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

Feasibility Report 08/07/2007

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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:

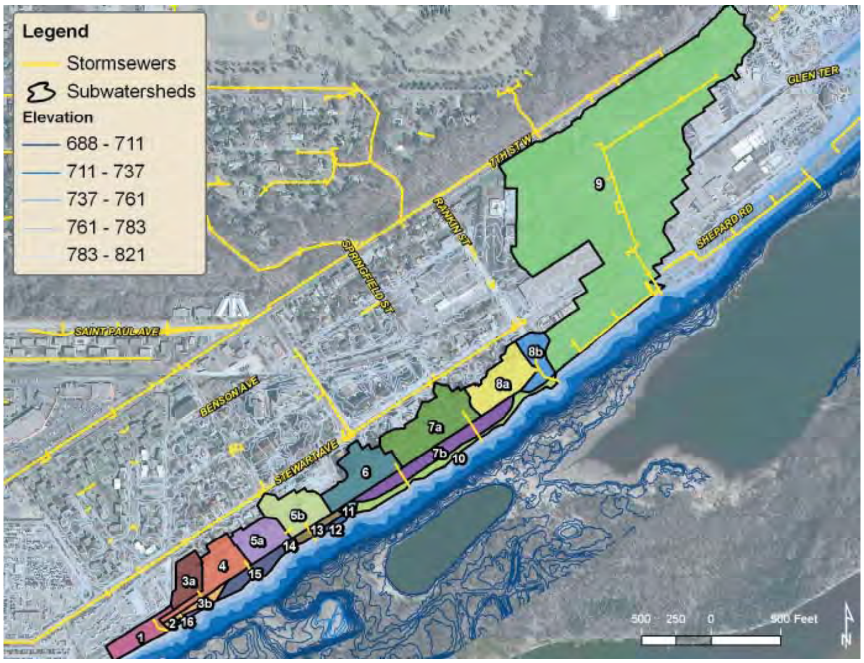
1.5-year	24-hour (2.5 inches)
2-year	24-hour (2.8 inches)
5-year	24-hour (3.6 inches)
10-year	24-hour (4.2 inches)
25-year	24-hour (4.8 inches)
50-year	24-hour (5.4 inches)
100-year	24-hour (6.0 inches)

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) Total Runoff Depth (in)	Max Flow (cfs)	Total Runoff Volume (ac-ft)	Total Runoff Volume (cu-ft)	50-yr 24-hr (5.4 inches) Total Runoff Depth (in)	Max Flow (cfs)	Total Runoff Volume (ac-ft)	Total Runoff Volume (cu-ft)	100-yr 24-hr (6.0 inches) 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

[redacted]	[redacted]												
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
[redacted]	[redacted]												
DISCHARGE OVER BLUFF	Pipe		Pipe	Pipe	Overland	Pipe	Pipe		Pipe	Pipe		Pipe	
[redacted]	[redacted]		[redacted]							[redacted]		[redacted]	
[redacted] ACTIVE EROSION SEVERITY	High		Medium	High		High	High		High	Very High		Extreme	
[redacted]	[redacted]		[redacted]							[redacted]		[redacted]	
POTENTIAL PARK INFRASTRUCTURE LOSS	Low		Low	Low		Low	Low		Low	High		Medium	
[redacted]	[redacted]		[redacted]							[redacted]		[redacted]	
PRIORITY (1-Low to 4-High)	2	1	1	2	1	1	2	2	2	3	3	3	3

[redacted]	[redacted]												
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
[redacted]	[redacted]												
DISCHARGE OVER BLUFF	Pipe						Overland	Overland	Overland	Overland	Pipe	Overland	Overland
[redacted]	[redacted]												
[redacted] ACTIVE EROSION SEVERITY	Extreme						Medium	Medium	Low	Medium	Medium	Medium	Low
[redacted]	[redacted]						[redacted]						
POTENTIAL PARK INFRASTRUCTURE LOSS	Medium						Low	Low	Low	Medium	Low	Low	Low
[redacted]	[redacted]						[redacted]						
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.

Option 1 – (Figure 2)

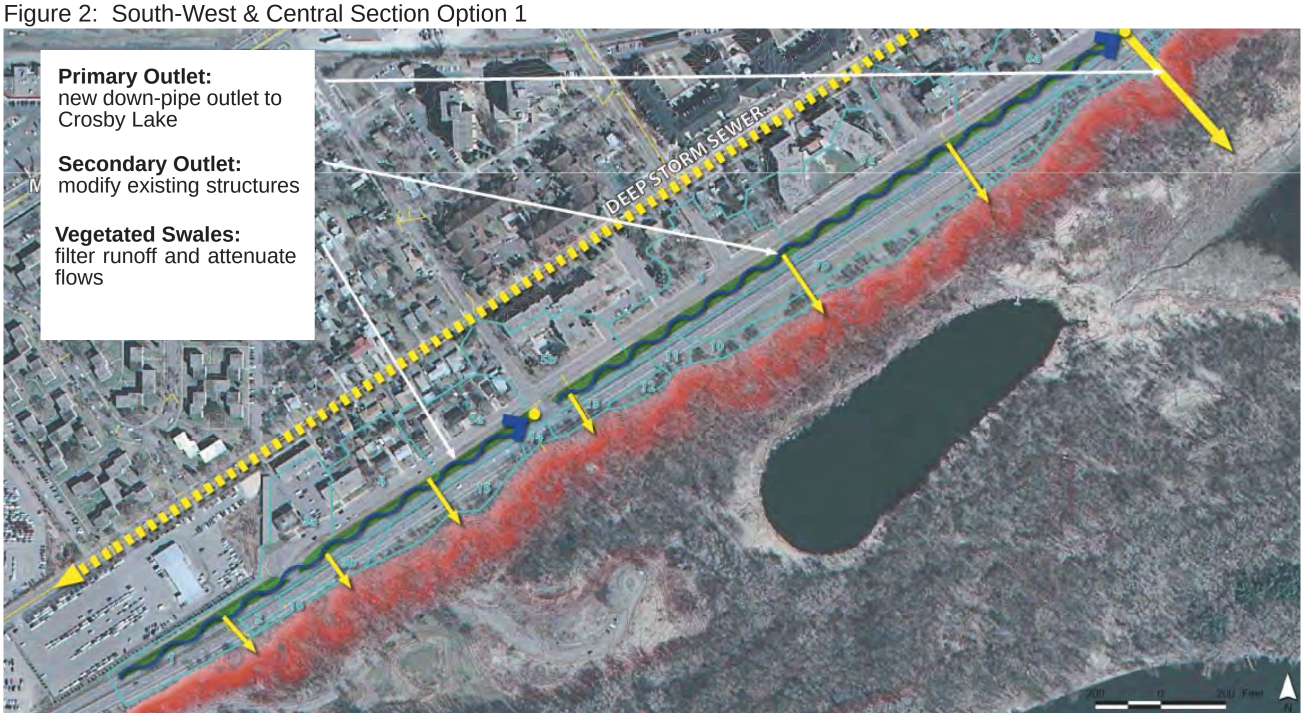
Existing ditch section along Youngman Ave. would be maintained and the outlets would all be fitted with two-stage or perforated standpipe (height approx. 1.5 feet) control structures. This scenario would utilize the existing pipes to continue discharging over the bluff.

- ► 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

			Existing Conditions		Option 1 *	
Rain Event	**Subwatershed**	**Pipe Name**	**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)

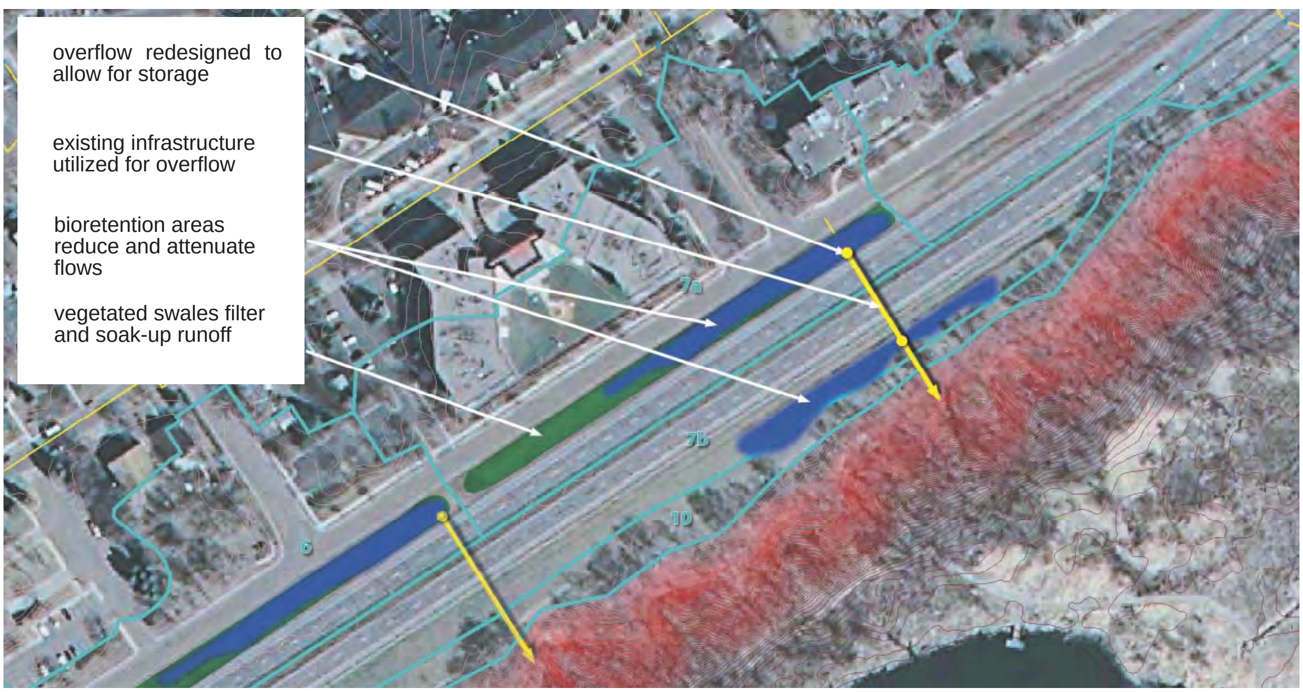
Ditch section along Youngman Ave. is slightly re-graded to bypass the existing outlets and utilize only two of the outlets as illustrated in Figure 2. Existing outlets would be fitted with 2-stage control structures (approx. height 1.5 feet). Secondary flows discharge via existing pipes to bluff.

- 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)

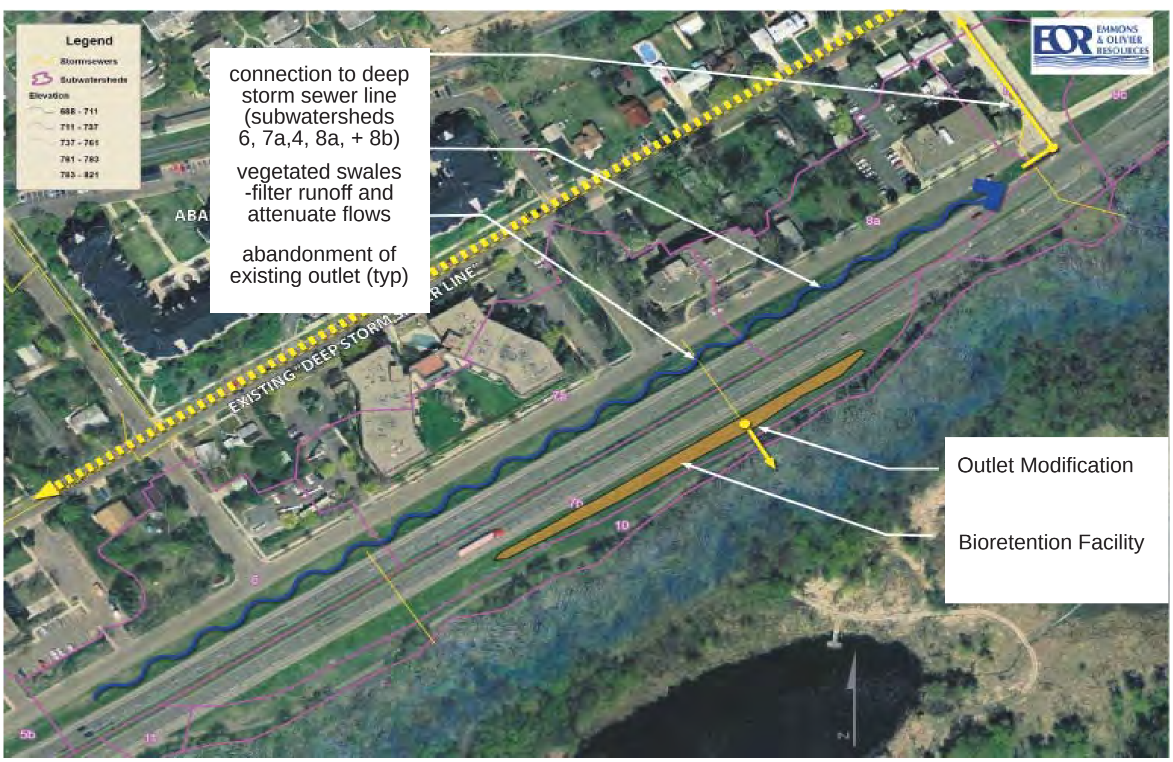
Table 8: Central Area Cost Estimate

	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)

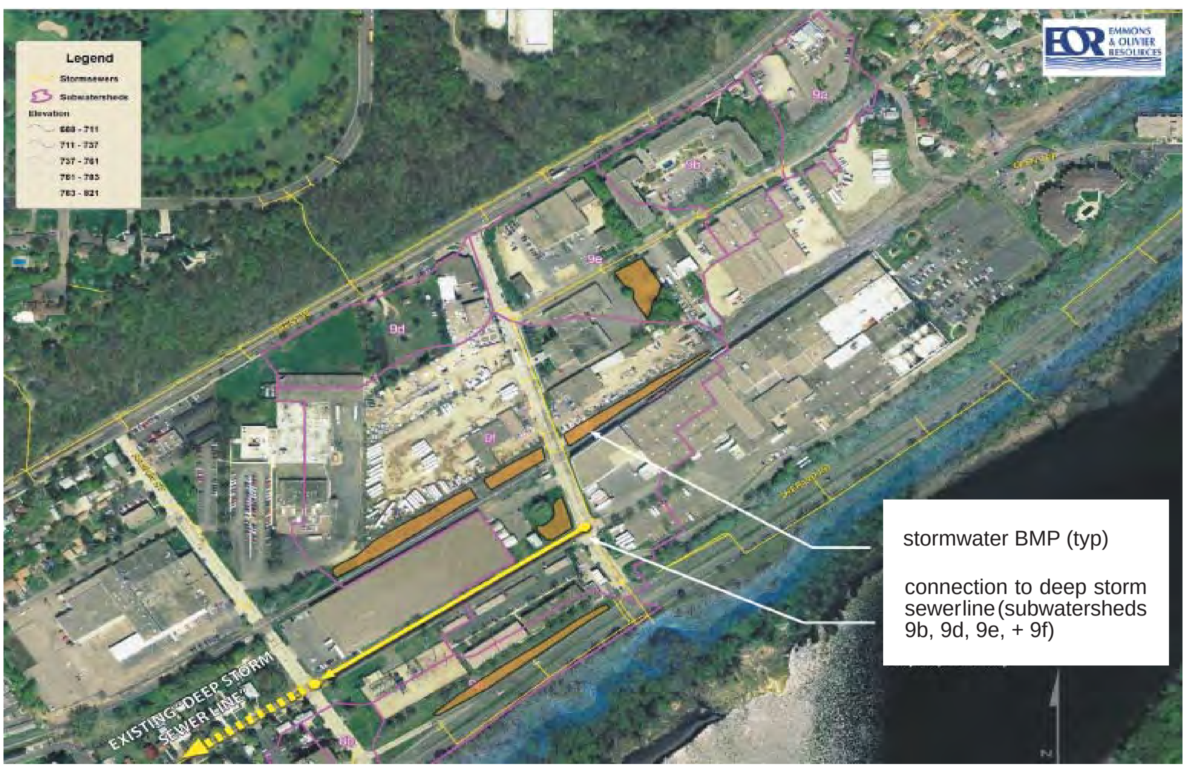
Table 9: North-East Area Cost Estimate

	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.

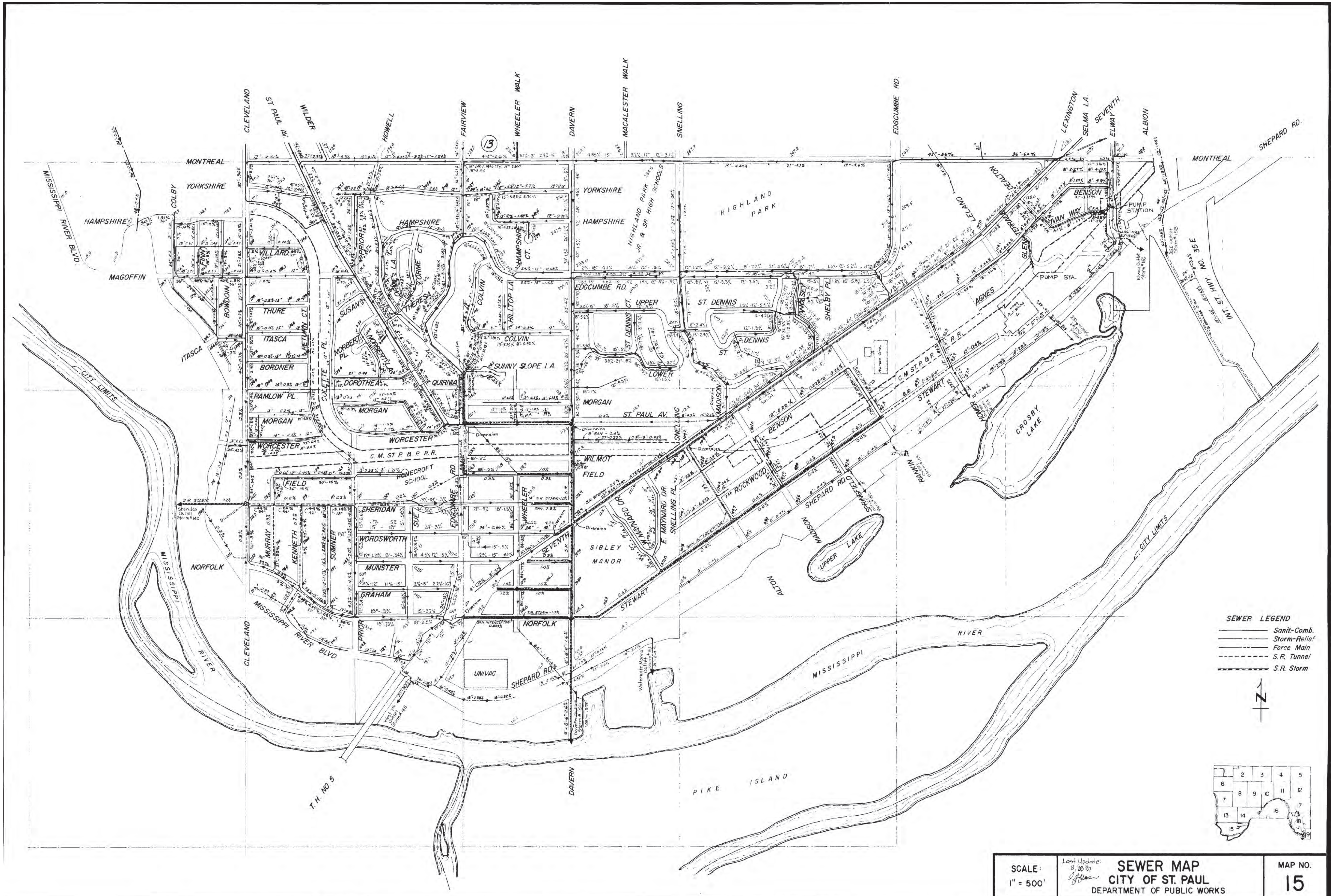
List of Appendices

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



CLEVELAND
ST. PAUL AV.
WILDER
HOWELL
FAIRVIEW
WHEELER WALK
DAVERN
MACALESTER WALK
SNELLING
EDGCUMBE RD.
LEXINGTON
SELMA LA.
SEVENTH
ELWAY
ALBION
SHEPARD RD.
MONTREAL
YORKSHIRE
HAMPSHIRE
MISSISSIPPI RIVER BLVD.
COLBY
MAGOFFIN
FINN
VILLARD
BOWDOIN
THURE
ITASCA
BORDNER
RAMLOW PL.
MORGAN
WORCESTER
FIELD
CULLIGAN PL.
NORBERT PL.
SUSAN
THERESA
ORME CT.
DOROTHEA
QUIRNIA
SUNNY SLOPE LA.
COLVIN
HILLTOP LA.
HAMPSHIRE CT.
HIGHLAND PARK
HIGHLAND PARK JR. & SR. HIGH SCHOOLS
EDGCUMBE RD.
ST. DENNIS
UPPER ST. DENNIS CT.
LOWER
SHELBY PL.
MADISON
ST. PAUL AV.
BENSON
WILMOT FIELD
ROCKWOOD
SNELLING PL.
E. MAYNARD DR.
W. MAYNARD DR.
SIBLEY MANOR
STEWART
ALTON
SPRINGFIELD
UPPER LAKE
CROSBY LAKE
RANKIN
HOMER
LELAND
DEALTON
GLEN TERRACE
AGNES
IVAN WAY
BENSON
PUMP STATION
PUMP STA.
C.M. ST. P. & P. R.R.
HOMECROFT SCHOOL
SHERIDAN
SUE
EDGCUMBE RD.
WHEELER
WORDSWORTH
MUNSTER
GRAHAM
MURRAY
KENNETH
SUMNER
PRIOR
NORFOLK
UNIVAC
MISSISSIPPI RIVER
CITY LIMITS
T.H. NO. 5
PIKE ISLAND
INT. ST. HWY. NO. 35E
Sheridan Outlet Storm #140
SEWER LEGEND
Sanit.-Comb.
Storm-Relief
Force Main
S.R. Tunnel
S.R. Storm
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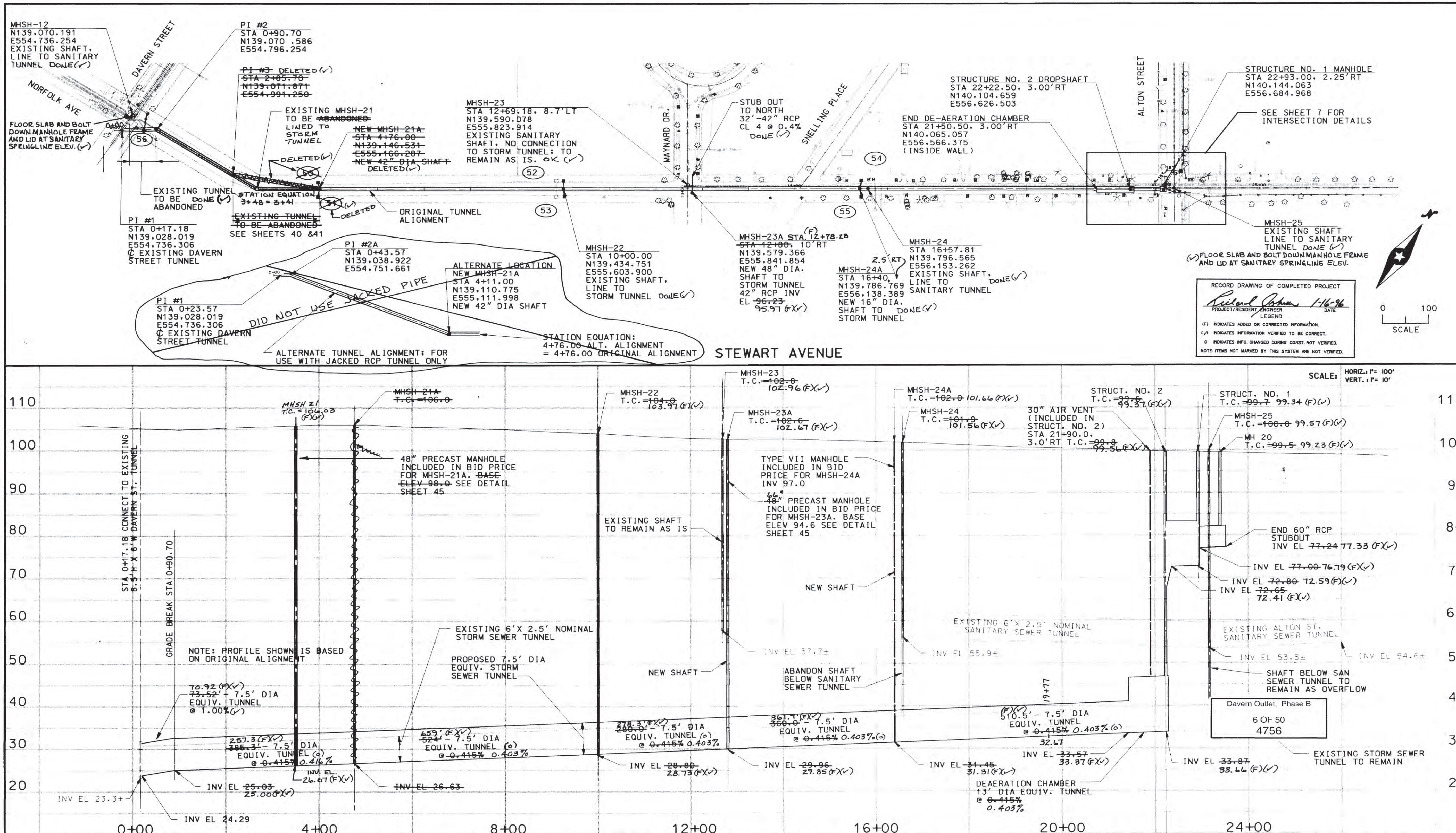
SCALE: 1" = 500'
Last Update
SEWER MAP
CITY OF ST. PAUL
DEPARTMENT OF PUBLIC WORKS
MAP NO.
15



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		- -			0 ——— 1"	
SEWER DR. NO. 11 DRWG. NO 5355		- -			IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY	CHK PWB
	NO.	DATE	BY	REVISION		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
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DATE 8-8-94
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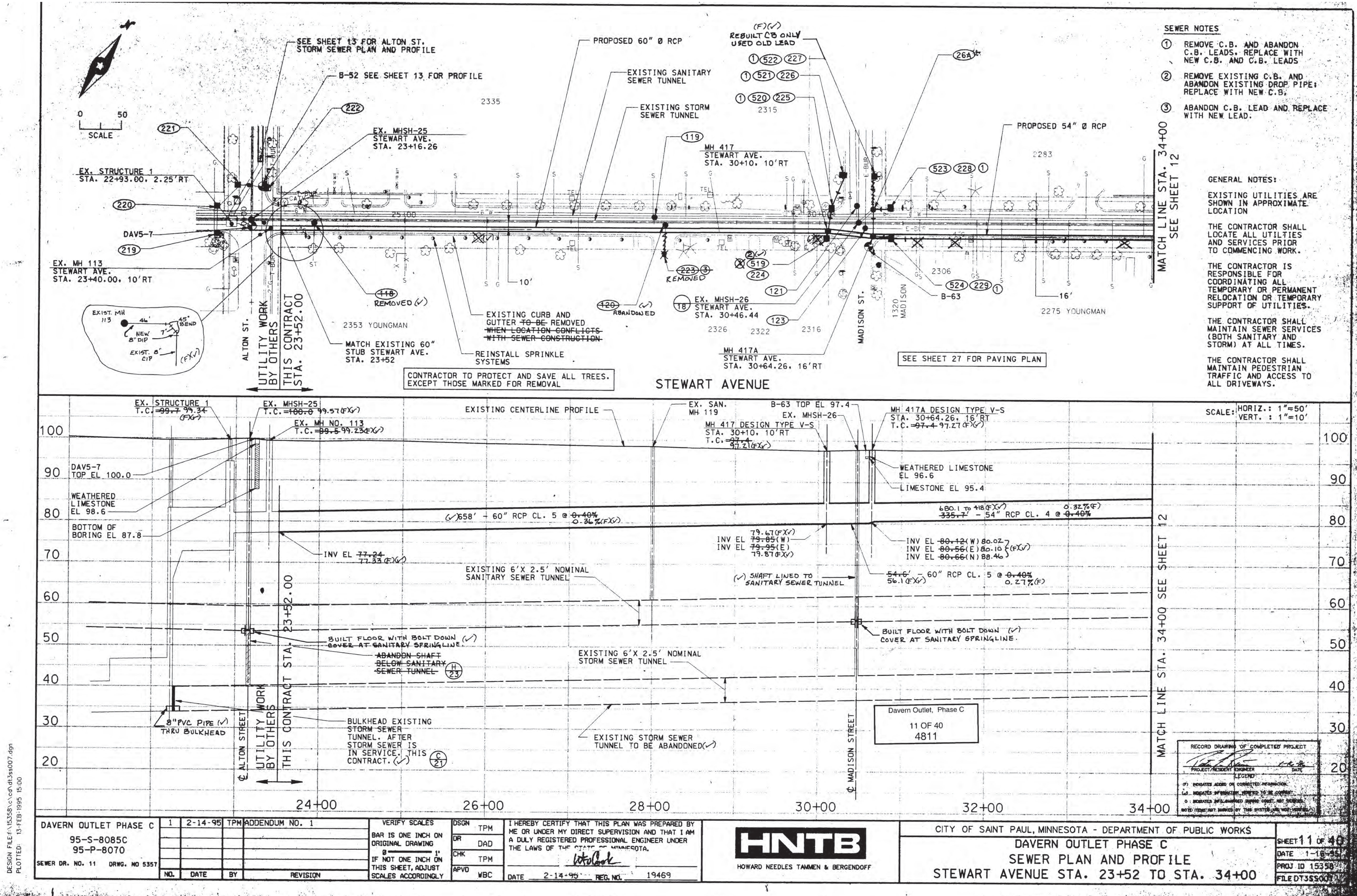
FILE DT2TU001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B-52 SEE SHEET 13 FOR PROFILE
PROPOSED 60" Ø RCP
EXISTING SANITARY SEWER TUNNEL
EXISTING STORM SEWER TUNNEL
(F)(✓) REBUILT CB ONLY USED OLD LEAD
SEWER NOTES
1 REMOVE C.B. AND ABANDON C.B. LEADS. REPLACE WITH NEW C.B. AND C.B. LEADS
2 REMOVE EXISTING C.B. AND ABANDON EXISTING DROP PIPE; REPLACE WITH NEW C.B.
3 ABANDON C.B. LEAD AND REPLACE WITH NEW LEAD.
0 50 SCALE
EX. MHSH-25 STEWART AVE. STA. 23+16.26
EX. STRUCTURE 1 STA. 22+93.00, 2.25'RT
MH 417 STEWART AVE. STA. 30+10, 10'RT
PROPOSED 54" Ø RCP
MATCH LINE STA. 34+00 SEE SHEET 12
GENERAL NOTES:
EXISTING UTILITIES ARE SHOWN IN APPROXIMATE LOCATION
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 SERVICES (BOTH SANITARY AND STORM) AT ALL TIMES.
THE CONTRACTOR SHALL MAINTAIN PEDESTRIAN TRAFFIC AND ACCESS TO ALL DRIVEWAYS.
DAV5-7
EX. MH 113 STEWART AVE. STA. 23+40.00, 10'RT
EXISTING CURB AND GUTTER TO BE REMOVED WHEN LOCATION CONFLICTS WITH SEWER CONSTRUCTION
EX. MHSH-26 STEWART AVE. STA. 30+46.44
MH 417A STEWART AVE. STA. 30+64.26, 16'RT
MATCH EXISTING 60" STUB STEWART AVE. STA. 23+52
REINSTALL SPRINKLE SYSTEMS
CONTRACTOR TO PROTECT AND SAVE ALL TREES. EXCEPT THOSE MARKED FOR REMOVAL
SEE SHEET 27 FOR PAVING PLAN
2353 YOUNGMAN
2275 YOUNGMAN
ALTON ST.
MADISON ST.
UTILITY WORK BY OTHERS
THIS CONTRACT STA. 23+52.00
STEWART AVENUE
EX. STRUCTURE 1 T.C. 99.34 (FX✓)
EX. MHSH-25 T.C. 99.57 (FX✓)
EX. MH NO. 113 T.C. 99.23 (FX✓)
EXISTING CENTERLINE PROFILE
EX. SAN. MH 119
B-63 TOP EL 97.4
EX. MHSH-26
MH 417 DESIGN TYPE V-S STA. 30+10, 10'RT T.C. 97.21 (FX✓)
MH 417A DESIGN TYPE V-S STA. 30+64.26, 16'RT T.C. 97.27 (FX✓)
SCALE: HORIZ.: 1"=50' VERT. : 1"=10'
DAV5-7 TOP EL 100.0
WEATHERED LIMESTONE EL 98.6
BOTTOM OF BORING EL 87.8
WEATHERED LIMESTONE EL 96.6
LIMESTONE EL 95.4
(✓) 658' - 60" RCP CL. 5 @ 0.36% (FX✓)
680.1 - 54" RCP CL. 4 @ 0.32% (F)
INV EL 77.33 (FX✓)
INV EL 79.67 (W) INV EL 79.87 (E)
INV EL 80.02 (W) INV EL 80.10 (E) INV EL 88.46 (N)
EXISTING 6'X 2.5' NOMINAL SANITARY SEWER TUNNEL
(✓) SHAFT LINED TO SANITARY SEWER TUNNEL
56.1 (FX✓) - 60" RCP CL. 5 @ 0.27% (F)
BUILT FLOOR WITH BOLT DOWN (✓) COVER AT SANITARY SPRINGLINE
ABANDON SHAFT BELOW SANITARY SEWER TUNNEL
EXISTING 6'X 2.5' NOMINAL STORM SEWER TUNNEL
8" PVC PIPE (✓) THRU BULKHEAD
BULKHEAD EXISTING STORM SEWER TUNNEL. AFTER STORM SEWER IS IN SERVICE. THIS CONTRACT. (✓)
EXISTING STORM SEWER TUNNEL TO BE ABANDONED (✓)
Davern Outlet, Phase C
11 OF 40
4811
RECORD DRAWING OF COMPLETED PROJECT
24+00
26+00
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30+00
32+00
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DAVERN OUTLET PHASE C
95-S-8085C
95-P-8070
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NO. DATE BY REVISION
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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
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CITY OF SAINT PAUL, MINNESOTA - DEPARTMENT OF PUBLIC WORKS
DAVERN OUTLET PHASE C
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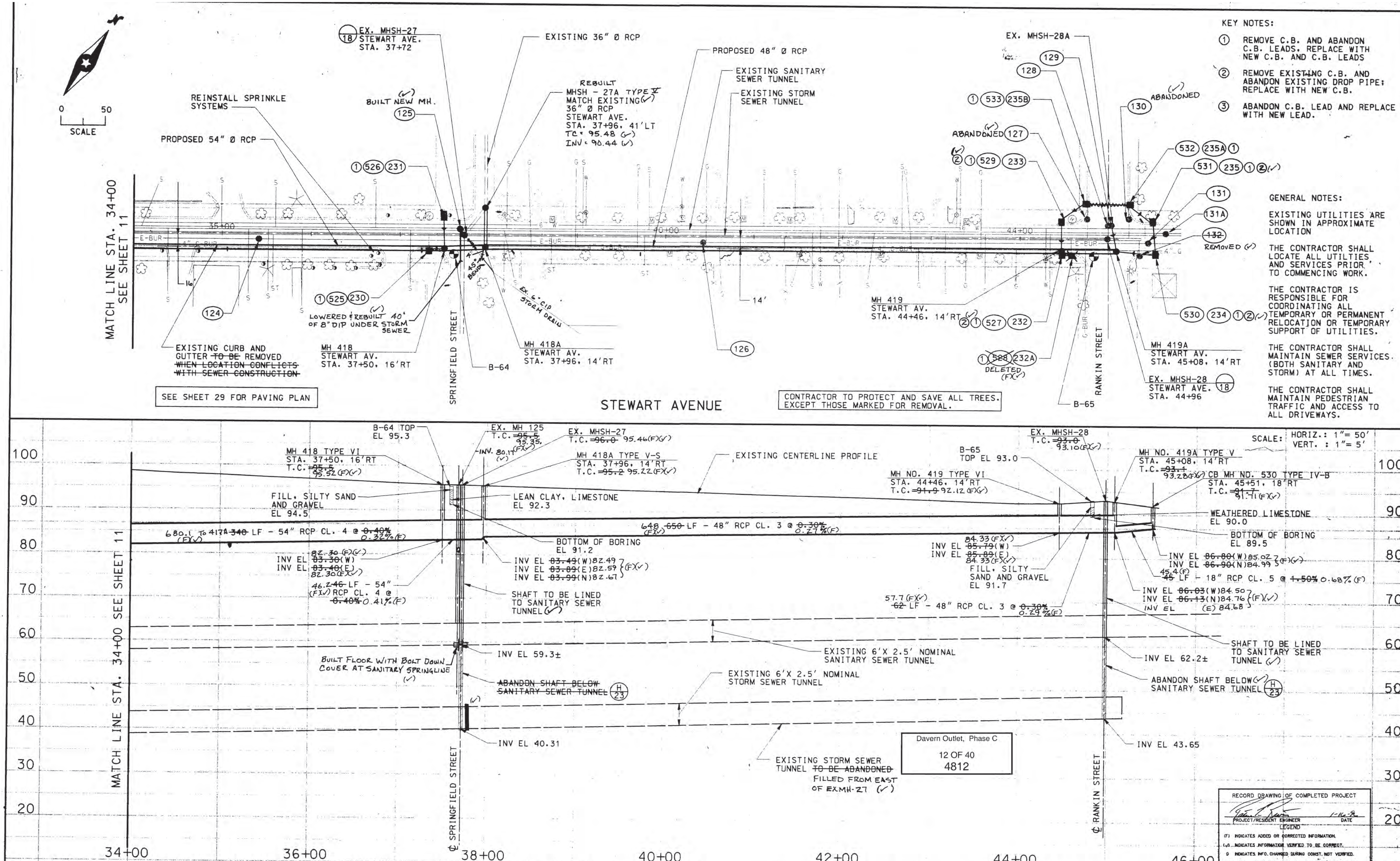

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DSGN TPM | DR DAD | CHK TPM | APVD WBC

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

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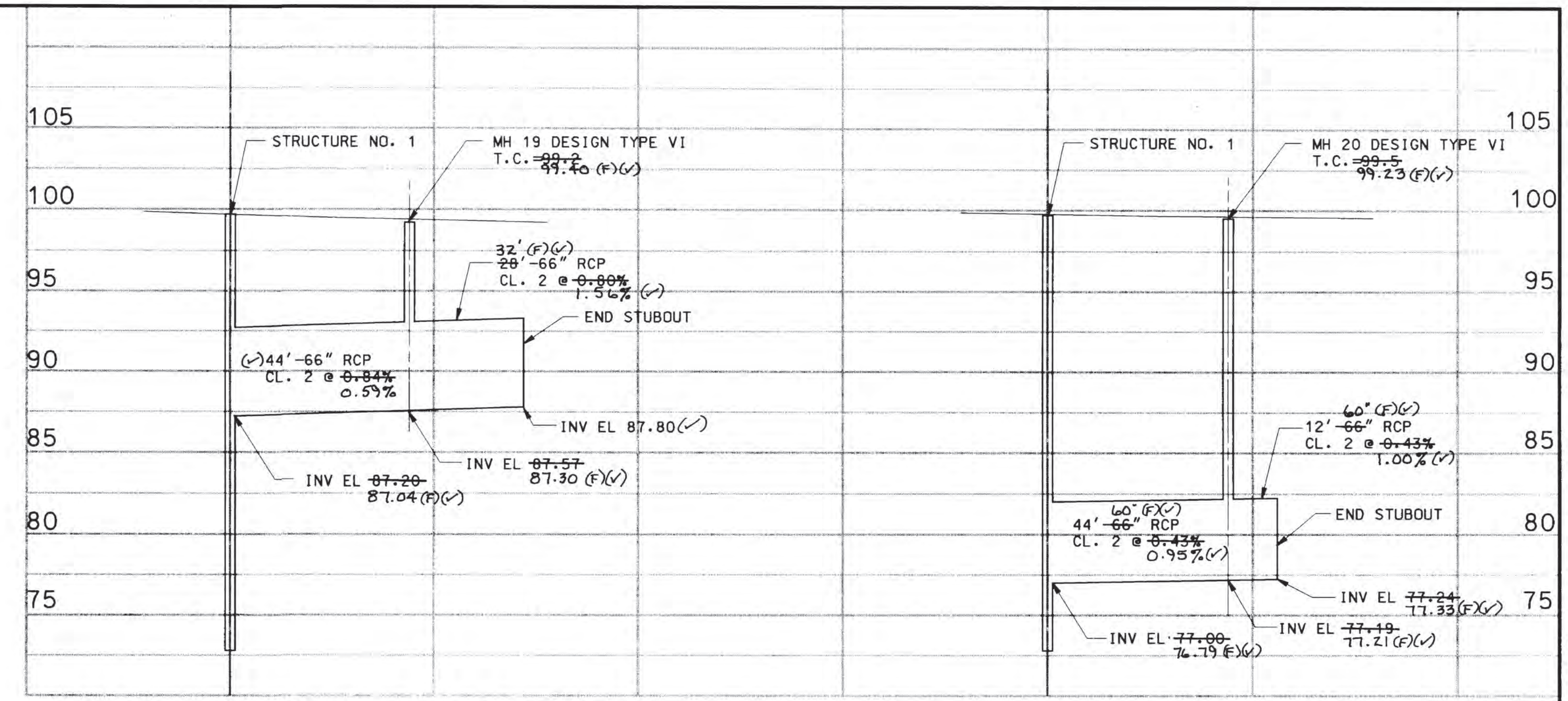
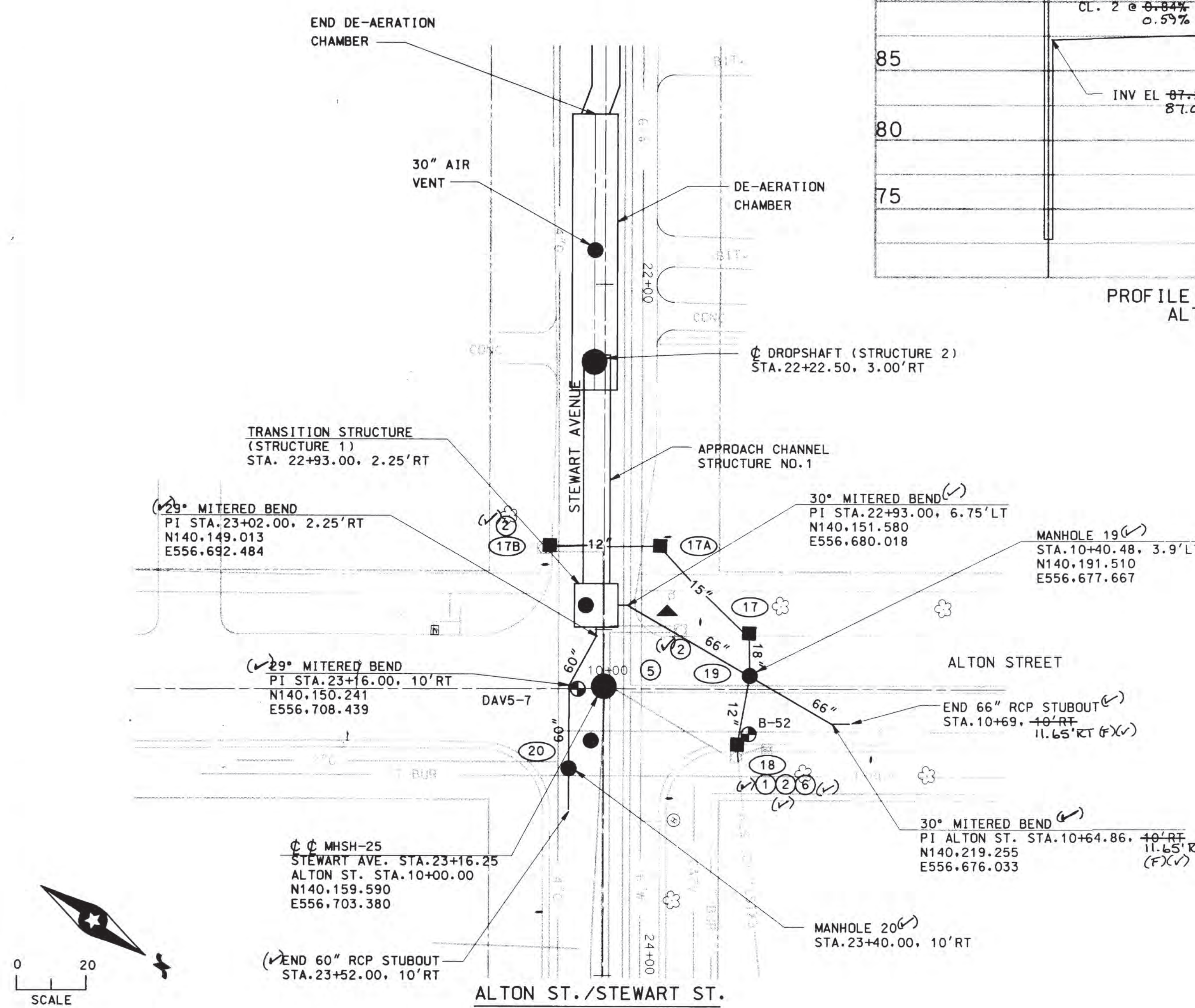


PROFILE 66" STUBOUT ON ALTON STREET

PROFILE 60" STUBOUT ON STEWART AVENUE



ALTON ST./STEWART ST.

INTERSECTION SEWER PLAN

Davern Outlet, Phase B
7 OF 50
4757

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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 Johnson 1-16-96
PROJECT/RESIDENT ENGINEER DATE
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(✓) INDICATES INFORMATION VERIFIED TO BE CORRECT.
0 INDICATES INFO. CHANGED DURING CONST. NOT VERIFIED.
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94-S-8085B		- -			BAR IS ONE INCH ON ORIGINAL DRAWING	DR DAD	Paul W. Blum	HOWARD NEEDLES TAMMEN & BERGENDOFF	DAVERN OUTLET PHASE B	DATE 8- 8-94
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Stewart Ave.

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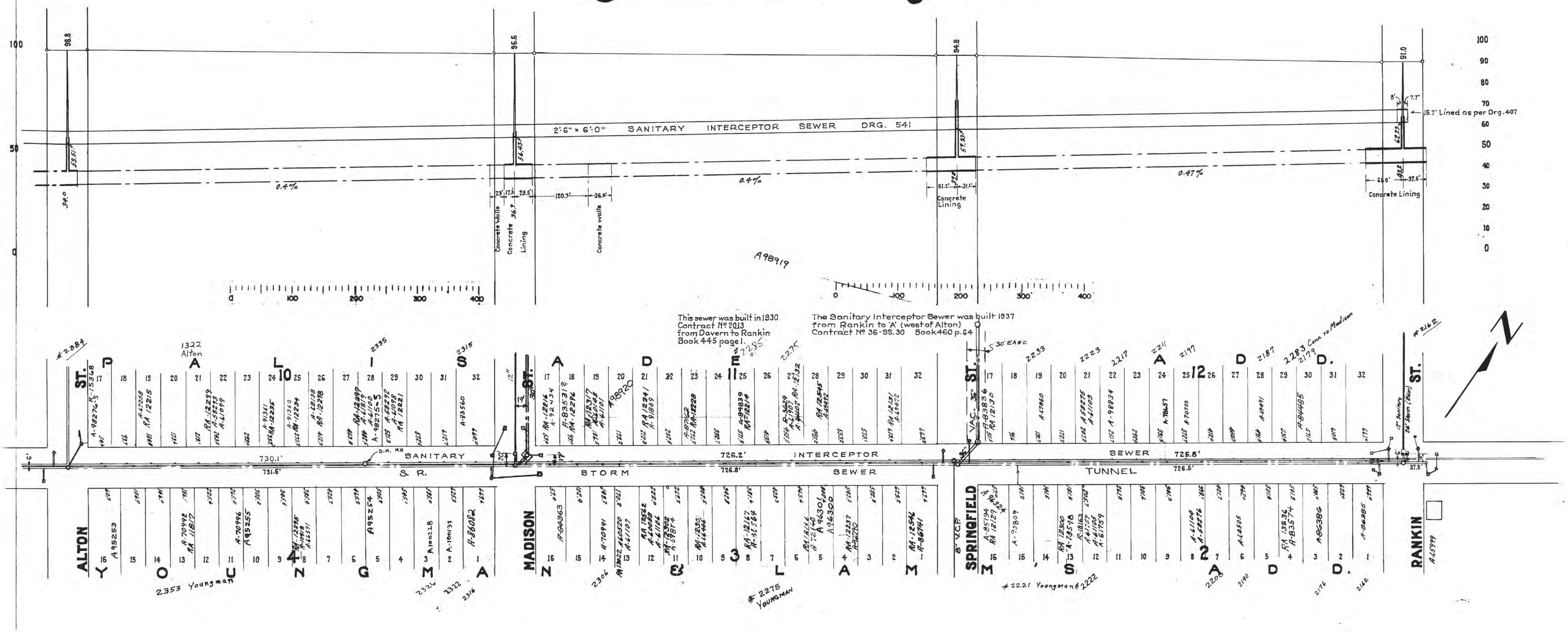
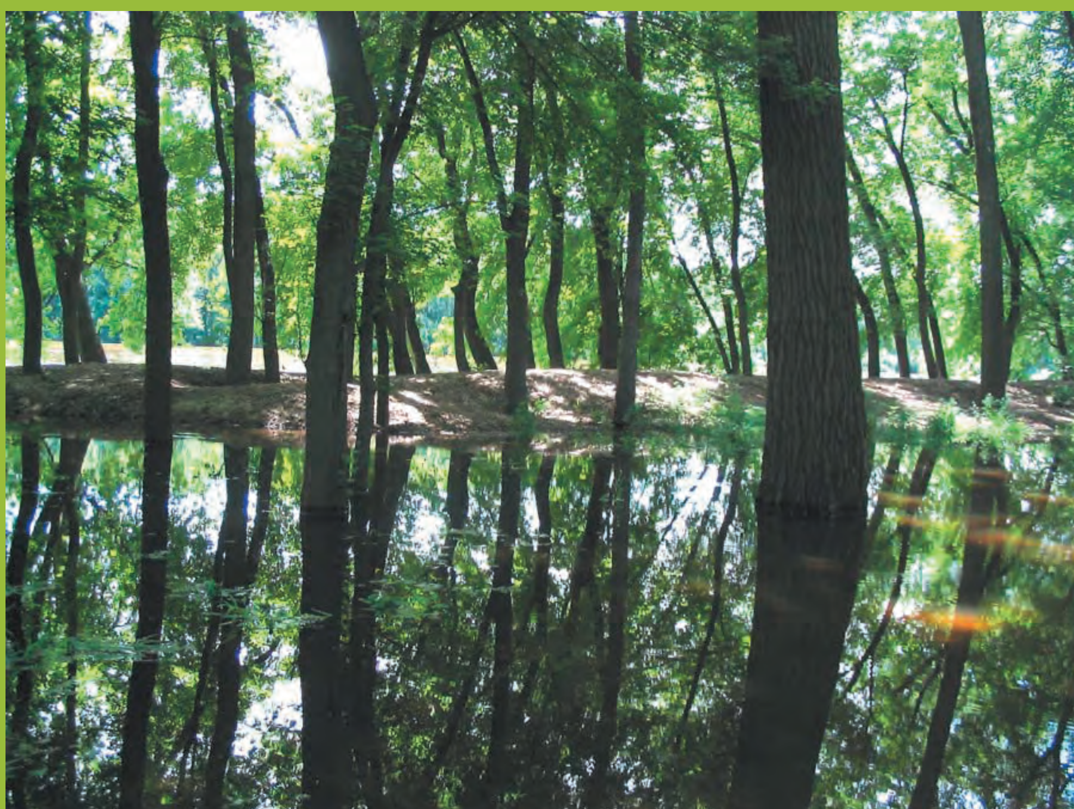


Crosby Farm Regional Park Ecological Inventory and Restoration Management Plan

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.

Table of Contents

List of Figures

Appendices:

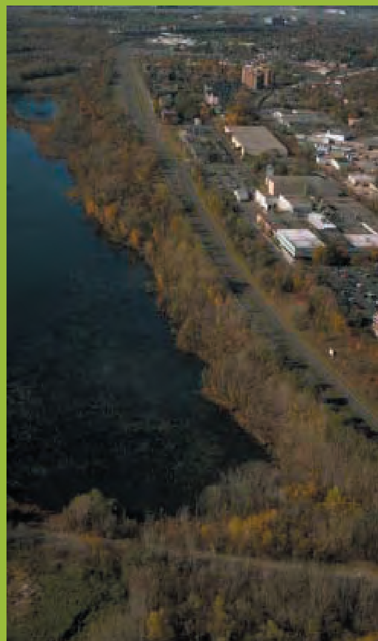
Crosby Park: Bluff Trail Project

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

Authors:
Dan Shaw
Carlos Fernandez
Courtney Skybak
Ryan Holdorf

June 2004

Table of Contents



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.

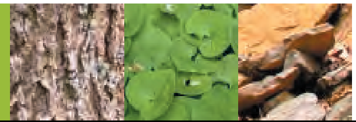
Funding for this project came from the Legislative Commission on Minnesota Resources and project partners included the City of Saint Paul, Great River Greening, and the Ramsey Soil and Water Conservation District.

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

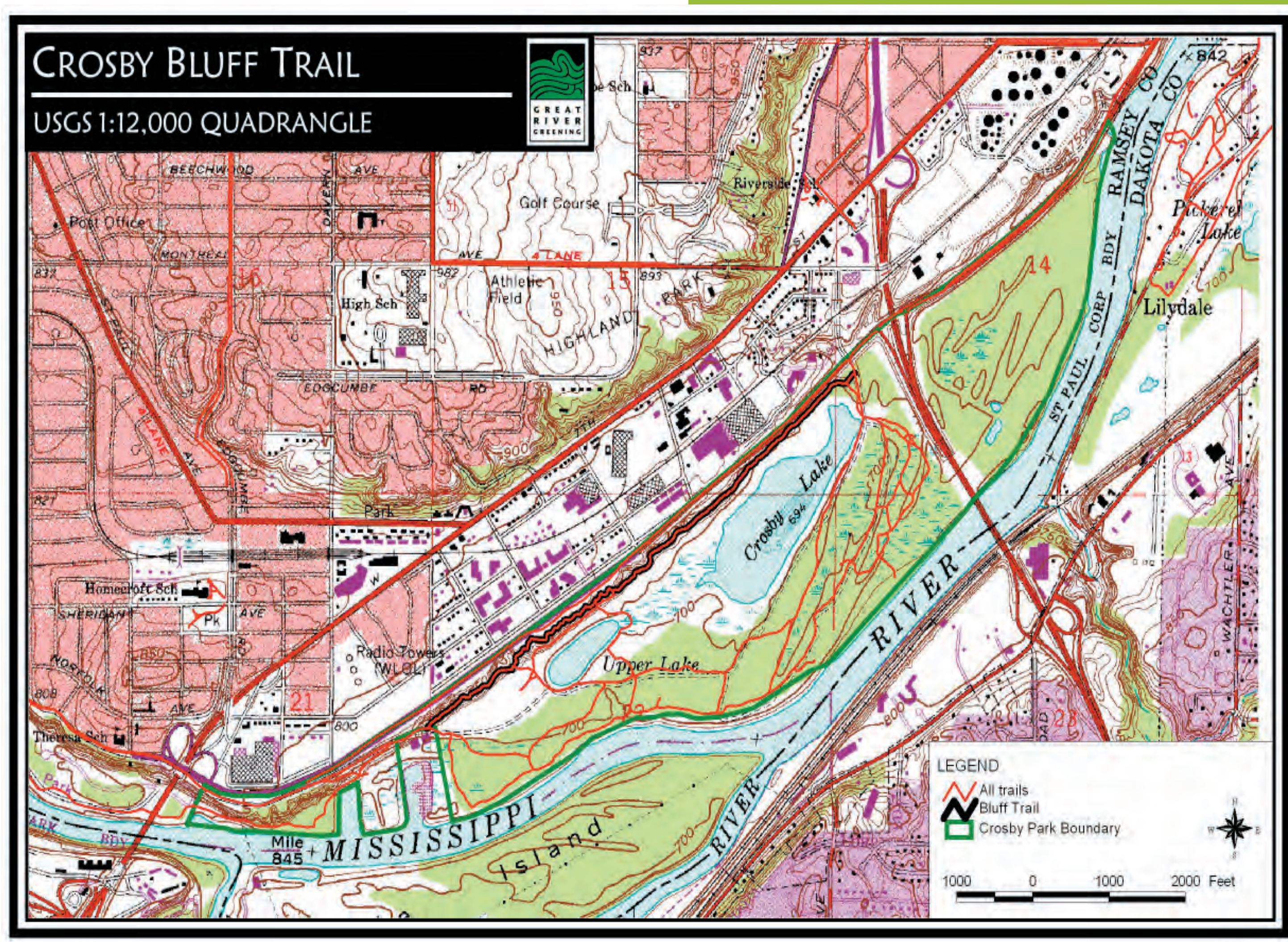
The soils on the bluff are highly erodable and as a result, trail use other than hiking should be discouraged. Mountain biking should be restricted to trails that are less prone to erosion and people and animals should be persuaded to stay on the trail. The trail plan recommends the removal of some unnecessary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

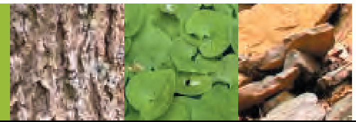
Trail Monitoring

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.

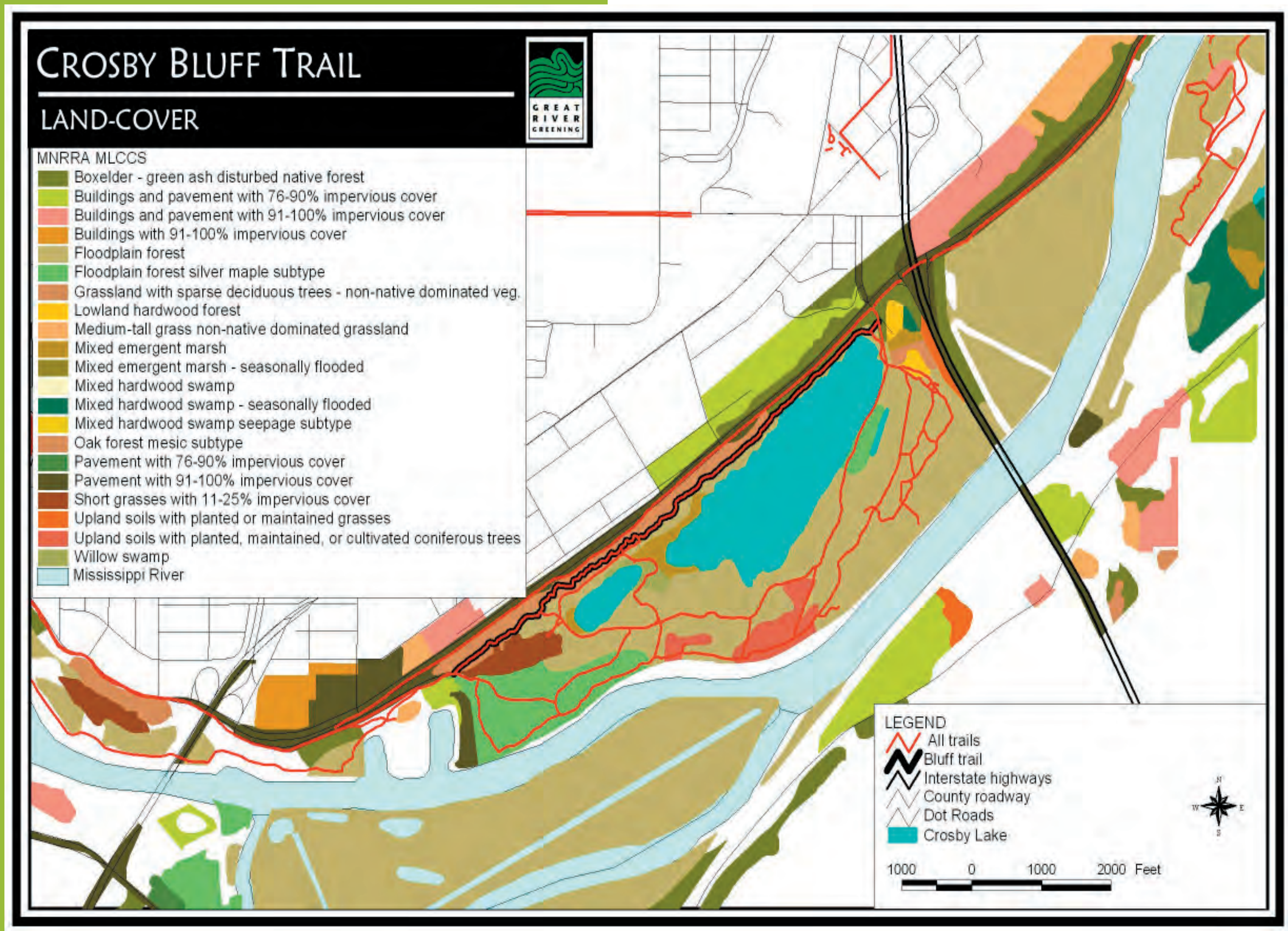
USGS Quadrangle

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

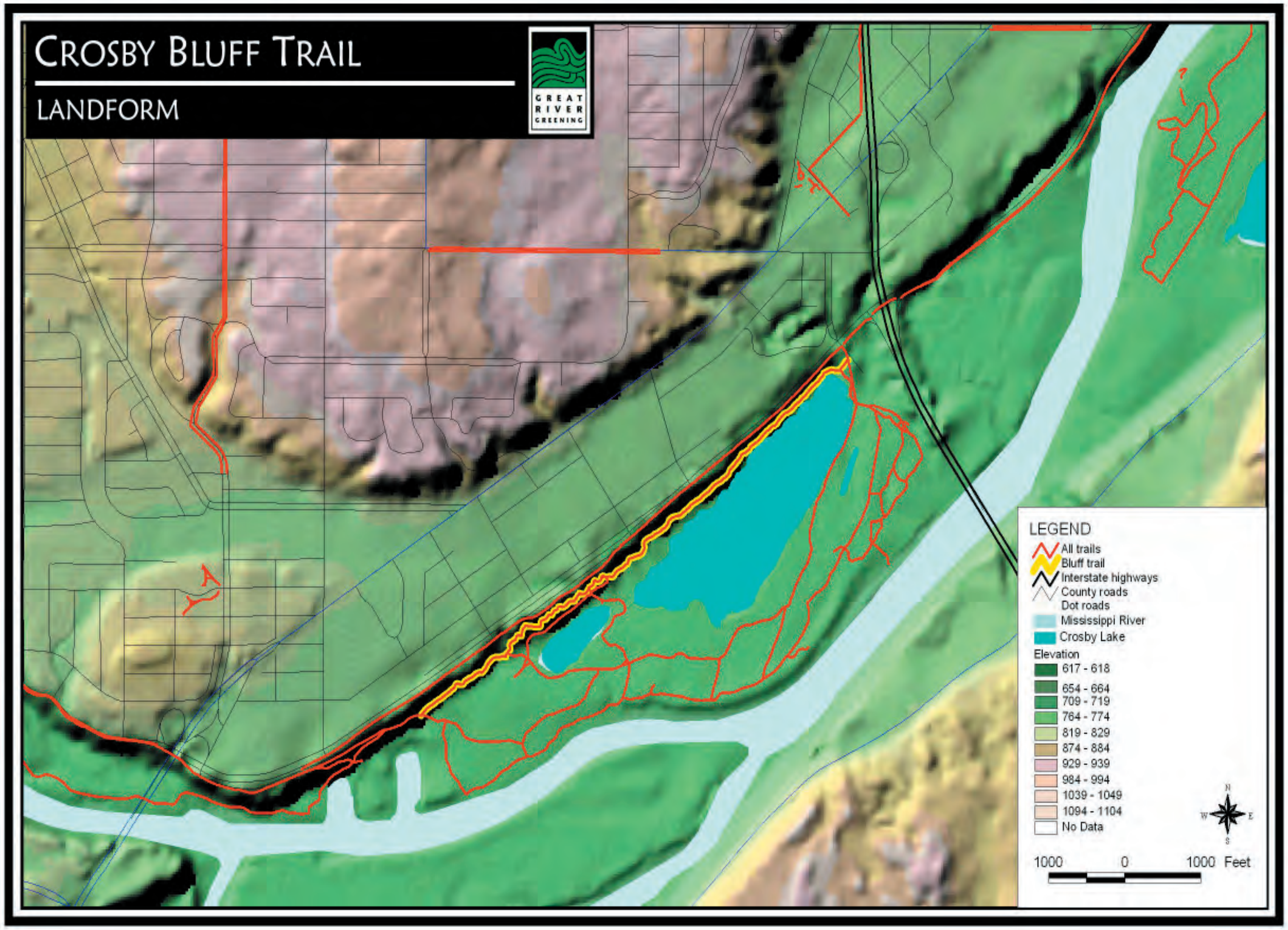


Land-Cover

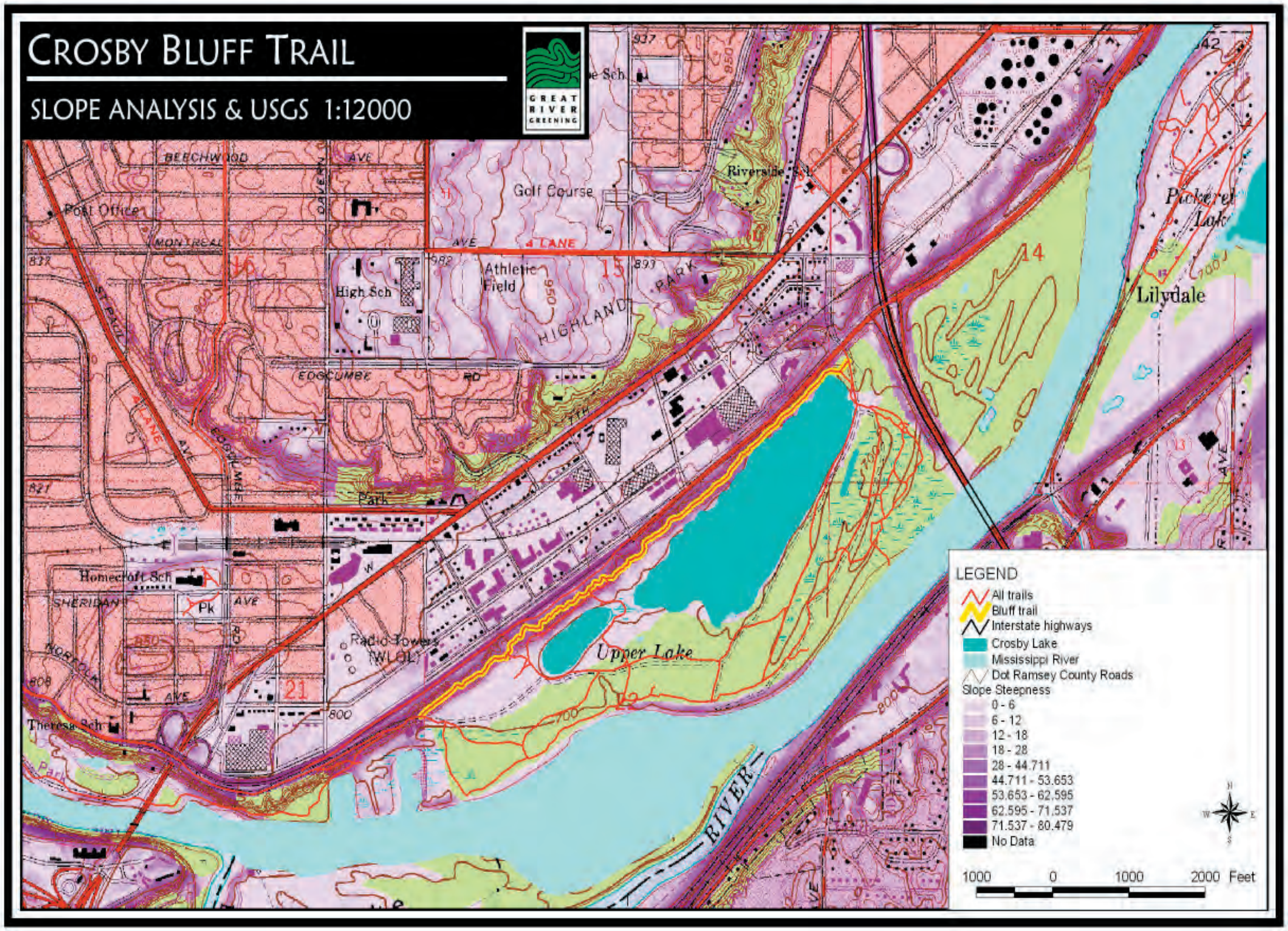
The land-cover map identifies the current biological layers contained within the Crosby Park area. The park is dominated by the Floodplain Forest land-cover type. but the bluff trail moves through mostly Oak Forest Mesic Subtype vegetation, with a portion of Boxelder-Green Ash Disturbed Native Forest 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

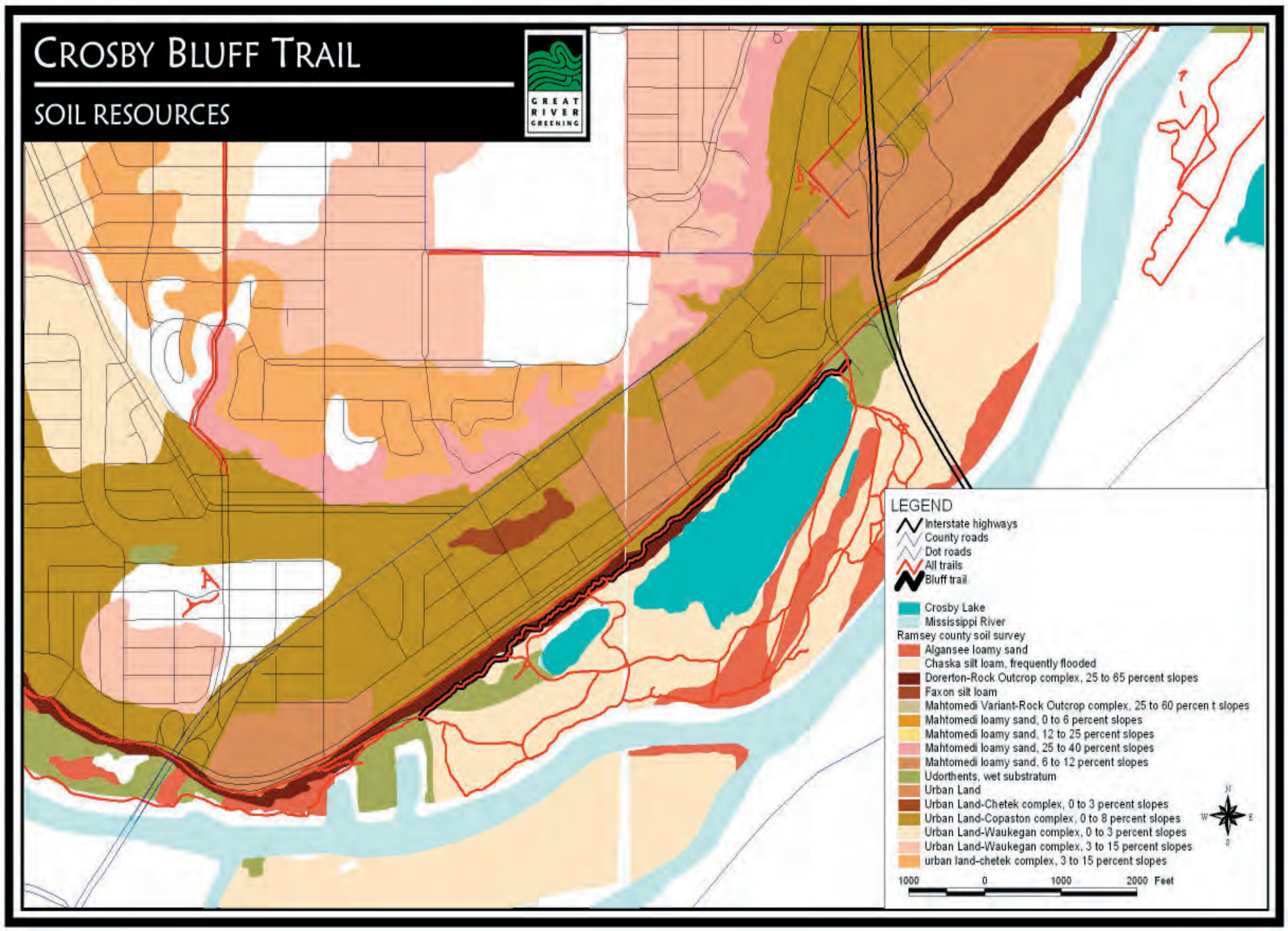


Slope

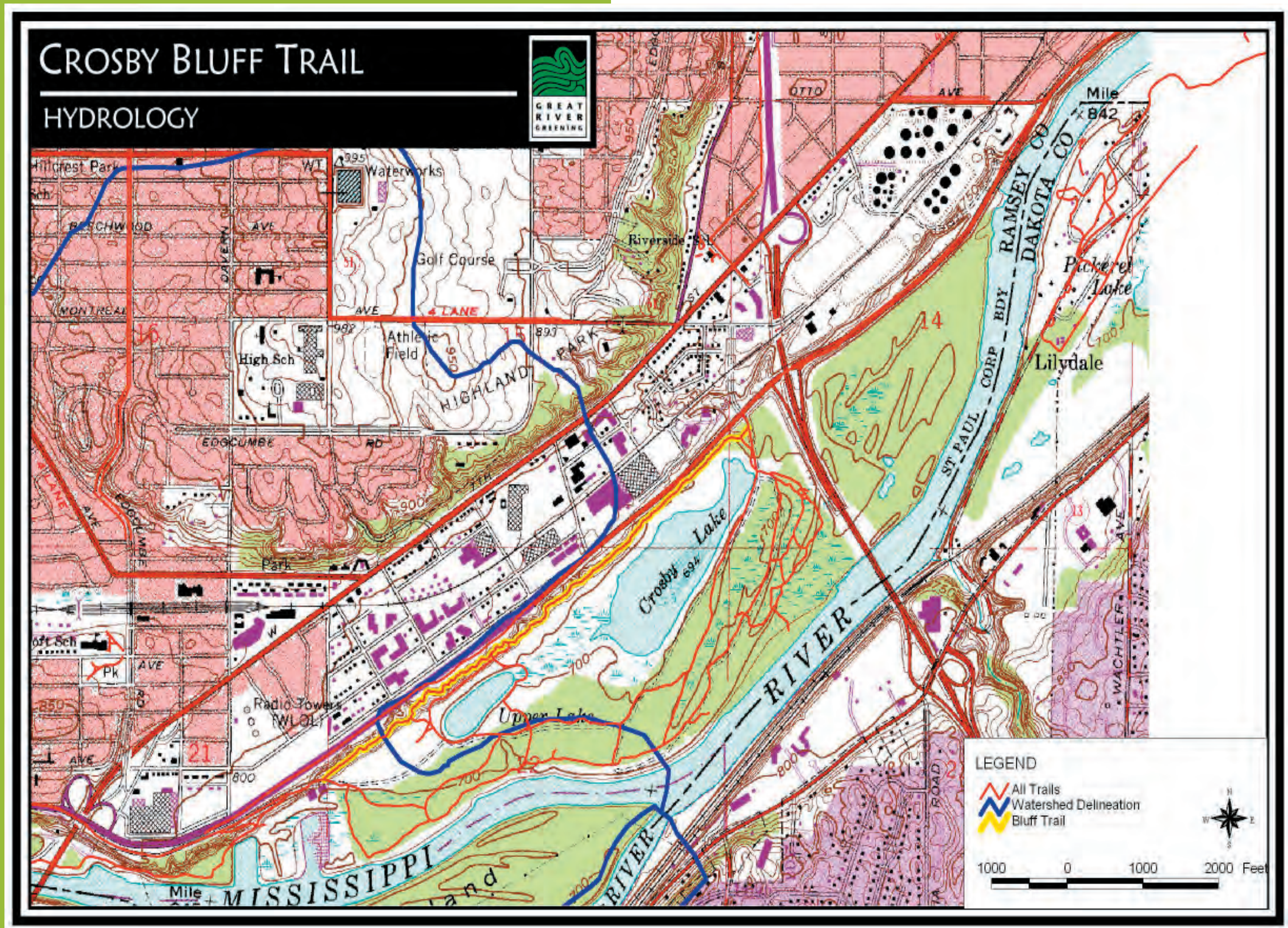
The Slope Analysis overlay on the USGS 1:12000 map identifies the steepness of slopes in and around the site. A measurement of slope steepness is useful in understanding the process of erosion, and the relationship between slope, soil stability, stormwater movement, and vegetation. Vegetation often has 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

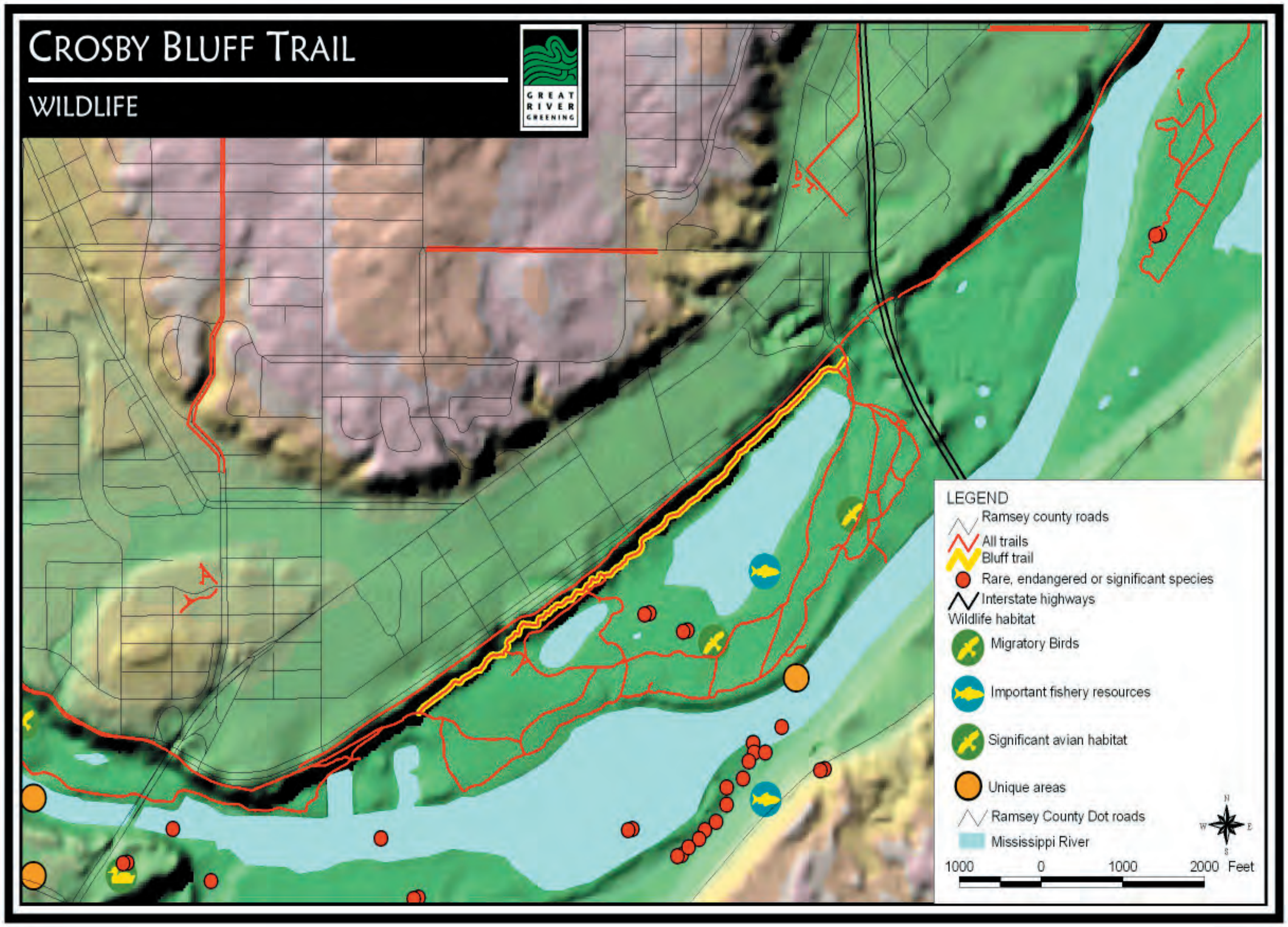


Hydrology

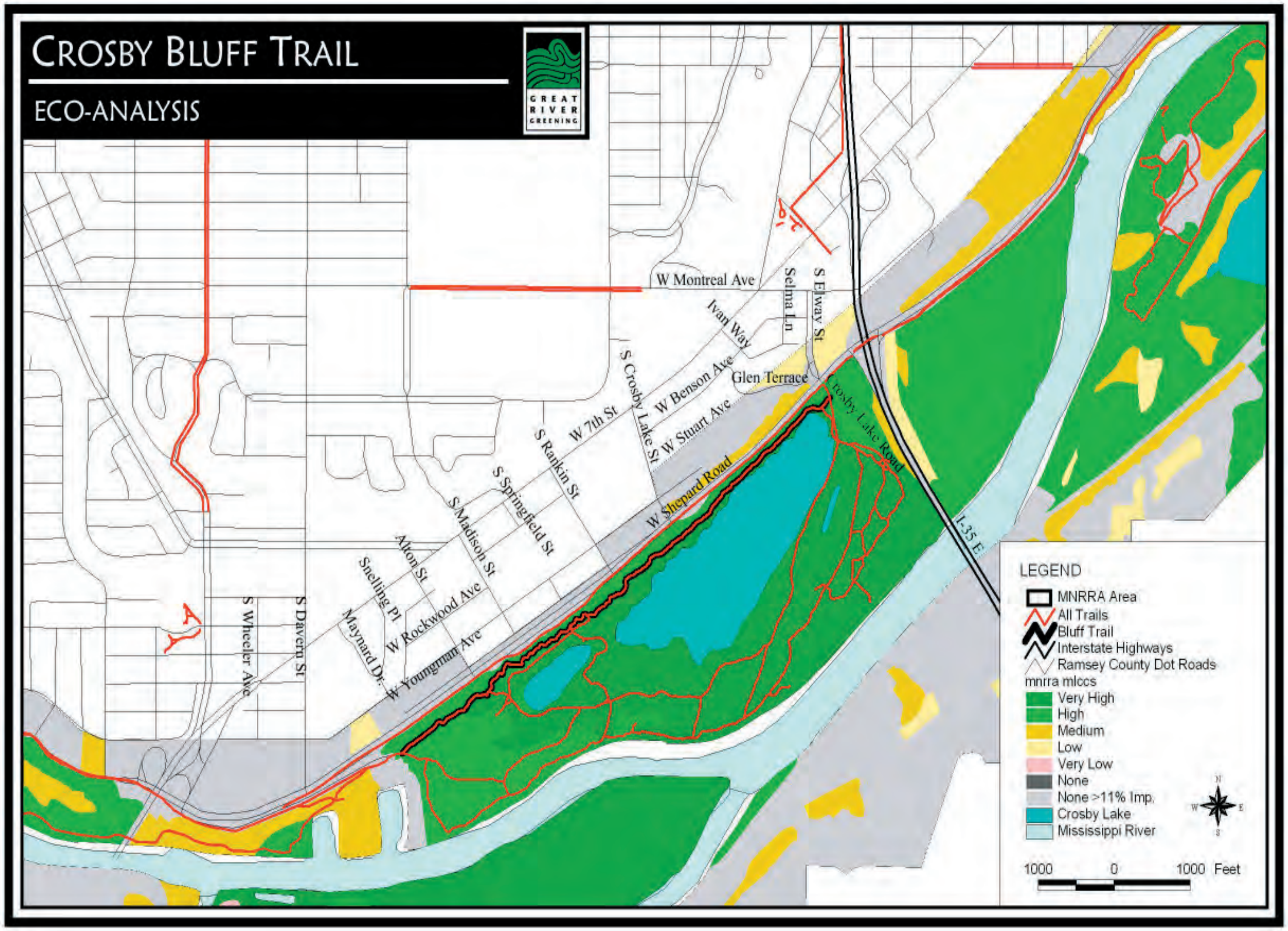
The Hydrology map identifies watershed boundaries in relation to trail location and the extent of Crosby Park. A watershed boundary divides the bluff trail into two portions. Stormwater in the area around the larger portion (to the east) drains into Crosby Lake. Stormwater in the area around the smaller,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



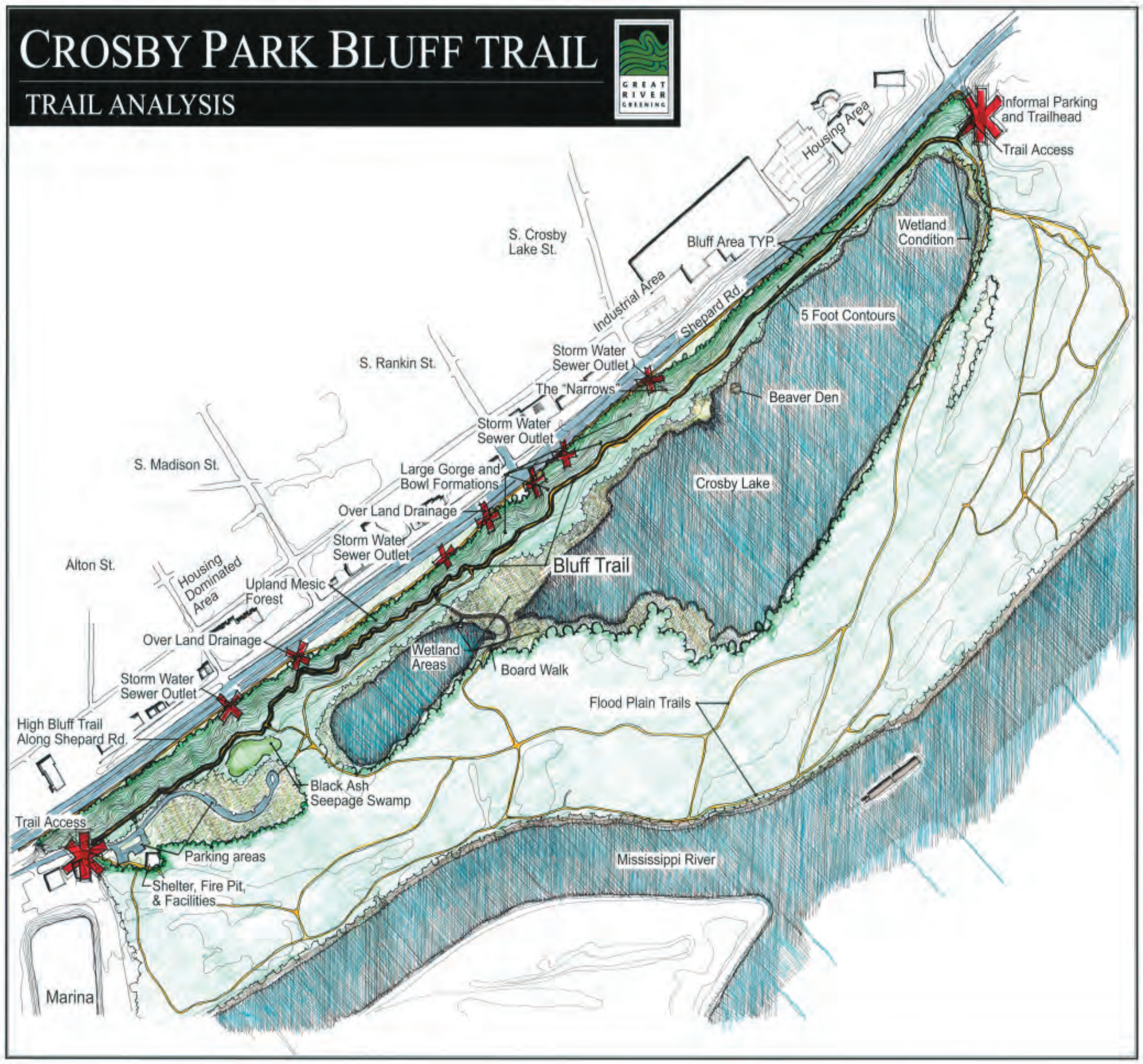
Resource Analysis of Intrinsic Qualities



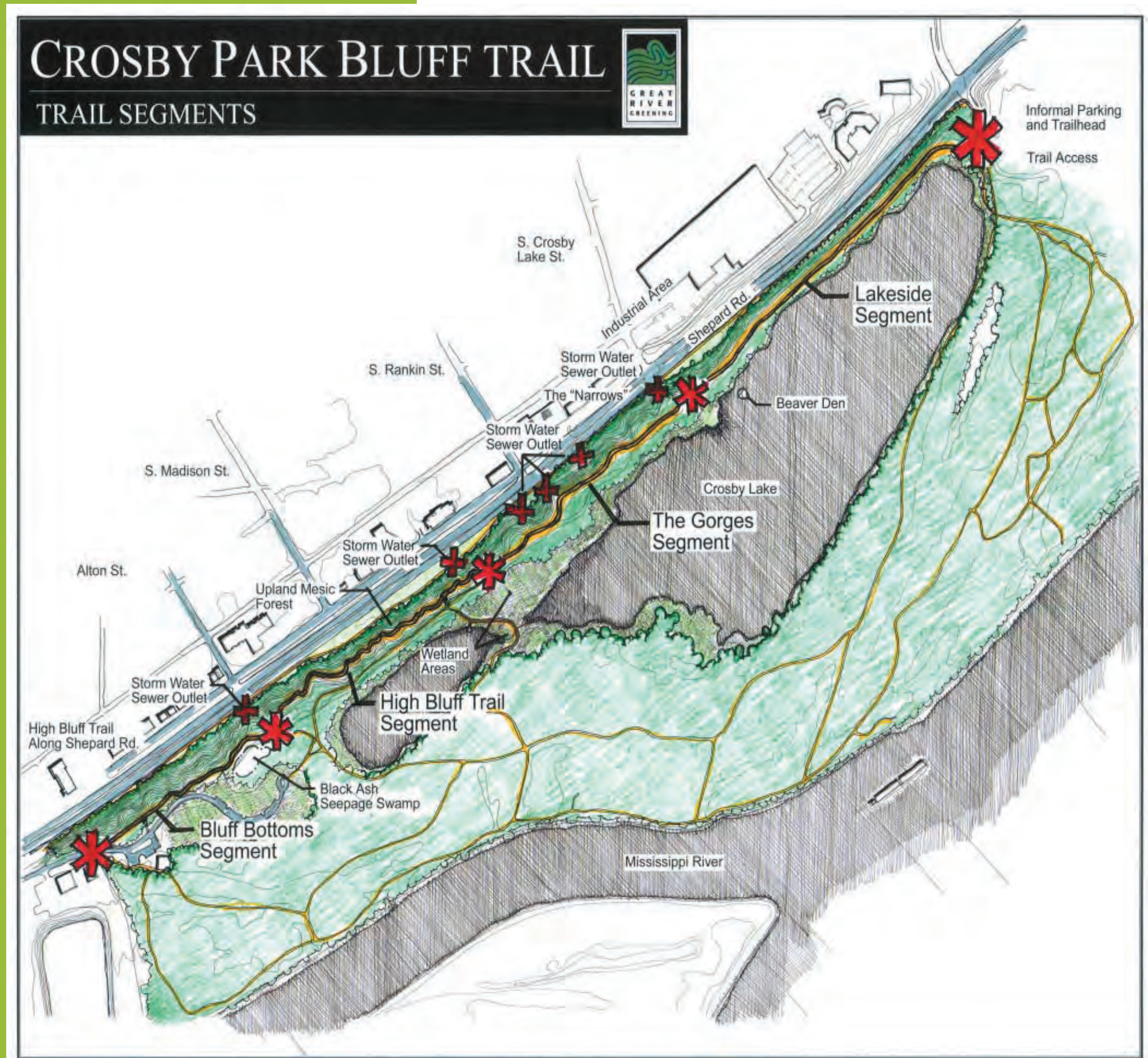
Eco-Analysis

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.

Site Analysis



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.

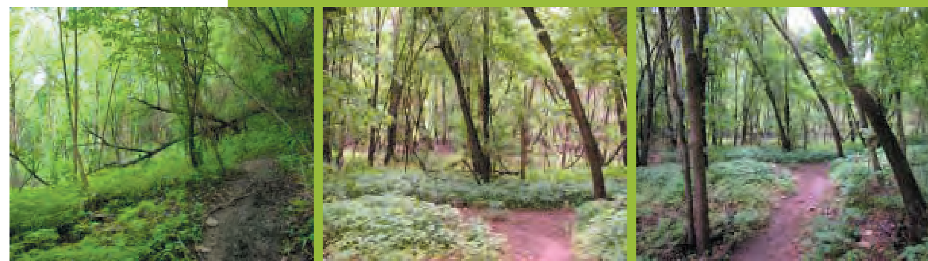
The second segment is the High Bluff Trail segment. It is characterized by the elevated location of the trail and the experience of being up in the trees and upon the steep bluff slopes.

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.

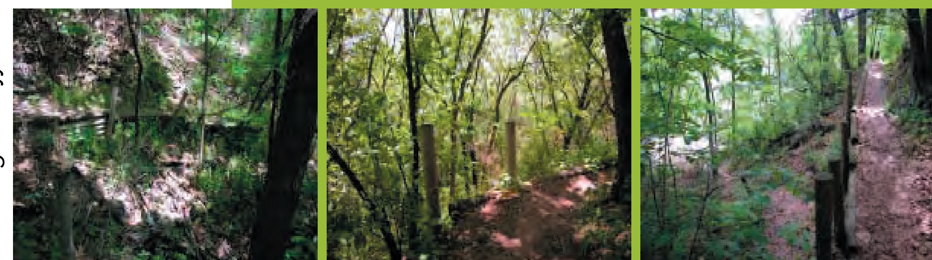
The fourth and final segment is the Lakeside segment. Here the trail moves near the edge of Crosby Lake, with framed views to the water.

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.

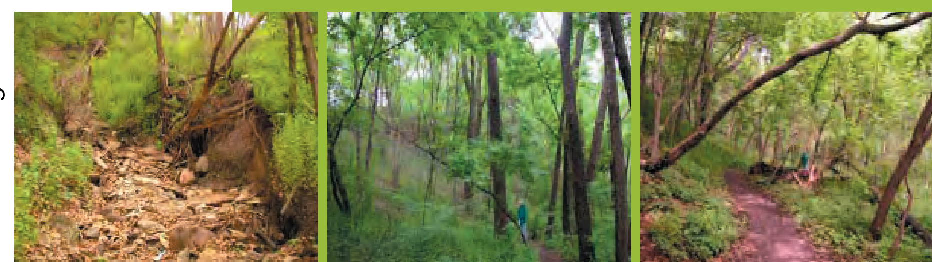
Bluff Bottoms



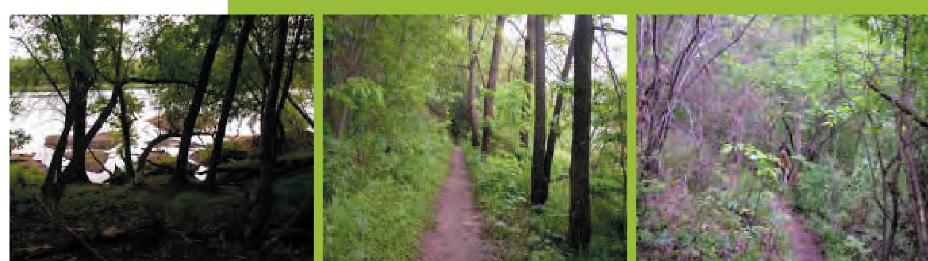
High Bluff



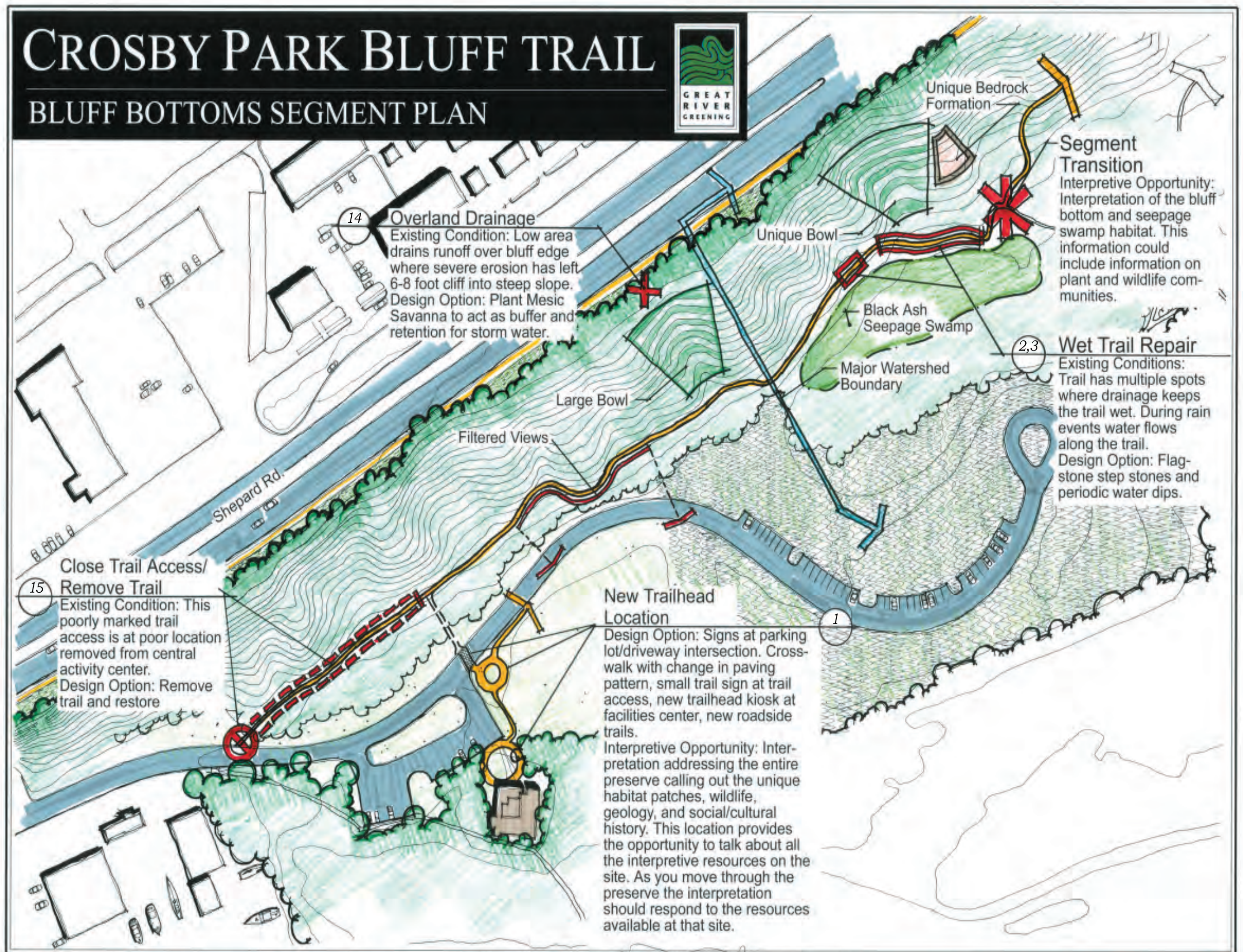
The Gorges



Lakeside

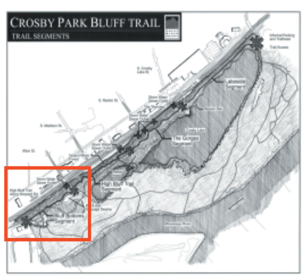


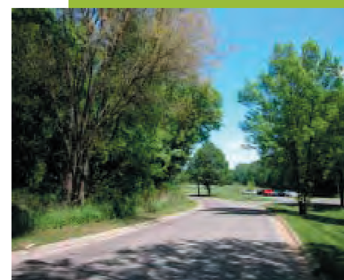
Trail Segment Plans

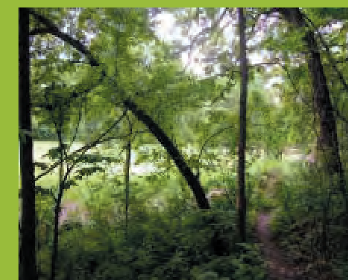


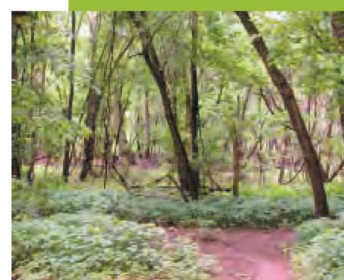
Trail Segment 1: Bluff Bottoms

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.

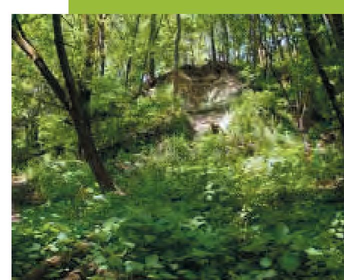


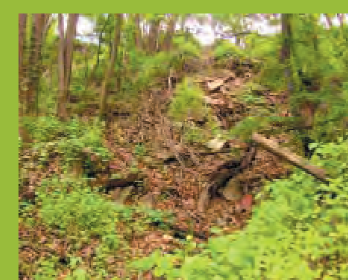

The entrance and parking lot, at the bluff trail's beginning.


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

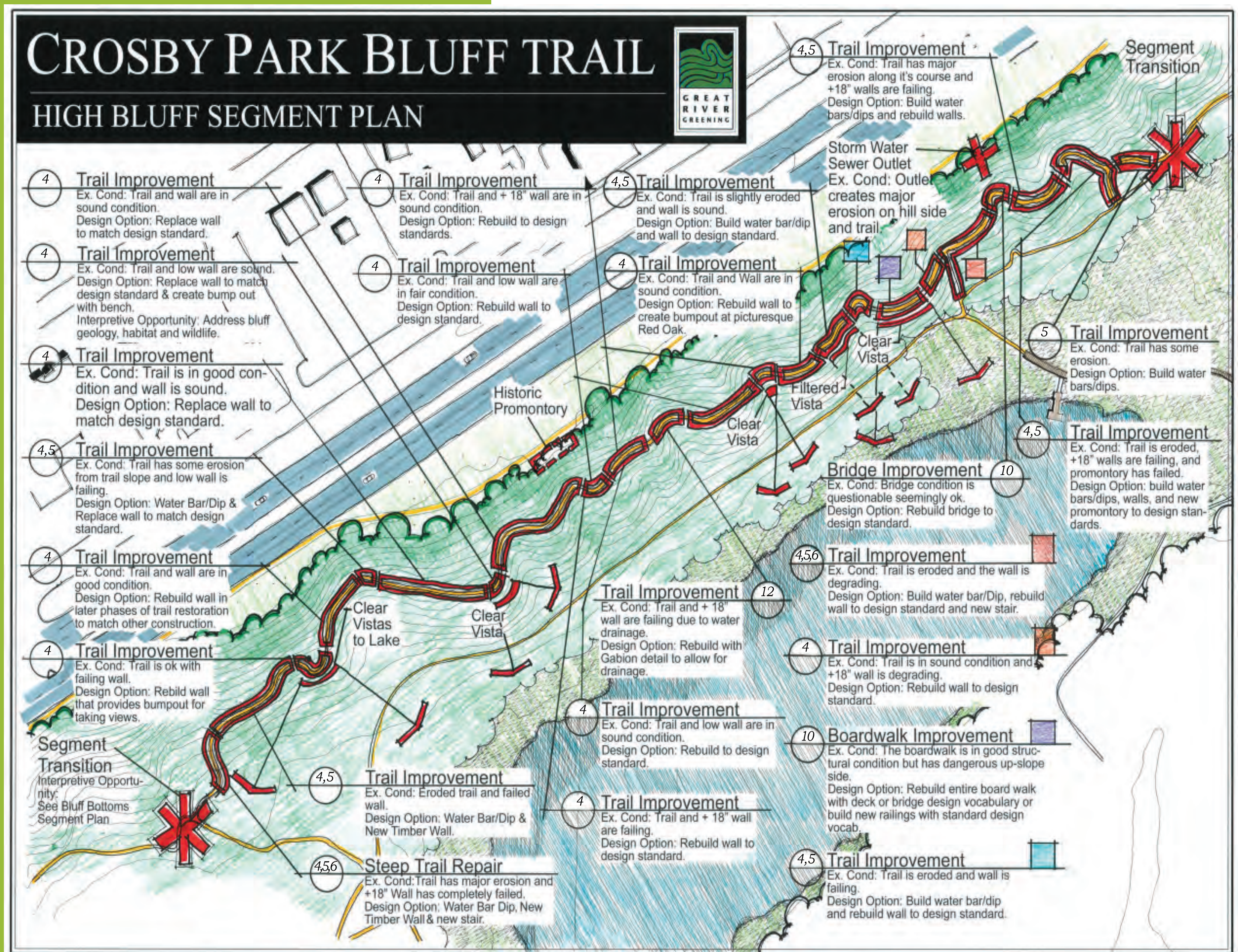

The black ash seepage swamp, along which the trail winds.


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.

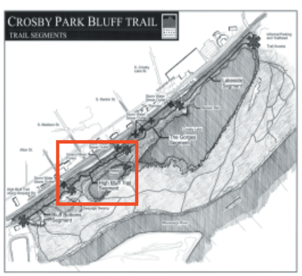
Trail Segment Plans

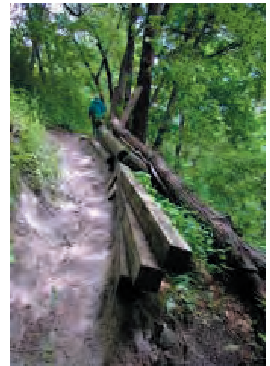


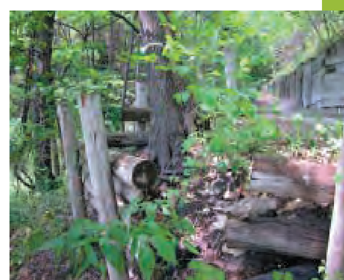
Trail Segment Plans

Trail Segment 2: High Bluff

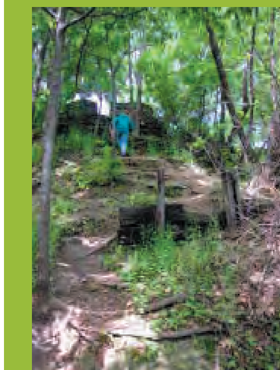
The Upper Bluff Trail Segment begins where the trail climbs the bluff slope, and ends where the trail descends again near the west end of Crosby Lake. The segment is characterized by an intimate relationship with the bluff and a feeling of prospect as the trail runs roughly halfway up the bluff slope. 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.

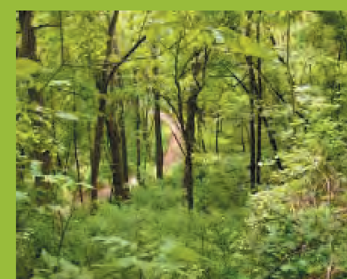



Start of segment, stairs recommended.

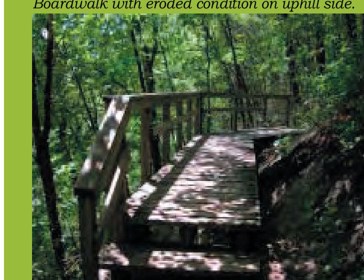

Severely eroded promontory.

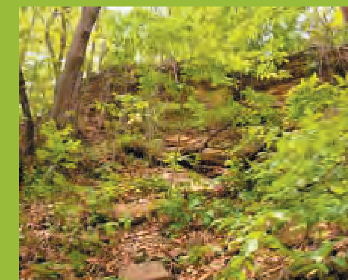

Most recent, sturdy timber wall.


Abandoned trail to old overlook.


Filtered views to paved trail below.

Boardwalk with eroded condition on uphill side.

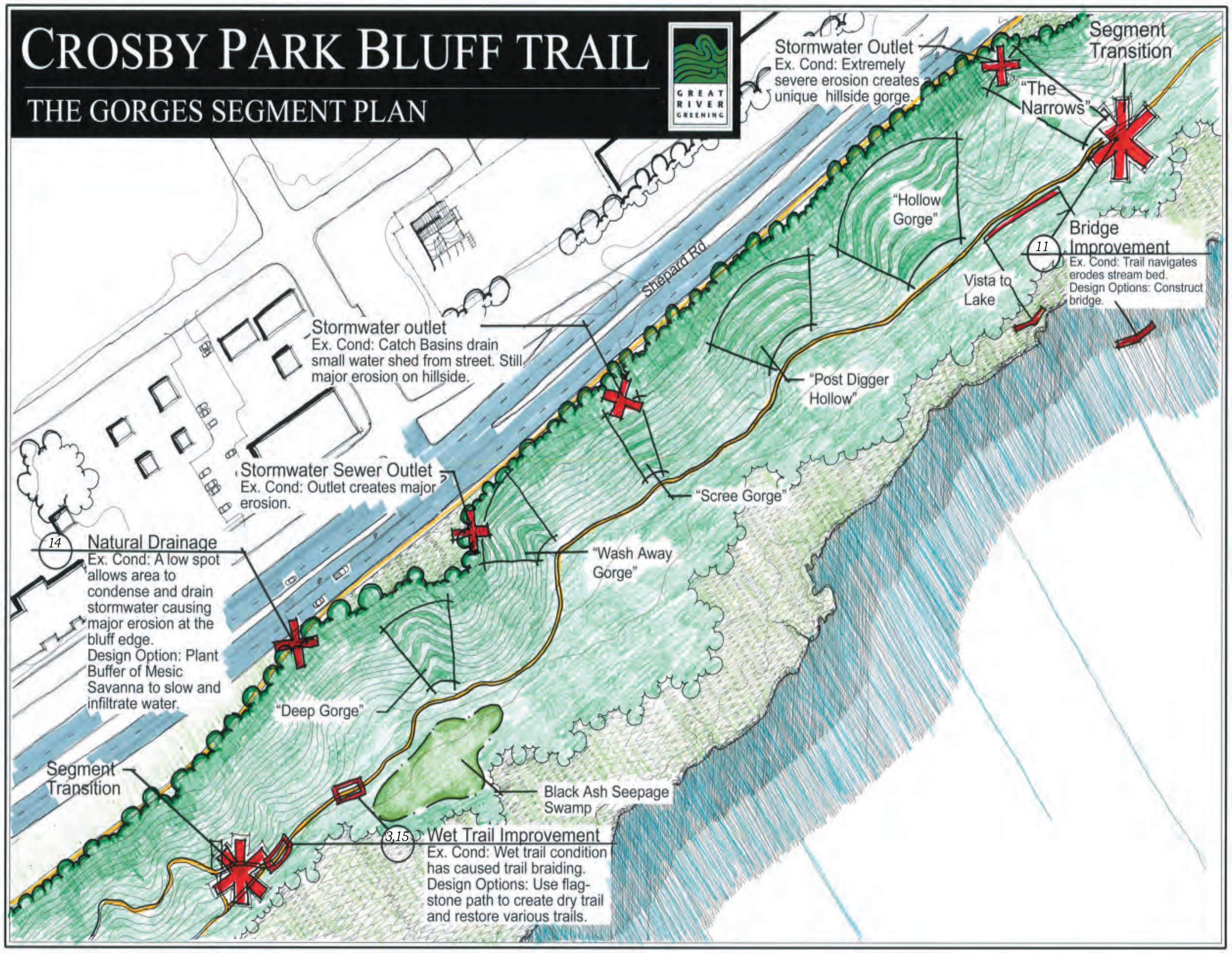



Limestone outcropping at top of bluff.


Water on trail, gabion's recommended.


Existing bridge.

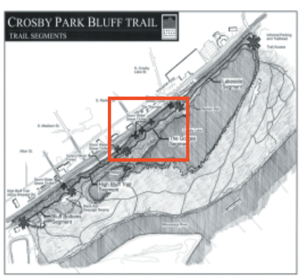
Trail Segment Plans

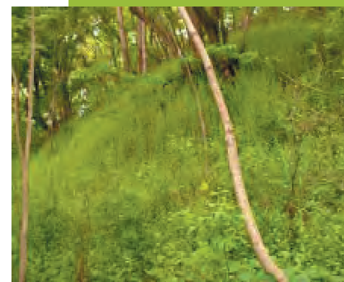


Trail Segment Plans

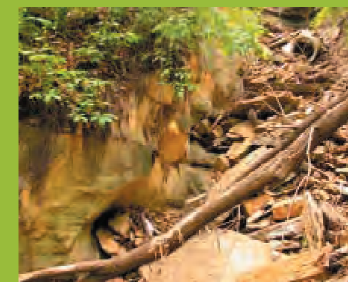
Trail Segment 3: The Gorges

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.

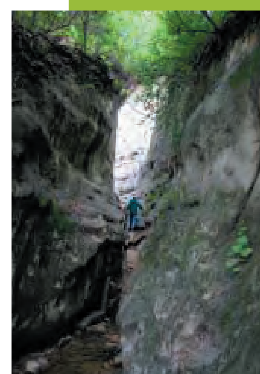




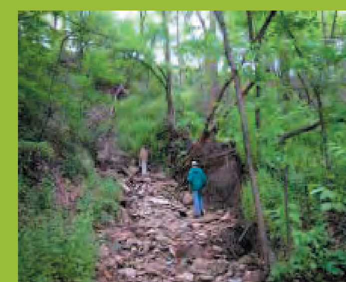
A particularly severe infestation of garlic mustard.



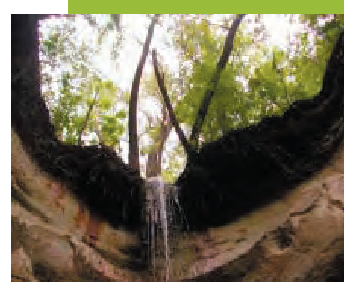
One of several severely eroded gorges, with sculpted sandstone walls and filled with rubble.



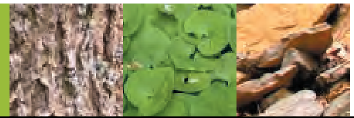
The entrance to the Narrows.



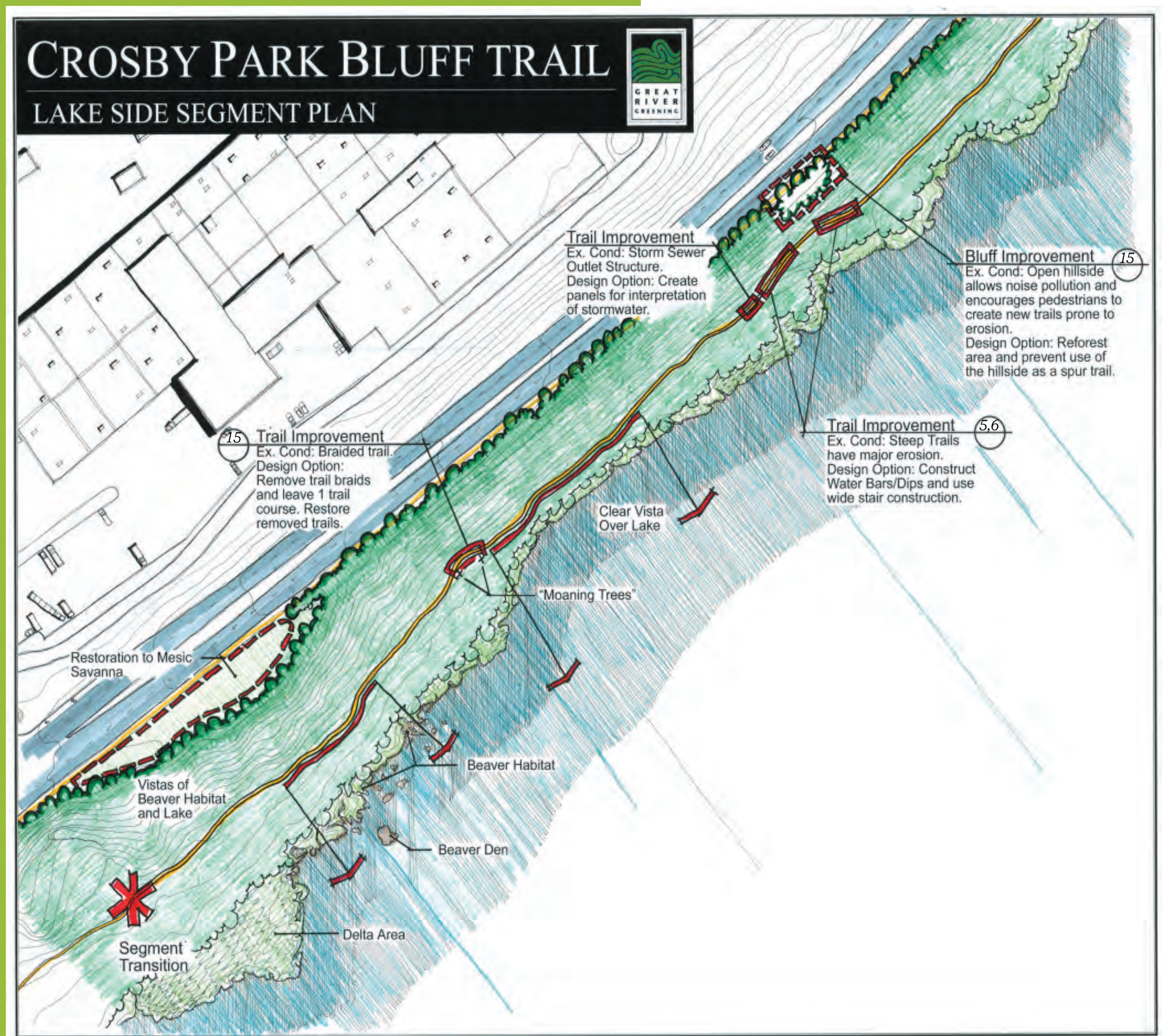
Another severely eroded gorge, above, with the cause of its erosion, a storm water pipe, below.



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

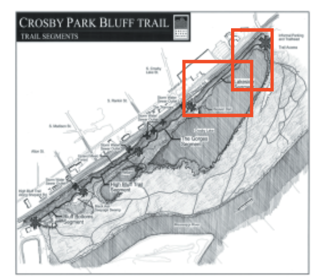


Trail Segment Plans

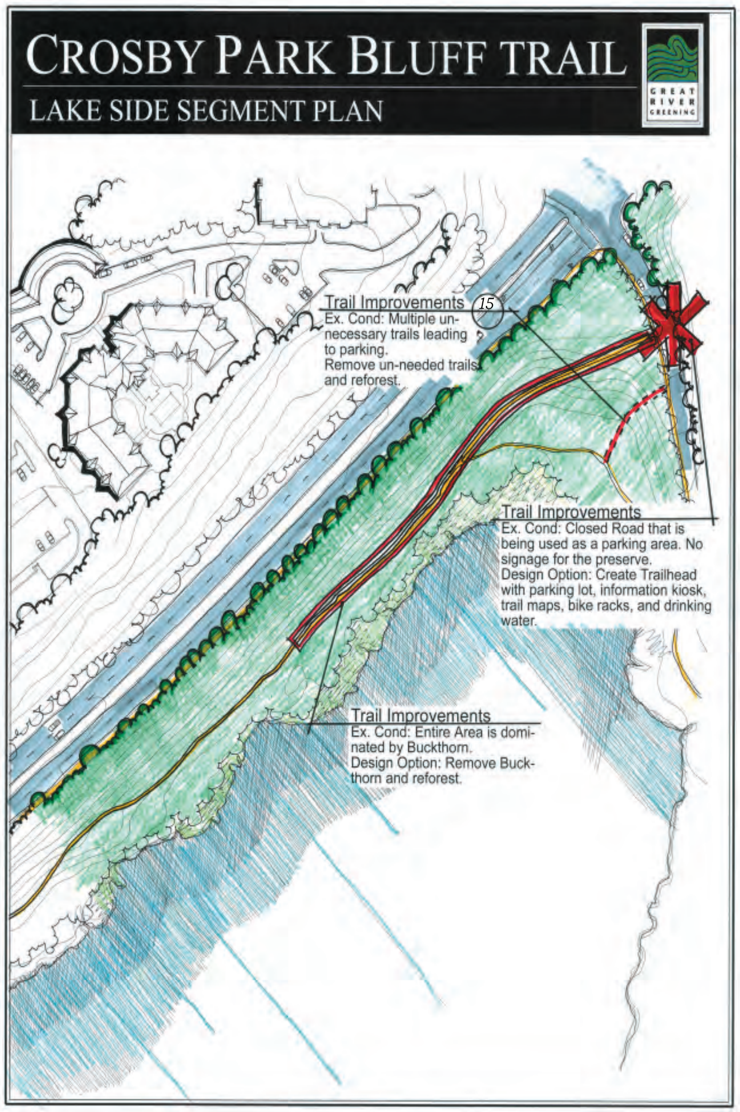


Trail Segment 4: Lakeside

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.



Trail Segment Plans



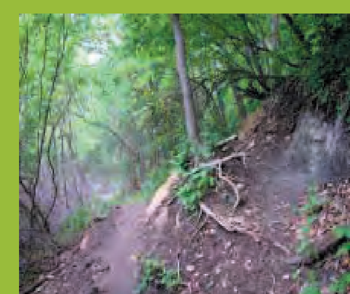

Sloped and eroded trail, where wide stairs are recommended.

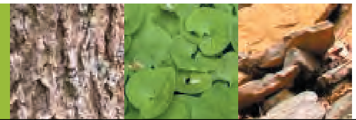

The informal parking and trailhead at the end of the bluff trail.


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

-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.

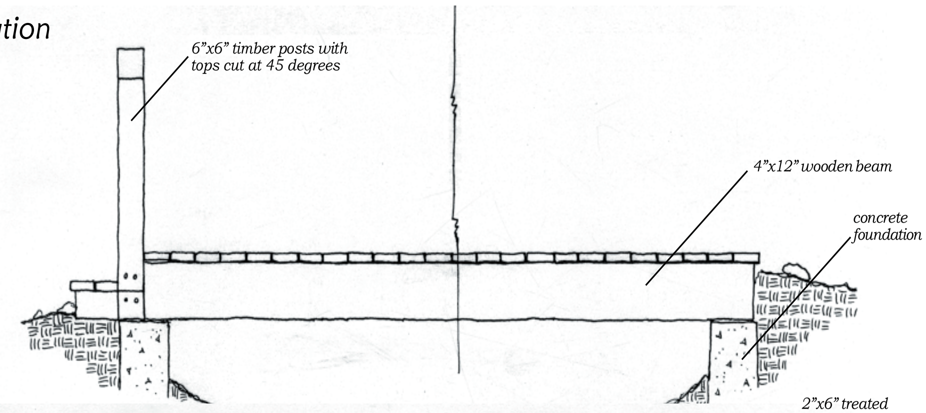
-See Detail #11 for beam-foundation connection.

Bluff Bottom, Wet Condition

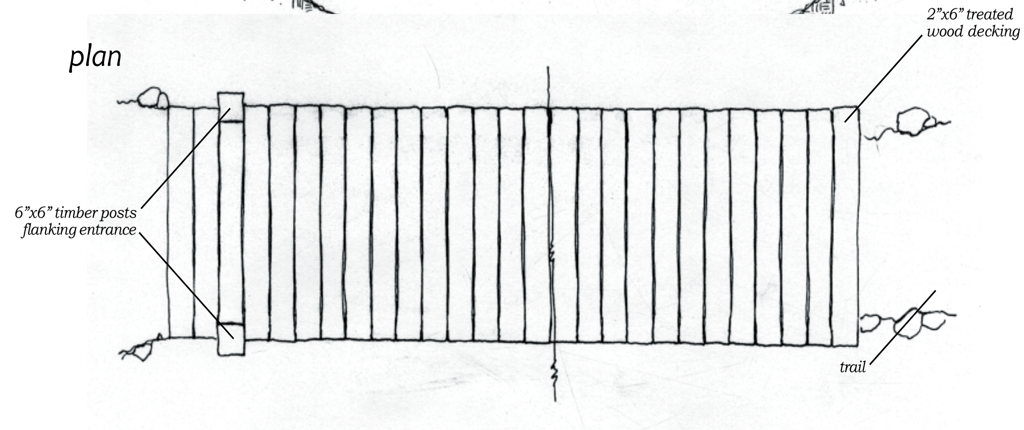
There are many areas at the bottom of the bluff where the flow and accumulation of water is a problem. The goal in these areas is to allow both the passage of water and the movement of people, without one impeding the other.

Detail #1: Trailhead Bridge

elevation

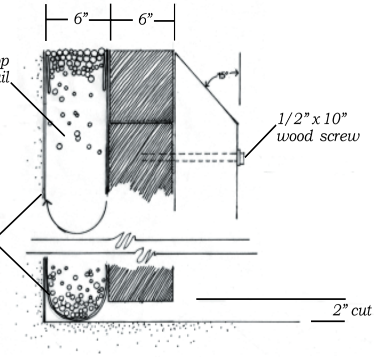


plan



Detail #2: Drainage Ditch w/ Crossing

wall section closeup



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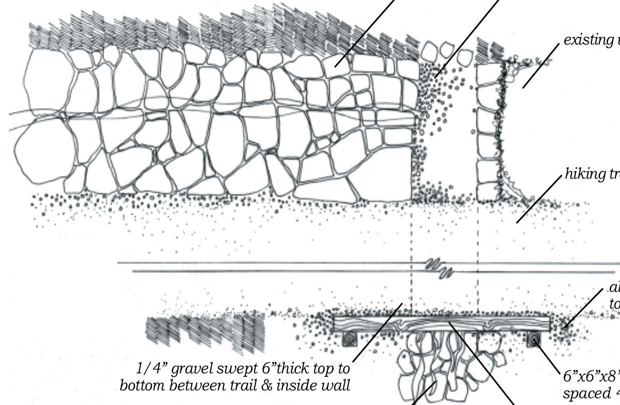
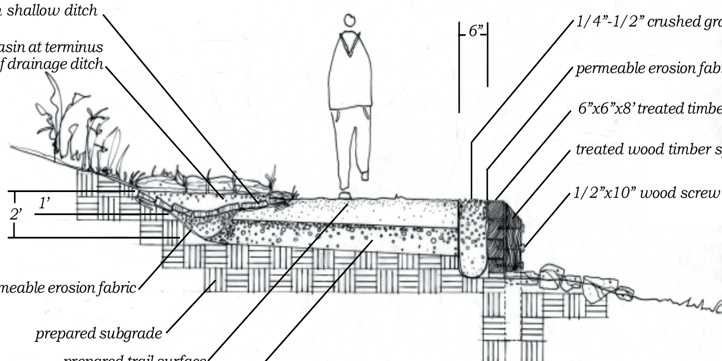
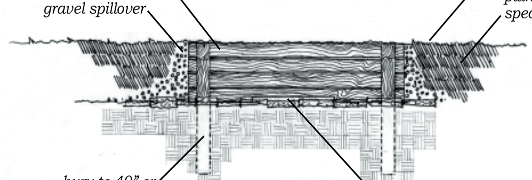


section



elevation

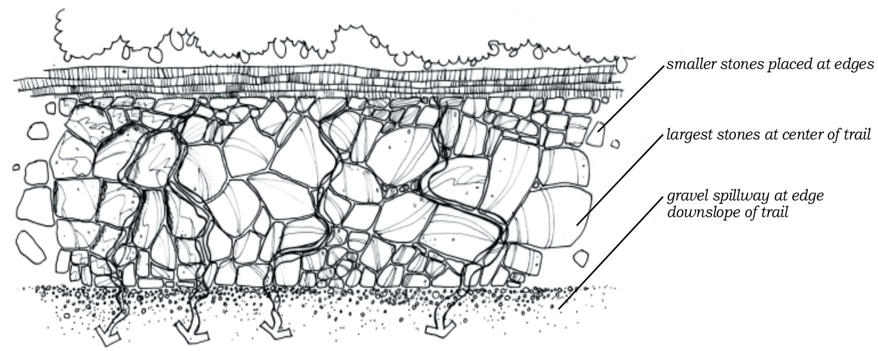


Design Details

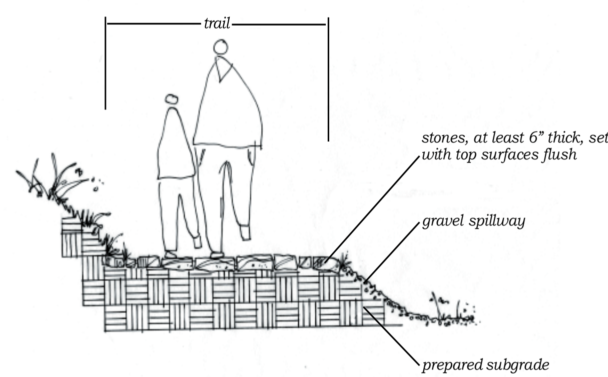
Detail #3: Stepping Stone Path

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.

plan



section

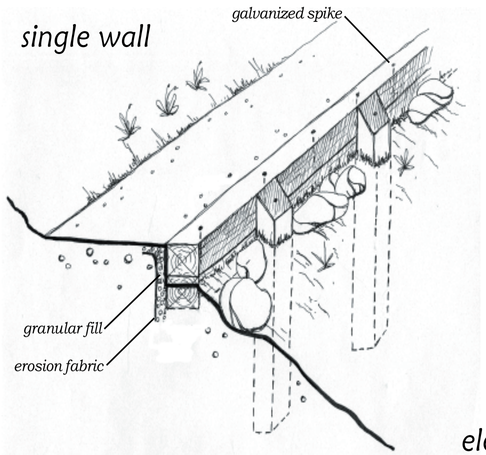


Steep Slope Condition

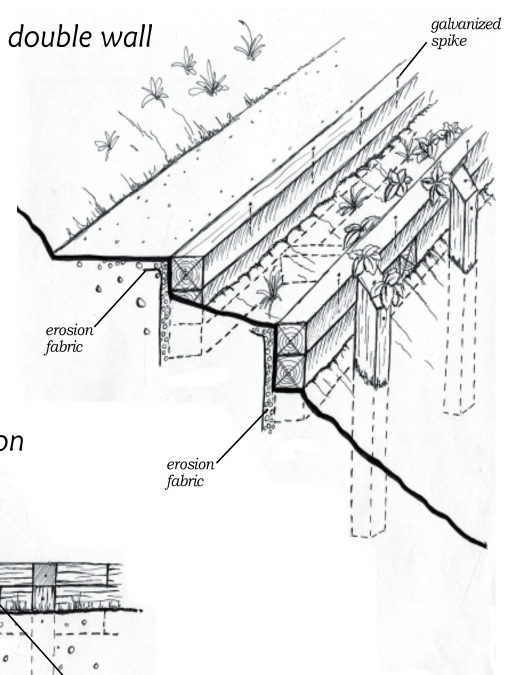
Erosion as a result of steep slopes is a problem all along the bluff, both on and off the trail. The following details offer solutions on these slopes. They seek to stabilize the slopes, allowing movement of people and water without excess movement of soil.

Detail #4: Retaining Wall

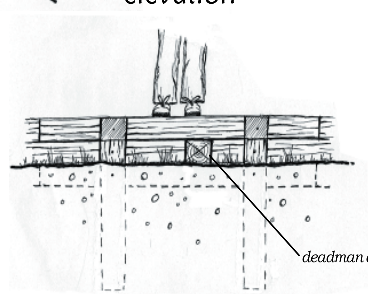
single wall



double wall



elevation



-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.

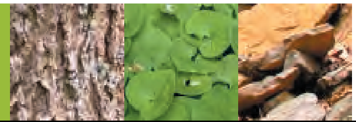
-Bury posts 3.5 feet deep or to the depth of bedrock.

-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.

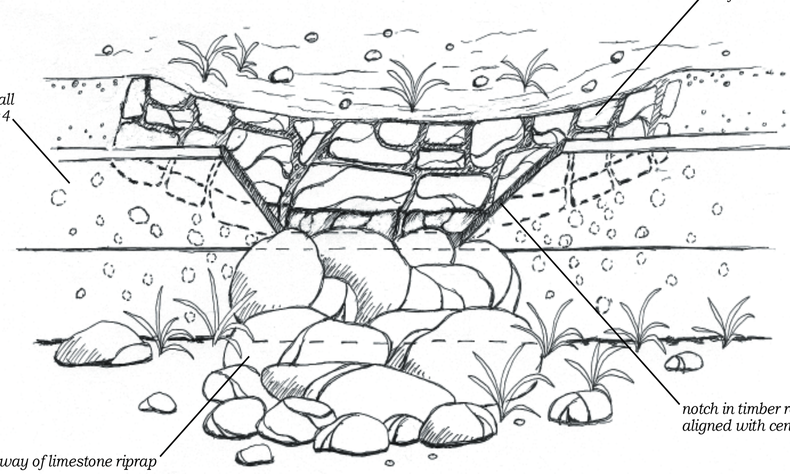
-Each step consist of a timber box that is constructed with 6 by 6 treated timbers that are connected with spikes

-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.

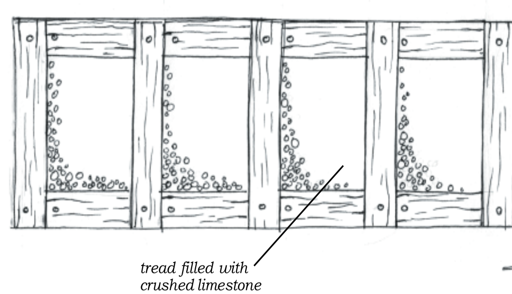
-Stairs should be placed to follow the contours of the slope to minimize grading

Detail #5: Drainage Dip

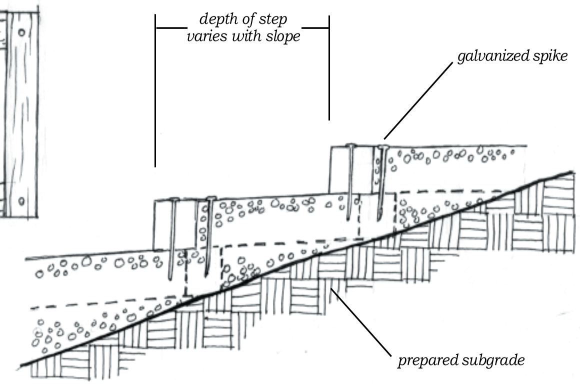


Detail #6: Stairs

plan

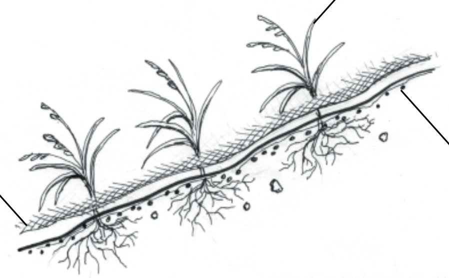


section



Design Details

Detail #7: Planting w/ Erosion Fabric



-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.

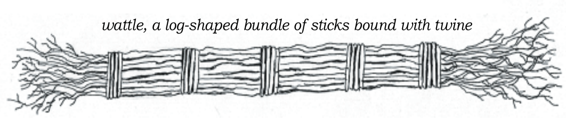
-The use of erosion fabric may be preferred over wattles for large areas, as it is easier to install. The drawback of only using erosion fabric is that it does not create changes in topography where moisture and organic material can collect.

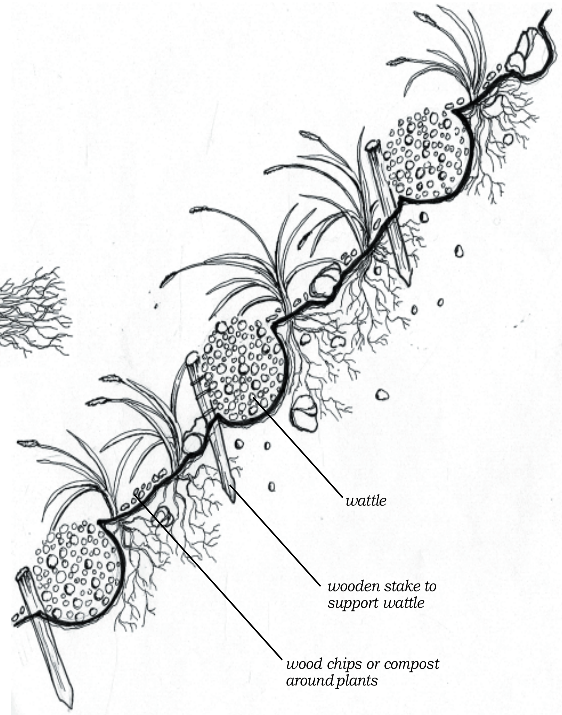
-In addition to seed, mature plants can be installed with erosion fabric. Slits can be cut in the fabric for the installation of plants.

-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.

Detail #8: Planting w/ 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.

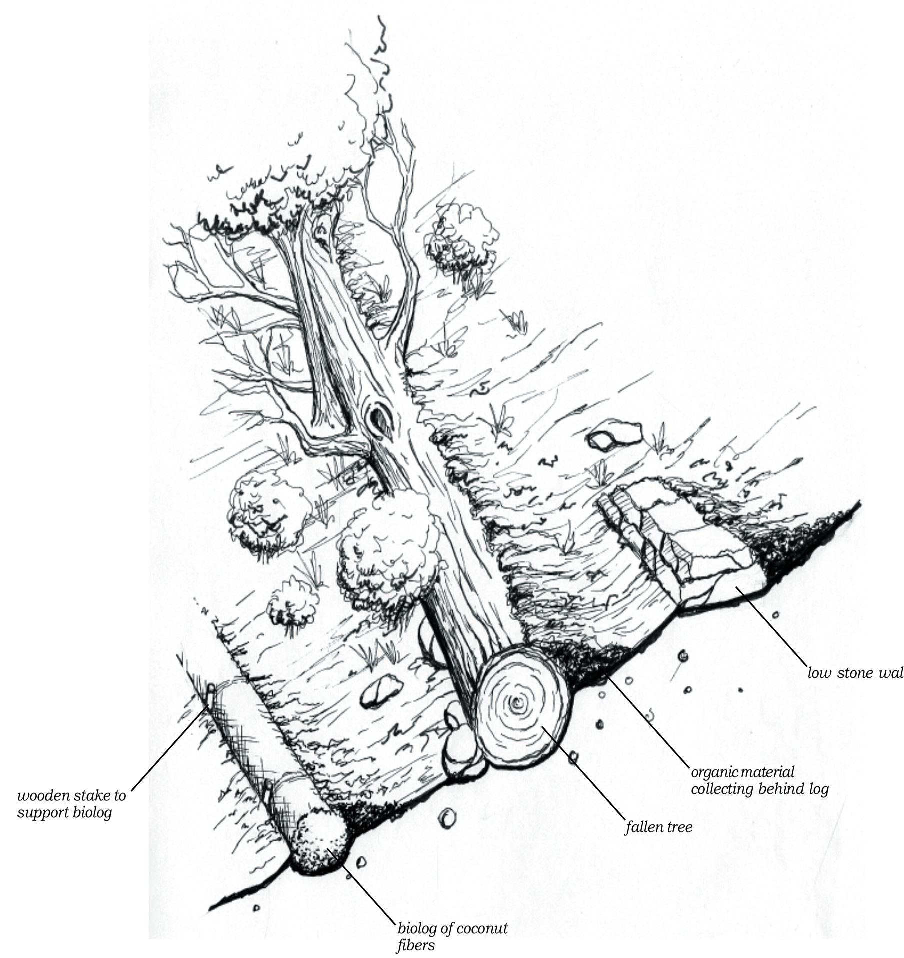
-In areas of severe erosion, an engineer should be involved to provide stabilization recommendations.

Design Details

Detail #9: Organic Collectors

-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.



Plants for Stabilization:

-Key groundlayer plant species for stabilization include:

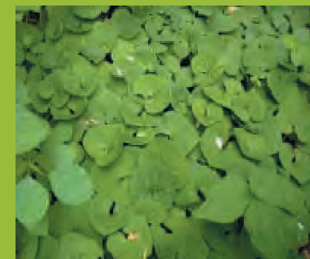
Wet ravines:

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**

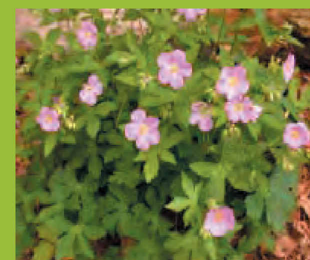
Dry ridges:

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**

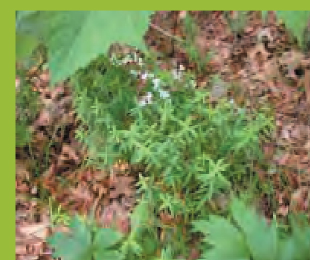
Note: * Denotes that the species can be planted from seed as well as containers. See companion ecological restoration plan for Crosby park for more extensive lists for bluff restoration.



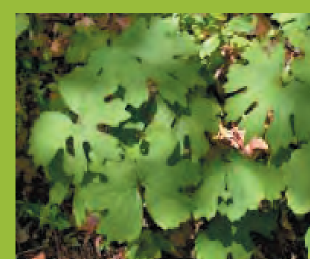
Wild Ginger - Asarum canadense



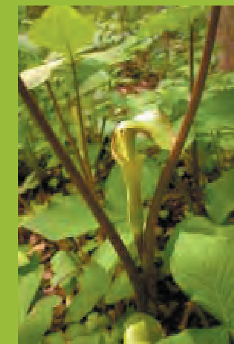
Wild Geranium - Geranium maculatum



Northern Bedstraw - Galium boreale

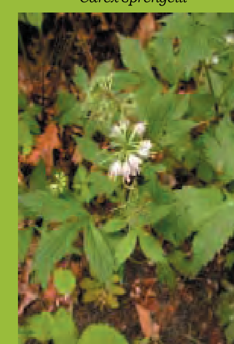


Bloodroot - Sanguinaria canadensis

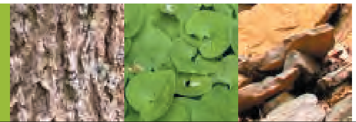


Jack in the pulpit
Arisaema triphyllum

Sprengel's Sedge
Carex sprengelii



Virginia Waterleaf
Hydrophyllum virginianum

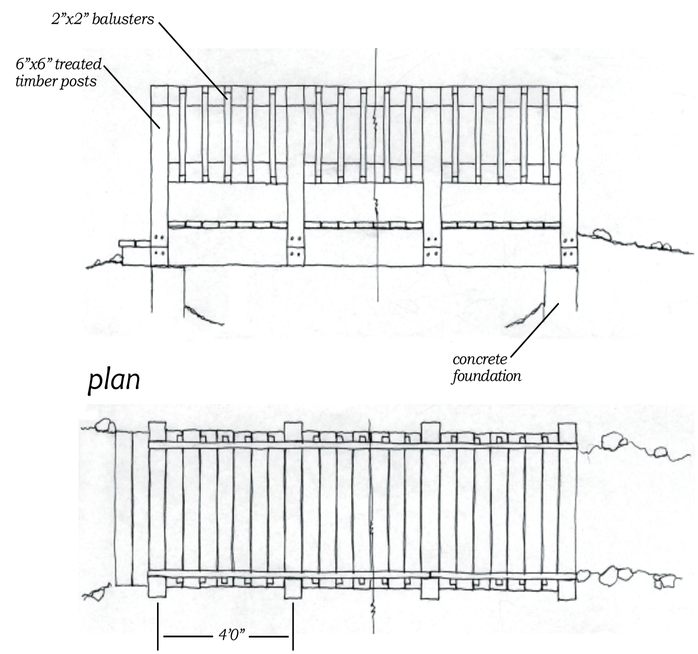


Wet Ravine Condition

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.

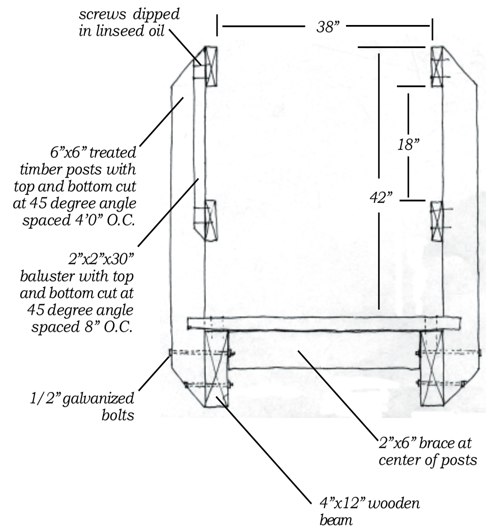
Detail #10: Bridge

elevation

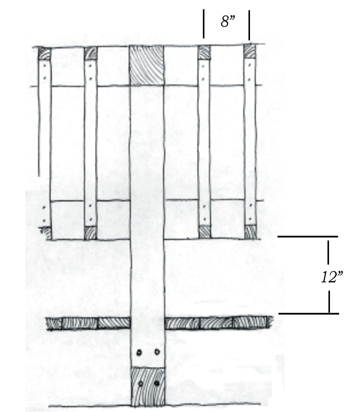


plan

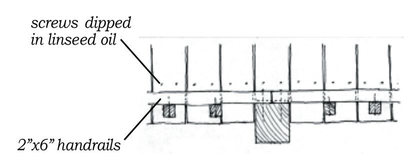
post & rail section



post & rail elevation



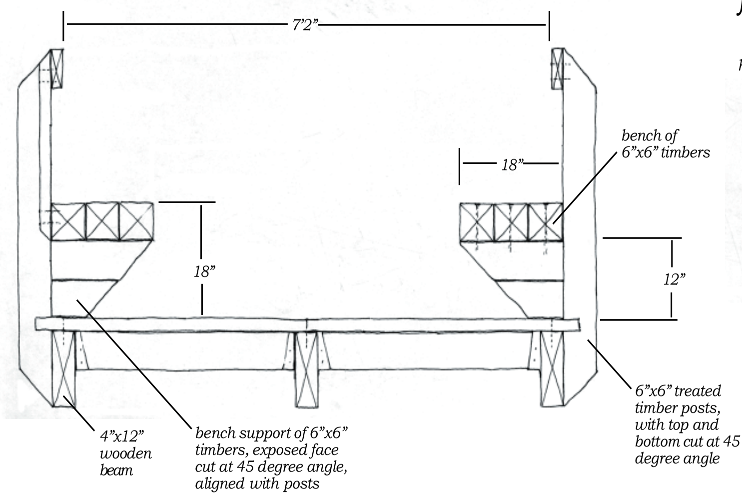
post & rail plan



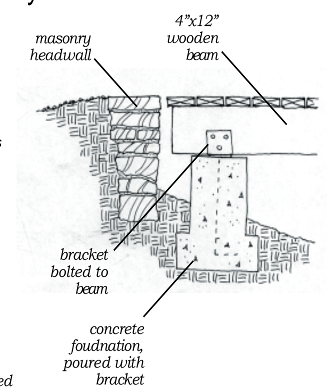
Design Details

Detail #11: Bridge w/ Seating

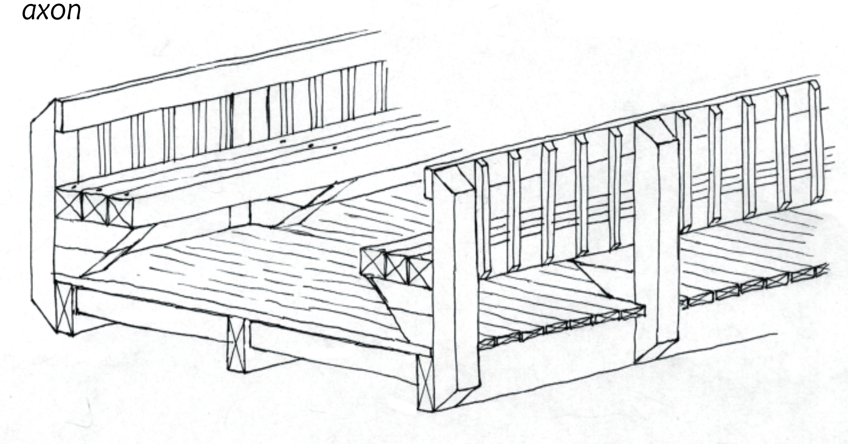
section



foundation connection



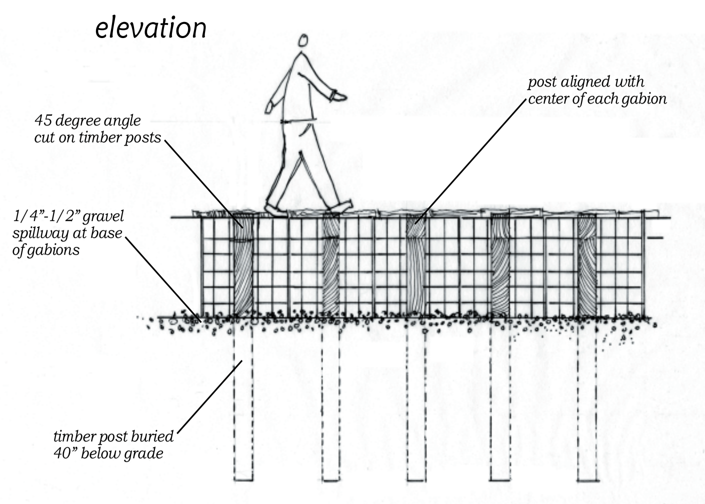
axon

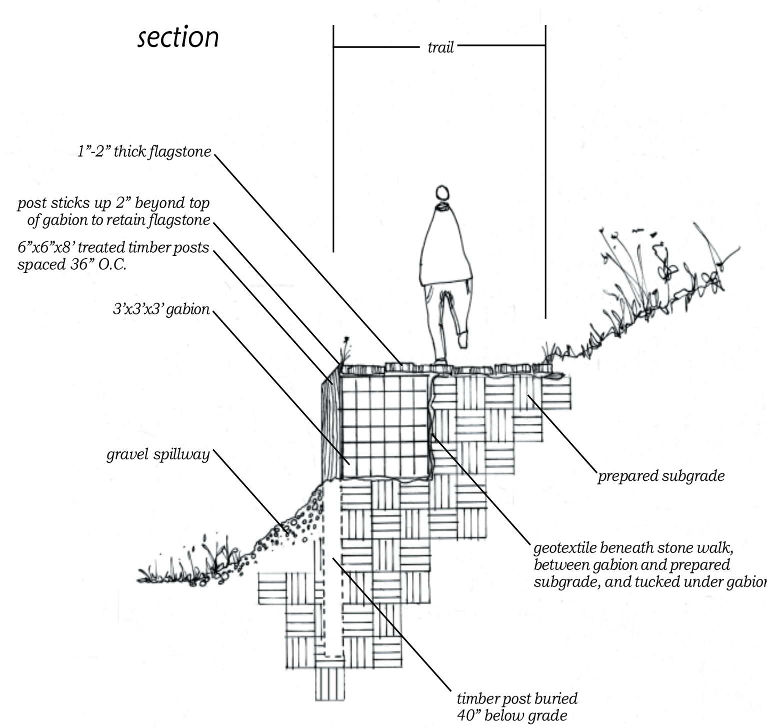


Design Details

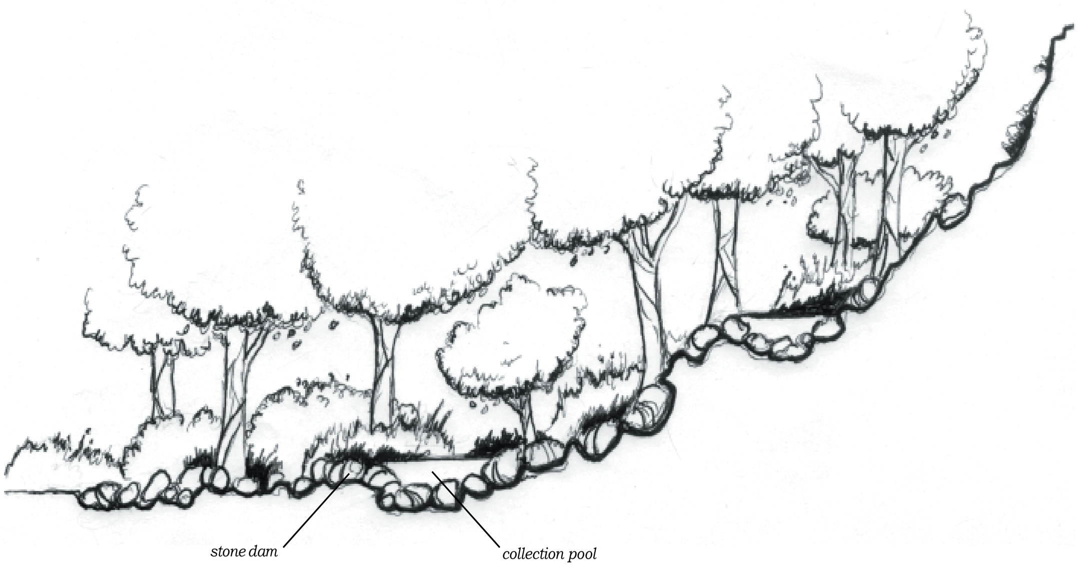
Detail #12: Gabion Wall

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.

Design Details

-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.

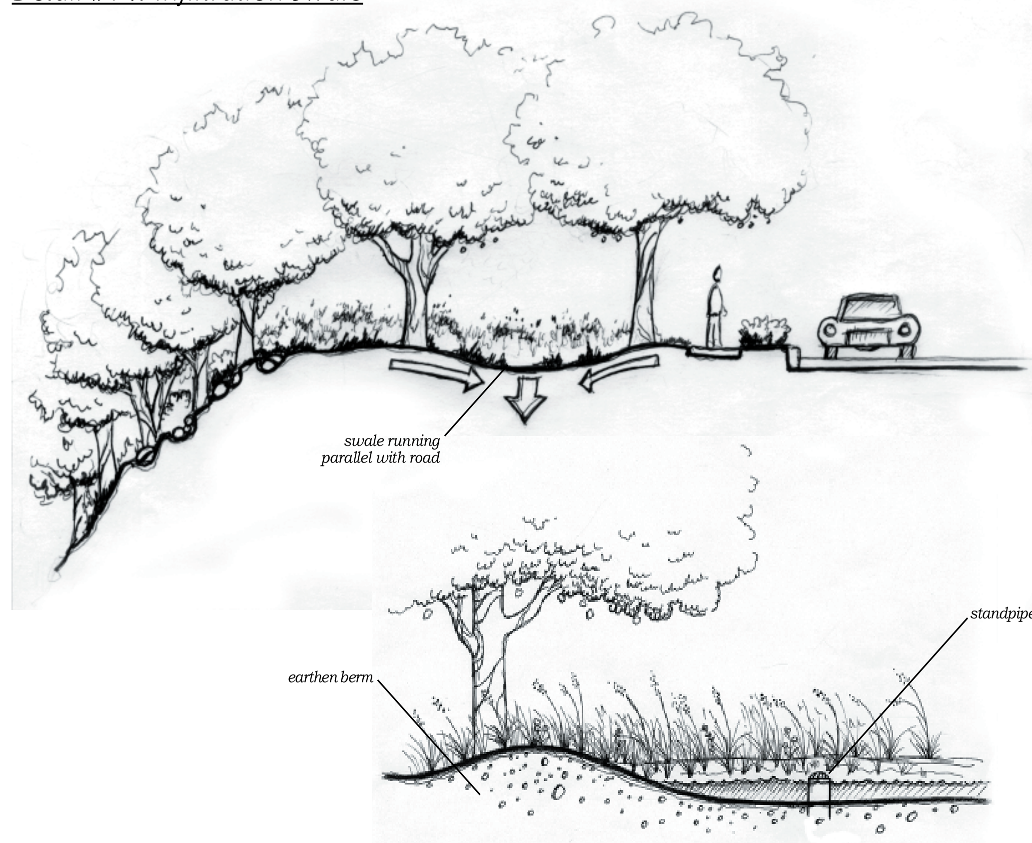
-The combination of constructing a berm and digging a gentle depression would allow water to pool and infiltrate on top of the bluff. There is currently a catch basin in the lawn that would require a standpipe.

-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

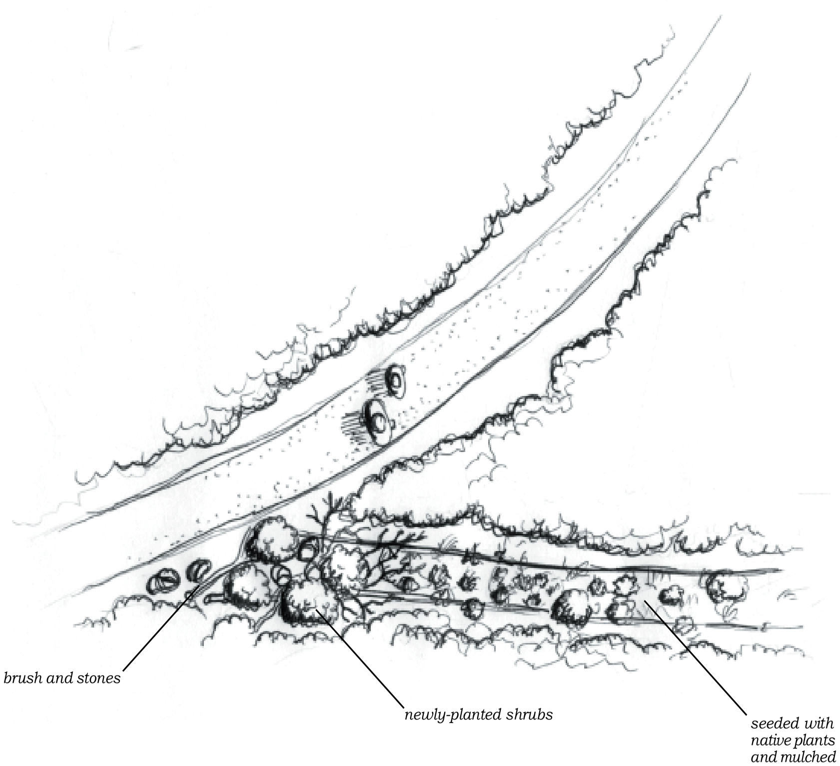
Many erosion problems along the bluff are due to stormwater runoff from the top of the bluff. Infiltrating stormwater at the top of the bluff would help alleviate this condition.

Detail #14: Infiltration Swale



Miscellaneous

Detail #15: Trail Closure



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

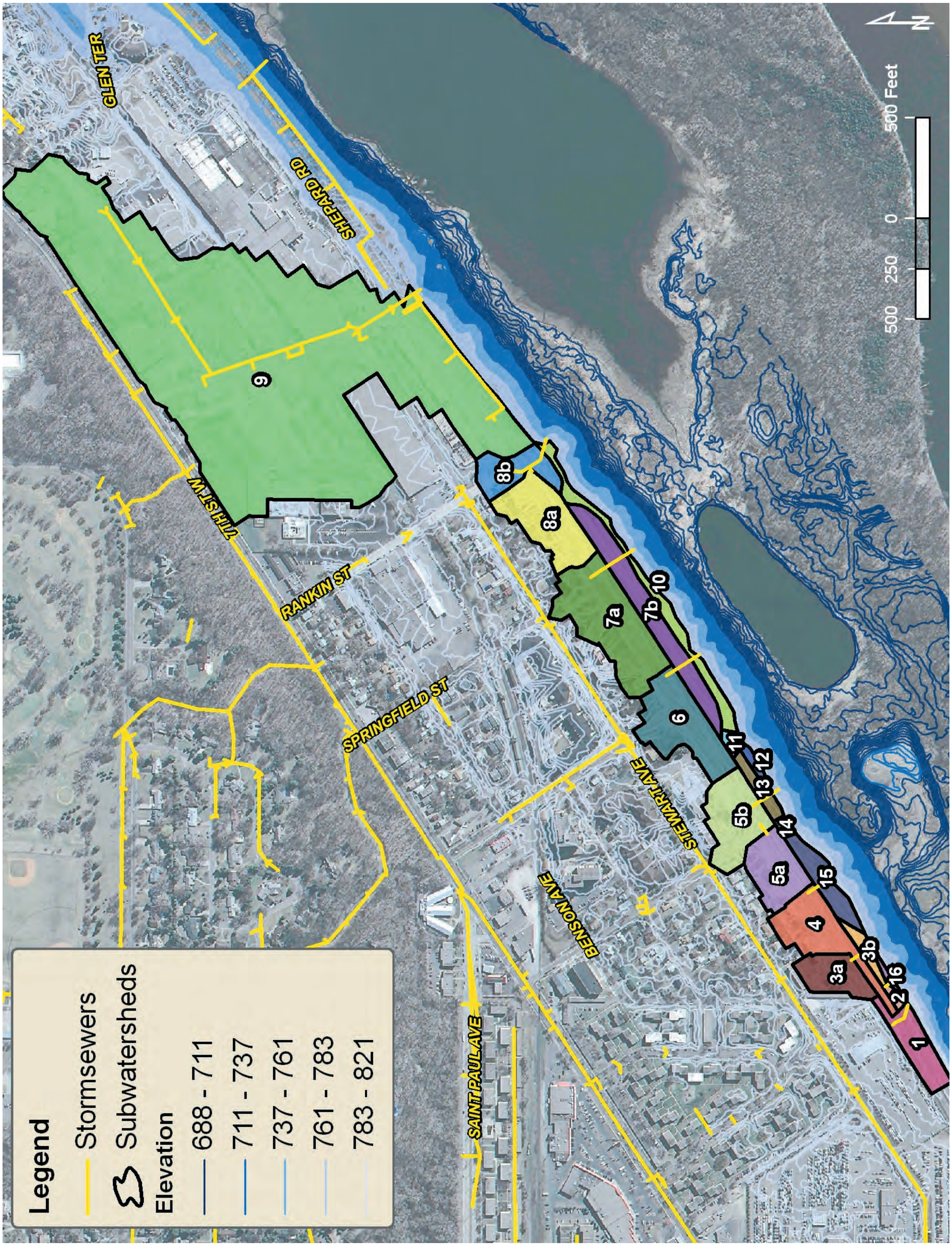
-Shrubs help camouflage trail openings and block access. Species with thorns, such as wild rose and native gooseberry, can be especially effective deterrents.

-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
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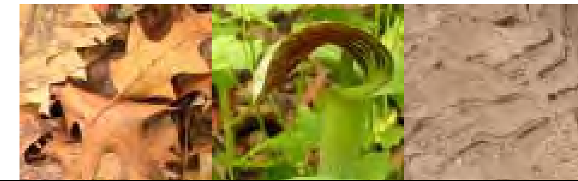

Crosby Park: Bluff Trail Project

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

Authors:
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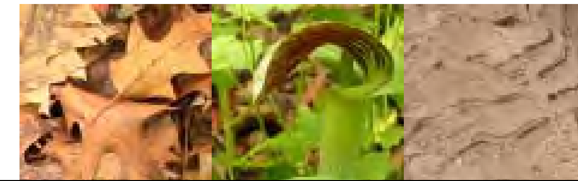
Carlos Fernandez
Courtney Skybak
Ryan Holdorf

June 2004

Table of Contents

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

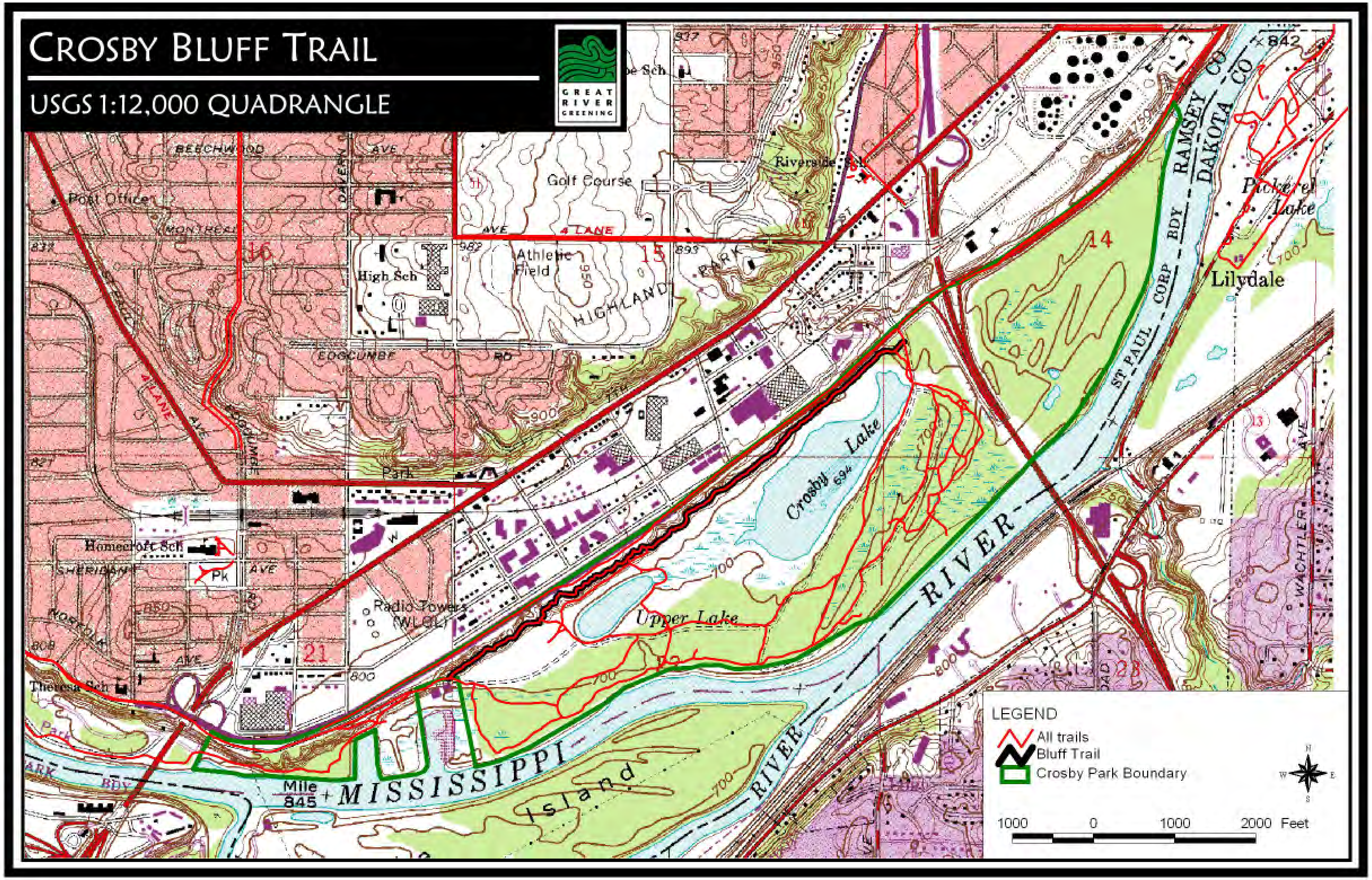
The soils on the bluff are highly erodable and as a result, trail use other than hiking should be discouraged. Mountain biking should be restricted to trails that are less prone to erosion and people and animals should be persuaded to stay on the trail. The trail plan recommends the removal of some unnecessary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

Trail Monitoring

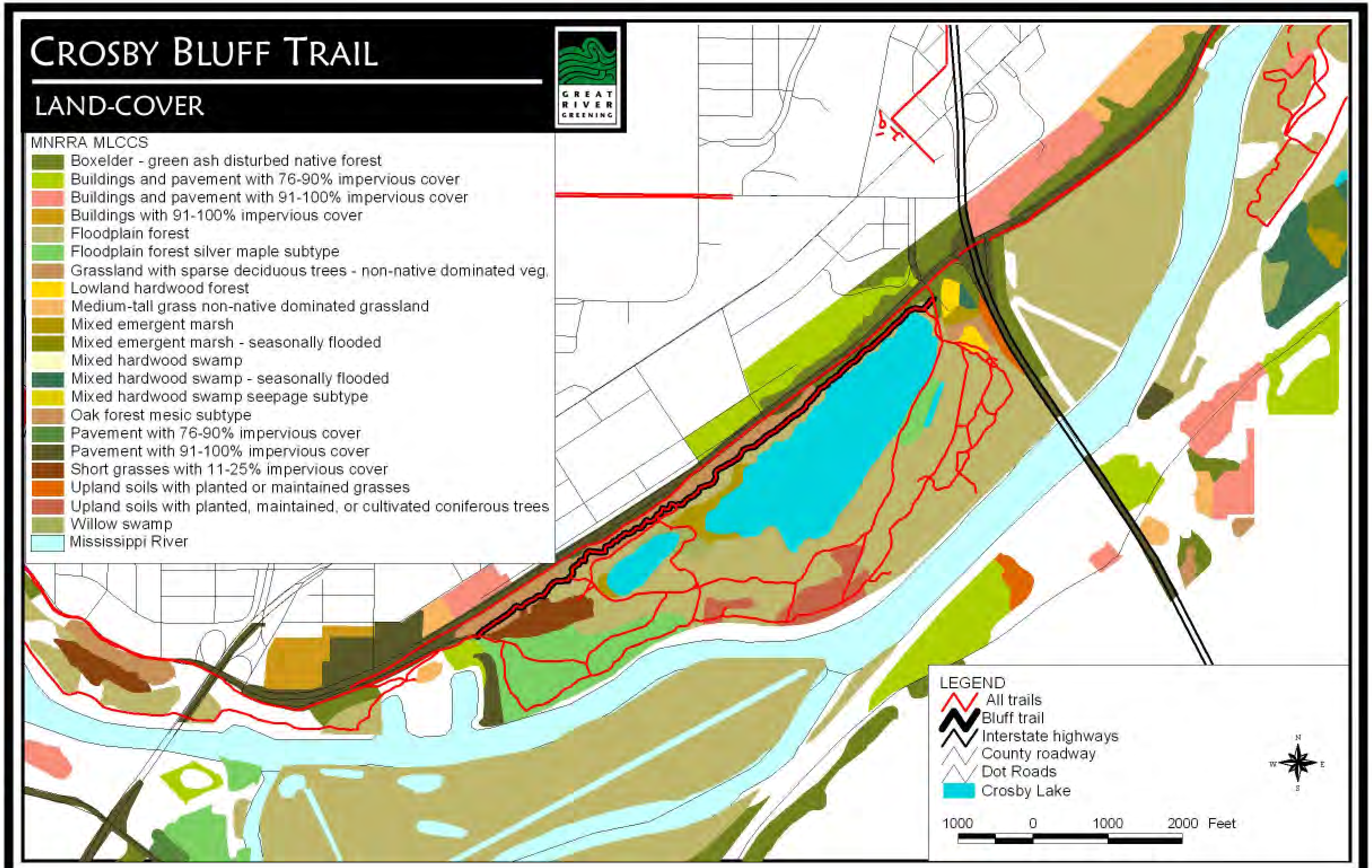
Periodic monitoring of the Bluff Trail will help prevent small problems from becoming more serious. Neighborhood residents can play an important role in monitoring for problems as part of the City of St. Paul's Eco Stewards program. Through this program, volunteers adopt project sites and conduct activities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

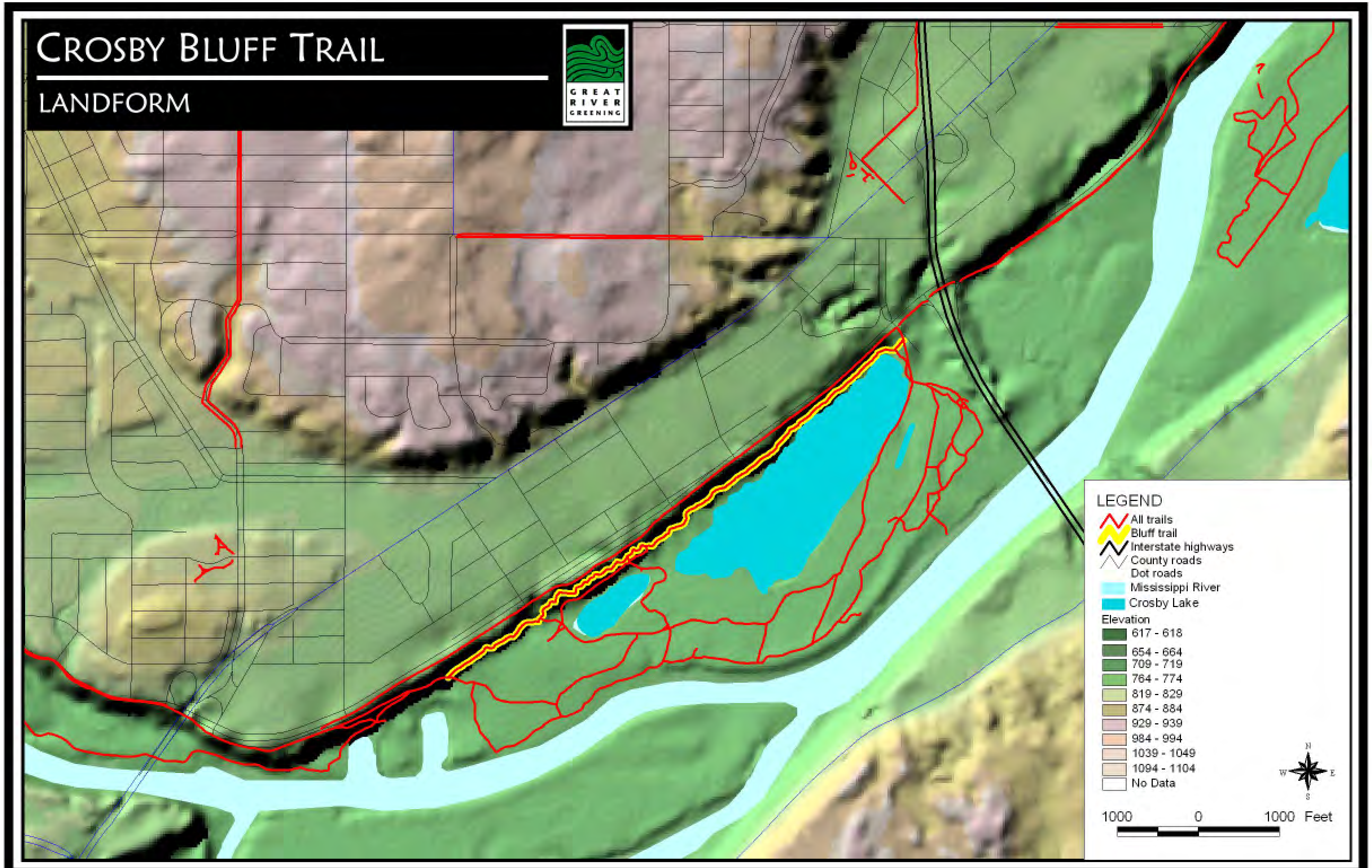


Resource Analysis of Intrinsic Qualities



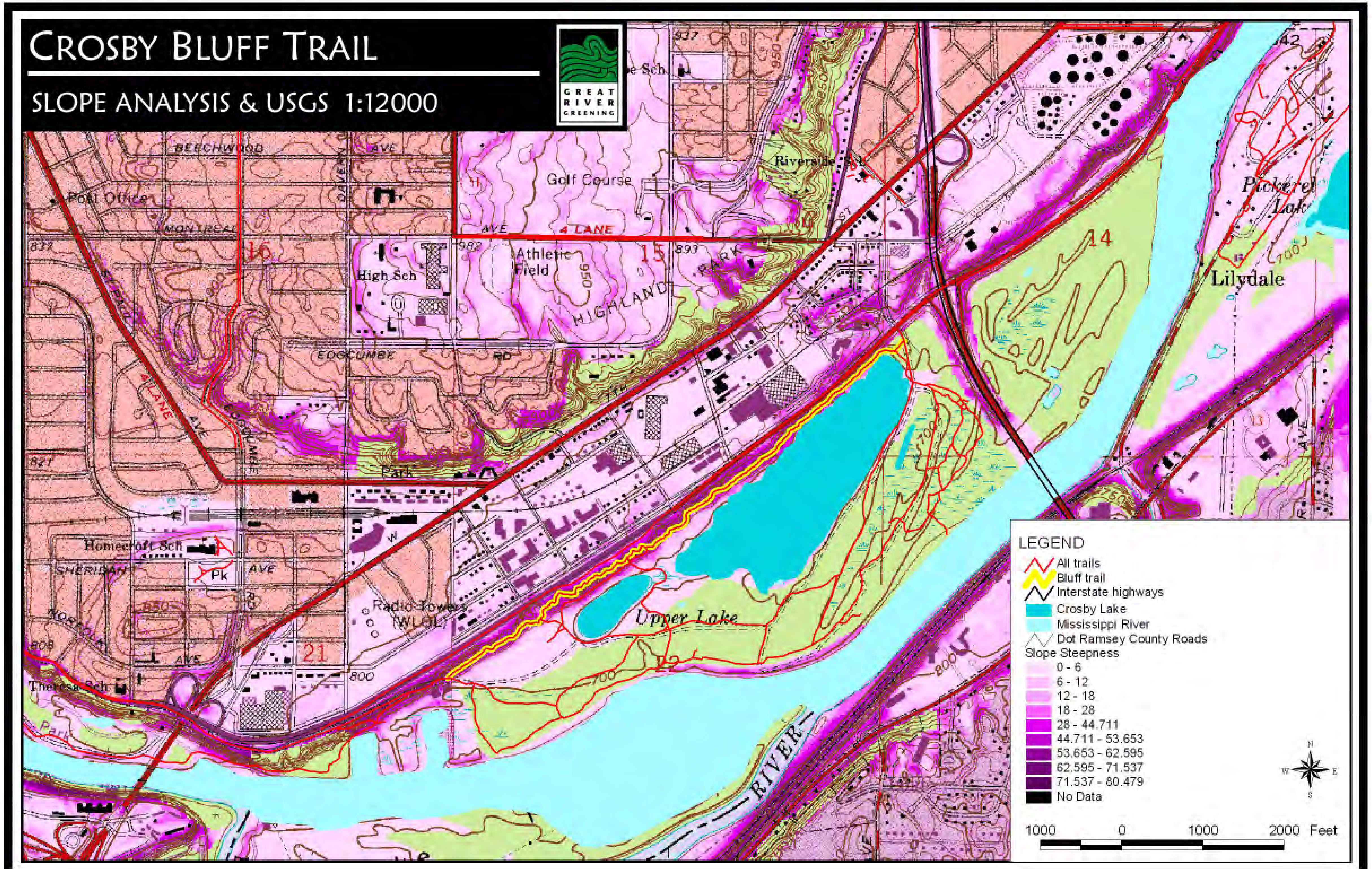
Land-Cover

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.

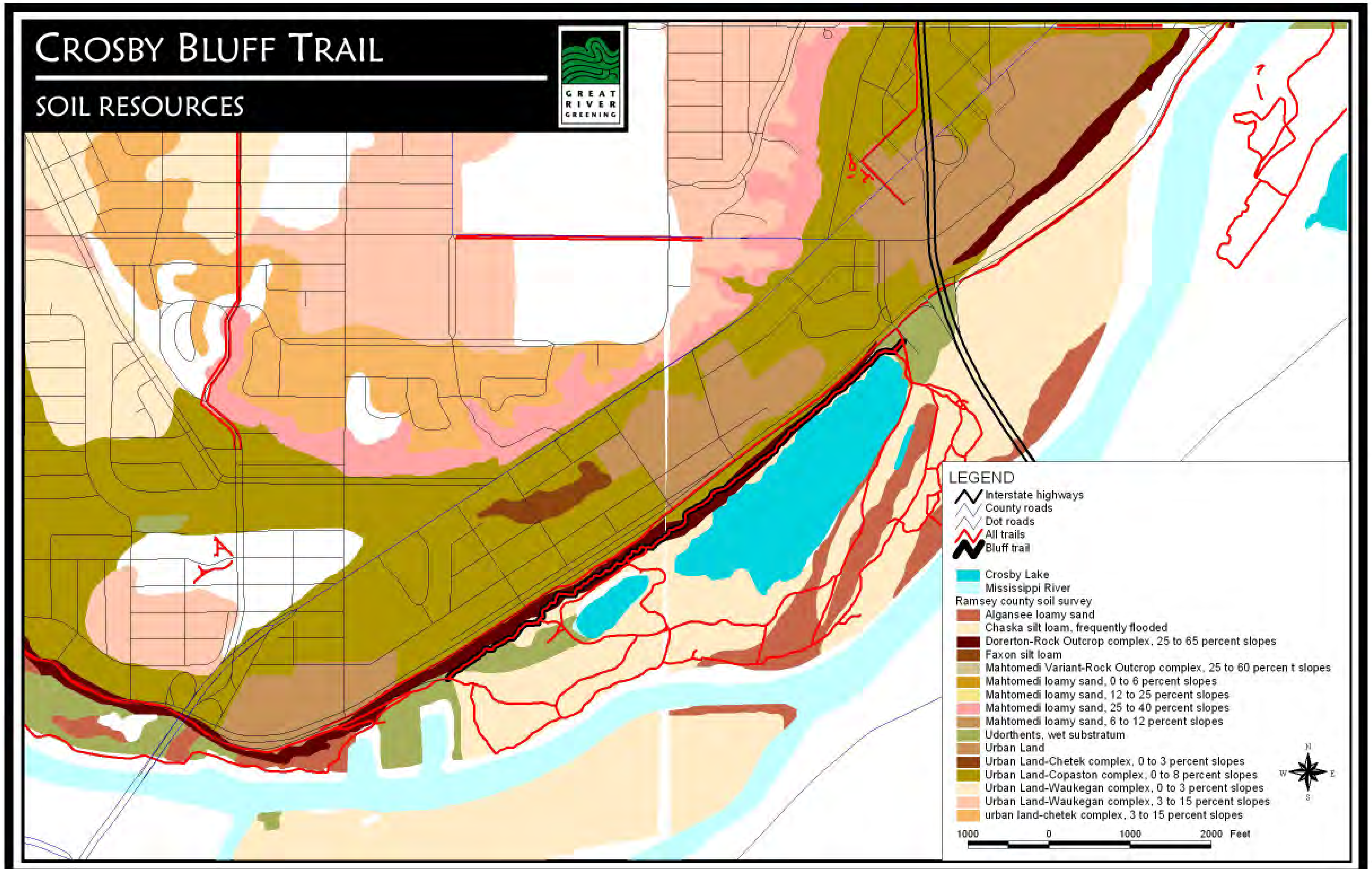


Slope

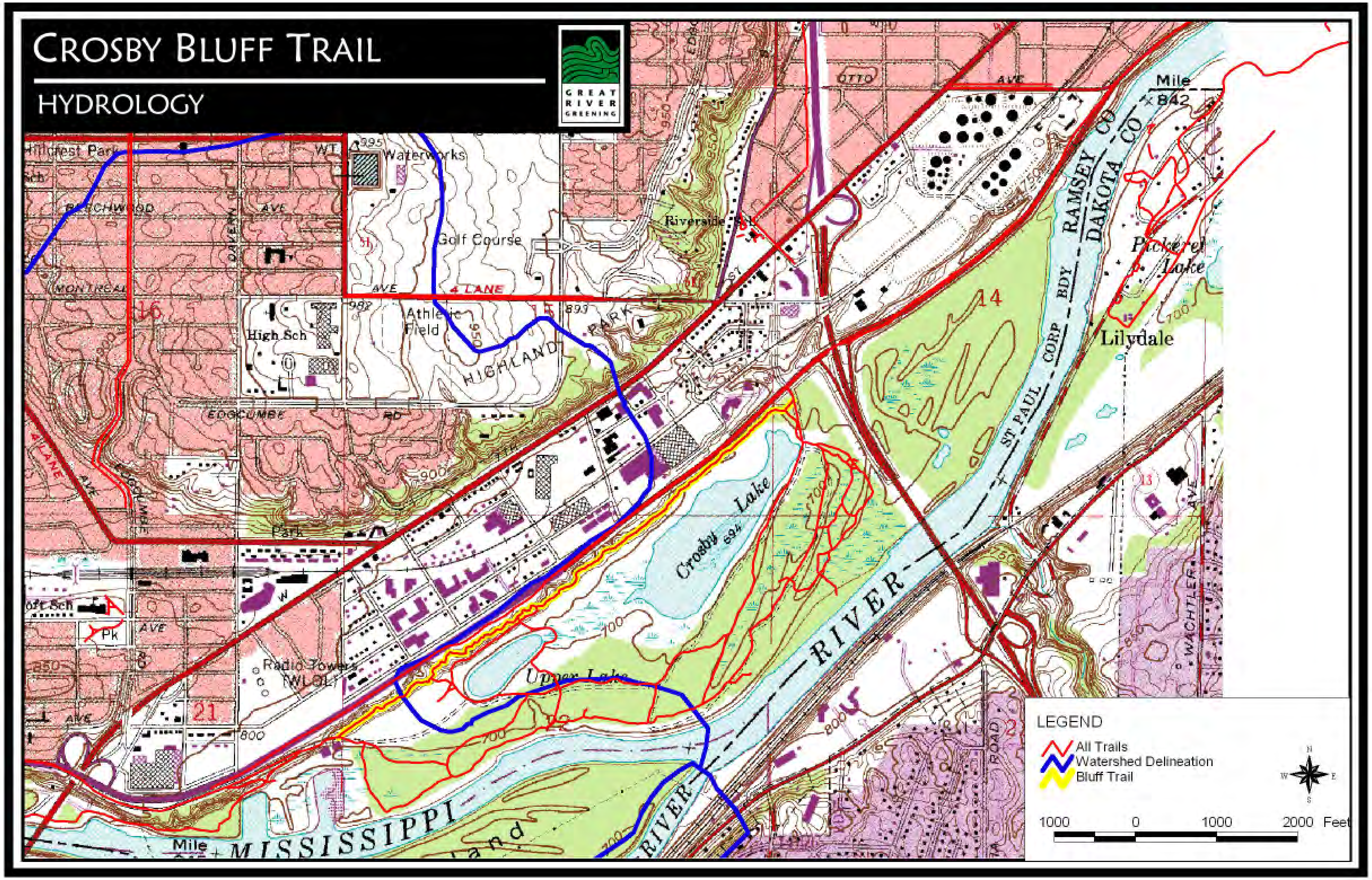
The Slope Analysis overlay on the USGS 1:12000 map identifies the steepness of slopes in and around the site. A measurement of slope steepness is useful in understanding the process of erosion, and the relationship between slope, soil stability, stormwater movement, and vegetation. Vegetation often has 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

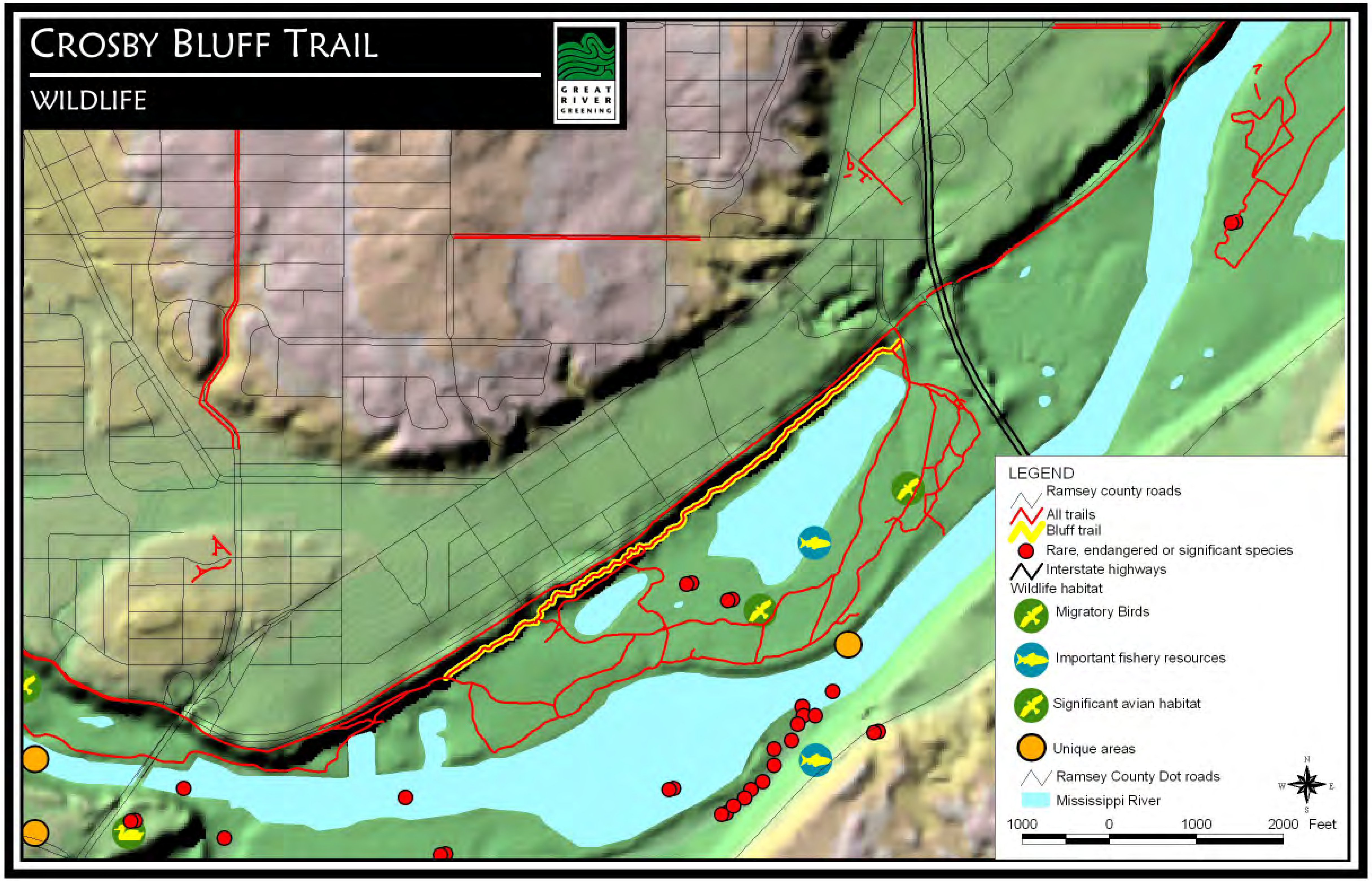


Hydrology

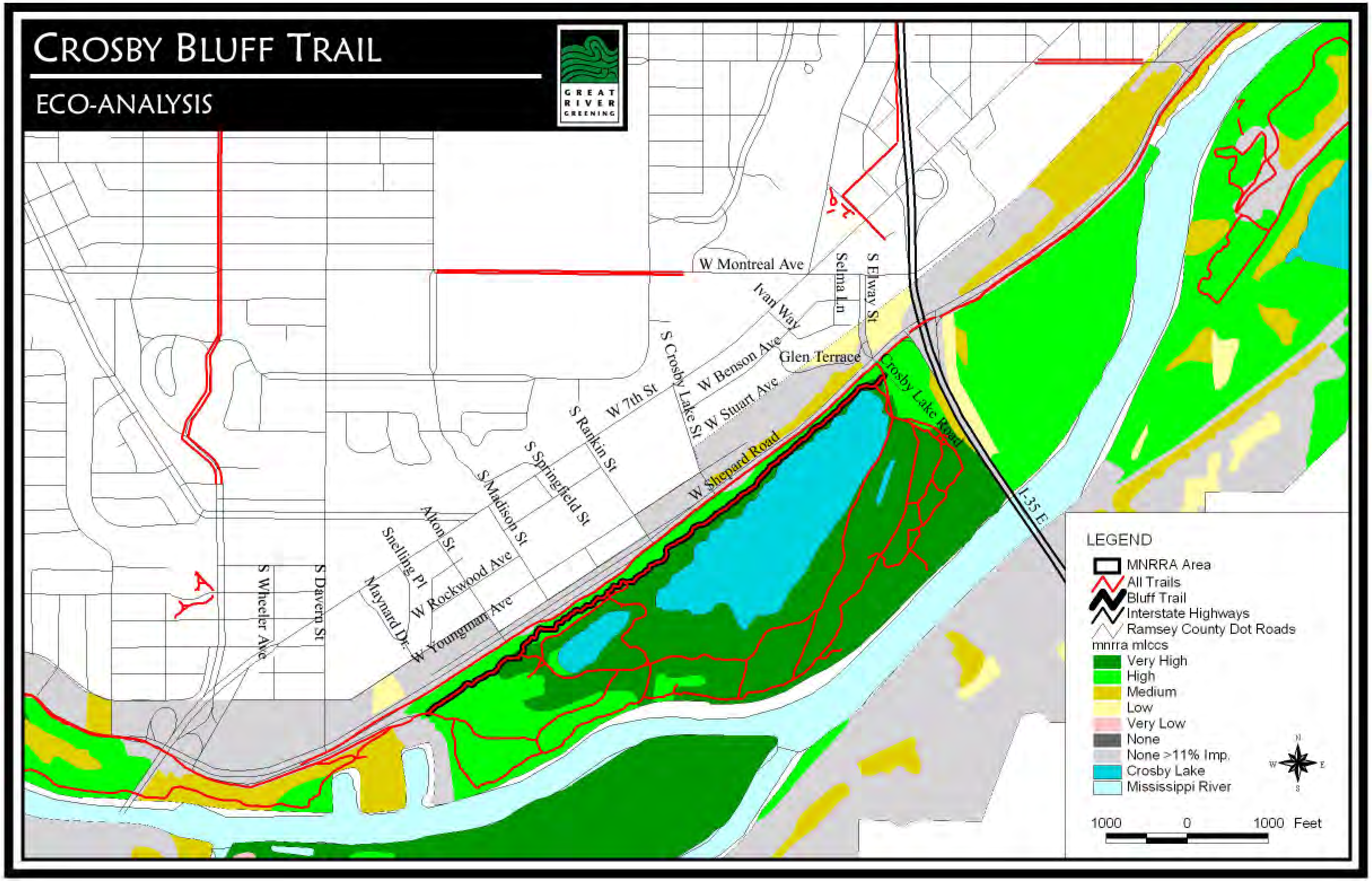
The Hydrology map identifies watershed boundaries in relation to trail location and the extent of Crosby Park. A watershed boundary divides the bluff trail into two portions. Stormwater in the area around the larger portion (to the east) drains into Crosby Lake. Stormwater in the area around the smaller,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



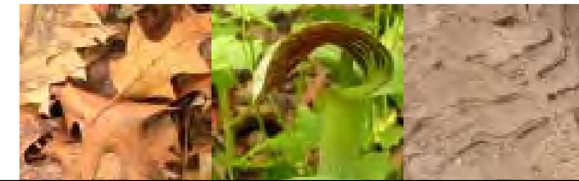
Resource Analysis of Intrinsic Qualities



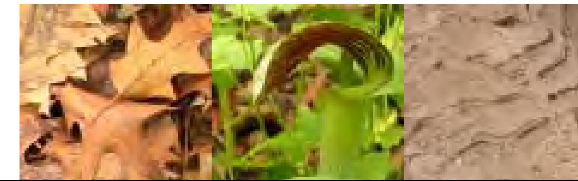
Eco-Analysis

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.

Site Analysis



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.

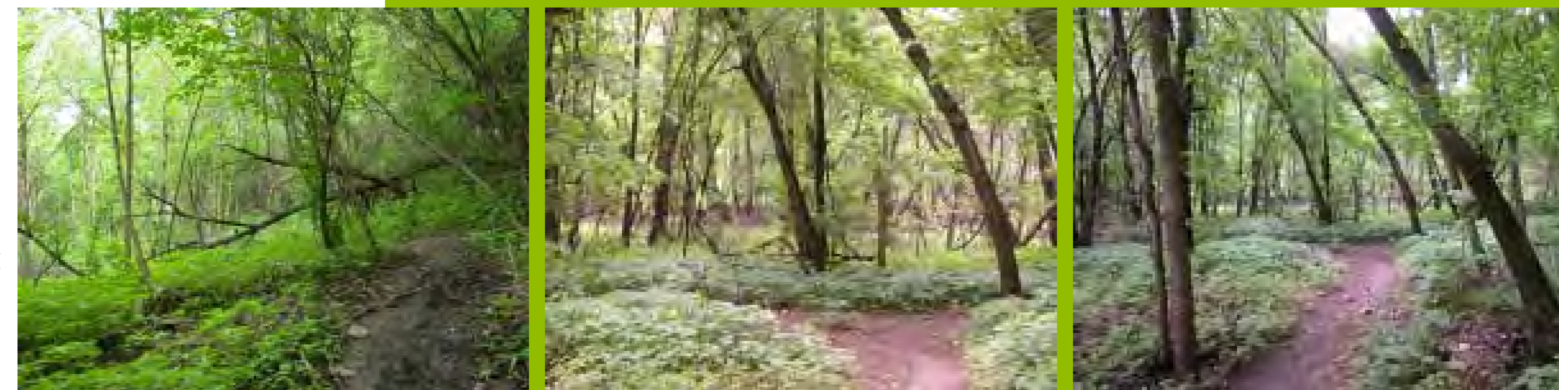
The second segment is the High Bluff Trail segment. It is characterized by the elevated location of the trail and the experience of being up in the trees and upon the steep bluff slopes.

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

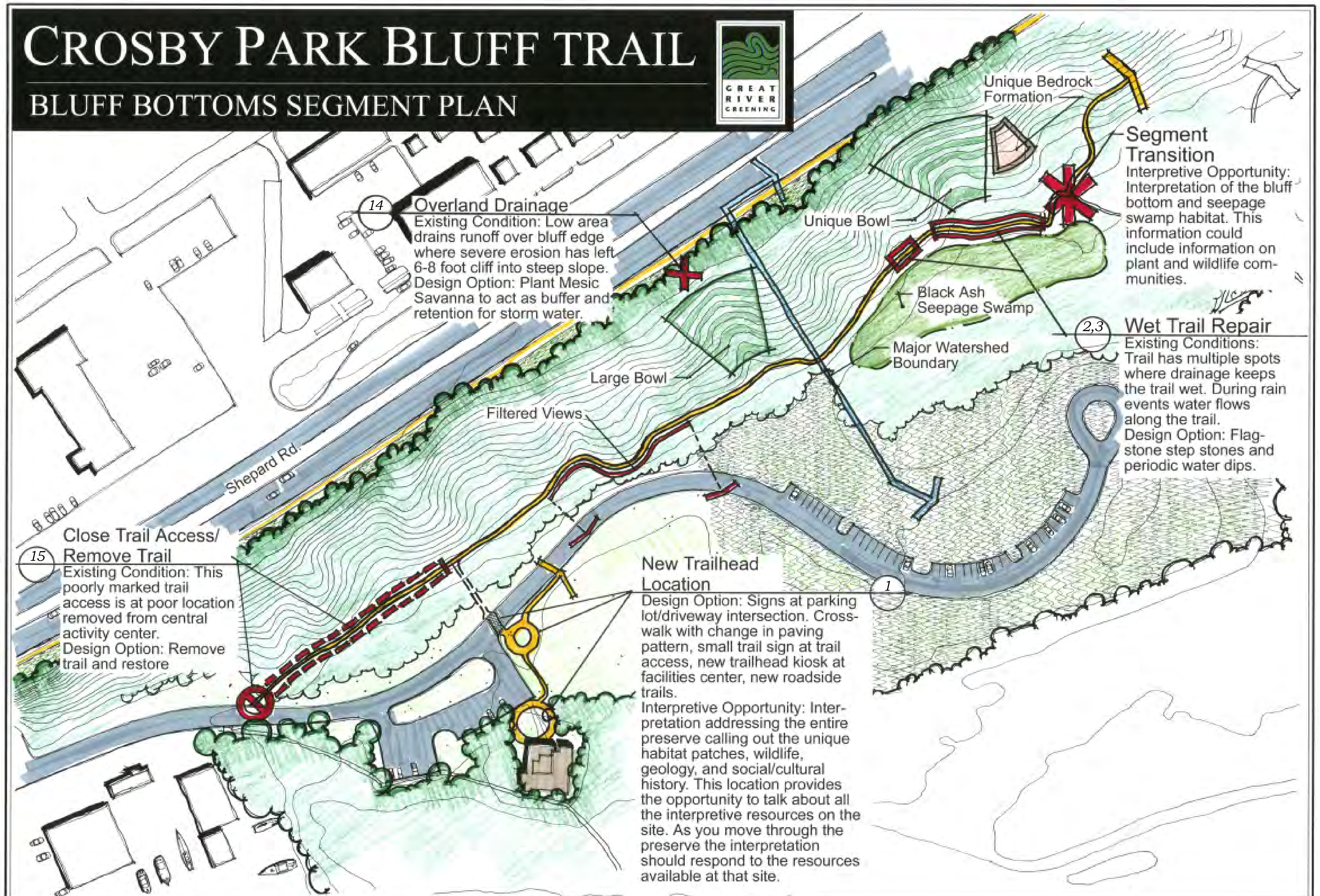


High Bluff

The Gorges

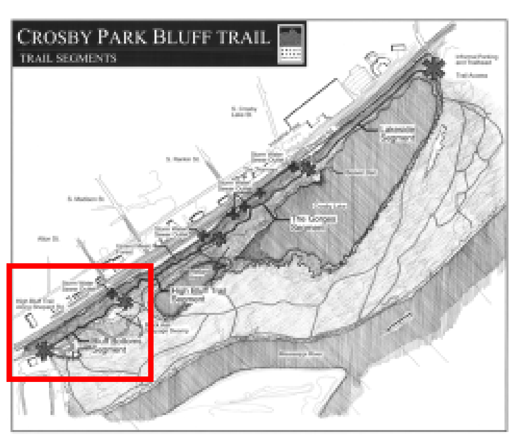
Lakeside

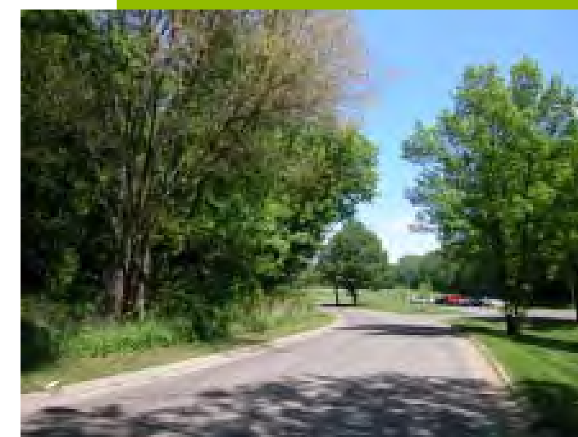
Trail Segment Plans



Trail Segment 1: Bluff Bottoms

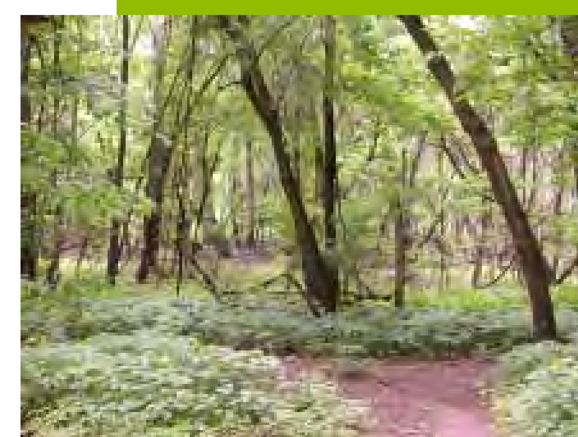
The Bluff Bottoms Trail Segment begins at the park's west parking lot and ends where the trail climbs the bluff slope. It begins with a strong sense of enclosure, pressed between the park access road and the bluff. Soon the space between the trail and road expands, and the rest of this trail segment 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.



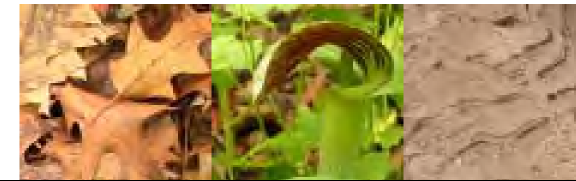
The black ash seepage swamp, along which the trail winds.

Water running through the trail after rain.

Sandstone bedrock exposed near the trail.

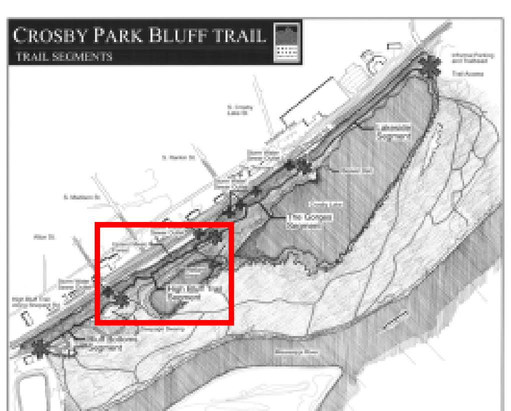
The unique bowl, filled and stabilized with rubble dumped from the top of the bluff.

Trail Segment Plans



Trail Segment 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.

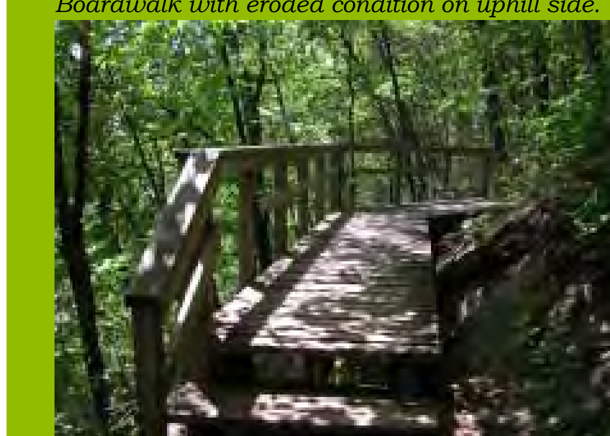

Limestone outcropping at top of bluff.


Severely eroded promontory.


Filtered views to paved trail below.

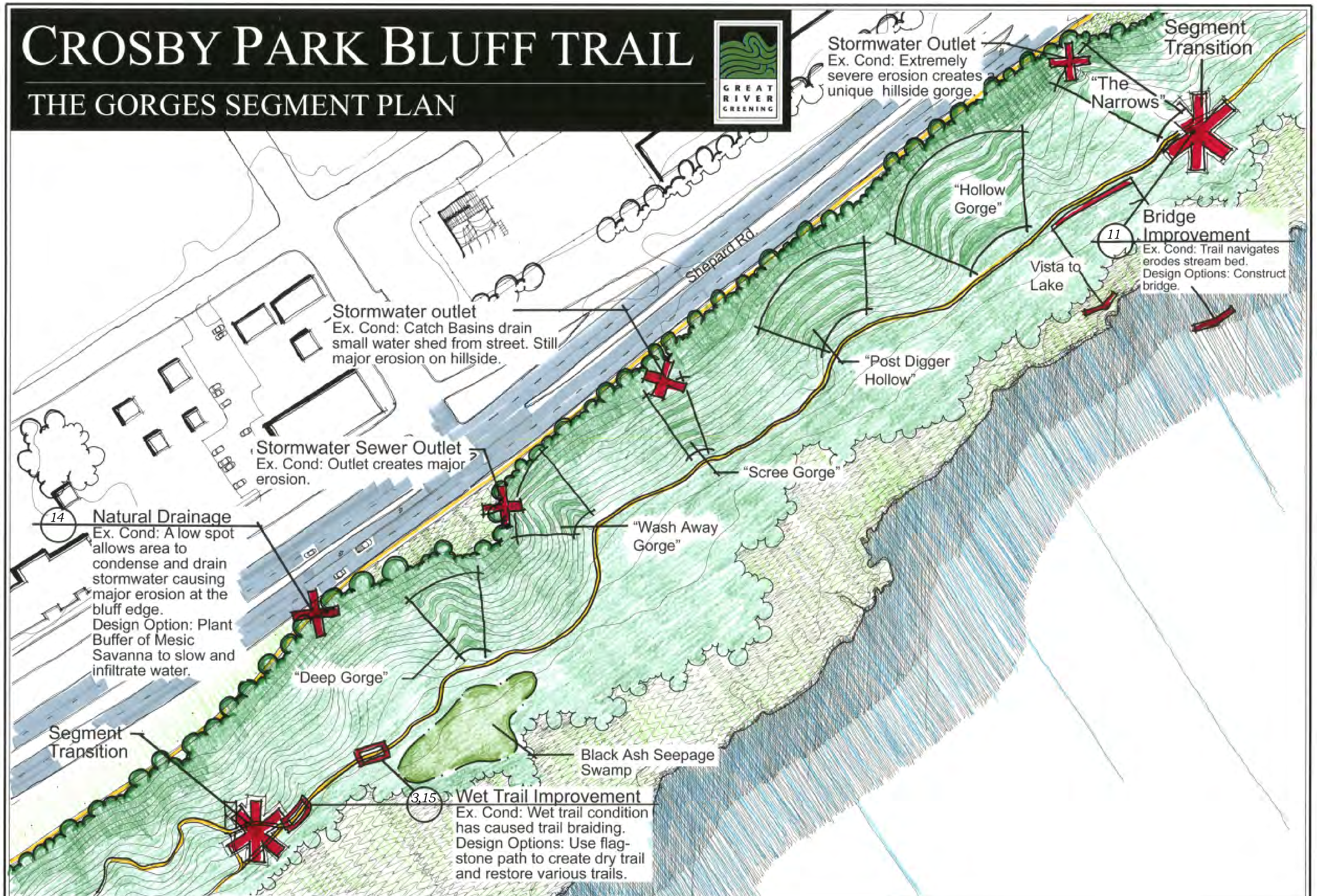

Water on trail, gabion's recommended.


Most recent, sturdy timber wall.

Boardwalk with eroded condition on uphill side.


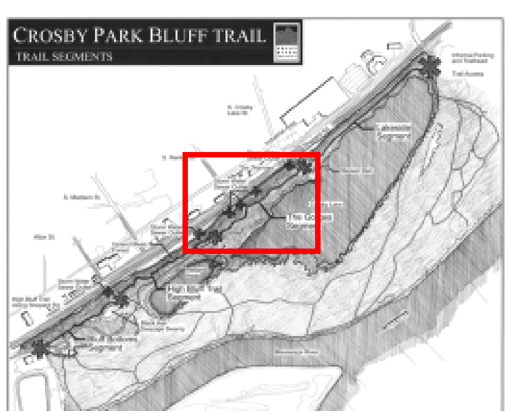

Existing bridge.

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.



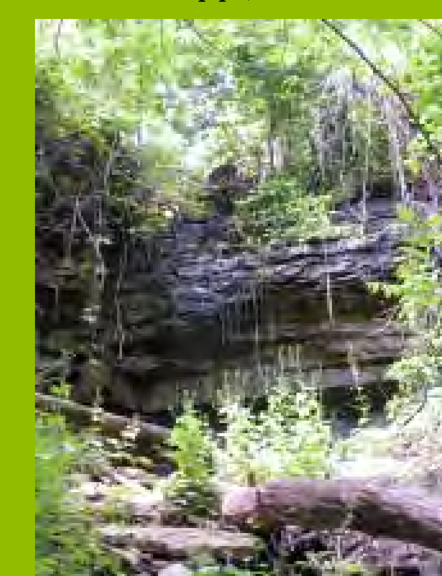
A particularly severe infestation of garlic mustard.

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

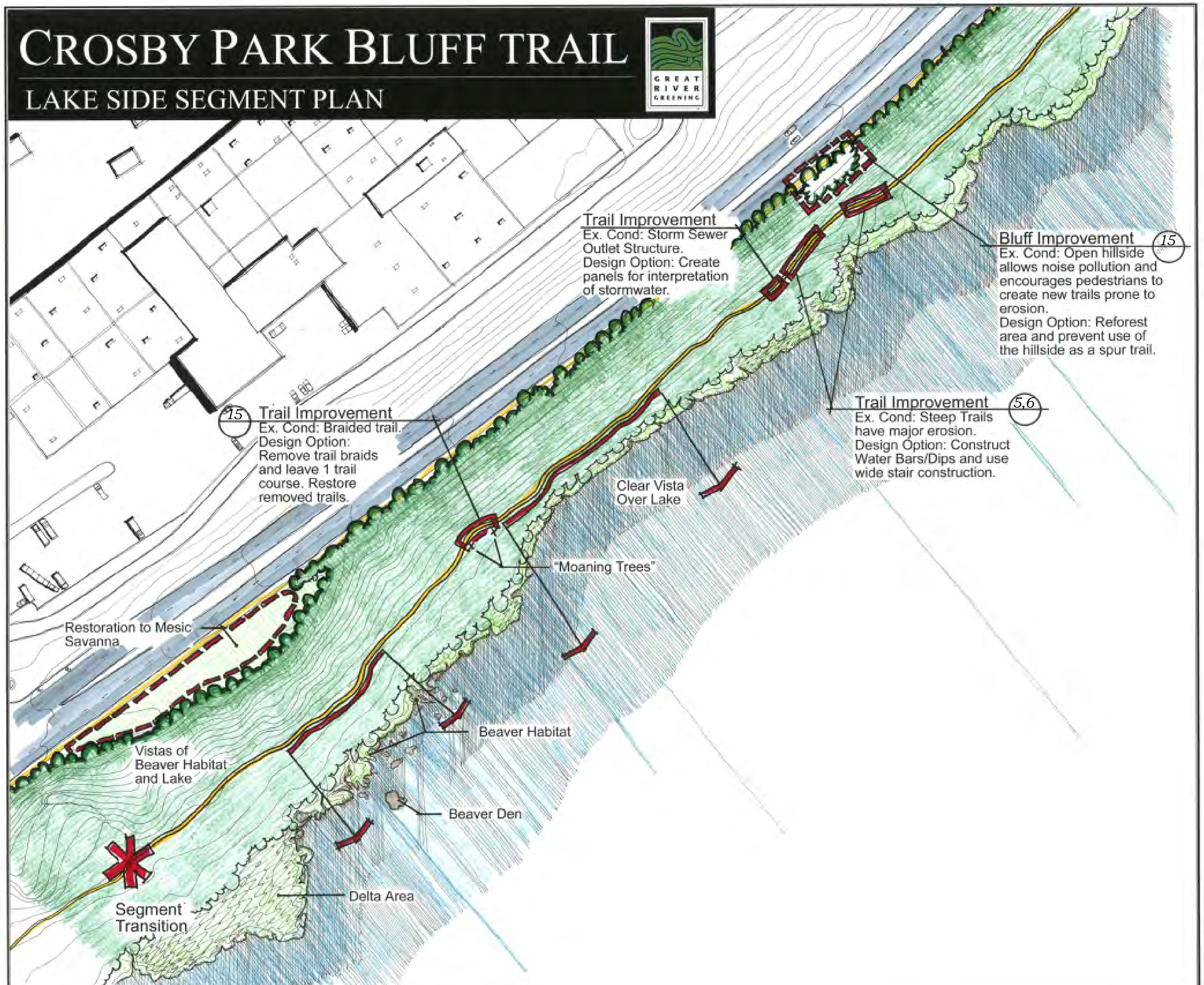
The entrance to the Narrows.

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.

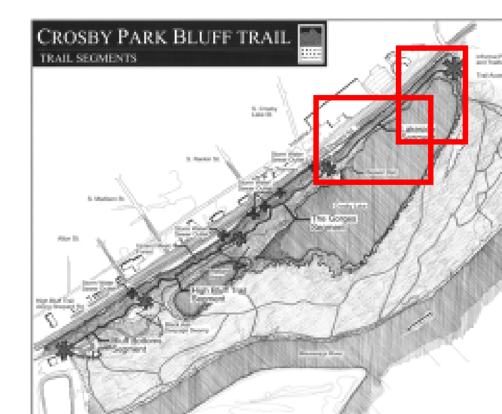


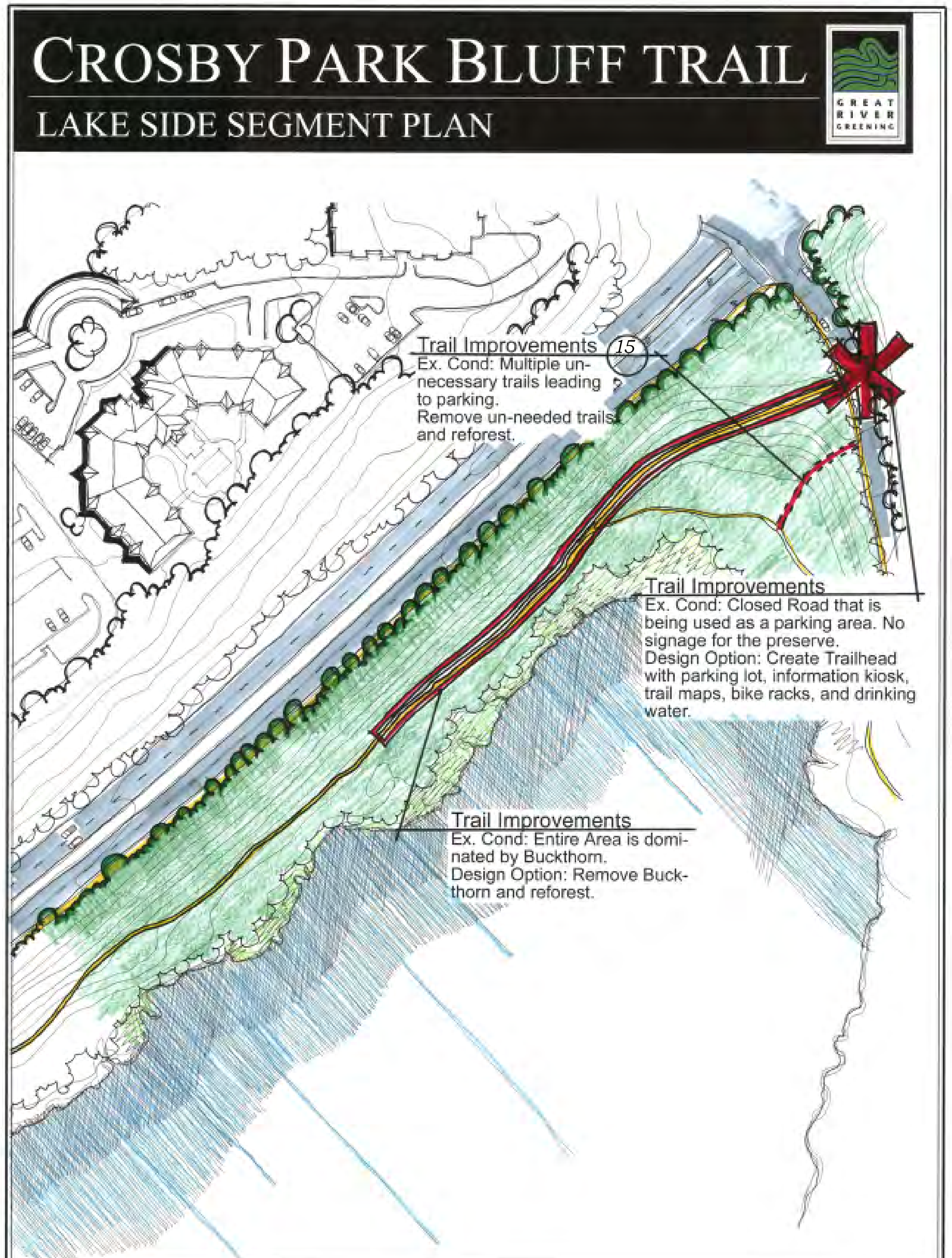
Trail Segment Plans



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.

Bluff Bottom, Wet Condition

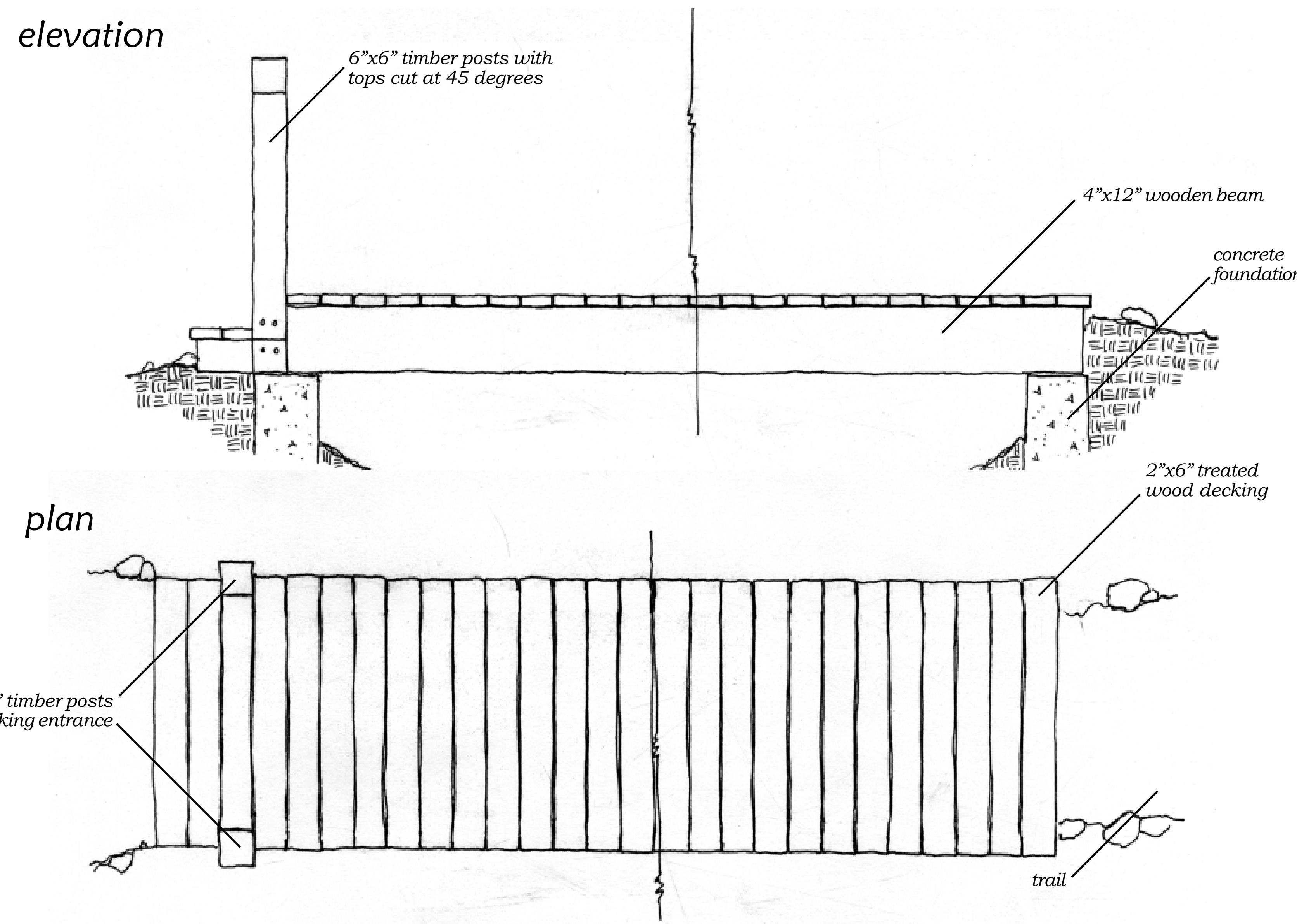
There are many areas at the bottom of the bluff where the flow and accumulation of water is a problem. The goal in these areas is to allow both the passage of water and the movement of people, without one impeding the other.

Detail #1: Trailhead Bridge

-Bridge is simple boardwalk without railing.

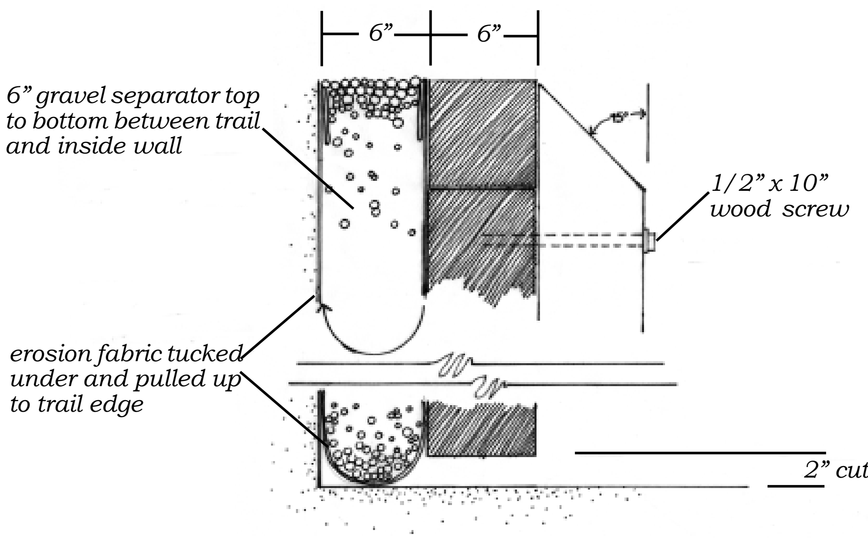
-6x6" posts, with tops cut at a 45 degree angle, mark the transition from the road crossing to the trailhead bridge. Timber posts bring design vocabulary of retaining walls to bridge structures.

-See Detail #11 for beam-foundation connection.

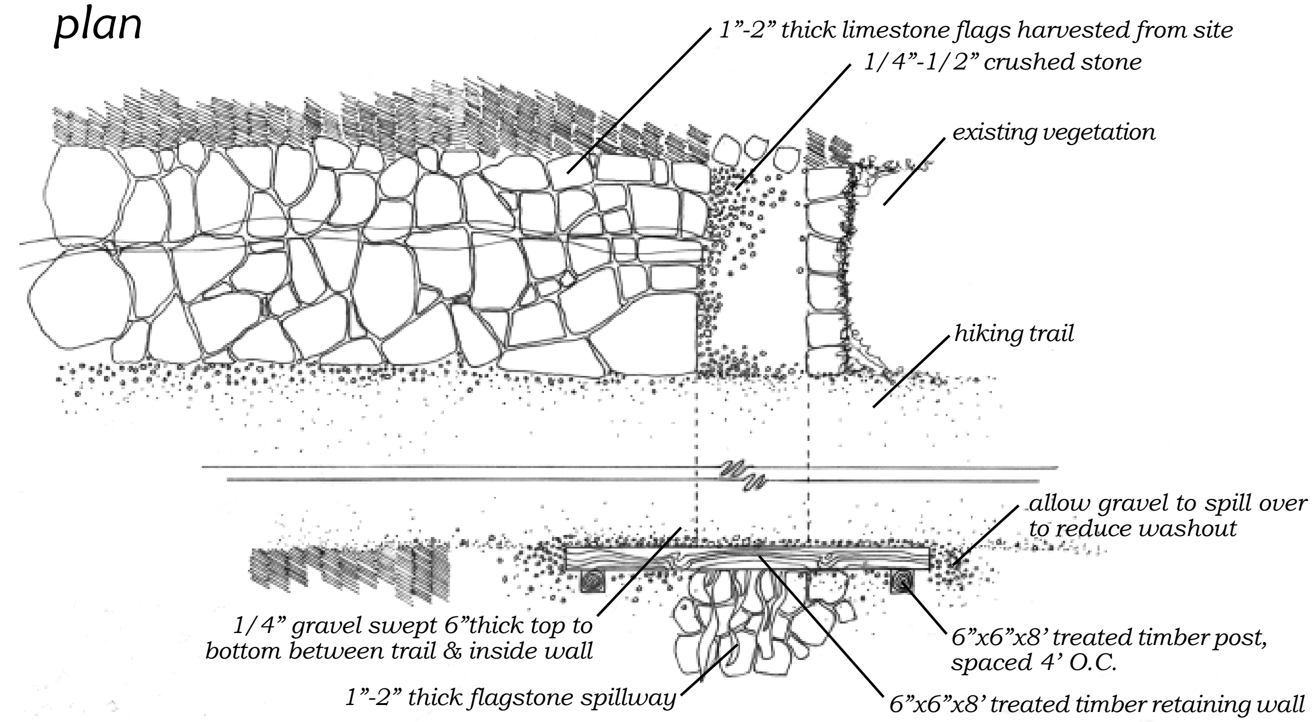


Detail #2: Drainage Ditch w/ Crossing

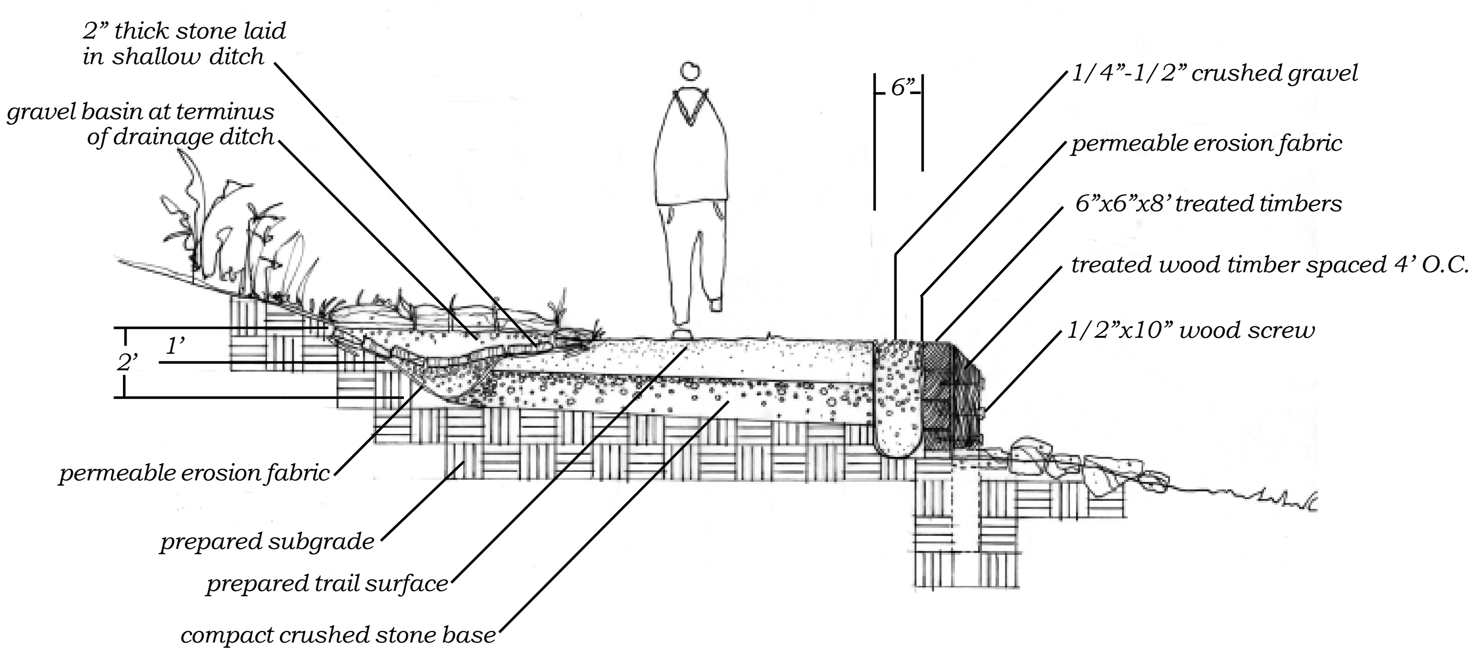
wall section closeup



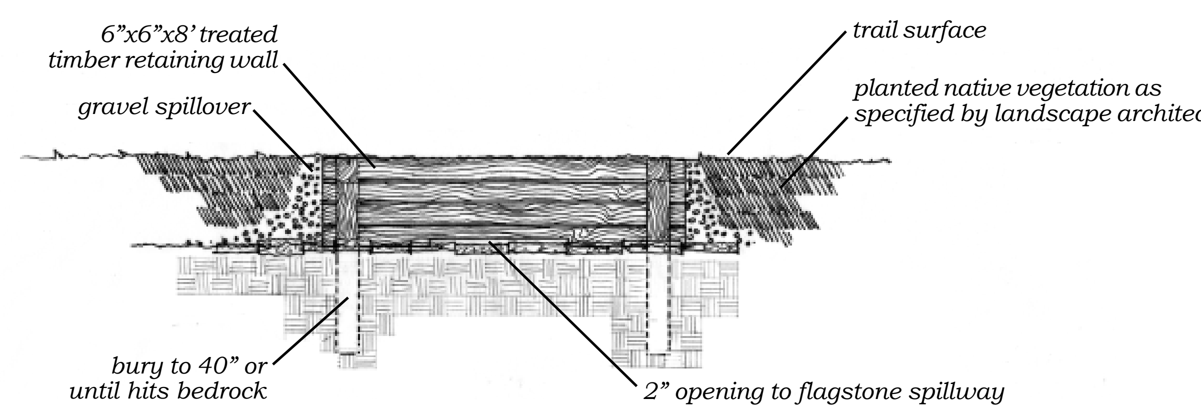
plan



section



elevation

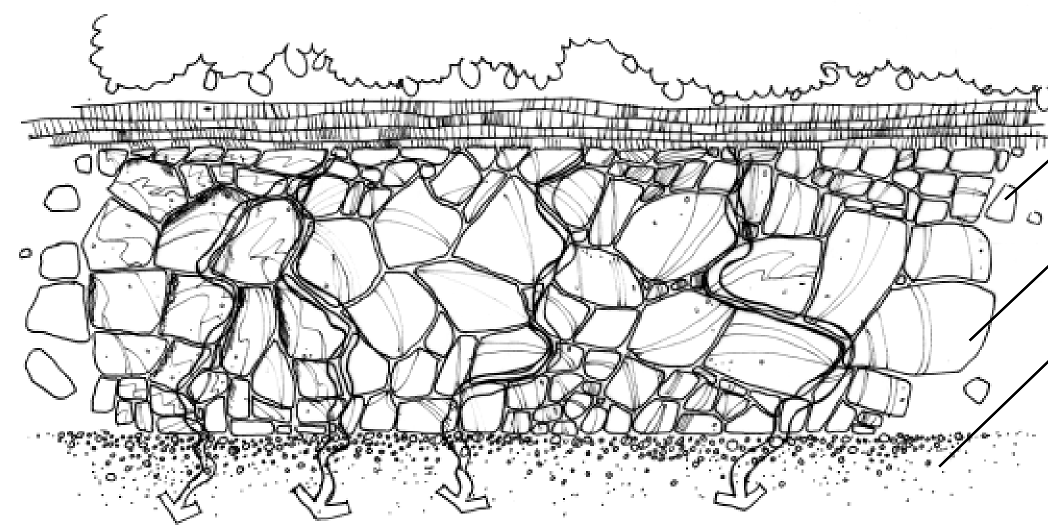


Design Details

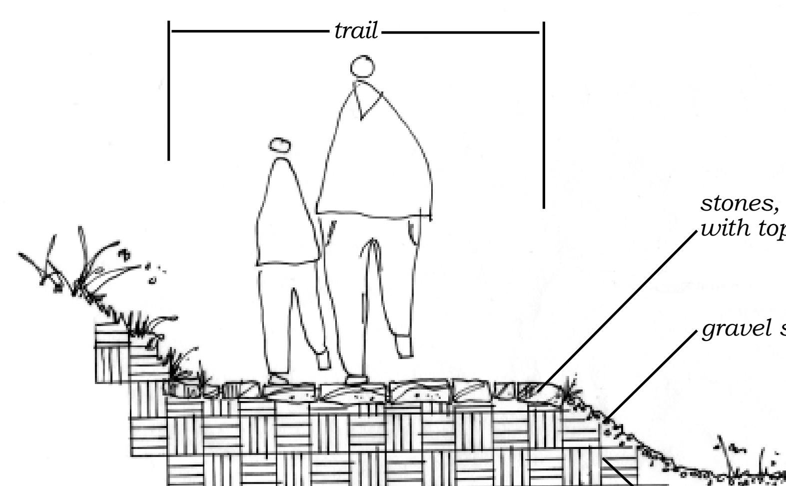
The purpose of the Stepping Stone Path detail is to keep the path dry for foot traffic, and to avoid the formation of large muddy patches in the trail after rain. It is meant to be applied in areas where heavy foot traffic intensifies the erosion process. Successful implementation of this design requires 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



section

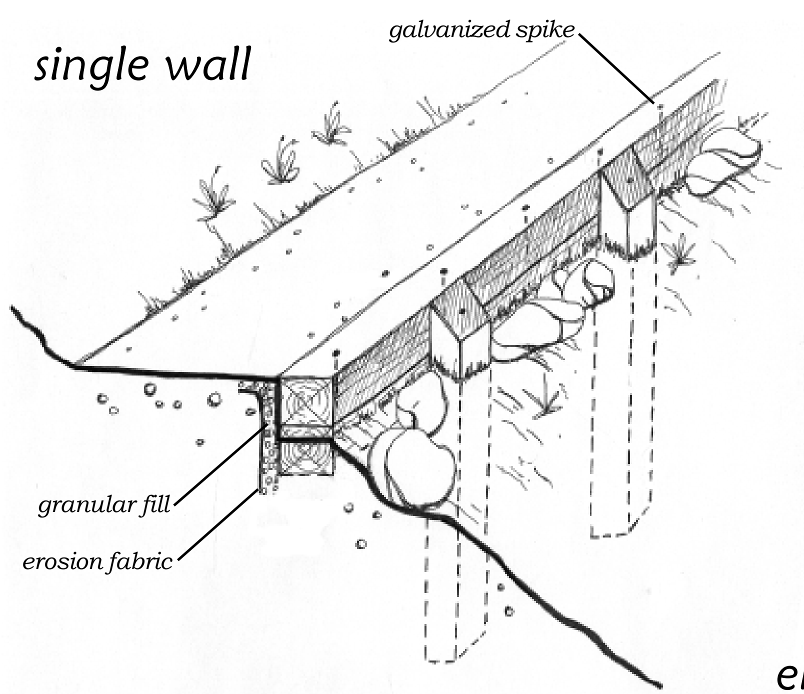


Steep Slope Condition

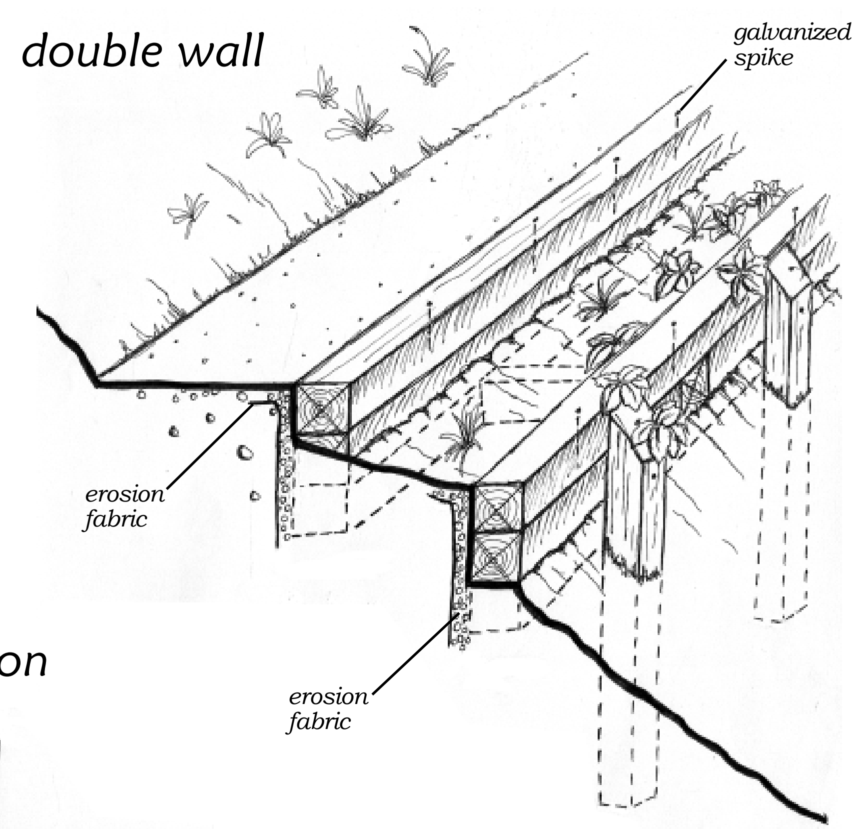
Erosion as a result of steep slopes is a problem all along the bluff, both on and off the trail. The following details offer solutions on these slopes. They seek to stabilize the slopes, allowing movement of people and water without excess movement of soil.

Detail #4: Retaining Wall

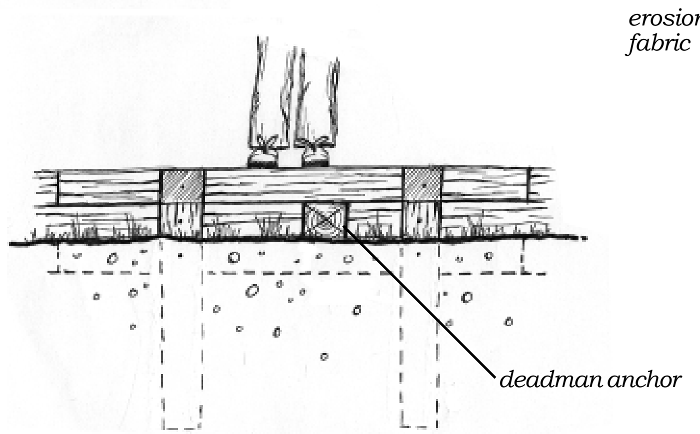
single wall



double wall



elevation



-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.

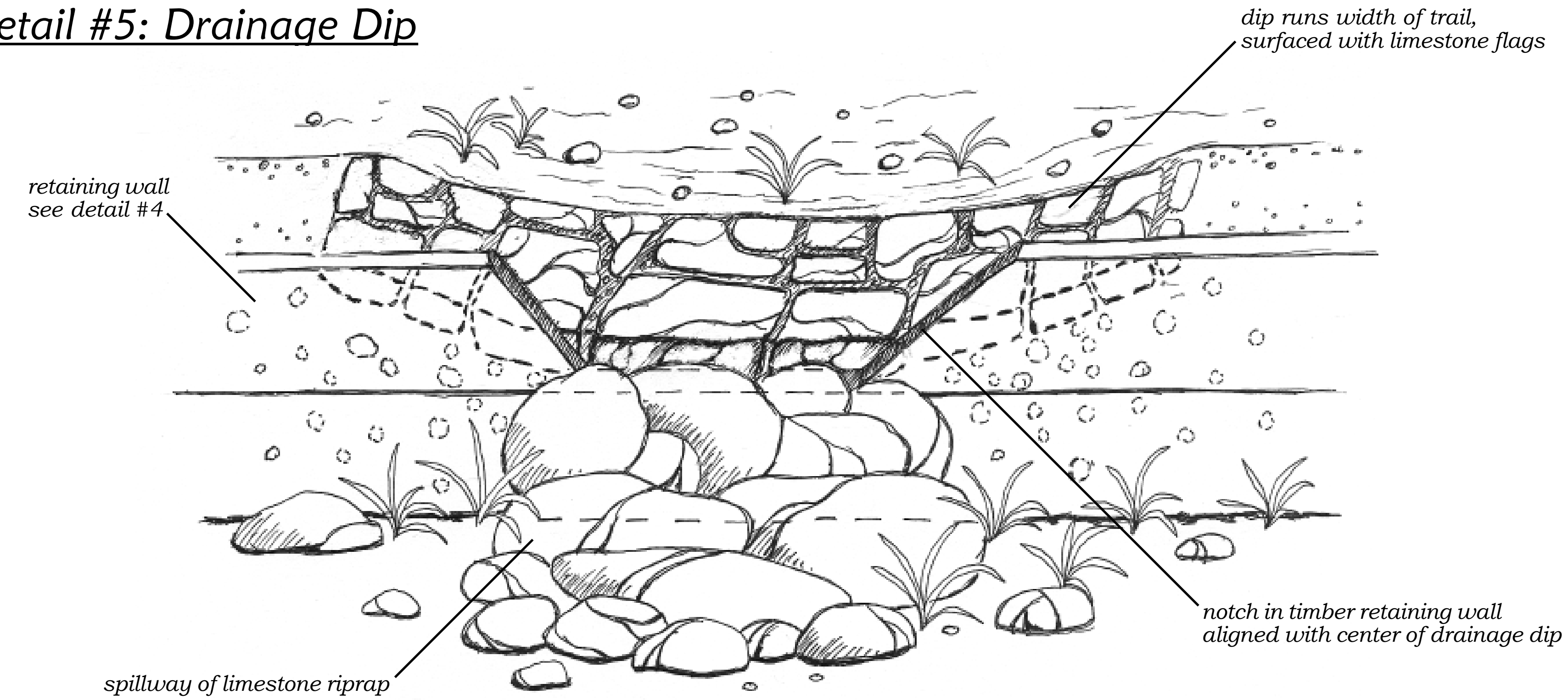
-Each step consist of a timber box that is constructed with 6 by 6 treated timbers that are connected with spikes

-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.

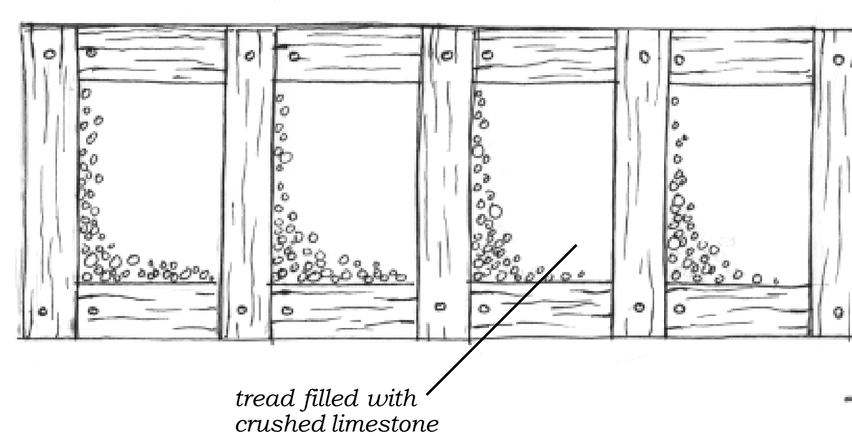
-Stairs should be placed to follow the contours of the slope to minimize grading

Detail #5: Drainage Dip

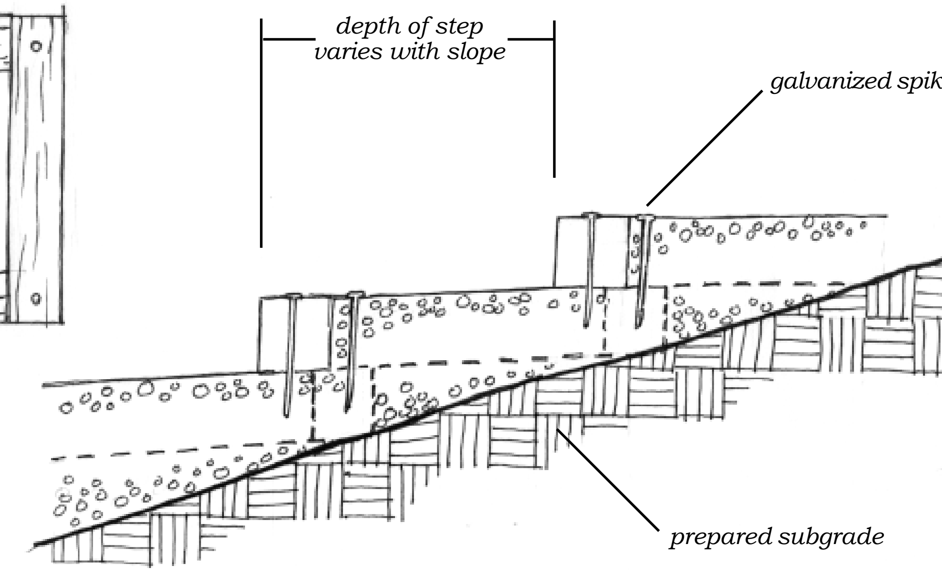


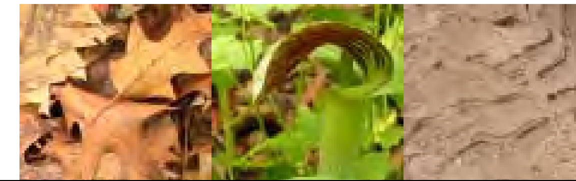
Detail #6: Stairs

plan

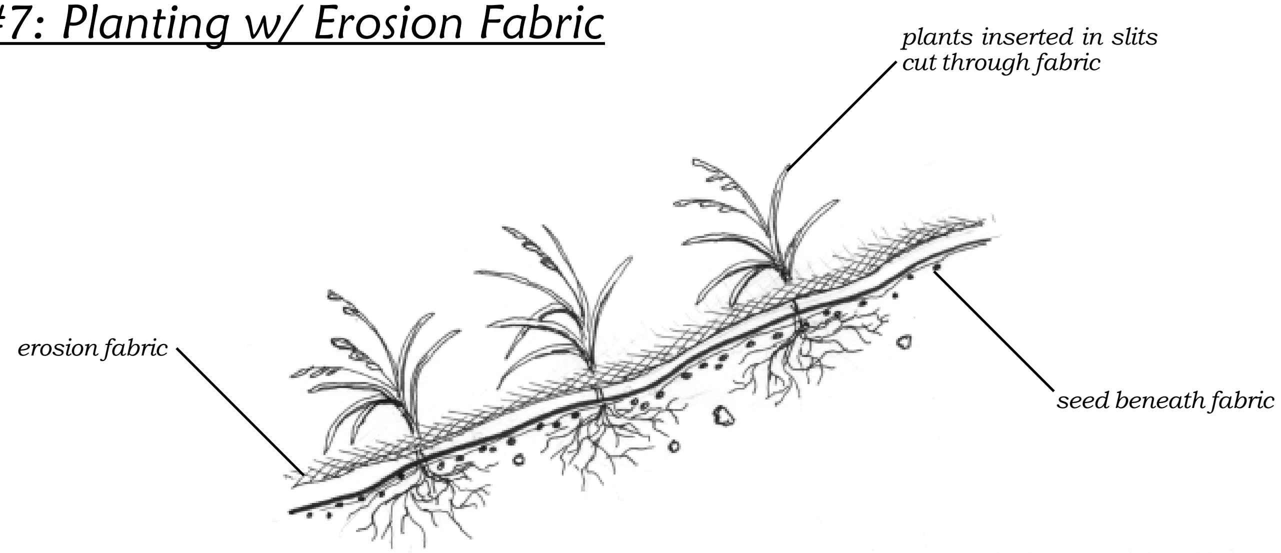


section

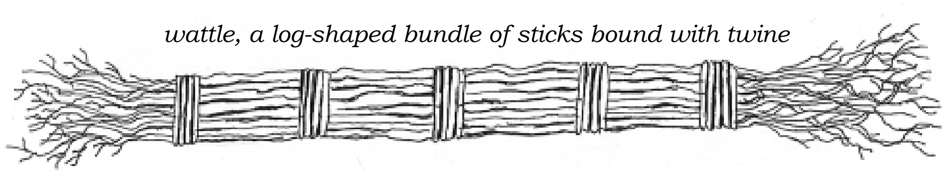


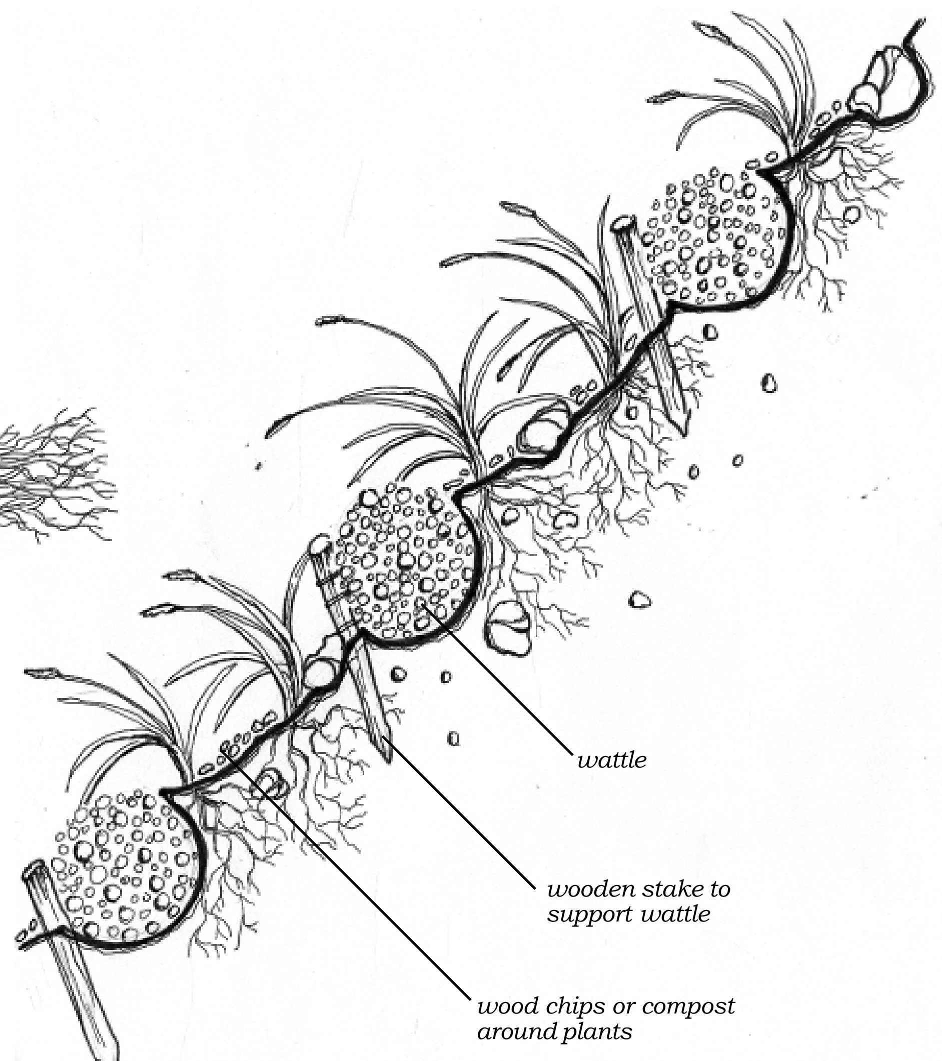


Detail #7: Planting w/ Erosion Fabric



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.

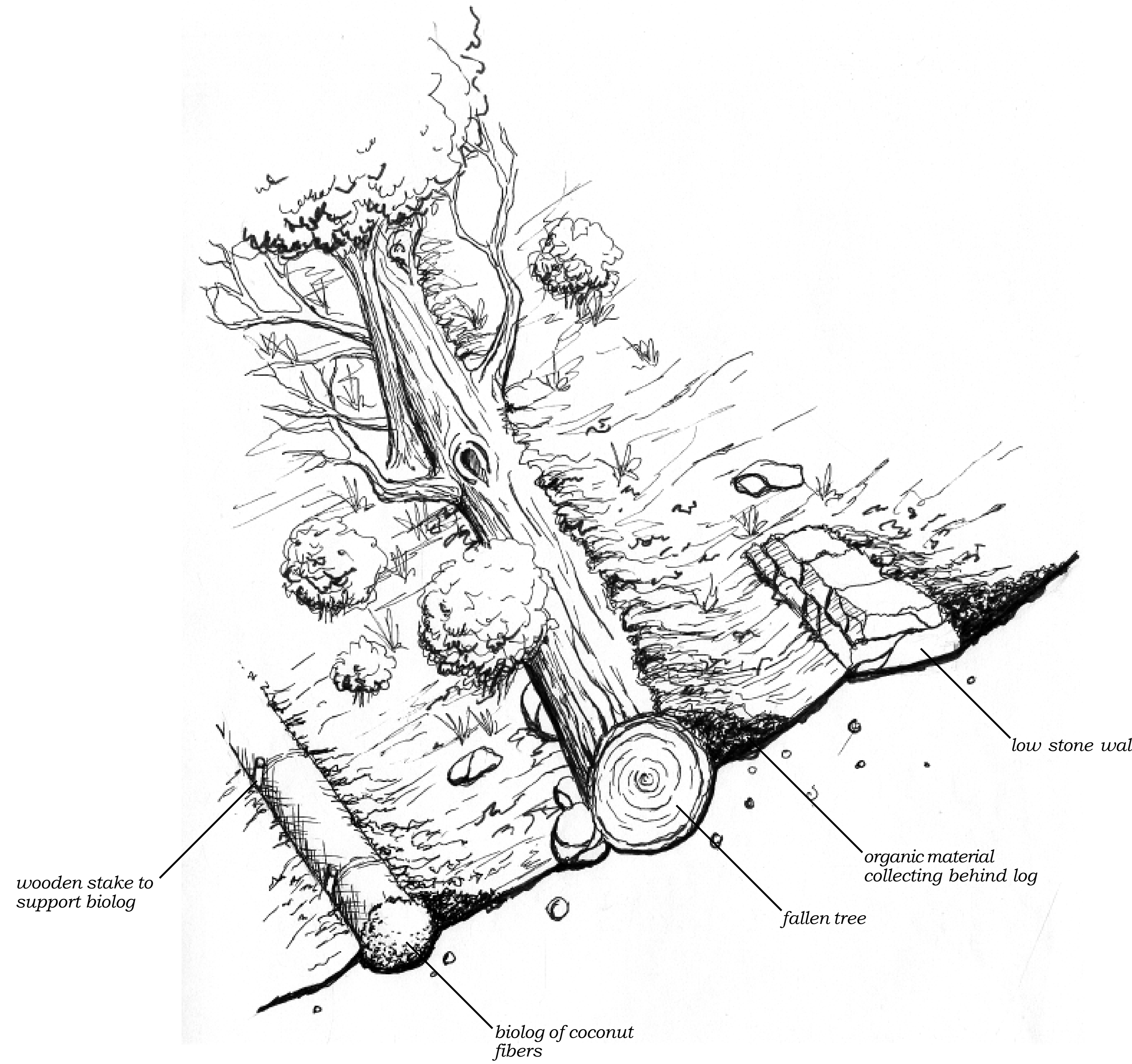
-In areas of severe erosion, an engineer should be involved to provide stabilization recommendations.

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



Design Details

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

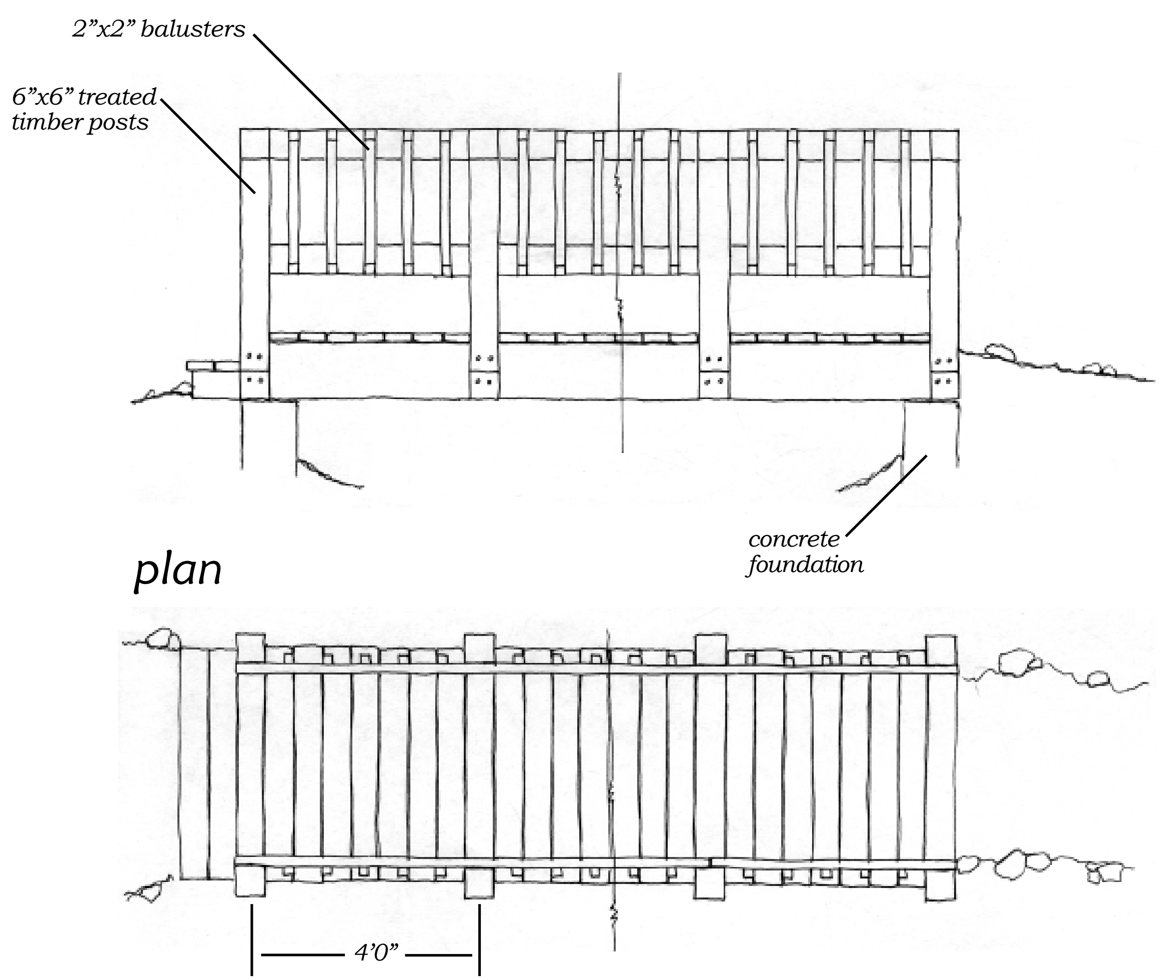
Wet Ravine Condition

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.

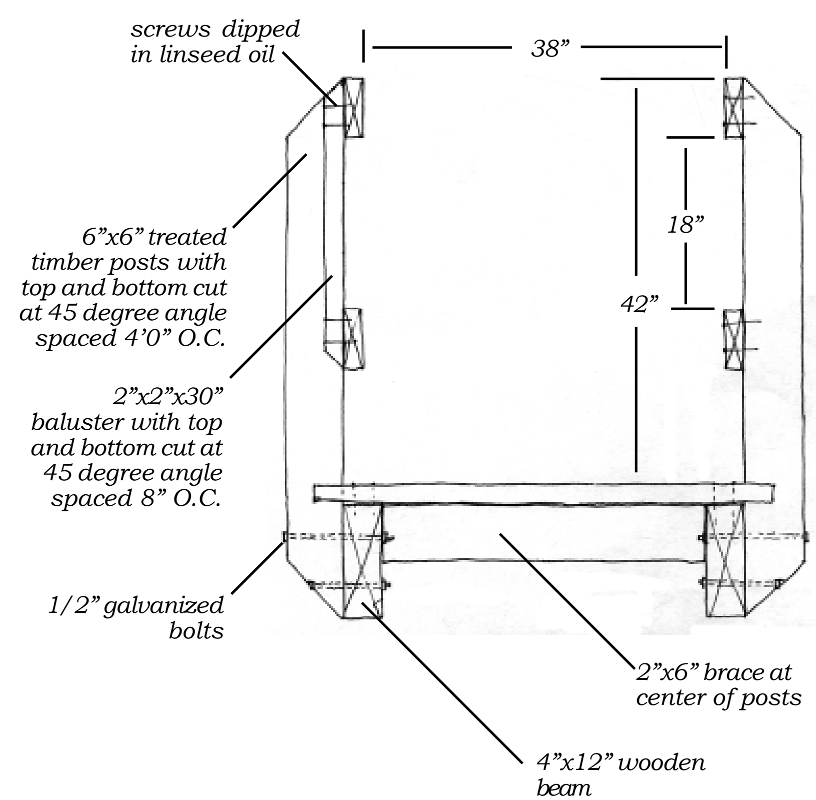
Detail #10: Bridge

elevation

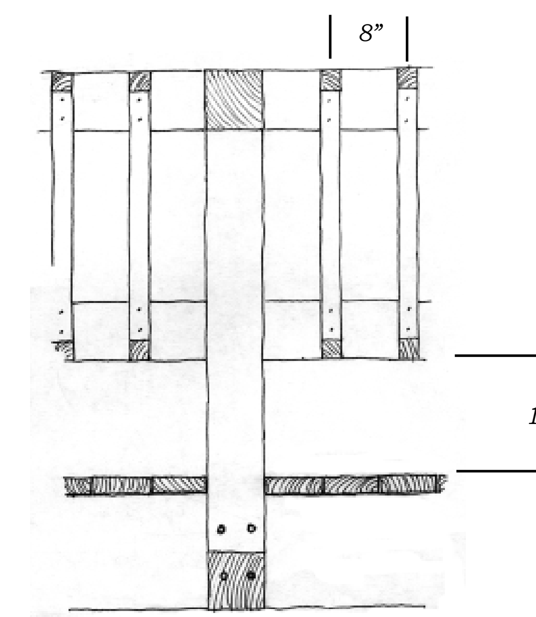
plan



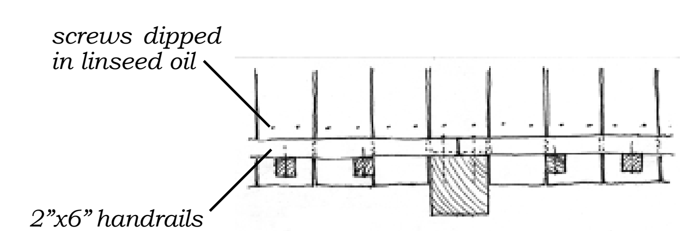
post & rail section



post & rail elevation

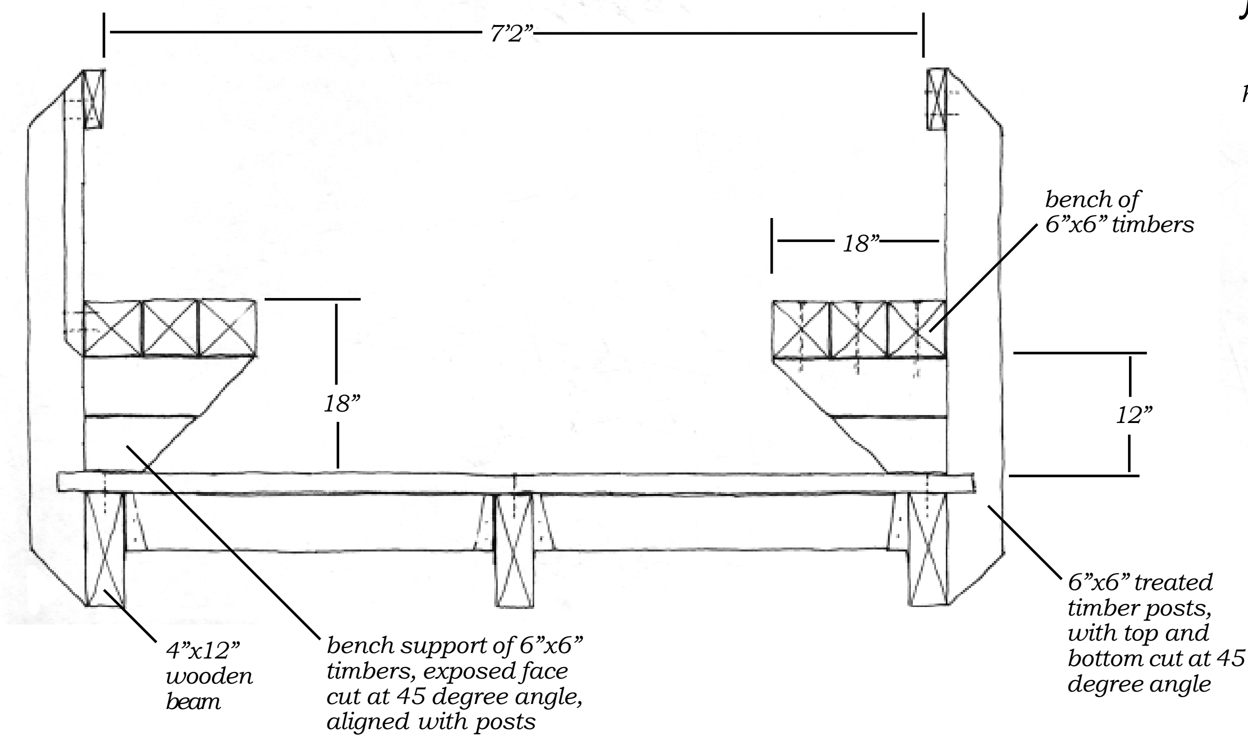


post & rail plan

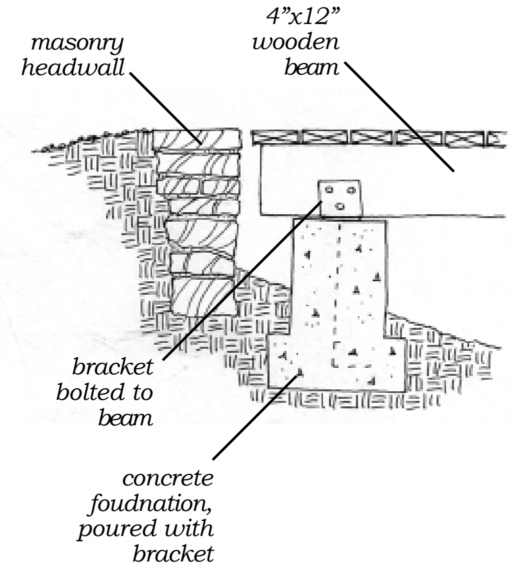


Detail #11: Bridge w/ Seating

section



foundation connection



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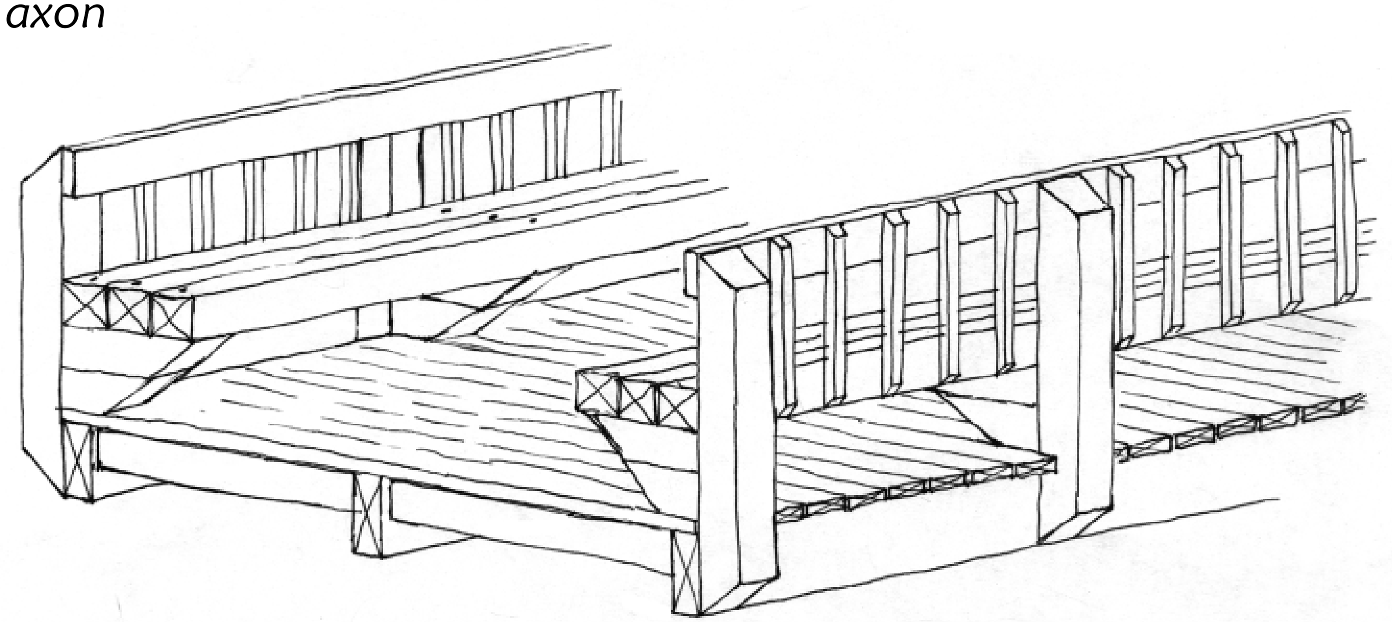
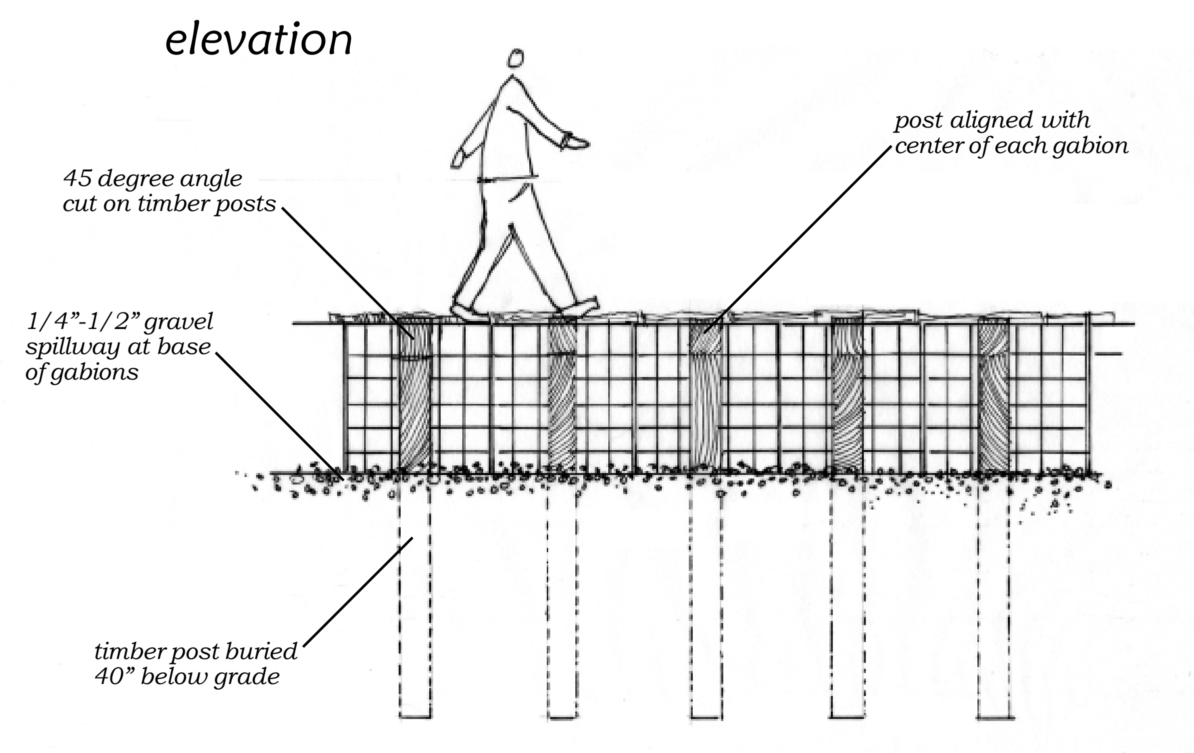
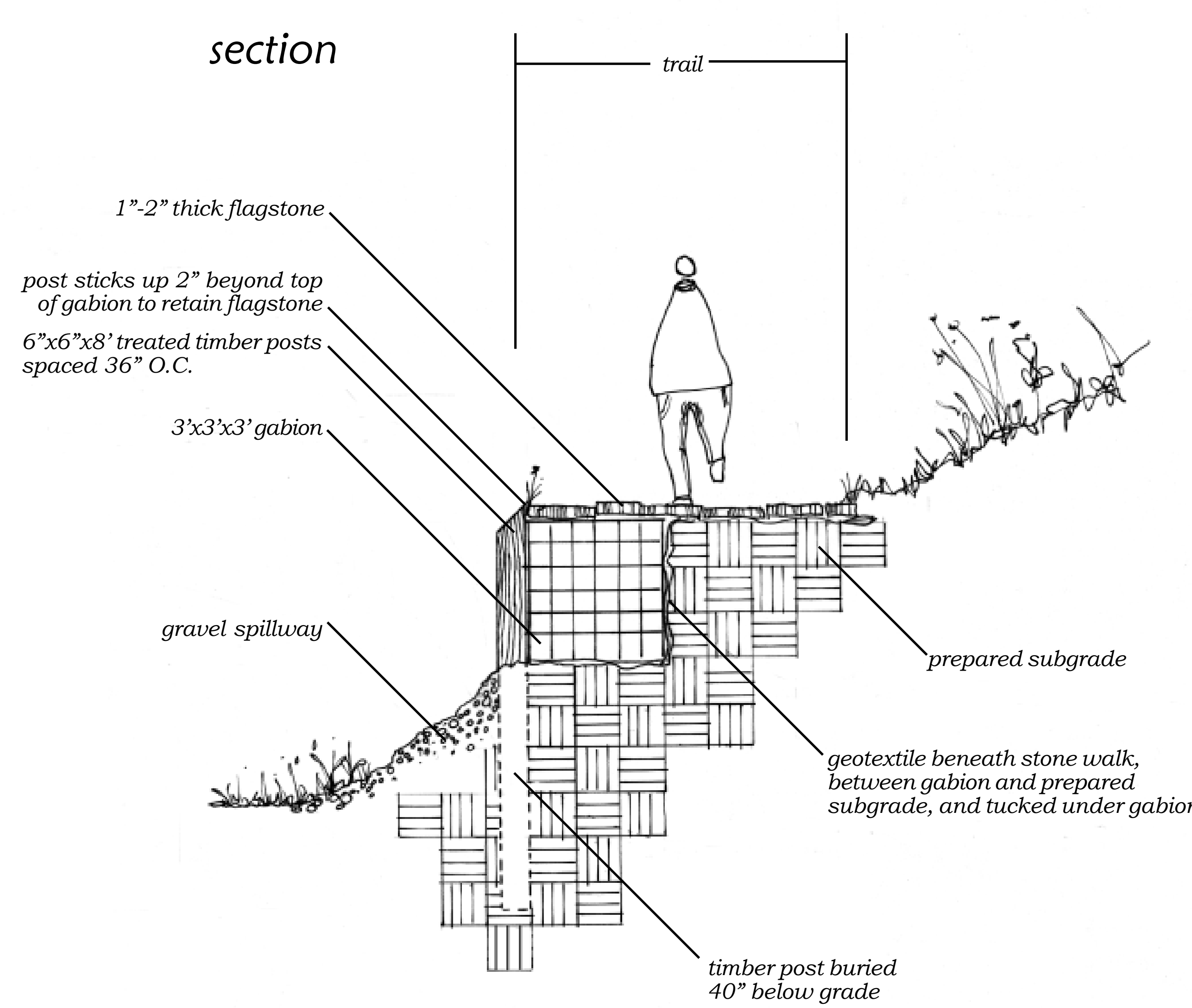


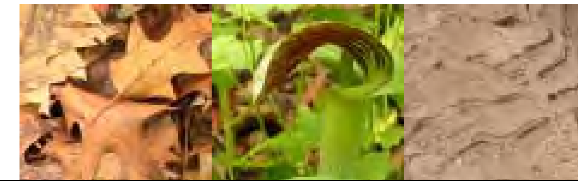
Design Details

Detail #12: Gabion Wall

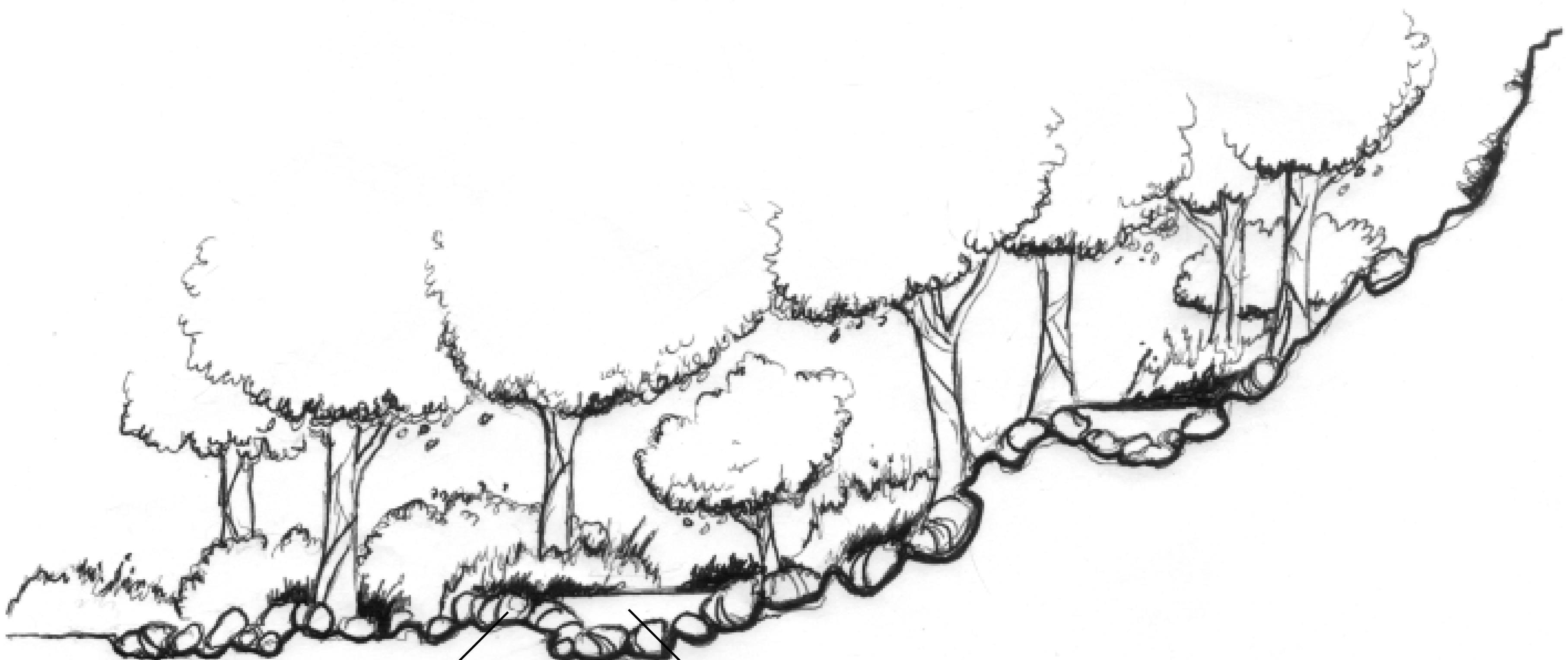
A gabion wall is a good solution where damp ravines exist along the bluff trail, and in areas where seeps along the trail contribute to trail washout and degradation. The gabion design allows water to pass beneath the trail while still maintaining the trail at a level grade. This structure is appropriate 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.

Design Details

-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.

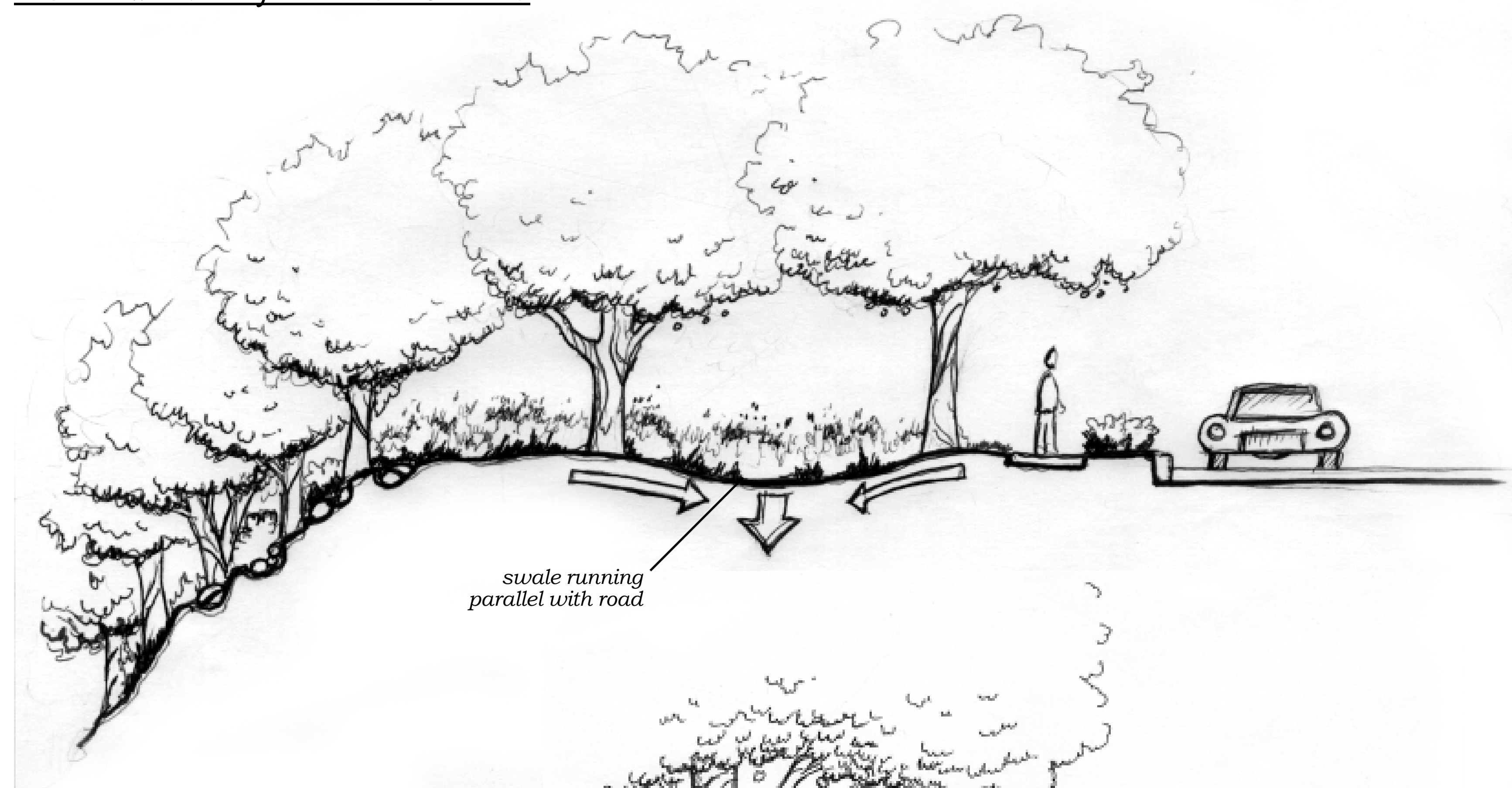
-The combination of constructing a berm and digging a gentle depression would allow water to pool and infiltrate on top of the bluff. There is currently a catch basin in the lawn that would require a standpipe.

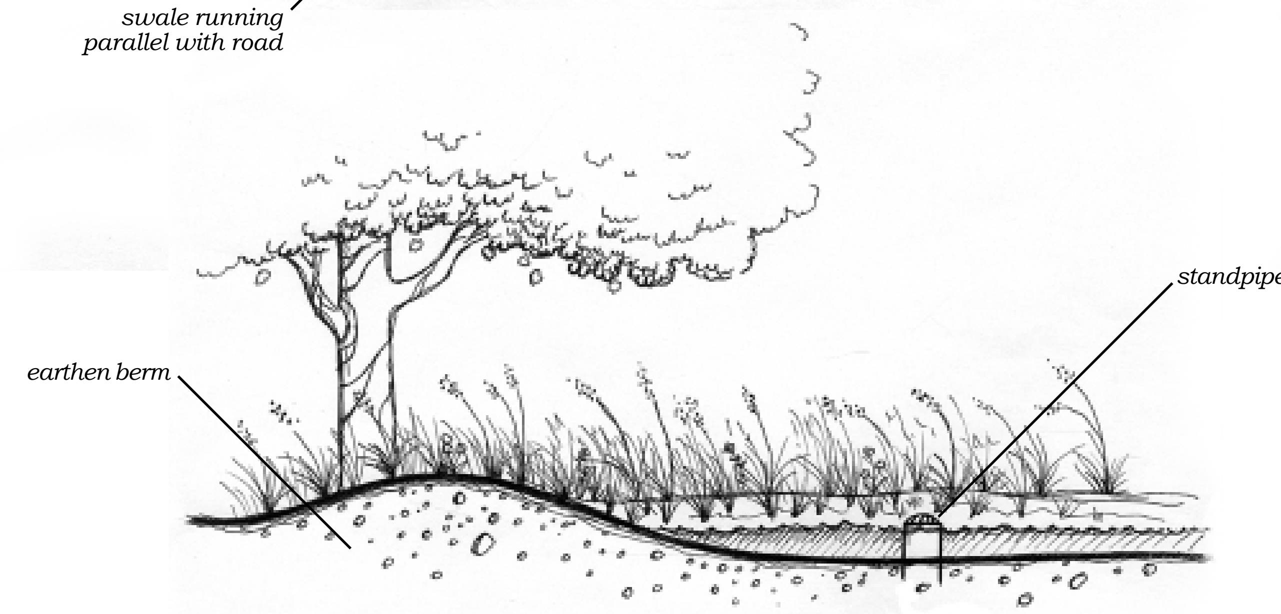
-Mesic oak savanna and wet meadow species should be planted in the infiltration swale to aid in the treatment of stormwater, increase wildlife habitat and increase the buffer between Shepard Road and the bluff.

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.

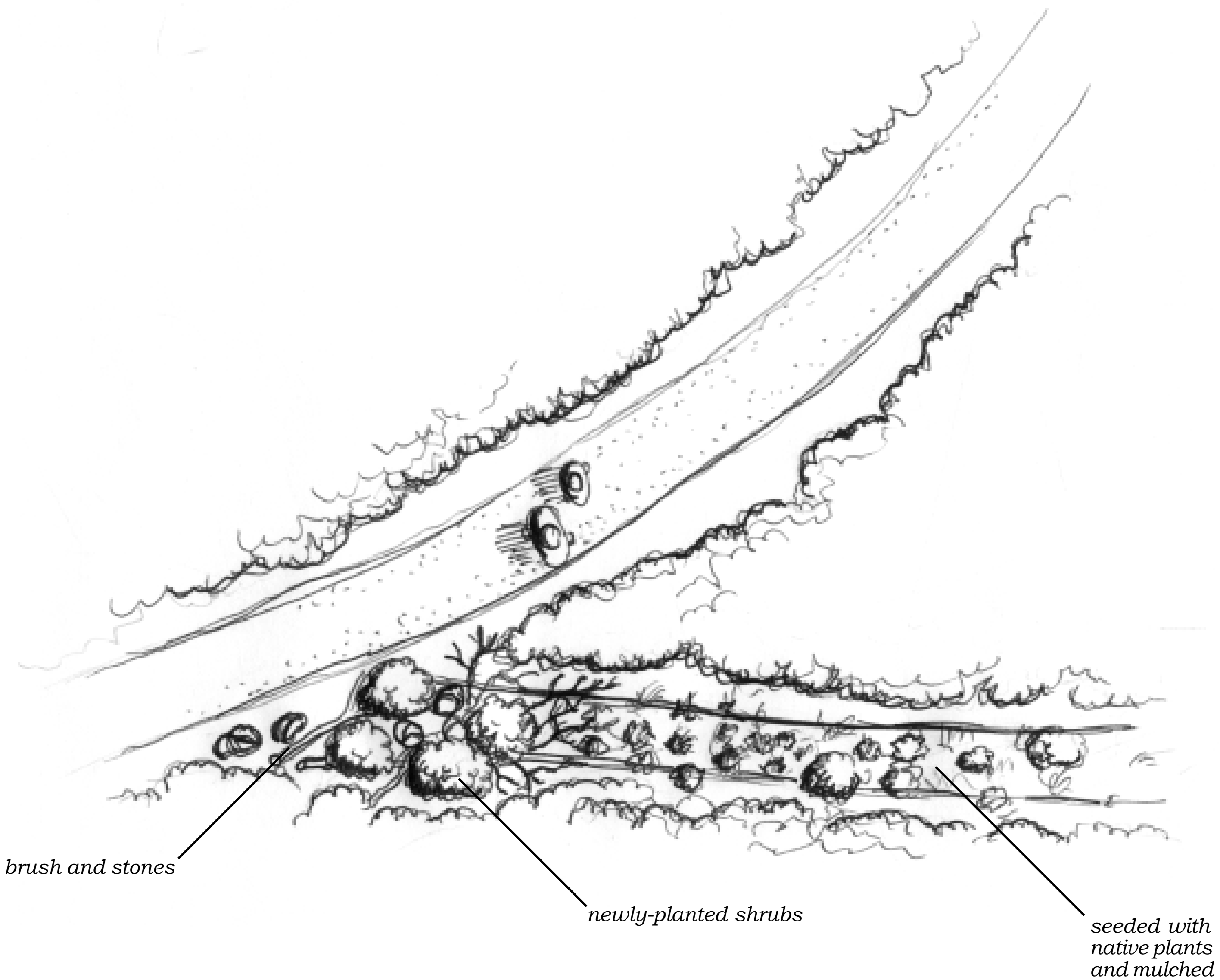
Detail #14: Infiltration Swale





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).

Hidden Falls Water Resource Development Feasibility Study

FINAL REPORT: NOVEMBER 11, 2014

PREPARED FOR:

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Contents

EXECUTIVE SUMMARY

The City of Saint Paul Department of Parks and Recreation, in partnership with the Capitol Region Watershed District, commissioned this feasibility study to evaluate and make recommendations regarding potential enhancement of water features at Hidden Falls Regional Park. The primary water feature considered is Hidden Falls Creek, which emerges from a storm sewer at the north end of the site, drops quickly in elevation through a water fall and a series of concrete lined steps, and flows through a wide, incised channel before passing through a very flat, stable channel to the Mississippi River.

The current condition of Hidden Falls Creek reflects the geologic history of the region as well as much more recent human activity. As glacial melt water carved the Minnesota and Mississippi River corridors, erosive processes similar to those that created Saint Anthony Falls, created Hidden Falls. The stream drops almost 100 ft along its relatively short route, creating a high energy, erosive system. Changes in the watershed have exacerbated this erosion potential by increasing flows associated with stormwater. During the 1930's and again in the 1980's, attempts were made to halt erosion of stream bed and bank materials by building stone walls in the upper reaches of the creek. The 1980's era work included extensive use of concrete to lock the channel bed and banks in place. The lower reach of the creek, where it flows through the Mississippi River floodplain, has remained stable and generally unmodified.

The Hidden Falls Creek watershed is expected to undergo significant changes in the next several years. Approximately two thirds of the watershed consists of a decommissioned Ford Motor Company Plant that is slated for redevelopment. The manner in which this site is developed together with the nature of the stormwater management system that is employed at the site will have a dramatic impact on the quality and quantity of stormwater that is delivered to Hidden Falls Creek. As part of this study, a range of potential future development scenarios and anticipated stormwater flows that may result from each were reviewed. If the site is developed with only the minimum required stormwater management practices, forces on stream bed and bank materials will be high and will necessitate use of very large rock material in constructing a stable channel. Due to the cost and impracticality of using extremely large stone in building the channel, we recommend that state of the art stormwater management practices be incorporated into the redevelopment of the Ford Plant site with a design goal of achieving pre-development peak stormwater flow rates from this site. In addition to reducing peak flow rates, stormwater management features that improve water quality should be incorporated to improve aesthetics and suitability for wildlife.

Several stream configuration alternatives were evaluated for their sustainability, value as park amenities, ecological and water resource benefits, and costs. Based on this evaluation, we offer several recommendations for enhancing Hidden Falls Creek.

In the upper reaches of the stream, we recommend eliminating the 1980's era wall that forms the east bank of the creek for much of the reach, and naturalizing that bank with stone and vegetation. This will decrease energy in several areas of the stream and reduce the need for concrete within the channel boundaries. It will also improve the stream for human and wildlife access. In this upper reach we also recommend removing the concrete along the channel bed and creating a more natural step-pool channel form. This form is very efficient at dissipating energy and consists of a series of drops over large stone material with a small pool at the base of each drop. We recommend leaving the west bank walls in place and restoring it where necessary to ensure that there remains room for a trail along that side of the stream. Access down to the water's edge from the trail may be incorporated where the valley is wide enough to accommodate such features.

At the downstream end of the enhanced step pool reach, we recommend incorporation of a final drop into a pool that is large enough to be visible and audible from the park pavilion area. This would be located where the stream currently makes a sharp bend to the west along the west valley wall. The intent is to draw people to the stream at that location, create a destination for sitting to enjoy the stream, and encourage exploration both upstream and downstream from that point. The pool at this location would be larger, and stable access to the edge of the water would be incorporated.

Downstream of this final step and pool, where the existing stream consists of natural but eroding materials, we recommend grading the south bank back to a sustainable slope and stabilizing it with natural vegetation. The bed of the channel in this reach is overly wide and should be sculpted to create a more concentrated low flow channel, while maintaining flood benches to allow stability during high flows. Just upstream of the pedestrian bridge in this reach, we propose removing the concrete bank stabilization structure and extending the grading and vegetation enhancement through that area. Downstream of this bridge, the stream is quite stable as it flows across the floodplain to the Mississippi River. We recommend leaving the stream as it currently exists through this reach to minimize disturbance of existing trees. See Figures 1 and 2 for an illustration of these recommendations.

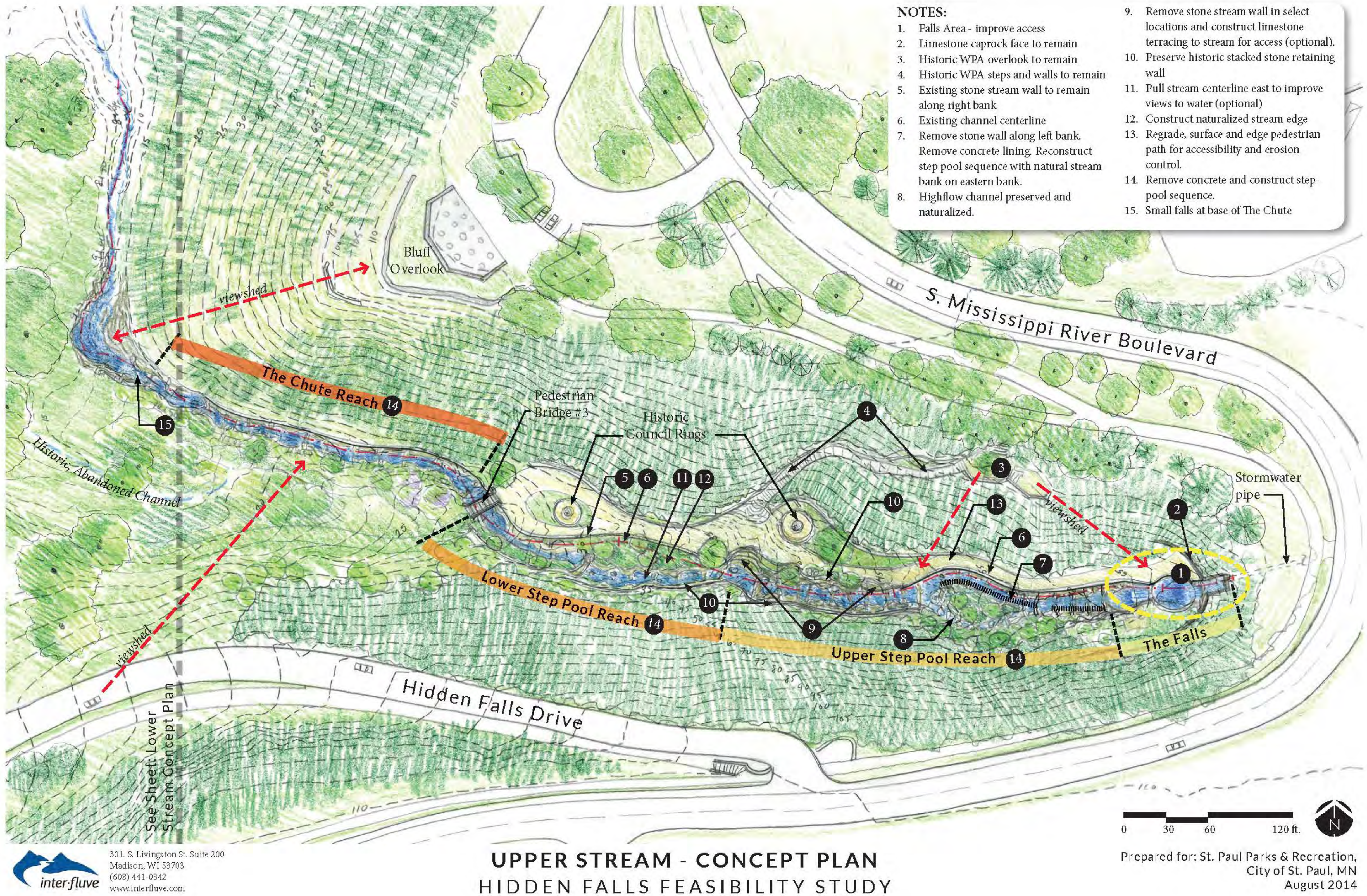

Figure 1: Recommendations for upper reaches of Hidden Falls Creek

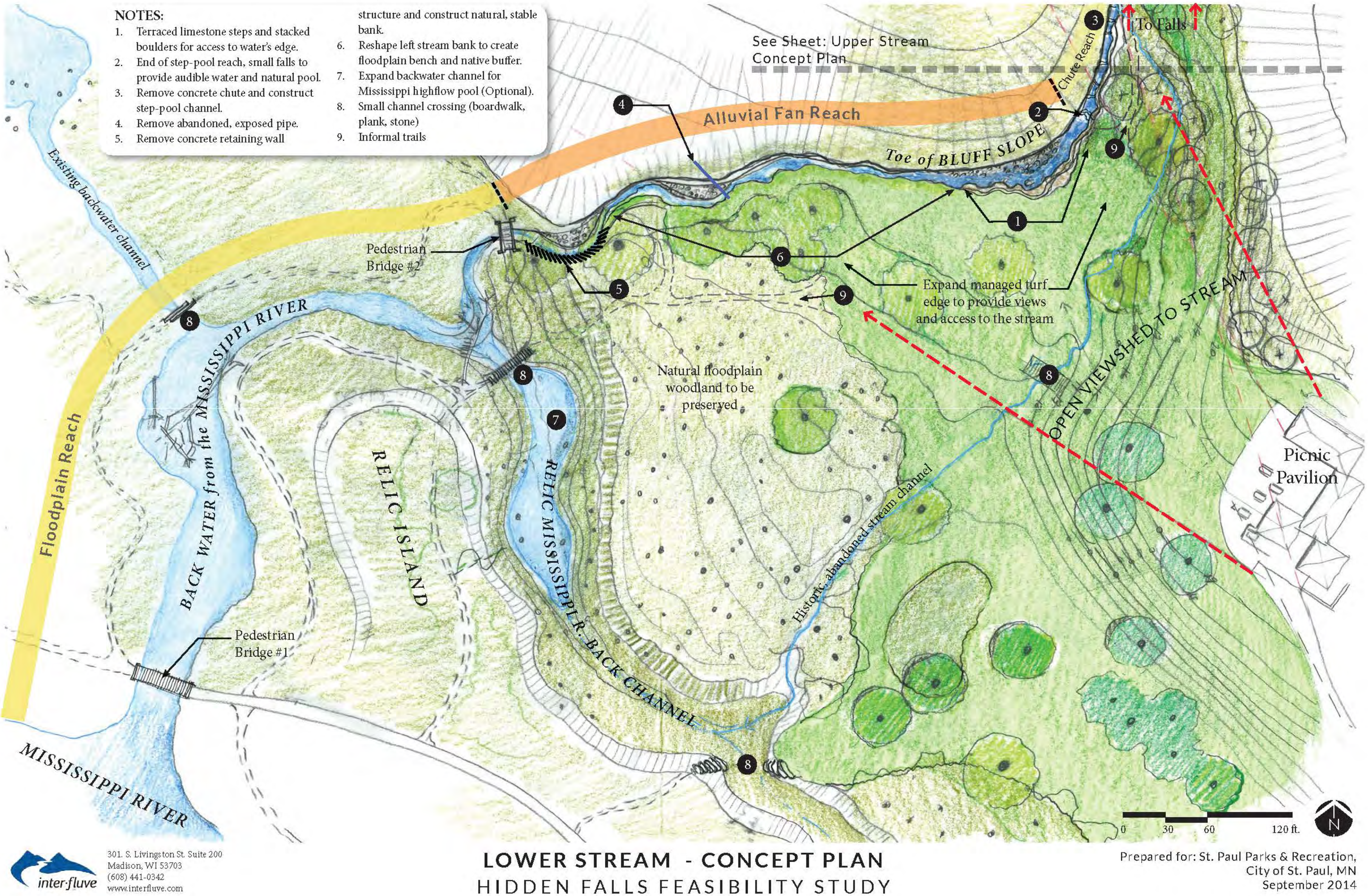

Figure 2: Recommendations for lower reaches of Hidden Falls Creek

INTRODUCTION

Hidden Falls Regional Park is a City of Saint Paul park located adjacent to the Mississippi River just over 2.5 miles upstream of the confluence of the Mississippi and Minnesota Rivers. The park features access to the Mississippi River, wooded trails, and a stream that drops dramatically from its outlet from the city storm sewer down a series of falls and manipulated step pools and across the Mississippi River floodplain to its confluence with the Mississippi River. The watershed of the stream includes older residential development, parkway and the abandoned Ford Plant Site, which is slated for redevelopment over the course of the next several years. At this time, the nature of the redevelopment has not been determined. The City of Saint Paul anticipates updating the Master Plan for Hidden Falls Park after key decisions regarding the redevelopment have been made. Prior to updating the Master Plan, the City is interested in better understanding the potential for enhancing the water features within the park. The City is coordinating with Capitol Region Watershed District (CRWD) to utilize this opportunity to enhance city residents' awareness, experience and understanding of water resources within the District, consistent with CRWD's watershed management plan theme, "Bring Water Back to St Paul."

The goals of this feasibility study are to:

- Evaluate the future stream flow sources and dynamics;
- Provide guidance regarding changes to the flow regime that will improve the quality of water features at the park;
- Identify alternative modifications to water features at the park and evaluate them relative to identified water feature objectives; and
- Provide concept-level analysis, drawings, and cost estimate for the preferred alternative.

The goals of water feature enhancement at Hidden Falls Park are:

- To provide high quality, sustainable, natural, low maintenance water resources for park users;
- To enhance park user interaction with and enjoyment of those features;
- To provide educational opportunities to enhance park users' understanding of water resources; and
- To enhance ecological function of water features.

This report reflects the research and analysis that was conducted to identify alternatives for enhancing the stream as it flows through the park. It also identifies impacts that the redevelopment project may have on and opportunities that it offers for enhancement of the stream at Hidden Falls Park.

HIDDEN FALLS PARK BACKGROUND

PROJECT LOCATION

Hidden Falls Regional Park is located in Saint Paul, Minnesota, adjacent to the Mississippi River just over 2.5 miles upstream of the confluence of the Mississippi and Minnesota Rivers (Figure 3). The geographic scope of this study is restricted to existing and proposed water features within the park.

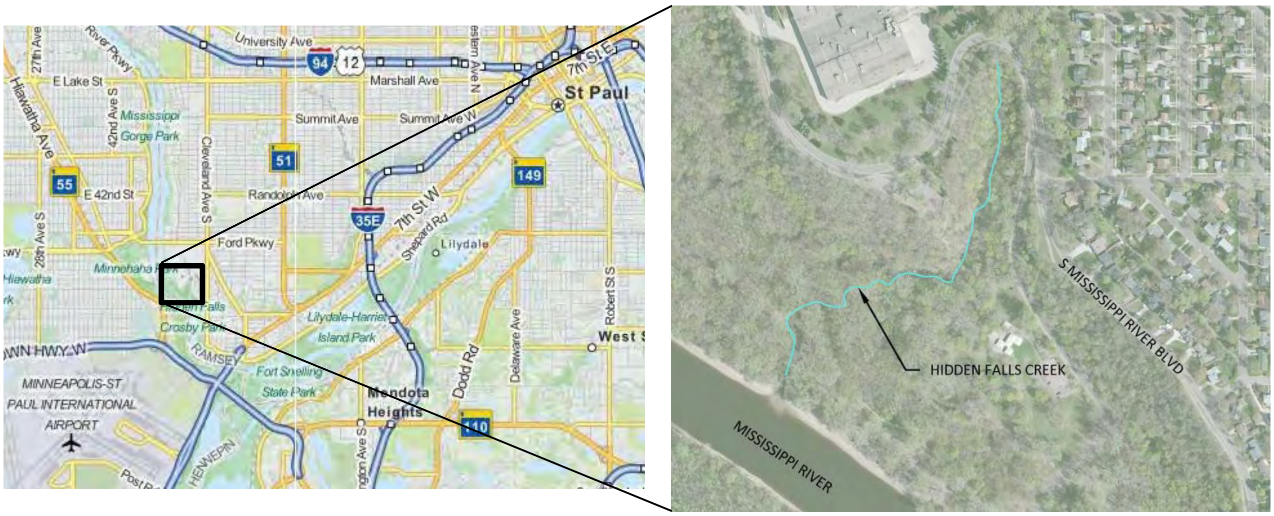

Figure 3: Project Location

GEOLOGIC HISTORY

To appreciate the scenic landscape of Hidden Falls Park and consider options for enhancing water features on the site, it is helpful to understand the fluvial geomorphological processes which formed it. Obvious features of the Mississippi River in this reach are the dramatic limestone and sandstone bluffs of a nearly 100 ft deep river gorge (Figure 4). The gorge was shaped starting at the end of the last ice age by glacial melt-water. Glacial Lake Agassiz— the largest of the glacial lakes from this age—drained southeast through Minnesota in Glacial River Warren from 11,700 to 9,500 years ago. In the vicinity of the Twin Cities, Glacial River Warren formed a valley in what is the present-day Minnesota River valley. When the River Warren reached and descended into a buried, pre-glacial river valley, east of St. Paul, an impressive waterfall formed. (Figure 5)

Figure 4: The sandstone and limestone bluffs on the right Mississippi River bank as visible from Hidden Falls

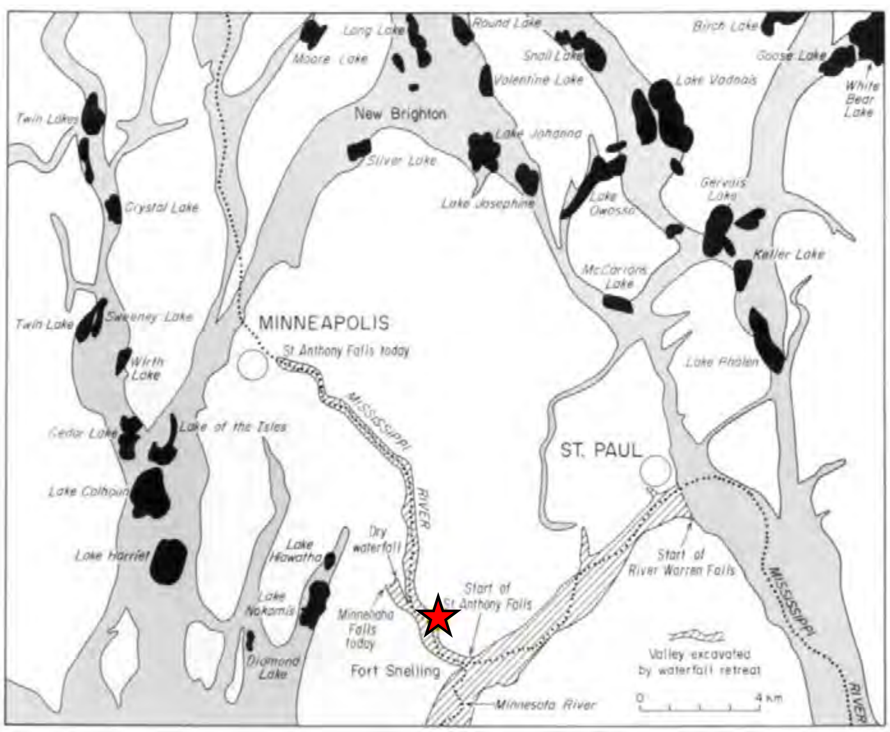

Figure 5: Diagram of the River Warren Falls and St. Anthony falls which carved the Mississippi River Gorge. The location of Hidden Falls Park is indicated by the star. (Wright, 1990)

River Warren Falls eroded through the bedrock, carving a gorge upstream through the force of a 60 m tall fall (Wright, 1990). The bedrock geology of this area is composed of sedimentary rock layers of sandstone, shale and limestone, formed 450 million years ago during the Ordovician age when this part of the earth was covered by an inland sea. From oldest (deepest) to youngest (nearest the surface) they include: St. Peters Sandstone, Glenwood Shale and Platteville Limestone. As the softer sandstone and shales eroded away, they undercut the more durable limestone above. This “caprock,” more erosion resistant rock underlain by more erodible material, reduced the rate of headcut progression but over time continued to succumb to the erosive energy of the flowing water. The undermined limestone caprock that made up the river bed of River Warren broke away in large blocks and slabs, and the incision upstream, or headcut, progressed.

At the location of Fort Snelling, as the River Warren Falls continued to migrate up river, the Mississippi River confluence was undercut and another headcut and falls began to carve out the Mississippi River Gorge we see today. This waterfall became St. Anthony Falls and is currently located 8 miles upstream of the confluence of the Minnesota and Mississippi Rivers, at Hennepin Island in downtown Minneapolis.

GEOLOGIC HISTORY OF HIDDEN FALLS PARK

The river terrace above the limestone visible along the bluff outlooks is topped with a mixture of stone and soil material deposited by retreating glaciers, referred to as glacial till. Eventually, the landscape developed into a rolling prairie and savanna on this higher terrace. Tributaries to the Mississippi River were left perched when the Saint Anthony falls migrated upstream. The energy of these tributaries falling into the incised Mississippi River channel eventually began to wear away at the limestone caprock, creating falls near the mouths of these tributaries. The Minnehaha Creek falls and Hidden Falls are good examples of these features. Based on the subsurface investigations at Hidden Falls Park, it appears likely that following this bedrock weathering, the Mississippi River deposited fine materials within the gorge as the head cut proceeded up the gorge. The elevation at which fine material was found suggests that the Mississippi River had not incised as deeply as it is today when those materials were deposited. This process of deposition in backwater areas adjacent to the river created layers of fine material under the coarse gravels and cobbles that later washed down the channel or rolled down the steep slopes as the head cut continued to migrate. Some of the weathered rock material from the gorge continued to wash down the ravine and was deposited in a fan formation at the base of the bluff and the edge of the Mississippi. Such alluvial fans are commonly found where the slope of a stream channel quickly transitions from very steep to very flat. As the incision progressed up the valley and delivered more rock to the alluvial fan, the channel through the fan likely increased in elevation due to deposited material, or aggraded, causing the channel to periodically abandon its channel and cut new channels down the fan. As is common with alluvial fan streams, the stream eventually moved to one side of the fan and now hugs the valley wall.

Figure 6: View of Hidden Falls showing the worn and undercut Platteville Limestone caprock, fallen limestone blocks and existing pools and cascades of upper falls

FORMATION OF THE LOWER PARK LANDSCAPE

The more recent fluvial processes of the Mississippi River have influenced the shape and topography of the lower areas within Hidden Falls Park. Through cyclic flooding and overbank flow, sediment deposits create bars, levees and floodplain surfaces with sizes and shapes that shift with flood events. Topographic patterns, historic aerial photos, and older maps all suggest that there have periodically been islands and backwater channels through the area. The evidence of these backwater channels is found in the landscape as swale-like features that are inundated when the river is high and dry when the river is low.

CULTURAL HISTORY OF THE PARK

THE PARK'S EARLY VISION

Early in the Twin City's history, the impressive natural beauty of the Mississippi River gorge was recognized and protected by planning visionaries. One such visionary was Horace William Shaler Cleveland (1814-1900), a prominent landscape architect who advocated for natural preservation of the riverway for the enjoyment by all (Figure 7). In 1887, Hidden Falls Park was envisioned by Horace Cleveland as one of four original park areas in the St. Paul area to be connected by, "an inter-linking network of scenic drives, parks, and river boulevards for the "United Cities" (Martin, 2001). Cleveland's philosophy "to preserve landscape features and the nature that shaped those features" (NPS, 2013), is very relevant today. He was known to advocate for using the existing topography and existing plants to keep his designs as natural as possible and create parks that could be enjoyed by everybody.

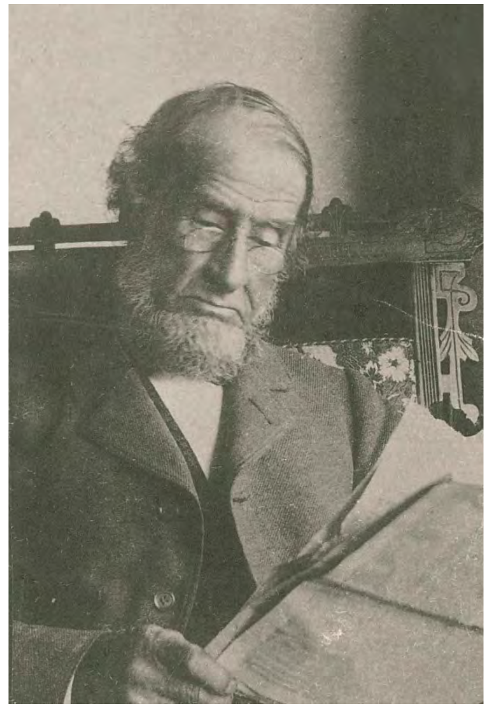

Figure 7: H.W.S. Cleveland, Landscape Architect, undated, Ramsey County Historical Society

At Hidden Falls Park, though a portion of the land temporarily served as a tree nursery, few other improvements were made in the park until 1936-37. During the mid 1930s, the Works Progress Administration (WPA) carried out extensive activities on the site, including construction of many of the stone walls that remain today. In the mid-1960s, work began on the park's four primary use areas, including the primitive areas, boat launching areas, general picnic area, and the scenic falls area. This work created the form and function of the park as it exists today. (Martin, 2001)

SCENIC FALLS AREA

In the upper channel, the WPA project built extensive dry-stacked limestone walls to create a series of overlooks, retaining walls, a grand staircase and large council rings along the western side of the ravine (Figure 8). It is possible that at least a portion of the stone used may have been salvaged from the site.

Figure 8: WPA era walls and grand staircase along the eastern edge of Hidden Falls Ravine

Hidden Falls Park and the overlook area at the falls do not appear on the National Register of Historic Places (http://www.mnhs.org/shpo/). Neither the Minnesota Historical Society, nor the Northwest Architectural Archives at the University of Minnesota hold archival architectural records of the construction of the WPA project. Structural modifications to the pools and falls were made in the 1980s, at which time new stone and concrete grout were placed in several areas.

GENERAL PICNIC AREA

The Picnic Pavilion is an architecturally interesting example of early 70s park architecture, centrally sited mid-distance between Hidden Falls and the Mississippi River (Figure 9). Construction documents for the pavilion, dated 1973, are archived in the Northwest Architectural Archives. Drawings illustrate construction plans and details for the pavilion as well as the boat launch and parking areas along the Mississippi River. Soil boring reports at the location of the pavilion provide further geotechnical information about soils in the alluvial fan (see Soils Section). Stone building materials and sources are also referenced (Lannon Stone quarried by Halquist Stone Company in Sussex, WI).

The Picnic Pavilion is still a relevant piece of architecture and part of the park plan. Its use can be reactivated through landscape design and trail planning to create better connections and visibility to the park water features, including the bluff, stream, and falls.

Figure 9: Picnic Pavilion, Looking north towards bluff

BOAT LAUNCH AREA

The boat launch area was designed at the same time as the general picnic pavilion and is sited at the far southern corner of the park where the Mississippi River bends to the south. A concrete boat ramp provides access for motorized craft with a sizeable parking lot for boaters, anglers and other park users. Grading and filling has eliminated any backwater or relic channel features that may have existed in this area.

Figure 10: Boat Launch area with limestone walls and fishing access

PARK CIRCULATION

Manicured turf landscape surrounds the picnic pavilion and boat launch areas, but the remainder of Hidden Falls Park is passively managed and is dominated by native vegetation. An asphalt pathway, southwest of the picnic pavilion, takes visitors to the levee along the Mississippi River and terminates at a laminated wood bridge which crosses the mouth of the Hidden Falls Creek. The trail along the cascade and falls portion of the creek is the only pathway along the stream. Bridges cross the stream at three locations – near the downstream end of the cascade reach, near the transition from alluvial fan to floodplain, and near the mouth of the stream. Primitive pathways have been forged by park goers. Circulation through the site could be improved by connecting pathways. Various site furnishings (picnic tables, benches and pedestrian structures) are decades old and many are in poor condition.

Figure 11: Mississippi R bank with picnic table

Figure 12: Bridge across Hidden Falls Creek at the Mississippi River

Future River, Park, and Development Plans

GREAT RIVER PASSAGE PLAN

The most recent masterplanning effort for Hidden Falls Park was part of the larger visioning of the Mississippi River corridor, *The Great River Passage: A Master Plan for St. Paul's 17 miles of Mississippi River Parklands*, adopted in April 2013. The masterplan is the product of a multi-partner collaboration of leaders with expertise regarding the river resource, and it thoughtfully and graphically offers a plan for the river corridor's future that is "more natural, more urban and more connected." The vision for the Hidden Falls Regional Park is described as follows:

> *Integration of the scenic and natural qualities of Hidden Falls with nature-based recreation will draw a wider variety of people to the river. A focus for expanding the recreation potential of the Upper Hidden Falls Park will be to restore and celebrate the park's existing natural qualities. Hidden Falls Creek would be restored and stabilized, and trail access to it improved, so that it becomes a premier destination in the park. Ford Plant site redevelopment would create a direct ecological and pedestrian link between the river corridor and the neighborhood. (City of Saint Paul Department of Parks and Recreation, 2012)*

The renderings in the Master Plan document for Hidden Falls depict an enhanced falls area that include the historic walls and a trail along the west side of the stream, a naturalized bank on the east side, and replacement of the stormsewer outlet with a bridge and daylighted stream upstream of Mississippi River Boulevard. A sketch of the lower reach of the stream shows access to the stream that allows visitor interaction with the water.

FORD MOTOR PLANT REDEVELOPMENT

The Ford Motor Company Plant, which is located just north and west of Hidden Falls Park and represents the vast majority of the watershed to the creek, closed in 2011 and was decommissioned in 2013. Removal of buildings and foundations is underway and is expected to be completed in 2015. The redevelopment of this site offers an exciting opportunity to re-create the space in a way that fits well with the adjacent neighborhood. The Ford redevelopment is also an opportunity to incorporate state-of-the-art stormwater management that will provide cleaner water, higher base flow, and lower peak flows for Hidden Falls Creek. Phase 1 of a planning study was concluded in 2007 and documents five potential development scenarios for the site – (1) industrial, (2) mixed use – light industrial/flex tech, (3) mixed use – office/institutional, (4) mixed use – urban village, and (5) mixed use – high density urban transit village (EDAW, 2007). The ultimate development plan is unknown at this time.

A study of the feasibility of incorporating low impact stormwater management practices into the development was conducted (Barr Engineering, 2009). This study contained several suggestions for stormwater management practices at the redevelopment site. Incorporating such practices into the site will be critical for improving water quality and reducing the flashy nature of flows in Hidden Falls Creek.

EXISTING CONDITIONS

TOPOGRAPHY

Topography of the park is characterized by the Mississippi River gorge and bluffs; the Hidden Falls Park ravine and alluvial fan; and the active floodplain and relic floodplain terraces and backwater channels of the Mississippi River. A cross-section through the Mississippi gorge, upstream of the Hidden Falls ravine, shows the typical dimensions of the gorge: roughly 750 feet between the gorge walls, with a steep, nearly vertical slope from a river terrace at an elevation of 800 feet down to the existing floodplain near 700 feet. The Mississippi River channel hugs the toe of the bluff at river right (southern bluff), and a relatively flat floodplain surface slopes gently to the toe of the left (or northern) bluff (Figure 13).

Figure 13: Google™ Earth Section of Mississippi River Gorge facing downstream

A cross-section through the Hidden Falls ravine shows the extent of ravine erosion from the face of the historic bluff, the extent and slope of the alluvial fan, and the floodplain of the Mississippi (Figure 14).

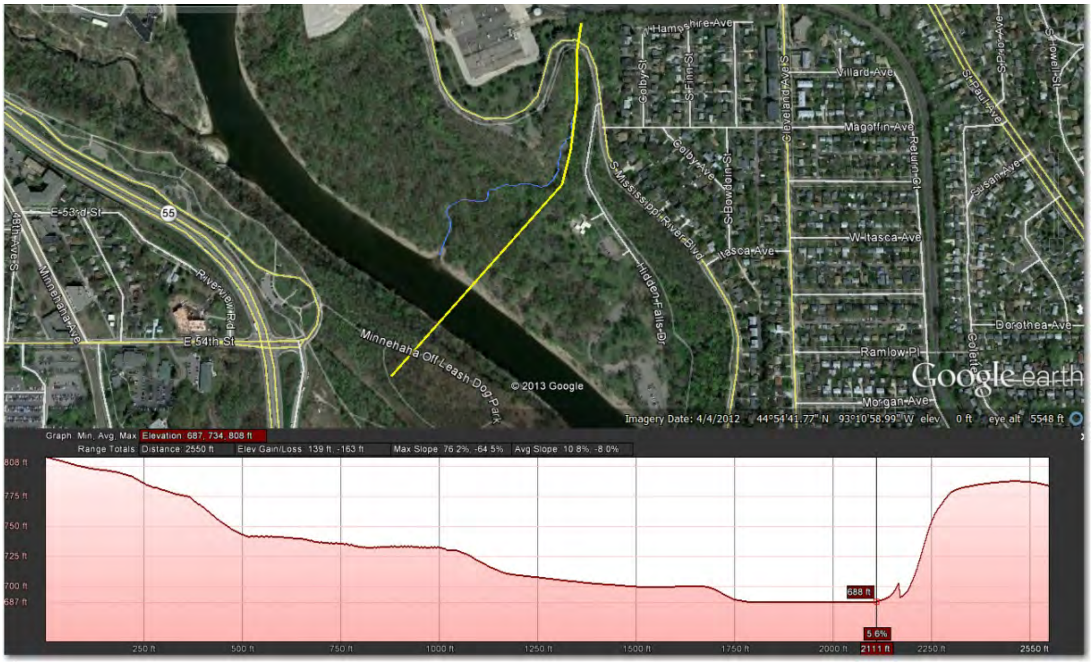

Figure 14: Google™ Earth section of Hidden Falls Ravine, through the park floodplain and across the Mississippi facing downstream

SOILS AND SUBSURFACE INVESTIGATIONS

WATERSHED SOILS

The landform of the upper watershed (above the falls) is a glacial outwash terrace. Soil development in the shallowly sloped, rolling plain has led to the development of silt loam layers characteristic of the broad prairies in the pre-settlement landscape. Since then, the watershed has been completely urbanized. The northeastern watershed is single-family residential development, while the northwestern watershed is currently dominated by the impervious expanse of the abandoned Ford Motor Plant. The USDA Web soil survey delineates two primary soil types of the residentially developed terrace in the watershed: Copaston and Waukegon complex soils, which are primarily loam and sand.

The USDA data base does not contain detailed information regarding soils underneath the Ford Plant Site. Borings drilled in that area as part of the redevelopment planning process suggest that a wide range of fill material, including gravel, sand, silt and clay, is present on the site (Barr, 2009). When environmental testing at the Ford site is completed by 2015, more information about the nature of the soils will be available. Site soils may change slightly as restoration and remediation activities, including establishment of interim stormwater management features, are completed over the next few years.

SITE SURFACE AND SUBSURFACE MATERIALS

The USDA data shows Dorerton-Rock outcrop complex along the edge of the bluff and ravine and floodplain soils in the lower regions of the site. This information was augmented with soil borings that were drilled on site, both through this feasibility study and during the pavilion design in the 1970s. The three borings taken in the vicinity of the pavilion showed 4-7 ft of clayey sand and silty clay fill material over 2 – 3.5 ft of micaceous silty sand. Beneath the micaceous silty sand, inorganic alluvial sand and silt lenses, characteristic of floodplain deposition, were found.

Ten borings were drilled on the site as part of this feasibility study (Braun Intertec Corp, 2014, attached as Appendix A). Boring locations are shown in Figure 15. Borings PP-1 to PP-4 were drilled in the steep section of the valley. These borings all showed a layer of poorly graded gravel below the topsoil layer. This gravel was identified as dolostone or limestone from the surrounding bluffs. The void space in the gravel was filled with finer material that likely infiltrated into the interstitial spaces after the gravel deposited. The lower borings in this area showed layers of clay and other fine material under the gravel deposits but above the bedrock elevation. This suggests potential deposition of fine material that may have been carried by the Mississippi River at a time before it had incised as deeply as it is today and before the headcut continued up the ravine to cover the deposits with the gravel. Bedrock elevations in these borings ranged from 728.8 at the northern most boring (PP-1) to 704.7 at the southern most boring (PP-4) and ranged from 11.5 to 22.5 ft below the existing ground elevation.

Borings PP-5 to PP-7 were drilled in the alluvial fan section of the valley. The northern most boring in this area (PP-5) showed a 3 ft layer of gravel just below the topsoil layer. Below the gravel layer, several layers of finer material were found with gravel mixed in. The other two borings did not contain layers dominated by gravel, but gravel was present in several of the layers.

Borings PP-8 to PP-10 were drilled in the Mississippi River floodplain section of the valley. They are characterized by distinct layering of primarily finer material including sands, silts and clays, which is consistent with a historical pattern of episodic flooding and deposition. Gravel that likely originated in the Hidden Falls ravine is present in some of the layers. PP-9 also contains several layers of fill, including bituminous material, which may reflect a previous trail or access road in that area.

In addition to the geotechnical borings that were drilled on the site, Inter-Fluve dug three hand cores (3-in diameter) in the alluvial fan area of the site. They were generally located east of borings PP-6 and PP-7, with two of them in the low part of what appears to be an historic channel through the alluvial fan (Figure 13). The third is at a higher elevation on what appears to be the former top of bank of an historic channel. At the northern location (CORE-3 in Figure

15) the ground elevation was 708.4, and the depth of the core was 6 ft. Therefore, the depth of the core was 702.4. The thalweg of the existing channel at the location nearest the core, 80 ft downstream of the end of the concrete chute, is 706.3. Through the coring, we found that the top 2 ft of soil was sand with gravel and angular cobbles. The 0.5 ft below the rocky layer was silt with clay. Below that, we encountered sand with silt.

At the core further down slope within the historic channel (CORE-2 in Figure 15), the ground elevation was 706.3, the deepest elevation of the core was 702.3, and the nearest stream thalweg elevation, near the bend in the stream, was 704.75. Similar to the core further upslope, the top 1.5 ft of the core contained sand, gravel and angular cobbles, while material below it was comprised of sand, clay, and silt. These cores suggest that if the historic channel did follow this path, it was near the existing ground surface, where the larger rock material is found. A third core (CORE-1 in Figure 13) was extracted approximately 20 ft northwest of this downslope core. It was outside of the dry channel and the existing ground was an elevation approximately 1 ft higher than the core taken within the channel. At this location there was a similar layer of sand with gravel and angular cobbles at the surface to a depth of approximately 1.5 ft.

Neither PP-6 nor PP-7 showed a similar dominant layer of large gravel and cobble at the surface. The ground elevation at the locations of the cores at the bottom of what appears to be an old channel (see Figure 15) is approximately 2 ft higher than the thalweg elevation in the existing channel near those locations. The presence of more gravel in this area at the surface and at a higher elevation than the current channel suggests that deposition of fractured material in the former active channel may have cause aggradation in and adjacent to that former channel. At some point, the stream flow likely spilled out of this aggraded channel to the side of the valley where it began to incise through relatively smaller material. Over time coarse material washed down to armor the new channel. This is consistent with typical alluvial fan evolution (Bridge 2003, Schumm 1987). Therefore, although it is likely that this channel historically served as the primary route across the alluvial fan, it is also likely that it shifted to its current position through natural evolutionary processes.

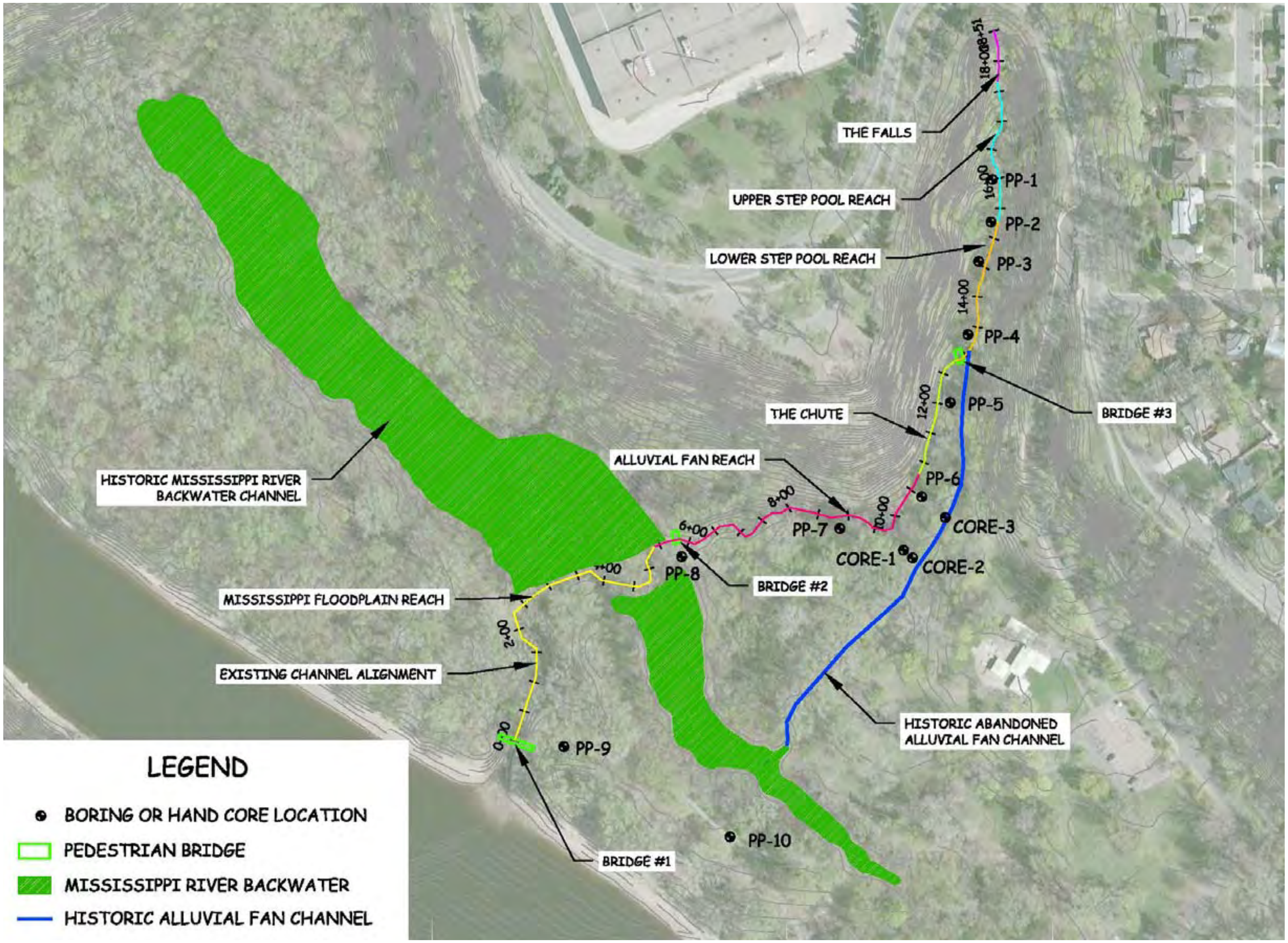

Figure 15 – Existing and Historic Water Features at Hidden Falls Park

HIDDEN FALLS CREEK REACHES

We have divided Hidden Falls Creek into six reaches defined by break points in channel slope. For the purpose of this report they are called: Floodplain Reach, Alluvial Fan Reach, The Chute, Lower Step Pool, Upper Step Pool, and The Falls (Figure 15). Table 1 shows measurements of channel reach lengths, elevations (feet), and slope based on a longitudinal-profile of the channel thalweg (low flow path of the channel) surveyed by Inter-Fluve in April, 2013.

Table 1 – Hidden Falls Creek Subreaches

Reach	Stations	Channel Length	US/DS Elev.	Δ Elev.	Slope %
Floodplain	0+00 – 5+39	539	693.21 – 688.96	4.25	0.79
Alluvial Fan	5+39 – 10+78	539	708.47 – 693.21	15.26	2.8
The Chute	10+78 – 12+77	199	716.43 – 708.47	7.96	4.0
Lower Step Pool	12+77 – 15+26	249	730.07 – 716.43	13.64	5.5
Upper Step Pool	15+26 – 17+64	238	753.89 – 730.07	23.81	10.0
The Falls	17+64 – 18+32	68	780.34 – 753.89	26.45	38.9

The Falls reach consists of two dramatic drops – a 19.2 ft drop from the emergence of the stream from the culvert to the large pool at the head of the reach, and a 7.2 ft drop below the pool. Downstream of these two large drops a series of steps and pools consisting of stone and concrete convey the stream for almost 500 ft before the stream passes under pedestrian bridge #3. The upper portion of this stretch (Upper Step Pool reach) is significantly steeper than the lower portion (Lower Step Pool reach). In both reaches, manmade stone walls hem the stream in and act as retaining walls to allow a foot path along the west side of the stream. Downstream of the bridge, the stream consists of a concrete chute with no steps for approximately 150 ft and a scoured unlined pool at the downstream end of the concrete channel (The Chute reach). Downstream of The Chute, the stream substrate transitions to native stone and sand as it flows across the alluvial fan that developed as the Hidden Falls ravine carved itself into the limestone and sandstone bluff. Historic incision and active bank erosion is evident in this Alluvial Fan reach as it appears widened and entrenched. Downstream of pedestrian bridge #2, the stream transitions to a flat sandy reach that appears to be regularly backwatered by the Mississippi River (Floodplain Reach). After passing under pedestrian bridge #1, the stream joins the

Mississippi River. Figures 17 through 25 illustrate the distinctive character of each of these reaches. Figure 16 illustrates the profile of these reaches.

Additional discussion of the characteristics of these reaches, typical characteristics of similar natural streams, and the relevance to preliminary design is provided in the Stream Design Considerations and Alternatives section of this report.

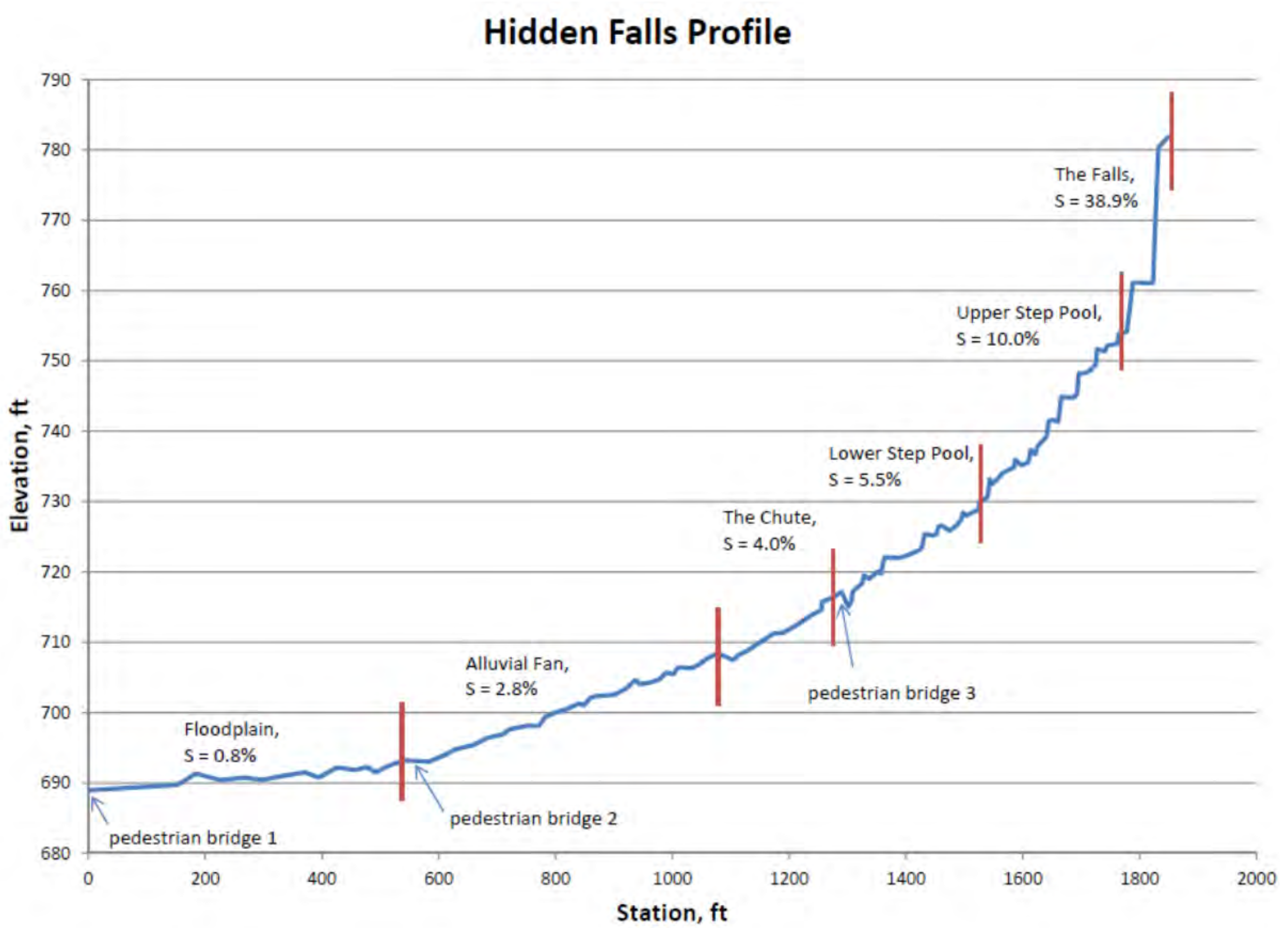

Figure 16: Longitudinal-profile - Existing Channel

Figure 17: The Falls

Figure 18: Upper Step Pool Reach looking downstream through the walls of the upper cascades and the ravine valley

Figure 19: Looking downstream from approximately Station 15+00 at the Lower Step Pool channel

Figure 20: Looking upstream from bridge #3 at Station 12+85 at the Lower Step Pool Reach

Figure 21: Looking upstream at The Chute along the base of bluff near Station 11+00 – 12+50

Figure 22: Alluvial Fan Reach - Bar development at toe of bluff upstream from Station 9+00

Figure 23: Alluvial Fan Reach - Bank erosion project on channel left looking downstream at Station 6+00 to bridge #2 crossing

Figure 24: Floodplain Reach, near Station 4+00

Figure 25: Floodplain Reach upstream from pedestrian bridge #1

HYDROLOGY

The hydrology of Hidden Falls Creek is determined by the flows generated as stormwater runoff from the watershed and conditions in the Mississippi River. The hydrology of the upper reaches will typically be independent of the water level in the Mississippi River, but in the floodplain and alluvial fan reaches, the water surface elevation of the river influences local hydraulics and sediment transport within the creek. When the Mississippi River is at high stage, the floodplain reach will fill with water that flows in from the Mississippi, high groundwater, and water from Hidden Falls that is backed up by high water downstream. When the Mississippi River is low, the groundwater level drops and the floodplain reach typically becomes dry as water that enters the reach from upstream quickly infiltrates into the sandy, rocky substrate.

Because the watershed of Hidden Falls Creek is very small and that of the Mississippi River is quite large, high flow conditions in the creek do not necessarily coincide with high flow conditions in the river. Mississippi River flows typically gradually rise seasonally, while flows in Hidden Falls Creek will be flashy and tied to localized weather events. Therefore, when considering critical conditions in the stream, particularly in those reaches potentially affected by backwater from the river, we will need to consider a range of flows in Hidden Falls Creek under both high and low water conditions within the Mississippi River.

STORMWATER QUANTITY ANALYSIS

Stream flow rates will have a significant impact on the design of all reaches of the stream. Larger flows will generally require larger stream cross sections and larger material lining the bed and banks to ensure long term sustainability. Peak stormwater discharge rates for a range of site conditions were determined for the Hidden Falls outfall. The analysis included a subwatershed analysis for the approximately 108 out of 116 acres of the Ford Plant potentially routed to the outfall and approximately 50.5 acres of a primarily residential area adjacent to the Ford Plant currently draining to the Hidden Falls outfall at the South Mississippi River Blvd crossing. The minor contribution to flows from the small, primarily pervious areas within the park that drain to the creek were assumed to be negligible for this study. Several watershed conditions were included to determine a full range of potential peak flows that were, are currently or could be directed to the outfall.

MODEL INPUT

Peak flows were estimated based on SCS and TR 20 methodology and applying the National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall values for the immediate area. All modeling was completed in HydroCAD. The 2, 10 and 100-year rainfall depths for a 24-hour storm duration are presented in Table 2.

Table 2 – NOAA Atlas 14 Rainfall Depths

Reoccurrence Interval (yr)	Rainfall Depth (in)
2	2.83
10	4.24
100	7.49

Although the City of Saint Paul's approved rainfall depths are less than the Atlas 14 values, it is anticipated that since the Atlas 14 values are fairly new, governmental agencies will be incorporating the Atlas 14 values into local and state ordinances in the near future. Existing curve numbers were generated from reviewing 2005 Land Use data and aerial photography. Watershed delineation and runoff overland flow paths were determined based on current LiDAR data transformed into two foot contours and the City of Saint Paul's storm sewer data.

SUBWATERSHED AREAS

The subwatershed areas and the corresponding drainage areas are depicted in Figure 23. Under existing conditions approximately 24.2 acres of the Ford Plant Subwatershed #1 area (bound by dashed purple line in Figure 26), are directed via a storm sewer to an outfall north or upstream of the Hidden Falls outfall. However, in the proposed and pre-settlement conditions, it's assumed that this additional area will be and was conveyed to the Hidden Falls outlet. In addition, based on the review of the Ford Plant's engineers existing and proposed condition delineation and design, it was assumed that 7.9 acres, comprising the Ford Plant Subwatershed #2 in the northwestern most portion of the site, will continue to be directed to an upstream outfall. Therefore, this area was not considered in the peak flow analysis for Hidden Falls. Lastly, it was assumed that although the ground surface topography indicates that approximately 12.75 acres of the Offsite B Subwatershed drain to the Ford Plant property, this area appears to be contained and conveyed through private storm sewer to the City's storm sewer network along Ford Parkway and/or Cleveland Ave. This should be verified during final design.

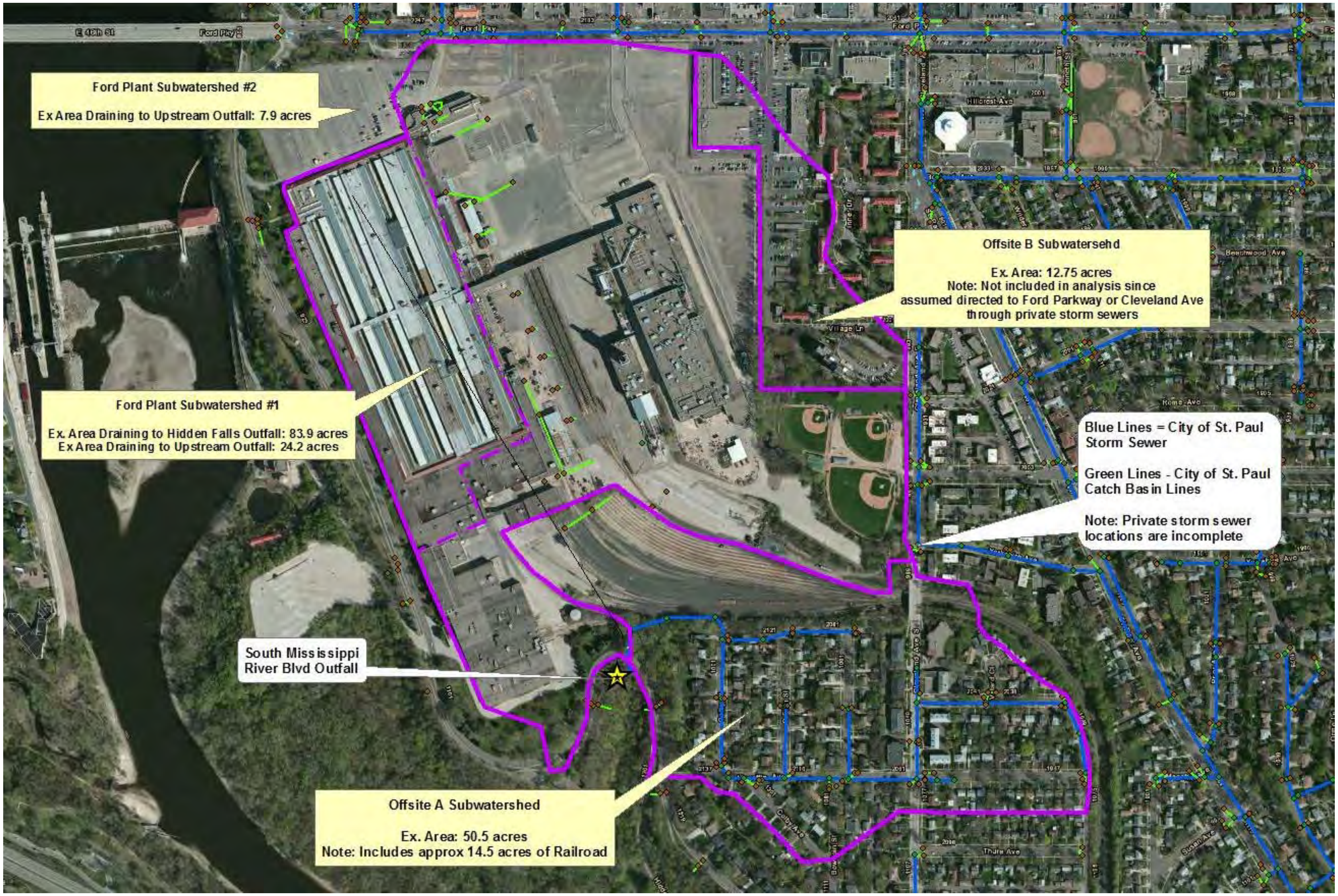

Figure 26: Subwatershed Areas

MODELED CONDITIONS

Four watershed conditions were modeled to determine a suite of potential design flows for Hidden Falls Creek. The conditions and the associated peak flows are described below and shown in Table 3.

Condition 1: Existing conditions. Hydrologic properties of the subwatersheds were based on the review of the Ford Plant's Existing Conditions Drainage Map and development of hydrologic properties for the Offsite A Subwatershed area. It was determined that the hydrologic inputs provided by the Ford Plant engineering study (TKDA, 2012) were appropriate and the data provided in that documentation was directly incorporated into our model.

Condition 2: Pre-settlement Conditions. A scenario that estimates the pre-settlement runoff condition was modeled to provide an estimate of the lowest peak flows that may someday be possible from the subwatersheds that drain to Hidden Falls. Although a portion of the watershed was developed at a time before significant stormwater management was incorporated into development, the Ford Plant redevelopment offers an opportunity to incorporate state of the art stormwater management that may approximate pre-settlement conditions. This scenario is based on the assumption that approximately 108 acres of the Ford Plant was directed to the Hidden Falls outfall and that the entire watershed area directed to the outfall was heavily wooded and consisted of hydrologic soil group B soils. Current soils indicate the watershed is mainly comprised of urban fill materials. Generated curve numbers and time of concentration values were based on typical values for a wooded area.

Condition 3: Proposed Interim Conditions. This scenario approximates conditions for the Ford Plant area and Railroad during the time between Ford Plant demolition and remediation and the time of redevelopment. It is our understanding that the enhancement of Hidden Falls Creek would occur after redevelopment of the Ford Plant site, but given uncertainty with the ultimate timing of redevelopment, it is worth considering the interim hydrologic conditions. The watershed and stormwater runoff properties were based on the Ford Plant's Proposed Conditions Drainage Area Map. Their proposed condition analysis provides preliminary sizing of select best management devices and identifies the amount of impervious cover within the transformed Ford Plant. The design includes approximately 14 acre-feet of live pool stormwater storage and accounts for 29 acres of impervious area within the 108 acre Ford Plant Site. For this condition, it was assumed that the railroad would be transformed into an open space area and 108 acres of the Ford Plant would be directed to the Hidden Falls Outfall. This analysis did not consider volume reduction provisions set by Capitol Region Watershed District. Although volume reduction devices can have a dramatic effect on flow conditions that occur during most of the time, they typically have a negligible effect on peak stream flow conditions during extreme events, which are the basis for establishing the size of the channel materials in this type of system.

Condition 4: Light Industrial Development. This scenario reflects conditions at the Ford Plant Site described as Scenario 1 outlined within the "Redevelopment of the Ford Motor Company Site" Phase 1 Summary Report, October 17, 2007 (EDAW, 2007). The proposed site curve number and time of concentration have been increased and decreased, respectively to reflect the development scenario. The BMPs applied to this condition are the same as the BMP's applied under Condition 3. Condition 4 assumes the railroad area would be transformed into open space. This development scenario represents a worst case scenario for runoff rates and peak flow rates potentially delivered to Hidden Falls Creek for storm events smaller than the 100 year event. The worst case scenario for the 100 yr event is limited by the City of Saint Paul's peak flow limitation as described in Condition 5. It should be noted that although the Light Industrial Development scenario was used to generate worst case flows, this type of development does not necessarily preclude delivery of better quality and quantity of water to Hidden Falls. If the site is developed for light industry, additional stormwater management practices can and should be considered to reduce the impact on local waterways.

Condition 5 – Maximum Peak Flow. This scenario was analyzed to determine the maximum peak stormwater runoff flow from the proposed reconstructed area based on applying the City of Saint Paul's peak flow limitation of 1.64 cfs/acre for the 100-year storm event. It was assumed that approximately 108 acres of the Ford Plant and 14.5 acres of the railroad would be held to this regulation during redevelopment, for a total regulated area of 122.5 acres. For the Offsite A subwatershed it was assumed that approximately 36 acres of the existing residential neighborhood would be unregulated. Individual peak flows for the Ford Plant and Railroad and the remaining residential neighborhood were added directly to determine a final outflow value directed to the Hidden Falls outlet.

Table 3 – Peak Flows for each Condition

Condition	Watershed Area (acres)	Peak Flows (cfs)		
		2-year	10-year	100-year
1	134.4	233	401	792
2	158.6	4	31	161
3	158.6	93	191	443
4	158.6	112	225	542
5	158.6	N/A	N/A	415

Consequently, the range of potential 2 and 10 year peak flows for the downstream channel is anticipated to be between Conditions 2 and 4. The range of potential flows for the 100 year event is expected to be between Conditions 2 and 5. All flows represent substantial reductions from the estimated existing condition (Condition 1).

STORMWATER QUALITY

Although it does not have as large an influence on the design parameters of the stream as water flow rates, stormwater quality will have an important influence on the project success. Better water quality in the stream will contribute to the park users' enjoyment of the creek and improve wildlife use of it. Full characterization of the existing chemical water quality in Hidden Falls is beyond the scope of this study. However, it is obvious that there are water quality deficiencies. Near the falls, there is a petrochemical smell emanating from the water that is quite unpleasant.

The redevelopment of the Ford Plant Site presents an exciting opportunity to achieve a higher standard of water quality within the creek. This will be important for improving park visitor's experience of the creek, improving suitability for wildlife, and offering critical educational opportunities. Transforming this stream to a clear, clean, vibrant stream will tell an inspiring story of renewed stewardship of water resources in Saint Paul.

STREAM DESIGN AND ALTERNATIVES

We examined the existing channel form in each of the reaches identified to determine the extent to which it conforms to natural channel form in these reaches. In enhancing the form and function of the stream through the park, understanding, accommodating, and mimicking the natural evolution of these types of streams will improve the sustainability and educational value of the project.

STEP POOL REACHES

NATURAL STEP POOL FORM

In natural streams with slopes greater than 3-5%, the bedform of the stream is typically observed as a series of steps and pools (Chin, et al., 2009). In channels with a wide range of substrate particle sizes, Curran and Wilcock (2005) observed step formation in a laboratory to occur through three primary mechanisms. One means of step formation was observed to begin with deposition of a large piece of bed material that subsequently traps additional material until the jam spans the entire channel width to form a step. Flow over this step then scours a pool downstream of the step. A second means of step formation was observed to occur when a large piece of bed material already exists in a particular location. Localized scour around that particle exposes it and allows it to begin trapping additional material that moves downstream creating a step and promoting scour on the downstream side, similar to the first mechanism. A mechanism that was less common in the laboratory runs was through periodic dune formation as smaller particles create bed deformation and surface wave development. While the step spacing is very regular for the dune formation, the step spacing appeared more random in the cases where steps formed due to deposition or exposure of an existing large grain.

These mechanisms are worth considering as we design a step pool system at Hidden Falls. The channel will be locked in place, and no significant sediment supply will be provided from the upstream watershed, which will continue to be a mix of stormsewer and non-deformable, non-erodible material. Therefore, steps will not be able to form on their own, and if the steps we install do not persist, we cannot expect the steps to re-form in a self-sustaining way. We propose mimicking the first and second mechanisms by installing the large material that forms the anchor elements of each step and locking smaller material against the larger pieces similar to the way natural transport mechanisms would arrange the steps. We propose excavating scour pools at the downstream sides of the steps to similarly mimic the natural step pool form.

We propose using typical geometric patterns as described in the literature to create the step pool form at Hidden Falls. In addition to the overall slope of the step pool reach, important variables in such channels include the step spacing, the step height, and the stone size (Figure 27). Although some researchers have found that step location and spacing is somewhat random depending on the location of key substrate pieces, many researchers have noted empirical relationships between these variables. Not surprisingly, the length and height of steps are typically related to the channel slope, with step length decreasing and step height increasing with increasing slope. Step height is usually 1 – 1.5 times the stone size that makes up the step.

The relationship between step height and step spacing has been studied by many researchers (Chin et al., 2009). Ideal step pool geometry has been described as having steps that are somewhat regularly spaced and a ratio of step height to step length (H/L) of approximately 1.5 times the slope of the channel. Abrahams et al. (1995) suggested this form has the greatest flow resistance and greatest stability. Empirical data suggests that (H/L)/S is typically between 1 and 2 (Chin et al., 2009).

Step length has also been correlated with channel width for step pool channels. Chin et al. (2009) noted that step length ranges from 1 to 4 times the channel width, with most step lengths in the range of 1 – 2 channel widths.

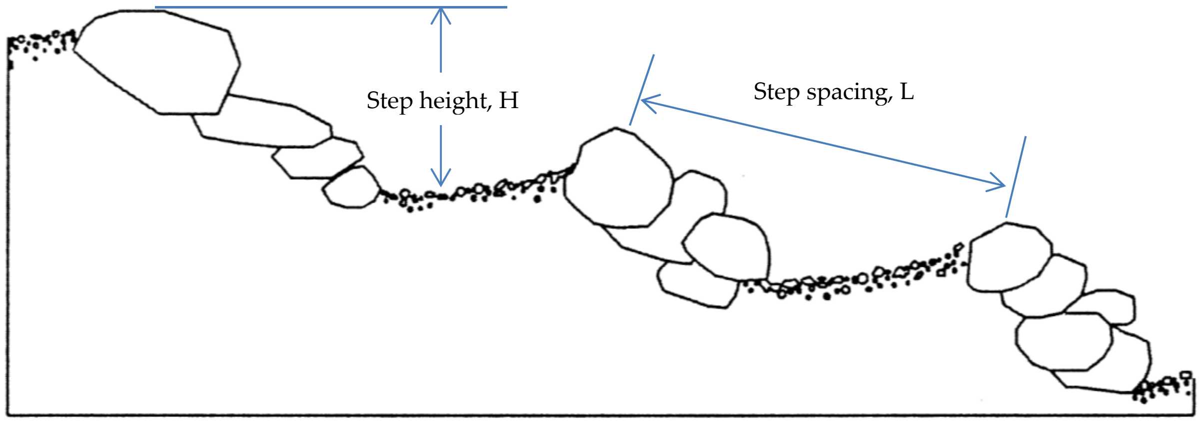

Figure 27: Step pool dimensions

EXISTING STEP POOL FORM AT HIDDEN FALLS

We examined the existing step pool channel form and compared it to the typical geometry patterns described in the literature to determine the extent to which the existing step geometry is within the range of typical step pool channel parameters. There is no historical record of the geomorphic form of Hidden Falls Creek prior to modification during the WPA era or even prior to the later modifications. There is no information available that indicates whether there was some perceived instability prior to either of the modifications. However, it is likely that the slope of the stream was not modified substantially and it is likely that the steep reaches of the stream existed as falls, cascades, and step pool systems prior to modification. It is possible that the modifications primarily cemented steps into their previous locations. A summary of the channel geometry as it exists in the upper two reaches is shown in Table 4.

Table 4 Existing Reach Average Channel Geometry for Step Pool Reaches

	Lower Step Pool Reach	Upper Step Pool Reach
Slope (S) ft/ft	0.055	0.10
Step Spacing (L), ft	30	24
Step Height (H), ft	2.0	2.4
(H/L)/S	1.23	1.02
Channel Width (W), ft	11	10
L/W	2.7	2.3

The channel width was most likely reduced in the areas where stone walls are now creating vertical banks, so the L/W was probably originally smaller than it is now. Regardless, the current values are within a typical range for natural step pool channels. The (Hs/L)/S ratio is lower than expected for the upper reach. The value near 1 suggests little to no pool depth below the drops, which is consistent with field observations. However, it is likely that pools were deeper before the concrete was placed in them. The presence of concrete currently eliminates scour potential in the pools.

Figure 28: Existing step pool reach at Hidden Falls Creek

The immobility of the concrete chute has precluded development of any step pool form in that reach. The slope in this reach suggests that continuation of a step pool channel in this reach is appropriate.

STEP POOL PRELIMINARY DESIGN

As described above, the step spacing and general form of the existing step pool reaches is within the range of what is typically observed in natural channels. However, the channel width is artificially constricted by the constructed stone walls in several locations, and the pool depth is restricted by presence of concrete. With respect to the overall form, we recommend increasing channel width, removing concrete lining and increasing the pool depth. In the concrete chute reach, we recommend removing the concrete and extending the step pool form through this reach using typical ratios for L/W and (H/L)/S.

Because much of the step pool design depends on the step height and the step height depends on the available stone size, a key component of the channel design is determining the minimum stone size that is expected to remain immobile for a range of flows. The recommended method for determining stone size for this application is the US Army Corps of Engineers' steep slope riprap design method. This method is appropriate for straight channels, with slopes ranging from 2 to 20% and entails application of the following equation:

$D_{30} = (1.95\ S^{0.555}\ q^{2/3})/g^{1/3}$, where
D_{30} = stone size for which 30% of the stone in the mix is smaller
S = slope of the bed
q = unit discharge = total flow/channel bottom width
g = acceleration due to gravity = 32.2 ft/s^2

Without dramatically changing the topography of the site by importing or exporting a large quantity of material, the slope of the channel will not change significantly. The variables we can manipulate are the total flow and/or the channel bottom width to achieve a reasonable stone size for forming the steps. Modifying the channel width in the upper reaches will require complete dismantling and potential rebuilding of the stone wall on one side of the stream in some locations. If a naturalized bank is desired on one side of the stream, consistent with the renderings developed for the Great River Passage Plan, rebuilding will not be necessary.

Many natural step pool channels become mobile and are reorganized as frequently as during a 25 yr flow event, but because investment in adjacent park features such as trails and bridges is not compatible with active channel evolution, the step pool reach of Hidden Falls should be designed to be immobile during larger flows. Flows with a 100 yr recurrence interval and smaller are appropriate for design. Using the USACE steep slope method, there is a positive relationship between discharge and D_{30}, and therefore using the largest flow in the range of design flows will provide the most conservative stone size. We calculated stone size for 100 yr flows of 160 cfs, which reflects the pre-settlement flow estimate, 300 cfs, which represents a flow between the pre-settlement estimate and the St Paul maximum allowable 100 yr flow, and 415 cfs which is the maximum allowable 100 yr flow. Table 5 summarizes the results of applying the Corps steep slope method of sizing stone to this plausible range of values for the variables over which we may have some control. A safety factor of 1.5 was applied, and the D_{90} (size for which 90% of the stone in the mix is smaller) was set at $1.45*D_{30}$ consistent with standard gradation tables (ACOE, 1994).

Not surprisingly, steeper narrow reaches subjected to larger flows require larger stone to achieve immobility. We recommend using limestone slab to match the native stone in the ravine, rather than using large rounded boulders. The economy of acquiring, transporting and placing smaller rock adds incentive for widening the channel consistent with the discussion of natural step pool channel form. Additionally, reducing peak flows within the channel will be very beneficial to the long term stability of the channel and should be emphasized in the redevelopment of the Ford Plant Site.

Table 5 – Estimated Stone Size Required (sizes in ft)

	w, ft	Width = 6 ft			Width = 10 ft			Width = 14 ft		
	Q_{100}, cfs	160	300	415	160	300	415	160	300	415
Upper Step Pool Reach	D_{30}(ft)	2.3	3.5	4.3	1.6	2.5	3.1	1.3	2.0	2.5
	D_{90} (ft)	3.3	5.0	6.3	2.4	3.6	4.5	1.9	2.9	3.6
Lower Step Pool Reach	D_{30} (ft)	1.6	2.5	3.1	1.2	1.8	2.2	0.9	1.4	1.8
	D_{90} (ft)	2.4	3.6	4.5	1.7	2.6	3.2	1.4	2.1	2.6
The Chute Reach	D_{30} (ft)	1.4	2.1	2.6	1.0	1.5	1.8	0.8	1.2	1.5
	D_{90} (ft)	2.0	3.0	3.8	1.4	2.2	2.7	1.1	1.7	2.1

ALTERNATIVES

Dramatic changes to public places often trigger opposition from people who currently appreciate the place. In enhancing the stream at Hidden Falls Park, we should be sensitive to this fact and try to maintain the qualities of the park that people enjoy while improving features that are less functional and less attractive. We propose maintaining the Falls reach of the stream. The first two drops can remain functionally as they are with improvements to the park space around them. The stone walls around the first pool can be restored where necessary, but the overall dimensions of the falls and the pool can remain the same.

A few alternatives are feasible for enhancing the step pool reaches. Given the value of increasing the width of the channel, removing the concrete lining from the channel bed, and using natural material that matches the surrounding environment, all of the alternatives include these features. For all alternatives, access to the channel may be improved by incorporating steps down from the trail to the channel, if desired. The key variables distinguishing the alternatives are (1) whether the mortared stone 1980's era walls are removed entirely on one side of the channel to achieve the greater width or simply moved and rebuilt (Figure 29); and (2) whether the channel is lined with clay to restrict infiltration. The value of these alternatives is summarized in Table 6 together with a no action alternative for comparison.

Figure 29: Upper step pool reach showing 1980's era walls considered for removal

Table 6 - Evaluation of Alternatives for Upper Reaches of Hidden Falls Creek

	Park Planning Considerations (Aesthetics, accessibility; education opportunities)	Ecological, Water Resource and Sustainability Considerations	Cost Considerations
Alternative 1 - No change	• No change to existing aesthetics; visible concrete; crumbling walls in some areas • Stream generally not accessible • Potential safety concerns with high steep walls with varying integrity	• No change to existing conditions • Stream not very accessible to wildlife • Stream not very attractive to wildlife	• No initial cost • Costs associated with repair of trail and bridge infrastructure as stream erosion progresses; ongoing costs of repairing walls and stream bed
Alternative 2 – Remove concrete bed lining; eliminate 1980's era mortared wall on east side of channel; build steps using limestone slab; access from the trail down to the stream may be incorporated	• Natural aesthetic replaces wall on east side of stream (this will be a positive change for some, negative for others) • Access can be incorporated to allow visitors to get down to the creek • Safety improved with ease of getting out of stream	• Wildlife access (ingress and egress) possible along east side • Naturalized bank suitable habitat for wildlife • Naturalized stream bed may support macroinvertebrates if water quality improved • Filtration and infiltration of water through natural stream bed	• Lower cost than Alt 2a, 3, 3a • Primary costs associated with wall and concrete removal; step pool construction, bank stabilization on east bank, wall repair on west bank
Alternative 2a – Same as Alt 2 but with addition of clay liner at bottom of pools to restrict infiltration	• Similar to Alt 2 • Less filtration and infiltration • More water delivered downstream to keep pools full	• Similar to Alt 2 • Less filtration and infiltration • More water delivered to downstream reaches	• Same as Alt 2 but with addition of clay liner cost
Alternative 3 – Remove concrete bed lining; move and/or lower 1980's era mortared wall on east side to widen channel in some locations; build steps using limestone slab	• Wall aesthetic maintained on east bank (positive for some, negative for others) • Access can be incorporated to allow visitors to get down to the creek • Safety improved slightly with access areas, but not as good as Alt 2	• Wildlife access remains limited • Naturalized stream bed may support macroinvertebrates if water quality improved • Filtration and infiltration of water through natural stream bed	• Higher cost than Alt 2 • Primary costs similar to Alt 2 but with additional reconstruction of walls instead of bank stabilization • Ongoing maintenance cost of walls higher than Alt 2
Alternative 3a – Same as Alt 3 but with addition of clay liner	• Similar to Alt 3	• Similar to Alt 3 • Less filtration and infiltration	• Same as Alt 3 but with addition of clay liner cost

ALLUVIAL FAN AND FLOODPLAIN REACHES

NATURAL ALLUVIAL FAN AND FLOODPLAIN FORM

Alluvial fans tend to develop in areas where a stream transitions rapidly from an area with a very steep slope to one of a very flat slope. The high shear stress in the steep slope area results in a corresponding high sediment transport rate. The sediment transport capacity quickly decreases as the stream moves into the flat slope area, and bed material delivered from the steep slope area is deposited. The fan shape may appear similar to a delta with branching streams, but typically not all of the channels are active at the same time. Instead, historic channels are often abandoned as deposition within the channel leads to local aggradation and the stream ultimately avulses. Avulsions occur during high flow conditions after significant aggradation has elevated the channel bed above other regions of the fan, and new channels are then cut through finer material in another region of the fan. The channel near the upstream end of the fan is often incised and steep. This new channel then begins to form a depositional lobe starting at the downstream end of the new channel and progressing upstream until aggradation in this new channel causes another avulsion.

Floodplains are areas that become inundated during high flow events. They are typically depositional areas. As turbulent flood flows carrying high sediment loads spread into vegetated floodplains, the water slows and is no longer capable of keeping sediment in suspension. The sediments deposit, and the flood waters recede. This episodic deposition pattern produces discrete strata in floodplain cores. In rivers with large supply of water and sediment, braiding can occur, causing island formation within the channel.

EXISTING STREAM FORM

In the Alluvial Fan reach of Hidden Falls Creek, the upper portion of the creek is incised. It is possible that the concrete chute was constructed to halt what was perceived to be problematic incision through that area. There is evidence of typical alluvial fan deposition patterns within the channel. As the slope decreases, there is considerable deposition of fragmented sedimentary rock that was likely delivered from the eroding ravine upstream.

There is also what appears to be an abandoned channel more centrally located on the alluvial fan. We examined the soil cores that we hand dug at two locations along the northern part of this alternative alignment to document potential evidence that this is an historic channel. As described previously in the subsurface investigation subsection, we cored to a depth of 4-6 ft at each location and found a layer of rock and sand at the surface.

Soil borings further from this channel do not show similar large rock in the upper soil layers. This suggests that this channel aggraded through deposition of rock material that washed down the ravine. The existing ground elevation in the abandoned channel further suggests that the channels evolved as expected in alluvial fan development. The elevation of the bed of the abandoned channel is approximately 2 feet higher than the bed elevation of the current channel. This is evidence that aggradation occurred in the historic channel to the point that a flood flow spilled out and was able to cut through finer material into a lower, steeper sloped channel.

Interestingly, the historic channel appears to cease at the location of a former Mississippi River backwater channel. This may be due to the timing of the abandonment of that channel relative to the formation and subsequent aggradation of the backwater channels. The former alluvial fan channel may have pre-dated Mississippi River deposition that formed the braiding and island development in this area, or it may have existing concurrently with the backwater channel. Aggradation of the Mississippi River floodplain in this area may have contributed to decreasing the slope of the alluvial fan channel, accelerating deposition and the avulsion to a new channel.

Figure 30: Incised alluvial fan channel with abandoned pipe

Imposed on the geologic evolution of the alluvial fan are the shorter term impacts of human modifications to the watershed and the stream. Continued erosion of the ravine has been halted through the concrete stabilization and the stormsewer pipe within the watershed. Even if a portion of the stream is daylighted upstream of the Mississippi River Blvd crossing, development adjacent to the stream will probably necessitate incorporation of stabilizing features that will continue to limit sediment supply to this reach. At the same time, increased impervious area within the watershed has increased peak flow rates and the erosive energy associated with storm events. While much of the ravine is locked in place with concrete, the erosive energy of these flows has continued to cut into the alluvial fan reach of the stream below the concrete chute.

The character of the Floodplain Reach of Hidden Falls Creek is dominated by the effects of the Mississippi River. The landforms that comprise the riparian area are the result of deposition from the Mississippi River, and they include evidence of historic island and backwater channel formation. The soil borings within this region of the park are indicative of floodplain soils, characterized by multiple distinct layers of alluvium. The backwater channels continue to become inundated during high flow in the river, and Hidden Falls Creek is backwatered by the Mississippi River during high flows. We would expect the mouth of Hidden Falls Creek to become a depositional area for material being transported by the large river, but the effect of dam construction and dredging associated with navigation in the river has limited the supply of sediment to this reach. When the Mississippi River is low, the lower reach of Hidden Falls Creek typically loses water to infiltration into the sands and gravels that comprise the floodplain in this area. This reach is often dry in the summer due to such infiltration.

LOWER REACH STREAM DESIGN

The lower reach of the stream transitions from a step pool system to a pool/riffle system that is dominated by its geologic history and the backwatering effects of the Mississippi River. The existing Alluvial Fan reach hugs the steep ravine slope on the right side and appears to have incised such that it is no longer connected to its floodplain. Smaller material has winnowed out of the stream bed in this reach such that it is now armored with the fragmented bedrock that has washed down the ravine and adjacent steep slope. Although the stream is characterized by active erosion in this reach, this is typical in alluvial fans.

Downstream of the existing pedestrian bridge #2, the Floodplain reach is a much flatter reach that is clearly backwatered by the Mississippi River during high flow conditions. The stream banks appear fairly stable and able to withstand the forces imparted by the lower energy flows through this reach. Because the stream banks are stable and the dimensions of the creek seem sufficiently well suited to the hydrologic conditions in this reach, no improvements to the stream form and function are required in this reach. Amenities to improve visitor access, understanding, and enjoyment of this reach should be considered.

ALTERNATIVES

The options for enhancing the stream in the lower reaches include doing nothing; leaving the channel in its existing alignment with modifications to the cross section to improve floodplain connectivity, bank stability, aesthetics and access in the Alluvial Fan reach; and moving the channel to a new location. These alternatives are detailed in the following sections and summarized in Table 7.

Alternative A – No Change

One option is to leave the lower reach alone and allow it to continue to evolve on its own. As described previously, the incision and active erosion evident in this reach is, at least to some degree, natural in an alluvial fan system. However, continued natural evolution of the reach may be hampered by limited sediment supply and increased flood flow rates due to human alterations. Although the existing condition of this reach offers an interesting geology story and provides educational opportunities for telling that story, the active erosion of the stream may be incompatible with maintaining park features, such as trails, adjacent to the stream.

Alternative B – Maintain Alignment and Modify Banks

A second option entails leaving the stream in its current alignment while improving the stability of the Alluvial Fan reach and improving park user access to it. The lower channel would continue to have distinct characteristics in the Alluvial Fan and Floodplain reaches. To improve stability, we would reshape the channel in this reach to include a connected floodplain bench. This would entail cutting into the left bank (looking downstream), and likely narrowing the base of the channel in some locations to construct a low flow channel. By cutting into the existing steep bank, we would also improve park user access to the stream as well as wildlife access to the stream. The abandoned pipe that has become exposed in this reach would be removed, and the concrete wall that currently forms the right bank just upstream of the pedestrian bridge would be removed entirely and replaced with a stable, natural bank.

The slope in the Alluvial Fan reach would be slightly higher than 2%. Streams with slopes of this magnitude typically have low sinuosity, and while they have some connection to a floodplain, they are often moderately entrenched. In the Rosgen stream classification system parlance, they are typically B channels which typically have a bankfull width to depth ratio that is greater than 12 and entrenchment ratio (floodprone area width/ bankfull width) between 1.4 and 2.2. An example of the modification anticipated for the channel cross section is illustrated in Figure 31.

The Floodplain reach channel would remain unchanged. This reach is regularly backwatered by the Mississippi River, and when the Mississippi River is low, it regularly is dry as the sandy/rocky floodplain allows all of the water to infiltrate. The slope in this reach is very flat, and banks appear fairly stable. Any park amenities that are considered for this area should be designed with consideration of the intermittent nature of this reach. For example, stream access locations would be attractive when there is water in the channel, but designers should also consider the aesthetics when the channel is dry.

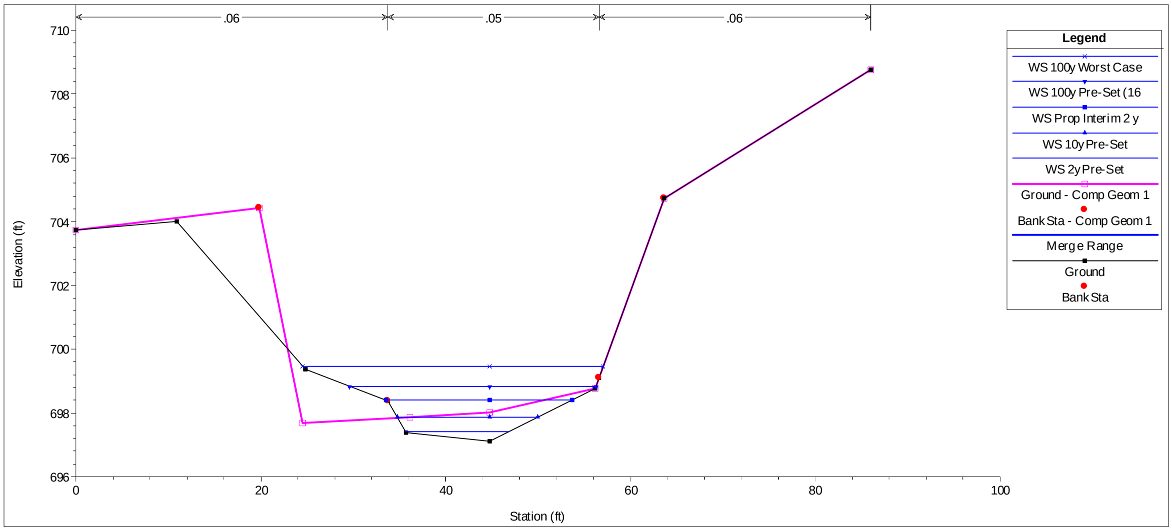

Figure 31: Existing cross section (pink) and potential proposed cross section (black) in the Alluvial Fan Reach

If Alternative B is selected, we propose extending the step pool reach approximately 100 ft past the end of the existing chute reach and have a final drop into a pool near station 10+00. This location is a bend in the stream and is closest to the pavilion area of the park. Its proximity to the parking area and pavilion suggest making this location a destination for park users. The sound and sight of the final drop from the step pool reach will be an attraction for park users. Further, since it is located at the end of the step pool reach before the stream traverses through the sandy floodplain, it is likely to perennially hold water. The area between the parking lot and this destination can be modified to include a path to this location or a larger swath of understory may be removed to create a more open space that directs people to this location. The stream bank can be augmented with natural stone to allow for access to the water without damage to the streambank.

Alternative C – Re-Occupy Historic Channel

An alternative to leaving the stream in its existing alignment is to pull it further south and east starting just upstream of the existing pedestrian bridge #2 to re-occupy the historic channel until it intersects with an existing backwater channel area. At this location, the channel would be routed north and west to re-join the existing alignment downstream of pedestrian bridge #2. The modified alignment would replace 850 feet of the existing channel with 1178 feet of new channel. The character of the reach from the upstream end to the junction with the former backwater channel (794 ft length) would be that of an alluvial fan channel with an average slope of 2.5%. The character of the lower part of this new channel (384 ft length) would be similar to the floodplain reach with a slope of approximately 1%.

As described previously, the information from the soil borings, the hand cores, and the topography in the park is consistent with the theory that this is an historic channel. The evidence also suggests that this channel was abandoned through typical alluvial fan evolution processes of aggradation and avulsion. Given that the elevation of the historic channel is 2 ft higher than the existing channel, placing the channel back in this historic channel would be counter to the direction of natural evolution of the channel. In order to increase the sustainability of the channel in this location and account for adjustments that had been made in upstream reaches when the channel avulsed, if the stream is relocated to this former alignment, the channel should be excavated so it is not perched above the other potential flow paths. Otherwise, there is risk of avulsion similar to what occurred historically. The rock layer near the existing ground surface could be removed and stockpiled, and a portion of the fine material underneath could be removed to achieve the proper grade. The salvaged rock would be replaced and augmented with material from offsite. Fine material could be used in part to fill the existing channel, but larger material should also be used to fill the existing channel to minimize the risk of avulsion. This would require considerable material handling and incur additional costs.

Alternative D – Re-Occupy Historic Channel and Cut New Floodplain Reach

A final option would be to relocate the alluvial fan reach as described in Alternative C but rather than route the stream back to the existing floodplain reach, the channel would be routed along the former backwater channel and an additional channel would be cut such that the creek enters the Mississippi River near the boat launch. The upper portion of this would be the same slope and length as described for Alternative C. The lower portion would be approximately 850 ft long with a slope of 0.5%. This would require considerably more excavation and bank stabilization features due to the added length. Additionally, forcing the stream to the south and east will require filling the historic channel to the north and west, which interrupts the historic backwater channel in that area and introduces regulatory complications associated with floodplain fill.

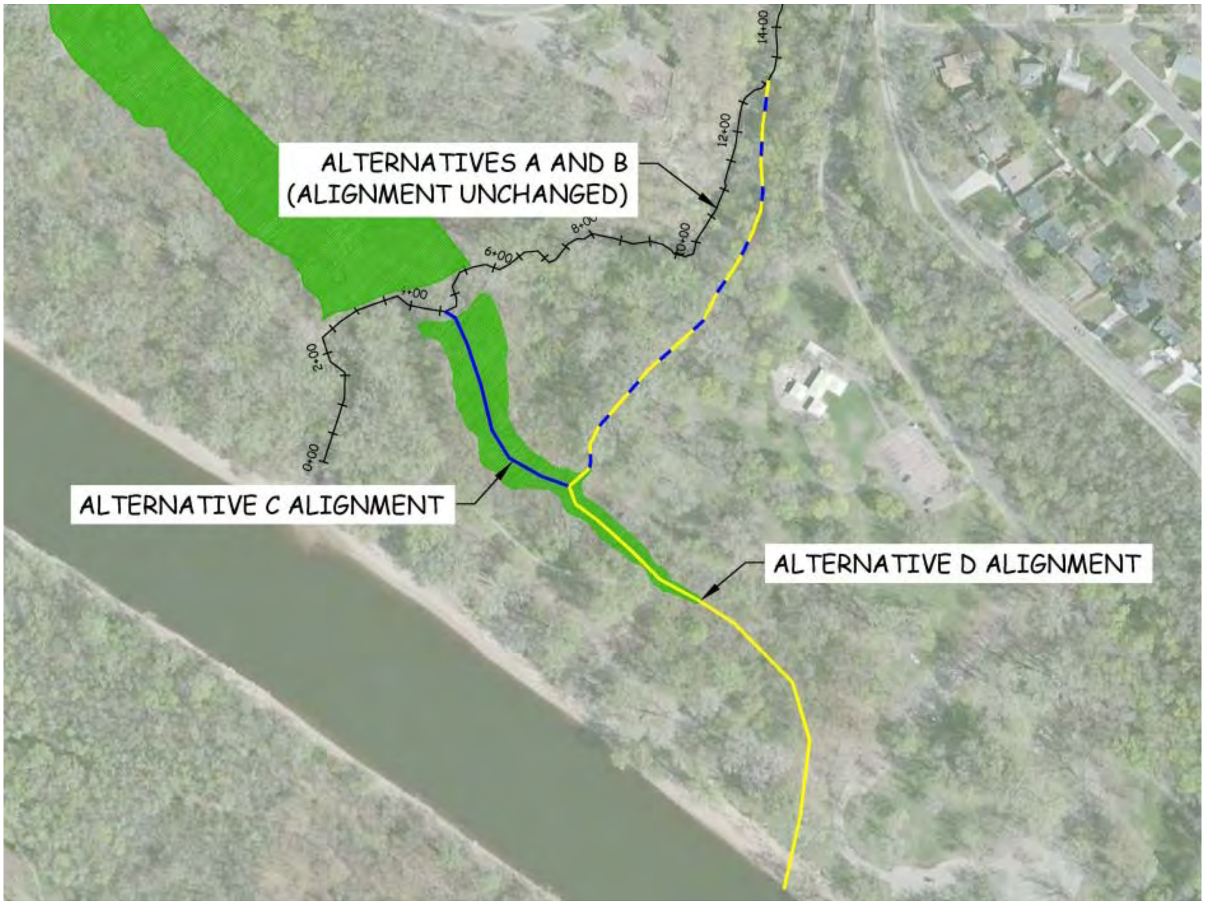

Figure 32: Alternative Alignment Options

Table 7 – Evaluation of Alternatives for Lower Reaches of Hidden Falls Creek

	Park Planning Considerations (Aesthetics, accessibility; education opportunities)	Ecological, Water Resource and Sustainability Considerations	Cost Considerations
Alternative A – No change	• Eroding streambanks, abandoned pipe, and wall treatments are unattractive • High steep banks preclude access • Preserves geologic story	• Floodplain remains disconnected • Least disturbance of existing riparian vegetation • Evolution of channel continues through erosion	• No initial cost • Costs associated with repair of trail and bridge infrastructure as stream erosion progresses
Alternative B - Maintain existing alignment – stabilize banks and bed in alluvial fan reach	• Eroding streambanks unattractive • Access to stream improved • Preserves most of geologic story	• Improved floodplain connection • Better access to stream for wildlife • Less disturbance of existing vegetation than Alt C or D • More likely to persist than Alt C or D	• Lower than Alt C or D • Primary cost items include earthwork to cut and fill along one bank; additional stone toe and bank stabilization along one bank
Alternative C – Occupy historic alluvial fan alignment; maintain existing floodplain reach	• Stream would be ~70 ft closer to existing shelter area • Access to stream improved • Reverses geologic history of alluvial fan	• Improved floodplain connection • Better access to stream for wildlife • More site disturbance than Alt B • Avulsion to new channel is a risk	• Considerably higher than Alt B; lower than Alt D • Primary cost items include earthwork to lower alluvial fan channel; additional stone for stream bed; bank stabilization on both sides
Alternative D – Occupy historic alluvial fan alignment; abandon floodplain reach and route new channel to boat launch area	• Stream would be ~70 ft closer to existing shelter area • Access to stream improved • Reverses geologic history of alluvial fan • More modification of Mississippi River backwater channel than Alt C	• Improved floodplain connection • Better access to stream for wildlife • Greatest site disturbance • Avulsion to new channel is a risk	• Highest Cost • Primary cost items include earthwork to lower alluvial fan channel and new floodplain channel; additional stone for stream bed; bank stabilization on both sides

RECOMMENDED ALTERNATIVES AND COST ESTIMATES

Inter-Fluve staff met with St Paul Parks and Recreation staff and Capitol Region Watershed District staff to discuss the alternatives for the upper and lower reaches of Hidden Falls Creek. The objective of the meeting was to reach consensus regarding preferred alternatives for which concept drawings and a conceptual cost estimate could be developed. It was agreed that based on information available at this point, Alternative 2 or 2a is preferred for the upper reach and Alternative B is preferred for the lower reach. Alternative 2 and B are preferred for several reasons including that they:

1. Provide the most sustainable stream channel;
2. Improve riparian and in-stream habitat;
3. Create a more natural aesthetic;
4. Balance cost and benefit;
5. Create the best opportunities for access and education;
6. Promote better usage of currently under-utilized areas of the park

These alternatives are described in more detail below and illustrated in the Concept Design Drawings in Appendix B and the plan view sketch attached as Appendix C.

UPPER REACHES

In the upper reaches of the creek, we recommend that all dry stacked WPA era walls remain in place and be repaired where necessary. We also recommend leaving the falls relatively unchanged. Some of the mortared stone around the pools may be replaced with natural stone, but the overall form should remain similar. The 1980's era wall on the east side of the stream should be removed to allow a wider channel to more effectively dissipate energy and allow use of smaller stone in the channel. The east bank should be graded back to a stable slope. The soils are very rocky due to material sliding down the steep valley slope, but vegetation should be incorporated to the extent possible. The west bank wall should remain and be repaired where necessary to serve as a retaining wall to continue to allow trail access on that side. Access to the stream from the trail is possible where there is room to incorporate steps from the trail down to the stream. To the extent possible, water flow through and across the mortar between the stones of this wall should be minimized to increase the lifespan of the mortar.

The concrete in the channel bottom should be removed and replaced with natural stone substrate throughout the reach. To achieve a naturally functioning system, smaller material can be used to make up the bottom of the pools, and a gradient from small to larger material should exist as the pool ends and transitions to the step. The steps should be comprised of material large enough to resist movement during a full range of flow conditions (see Table 5). The stone should match the limestone within the valley and can be placed to give the appearance of fractured bedrock typical of step pool channels. The steps should be spaced and configured to simulate natural step pools (see previous section "Natural Step Pool Form").

Figure 33 – East wall and concrete lining should be removed in the upper step pool reach.

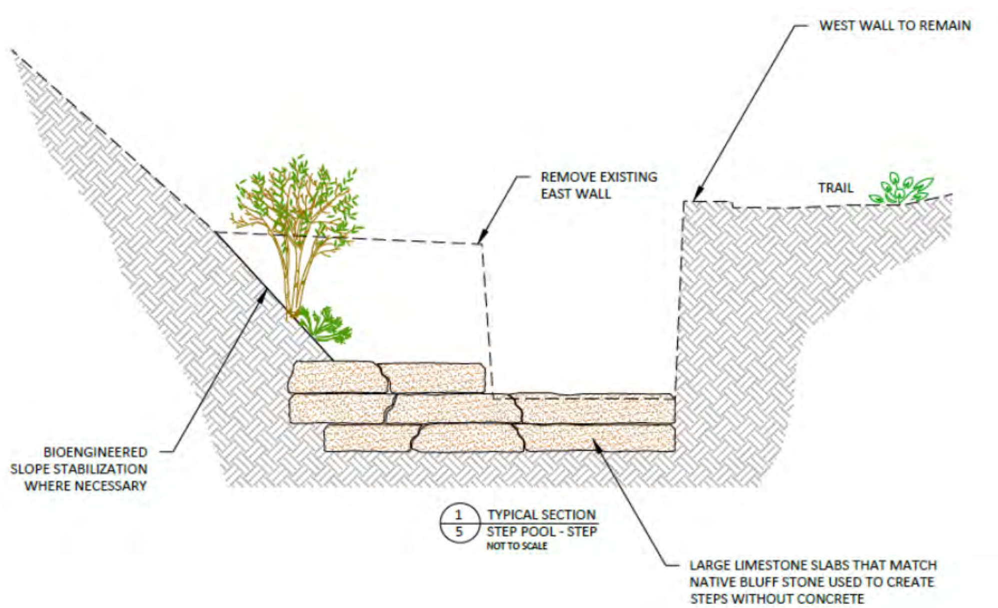

Figure 34: Detail of proposed wall removal and step construction

Figure 35: Proposed changes in lower step pool reach

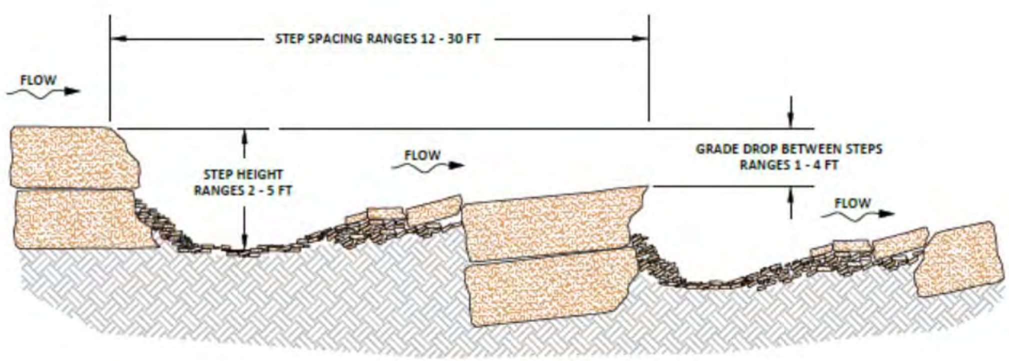

Figure 36: Detail of longitudinal profile of stream with naturalized steps and pools

The entire concrete chute should be removed and replaced with the same natural step pool form. We propose ending the step pool reach just upstream of the existing bend in the stream, near Station 10+00 (see Concept Drawings, Appendix B and Figure 1). A final step should be designed with a larger drop that creates a small water fall into a pool. This location can be an attractive stream access feature that is visible and audible from the pavilion and can draw people to the creek.

Figure 37: This bend in the stream should be designed as the final drop from the step pool reach into a large pool that is accessible to park users.

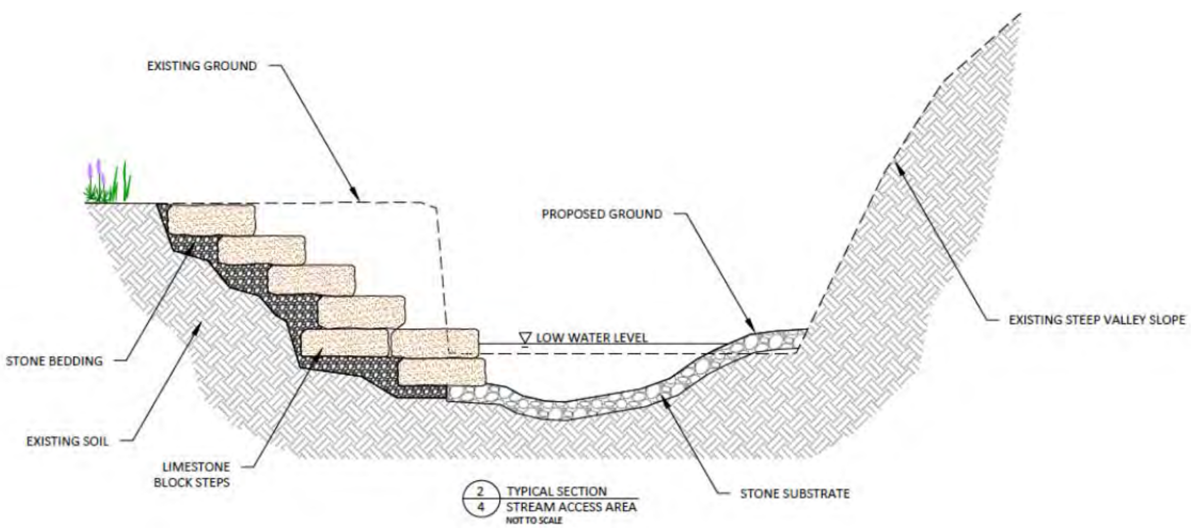

Figure 38: Detail cross section of stream access and pool near final drop.

State-of-the-art stormwater management should be incorporated into the redevelopment of the Ford site. The objective of these features should be to store and slowly release baseflow with the greatest duration practical and reduce peak stream flows to mimic pre-development runoff rates. Peak flows estimated as representative of pre-development conditions are described in the Hydrology section of this report – the 2 yr, 10 yr, and 100 y peak flows were estimated as 4, 31 and 161 cfs, respectively. If nearly continuous baseflow is possible, clay liners should not be necessary in the pools. If baseflow remains negligible for much of the time, a clay liner may be considered for a portion of the pools, particularly the larger pool near Station 10+00 that is to serve as a point of access.

Lower Reaches

To maximize long term sustainability of the stream, we propose leaving the stream in its current alignment through the lower reaches. From the end of the step pool reach to the middle pedestrian bridge, the stream cross section should be modified to improve channel stability and aesthetics. The valley wall on the right side of the stream (looking downstream) contains large quantities of fractured rock that provides adequate stability on that side. Additionally, there are currently no trails on that side of the stream and there is not room for future trails that could be subject to damage by erosion. Therefore, the right bank can remain unchanged. The left bank is very high and steep, and it appears to be actively eroding. The channel is wide. We propose reshaping the stream bed, supplementing with additional stone as necessary to create a low flow channel and floodplain bench. The left bank should be graded back to achieve a maximum slope of 3:1. It should be covered with temporary erosion control fabrics to provide short term stability and planted with native vegetation along the entire slope to provide long term stability.

Figure 39: Stable right bank and steep, eroding left bank. Left bank should be graded and stabilized. Channel bed should be reshaped to include a low flow channel and floodplain bench.

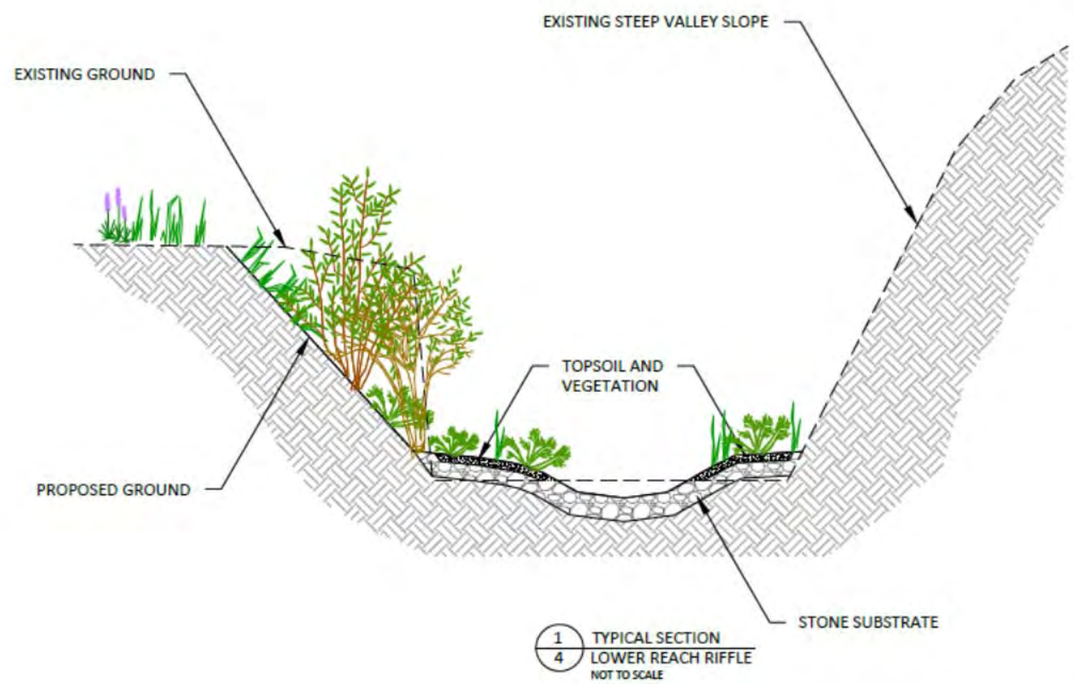

Figure 40: Detail of recommended grading and slope stabilization in lower reach.

The existing pipe located in this reach should be removed. Given that the history of this pipe is uncertain, additional investigation will be necessary to safely remove it. The existing concrete bank stabilization upstream of bridge 2 should also be removed. The bank should be graded and stabilized as described above.

The historic abandoned alluvial fan channel is an interesting geologic relic and presents an opportunity. We recommend incorporating crossings over this channel into the trails system within the park and highlighting the geologic history of the site through interpretive signage at these crossings. Additional hydraulic modeling should be conducted during final design when future flow conditions are better understood to determine if this channel can and should serve as an overflow channel during peak flows.

Figure 41: Existing bank armor to be removed.

Figure 42: Pipe to be removed.

We recommend leaving the floodplain reach downstream of bridge 2 unchanged. This reach appears to be very stable. The hydrology of this reach depends heavily on the stage of the Mississippi River and is therefore quite variable. Park planning efforts should account for this variability to ensure landscape features accommodate a flooded stream as well as a dry sand channel depending on the season.

COST ESTIMATE

Conceptual cost estimates are shown in Table 8. These costs only reflect the costs associated with improvements to the stream and stream banks. Other site improvement costs, such as additional foot bridges, site cleanup, expansion of managed turf, and potential changes to the historic alluvial fan channel, are not included. There is significant uncertainty in these estimates, particularly given the uncertainty related to future development of the Ford site and related hydrology. Additionally, the site is unique and several of the work items listed are atypical. As such, bids from different contractors can be expected to vary widely.

Table 8 – Conceptual Cost Estimate

Item	Task	Quantity	Unit	Unit Cost	Total Est. Cost
1	**Mobilization, Access, ESC**	1	LS		$ 69,200
2	**Clearing**	0.5	ACRE	$ 6,000	$ 3,000
3	**Grouted Stone Removal**	60	CY	$ 150	$ 9,000
4	**Concrete Channel Lining Removal**	130	CY	$ 150	$ 19,500
5	**Bank Armor Removal**	100	CY	$ 150	$ 15,000
6	**Pipe Removal**	50	LF	$ 30	$ 1,500
7	**Stone Wall Repair**	600	SF	$ 40	$ 24,000
8	**Earthwork - Bank Grading**	2000	CY	$ 15	$ 30,000
9	**Limestone Slab**	650	TON	$ 400	$ 260,000
10	**Stream Substrate Stone**	300	CY	$ 80	$ 24,000
11	**Surface Fabric**	1500	SY	$ 6	$ 9,000
12	**Riparian plantings along new bank**	2200	SY	$ 30	$ 66,200
	Contingency				30%
	Total				$ 690,000

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APPENDIX A – SOIL BORING REPORT

BRAUN INTERTEC

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February 14, 2014 Project SP-13-07975

Brian C. Tourtelotte
Senior Landscape Architect
Saint Paul Parks and Recreation
25 W. 4th Street, Suite 400
Saint Paul, MN 55102

Re: Factual Report of Subsurface Investigation
Hidden Falls Regional Park
St. Paul, Minnesota

Dear Mr. Tourtelotte:

We are pleased to present this factual report describing our subsurface evaluation conducted at Hidden Falls Regional Park in St. Paul Minnesota. The scope of the project is illustrated in the CAD drawing included as an attachment to this report. A summary of the subsurface profile encountered and groundwater conditions are included with the attached Log of Boring.

Based on the Request for Proposal (RFP) contained in an email from Mr. Tourtelotte dated, December 4, 2013, the project includes the restoration of the stream which flows into the Mississippi River at Hidden Falls Regional Park in St. Paul Minnesota. Four segments of the stream were analyzed as listed below:

- The *Upper Reach* extends approximately 500 feet and is underlain with shallow bedrock. Four borings were drilled adjacent to the stream. Bedrock was encountered from 11 ½ to 22 ½ feet below grade which represents 10.4 to 34.5 feet based on St. Paul datum elevation.

- The *Chute* is a relatively steep section of the stream which flows in a concrete-lined channel for approximately 200 ft. Two borings were drilled adjacent to the Chute to approximate 10 feet.

- The *Lower Reach* extends approximately 900 feet. Three borings were drilled to an approximate depth of 10 feet.

- One boring was drilled to approximately of 20 feet in the *Flood Plain*.

Project Background and Purpose

We understand that the overall goal of this subsurface evaluation was to proved preliminary information for stream restoration through Hidden Falls Regional Park in St. Paul Minnesota. Further geotechnical investigation will be necessary as funding becomes available.

Log of Borings

Log of Boring sheets for our geo-probe borings are included as an attachment. These logs identify and describe the geologic materials that were penetrated and groundwater measurements.

Soil classification of the retrieved continuous sampling was completed by a geotechnical engineer. A photographic log was also completed during this analysis describing the soil samples retrieved from each boring. The continuous sample was retrieved from the bore hole in five foot sample tubes. Gravel or cobbles larger in diameter than the continuous sampler diameter can restrict the opening and minimize sample retrieval. With the large amount of gravel and cobbles in the exploration site due to slough off from the surrounding bluffs, some quantities retrieved were approximately 50% or less, although the majority of the sample tubes were recovered with 67% or greater.

Gravel identified in the samples is generally fragmented dolostone or limestone from the surrounding bluffs. Fragments to 1 ½ inches were recovered in the continuous sampling tube.

Strata boundaries were inferred from changes in the recovered samples. Due to the fact that 100% of each sample was not recovered, the strata boundary depths are approximate in most cases. The boundary depths likely vary away from the boring locations, and the boundaries themselves may also occur as gradual rather than abrupt transitions.

Groundwater

Groundwater was observed in two of the ten borings. The groundwater summary is included in Table 1 below.

Table 1. Summary of Groundwater

Boring #	Depth to Groundwater [ft]	Groundwater Elevation [ft] MSL	Groundwater Elevation [ft] St. Paul Datum *
PP-8	8	691.1	-3.2
PP-10	12	689.8	-4.5

*****St. Paul datum = 694.26 [ft] MSL as reported, http://survey.ci.stpaul.mn.us/benches/leg-notes.pdf

Given the general cohesive nature of the geologic materials encountered, it is likely that insufficient time was available for groundwater to seep into the borings and rise to its hydrostatic level. Piezometers or monitoring wells would be required to confirm if groundwater was present within the depths explored. Seasonal and annual fluctuations of groundwater should also be anticipated.

Bedrock

Borings PP-1 through PP-4 were drilled in the upper reach of the stream to refusal depth (bedrock) which was anticipated at 15 feet below existing grade. Table 2 summarizes bedrock elevations encountered in the upper reach.

Table 2. Summary of Bedrock Elevations

Boring #	Depth to Bedrock [ft]	Bedrock Elevation [ft] MSL	Bedrock Elevation [ft] St. Paul Datum *
PP-1	11 ½	728.8	34.5
PP-2	22 ½	711.4	17.1
PP-3	14	714.8	20.5
PP-4	17 ½	704.7	10.4

*St. Paul datum = 694.26 [ft] MSL as reported, http://survey.ci.stpaul.mn.us/benches/leg-notes.pdf

Remarks

In performing its services, Braun Intertec used that degree of care and skill ordinarily exercised under similar circumstances by reputable members of its profession currently practicing in the same locality. No warranty, express or implied, is made.

If you have any questions about this report, please contact Robert Malecha at 612.910.1779.

Sincerely,

BRAUN INTERTEC CORPORATION

Robert Malecha, EIT
Staff Engineer

Loren W. Braun, PE
Senior Engineer

Attachments:
Log of Borings
Photo Log of Continuous Sample
CAD Sketch of Project Extent
Boring Geo-Spacial Data

BRAUN INTERTEC

LOG OF BORING

Braun Project SP-13-07975
Geotechnical Evaluation
Hidden Falls
Mississippi River Boulevard/Hidden Falls Drive
St. Paul, Minnesota

BORING: **PP-1**

LOCATION: See attached sketch.

DRILLER: M. Barber | METHOD: Geoprobe | DATE: **1/29/14** | SCALE: **1" = 4'**

Elev. feet 46.0	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
45.0	1.0	SM	SILTY SAND with GRAVEL, black, frozen. (Top Soil)			
41.0	5.0	GP-GM	POORLY GRADED GRAVEL with SILT, Clay deposits, brown, frozen to moist. (Alluvium)			
37.0	9.0	GP-GC	POORLY GRADED GRAVEL with CLAY, brown, moist. (Alluvium)			
36.0	10.0	GP-GC	POORLY GRADED GRAVEL with CLAY, with Gravel, gray to green, moist. (Alluvium)			
34.5	11.5	SC	CLAYEY SAND with GRAVEL, gray to green, wet. (Alluvium)			
			REFUSAL OF AUGER AT 11 1/2 FEET.			
			Water not observed while drilling.			
			Boring then backfilled with dry bentonite chips.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project SP-13-07975 Geotechnical Evaluation Hidden Falls Mississippi River Boulevard/Hidden Falls Drive St. Paul, Minnesota	BORING: PP-2 LOCATION: See attached sketch.

DRILLER: M. Barber	METHOD: Geoprobe	DATE: 1/29/14	SCALE: 1" = 4'

Elev. feet 39.6	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
38.1	1.5	PT	PEAT, interbedded with Sand and Peat, frozen. (Top Soil)			
28.6	11.0	GP-GM	POORLY GRADED GRAVEL with SILT, sluff rock layers of LEAN CLAY Sand seams. brown, frozen to moist. (Alluvium)			
27.1	12.5	CL	LEAN CLAY with GRAVEL, brown, moist. (Alluvium)			
23.6	16.0	CL	LEAN CLAY, trace of Gravel, green to gray, wet. (Alluvium)			
19.6	20.0	CL	LEAN CLAY with SAND, trace of Gravel, brown, wet. (Alluvium)			
17.1	22.5	CL	LEAN CLAY, trace of Gravel, reddish-brown, wet. (Alluvium)			
			END OF BORING. REFUSAL OF AUGER AT 22 1/2 FEET. Boring then backfilled with dry bentonite chips.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project SP-13-07975 Geotechnical Evaluation Hidden Falls Mississippi River Boulevard/Hidden Falls Drive St. Paul, Minnesota	BORING: **PP-3** LOCATION: See attached sketch.
DRILLER: M. Barber METHOD: Geoprobe	DATE: **1/29/14** SCALE: **1" = 4'**

Elev. feet 34.5	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
32.5	2.0	SM	SILTY SAND with GRAVEL, organic, dark brown, frozen. (Top Soil)			
26.0	8.5	GP-GM	POORLY GRADED GRAVEL with SILT, Clay deposits, brown, frozen to moist. (Alluvium)			
24.5	10.0	SP-SM	POORLY GRADED SAND with SILT, gray to brown, moist. (Alluvium)			
21.0	13.5	CL	SANDY LEAN CLAY with GRAVEL, brown, moist. (Alluvium)			
20.5	14.0	SP	POORLY GRADED SAND, fine-grained, light brown, moist. Possible docomposed limestone. (Alluvium)			
			REFUSAL OF AUGER AT 14 FEET. Water not observed while drilling. Boring then backfilled with dry bentonite chips.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project SP-13-07975 Geotechnical Evaluation Hidden Falls Mississippi River Boulevard/Hidden Falls Drive St. Paul, Minnesota	BORING: PP-4 LOCATION: See attached sketch.

DRILLER: M. Barber	METHOD: Geoprobe	DATE: 1/29/14	SCALE: 1" = 4'

Elev. feet 27.9	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
26.4	1.5	SM	SILTY SAND with GRAVEL, black, frozen. (Top Soil)			
25.9	2.0	SP-SM	POORLY GRADED SAND with SILT, light brown. (Alluvium)			
22.9	5.0	CL	SANDY LEAN CLAY with GRAVEL, brown, frozen to moist. (Alluvium)			
21.9	6.0	CL	LEAN CLAY, trace of Gravel, organic, black, moist. (Alluvium)			
13.9	14.0	GP-GM	POORLY GRADED GRAVEL with SILT, Clay deposits, brown, moist. (Alluvium)			
10.4	17.5	CL	SANDY LEAN CLAY, reddish-brown, wet. (Alluvium)			
			REFUSAL OF AUGER AT 17 1/2 FEET. Boring then backfilled with dry bentonite chips.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project SP-13-07975
Geotechnical Evaluation
Hidden Falls
Mississippi River Boulevard/Hidden Falls Drive
St. Paul, Minnesota

BORING: **PP-5**

LOCATION: See attached sketch.

DRILLER: M. Barber	METHOD: Geoprobe	DATE: **1/29/14**	SCALE: **1" = 4'**

Elev. feet 23.0	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
22.0	1.0	SM	SILTY SAND, fine-grained, interbedded with Peat and Sand, black, frozen. (Top Soil)			
19.0	4.0	GP-GM	POORLY GRADED GRAVEL with SILT, with gravel to 1 1/2" Gravel, brown, frozen. (Alluvium)			
18.0	5.0	CL	SANDY LEAN CLAY with GRAVEL, dark brown, moist. (Alluvium)			
14.0	9.0	SP-SM	POORLY GRADED SAND with SILT, with Gravel, brown, moist. (Alluvium)			
13.0	10.0	SM	SILTY SAND, with ghravel to 1 1/2" Gravel, dark brown, moist. (Alluvium)			
			END OF BORING. Water not observed while drilling. Boring then backfilled with dry bentonite chips.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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Braun Project SP-13-07975
Geotechnical Evaluation
Hidden Falls
Mississippi River Boulevard/Hidden Falls Drive
St. Paul, Minnesota

BORING: **PP-6**

LOCATION: See attached sketch.

DRILLER: M. Barber	METHOD: Geoprobe	DATE: **1/29/14**	SCALE: **1" = 4'**

Elev. feet 17.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
15.9	1.5	SP	POORLY GRADED SAND, fine- to medium-grained, brown, frozen. (Alluvium)			
15.4	2.0	PT	PEAT, trace of roots/leaves, black, frozen. (Burried Top Soil)			
12.4	5.0	SP-SM	POORLY GRADED SAND with SILT, fine- to coarse-grained, with Gravel up to 1 1/2", brown, wet. (Alluvium)			
9.9	7.5	ML	SILT, trace of Gravel, dark SILT layering at 6', light brown, moist. (Alluvium)			
7.4	10.0	ML	SANDY SILT, trace of Gravel, dark brown, moist. (Alluvium)			
			END OF BORING.			
			Water not observed while drilling.			
			Boring then backfilled with dry bentonite chips.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project SP-13-07975
Geotechnical Evaluation
Hidden Falls
Mississippi River Boulevard/Hidden Falls Drive
St. Paul, Minnesota

BORING: **PP-7**

LOCATION: See attached sketch.

DRILLER: M. Barber	METHOD: Geoprobe	DATE: **1/29/14**	SCALE: **1" = 4'**

Elev. feet 13.5	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
12.0	1.5	ML	SANDY SILT, interbedded Sand and Peat, black, frozen. (Top Soil)			
10.5	3.0	SM	SILTY SAND, trace of roots, trace of Gravel, dark brown, frozen. (Alluvium)			
9.0	4.5	ML	SILT, light brown to reddish-brown, frozen. (Alluvium)			
3.5	10.0	ML	SANDY SILT, trace of Gravel, Sand seam at 6 1/2' and 9", dark brown, moist. (Alluvium)			
			END OF BORING. Water not observed while drilling. Boring then backfilled with dry bentonite chips.			

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

BRAUN INTERTEC

Braun Project SP-13-07975
Geotechnical Evaluation
Hidden Falls
Mississippi River Boulevard/Hidden Falls Drive
St. Paul, Minnesota

BORING: **PP-8**

LOCATION: See attached sketch.

DRILLER: M. Barber | METHOD: Geoprobe | DATE: **1/29/14** | SCALE: **1" = 4'**

Elev. feet 4.8	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
3.3	1.5	ML	SANDY SILT, interbedded with Sand/Peat, black, frozen. (Top Soil)			
1.8	3.0	SM	SILTY SAND, fine-grained, brown, frozen. (Alluvium)			
1.3	3.5	SP	POORLY GRADED SAND, fine-grained, trace of Gravel, light brown, moist. (Alluvium)			
0.8	4.0	ML	SILT, Clay deposits, dark brown, moist. (Alluvium)			
0.3	4.5	ML	SILT, Clay deposits, reddish-brown, moist. (Alluvium)			
-0.2	5.0	ML	SILT, light brown, moist. (Alluvium)			
-2.7	7.5	ML	SILT, light brown to reddish-brown, moist to waterbearing. (Alluvium)		▽	An open triangle in the water level (WL) column indicates the depth at which groundwater was observed while drilling.
-4.2	9.0	CL	LEAN CLAY, with Silt seams, gray, waterbearing. (Alluvium)			
-4.7	9.5	CL	LEAN CLAY, reddish-brown, waterbearing. (Alluvium)			
-5.2	10.0	ML	SILT, fat Clay seams, gray to red, waterbearing. (Alluvium)			

END OF BORING.

Water observed at 8 feet while drilling.

Boring then backfilled with dry bentonite chips.

(See Descriptive Terminology sheet for explanation of abbreviations)

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LOG OF BORING

Braun Project SP-13-07975
Geotechnical Evaluation
Hidden Falls
Mississippi River Boulevard/Hidden Falls Drive
St. Paul, Minnesota

BORING: **PP-9**

LOCATION: See attached sketch.

DRILLER: M. Barber	METHOD: Geoprobe	DATE: **1/29/14**	SCALE: **1" = 4'**

Elev. feet 4.4	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
3.8	0.6	TS	Organic, interbedded Sand and Peat, black, frozen.			
2.9	1.5	FILL	FILL: Poorly Graded Sand with Silt, brown, frozen.			
2.4	2.0	FILL	FILL: Bituminous, possible burried trail, black.			
1.9	2.5	FILL	FILL: GP-GM, possible Class V aggregate base, brn, frozen.			
1.4	3.0	FILL	FILL: Sandy Silt, brown.			
0.9	3.5	FILL	FILL: Bituminous, possible burried trail, black.			
-0.6	5.0	SM	SILTY SAND, fine-grained, light brown, moist. (Alluvium)			
-2.6	7.0	ML	SANDY SILT, brown, moist. (Alluvium)			
-4.1	8.5	GP-GM	POORLY GRADED GRAVEL with SILT, brown, moist. (Alluvium)			
-5.6	10.0	ML	SILT, fat Clay lens, light brown, moist. (Alluvium)			

END OF BORING.

Water not observed while drilling.

Boring then backfilled with dry bentonite chips.

(See Descriptive Terminology sheet for explanation of abbreviations)

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BRAUN INTERTEC

LOG OF BORING

Braun Project SP-13-07975
Geotechnical Evaluation
Hidden Falls
Mississippi River Boulevard/Hidden Falls Drive
St. Paul, Minnesota

BORING: **PP-10**

LOCATION: See attached sketch.

DRILLER: M. Barber	METHOD: Geoprobe	DATE: **1/29/14**	SCALE: **1" = 4'**

Elev. feet 6.5	Depth feet 0.0	Symbol	Description of Materials (Soil-ASTM D2488 or D2487, Rock-USACE EM1110-1-2908)	BPF	WL	Tests or Notes
5.5	1.0	PT	PEAT, interbedded with Peat and Sand, black, frozen. (Top Soil)			
4.5	2.0	CL	LEAN CLAY with GRAVEL, green to brown, frozen. (Alluvium)			
4.0	2.5	GP-GM	POORLY GRADED GRAVEL with SILT, medium- to coarse-grained, brown, frozen. (Alluvium)			
3.0	3.5	SM	SILTY SAND, trace of Gravel, dark brown, moist. (Alluvium)			
1.5	5.0	SP-SM	POORLY GRADED SAND with SILT. (Alluvium)			
0.5	6.0	SM	SILTY SAND, dark brown, moist. (Alluvium)			
-6.5	13.0	SP-SM	POORLY GRADED SAND with SILT, fine- to medium-grained, light brown, moist. (Alluvium)			
-10.5	17.0	SP-SM	POORLY GRADED SAND with SILT, gray to brown, wet to waterbearing. (Alluvium)		▽	
-13.5	20.0	GP-GM	POORLY GRADED GRAVEL with SILT, gray, waterbearing. (Alluvium)			

END OF BORING.

Water observed at 17 feet while drilling.

Boring then backfilled with dry bentonite chips.

(See Descriptive Terminology sheet for explanation of abbreviations)

LOG OF BORING N:\GINT\PROJECTS\STPAUL\2013\07975.GPJ BRAUN_V8_CURRENT.GDT 2/14/14 11:58

Photo 1

Boring:	PP1	Project: SP-13-07975
Depth:	Surface to 5 feet	BRAUN INTERTEC
Recovery:	42 inches	
Date:	2/3/14	

Photo 2

Boring:	PP1	Project: SP-13-07975
Depth:	5 feet to 10 feet	BRAUN INTERTEC
Recovery:	28 inches	
Date:	2/3/14	

Boring: PP1
Depth: 10 feet to 11.5 feet
Recovery: 18 inches
Date: 2/3/14

Project: SP-13-07975

Boring:	PP2	Project: SP-13-07975
Depth:	Surface to 5 feet	
Recovery:	36 inches	
Date:	2/3/14	

Boring:	PP2	Project: SP-13-07975
Depth:	5 feet to 10 feet	
Recovery:	26 inches	
Date:	2/3/14	

Boring:	PP2	Project: SP-13-07975
Depth:	10 feet to 15 feet	
Recovery:	38 inches	
Date:	2/3/14	

BRAUN INTERTEC

Boring:	PP2	Project: SP-13-07975
Depth:	15 feet to 20 feet	
Recovery:	38 inches	
Date:	2/3/14	

Photo 8

Boring:	PP2	Project: SP-13-07975
Depth:	20 feet to 22.5 feet	BRAUN INTERTEC
Recovery:	26 inches	
Date:	2/3/14	

Photo 9

Boring:	PP3	Project: SP-13-07975
Depth:	Surface to 5 feet	BRAUN INTERTEC
Recovery:	40 inches	
Date:	2/3/14	

Boring: PP3
Depth: 5 feet to 10 feet
Recovery: 32 inches
Date: 2/3/14

Project: SP-13-07975

BRAUN INTERTEC

Photo 11

Boring:	PP3	Project: SP-13-07975
Depth:	10 feet to 14 feet	
Recovery:	24 inches	
Date:	2/3/14	

Boring:	PP4	Project: SP-13-07975
Depth:	Surface to 5 feet	
Recovery:	34 inches	
Date:	2/3/14	

BRAUN INTERTEC

Photo 13

Boring: PP4
Depth: 5 feet to 10 feet
Recovery: 22 inches
Date: 2/3/14

Project: SP-13-07975

BRAUN INTERTEC

Boring:	PP4
Depth:	10 feet to 15 feet
Recovery:	20 inches
Date:	2/3/14

Photo 15

Boring:	PP4	Project: SP-13-07975
Depth:	15 feet to 17.5 feet	BRAUN INTERTEC
Recovery:	18 inches	
Date:	2/3/14	

Photo 16

Boring:	PP5	Project: SP-13-07975
Depth:	Surface to 5 feet	
Recovery:	40 inches	
Date:	2/3/14	

BRAUN INTERTEC

Photo 17

Boring:	PP5	Project: SP-13-07975
Depth:	5 feet to 10 feet	
Recovery:	28 inches	
Date:	2/3/14	

Photo 18

Boring:	PP6	Project: SP-13-07975
Depth:	Surface to 5 feet	
Recovery:	34 inches	
Date:	2/3/14	

Boring:	PP6	Project: SP-13-07975
Depth:	5 feet to 10 feet	BRAUN INTERTEC
Recovery:	42 inches	
Date:	2/3/14	

Photo 20

Boring:	PP7	Project: SP-13-07975
Depth:	Surface to 5 feet	
Recovery:	48 inches	
Date:	2/3/14	

Photo 21

Boring:	PP7	Project: SP-13-07975
Depth:	5 feet to 10 feet	
Recovery:	40 inches	
Date:	2/3/14	

Boring:	PP8	Project: SP-13-07975
Depth:	Surface to 5 feet	BRAUN INTERTEC
Recovery:	38 inches	
Date:	2/3/14	

Photo 23

Boring:	PP8	Project: SP-13-07975
Depth:	5 feet to 10 feet	
Recovery:	60 inches	
Date:	2/3/14	

BRAUN INTERTEC

Boring:	PP9	Project: SP-13-07975
Depth:	Surface to 5 feet	
Recovery:	45inches	
Date:	2/3/14	

Boring:	PP9	Project: SP-13-07975
Depth:	5 feet to 10 feet	BRAUN INTERTEC
Recovery:	40 inches	
Date:	2/3/14	

Photo 26

Boring:	PP9	Project: SP-13-07975
Depth:	8.5 feet to 10 feet	
Recovery:	N/A	
Date:	2/3/14	

Photo 27

Boring:	PP10	Project: SP-13-07975
Depth:	Surface to 5 feet	BRAUN INTERTEC
Recovery:	45 inches	
Date:	2/3/14	

Boring: PP10
Depth: 5 feet to 10 feet
Recovery: 30 inches
Date: 2/3/14

Project: SP-13-07975

Boring: PP10
Depth: 10 feet to 15 feet
Recovery: 32 inches
Date: 2/3/14

Project: SP-13-07975

Photo 30

Boring:	PP10	Project: SP-13-07975
Depth:	15 feet to 20 feet	
Recovery:	16 inches	BRAUN INTERTEC
Date:	2/3/14	

Geo Probe on Re-enforced Bridge

Project: SP-13-07975

BRAUN INTERTEC

Date: 2/3/14

◈ DENOTES APPROXIMATE LOCATION OF PUSH PROBE BORING

N

75' 0 150'

SCALE: 1" = 150'

BRAUN INTERTEC
11001 Hampshire Avenue So.
Minneapolis, MN 55438
PH. (952) 995-2000
FAX (952) 995-2020

PUSH PROBE BORING LOCATION SKETCH

GEOTECHNICAL EVALUATION
HIDDEN FALLS
MISSISSIPPI RIVER BLVD / HIDDEN FALLS DR
SAINT PAUL, MINNESOTA

Project No:	SP1307975
Drawing No:	SP1307975
Scale:	1" = 150'
Drawn By:	BJB
Date Drawn:	1/31/14
Checked By:	BM
Last Modified:	1/31/14
Sheet: of	Fig:

F:\SP\2013\SP1307975.dwg,BLAND,1/31/2014 11:14:23 AM

Points

Project : sp1307975

User name	bbertram	**Date & Time**	10:57:24 AM 1/31/2014
Coordinate System	Ramsey99	**Zone**	Ramsey99
Project Datum	Ramsey96		
Vertical Datum		**Geoid Model**	Minn99 (Geoid99 Conus)
Coordinate Units	US survey feet		
Distance Units	US survey feet		
Height Units	US survey feet		

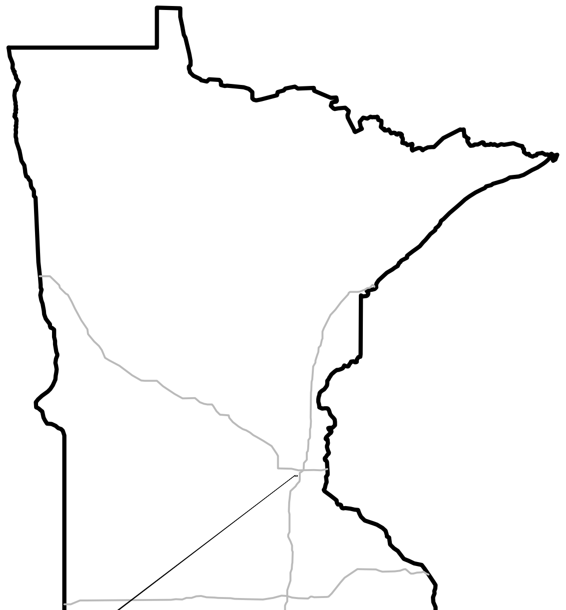
Point listing

Name	Northing	Easting	Elevation	Feature Code
110	143207.059	549499.808	740.296	PP-1
109	143137.564	549497.724	733.906	PP-2
108	143073.059	549477.507	728.769	PP-3
107	142953.381	549459.977	722.154	PP-4
106	142842.016	549430.838	717.288	PP-5
105	142688.113	549384.651	711.677	PP-6
104	142636.211	549250.470	707.789	PP-7
101	142131.759	549070.947	700.770	PP-10
103	142590.173	548991.959	699.057	PP-8
102	142279.514	548799.231	698.725	PP-9

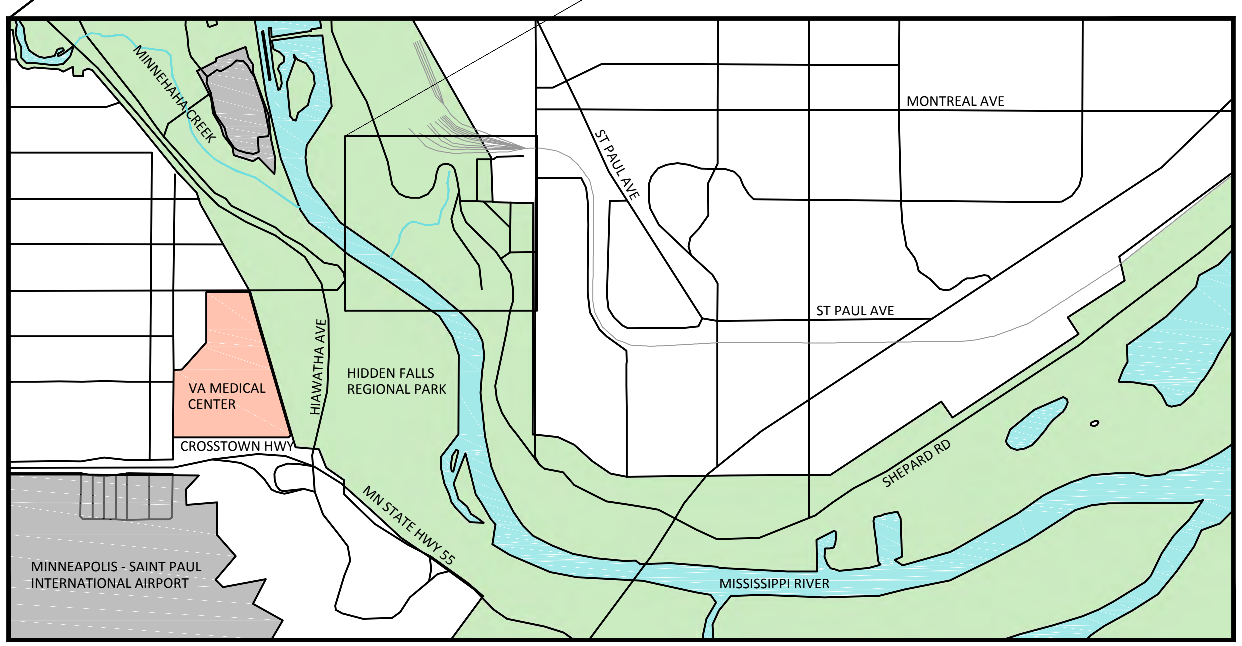
Back to top

APPENDIX B – CONCEPT DRAWINGS

HIDDEN FALLS FEASIBILITY STUDY
CITY OF ST PAUL, MN
ST PAUL PARKS & RECREATION



MINNESOTA STATE MAP
NOT TO SCALE



VICINITY MAP
NOT TO SCALE

LOCATION MAP
SCALE: 1" = 500'

SHEET INDEX:

1 - TITLE, SHEET INDEX & MAPS
2 - EXISTING CONDITIONS
3 - PROPOSED CONDITIONS PLAN & PROFILE
4 - TYPICAL SECTIONS SHEET 1 OF 2
5 - TYPICAL SECTIONS SHEET 2 OF 2

NO.	DATE	REVISION DESCRIPTION
1	XX/XX/14	30% SUBMITTAL

DRAWN	DESIGNED	CHECKED
CP	BW	BW, MM

APPROVED	DATE	PROJECT
BW	8/15/2014	----

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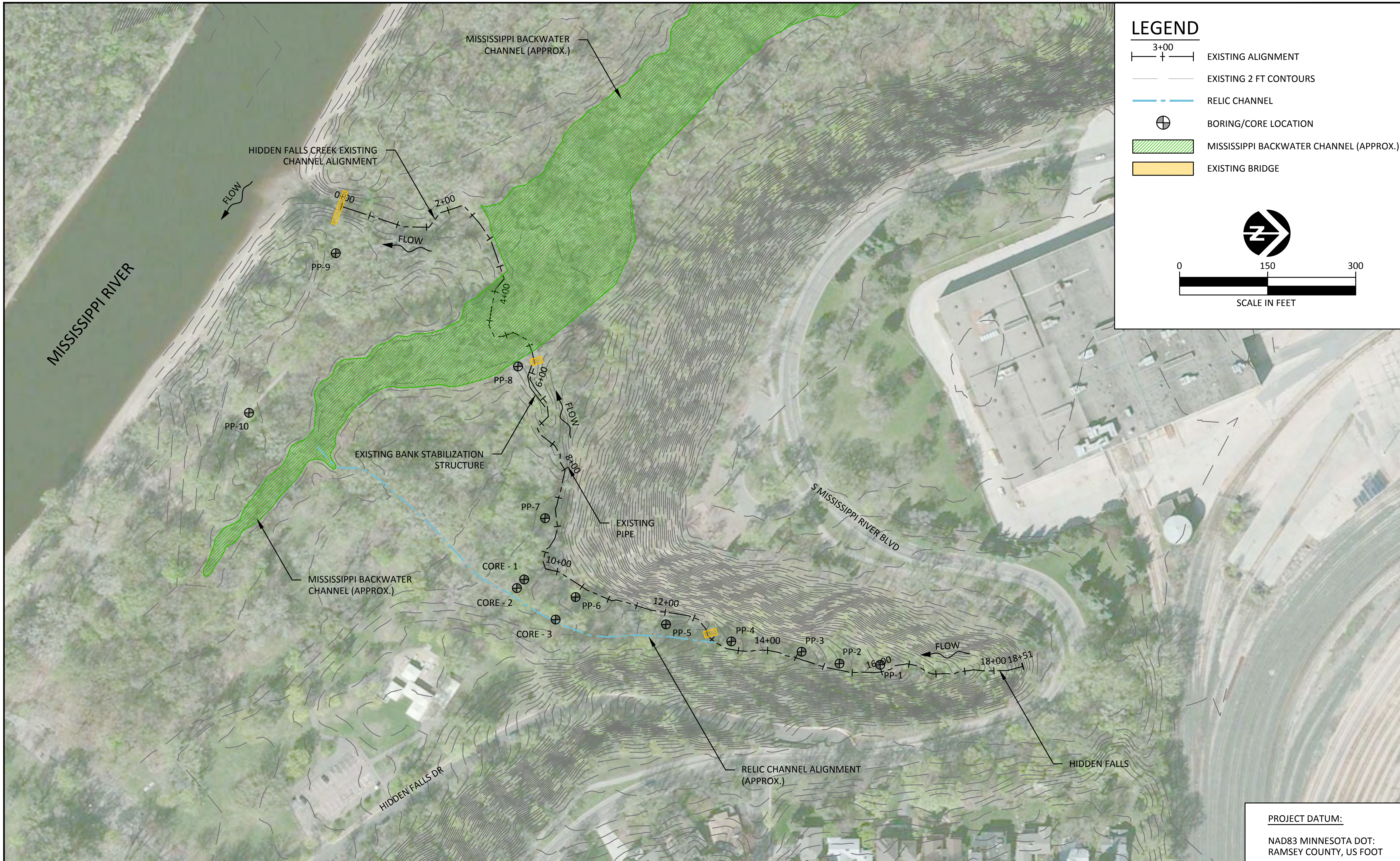
TITLE, SHEET INDEX & MAPS

SHEET
1 OF 5



NO.	DATE	REVISION DESCRIPTION
1	XX/XX/14	30% SUBMITTAL

CP — DRAWN; BW — DESIGNED; BW, MM — CHECKED
BW — APPROVED; 6/13/14 — DATE; ---- — PROJECT

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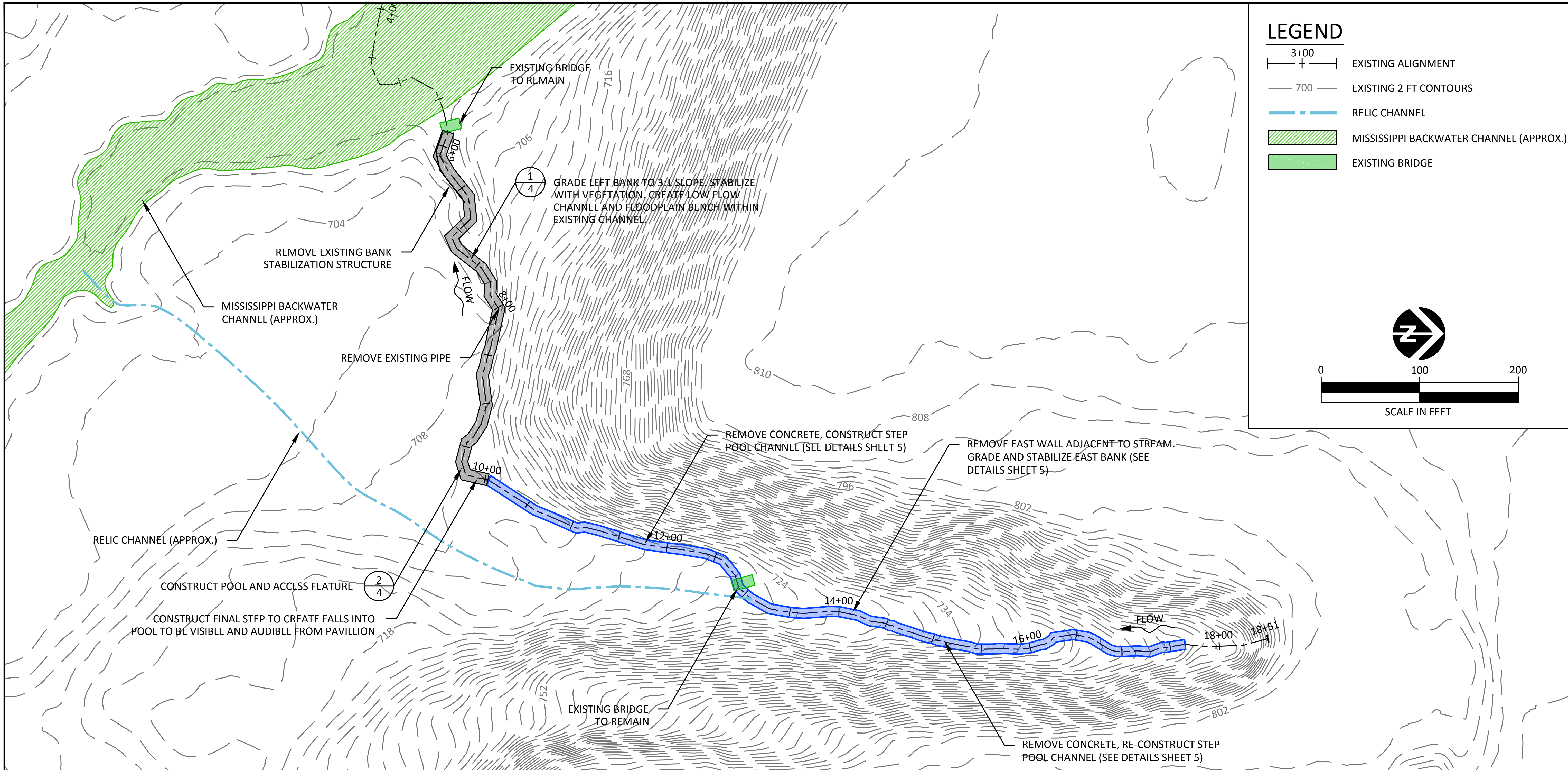
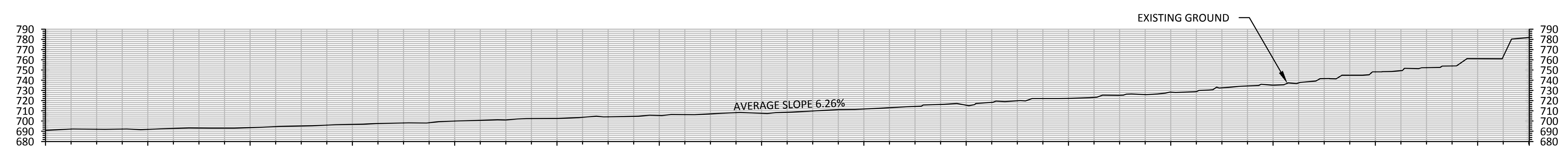
EXISTING CONDITIONS

SHEET 2 OF 5





EXISTING & PROPOSED PROFILE

NO.	DATE	REVISION DESCRIPTION
1	XX/XX/14	30% SUBMITTAL

DRAWN	DESIGNED	CHECKED
CP	BW	BW, MM
APPROVED	**DATE**	**PROJECT**
BW	6/13/14	----

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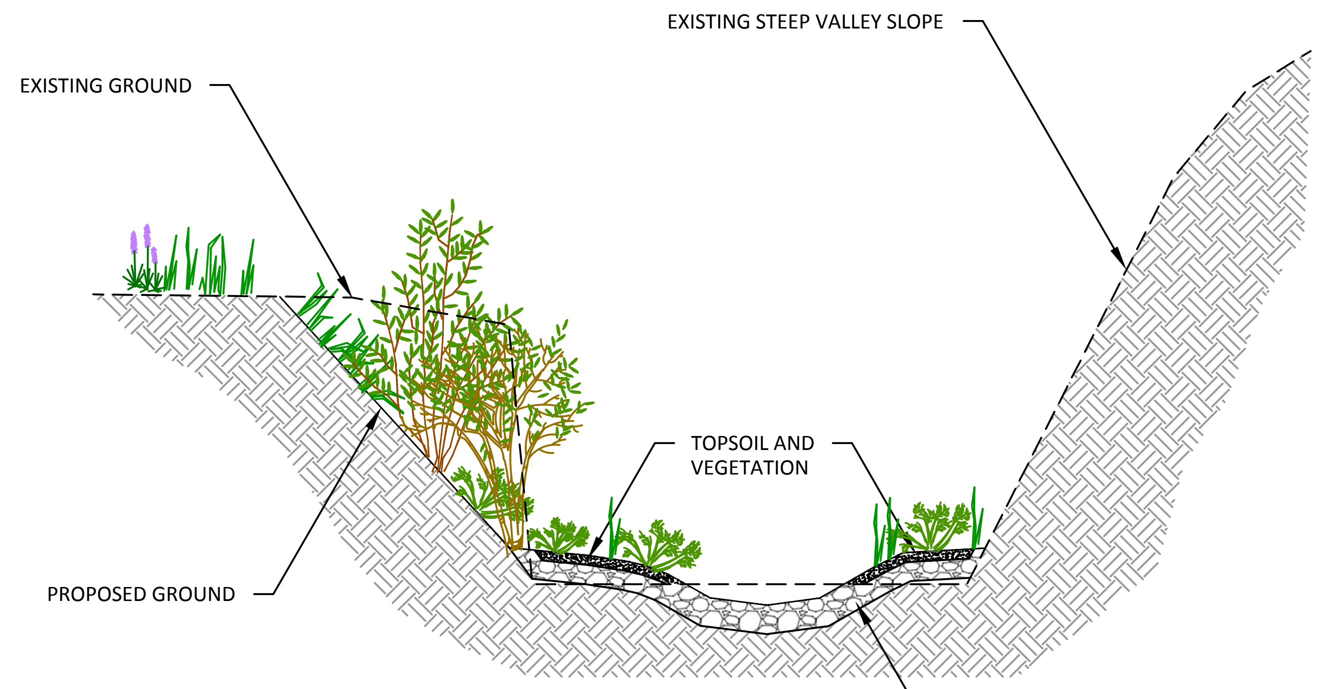
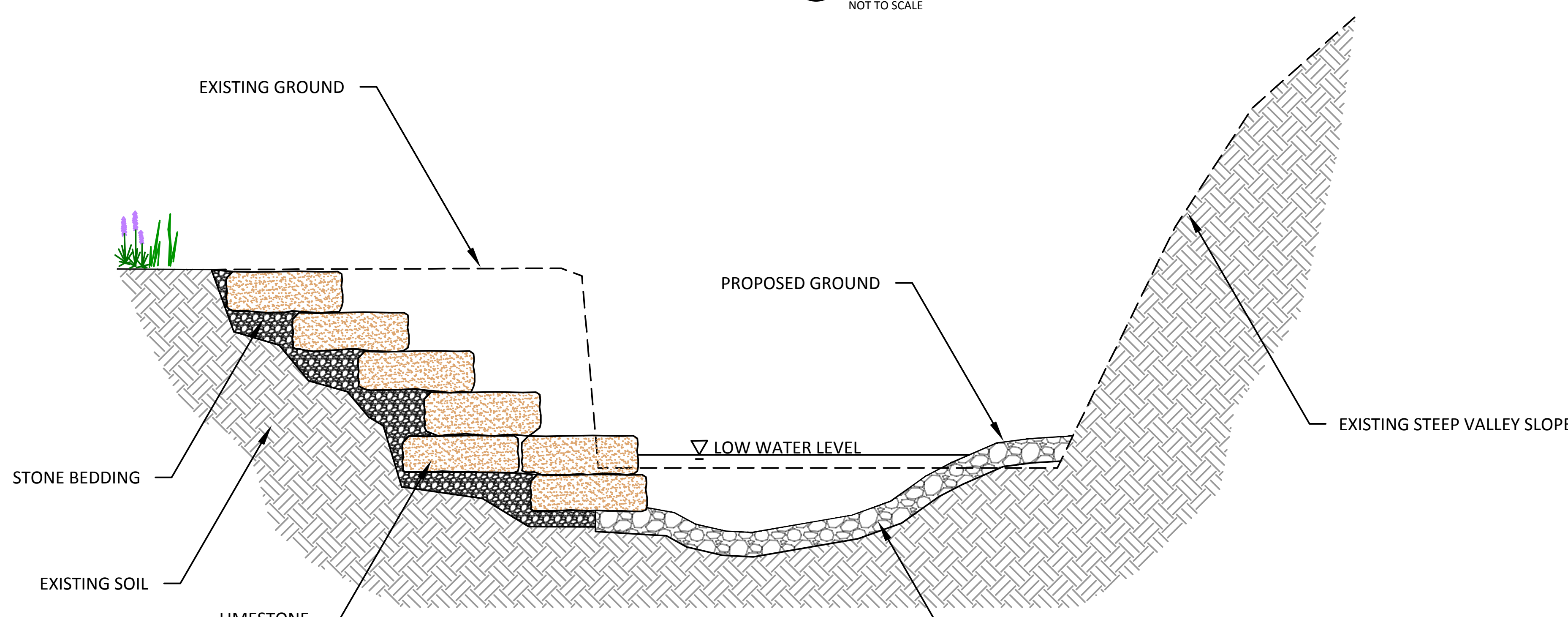
PROPOSED CONDITIONS
PLAN & PROFILE

SHEET
3 OF 5



1 / 4 TYPICAL SECTION
LOWER REACH RIFFLE
NOT TO SCALE



2 / 4 TYPICAL SECTION
STREAM ACCESS AREA
NOT TO SCALE

NO.	DATE	REVISION DESCRIPTION
1	XX/XX/14	30% SUBMITTAL

DRAWN	DESIGNED	CHECKED
CP	BW	BW, MM
APPROVED	**DATE**	**PROJECT**
BW	6/13/14	----

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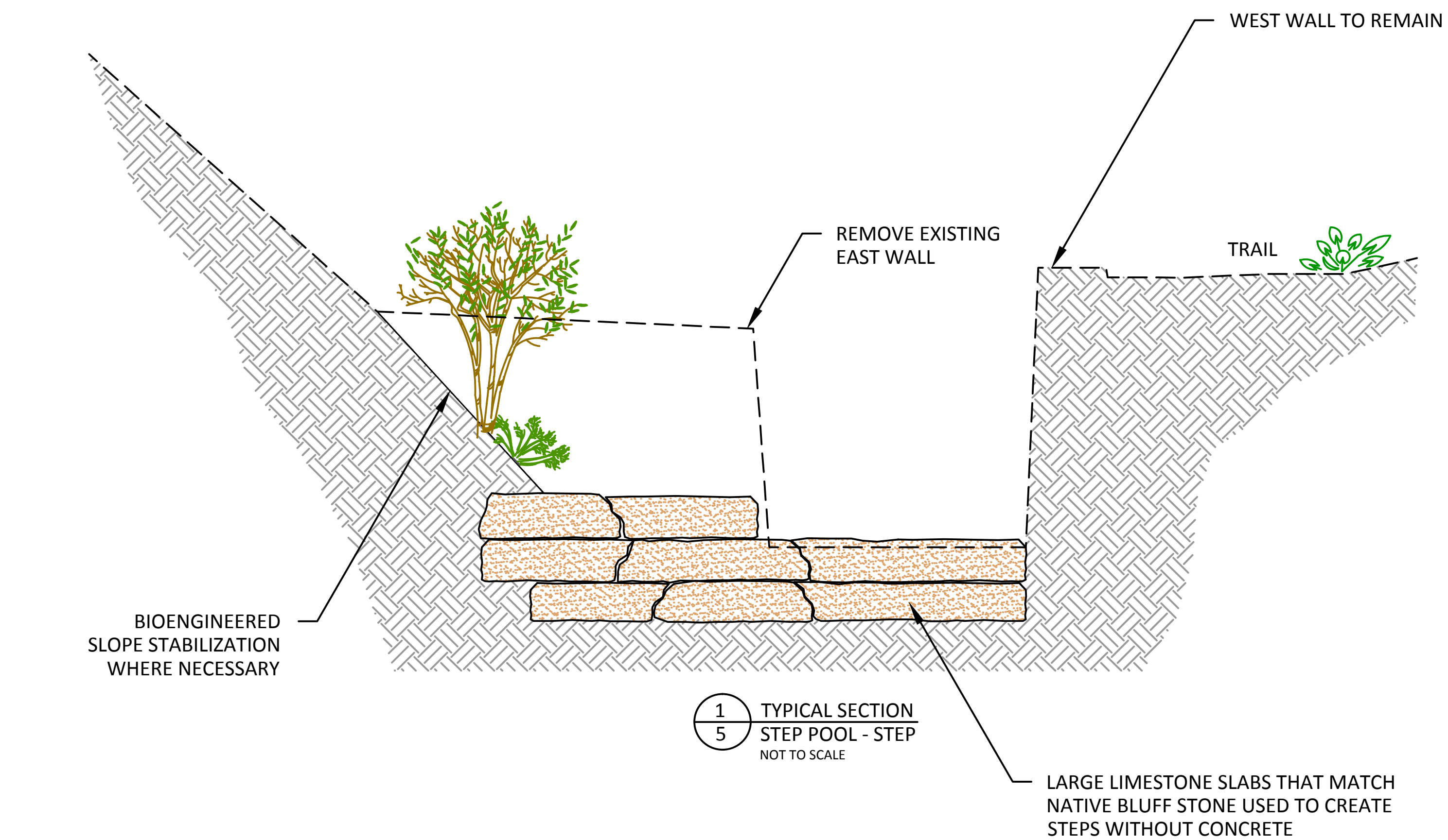
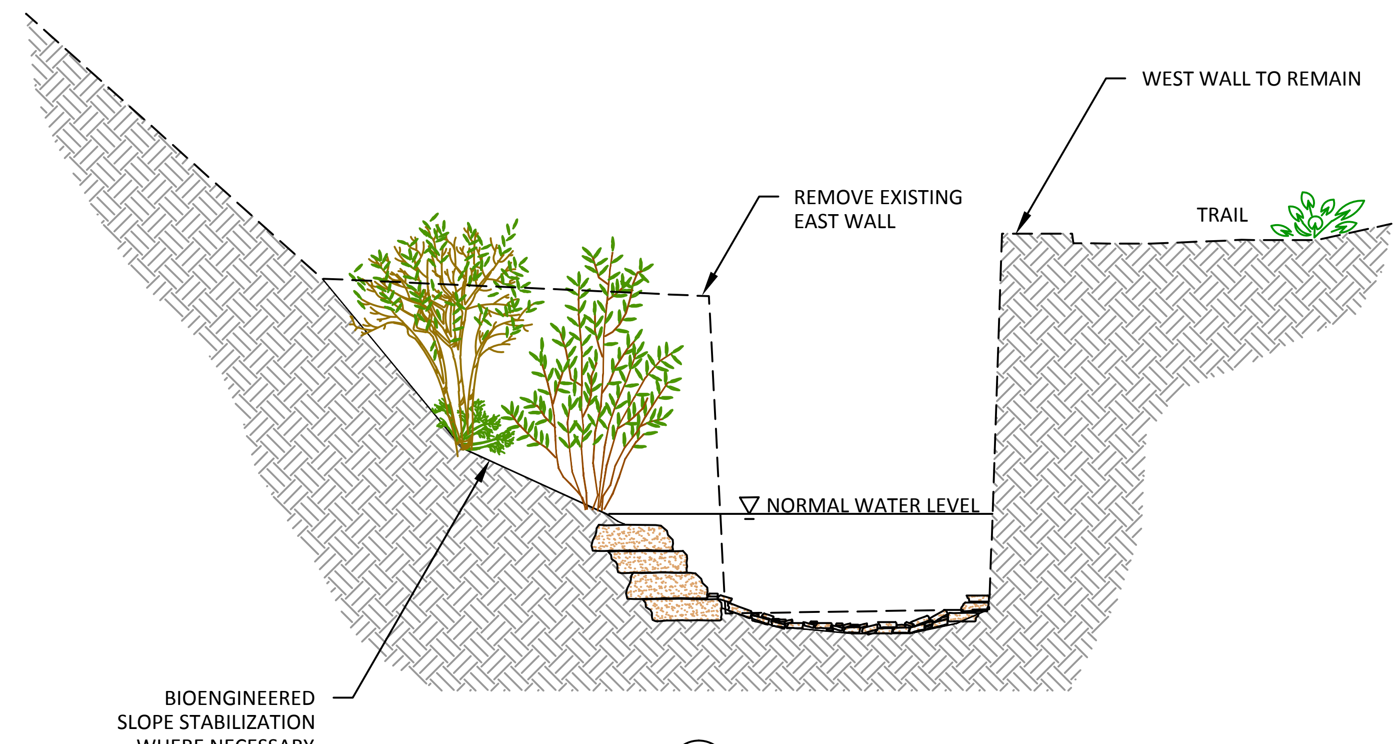
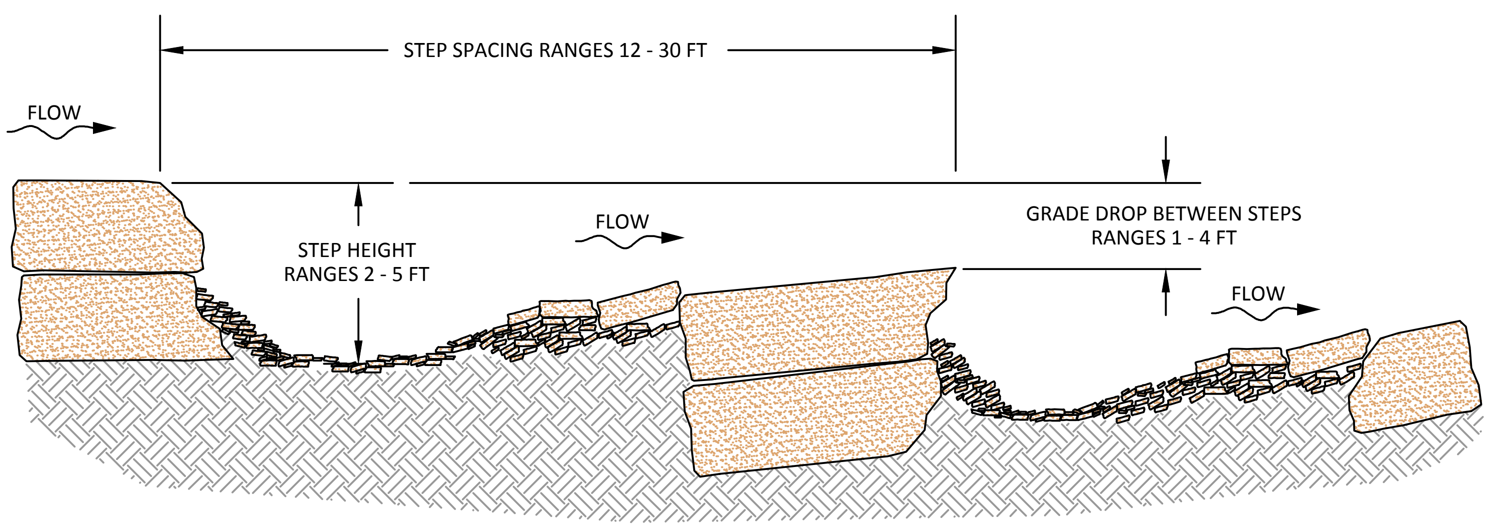
TYPICAL SECTIONS
SHEET 1 OF 2



1/5 TYPICAL SECTION
STEP POOL - STEP
NOT TO SCALE



2/5 TYPICAL SECTION
STEP POOL - POOL
NOT TO SCALE



3/5 TYPICAL SECTION
LONGITUDINAL STEP POOL SEQUENCE
NOT TO SCALE

NO.	DATE	REVISION DESCRIPTION
1	XX/XX/14	30% SUBMITTAL

CP	BW	BW, MM
DRAWN	DESIGNED	CHECKED
BW	6/13/14	----
APPROVED	DATE	PROJECT

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TYPICAL SECTIONS
SHEET 2 OF 2

APPENDIX C – CONCEPT SKETCH

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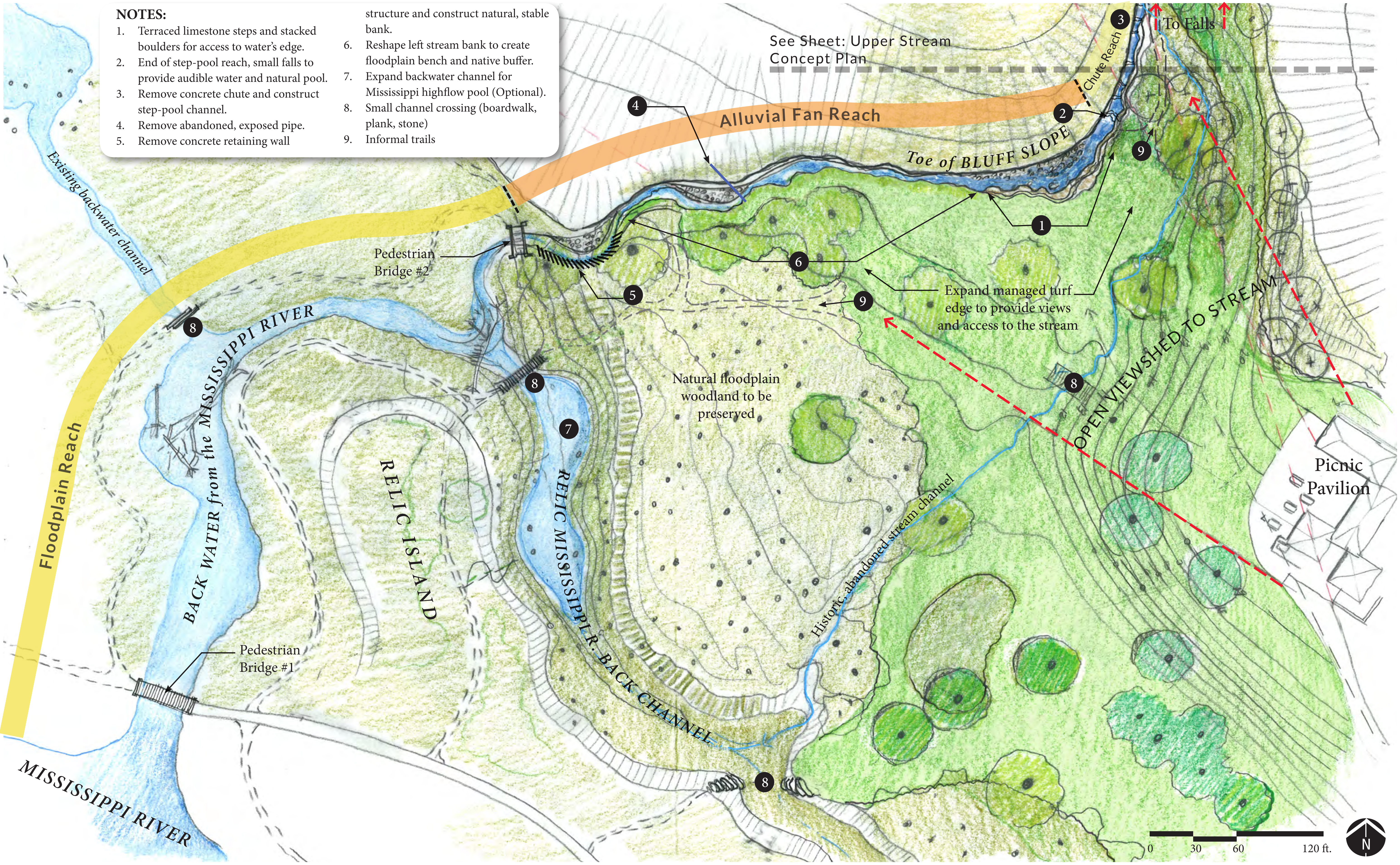
CONCEPT PLAN - OVERALL STREAM

HIDDEN FALLS FEASIBILITY STUDY

Prepared for: St. Paul Parks & Recreation,
City of St. Paul, MN
September 2014



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LOWER STREAM - CONCEPT PLAN

HIDDEN FALLS FEASIBILITY STUDY

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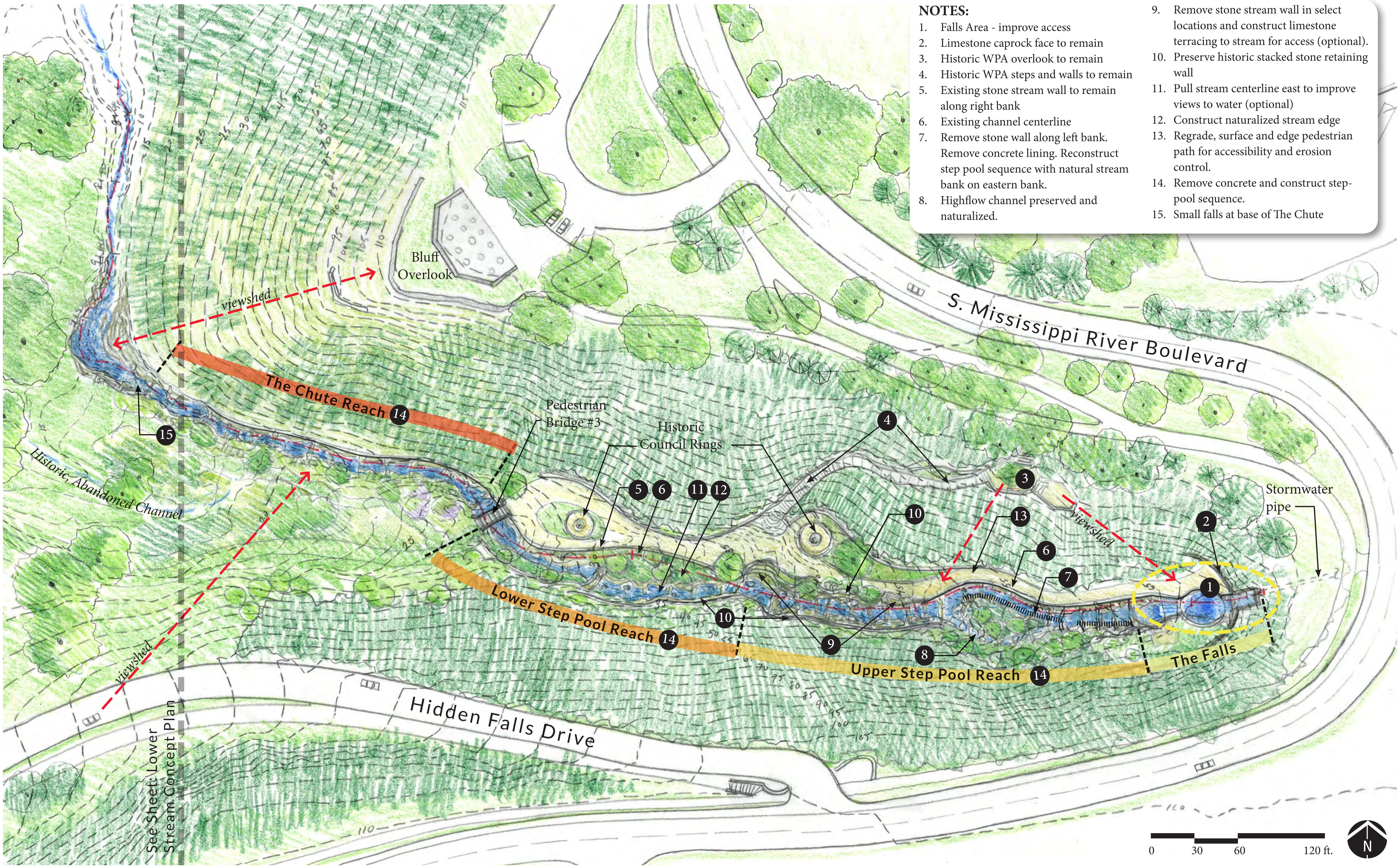
September 2014



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UPPER STREAM - CONCEPT PLAN

HIDDEN FALLS FEASIBILITY STUDY

Prepared for: St. Paul Parks & Recreation,
City of St. Paul, MN
August 2014