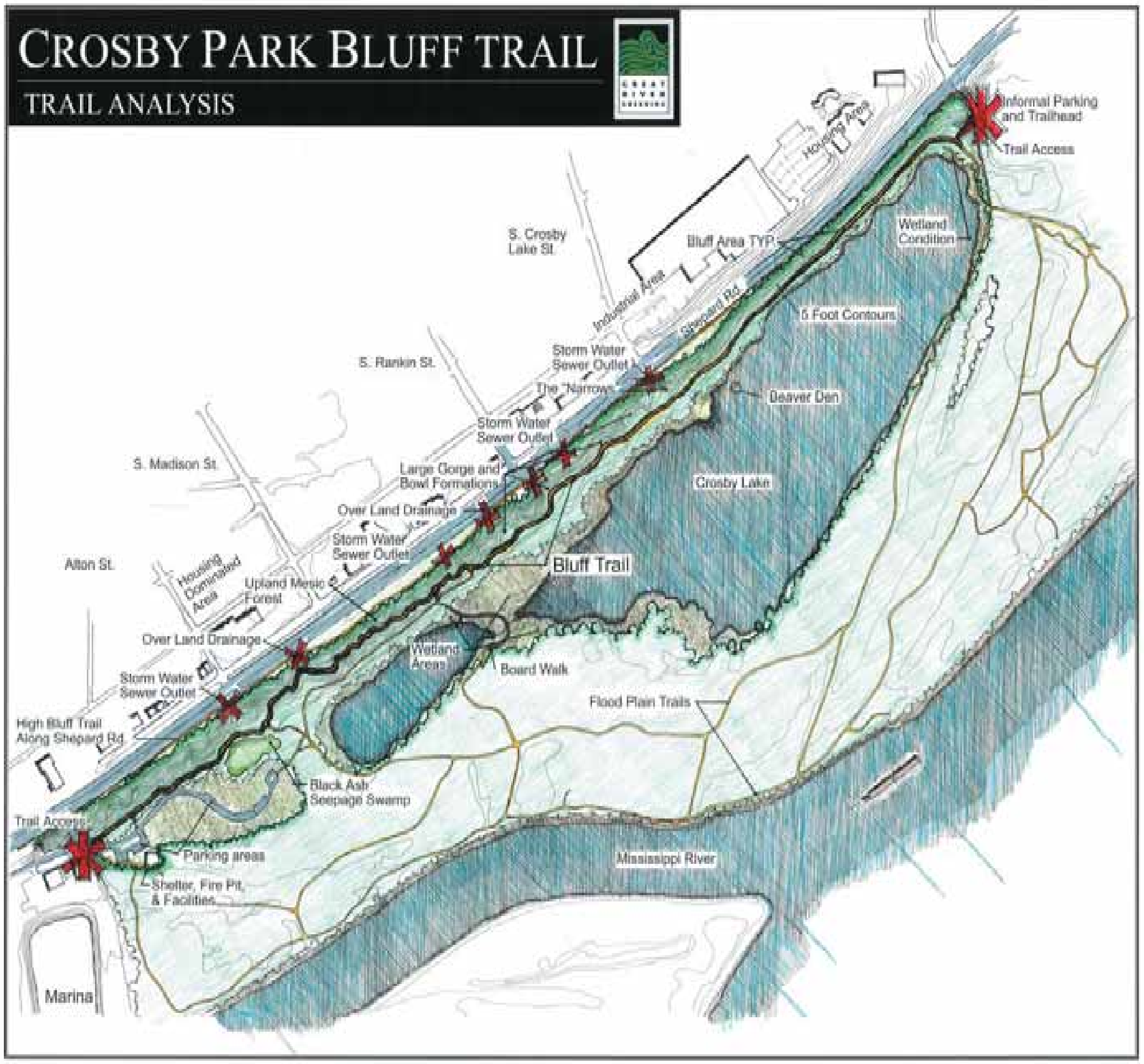


Resource Analysis of Intrinsic Qualities



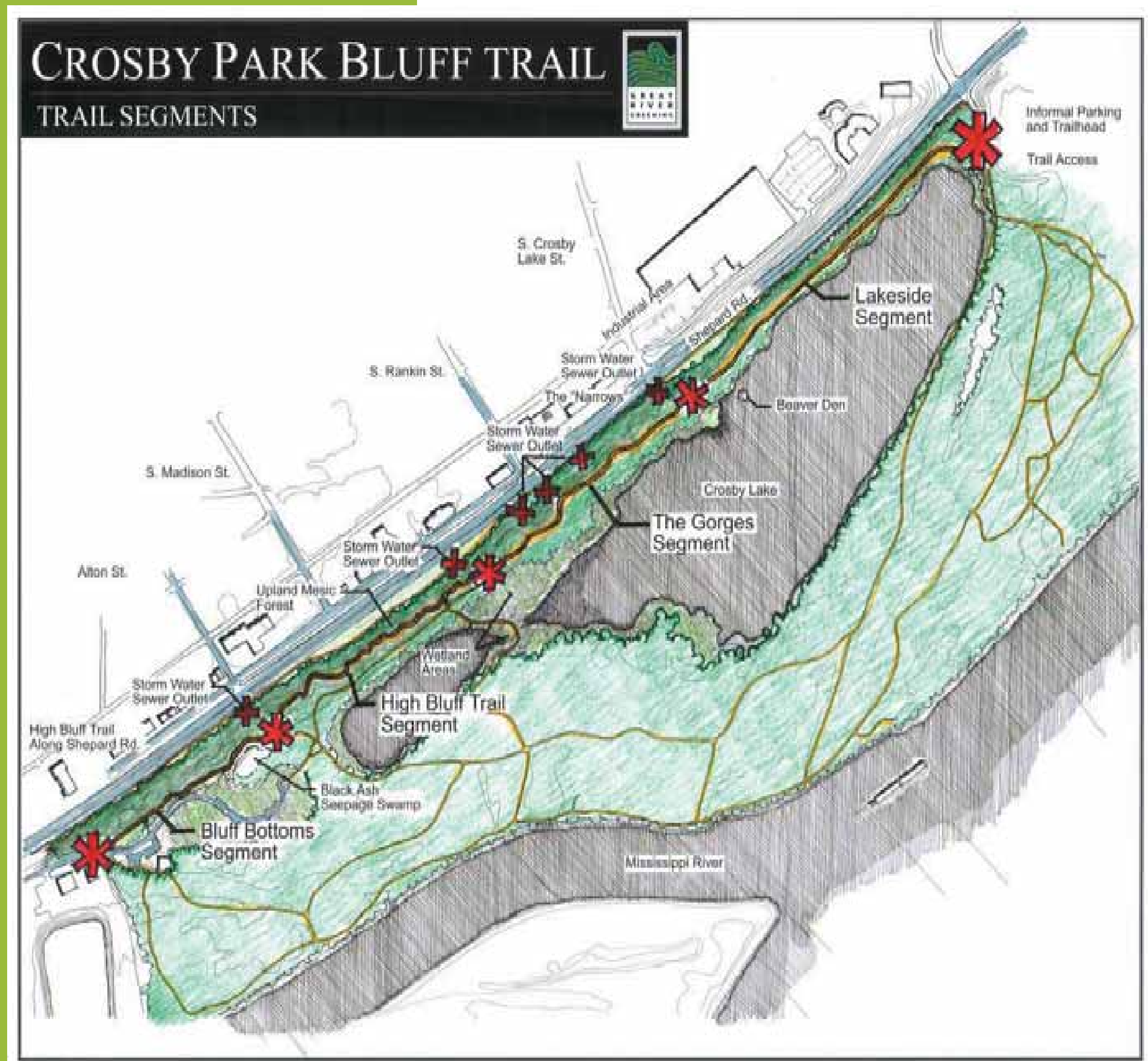
Eco-Analysis

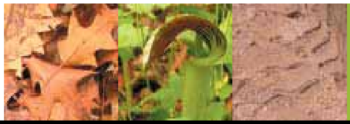
The Eco-Analysis map identifies which areas in and around Crosby Park that contain the greatest ecological value to guide an informed design and set of recommendations. Areas were rated by using the ecological protocol for open space protection opportunities in the Mississippi National River and Recreation Area (MNRRA). The protocol evaluates MLCCS (Minnesota Land Cover Classification System) polygons and classifies each polygon by numerical ranking. Numerical values are then grouped together to give a simplified ranking: ranging from very high to very low. Nearly all of Crosby Park ranks as high or very high in ecological value.



CROSBY PARK BLUFF TRAIL
TRAIL ANALYSIS
Informal Parking and Trailhead
Trail Access
Housing Area
Bluff Area TYP.
Wetland Condition
S. Crosby Lake St.
Industrial Area
Shepard Rd.
5 Foot Contours
Storm Water Sewer Outlet
The "Narrows"
S. Rankin St.
Beaver Den
Storm Water Sewer Outlet
S. Madison St.
Large Gorge and Bowl Formations
Crosby Lake
Over Land Drainage
Storm Water Sewer Outlet
Bluff Trail
Alton St.
Housing Dominated Area
Upland Mesic Forest
Over Land Drainage
Wetland Areas
Board Walk
Storm Water Sewer Outlet
Flood Plain Trails
High Bluff Trail Along Shepard Rd.
Black Ash Seepage Swamp
Trail Access
Parking areas
Shelter, Fire Pit, & Facilities
Mississippi River
Marina

Bluff Trail Plan





Trail Segment Plans

Bluff Trail Segments:

The Bluff Trail can be divided into four distinct segments, each with its own special character.

Moving from west to east, the first segment is the Bluff Bottoms segment. It is characterized by the location of the trail at the base of the bluffs, first near the west parking lot and then along the edge of a black ash seepage swamp.

The second segment is the High Bluff Trail segment. It is characterized by the elevated location of the trail and the experience of being up in the trees and upon the steep bluff slopes.

The third segment is the Gorges segment. Here the trail moves down to the base of the bluffs once more, which features a number of broad, bowl-shaped ravines and narrow, eroded gorges.

The fourth and final segment is the Lakeside segment. Here the trail moves near the edge of Crosby Lake, with framed views to the water.

On the following pages, each trail segment is dealt with individually, identifying specific problem areas along the trail. For each portion of the trail, the current condition of the trail and supporting structures is given, followed by design recommendations to improve the condition. The number(s) listed with each recommendation refer to specific design details, arranged by number, in the final portion of the document. Restoration of native vegetation is needed along the entire trail, so there are no specific points indicated for this recommendation. For planting details and considerations, see Design Details #7, #8, and #9.

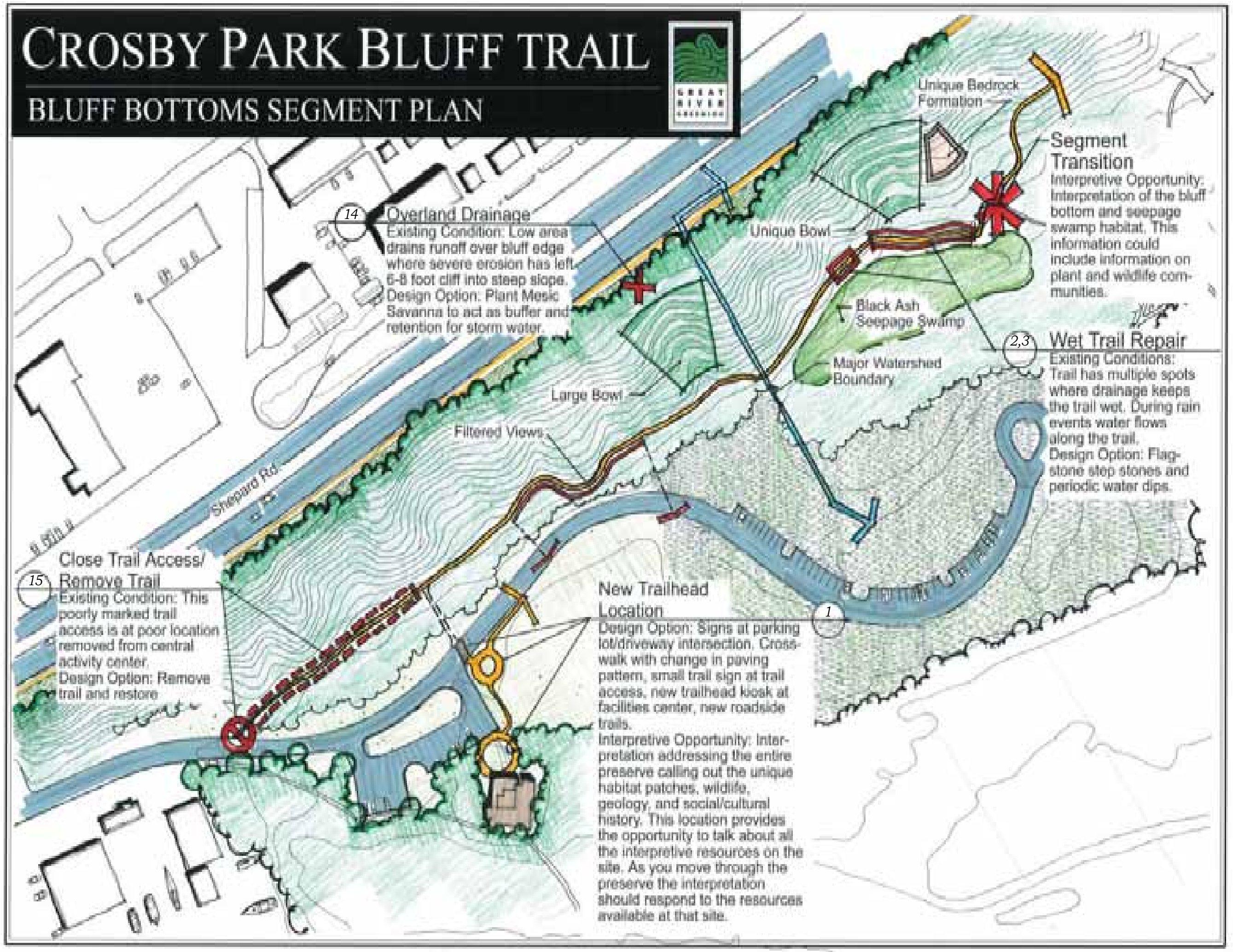
Bluff Bottoms

High Bluff

The Gorges

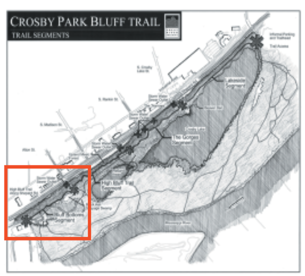
Lakeside

Trail Segment Plans



Trail Segment 1: Bluff Bottoms

The Bluff Bottoms Trail Segment begins at the park's west parking lot and ends where the trail climbs the bluff slope. It begins with a strong sense of enclosure, pressed between the park access road and the bluff. Soon the space between the trail and road expands, and the rest of this trail segment runs between the bluff and a black ash seepage swamp. In the swamp the understory is open, filled with the slender trunks of black ash trees. This entire segment is characterized by wet soil conditions, with muddy trails after rain. The depressed area between the trail and road becomes inundated after storms, and there is no outlet for this stormwater except for slow infiltration into the ground. In general, the native vegetation is relatively high in quality along this segment of the trail, with patches of wild ginger, jack-in-the-pulpit, bloodroot, and trout lily. Infestations of garlic mustard are less severe here than in the other segments.



The entrance and parking lot, at the bluff trail's beginning.

Filtered views from the trail to the acces road and lawn area.

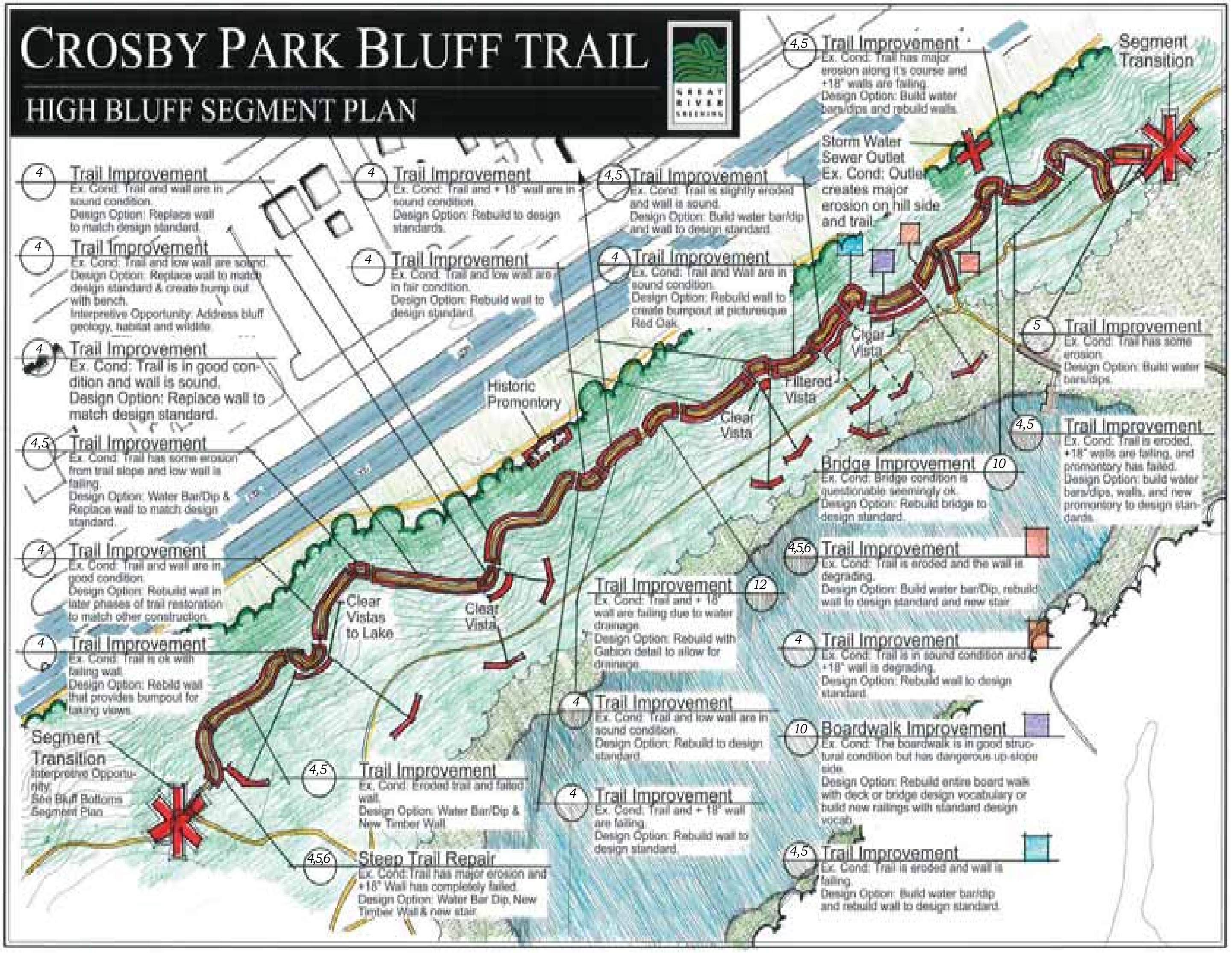
The black ash seepage swamp, along which the trail winds.

Water running through the trail after rain.

Sandstone bedrock exposed near the trail.

The unique bowl, filled and stabilized with rubble dumped from the top of the bluff.

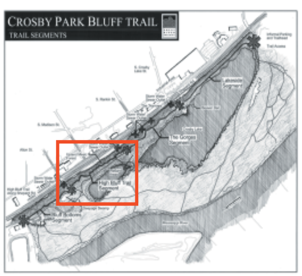
Trail Segment Plans



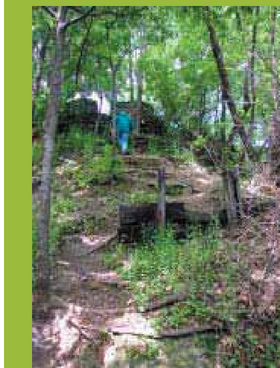
Trail Segment Plans

Trail Segment 2: High Bluff

The Upper Bluff Trail Segment begins where the trail climbs the bluff slope, and ends where the trail descends again near the west end of Crosby Lake. The segment is characterized by an intimate relationship with the bluff and a feeling of prospect as the trail runs roughly halfway up the bluff slope. The trail twists and turns with each ridge and draw, hugging the fissured topography. Though Shephard Road is not far away at the top of the slope, the presence of its traffic is not strongly felt. However, the impact of stormwater from its surface is seen in the eroded draws. At many points the trail position is quite precarious, with steep slopes above and below. The understory vegetation is open enough to allow views to the flatland below and well up the bluff slope. Erosion is a serious issue along the entire length of this segment, both on the trail itself and on the adjacent slopes. Of all the segments, this is the one on which mountain biking should be most discouraged. The presence of staircases at either end of the trail segment should help keep bikes on the lower trails that are less prone to erosion. A staircase already exists at the east end of the segment, and we recommend adding one at the west end.



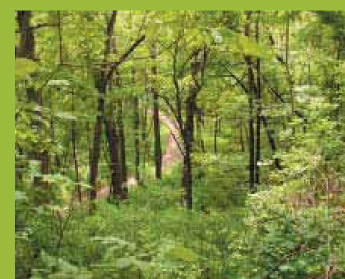
Start of segment, stairs recommended.



Abandoned trail to old overlook.

Limestone outcropping at top of bluff.

Severely eroded promontory.



Filtered views to paved trail below.

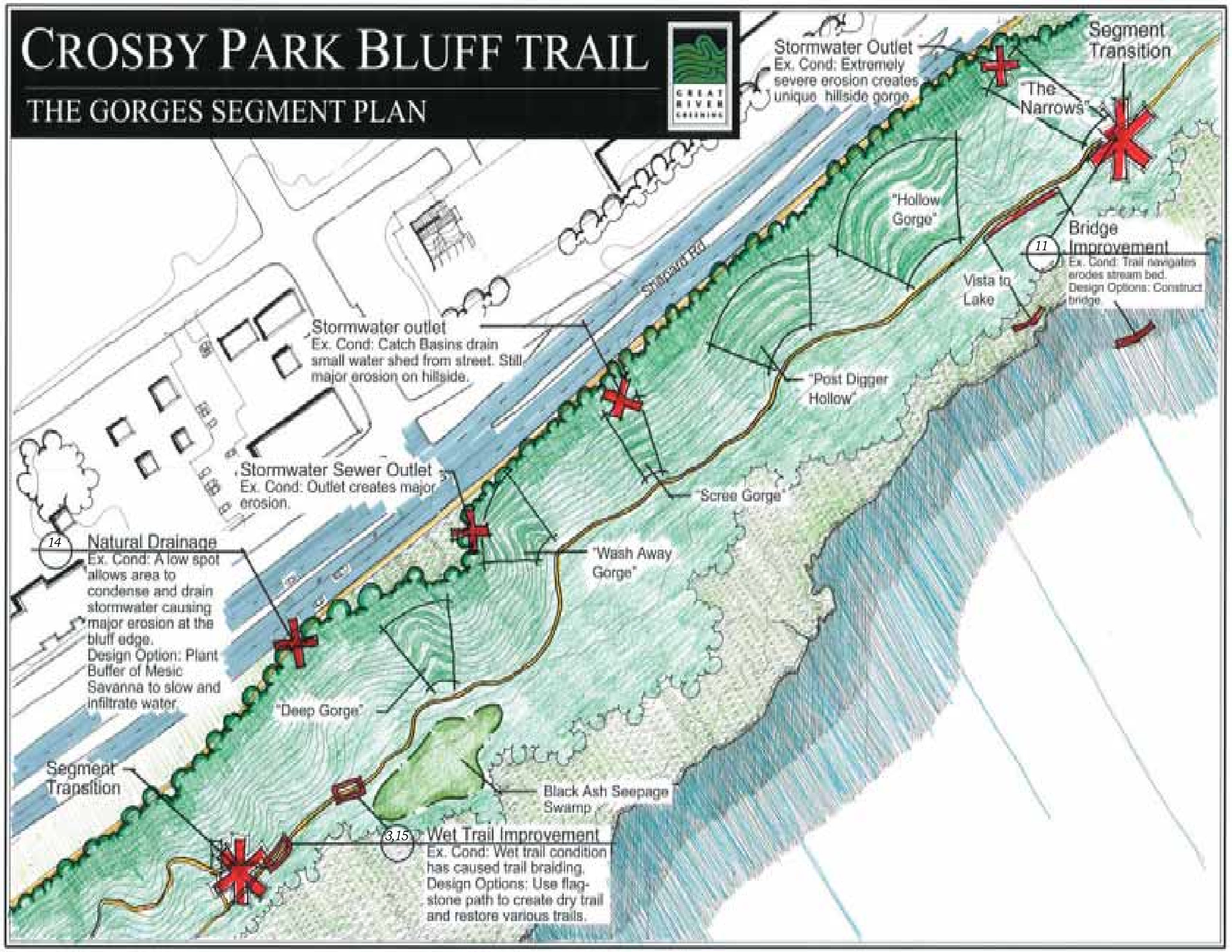
Water on trail, gabion's recommended.

Most recent, sturdy timber wall.

Boardwalk with eroded condition on uphill side.

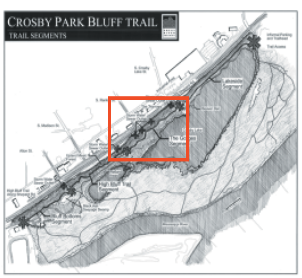
Existing bridge.

Trail Segment Plans



Trail Segment 3: The Gorges

The Gorges Trail Segment begins at the staircase near the west end of Crosby Lake and ends at the dramatic canyon feature referred to in this document as "The Narrows." Here the trail is at the base of the bluff, with a few short climbs over ridges that reach across the trail. The bluff has a strong presence here, experienced as a series of broad, bowl-shaped draws and narrower ravines. The south side of the trail alternates between open black ash seepage swamp and more enclosed lowland forest, with occasional filtered views of the lake. Many of the draws are severely and spectacularly eroded, the result of several stormwater outlets at the top of the bluff. The most dramatic of all the gorges, The Narrows, marks the end of this segment. It is a narrow, twisting canyon carved directly out of the sandstone bedrock and cutting straight back into the bluff. Where runoff from the narrows enters Crosby Lake, there is a large sandy delta.

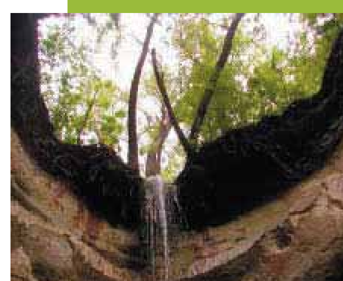


A particularly severe infestation of garlic mustard.

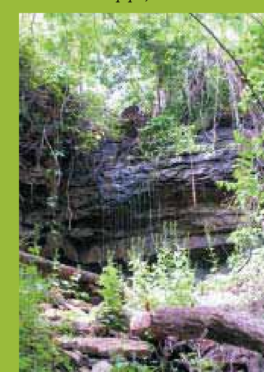
One of several severely eroded gorges, with sculpted sandstone walls and filled with rubble.

The entrance to the Narrows.

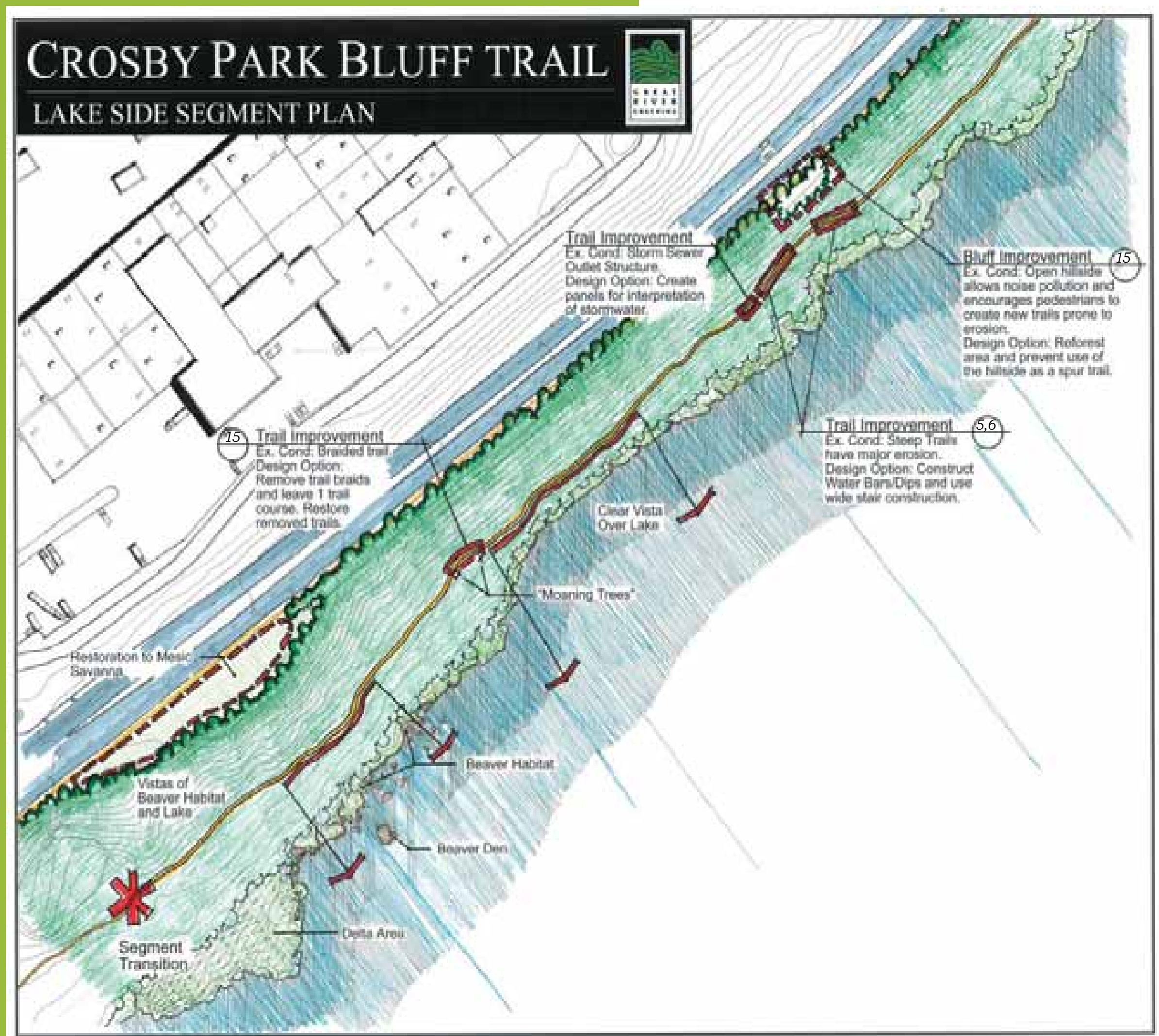
Another severely eroded gorge, above, with the cause of its erosion, a storm water pipe, below.



The falls at the top of the Narrows, only a trickle in dry weather.

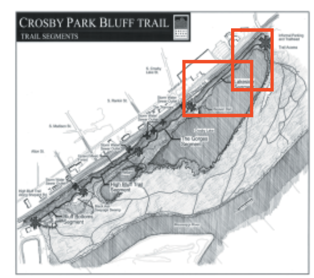


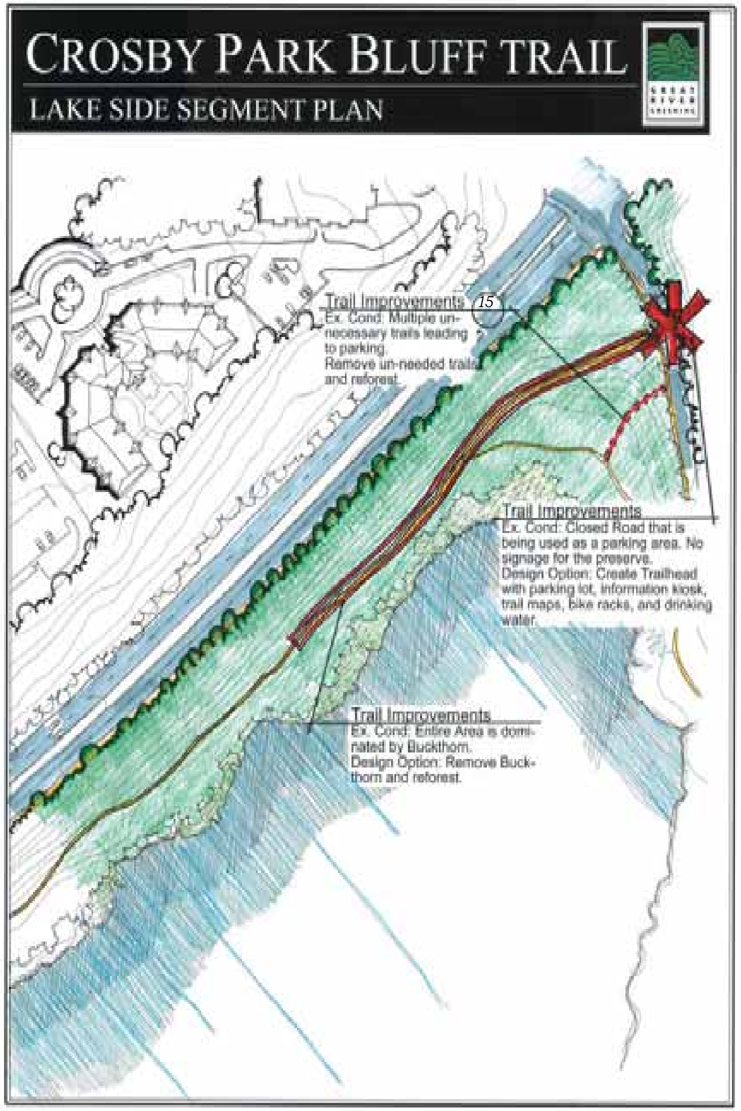
Trail Segment Plans



Trail Segment 4: Lakeside

The Lakeside Trail Segment begins at The Narrows and ends at the access road at the east end of Crosby Lake. This is the longest segment of the trail. It runs mostly at the base of the bluff, with a few short climbs up the slope followed shortly by descents. Here the distance between the bluff and the lake is quite narrow, so the trail remains relatively close to the water's edge. If the experience of the previous segment was dominated by the bluff, this segment is dominated by the water. The segment begins with views to a massive beaver lodge, surrounded by evidence of the beavers' handiwork on the vegetation and in the lake itself. There is also evidence of human activity in this area in the form of small concrete foundations and a large cave carved out of a sandstone ridge. As the trail moves eastward, the presence of traffic on Shephard Road becomes more noticeable as the road slowly descends with the diminishing bluff. A significant feature near the end of the segment is a massive stormwater outlet structure. Beyond the outlet structure, the trail becomes more enclosed as it winds through an area where dense stands of buckthorn have not yet been removed.





Sloped and eroded trail, where wide stairs are recommended.

The informal parking and trailhead at the end of the bluff trail.

Sandy delta where water from the Narrows enters Crosby Lake.

Large beaver den east of the delta.

Large storm water outlet structure, an opportunity for interpretation.

Braided trail, where one should be closed and the other improved.

Design Details

Bluff Bottom, Wet Condition

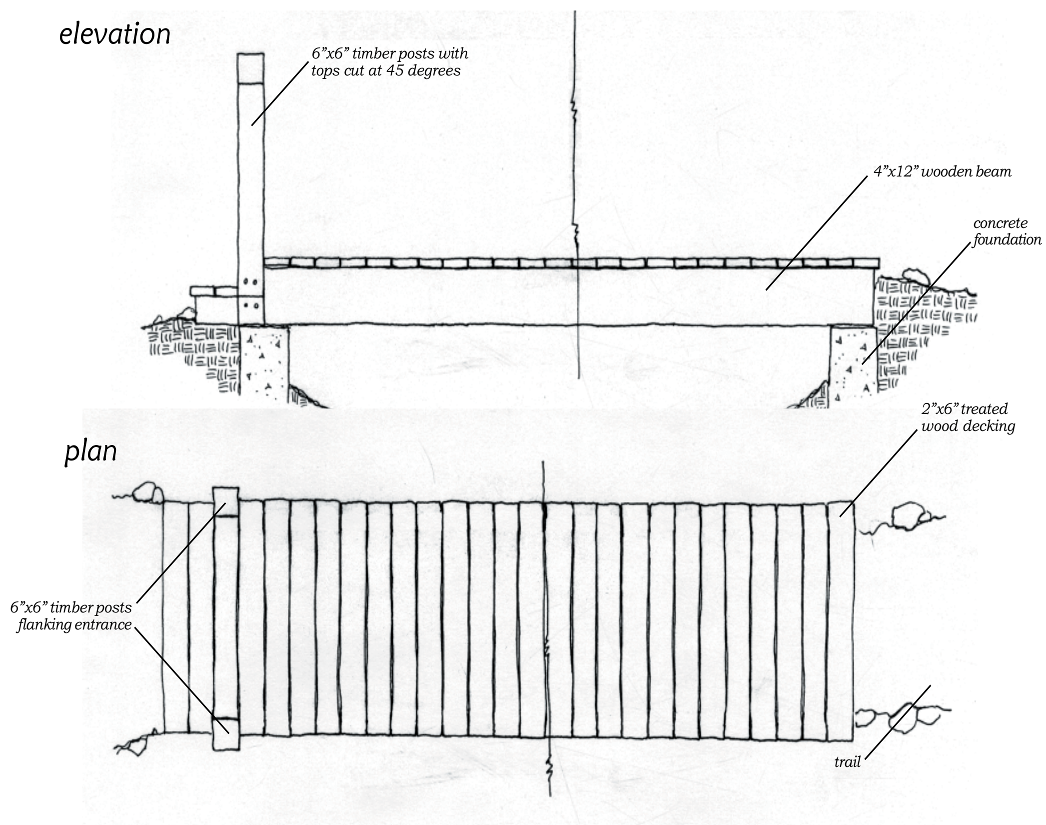
There are many areas at the bottom of the bluff where the flow and accumulation of water is a problem. The goal in these areas is to allow both the passage of water and the movement of people, without one impeding the other.

Detail #1: Trailhead Bridge

-Bridge is simple boardwalk without railing.

-6x6" posts, with tops cut at a 45 degree angle, mark the transition from the road crossing to the trailhead bridge. Timber posts bring design vocabulary of retaining walls to bridge structures.

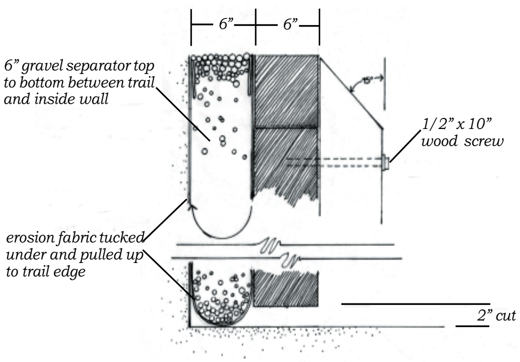
-See Detail #11 for beam-foundation connection.



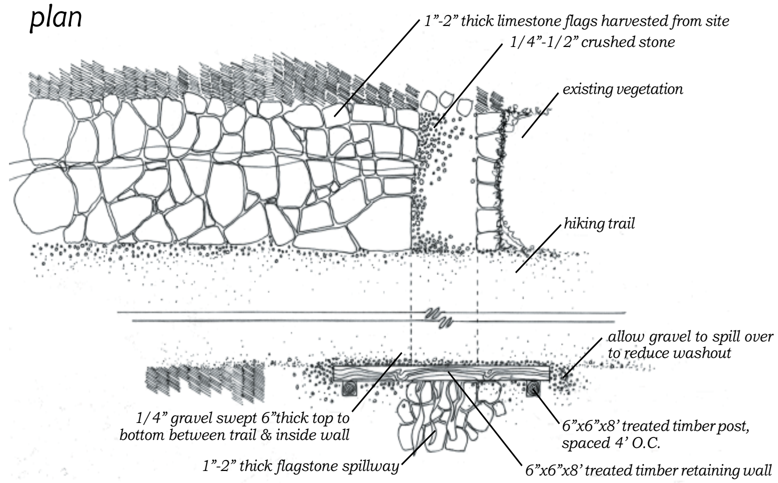
Design Details

Detail #2: Drainage Ditch w/ Crossing

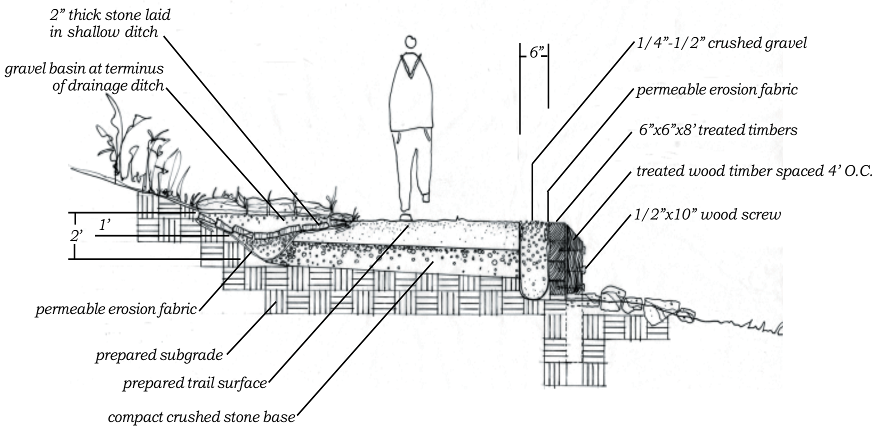
wall section closeup



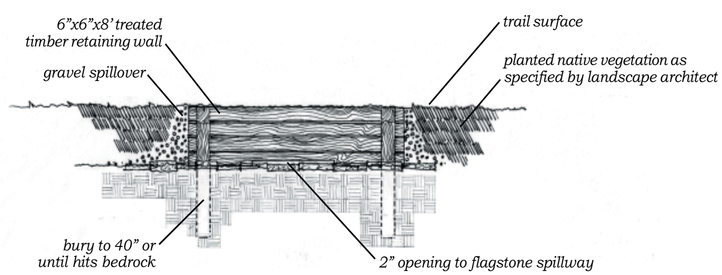
plan

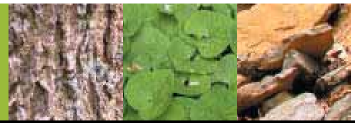


section



elevation



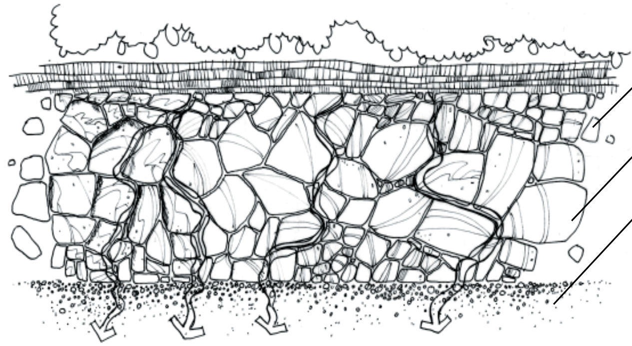


Design Details

The purpose of the Stepping Stone Path detail is to keep the path dry for foot traffic, and to avoid the formation of large muddy patches in the trail after rain. It is meant to be applied in areas where heavy foot traffic intensifies the erosion process. Successful implementation of this design requires that the stepping stones be thick enough (approx. 6") and firmly set into the trail so that washout does not occur. Limestone rubble of appropriate dimensions found on site may be used. The gravel spillway functions to slow down sheet flow off the trail.

Detail #3: Stepping Stone Path

plan



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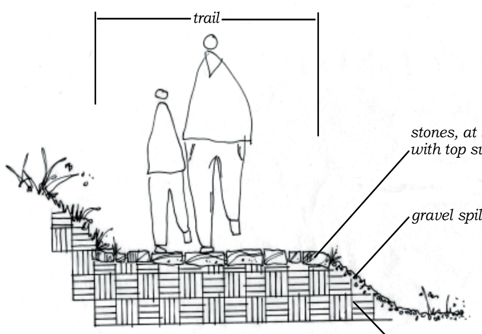
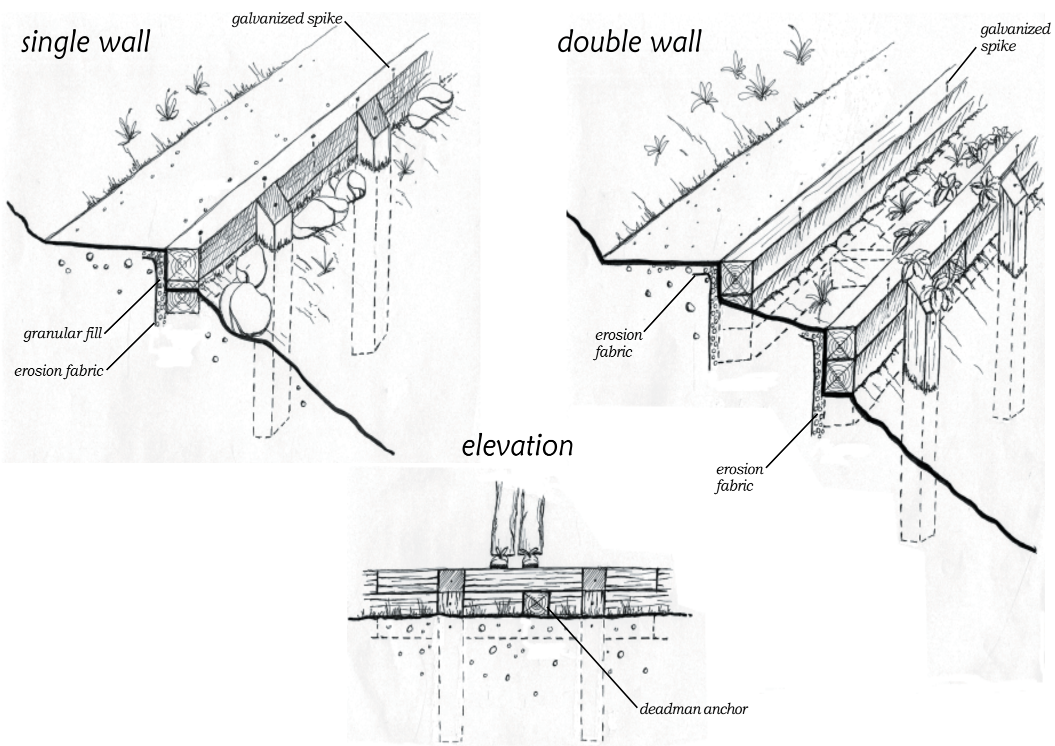


Steep Slope Condition

Erosion as a result of steep slopes is a problem all along the bluff, both on and off the trail. The following details offer solutions on these slopes. They seek to stabilize the slopes, allowing movement of people and water without excess movement of soil.

Detail #4: Retaining Wall



-Construct walls with 6 by 6 timber posts and rails.

-Use 3/8" galvanized spikes 10 - 12" long.

-Utilize a minimum of 4 spikes per 8', with 2 spikes at connection points.

-Replace existing telephone pole walls with timber walls as they decompose.

-Utilize gravel or limestone debris and erosion fabric behind timber walls to facilitate infiltration of rainwater.

-Utilize drainage dips (see detail #5) along wall sections to divert water.

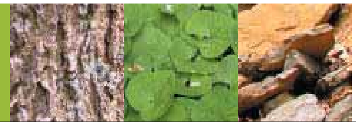
-Bury posts 3.5 feet deep or to the depth of bedrock.

-Bury at least one rail into the ground for sufficient stability.

-Double walls should be utilized for walls higher than 3-feet to break up the visual effect and help divert water.

-Utilize dead man anchoring with double walls.

-Utilize plantings between double walls to soften edges and increase absorption of rainwater.



Design Details

-The drainage dip is a method of diverting rainwater from the trail surface, similar to a water bar.

-Drainage dips utilize gaps in timber walls where water is directed via stone depressions from the trail surface.

-Gaps between the rocks that compose the stone depressions should be filled with a porous material such as gravel.

-Utilize stone rip-rap to slow the flow of water off of the trail

Drainage Dip Spacing

Percent Grade	Spacing between Drainage Dips
5	80 ft.
10	40 ft.
15	30 ft.
25+	20 ft.

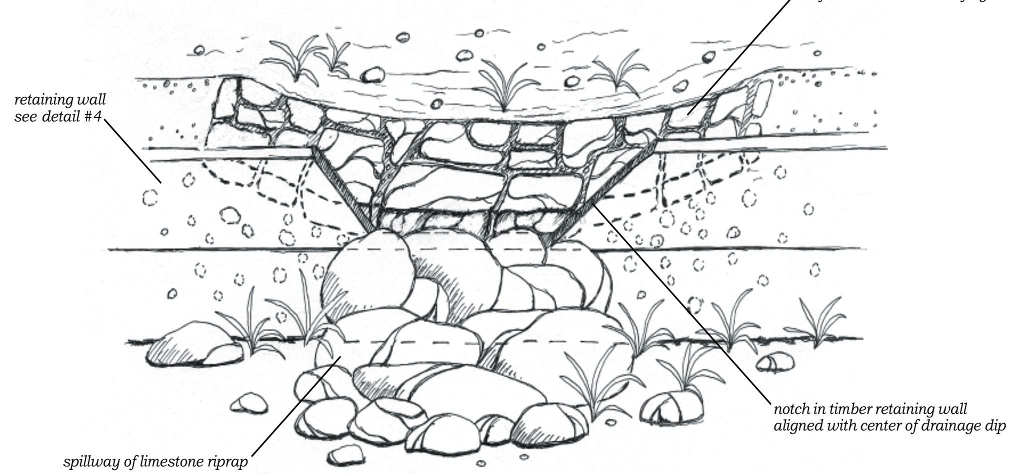
-Each step consist of a timber box that is constructed with 6 by 6 treated timbers that are connected with spikes

-The size of timber boxes will vary depending on the required width of the trail segment and the steepness of the slope being navigated.

-During construction, each box should be filled with class 5 limestone and boxes should overlap one another, leaving a tread depth that is appropriate for the slope.

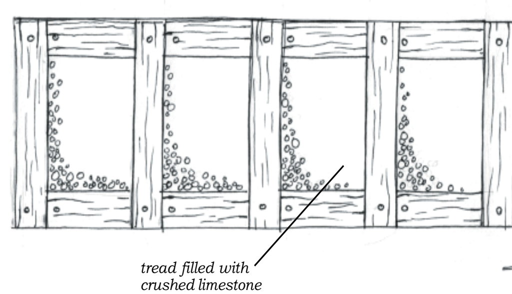
-Stairs should be placed to follow the contours of the slope to minimize grading

Detail #5: Drainage Dip

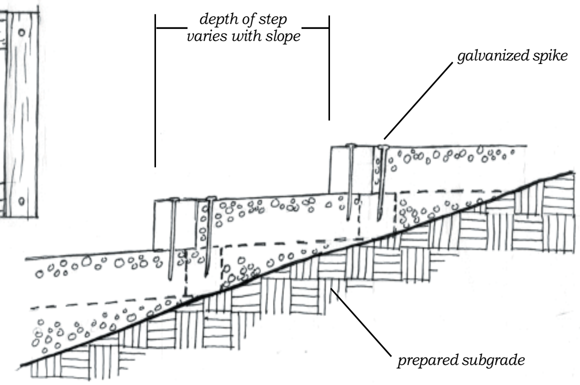


Detail #6: Stairs

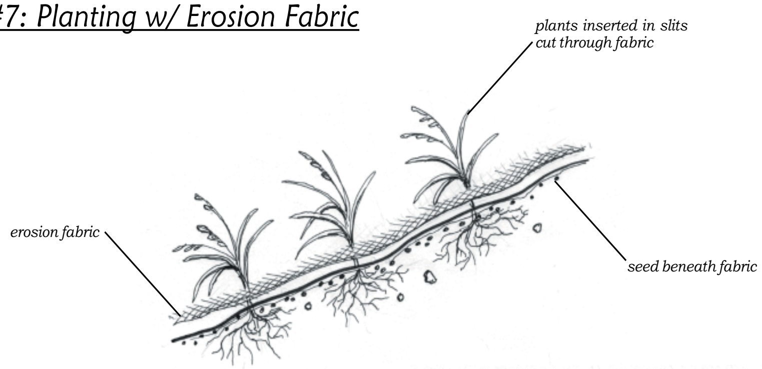
plan



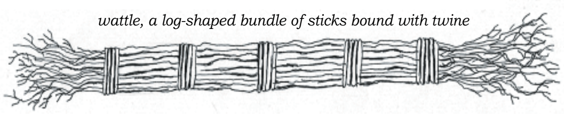
section

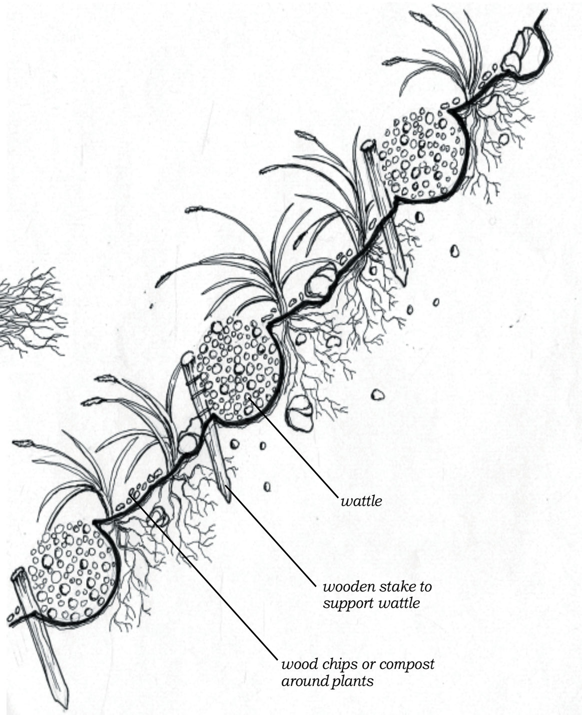


Detail #7: Planting w/ Erosion Fabric



Detail #8: Planting w/ Wattles





-Erosion fabric should be utilized wherever seeding will be a component of a planting.

-Seeding is generally recommended when relatively large areas are being planted and containerized plantings are not cost effective. If local seed is available it is often a good idea to utilize it in addition to installing mature plants in case the planting is unsuccessful.

-The use of erosion fabric may be preferred over wattles for large areas, as it is easier to install. The drawback of only using erosion fabric is that it does not create changes in topography where moisture and organic material can collect.

-In addition to seed, mature plants can be installed with erosion fabric. Slits can be cut in the fabric for the installation of plants.

-Erosion fabric can also be utilized in combination with wattles. In this instance, trenches for the wattles are dug and then the fabric is laid. Subsequently, the wattles should be placed over the fabric.

-Use wire or cornstarch staples to secure erosion fabric and wooden stakes to secure wattles.

-Brush wattles or biologs can be utilized to stabilize slopes and create plateaus where plants can receive increased moisture.

-Once plants are established, their root systems will help stabilize the slope.

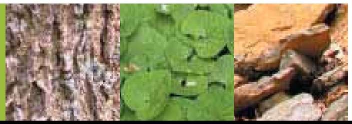
-Bundle wattles together with twine. Bury about half of the wattle into the slope and utilize wood stakes to secure them to the slope.

-Wattles should be installed before seed and plants are installed.

-Two or three inches of wood chips should be spread around plants.

-Compost should be used instead of wood chips for slopes greater than 3:1. The compost will hold better to the slope than wood chip, but will decompose more quickly.

-In areas of severe erosion, an engineer should be involved to provide stabilization recommendations.

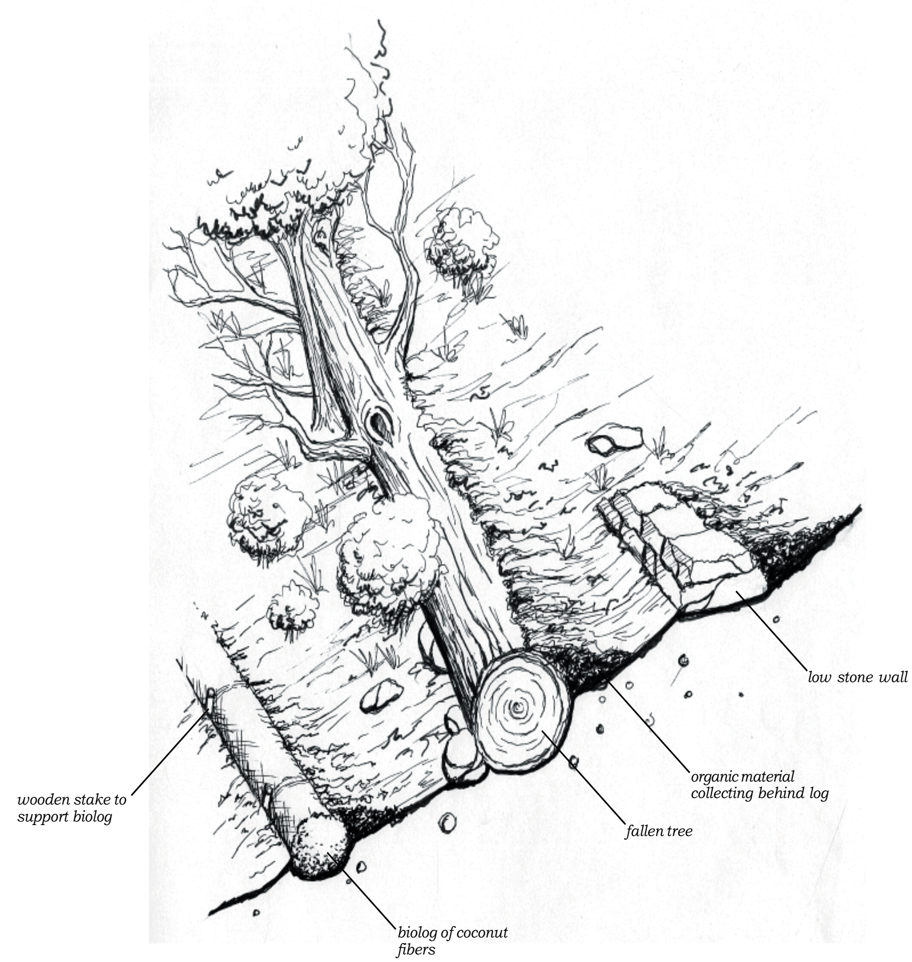


Design Details

-A primary need is to stop the movement of soil and encourage the build-up of organic material that will aid in stabilization and plant establishment.

-Downed trees, biologs made from coconut fiber and small rock walls can be utilized as checks to stop erosion and collect organic material.

Detail #9: Organic Collectors



Plants for Stabilization:

-Key groundlayer plant species for stabilization include:

Wet ravines:

Lady fern	*Athyrium filiz-femina*
Jack in the pulpit	*Artemisia triphylum*
Wild ginger	*Asarum canadense*
Woodland sedge	*Carex blanda*
Wild geranium	*Geranium maculatum*
Virginia waterleaf	*Hydrophyllum virginianum**
Ostrich fern	*Matteuccia struthiopteris*
Virginia creeper	*Parthenocissus inserta*
Bloodroot	*Sanguinaria canadensis*
Woodland meadow rue	*Thalictrum dioicum**

Dry ridges:

Thimbleweed	*Anemone cylindrica**
Columbine	*Aquilegia canadensis**
Heart leaved aster	*Aster cordifolius**
Harebell	*Campanula rotundifolia**
Pennsylvania sedge	*Carex pennsylvanica*
Curly-styled wood sedge	*Carex rosea*
Sprengel's sedge	*Carex sprengelii**
Northern bedstraw	*Galium boreale**
Woodland sunflower	*Helianthus divaricatus**
False Solomon's seal	*Smilacina racemosa**
Zig Zig goldenrod	*Solidago flexicaulis**

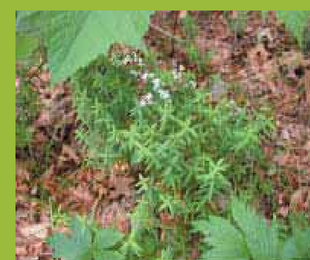
Note: * Denotes that the species can be planted from seed as well as containers. See companion ecological restoration plan for Crosby park for more extensive lists for bluff restoration.

Wild Ginger - Asarum canadense

Jack in the pulpit
Arisaema triphyllum

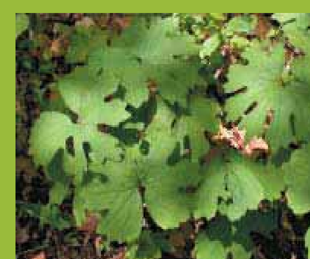
Wild Geranium - Geranium maculatum

Sprengel's Sedge
Carex sprengelii



Northern Bedstraw - Galium boreale

Virginia Waterleaf
Hydrophyllum virginianum



Bloodroot - Sanguinaria canadensis

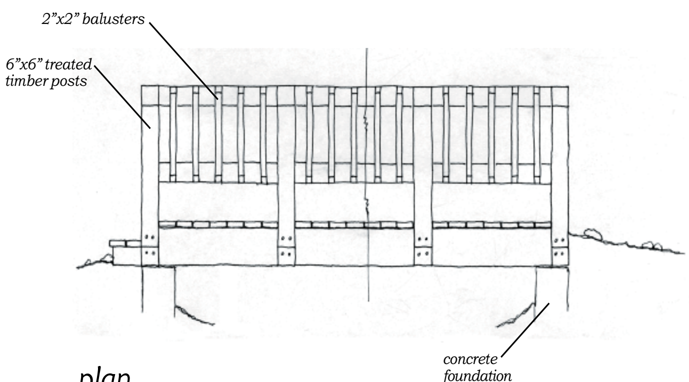
Design Details

Wet Ravine Condition

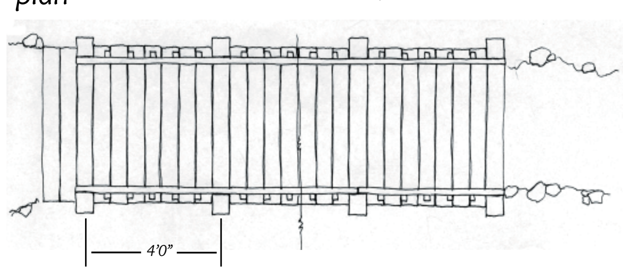
The most severely eroded areas of the bluff trail are in the ravines, where stormwater repeatedly scours out the base of the ravines and the sides collapse. Some such erosion is a naturally-occuring condition, but here it is aggravated by the presence of storm water outlets at the top of the bluff, bringing water in much larger quantities than would naturally exist. This dramatic erosion cannot be slowed or stopped without dealing with the stormwater outlets. However, we can help people navigate the ravines while still allowing water to pass through.

Detail #10: Bridge

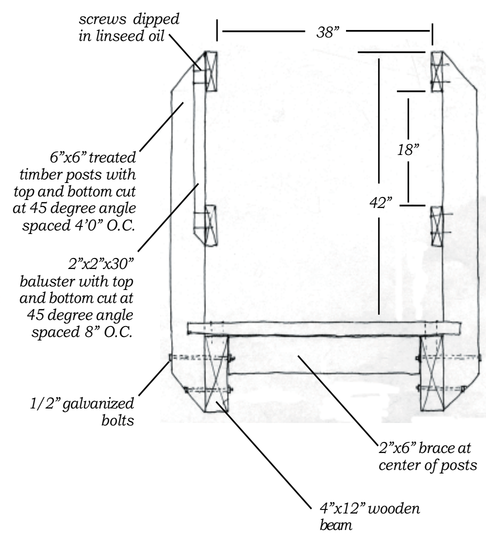
elevation



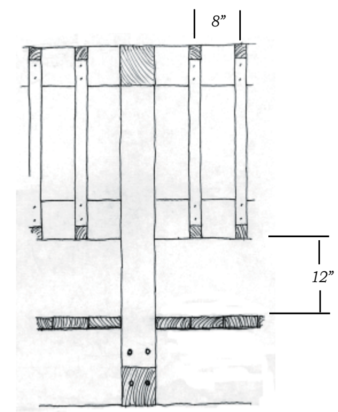
plan



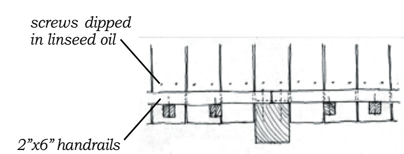
post & rail section

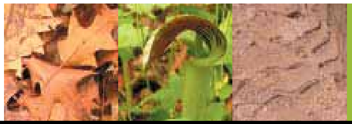


post & rail elevation



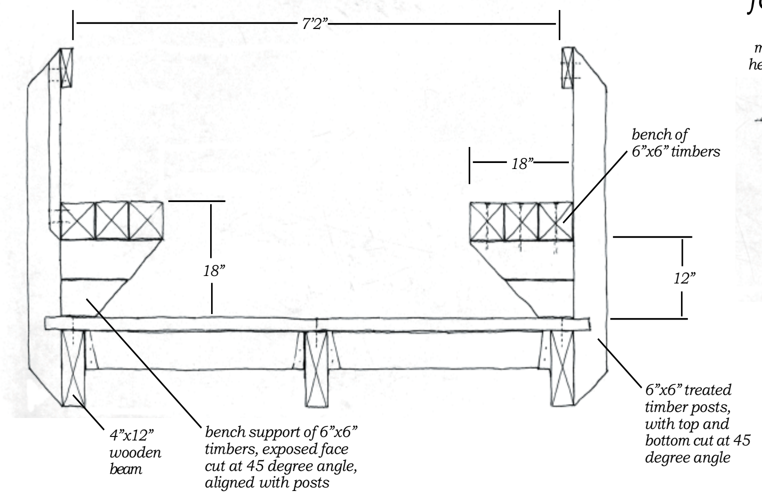
post & rail plan



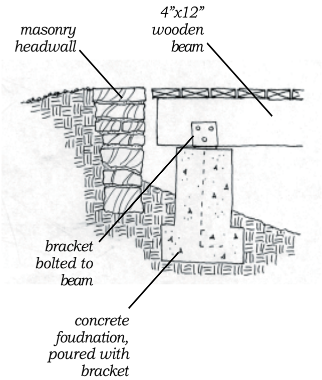


Detail #11: Bridge w/ Seating

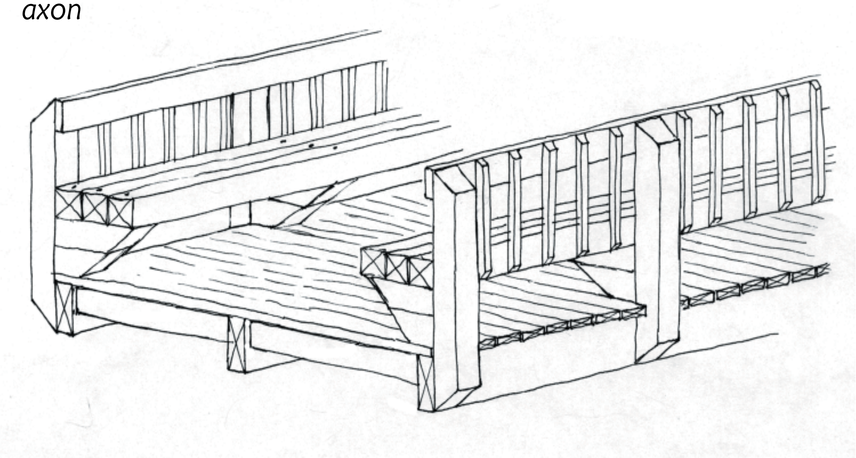
section



foundation connection



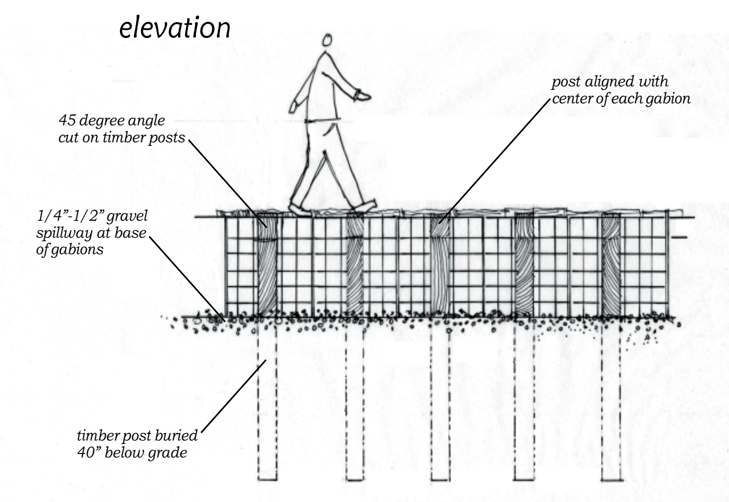
axon

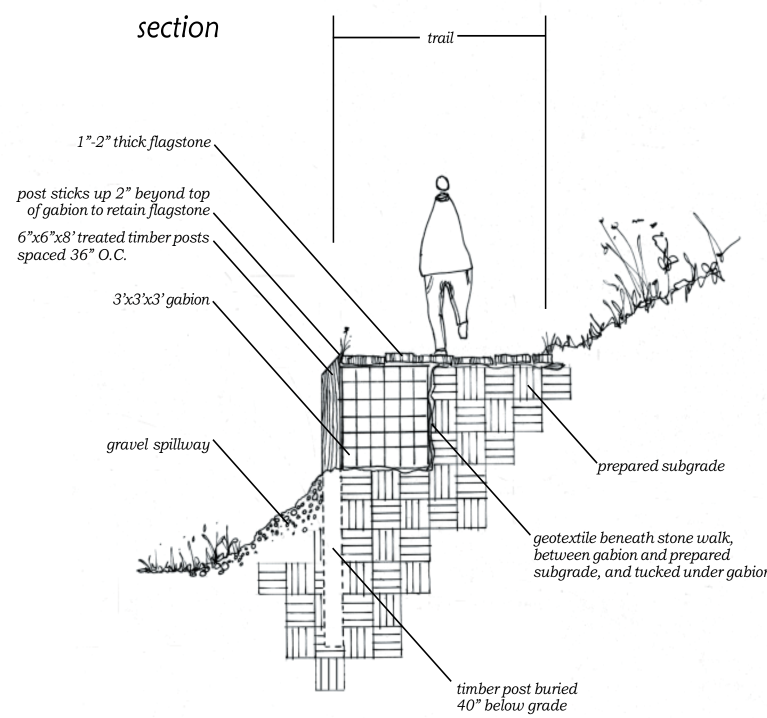


Design Details

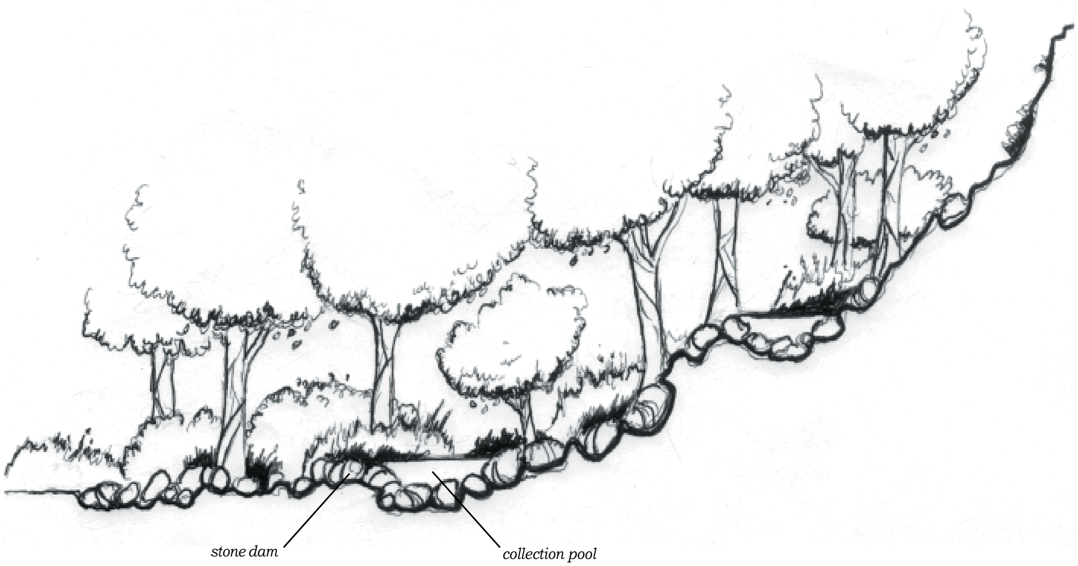
Detail #12: Gabion Wall

A gabion wall is a good solution where damp ravines exist along the bluff trail, and in areas where seeps along the trail contribute to trail washout and degradation. The gabion design allows water to pass beneath the trail while still maintaining the trail at a level grade. This structure is appropriate in ravines where there is water present, but not enough to require a bridge.





Detail #13: Collection Pools



-Collection Pools are designed to provide a water source for plants and animals that utilize the bluff.
-Pools should be constructed in ravines where there is at least a periodic flow of water and a significant amount of stone to move around.
-Pools are constructed by moving stone to create depressions behind small dams that will collect water. Typically, pools will be around 3 by 3 feet and 2-feet deep.

-An infiltration area should be constructed at the top of the bluff in the existing lawn.

-Currently there is no curb and gutter along this section of Shepard Road and stormwater flows over the bluff.

-Water flowing over the bluff is a significant source of erosion in ravines.

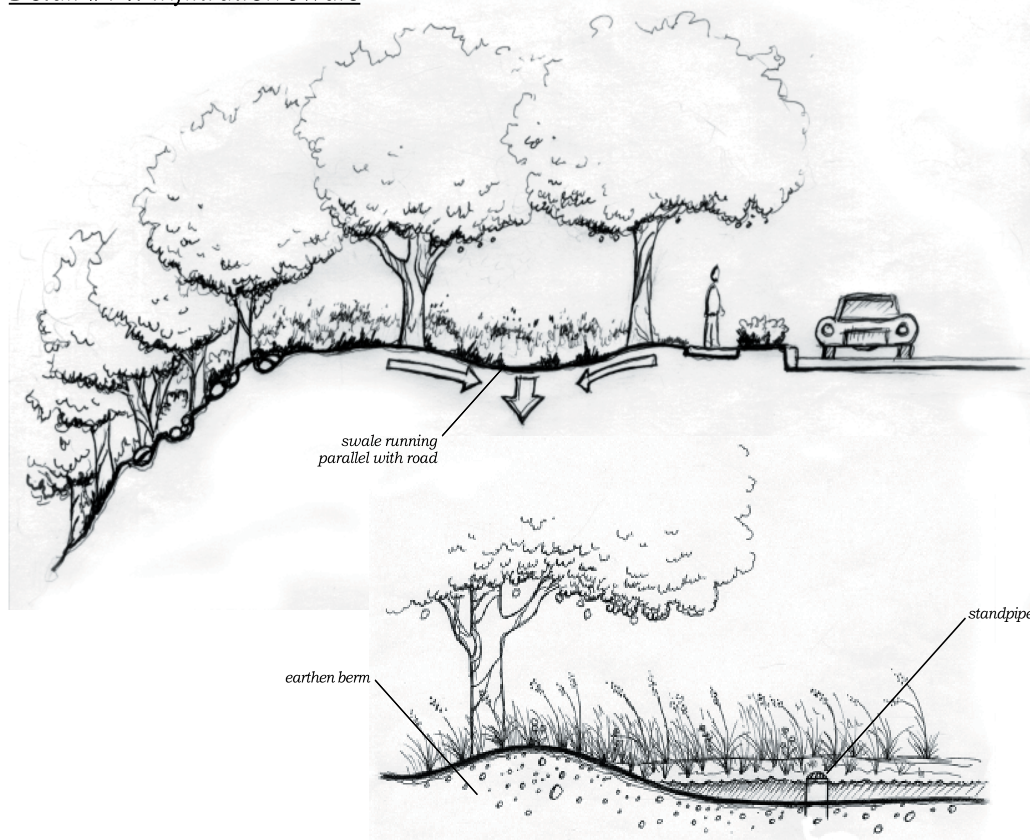
-The combination of constructing a berm and digging a gentle depression would allow water to pool and infiltrate on top of the bluff. There is currently a catch basin in the lawn that would require a standpipe.

-Mesic oak savanna and wet meadow species should be planted in the infiltration swale to aid in the treatment of stormwater, increase wildlife habitat and increase the buffer between Shepard Road and the bluff.

Bluff Top Condition

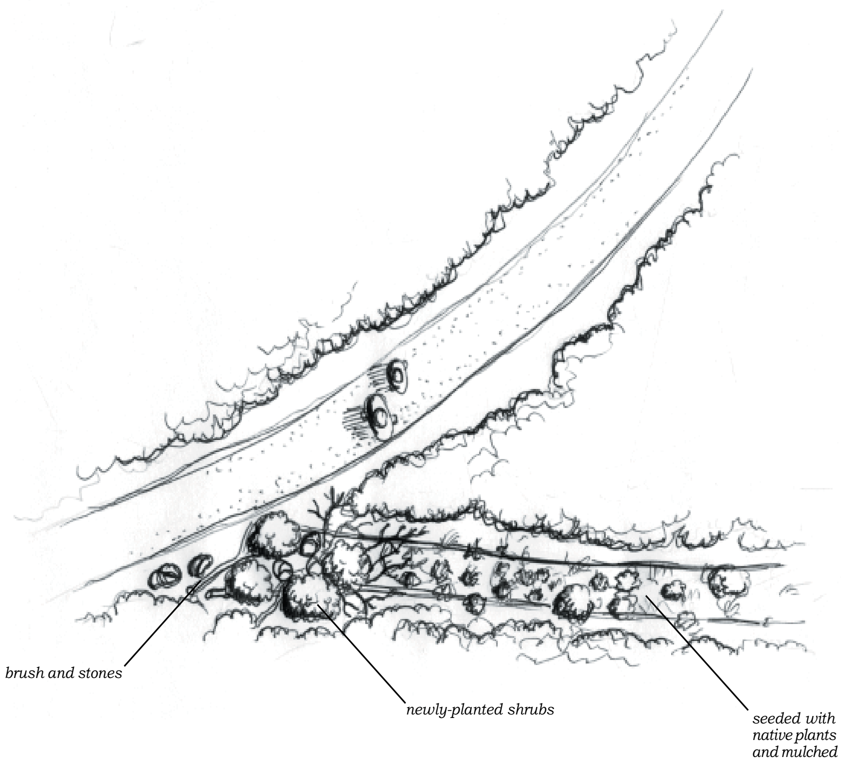
Many erosion problems along the bluff are due to stormwater runoff from the top of the bluff. Infiltrating stormwater at the top of the bluff would help alleviate this condition.

Detail #14: Infiltration Swale



Miscellaneous

Detail #15: Trail Closure



-A combination of shrubs, stone, and brush should be utilized to close trails.

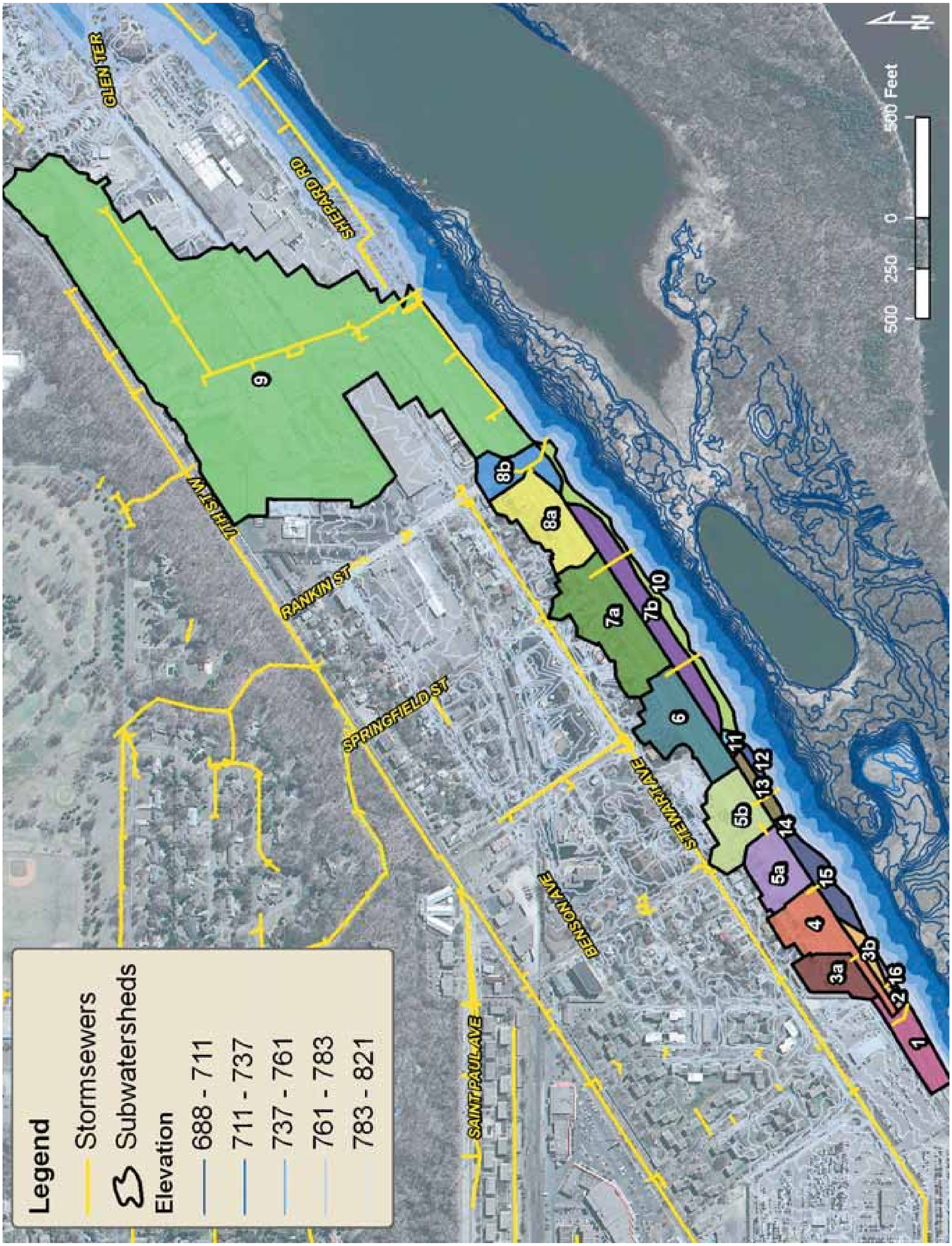
-Shrubs help camouflage trail openings and block access. Species with thorns, such as wild rose and native gooseberry, can be especially effective deterrents.

-Rock should be buried part way into the ground and will help deter walkers.

-Brush should be stacked near the entrance to the trail and will also camouflage the entrance to the trail and deter walkers.

-Trail surfaces should be lightly tilled and reseeded with a native seed mix suited to the site. The seeding should then be rolled with a lawn roller and mulched with clean straw. Erosion fabric should be used on slopes steeper than 4:1 (See Detail #7).

Figure 1


Legend
Stormsewers
Subwatersheds
Elevation
688 - 711
711 - 737
737 - 761
761 - 783
783 - 821
GLEN TER
SHEPARD RD
7TH ST W
RANKIN ST
SPRINGFIELD ST
STEWART AVE
BENSON AVE
SAINT PAUL AVE
9
8b
8a
7a
7b
10
6
11
12
13
5b
14
5a
15
4
3b
3a
16
2
1
500 250 0 500 Feet
N

APPENDIX H – Implementation Projects/Activities Cost Estimates

Memorandum

1800 Pioneer Creek Center, Maple Plain, MN 55359
Phone: 763-479-4200 Fax: 763-479-4242

To: Joe Bischoff, Wenck Associates, Inc.

From: Jeremy Schultz, Wenck Associates, Inc.

Date: June 1, 2011

Subject: Cost Estimate for Crosby Lake Watershed Improvement Projects

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Option 1 – Expansion of existing depression west of 35E and south of Shepard Road
Project not recommended.

Option 2 – Excavate a sedimentation basin along 35E

Option 2 - Excavate a Sedimentation Basin along 35E				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Mobilization	1	EA	$ 15,000	$ 15,000
Clearing and Grubbing	3	Acre	$ 5,000	$ 12,500
Excavation	13,550	Cu Yd	$ 15	$ 203,250
Erosion Control	1	EA	$ 15,000	$ 15,000
Contingencies	1	EA	20%	$ 49,150
Construction Cost	--	--	--	$ 294,900
Construction Management Services	1	EA	5%	$ 14,745
Design Fee	1	EA	20%	$ 58,980
Total Investment Cost				$368,625
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 2,000	$ 2,000
Annual Operation Costs				$ 2,000
Project Present Value				
Investment Cost				$ 368,625
Economic life	30	yr.		
Present Value of Annual Operating Costs over Lifetime				$ 36,784
Total Present Value				$ 405,409
Project Annual Cost				
Annual cost (annuity)				$ 22,000

Interest rate assumed for present value = 3.50%

Option 3 – St Paul Parks parking lots east of Crosby Lake
If constructed the project would have to meet all CRWD rules and costs would be the responsibility of the City of St. Paul.

Option 4 –Stormwater Diversion along Shepard Road

The construction cost estimates for these projects were determined for the Crosby Farm Park Bluff Stabilization / Restoration Feasibility Report. Project contingencies, annual operations and overhaul costs were added to the original construction costs in the tables below. For the stormwater diversion that would occur in subwatershed CR02 see the following cost estimate and corresponding figure.

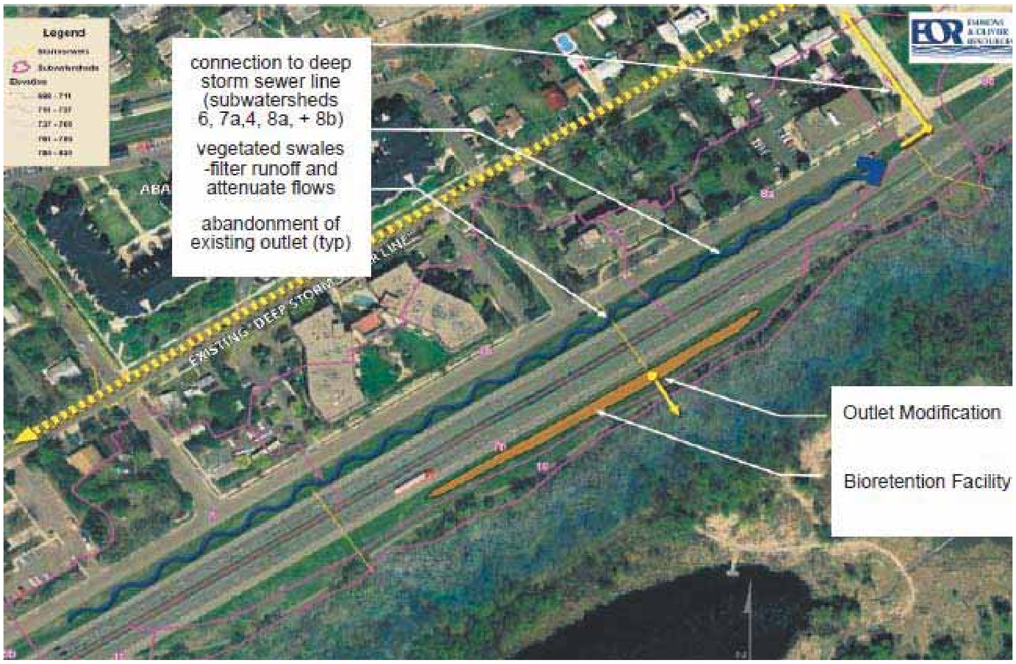
Option 4 - Stormwater Diversion along Shepard Road in Subwatershed CR02				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Ditch / Swale Improvements (Re-vegetation)	1.03	AC	$ 15,000	$ 15,450
Existing Outlet Standpipe Modifications	7	EA	$ 250	$ 1,750
Install Deep Sewer Outlet Piping 30" RCP	340	LF	$ 75	$ 25,500
Upgrade Alton Crossing 24" RCP	65	LF	$ 40	$ 2,600
24" Apron & Trash Guard	2	EA	$ 1,200	$ 2,400
Manhole	1	EA	$ 2,500	$ 2,500
Saw cut Pavement	827	LF	$ 2.5	$ 2,068
Removals	75	CY	$ 8	$ 600
Replace Paving & Base	440	SY	$ 12.6	$ 5,544
Contingencies	1	ea.	20%	$ 11,682
Construction Cost	--	--	--	$ 70,094
Construction Management Services	1	EA	5%	$ 3,505
Design Fee	1	EA	20%	$ 14,019
Total Investment Cost				$ 87,600
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,000	$ 1,000
Annual Operation Costs				$ 1,000
Overhaul Cost at 15 years				
Ditch / Swale Maintenance & Sediment Removal	1	EA	$ 5,000	$ 5,000
Pipe & Manhole Maintenance / Cleaning	1	EA	$ 2,000	$ 2,000
Replacement occurs at:	15	yr.		
Total replacement costs				$ 7,000
Project Present Value				
Investment Cost				$ 87,600
Economic life	30	yr.		
Present Value of 15 yr Replacement				$ 4,180
Present Value of Annual Operating Costs over Lifetime				$ 18,400
Total Present Value				$ 110,180
Project Annual Cost				
Annual cost (annuity)				$ 5,990

Interest rate assumed for present value = 3.50%

For the stormwater diversion that would occur in subwatershed CR04 the cost estimate and corresponding figure are provided below.

Option 4 - Stormwater Diversion along Shepard Road in Subwatershed CR04				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Ditch / Swale Improvements (Re-vegetation)	1.79	AC	$ 15,000	$ 26,850
Existing Outlet Standpipe Modifications	7	EA	$ 250	$ 1,750
Install Deep Sewer Outlet Piping 24" RCP	360	LF	$ 40	$ 14,400
Manhole	1	EA	$ 2,500	$ 2,500
24" Apron & Trash Guard	1	EA	$ 1,200	$ 1,200
Saw cut Pavement	754	LF	$ 2.5	$ 1,885
Removals	70	CY	$ 8.00	$ 560
Replace Paving & Base	410	SY	$ 13	$ 5,166
Contingencies	1	ea.	20%	$ 10,862
Construction Cost	--	--	--	$ 65,173
Construction Management Services	1	EA	5%	$ 3,259
Design Fee	1	EA	20%	$ 13,035
Total Investment Cost				$ 81,500
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,000	$ 1,000
Annual Operation Costs				$ 1,000
Overhaul Cost at 15 years				
Ditch / Swale Maintenance & Sediment Removal	1	EA	$ 5,000	$ 5,000
Pipe & Manhole Maintenance / Cleaning	1	EA	$ 2,000	$ 2,000
Replacement occurs at:	15	yr.		
Total replacement costs				$ 7,000
Project Present Value				
Investment Cost				$ 81,500
Economic life	30	yr.		
Present Value of 15 yr Replacement				$ 4,180
Present Value of Annual Operating Costs over Lifetime				$ 18,400
Total Present Value				$ 104,080
Project Annual Cost				
Annual cost (annuity)				$ 5,660

Interest rate assumed for present value = 3.50%



For the stormwater diversion that would occur in subwatershed CR06 the cost estimate and corresponding figure are provided below.

Option 4 - Stormwater Diversion along Shepard Road in Subwatershed CR06				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Ditch / Swale Improvements (Re-vegetation)	1.315	AC	$ 15,000	$ 19,725
Existing Outlet Standpipe Modifications	1	EA	$ 250	$ 250
Contingencies	1	ea.	20%	$ 3,995
Construction Cost	--	--	--	$ 23,970
Construction Management Services	1	EA	5%	$ 1,199
Design Fee	1	EA	20%	$ 4,794
Total Investment Cost				$ 30,000
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,000	$ 1,000
Annual Operation Costs				$ 1,000
Overhaul Cost at 15 years				
Ditch / Swale Maintenance & Sediment Removal	1	EA	$ 5,000	$ 5,000
Pipe Maintenance / Cleaning	1	EA	$ 1,000	$ 1,000
Replacement occurs at:	15	yr.		
Total replacement costs				$ 6,000
Project Present Value				
Investment Cost				$ 30,000
Economic life	30	yr.		
Present Value of 15 yr Replacement				$ 3,580
Present Value of Annual Operating Costs over Lifetime				$ 18,400
Total Present Value				$ 51,980
Project Annual Cost				
Annual cost (annuity)				$ 2,830

Interest rate assumed for present value = 3.50%

Option 5 - St Paul Parks parking lot reconstruction west of Crosby Lake

Based on similar recently constructed projects the cost of design and construction is approximately $20 / square foot.

Option 5 - St. Paul Parks Parking Lot Reconstruction West of Crosby Lake				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Rain Garden	5,000	SF	$ 20	$ 100,000
Contingencies	1	EA	20%	$ 20,000
Construction Cost	1	EA	--	$ 120,000
Total Investment Cost				$ 120,000
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,500	$ 1,500
Annual Operation Costs				$ 1,500
Overhaul Cost at 15 years				
Maintenance & Plant Replacement	2,500	SF	$ 20	$ 50,000
Replacement occurs at:	15	yr.		
Total replacement costs				$ 50,000
Project Present Value				
Investment Cost				$ 120,000
Economic life	30	yr.		
Present Value of 10 yr Replacement				$ 29,800
Present Value of Annual Operating Costs over Lifetime				$ 27,600
Total Present Value				$ 177,400
Project Annual Cost				
Annual cost (annuity)				$ 9,650

Interest rate assumed for present value = 3.50%

Option 6 – Infiltration basin expansion along 7th Street

Option 6 - Infiltration Basin Expansion along 7th Street				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Mobilization	1	EA	$ 5,000	$ 5,000
Clearing and Grubbing	1	Acre	$ 5,000	$ 5,000
Excavation	3,875	Cu Yd	$ 15	$ 58,125
Erosion Control	1	EA	$ 10,000	$ 10,000
Contingencies	1	EA	20%	$ 15,625
Construction Cost	--	--	--	$ 93,750
Construction Management Services	1	EA	5%	$ 4,688
Design Fee	1	EA	20%	$ 18,750
Total Investment Cost				$ 117,000
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,000	$ 1,000
Annual Operation Costs				$ 1,000
Overhaul Cost at 15 years				
Maintenance & Plant Replacement	1.0	EA	$ 25,000	$ 25,000
Replacement occurs at:	15	yr.		
Total replacement costs				$ 25,000
Project Present Value				
Investment Cost				$ 117,000
Economic life	30	yr.		
Present Value of 15 yr Replacement				$ 14,900
Present Value of Annual Operating Costs over Lifetime				$ 18,400
Total Present Value				$ 150,300
Project Annual Cost				
Annual cost (annuity)				$ 8,170

Interest rate assumed for present value = 3.50%

Option 7 – Infiltration basin at the NE corner of Elway and Shepard
Project not recommended.

Option 8 – Stormsewer diversion to underground infiltration
Project not recommended.

Option 9 – Highland Creek Bank Stabilization Site 1
Based on similar recently constructed projects the cost of construction is approximately$115 per linear foot. Project length is estimated.

Option 9 -Highland Creek Bank Stabilization Site 1				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Bank Stabilization	300	LF	$ 115	$ 34,500
Contingencies	1	EA	20%	$ 6,900
Subtotal, Construction	--	--	--	$ 41,400
Construction Management Services	1	EA	5%	$ 2,070
Design Fee	1	EA	20%	$ 8,280
Total Investment Cost				$ 51,750
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 500	$ 500
Annual Operation Costs				$ 500
Overhaul Cost at 10 years				
Bank Repairs	1	EA	$ 5,000	$ 5,000
Replacement occurs at:	10	yr.		
Replacement occurs at:	20	yr.		
Total replacement costs				$ 5,000
Project Present Value				
Investment Cost				$ 51,750
Economic life	30	yr.		
Present Value of 10 yr Replacement				$ 3,540
Present Value of 20 yr Replacement				$ 2,510
Present Value of Annual Operating Costs over Lifetime				$ 9,200
Total Present Value				$ 67,000
Project Annual Cost				
Annual cost (annuity)				$ 3,640

Interest rate assumed for present value = 3.50%

Option 10 – Highland Creek Bank Stabilization Site 2

Based on similar recently constructed projects the cost of construction is approximately$115 per linear foot. Project length is estimated.

Option 10 -Highland Creek Bank Stabilization Site 2				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Bank Stabilization	325	LF	$ 115	$ 37,375
Contingencies	1	ea.	20%	$ 7,475
Subtotal, Construction	--	--	--	$ 44,850
Construction Management Services	1	EA	5%	$ 2,243
Design Fee	1	EA	20%	$ 8,970
Total Investment Cost				$ 56,100
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 500	$ 500
Annual Operation Costs				$ 500
Overhaul Cost at 10 years				
Bank Repairs	1	EA	$ 5,000	$ 5,000
Replacement occurs at:	10	yr.		
Replacement occurs at:	20	yr.		
Total replacement costs				$ 5,000
Project Present Value				
Investment Cost				$ 56,100
Economic life	30	yr.		
Present Value of 10 yr Replacement				$ 3,540
Present Value of 20 yr Replacement				$ 2,510
Present Value of Annual Operating Costs over Lifetime				$ 9,200
Total Present Value				$ 71,350
Project Annual Cost				
Annual cost (annuity)				$ 3,880

Interest rate assumed for present value = 3.50%

Option 11 – Griggs / Scheffer Residential Street Vitality Program

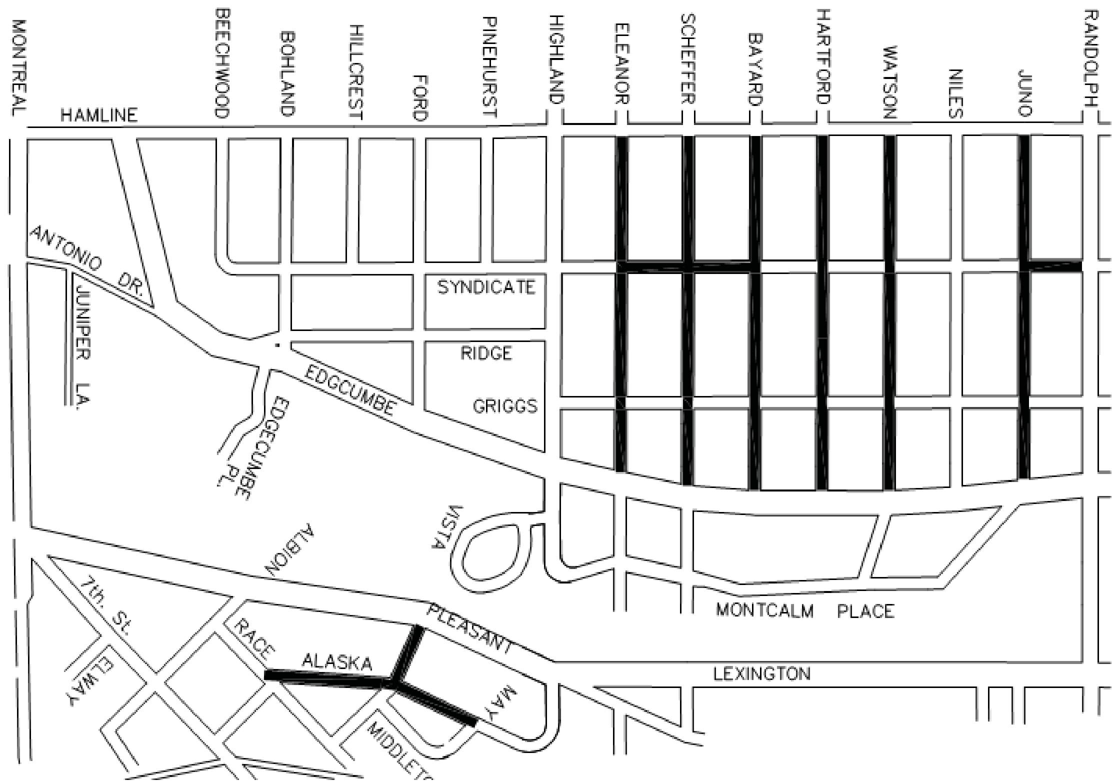
The CRWD has established a cost cap for linear projects of $30,000 per acre of impervious surface. It was assumed that this cap would be reached in determining the cost estimate of the project.

Option 11 - Grigg / Scheffer Residential Street Vitality Program				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
LID Green Infrastructure (CRWD cap on cost for volume reduction is $30,000)	8.75	AC	$ 30,000	$ 262,500
Total Investment Cost				$ 262,500
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,500	$ 1,500
Annual Operation Costs				$ 1,500
Overhaul Cost at 10 years				
Green Infrastructure Repairs	8.75	EA	$ 6,000	$ 52,500
Replacement occurs at:	10	yr.		
Replacement occurs at:	20	yr.		
Total replacement costs				$ 52,500
Project Present Value				
Investment Cost				$ 262,500
Economic life	30	yr.		
Present Value of 10 yr Replacement				$ 37,200
Present Value of 20 yr Replacement				$ 26,400
Present Value of Annual Operating Costs over Lifetime				$ 27,600
Total Present Value				$ 353,700
Project Annual Cost				
Annual cost (annuity)				$ 19,200

Interest rate assumed for present value = 3.50%

Note:
Costs shown above do not include roadway repairs

A map produced by the City of Saint Paul Department of Public Works is shown below. The highlighted segments are proposed to be reconstructed in 2012.



Option 12 – Madison / Benson Residential Street Vitality Program

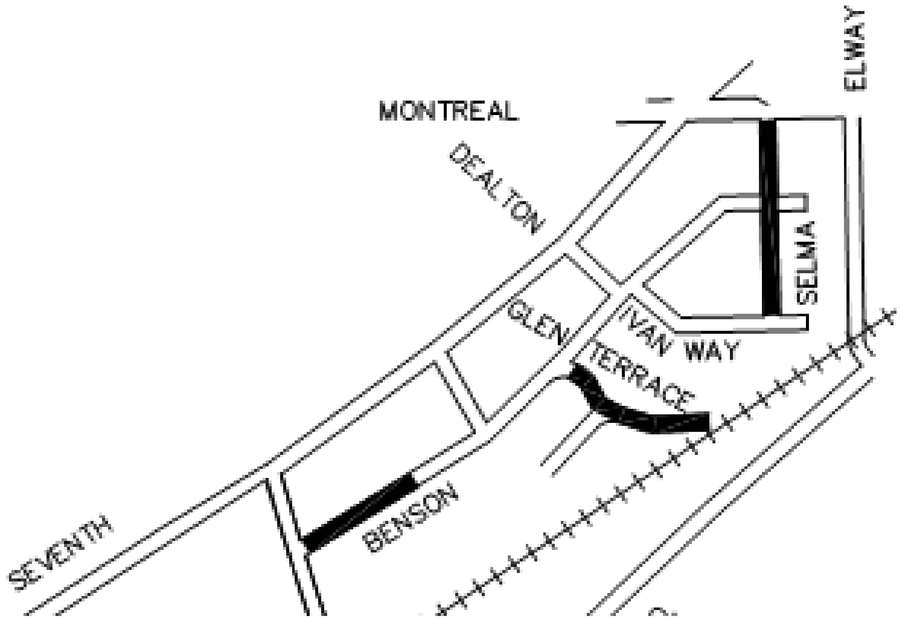
The CRWD has established a cost cap for linear projects of $30,000 per acre of impervious surface. It was assumed that this cap would be reached in determining the cost estimate of the project.

Option 12 - Madison / Benson Residential Street Vitality Program				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
LID Green Infrastructure (CRWD cap on cost for volume reduction is $30,000)	1.10	AC	$ 30,000	$ 33,000
Total Investment Cost				$ 33,000
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,500	$ 1,500
Annual Operation Costs				$ 1,500
Overhaul Cost at 10 years				
Green Infrastructure Repairs	1.10	EA	$ 6,000	$ 6,600
Replacement occurs at:	10	yr.		
Replacement occurs at:	20	yr.		
Total replacement costs				$ 6,600
Project Present Value				
Investment Cost				$ 33,000
Economic life	30	yr.		
Present Value of 10 yr Replacement				$ 4,680
Present Value of 20 yr Replacement				$ 3,320
Present Value of Annual Operating Costs over Lifetime				$ 27,600
Total Present Value				$ 68,600
Project Annual Cost				
Annual cost (annuity)				$ 3,730

Interest rate assumed for present value = 3.50%

Note:
Costs shown above do not include roadway repairs

A map produced by the City of Saint Paul Department of Public Works is shown below. The highlighted segments are proposed to be reconstructed in 2012.



Option 13 - Fairview / Bohland Residential Street Vitality Program
This project was originally considered but was found to be outside of the Crosby Lake Watershed District.

Option 14 - Golf course stormwater and fertilizer management

Option 15 – Long term open space and forest protection

Option 16 – Shepard Road Low Impact Development
During street reconstruction low impact development infrastructure could be implemented to meet the District's rules. Green space is not available alongside the road or bike trail for infiltration practices.

Option 17 – Education and Outreach

Option 18 - Street Sweeping

Estimated Cost: $100,000 to 200,000 per new sweeper, $65-85 per mile of operation and maintenance.

Option 19 –Bluff protection

The costs associated with this project are based on recent bids of similar projects. The total length of this project is estimated to be 1750 feet (7 ravines, 250 feet each).

Option 19 - Bluff Protection				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Bank Stabilization	1,750	LF	$ 115	$ 201,250
Contingencies	1	ea.	20%	$ 40,250
Subtotal, Construction	--	--	--	$ 241,500
Construction Management Services	1	EA	5%	$ 12,075
Design Fee	1	EA	20%	$ 48,300
Total Investment Cost				$301,875
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 500	$ 2,000
Annual Operation Costs				$ 2,000
Overhaul Cost at 10 years				
Bank Repairs	1	EA	$ 30,000	$ 30,000
Replacement occurs at:	10	yr.		
Replacement occurs at:	20	yr.		
Total replacement costs				$ 30,000
Project Present Value				
Investment Cost				$ 301,875
Economic life	30	yr.		
Present Value of 10 yr Replacement				$ 21,300
Present Value of 20 yr Replacement				$ 15,100
Present Value of Annual Operating Costs over Lifetime				$ 36,800
Total Present Value				$ 375,075
Project Annual Cost				
Annual cost (annuity)				$ 20,400

Interest rate assumed for present valu 3.50%

Option 20 –Bioinfiltration areas

The cost estimate for this project was determined for the Crosby Farm Park Bluff Stabilization / Restoration Feasibility Report.

Option 20 - Bio-Infiltration Areas				
Item	**Quantity**	**Unit**	**Unit Cost**	**Cost**
Investment Cost Estimate				
Bio-Infiltration Areas	683	SY	$ 45	$ 30,731
Contingencies	1	EA	20%	$ 6,146
Subtotal, Construction	--	--	--	$ 36,877
Construction Management Services	1	EA	5%	$ 1,844
Design Fee	1	EA	20%	$ 7,375
Total Investment Cost				$ 46,096
Annual Operating Cost				
Annual Operation & Maintenance	1	EA	$ 1,000	$ 1,000
Annual Operation Costs				$ 1,000
Overhaul Cost at 15 years				
Bank Repairs	340	EA	$ 45	$ 15,300
Replacement occurs at:	15	yr.		
Total replacement costs				$ 15,300
Project Present Value				
Investment Cost				$ 46,096
Economic life	30	yr.		
Present Value of 15 yr Replacement				$ 9,130
Present Value of Annual Operating Costs over Lifetime				$ 18,400
Total Present Value				$ 73,626
Project Annual Cost				
Annual cost (annuity)				$ 4,000

Interest rate assumed for present value : 3.50%

Locations of the bioinfiltration areas are shown below.