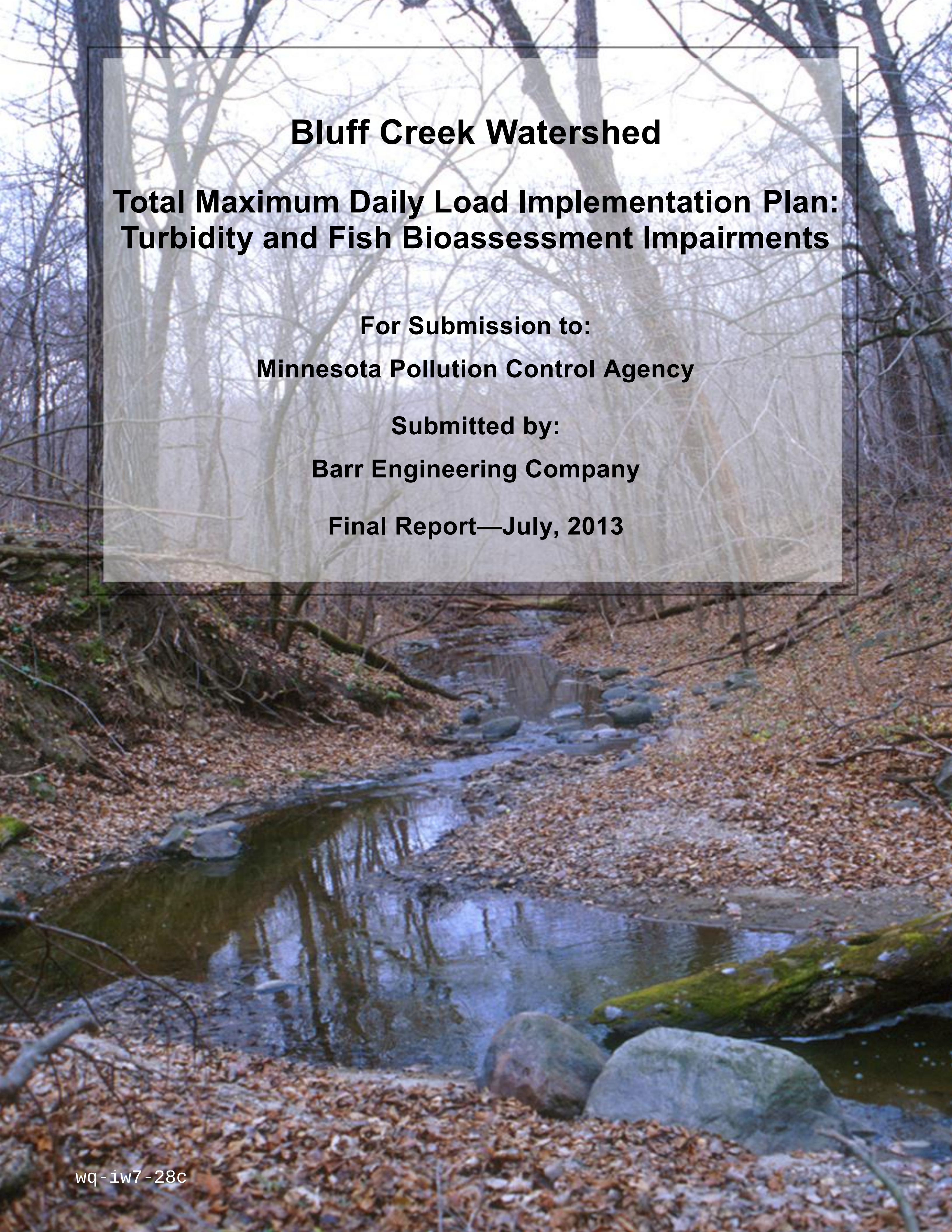

Bluff Creek Watershed

Total Maximum Daily Load Implementation Plan: Turbidity and Fish Bioassessment Impairments

For Submission to:

Minnesota Pollution Control Agency

Submitted by:

Barr Engineering Company

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Bluff Creek Watershed Total Maximum Daily Load Implementation Plan: Turbidity and Fish Bioassessment Impairments

Prepared for
Minnesota Pollution Control Agency

July, 2013

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List of Acronyms/Abbreviations

ac	acre
AUID	assessment unit identification number
BMP(s)	best management practice(s)
cm	centimeters
CR	County Road
Cr	Creek
EPA (U.S.)	Environmental Protection Agency
FNU	formazin nephelometric units
IBI	Index of Biotic Integrity
kg	kilograms
LA	load allocation
MCES	Metropolitan Council Environmental Services
MDH	Minnesota Department of Health
mg/L	milligrams per liter
Mn/DOT	Minnesota Department of Transportation
MOS	margin of safety
MPCA	Minnesota Pollution Control Agency
MRAP	Minnesota River Assessment Project
MS4	Municipal Separate Storm Sewer System
NA	not applicable
NLCD	National Land Cover Dataset
NPDES	National Pollutant Discharge Elimination System
NTRU	nephelometric turbidity ratio units
NTU	nephelometric turbidity units
TMDL	total maximum daily load
TSS	total suspended solids
USGS	United States Geological Survey
WLA	wasteload allocation
WOMP	Watershed Outlet Monitoring Program

1.0 Introduction

This document presents the Implementation Plan for the Bluff Creek Total Maximum Daily Load (TMDL). Bluff Creek is listed on the 2002 and 2004 Minnesota Section 303(d) List of Impaired Waters due to impairment of turbidity and low fish Index of Biological Integrity (IBI) scores. A TMDL for Bluff Creek has been developed.

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) requires states to develop TMDLs for water bodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loading of pollutants or other quantifiable parameters for a water body based on the relationship between pollution sources and instream conditions. By following the TMDL process, states can establish water quality-based controls to reduce pollution from both point and non-point sources and restore and maintain the quality of their water resources.

Once a TMDL is established, an Implementation Plan must be developed. The Implementation Plan is designed to ensure that the management actions identified by the TMDL will be carried out. The Implementation Plan provides information on management measures and regulatory controls; timelines for implementation of management measures and attainment of water quality standards; a monitoring plan designed to determine the effectiveness of implementation actions; and description of adaptive management procedures.

1.1 Impairment Listing

In 2002, Bluff Creek was listed on the 303(d) list of impaired waters for elevated turbidity levels measured at the Metropolitan Council Environmental Services (MCES) Watershed Outlet Monitoring Program (WOMP) station located on the main stem of the creek downstream of Old Highway 212 (Table 1.1). Turbidity in water is caused by suspended sediment, organic material, dissolved salts and stains that scatter light in the water column making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, increase the cost of treatment for drinking or food processing uses and can harm aquatic life. Aquatic organisms may have trouble finding food, gill function may be affected and spawning beds may be covered. In addition, greater thermal impacts may result from increased sediment deposition in the stream.

In 2004, Bluff Creek was placed on the Minnesota Pollution Control Agency's (MPCA) list of impaired waters in need of a Total Maximum Daily Load (TMDL) study for impaired biota due to low fish IBI scores (Table 1.1). For the Minnesota River Basin, biological impairment for fish is defined as failing to meet the MRAP (Bailey et al., 1994) IBI impairment threshold score of 30 or greater out of a possible score of 60. Only streams with a watershed area of at least 5 square miles are obligated to meet the MRAP IBI impairment threshold.

Table 1.1 Bluff Creek watershed 303(d) impairments addressed in this report

Reach	Description	Year listed	Assessment Unit ID	Affected Use	Pollutant or Stressor
Bluff Creek	Headwaters to Rice Lake (27-0132-00)	2004	07020012-710	Aquatic life	Fish bioassessments
Bluff Creek	Headwaters to Rice Lake (27-0132-00)	2002	07020012-710	Aquatic life	Turbidity

1.2 Geographic Extent

Bluff Creek is a small tributary of the Lower Minnesota River located in Carver County. The stream begins at the headwaters located near Trunk Highway 41 in the north and discharges into the Minnesota River Floodplain in the south (Figure 1.1). The catchment area at the outlet of Bluff Creek into Rice Lake is 5.8 square miles, the total length of the main stem is 6.8 miles, the mean streamwise slope varies between 0.08 percent and 0.70 percent, and the creek is moderate to fully entrenched for most of its course (Barr Engineering Company, 1996). The watershed land use of the upper reaches is primarily comprised of urban land use with some areas of forested upland and meadow. The middle reach notes a mix of land uses and is rapidly urbanizing. The lower reach notes steep valley walls, is highly sinuous, and lined with trees. According to the 2006 National Land Cover Database developed by the USGS (Fry et al, 2011) developed areas encompass nearly 50% of the watershed, with low intensity development representing the largest portion (21%), along with medium intensity (13%) and developed open space (12%). Agricultural land covers nearly 30% of the watershed, consisting of pasture/hay (17%) and cultivated crops (13%). Undeveloped land covers the remaining 20% of the watershed, with deciduous forest (14%) covering the majority of this land use. About 85 percent of the catchment is covered by high-relief, hummocky glacial deposits of loamy till, with some localized organic deposits of muck. It is worth mentioning that Lusardi (1997) delineated discontinuous scarps along the relatively flat middle reach referred to above. These scarps could be tracking a former (in geologic time scale), relatively wide fluvial channel, which presumably has been filled with sediment from the adjacent highly-erodible upland areas that the creek has not had the capacity to transport downstream. The remaining lower 15 percent of the catchment is covered by low-relief glacial deposits of loamy till in the upland areas, where the stream corridor is covered by more recent slopewash deposits of sand and gravel material (Barr Engineering Company, 2006).

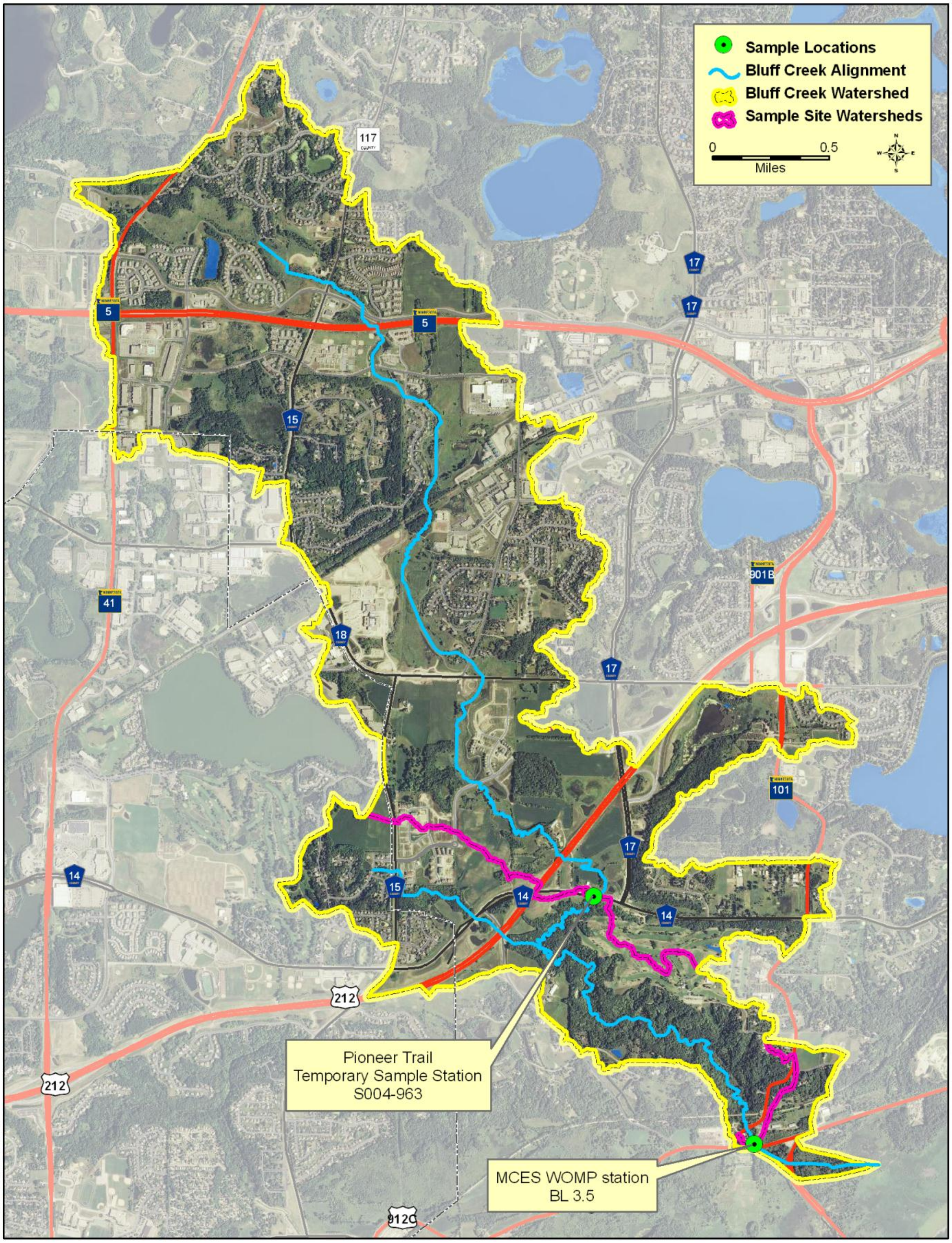

Figure 1.1 Bluff Creek watershed overview

2.0 Turbidity

The following sections briefly summarize the detailed analysis conducted in the Bluff Creek TMDL report (Barr Engineering Company, 2013).

2.1 Existing Water Quality and Standards

Water quality standards are established to protect the designated uses of the state's waters. Bluff Creek is classified as a type 2B and 3C water. The Class 2B water quality standard for turbidity is a chronic standard of 25 NTU (nephelometric turbidity units), which is the highest concentration of a pollutant to which organisms can be exposed indefinitely without causing chronic toxicity.

Turbidity, recorded using the optical properties of a water sample, is derived from suspended sediments, organic material, dissolved salts and stains. This analysis focused primarily on the suspended sediment and organic material components, as they appear to be the primary factors of turbidity in this watershed. In order to evaluate and establish loads the surrogate measure of total suspended solids (TSS) was used. This parameter shows a good correlation with turbidity, based on regressions done on the monitoring data.

Continuous turbidity probe measurements were taken at the two stations: Pioneer Trail station, a temporary station only installed in the summer of 2008; and the Bluff Creek WOMP station, a permanent station operated by the MCES (Figure 1.1). Lab turbidity samples were collected at stream monitoring sites coincidental with the continuous turbidity measurements. FTS DTS-12 turbidity probes installed in Bluff Creek recorded turbidity data (in FNU units) and stream flow at 15 minute intervals. Relationships were developed to relate the recorded turbidity in units of FNU to NTU and then finally to TSS.

The NTU to TSS relationship was used to convert the 25 NTU standard to a TSS measurement for the water quality duration curves. For the Pioneer Trail sampling location the 25 NTU standard is equivalent to a TSS concentration of 75 mg/L. At the WOMP sampling location a concentration of 120 mg/L TSS is equivalent to the 25 NTU standard.

2.2 Turbidity Sources

Major sources of turbidity in the Bluff creek watershed were determined to be poorly vegetated ravines, streambanks, bluffs, and gullies and impervious surfaces.

Poorly Vegetated Ravines, Streambanks, Bluffs and Gullies

It is evident from field observation and aerial photos that dense forest canopy occupies the riparian areas of the lower valley of the creek. This canopy cover limits the growth of vegetation that could stabilize ravines, streambanks and ephemeral gullies adjacent to intermittent and permanent waterways. In addition, classic gully erosion is occurring in other poorly vegetated areas of the watershed that receive concentrated flow. Runoff from these sources may enter streams directly and is not slowed to allow sediments to filter out.

Significant bank erosion on the creek was noted during an erosion inventory conducted in 2007, as well as large slope failures in the valley that were not necessarily associated with a ravine. Ravine erosion, for the most part, is occurring independently of Bluff Creek, and is due to overland runoff, irrigation practices, and/or groundwater seepage.

Impervious Surfaces

Impervious surfaces (roads, parking lots, roofs, etc.) can contribute to excess turbidity directly via sediment and phosphorus delivery and indirectly via increased runoff volume leading to increased bank/bed erosion. Impervious surface area has increased in the watershed during the last few decades and is expected to continue increasing in the future as agricultural and low-density developments are converted to higher density urban and suburban land uses. The majority of the impervious surfaces in the Bluff Creek watershed are addressed by NPDES stormwater permits. Limited exceptions may be present for impervious areas in rural areas and/or new impervious areas that are less than 1 acre.

2.3 TMDL Results Summary

2.3.1 TMDL Allocations

A TMDL is a calculation of the maximum amount of pollutant that a waterbody can receive and still meet water quality standards and/or designated uses. It is the sum of the loads of a single pollutant from all contributing point and nonpoint sources. TMDLs consist of three main components: WLA, LA, and MOS. In this case, the WLA includes only regulated stormwater sources divided into two sub-categories: the MS4 permitted stormwater sources (which includes individual allocations for each MS4), as well as the construction and industrial permitted stormwater category. There are no permitted wastewater facilities in the Bluff Creek watershed. The LA, reported as a single category, includes both watershed runoff and other sources. The third component, MOS, is the part of the allocation that accounts for uncertainty in the development of the loads.

The three components (WLA, LA, and MOS) were calculated as a total maximum daily load of TSS. As described in Section 2.1, TSS is used as a surrogate for turbidity based on a correlation between the two. While nutrients (i.e., phosphorus) may play a role in turbidity during portions of the year, we lack a robust enough dataset to establish an adequate correlation between nutrients, algae and turbidity upon which to base loading allocations. However, reducing the delivery of sediment will also reduce the delivery of nutrients and nutrient reduction should be considered when sediment reduction practices are implemented.

The methodology used to derive and express the TSS load components was based on the duration curve approach. For each impaired reach and flow condition, the total loading capacity or "TMDL" was divided into its component WLA, LA, and MOS. The allocations were distributed to each WLA entity, as well as the LA, based on an even distribution of load that corresponded with the contributing watershed area. It should be noted that this method implicitly assumes that observed stream flows and flow regimes must remain constant over time.

The Bluff Creek WOMP station flow rates measured from 2008 through 2010 were divided into five flow categories representing ranges of observed flow rates (see Figure 2.1): high flows (the highest 10% of observed flows i.e. 0-10%), moist conditions (10-40%), mid-range flows (40-60%), dry conditions (60-90%) and low flows (90-100%). The five categories were used to calculate the total suspended solid loading capacities and allocations for the Bluff Creek WOMP station (Table 2.1). The total daily loading capacity was calculated using the mid-point flow rate for each of the flow zones and the 120 mg/L TSS concentration which corresponds to the 25 NTU standard. This analysis results in total daily load capacities of 8.03, 1.41, 0.82, 0.46 and 0.13 tons/day for the high, moist, mid, dry and low flow zones respectively. The reach of Bluff Creek extends beyond the location of the WOMP station therefore the load capacities were adjusted based on the total watershed area compared to the watersheds area up to the WOMP station. Using this adjustment the total daily load capacities for the entire Bluff Creek reach were 8.22, 1.44, 0.84, 0.47 and 0.13 tons/day for the high, moist, mid, dry and low flow zones respectively. This loading capacity was then divided between MOS, WLA, and LA components. These result in 47.3% of the capacity being allocated to MS4 NPDES requirements, 42.6% allocated to LAs, 0.1% allocated to construction and industrial stormwater and 10% applied to the MOS.

Table 2.1 Total suspended solids loading capacities and allocations (AUID: 07020012-710)

	Flow Zone				
	High (5%)	**Moist (25%)**	**Mid (50%)**	**Dry (75%)**	**Low (95%)**
	Tons/day				
TOTAL DAILY LOADING CAPACITY	8.22	1.44	0.84	0.47	0.13
Wasteload Allocation					
Communities Subject to MS4 NPDES Requirements					
Mn/DOT Metro MS4	0.68	0.12	0.07	0.04	0.01
Carver County MS4	0.13	0.02	0.01	0.01	0.002
Chaska City MS4	0.27	0.05	0.03	0.02	0.004
Chanhassen City MS4	2.80	0.49	0.29	0.16	0.04
Construction and Industrial Stormwater	0.008	0.002	0.001	<0.001	<0.001
Load Allocation	3.50	0.61	0.36	0.20	0.06
Margin of Safety	0.82	0.14	0.08	0.05	0.01
	Percent of total daily loading capacity				
TOTAL DAILY LOADING CAPACITY	100%	100%	100%	100%	100%
Wasteload Allocation					
Communities Subject to MS4 NPDES Requirements					
Mn/DOT Metro MS4	8.3%	8.3%	8.3%	8.3%	8.3%
Carver County MS4	1.6%	1.6%	1.6%	1.6%	1.6%
Chaska City MS4	3.3%	4.2%	4.2%	4.2%	4.2%
Chanhassen City MS4	34.1%	34.1%	34.1%	34.1%	34.1%
Construction and Industrial Stormwater	0.1%	0.1%	0.1%	0.1%	0.1%
Load Allocation	42.6%	42.6%	42.6%	42.6%	42.6%
Margin of Safety	10%	10%	10%	10%	10%

2.3.2 Load and Water Quality Duration Curves

Load duration curves were created for all three years combined (2008-2010) at the Bluff Creek WOMP station (Figures 2.1). Load duration curves plot the corresponding TSS load (tons/day) calculated using the 15 minute interval flow rate (cfs) and TSS concentration (mg/L), converted from the NTU turbidity measurement, against the flow percentile rank percentage for each measurement.

At the Bluff Creek WOMP station the highest TSS loads occurred during the high and moist flow zones. Median loads over the three year period (Figure 2.1) were calculated as 8.9, 0.0575, 0.0085, 0.0045, and 0.0006 tons/day for the high moist, mid, dry and low flow zones respectively. This increased load is not simply due to an increase in flowrate as the highest concentrations of TSS also occur in the high and moist flow zones (Figure 2.2). Median concentrations for the three year period were recorded as 118.8, 4.4, 1.2, 1.1 and 0.5 mg/L for the high moist, mid, dry and low flow zones respectively. The 90 percentile concentrations were 892, 47, 6.9, 5.7 and 2.4 mg/L for the high moist, mid, dry and low flow zones respectively.

The 25 NTU standard was calculated by taking the product of the 120 mg/L TSS equivalent and the flow rate at various percentages. This curve is displayed with a red line in Figures 2.1 and 2.2 along with the 90th percentile and median loads for the 5 flow zones. The 90th percentile in the high flow zones is above the NTU standard in all years. Moist conditions, mid-range, dry and low flows are meeting the surrogate standard in all years.

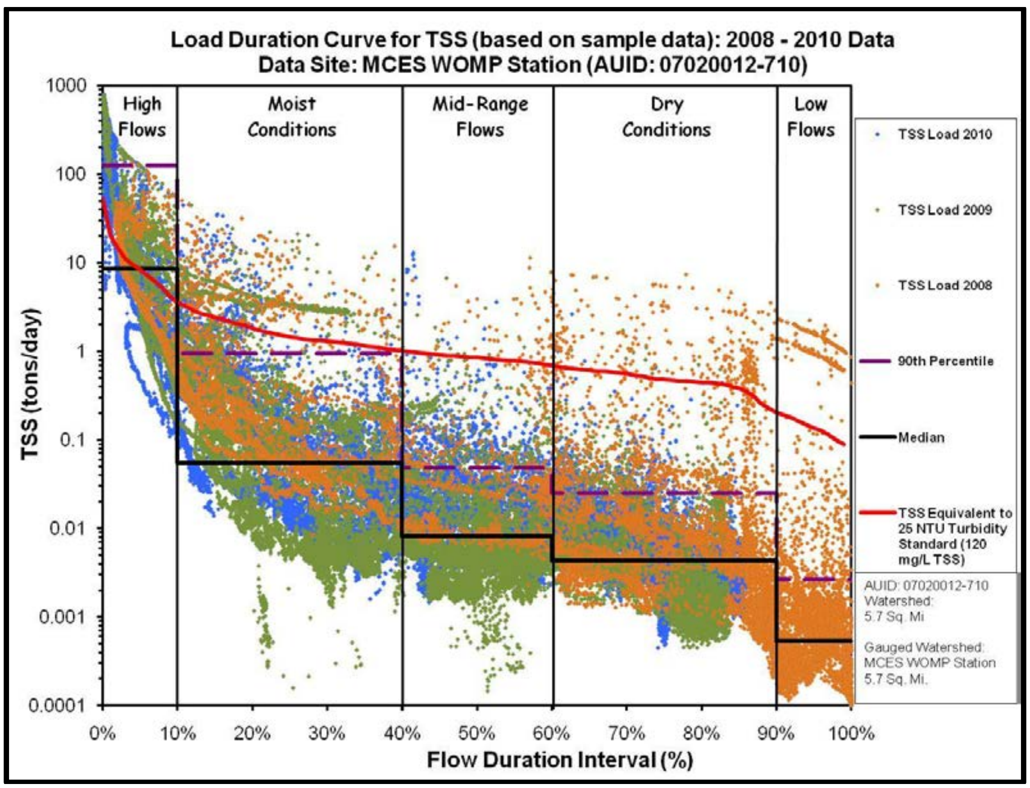

Figure 2.1 Load duration curve 2008-2010 (AUID: 07020012-710)

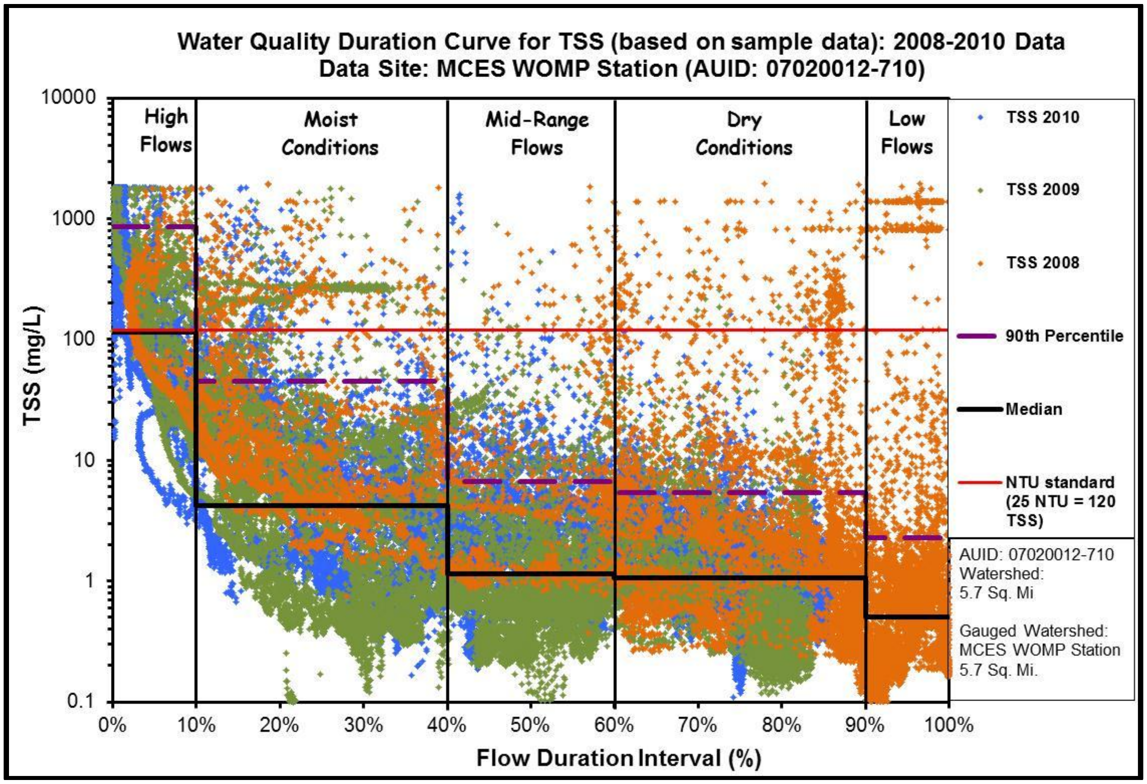

Figure 2.2 Water quality duration curve 2008-2010 (AUID: 07020012-710)

At the temporary station set up at Pioneer Trail for year 2008 the median TSS loads from Pioneer Trail were 0.1825 tons/day for high flows and 0.0151 tons/day for moist conditions. No data was available for the mid-range, dry range and low flows. The median concentrations were recorded at 15.0 mg/L for the high ranges and 4.7 mg/L for the moist conditions.

2.3.3 Loading Reductions

As indicated in Figures 2.1 and 2.2, the monitored 90th percentile TSS loading is above the NTU standard for all of the combined years under the high flow conditions, while the moist conditions, mid-range, dry and low flows are below the standard in all years. As a result, the high flow condition is the only flow for which a TMDL must be developed and this indicates that loading reductions are only needed under the high flow condition to meet the turbidity standard. No reductions would be required under the other four flow conditions. As discussed in Section 2.3.1, the total daily load capacity for the entire Bluff Creek reach was 8.22 tons/day for the high flow condition and was allocated to each of the individual TSS sources in Table 2.1. Since the 90th percentile TSS concentration over the three year monitoring period (Figure 2.2) was 892 mg/L for the high flow condition, this translates to a loading rate of 61.1 tons/day and would require an approximately 87%

load reduction to meet the standard under the high flow condition, which is being equally applied to all of the load and wasteload allocation components, as shown in Table 2.2. Table 2.2 also shows the estimated TSS loadings under existing (2008) conditions, the allocated loadings and a load reduction percentage of 88% that would be required for each component of the TMDL (from Table 3.1) under the high flow condition to accommodate the margin of safety. Table 2.2 contains the WLAs that must be addressed by regulated MS4s to meet the necessary load reduction for the Bluff Creek impairments under the high flow condition.

Table 2.2 Existing total suspended solids loading estimates, loading allocations and loading reductions for the high flow condition

	Tons/day		Load Reduction Percentage (%)
	Existing TSS Loading Estimates	TMDL Allocations	
TOTAL DAILY LOADING	61.10	8.22	87
Wasteload Allocation			
Communities Subject to MS4 NPDES Requirements			
Mn/DOT MS4 NPDES	5.62	0.68	88
Carver County MS4 NPDES	1.08	0.13	88
Chaska MS4 NPDES	2.23	0.27	88
Chanhassen MS4 NPDES	23.16	2.80	88
Construction and Industrial Stormwater	0.066	0.008	88
Load Allocation	28.94	3.50	88
Margin of Safety	--	0.82	--

2.4 TSS Modeling Results

The P8 water quality model was developed to simulate TSS loads in the Bluff Creek watershed. P8 (Program for Predicting Polluting Particles Passage thru Pits, Puddles, & Ponds) is a model developed to examine pollutant loading in urban watersheds. P8 is an industry standard model using National Urban Runoff Program (NURP) data for loading estimates based on data collection. The information provided in this section is a summary of the modeling results. A detailed discussion of the P8 modeling is included in the Bluff Creek TMDL Report (Barr Engineering Company, 2013).

The P8 model was calibrated using 2008 monitoring data collected between 6/25/2008 and 11/17/2008 for runoff volume and TSS load. The model accurately predicted total runoff volume at both sites as well as TSS loads at the Pioneer Trail station (Table 2.3). Peak flow rates during the same time period also compare well with measured results. Both the modeling and monitoring data show increased TSS concentrations in the lower reach of the creek during the calibration period. The monitoring data indicate that ~30,000 lbs of additional TSS loading enters the creek downstream of the Pioneer Trail station with just 60 acre-ft of additional runoff (equivalent to a flow-weighted mean concentration of 184 mg/L). This increases the flow-weighted mean TSS concentration from 14.6 mg/L at the Pioneer Trail station to 48.6 mg/L at the WOMP station. The calibrated model was then used to calculate flow rates in the various ravines contributing to the lower reach of Bluff Creek to assess erosion potential. Precipitation data from 1990-2008 from the Minneapolis/St. Paul International airport was used for this simulation. Results are discussed in the Implementation Section (Section 4.0).

Table 2.3 Modeling and monitoring data comparison for the calibration period (6/25/2008 – 11/17/2008)

Data Set	Total volume (Acre-ft)	Average flow rate (cfs)	Peak flow rate (cfs)	Average TSS concentration (mg/L)	TSS load (lbs)
Modeled WOMP	311	1.1	39.0	13.7	12,800
Measured WOMP	312	1.1	42.6	48.6	41,287
Modeled Pioneer Trail	264	0.9	17.0	12.8	9,500
Measured Pioneer Trail	250	0.9	17.7	14.6	9,900

2.5 Overall Conclusions from Turbidity-Related Monitoring and Sediment Sources Requiring Load Reductions

Some of the conclusions to be drawn from the development of the turbidity TMDL are the following:

- Based on the available data the watershed turbidity impairment appears to be "significant" in that half of the wet-weather turbidity readings from three years of sampling are above the surrogate standard at the Bluff Creek WOMP (MCES BL 3.5) station. The largest quantity of sediment is added to the creek downstream of the Pioneer Trail sampling station during high flow events (0-10% flow duration). During 2008 the median TSS load for the high flow event at Pioneer Trail was 0.1825 tons/day. At the Bluff Creek WOMP station the median TSS load was 5.36 tons/day. The median TSS concentrations for the high flow events were 15.0 and 77.2 mg/L at the Pioneer Trail and WOMP stations respectively. This large influx of sediment occurs in the lower valley even though only 1.3 of the 5.7 square miles of total watershed area enters Bluff Creek downstream of the Pioneer Trail station.

- Primary sources contributing TSS within this watershed are streambank and bluff erosion, as well as poorly vegetated ravines and gullies. These sources of sediment are contributing excess TSS loadings, mobilized by stormwater runoff from the watershed under high flow conditions.
- The calculated Total Maximum Daily Load (TMDL) of TSS that serves as the loading capacity for each reach is based on the TSS concentration equivalent to the 25 NTU standard. To meet the standard, total daily loads at the Bluff Creek WOMP station have to be equal to or lower than 8.22 tons/day for high flows (0-10% flow duration), 1.44 tons/day for moist conditions (10-40% flow duration), 0.84 tons/day for mid-range flows (40-60% flow duration), 0.47 tons/day for dry conditions (60-90% flow duration intervals), and 0.13 tons/day for low flows (90-100% flow duration).
- To meet the turbidity standard load reductions of 87% are needed during high flow conditions (0-10% flow duration). Loads during all other flow conditions (moist conditions, mid-range flows, dry conditions and low flows) currently meet the turbidity standard.

3.0 Biological Stressors Summary

The Bluff Creek Biological Stressor Identification Report determined the stressors causing the stream's biological (fish) impairment (Barr Engineering Company, 2010). Four primary stressors affecting biotic integrity in Bluff Creek were identified: sediment, metals, flow, and habitat fragmentation. One of those stressors – sediment – is addressed in Section 2.0.

A second stressor - metals – appears to be related to TSS loads and therefore is very likely to be addressed by achieving TMDL wasteload and load allocations through this TMDL. The data indicate metals are entering Bluff Creek with sediment during periods of high flow. Hence, sediment load reductions could also reduce metal loads to Bluff Creek.

Two of the stressors – habitat fragmentation and flow – are not associated with a specific pollutant for which a TMDL can be developed.

Habitat fragmentation is considered a possible stressor because a large drop at the downstream end of the regional trail culvert (Figure 3.1) interrupts the connectivity of Bluff Creek. This interruption of connectivity prevents passage of fish between upstream and downstream reaches of Bluff Creek. Such isolation may increase mortality due to separation from food sources and prevent replenishment of the species when disease or other stressors reduce the population. Isolation may lead to the demise of a fishery, including extinction (Letcher et al., 2007). Evaluation of Bluff Creek stream reaches upstream and downstream of the culvert indicates upstream reaches were impaired while a downstream reach was not impaired. The data indicate habitat fragmentation has adversely impacted Bluff Creek's fishery and has resulted in impairment of stream reaches located upstream of the culvert (Barr Engineering Company, 2010).

Figure 3.1 Large drop at downstream end of regional trail culvert (looking upstream)

Design and construction of a ramp structure at the culvert outlet is recommended to provide fish passage, thus removing the habitat fragmentation stressor in Bluff Creek. Further details on the design and construction of this fish passage are given in Section 4.1.1.1.

High flows were identified as a stressor to the stream's biological community because of its interaction with sediment, metals, and habitat fragmentation. High flows not only increase sediment and metals loading to Bluff Creek, but also exacerbate the stress to the biological community caused by habitat fragmentation. High flows move fish downstream from the regional trail culvert and habitat fragmentation prevents the fish from returning to the upstream location and replenishing the fish community. To prevent the current problem from worsening with future development, it was recommended that management measures to prevent anthropogenic flow increases should be employed now and in the future (Barr Engineering Company, 2010).

Figure 3.2 Eroding left stream bank immediately downstream of culvert outlet

Problems with high flow could be addressed by achieving the same goals discussed previously: sediment TMDL wasteload and load reductions through this TMDL and designing and constructing a ramp structure at the culvert outlet. Sediment load reduction would remove both sediment and metals as stressors to Bluff Creek. Fish passage at the culvert outlet would remove habitat fragmentation as a stressor. Because flow is only a problem when high flows interact with these stressors, removal of the stressors would also eliminate high flows as a stressor to Bluff Creek. Reductions in anthropogenic high flow rates could also be achieved through general stormwater practices. Placement of detention/infiltration BMPs to manage stormwater runoff would decrease the peak flow rates reducing high flow as a stressor.

Finally, due to the cold temperatures found in Bluff Creek and the possible suitability towards cold water fish species, a Use Attainability Analysis is recommended to evaluate whether the current Use Class or a different Use Class more reflective of the cold temperatures is appropriate.

4.0 Implementation

4.1 Municipal (MS4) Stormwater Implementation

The results of the TMDL monitoring and modeling show an increased TSS load downstream of the Pioneer Trail station resulting in TSS concentrations above the surrogate standard. It appears that a major component to this increased TSS load is erosion of ravines, stream banks and bluffs in the lower reach of Bluff Creek. An analysis of the ravines, stream banks, and bluffs was completed to determine erosion severity and also implementation cost needed for remediation.

As previously discussed, runoff volume and peak flow associated with conversion of natural land cover and increased density of development will need to be kept in check or reduced, especially for direct tributary flows to the lower valley of Bluff Creek to minimize bank, bluff, ravine and gully erosion in the watershed. Sections 4.1.4 describes the implementation priority ranking for specific stabilization projects that have been identified and Section 4.1.5 describes implementation of other BMPs that are intended to address stormwater runoff in the Bluff Creek watershed. In addition, water management requirements contained in the City of Chanhassen's Surface Water Management Plan, the Riley-Purgatory-Bluff Creek Watershed District's (RPBCWD) Watershed Management Plan, the Carver County Water Plan, and the City of Chaska's Comprehensive Plan will need to be updated to ensure that BMP implementation will adequately address the pollutant sources and impairments in the Bluff Creek watershed.

4.1.1 Erosion Survey

An inventory and assessment of the Bluff Creek Lower Valley completed in 2007 identified sites contributing sediment to Bluff Creek, the erosion severity at those sites and feasible options for reducing sources of sediment to the stream. Erosion severity was divided into four categories: stable, minor, moderate and severe. In addition to the ravine stabilizations areas, bluff slope failures and stream bank areas needing stabilization were evaluated. Finally, the Bluff Creek crossing of the Hennepin County Regional Trail Corridor was inspected to determine fish passage options to address habitat fragmentation. The following paragraphs detail the 22 individual sites identified in the 2007 survey, recommended management measures to reduce sediment loading to Bluff Creek, and a conceptual cost estimate. Each site is discussed individually based on the numbered erosion survey site locations shown on Figure 4.1. Section 4.1.23 provides a general discussion of stream channel erosion sources, including 18 main channel scarps (all of which are indicated by site number 23 in Figure 4.1) that were inventoried in the spring of 2013.

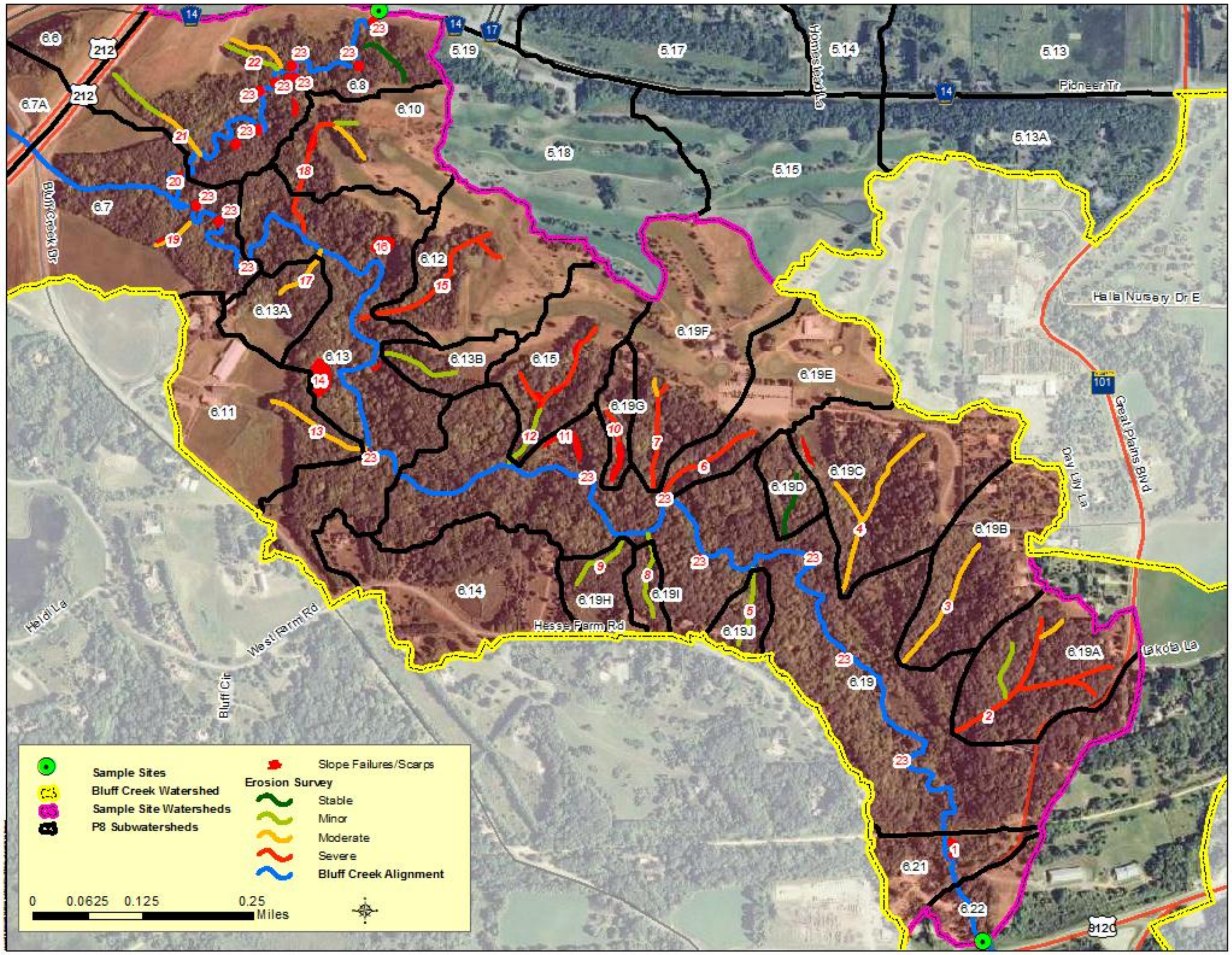

Figure 4.1 Bluff Creek channel survey downstream of Pioneer Trail sample station. Includes watershed IDs (black text) and erosion survey site numbers (red text).

4.1.1.1 Site 1

Site Description

This site includes the downstream end of the regional trail crossing culvert and an eroded bank immediately downstream of the culvert. The stream channel has downcut significantly below the culvert, and the culvert is being undermined. Left unchecked, the culvert may begin to fail. The large drop at the downstream end of the culvert prevents fish passage to upstream reaches (see Figure 4.2 and Figure 4.3).

Figure 4.2 Large drop and undermining at downstream end of regional trail culvert (Site 1)

Figure 4.3 Large bank failure downstream of culvert outlet on left bank (Site 1)

Recommendations

Evaluate the structural condition of the culvert and make necessary repairs to prevent further undermining, including a rock energy dissipation structure. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation. Grade eroded banks, add toe protection to prevent further undercutting and plant with native plantings.

Habitat fragmentation should be addressed at the downstream end of the regional trail crossing culvert by designing and constructing a ramp structure to provide fish passage. The ramp could be constructed of either concrete or natural rock material. Natural rock material is recommended as it would offer greater flexibility, be less susceptible to scour or undercutting, and would be more aesthetically appealing. The first step in the fish passage project is completion of a concept level design of the ramp, which would include the collection of existing site information, detailed site topographical survey, structural evaluation of the culvert, development of design sketches and a conceptual-level cost estimate. This phase would include initial discussion with agency representatives.

Conceptual Cost Estimate (Planning and Implementation)

$130,000

4.1.1.2 Site 2

Site Description

Site 2 consists of an approximately 1,000-feet long main ravine with a 600-foot long side ravine on the north side of the valley. The main ravine receives drainage via a corrugated metal pipe from Mandan Circle, with severe erosion below the discharge point. A large sand deposit exists about halfway down the main ravine. The tributary ravine receives drainage from MN TH 101 and has numerous sub-tributary ravines (see Figure 4.4 and Figure 4.5).

Figure 4.4 Large Headcut in Main Ravine Below Pipe Outlet from Mandan Circle (Site 2)

Figure 4.5 Tributary Ravine with Exposed Tree Roots (Site 2)

Recommendation

Review condition and design of storm sewer pipe from Mandan Circle, and, at a minimum, provide energy dissipation (such as riprap) at pipe outlet. Provide grade control stabilization of main ravine and tributary ravine after watershed flows have been controlled. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation. Grade steep banks and plant with native plantings.

Conceptual Cost Estimate (Planning and Implementation)

$400,000

4.1.1.3 Site 3

Site Description

Site 3 consists of an approximately 850-foot long main ravine on the north side of the valley with moderate erosion. The ravine receives drainage from an 18-inch corrugated metal pipe from Creekwood Drive. The pipe conveys discharge from a pond on the north side of Creekwood Drive. There are several headcuts along the ravine, but no severe slope failures. A sand deposit is present at the bottom of the ravine (see Figure 4.6 and Figure 4.7).

Figure 4.6 Headcut Followed by Sand Deposit in Lower Part of Ravine (Site 3)

Figure 4.7 Headcutting in the Upper Part of the Ravine (Site 3)

Recommendation

Review condition and design of storm sewer pipe from Creekwood Drive. Review design of pond outlet and provide extended detention outlet to reduce the frequency and magnitude of the high flows, if necessary. Provide energy dissipation at pipe outlet and grade control stabilization in the eroded ravine. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$240,000

4.1.1.4 Site 4

Site Description:

Site 4 has an approximately 750-foot long main ravine with a 600-foot secondary ravine on the north side of the valley. Main ravine has moderate erosion, while the secondary ravine requires additional investigation. The main ravine receives drainage from a 24-inch above-ground corrugated metal pipe that originates from the east end of the Bluff Creek Golf Course parking lot. The ravine bottom is well armored and fairly broad, with occasional slope failures along the banks (see Figure 4.8 and Figure 4.9).

Figure 4.8 Well-armored channel bottom with occasional slope failures at lower part of ravine (Site 4)

Figure 4.9 Pipe inlet in poor condition from east end of golf course parking lot (Site 4)

Recommendation

Review condition and design of storm sewer pipe from adjoining property owner. Provide energy dissipation at pipe outlet and grade control stabilization in the eroded ravine. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$290,000

4.1.1.5 Site 5

Site Description

Site 5 consists of an approximately 500-foot long, steep ravine on the south side of the valley with minor erosion. This ravine has a small watershed, with Hesse Valley Road at the head of the ravine (see Figure 4.10 and Figure 4.11).

Figure 4.10 Above view of short, steep ravine (Site 5)

Figure 4.11 Yard waste dumping onto failed slope (Site 5)

Recommendation

Monitor every five years. Evaluate existing vegetation and thin trees where possible to encourage growth of ground vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$30,000, assuming that tree thinning will be required in some areas.

4.1.1.6 Site 6

Site Description

Site 6 consists of an approximately 600-foot long ravine on the north side of the valley with severe erosion. The ravine originates from a point approximately 150-feet south of the Bluff Creek golf course parking lot. The ravine is narrow and incised, with a significant headcut approximately 1/3 distance from the bottom. Ravine terminates in a steep gully leading to the creek, with an adjacent failure on the creek bank (see Figure 4.12 and Figure 4.13).

Figure 4.12 Large headcut in lower part of ravine (Site 6)

Figure 4.13 View of ravine (Site 6)

Recommendation

Review drainage and groundwater seepage of ravine to determine cause of erosion. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation. Provide grade control and energy dissipation in ravine and provide better transition to Bluff Creek. Grade eroding banks and revegetate with native vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$300,000

4.1.1.7 Site 7

Site Description

Site 7 consists of an approximately 700-foot long ravine on the north side of the valley with severe erosion. The mouth of the ravine is near that of Ravine 6, while the head of the ravine is approximately 300-feet west of the Bluff Creek golf course parking lot. The ravine is narrow and incised, with several significant headcuts. A 12-inch pipe drains to this ravine from the golf course. A trickle of surface water flow was observed, but groundwater seepage may also be a contributing factor. A sand deposit was observed at the bottom of the ravine near the creek (see Figure 4.14 and Figure 4.15).

Figure 4.14 Large headcut in middle part of ravine (Site 7)

Figure 4.15 Crack foretelling impending slope failure (Site 7)

Recommendation

Review drainage and groundwater seepage of ravine to determine cause of erosion. Determine source of pipe drainage and possible stormwater detention options. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation. Provide grade control and energy dissipation in ravine and groundwater control, in the form of horizontal or toe drains, as needed. Grade eroding banks and revegetate with native vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$370,000

4.1.1.8 Site 8

Site Description

Site 8 consists of an approximately 500-foot long ravine on the south side of the valley with minor erosion. The ravine originates near Hesse Farm Road and has a small tributary watershed. Although it is steep, there is only minor erosion evident in this ravine (see Figure 4.16 and Figure 4.17).

Figure 4.16 Above view of ravine (Site 8)

Figure 4.17 View of ravine top (Site 8)

Recommendation

Monitor every five years. Evaluate existing vegetation and thin tree vegetation where possible to encourage growth of ground vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$20,000, assuming that tree thinning will be required in some areas.

4.1.1.9 Site 9

Site Description

Site 9 consists of an approximately 400-foot long ravine on the south side of the valley with minor erosion. The ravine originates about 30-feet north of Hesse Farm Road and has a small tributary watershed. Although it is very steep, there is only minor erosion evident in this ravine (see Figure 4.18 and Figure 4.19).

Figure 4.18 Above view of ravine (Site 9)

Figure 4.19 Yard waste dumping in ravine (Site 9)

Recommendation

Monitor every five years. Evaluate existing vegetation and thin tree vegetation where possible to encourage growth of ground vegetation.

Conception Cost Estimate (Planning and Implementation)

$20,000, assuming that tree thinning will be required in some areas.

4.1.1.10 Site 10

Site Description

Site 10 consists of an approximately 450-foot long ravine on the north side of the valley with severe erosion. The head of the ravine originates at a path from the golf course. It is unclear what the purpose of the path is, and it may be abandoned. Lower half of the ravine is deeply eroded and has been for some time, with vegetation re-established on portions of the eroded slopes. Exposed soils are dense sandy clay, with some strata resembling sandstone (see Figure 4.20 and Figure 4.21).

Figure 4.20 30-foot deep slope failure area (Site 10)

Figure 4.21 Failed sidewall (Site 10)

Recommendation

Review drainage and groundwater seepage of ravine to determine cause of erosion. Determine purpose of golf course path and drainage from golf course. Evaluate existing vegetation and thin trees where necessary to provide greater sunlight to ground vegetation. Provide grade control and energy dissipation in ravine and provide better transition to Bluff Creek. Grade eroding banks and revegetate with native vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$220,000

4.1.1.11 Site 11

Site Description

This site consists of a very large slope failure on the north valley wall. A much smaller slope failure is nearby immediately adjacent to the creek. The larger slope failure has been present for over 80 years, and the lower embankment has largely revegetated with grasses and small trees. The upper, more vertical banks continue to slowly erode. The original failure may have been induced by groundwater seepage or streambank erosion, but the upper vertical bank is probably no longer influenced by these factors (see Figure 4.22 and Figure 4.23).

Figure 4.22 Large slope failure with Revegetated lower bank (Site 11)

Figure 4.23 Bank failure on creek (Site 11)

Recommendation

Review drainage patterns of failure area and store and/or redirect local drainage around eroding slopes as needed to reduce concentrated flow over the bank. Grade the vertical upper banks and revegetate with native vegetation. Stabilize slope failure adjacent to creek and redirect creek away from the bank toe. Revegetate stabilized bank and provide erosion control.

Conceptual Cost Estimate (Planning and Implementation)

$290,000

4.1.1.12 Site 12

Site Description

Site 12 consists of an approximately 1,000-foot long ravine on the north side of the valley with a 225-foot tributary ravine, both having severe erosion. The lower 350 feet of the ravine is relatively stable, indicating that the ravine may be the result of a headcut that has been slowly migrating up the valley wall. The heads of both the main ravine and the tributary ravine are at the south perimeter of the golf course (see Figure 4.24 and Figure 4.25).

Figure 4.24 Severe erosion in upper part of main ravine (Site 12)

Figure 4.25 Stable lower extent of ravine with a sandy channel (Site 12)

Recommendation

Review drainage and groundwater seepage of ravine to determine cause of erosion. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation. Provide grade control and energy dissipation in ravine. Control groundwater seepage if necessary. Grade eroding banks and revegetate with native vegetation.

Conceptual Estimate (Planning and Implementation)

$350,000

4.1.1.13 Site 13

Site Description

Site 13 consists of an approximately 650-foot long ravine on the west side of the valley with moderate erosion. The head of the ravine is at a hobby farm. A promiscuous dump is present on the site. Materials present consisted primarily of yard wastes and general building materials. Soils and historic aerial photographs indicate that a wetland existed upstream of this channel at one time. The wetland site currently has a surface tile intake and is being used as cropland. A minor bank failure is present near the mouth of the ravine at Bluff Creek, but does not appear likely to develop into a more severe erosion problem (see Figure 4.26 and Figure 4.27).

Figure 4.26 Yard waste and building materials at the head of the ravine (Site 13)

Figure 4.27 Debris present at midpoint of ravine (Site 13)

Recommendation

The drainage hydrology of the ravine should be reviewed to determine if reductions in flow rate and volume can be made. Address dumping problem with resident to allow for vegetative growth and reduce the potential for erosion. Evaluate existing vegetation and thin trees where necessary to provide greater sunlight to ground vegetation. Monitor ravine and stream bank for worsening erosion.

Conceptual Cost Estimate (Planning and Implementation)

$20,000, assuming that tree thinning will be required in some areas.

4.1.1.14 Site 14

Site Description

This site consists of a very large slope failure on the west valley wall, directly north of Site 13. The failure is approximately 300-feet across. Wet soils on the lower part of the failure indicate that groundwater probably plays a role in this failure. The upper vertical bank is comprised of very dense sandy clay. Timber debris and sand from the failure has accumulated at a bend in Bluff Creek (see Figure 4.28 and Figure 4.29).

Figure 4.28 Large slope failure with wet soils on lower area and dense sandy clay soils on upper bank (Site 14)

Figure 4.29 Timber debris and sand deposit at channel bend (Site 14)

Recommendation

Review watershed drainage and groundwater seepage to determine cause of failure. Control groundwater seepage, in the form of horizontal or toe drains, if necessary. Stabilize upper vertical bank and revegetate entire slope with native vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$460,000

4.1.1.15 Site 15

Site Description

Site 15 consists of an approximately 1,000-foot long ravine on the east side of the valley with severe erosion in the form of slope failures along the ravine. The ravine originates at the southwest perimeter of the Bluff Creek golf course and conveys local drainage from the golf course. The head of the ravine is split, and each side is advancing into the golf course. A new 12-inch plastic drain pipe has been installed in the east branch of the split in an attempt to curb the erosion, with fill and geotextile placed in the eroded ravine. A gully has formed in the fill material, however. A path crosses the ravine with a bridge, but the bridge abutments will soon be affected by the erosion. The lower part of the ravine is older and more stable, with a well-developed channel carrying flow to Bluff Creek (see Figure 4.30 and Figure 4.31).

Figure 4.30 Looking down the ravine from golf cart bridge (Site 15)

Figure 4.31 New pipe outlet from golf course (Site 15)

Recommendation

Review drainage and groundwater seepage of ravine to determine cause of erosion. Work with golf course to develop alternative runoff management, such as infiltration or extended stormwater detention. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation. Provide grade control and energy dissipation in ravine. Control groundwater seepage if necessary. Grade eroding banks and revegetate with native vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$520,000

4.1.1.16 Site 16

Site Description

This site consists of a large slope failure on the east valley wall. The failure is approximately 200-feet across and 80-feet high. Groundwater probably plays a role in this failure. The upper vertical bank is comprised of very dense sandy clay. This site is near the west perimeter of the golf course, and an abandoned drain pipe is evident at the top of the ravine (see Figure 4.32 and Figure 4.33).

Figure 4.32 Large slope failure with wet Soils on Lower Area and dense sandy clay soils on upper bank. (Site 16)

Figure 4.33 Upper vertical bank with dense clayey sand or soft sandstone (Site 16)

Recommendation

Review watershed drainage and groundwater seepage to determine cause of failure. Divert/infiltrate runoff and control groundwater seepage if necessary. Stabilize upper vertical bank and revegetate entire slope with native vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$400,000

4.1.1.17 Site 17

Site Description

Site 17 consists of an approximately 380-foot long ravine on the east side of the valley with moderate erosion. The head of the ravine originates at the same hobby farm as site 13, with yard waste present. Some headcutting is evident, especially near the top and bottom of the ravine. The middle portion is relatively stable (see Figure 4.34 and Figure 4.35).

Figure 4.34 Some headcutting present at the head of the ravine (Site 17)

Figure 4.35 Stable middle portion of ravine (Site 17)

Recommendation

Review drainage hydrology of ravine to determine if improvements can be made. Address dumping problem with resident. Provide grade control to reduce headcutting. Evaluate existing vegetation and thin trees where necessary to provide greater sunlight to ground vegetation. Stabilize headcut areas. Monitor ravine and stream bank for worsening erosion.

Conceptual Cost Estimate

$50,000 (includes 30% engineering, legal, and administration, and 20% contingency).

4.1.1.18 Site 18

Site Description

Site 18 consists of an approximately 1,000-foot long ravine on the east side of the valley with severe erosion in the form of slope failures and a 10 to 15-foot deep headcut approximately 40 yards up the ravine from Bluff Creek. The ravine originates at the west side of the Bluff Creek golf course and conveys local drainage. Portions of the ravine are older, with vegetation present on the bottom and side slopes. Groundwater seepage may play a role in the frequent slope failures, or they may occur following significant flood events. There is another nearby slope failure about 150 feet north of this ravine. Stabilization of this failure could be accomplished at the same time (see Figure 4.36 and Figure 4.37).

Figure 4.36 Looking down the ravine from golf cart bridge (Site 18)

Figure 4.37 Pipe outlet from golf course (Site 18)

Recommendation

Review drainage and groundwater seepage of ravine to determine cause of erosion. Work with golf course to develop alternative runoff management, such as infiltration or extended detention. Evaluate existing vegetation and thin trees where possible to provide greater sunlight to ground vegetation. Provide grade control and energy dissipation in ravine. Control groundwater seepage if necessary. Grade eroding banks and revegetate with native vegetation.

Conceptual Cost Estimate (Planning and Implementation)

$520,000

4.1.1.19 Site 19

Site Description

Site 19 consists of an approximately 250-foot long ravine on the west side of the valley with moderate erosion. The head of the ravine originates at the same hobby farm as site 13, with brushy debris at the head of the ravine. A slope failure also exists near the head of the ravine (see Figure 4.38).

Figure 4.38 Slope failure near head of ravine (Site 19)

Recommendation

Review drainage hydrology of ravine to determine if improvements can be made. Address dumping problem with owner. Provide grade control to reduce headcutting. Evaluate existing vegetation and thin trees where necessary to provide greater sunlight to ground vegetation. Stabilize slope failure. Monitor ravine for worsening erosion.

Conceptual Cost Estimate (Planning and Implementation)

$30,000, assuming that tree thinning will be required in some areas.

4.1.1.20 Site 20

Site Description

This site consists of an approximately 400-foot long reach of Bluff Creek having severe bank erosion. The erosion is occurring primarily on the east side of the valley wall where the stream abuts it. The stream is highly meandering in this reach, with some downed timber which tends to exacerbate the problem (see Figure 4.39).

Figure 4.39 Bank erosion on outside of bend (Site 20)

Recommendation

Access is difficult to this reach, making construction difficult. Reach is more likely to self-stabilize if vegetation is managed. Trees should be thinned to provide greater sunlight to ground vegetation. Erosion should be monitored to determine whether condition is worsening.

Conceptual Cost Estimate (Planning and Implementation)

$20,000, assuming that tree thinning will be required in some areas.

4.1.1.21 Site 21

Site Description

Site 21 consists of an approximately 725-foot long ravine on the west side of the valley with minor to moderate erosion. The lower half of the ravine has moderate erosion, while the upper half has minor erosion. Highway 212 construction altered the natural drainage to the head of the ravine. Some headcutting and bank erosion is evident throughout the ravine (see Figure 4.40 and Figure 4.41).

Figure 4.40 Headcutting and slope erosion at head of ravine (Site 21)

Figure 4.41 Highway 212 construction at head of ravine (Site 21)

Recommendation

Review drainage hydrology of ravine to determine how it has changed with Highway 212 construction. Evaluate existing vegetation and thin trees where necessary to provide greater sunlight to ground vegetation. Monitor ravine to see if condition worsens.

Conceptual Cost Estimate (Planning and Implementation)

$20,000, assuming that tree thinning will be required in some areas.

4.1.1.22 Site 22

Site Description

Site consists of two parallel 350-foot long ravines on the west side of the valley near the new Highway 212 construction. The southern ravine has minor erosion (see Figure 4.42) while the northern ravine has moderate erosion. Highway 212 construction reduced the natural drainage area to the ravines, but construction runoff had previously resulted in a gully forming at the head of the north ravine in the summer of 2007.

Figure 4.42 Minor erosion at southern ravine (Site 22)

Recommendation

Review drainage hydrology of ravines to determine how they are affected by Highway 212 construction. Evaluate existing vegetation and thin trees where necessary to provide greater sunlight to ground vegetation. Monitor ravines to see if condition worsens.

Conceptual Cost Estimate (Planning and Implementation)

$20,000, assuming that tree thinning would be required in some areas.

4.1.1.23 Stream Stabilization

Description

The Bluff Creek stream channel itself was re-examined for unstable areas during the spring of 2013. Much of the lower reach of the stream was observed to be stable, although some segments of downcutting and bank erosion were observed, including 18 main channel scarps were that were identified (and indicated by site number 23 on Figure 4.1). Main channel scarps (such as the example site shown in Figure 4.43) represent a significant source of sediment since the Bluff Creek flow is actively eroding higher banks (typically between 10 to 40 feet high) located outside of the natural floodplain (where bank heights are typically less than 10 feet).

Figure 4.43 Example of main channel scarp along Bluff Creek

Recommendation

It is recommended that a more detailed survey be performed of the stream itself, with a survey of the thalweg profile and periodic cross-sections. Several cross-sections were surveyed in 1997 and those cross-sections should be re-surveyed for comparison. This survey should be performed during leaf-off season so that GPS readings can be recorded. It is expected that, at a minimum, erosion from main channel scarps will need to be addressed by re-grading the slope, stabilizing with native vegetation and/or diverting the stream away from the toe of the slope.

Conceptual Cost Estimate (Planning and Implementation)

For cost estimating purposes, a placeholder cost of $1,000,000 was assigned for stream stabilization activities and a cost estimate of $50,000 was assigned for the detailed stream survey.

4.1.2 Terrain Analysis

A terrain analysis was conducted for each of the ravines through the calculation of the Stream Power Index (SPI) to further assess the erosion potential for each ravine. The SPI is a function of both slope and tributary flow accumulation values, which can be thought of as the volume of water flowing to a particular point on the ground. The SPI represents the ability of intermittent overland flow to create erosion, but the SPI values are not differentiated based on soil types or land cover effects on runoff volume or erosion. SPI values were calculated for every 100 ft^2 of the Bluff Creek watershed. The top 5 % of values are displayed in Figure 4.44 along with the peak SPI value and location for each of the ravine watersheds. For example, the ravine in Subwatershed 18 has the highest peak SPI value of 6.92 and, based on our field evaluation of the magnitude and extent of erosion, should be one of the first sites stabilized in the future.

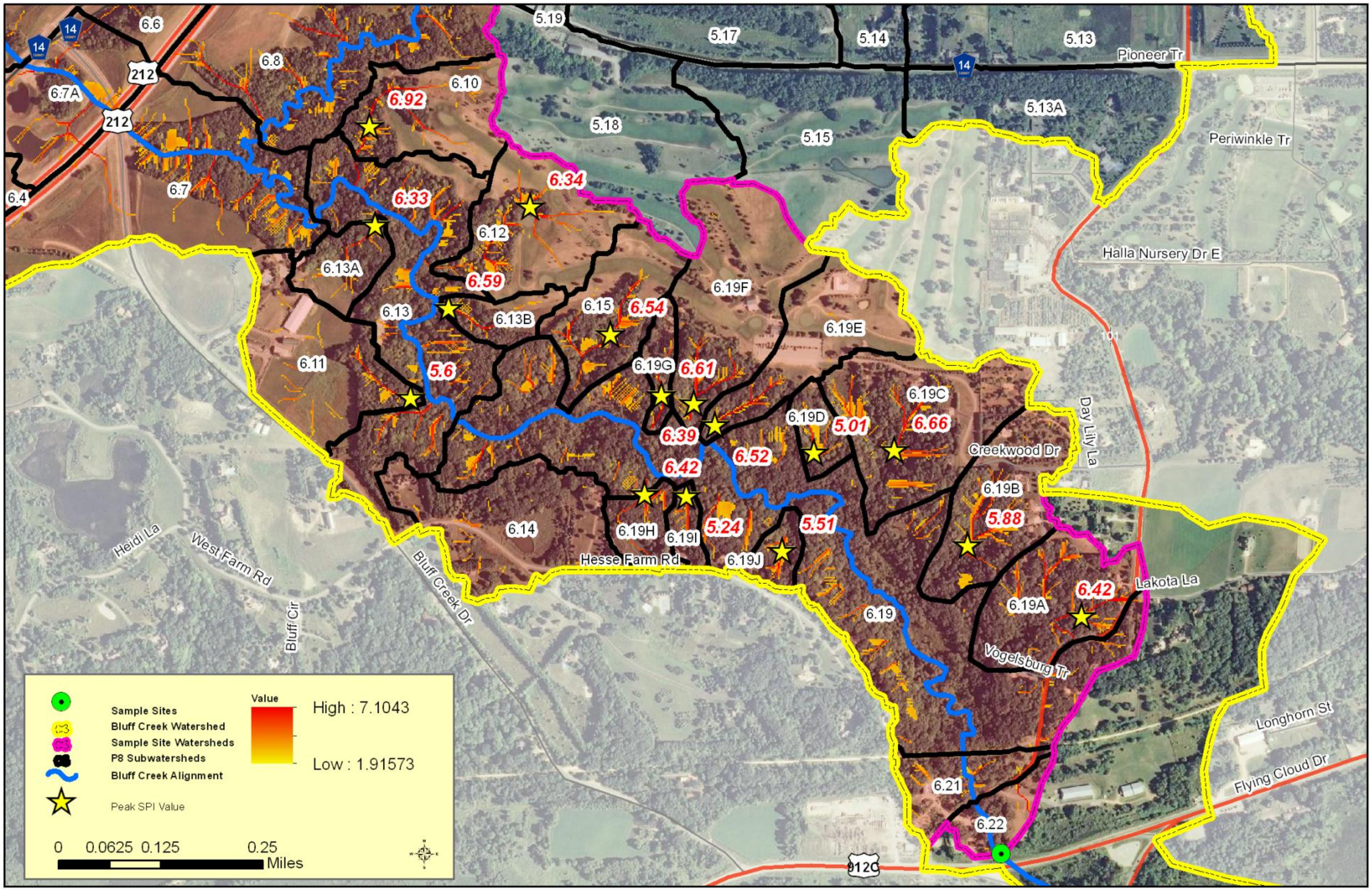

Figure 4.44 Bluff Creek terrain analysis. Figure displays subwatershed IDs (black text) and peak SPI locations and values (red text) for each watershed.

4.1.3 Combined Analysis

The terrain analysis, erosion survey and P8 modeling results were combined to help assess each of the ravines in the lower reach of Bluff Creek. Table 4.1 shows the results including: the ravine erosion classification displayed in Figure 4.1; annual peak flow, runoff volume and number of events modeled in a year that produced runoff volume >= 0.01 acre-ft obtained from the P8 model discussed in section 2.4; and the max SPI value and average of the top 5 % SPI values (Figure 4.44) for each of the ravine watersheds obtained through the terrain analysis.

Table 4.1 Combined ravine erosion analysis

P8 watershed	Erosion Site Number	Ravine Erosion Classification	1990 - 2008 P8 Model			Terrain Analysis	
			Peak Flow (cfs)	Total Annual Runoff Volume (acre-ft)	Runoff Events[1] (#)	Max SPI	Average SPI
6.19D	--*	Stable	1.7	0.18	1	5.01	2.69
6.19H	9	Minor	2.0	0.26	1	6.42	3.38
6.19I	8	Minor	1.0	0.12	1	5.24	3.52
6.19J	5	Minor	1.4	0.21	1	5.51	3.28
6.13B	--*	Minor	2.2	0.51	6	6.59	3.29
6.19B	3	Moderate	8.1	2.37	21	5.88	2.98
6.19C	4	Moderate	11.3	3.41	24	6.66	3.05
6.13A	17	Moderate	2.6	0.30	1	6.33	3.21
6.11	13	Moderate	10.3	4.49	27	5.6	2.87
6.15	12	Severe/Minor	6.2	1.66	18	6.54	3.2
6.19A	2	Severe	6.9	1.55	17	6.42	3.49
6.19E	6	Severe	11.0	4.24	26	6.52	3.55
6.19F	7	Severe	13.2	5.50	27	6.39	3.43
6.19G	10	Severe	1.6	0.22	1	6.61	4.03
6.12	15	Severe	8.0	2.80	24	6.34	3.05
6.10	18	Severe	6.8	1.29	11	6.92	3.5

[1]Number of events with a modeled runoff volume >= 0.01 acre-ft
*Stable/Minor erosion: detailed erosion analysis/cost estimate not conducted

The results in this table were grouped in Figure 4.45. Figure 4.45 shows the relationship between the average SPI and the modeled peak flow rate between 1990 and 2008 grouped by ravine erosion severity. On average, ravines with low modeled peak runoff rates were surveyed as having either stable or minor erosion. Ravines with a higher Stream Power Index showed minor erosion when compared to the stable ravines. Ravines surveyed with moderate erosion displayed higher average modeled peak flow rates with comparable SPI values than both ravines with minor or stable erosion. On average, ravines surveyed as having severe erosion had both higher SPI values and modeled peak flow rates than the ravines surveyed with minor or stable erosion and higher SPI values than those surveyed as having moderate erosion. The results show the importance of minimizing flow volume and runoff rates within the areas tributary to each ravine. It is expected that peak flow rates will need to be comparable to those observed in the stable channels or channels with minor erosion to ensure that stabilized ravine channels will not contribute excess sediment to Bluff Creek.

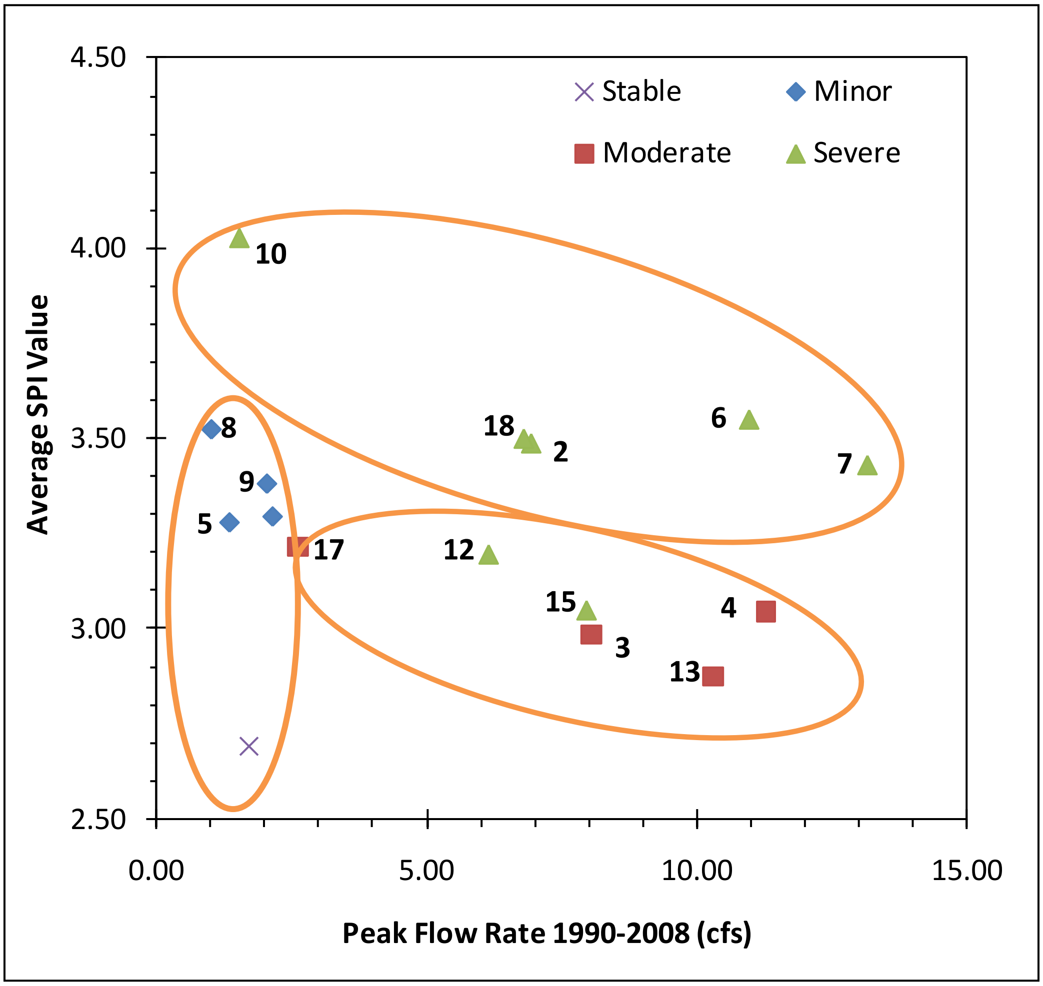

Figure 4.45 Ravine stability comparison between the modeled peak flow rates in each ravine and the average of the top 5% SPI values shown in Table 4.1.

4.1.4 Implementation Priority Ranking

Using the results from Figure 4.45 and the severity rankings from the erosion survey implementation sites were grouped into three priority rankings. Priority 1 sites include the 5 ravines located in the severe grouping in Figure 4.45 plus the two sites with severe slope failure and bank erosion. Priority 2 sites include 4 moderate erosion and 2 severe erosion ravines located in the moderate grouping in Figure 4.45, the three moderate erosion slope failure and bank erosion sites listed along with the stream stabilization along with entire lower reach. The remaining sites listed as having minor erosion were listed as Priority 3. Based on based on the field evaluation (conducted in the spring of 2013) of the magnitude and extent of active erosion, erosion site #15 was included with the Priority 1 sites. Table 4.2 lists all of the erosion sites (based on erosion survey site numbers contained in Figure 4.1) grouped by priority and includes cost information for each site. Implementation of all feasible options for reducing nonpoint sources of sediment to the stream and design and construction of a ramp to allow fish passage at the regional crossing trail culvert is estimated to cost approximately $5.82 million. The implementation of only priority 1 sites would cost $3.56 million, priority 2 sites would cost $2.15 million and priority 3 sites would cost $110,000. Of the total costs shown in Table 4.2, it is estimated that 15% of the cost will be expended to address permitted stormwater runoff, while the remainder will be spent to address nonpermitted stormwater runoff.

4.1.5 Implementation of Other BMPs for Municipal Stormwater

To meet the MS4 WLAs, municipal stormwater activities are required to meet the conditions of the Municipal Separate Storm Sewer Systems (MS4) General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit. This is accomplished by management of MS4s through a Storm Water Pollution Prevention Program (SWPPP) instituted by each of the permittees. Each SWPPP must be designed and managed to reduce the discharge of pollutants to the maximum extent practicable, with BMPs intended to address each one of the six minimum control measures included in the general permit. The MS4 General Permit requires Permittees to establish a schedule at the time of application for the implementation of BMPs that demonstrates progress toward meeting all applicable WLAs. This includes the actions to be completed each year and the dates for their implementation. Annual reports submitted to the MPCA in June of each year will also provide a cumulative estimate of the progress each Permittee has made in reducing their loading, consistent with the WLA(s). To prevent the current biological (fish) and turbidity impairments from worsening with future development or redevelopment, stormwater runoff BMPs (rainwater gardens, infiltration and/or detention basins) should be implemented both in the upper watershed and headwater locations to ravine sources to mitigate anthropogenic flow increases now and in the future.

Table 4.2 Implementation project site data and estimated costs for Bluff Creek restoration activities.

Cost Item/ Erosion Site #	Activity	Grade	Priority/Scheduling	Estimated Cost[1]	Responsible MS4s
A	Water Quality Monitoring	--	1	$30,000	City of Chanhassen
B	Stream Channel/Erosion Rate Survey	--	1	$50,000	City of Chanhassen
C	Localized Runoff Evaluation	--	1	$20,000	City of Chanhassen
23	Stream Scarp Stabilization	Severe	1	$1,000,000	All MS4s
1	Bank Repair/Culvert Restoration	Severe	1	$130,000	City of Chanhassen
15	Ravine Stabilization/Runoff Controls[2]	Severe	1	$520,000	City of Chanhassen
18	Ravine Stabilization/Runoff Controls[2]	Severe	1	$520,000	City of Chanhassen
6	Ravine Stabilization/Runoff Controls[2]	Severe	1	$300,000	City of Chanhassen
10	Ravine Stabilization/Runoff Controls[2]	Severe	1	$220,000	City of Chanhassen
7	Ravine Stabilization/Runoff Controls[2]	Severe	1	$370,000	City of Chanhassen
2	Ravine Stabilization/Runoff Controls[2]	Severe	1	$400,000	Chanhassen, MnDOT
14	Slope Stabilization	Severe	2	$460,000	City of Chanhassen
12	Ravine Stabilization/Runoff Controls[2]	Severe/Minor	2	$350,000	City of Chanhassen
20	Bank Stabilization	Moderate	2	$20,000	City of Chanhassen
3	Ravine Stabilization/Runoff Controls[2]	Moderate	2	$240,000	City of Chanhassen
4	Ravine Stabilization/Runoff Controls[2]	Moderate	2	$290,000	City of Chanhassen
11	Slope Stabilization	Moderate	2	$290,000	City of Chanhassen
13	Ravine Stabilization	Moderate	2	$20,000	City of Chanhassen
16	Slope Stabilization	Moderate	2	$400,000	City of Chanhassen
17	Ravine Stabilization	Moderate	2	$50,000	City of Chanhassen
19	Ravine Stabilization	Moderate	2	$30,000	City of Chanhassen
21	Ravine Stabilization	Moderate/Minor	3	$20,000	Chanhassen, MnDOT
22	Ravine Stabilization	Moderate/Minor	3	$20,000	Chanhassen, MnDOT
5	Ravine Stabilization	Minor	3	$30,000	City of Chanhassen
8	Ravine Stabilization	Minor	3	$20,000	City of Chanhassen
9	Ravine Stabilization	Minor	3	$20,000	City of Chanhassen
			GRAND TOTAL	**$5,820,000**	

[1]Construction costs include planning/implementation (mobilization, engineering/design, contingencies); easement costs not included
[2]Construction costs include cost to implement stormwater runoff BMPs (rainwater gardens, infiltration and/or detention basins) in headwater locations

For the purposes of this TMDL, 2008 represents the baseline condition that future implementation activities should be measured against. MS4s will be able to take credit for BMPs implemented since the baseline.

As previously discussed, increases in runoff volume and peak flow associated with conversion of natural land cover and increased density of development lead to a shift in the flow duration characteristics, which in turn, correspond with higher rates of sediment delivery capacity in the stream that contributes to bank, bluff, ravine and gully erosion and represents a significant stressor to aquatic life in Bluff Creek.

The Minnesota Stormwater Manual (MPCA, 2008) provides guidance on key factors to consider in the selection of the appropriate BMPs for implementation within the urbanized areas of the basin and provides guidance on better site design/low impact development that is intended to reduce impervious cover (and runoff volumes), conserve natural areas and more effectively treat stormwater runoff. It is recommended that infiltration practices (rainwater gardens, infiltration basins, swales, etc.) and improved site design be used to mitigate the impacts of future watershed development. The Minnesota Stormwater Manual can be found at http://stormwater.pca.state.mn.us/index.php/Stormwater_Manual_Table_of_Contents.

4.2 Construction Stormwater Implementation

The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites ≥ 1 acre expected to be active in the watershed at any one time, and the Best Management Practices (BMPs) and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at construction sites are defined in the State's NPDES/SDS General Stormwater Permit for Construction Activity (MNR100001). If a construction site owner/operator obtains coverage under the NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, including those related to impaired waters discharges and any applicable additional requirements found in Appendix A of the Construction General Permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local construction stormwater requirements must also be met.

4.3 Industrial Stormwater Implementation

The wasteload allocation for stormwater discharges from sites where there is industrial activity reflects the approximate area in the watershed for which NPDES industrial stormwater permit coverage may be required, and the BMPs and other stormwater control measures that should be implemented at the sites to limit the discharge of pollutants of concern. The BMPs and other stormwater control measures that should be implemented at the industrial sites are defined in the State's NPDES/SDS Industrial Stormwater Multi-Sector General Permit (MNR050000) or NPDES/SDS General Permit for Construction Sand & Gravel, Rock Quarrying and Hot Mix Asphalt Production facilities (MNG490000). If a facility owner/operator obtains coverage under the appropriate NPDES/SDS General Stormwater Permit and properly selects, installs and maintains all BMPs required under the permit, the stormwater discharges would be expected to be consistent with the WLA in this TMDL. It should be noted that all local stormwater management requirements must also be met.

4.4 Implementation Schedule

Priority 1 sites will be addressed first followed by Priority 2 and then finally, Priority 3 sites. As the sites are remediated the continued monitoring effort discussed in Section 4.5 will be used to determine if further turbidity reduction is needed before advancing to the next priority group.

4.5 Monitoring

The goals of this monitoring program are generally to both evaluate progress towards the water quality and biotic targets provided in the TMDL and to inform and guide implementation activities discussed in this plan. The impaired water body will remain listed until water quality standards and biotic integrity are met. Monitoring will primarily be conducted by local staff.

4.5.1 Turbidity

At a minimum monitoring will be continued at the Bluff Creek WOMP (MCES BL 3.5) site for assessment/study purposes. This monitoring will occur during the open water season and at a frequency and timing similar to previous turbidity assessment monitoring. This site is currently being monitored by the Metropolitan Council through their WOMP program. In addition to turbidity, other parameters including TSS, total suspended volatile solids and chlorophyll-*a* will be analyzed by Metropolitan Council in samples to evaluate mineral versus algal sources of suspended solids, which will better target implementation efforts. Future monitoring results should be summarized on a flow and water quality duration curve basis to allow for interpretation of the influence from climatic variations.

The RPBCWD conducted water quality monitoring at two Bluff Creek sites in 2012 and will continue water quality monitoring in 2013 (and the foreseeable future) at three Bluff Creek sites. The three monitoring sites are located at the Coulter Blvd./Stone Creek Dr. (B1), Bluff Creek Blvd./River Rock Dr. (B2) and the Pioneer Trail (B3) crossings of Bluff Creek. The monitoring will consist of grab samples collected twice per month and analyzed for total phosphorus, dissolved oxygen, ORP (oxidation reduction potential), pH, specific conductivity, temperature, transparency tube, turbidity and total suspended solids, in addition to instantaneous stream velocity/discharge measurements. Fish and macro-invertebrate sampling and analysis have also been conducted at the B2 site.

It is also recommended that future monitoring efforts include a recurrence of the flow and turbidity monitoring that was conducted at the Pioneer Trail crossing of Bluff Creek in 2008 as a part of the TMDL study. The results of this monitoring will continue to allow for upper watershed sources of sediment to be differentiated from lower valley runoff and erosion. The estimated cost for the first year of this water quality monitoring is included in Item A of Table 4.2.

4.5.2 Metals and Biological Monitoring

Paired biological (fish and invertebrates) and metals monitoring using “clean hands/dirty hands” methodology for sampling and analysis will occur at the Bluff Creek WOMP (MCES BL 3.5) site to confirm metals contamination. It is recommended that biological samples (fish and invertebrates) also be collected at Stations B-1, 00MN009, and 00MN008 to confirm adverse impacts of metals contamination on Bluff Creek biota.

4.5.3 Geomorphology

This implementation plan and a 2007 report (Barr Engineering Company, 2007), detailing streambank and ravine erosion, recommend that the severe and moderate erosion sites be stabilized and revegetated, with the role of groundwater evaluated and addressed at each site as necessary. Vegetation management is recommended throughout the lower valley. Improving sunlight penetration to the lower plant story will improve ground cover and provide greater resistance to future erosion.

If stabilization of the erosion sites is not undertaken immediately, they should be monitored to determine the rate of erosion. This could be accomplished by establishing benchmarks and performing high-definition laser scanning of severe erosion sites, which would be difficult to survey using traditional methods. The survey should be repeated every 2 to 3 years or following severe runoff events. Monitoring the sites over a period of years will provide a better picture of which erosion sites are most active. The estimated cost for surveying two sites with severe erosion is included in Item B of Table 4.2. In addition, a geotechnical investigation should be performed to gain insight into the role soils and groundwater play in the erosion processes. Finally, a more detailed investigation of local runoff rates, available storage and stormwater conveyances to the ravines should be performed to determine if upland best management practices can be implemented to reduce the rate of runoff and likelihood of erosion in the ravines. The estimated cost for evaluating localized runoff, storage and stormwater conveyances tributary to ravines is included in Item C of Table 4.2.

Much of the stream itself was observed to be stable, although some reaches of down cutting and bank erosion were observed. It is recommended that a more detailed survey of the stream itself, with a survey of the thalweg profile and periodic cross-sections. Several cross-sections were surveyed in 1997 and those cross-sections should be re-surveyed early in the implementation schedule for comparison and to establish a baseline measure of stream stability. This survey should be performed during leaf-off season so that GPS readings can be recorded. The estimated cost for the stream channel survey is included in Item B of Table 4.2.

4.6 Adaptive Management

An adaptive management approach will be implemented to assess the impact each of the implementation actions are having on the turbidity levels in Bluff Creek. An adaptive management plan includes continued water quality monitoring as each of the improvements are implemented. Items will be conducted based on the priority outlined in section 4.3. If water quality is shown to improve it is suggested that the approach is working and the implementation will continue. However if water quality is not shown to improve the approach will be evaluated and adjusted in order to meet the required water quality levels.

4.7 Reasonable Assurance

When establishing a TMDL, reasonable assurances must be provided demonstrating the ability to reach and maintain water quality endpoints. Several factors control reasonable assurances including a thorough knowledge of the ability to implement BMPs, the state and local authority to implement, as well as the overall effectiveness of the BMPs. The explicit margin of safety applied to this TMDL, at all portions of the flow regime, also provides reasonable assurance that the standards will be met with the allocated loadings.

The ultimate goal of the Implementation Plan is to achieve the identified load reductions in Bluff Creek needed to reach the State Standard for turbidity. The following should be considered as reasonable assurance that implementation will occur and result in sediment load reductions in the listed waters toward meeting their designated uses:

- Monitoring will be conducted to track progress and suggest adjustment in the implementation approach.

- Watershed management standards and specifications are in place for the common elements relating to watershed resource management (e.g. water quantity, water quality, erosion and sediment control, wetland protection, financing, regulatory responsibility and public education) in various local plans. Water management requirements are contained in the City of Chanhassen's Surface Water Management Plan, the RPBCWD Watershed Management Plan, the Carver County Water Plan, and the City of Chaska's Comprehensive Plan.

- Regulated MS4s (Mn/DOT, Chanhassen, Chaska, Carver County) must determine whether they are currently meeting their WLA(s). If any WLA is not being met at the time of application for permit coverage, a list of BMPs, included as part of a compliance schedule must accompany their application for coverage under the MS4 General Permit. This includes the BMPs to be implemented in the current five-year permit term as well as dates for their implementation. Additionally, annual reports to the MPCA will include an estimation of cumulative progress made by each MS4 toward achieving their WLA(s). Compliance will be evaluated by the MPCA based on the implementation of all conditions of the MS4 General Permit, including any compliance schedules.

- Local units of government associated with Bluff Creek are committed to implementing actions to address stressors to fish biota such as habitat fragmentation and stormwater flow.

4.8 Education and Outreach

The City of Chanhassen provides educational and outreach opportunities to various audiences on a wide variety of stormwater management and water quality issues. The City has a Memorandum of Understanding with Carver County WMO for educational resources and outreach. Current opportunities include rain garden workshops, classes on landscaping, tree management among others. The City provides a water quality hotline that residents can call to obtain information on surface water projects as well as ask surface water related questions. The RPBCWD also conducts educational activities for watershed residents and businesses.

4.9 Public Participation

Over the course of this project a variety of stakeholder participation and outreach efforts have been conducted. To-date, three stakeholder meetings have been conducted to discuss the project work plan and schedule, watershed monitoring and data collection activities, review and comment on the development of the Stressor Identification report, preliminary results of water quality monitoring and pollutant allocations and TMDL implementation strategies. Stakeholder participants at the meetings included representatives from the following entities:

- City of Chanhassen
- Minnesota Pollution Control Agency
- Minnesota Department of Natural Resources
- Minnesota Department of Transportation
- Minnesota Board of Water and Soil Resources
- Metropolitan Council
- Carver County
- Lower Minnesota River Watershed District
- Riley-Purgatory-Bluff Creek Watershed District
- City of Chaska
- City of Eden Prairie

4.10 Interim Milestones

It can take many years for stream systems to respond to sediment load reduction and stormwater runoff control activities in the watershed. Interim measures will need to be implemented to assess the progress toward achieving the water quality standards and restoration of biotic integrity. These activities could include:

- Tracking of new BMPs retrofit into the watershed, including the number, types, and estimated load reduction for each
- Tracking of redevelopment projects within the watershed that could incorporate new or oversized BMPs, including the types and estimated load reductions for each
- Tracking of the participation of private property owners in existing programs to implement rainwater gardens, native creek buffers, etc. including their location and type of project implemented
- Documentation of new or modified educational materials and activities that address sediment management and control of stormwater runoff

These milestones will provide information that documents the progress being made to achieve the TMDL even when water quality improvement is not yet observed in the creek. The water quality monitoring program for this *TMDL Implementation Plan* is discussed in Section 4.5.

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