Bluff Creek Watershed

Total Maximum Daily Load Report: Turbidity and Fish Bioassessment Impairments

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Prepared for
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Table of Contents

List of Tables

List of Figures

List of Appendices

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 Systems
NA	not applicable
NLCD	National Land Cover Database
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

TMDL SUMMARY

EPA/MPCA Required Elements	Summary	TMDL Page #
Location	Bluff Creek watershed; South Central Minnesota; Carver County; Minnesota River Basin	5
303(d) Listing Information	1 listing for turbidity, and 1 listing for Fish bioassessment impairments; *see Table 1.1*	2
Applicable Water Quality Standards/ Numeric Targets	*See Section 2.1*	3
Loading Capacity (expressed as daily load)	*See Section 3.4.2*	28
Wasteload Allocation	*See Section 3.4.2*	28
Load Allocation	*See Section 3.4.2*	28
Margin of Safety	Explicit MOS of ten percent used; *see Section 3.3.2*	23
Seasonal Variation	Load duration curve methodology accounts for seasonal variation; *see Section 3.6*	35
Reasonable Assurance	NPDES permits provide assurance for permitted stormwater sources to comply with WLAs. *see Section 8.0.*	61
Monitoring	A general overview of follow-up monitoring is included; *see Section 5.0.*	42
Implementation	A discussion of factors to consider for implementation is provided, as well as a rough approximation of the overall implementation cost to achieve the TMDL. (A separate more detailed implementation plan will be developed at a later date.) *See Section 7.0.*	51
Public Participation	Various public participation and outreach efforts were conducted; *see Section 9.0.*	63

Executive Summary

The Clean Water Act, Section 303(d), requires that every two years states publish a list of waters that do not meet water quality standards and do not support their designated uses. These waters are then considered to be "impaired". Once a waterbody is placed on the impaired waters list, a Total Maximum Daily Load (TMDL) must be developed. The TMDL provides a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards. It is the sum of the individual wasteload allocations (WLAs) for point or permitted sources, load allocations (LAs) for nonpoint or nonpermitted sources and natural background, plus a margin of safety (MOS). Bluff creek is listed by the Minnesota Pollution Control Agency (MPCA) as impaired for aquatic life use due to excess turbidity levels and low fish biota scores. The Bluff Creek TMDL Biological Stressor Identification Report (http://www.pca.state.mn.us/index.php/view-document.html?gid=13751) identified sediment, metals, habitat fragmentation, and flow as stressors to fish biota (Section 4 and Appendix D). Although this TMDL Report discusses all of these stressors, the TMDL equation is only written for total suspended solids (TSS) which represents a surrogate for both turbidity and fish biota.

Bluff Creek is a small tributary of the Lower Minnesota River. The stream begins at the headwaters located near Trunk Highway 41 on the north and discharges into the Minnesota River Floodplain. The catchment area at the confluence of Bluff Creek with Rice Lake is 5.8 square miles, the total length of the main stem is 6.8 miles, the mean stream slope varies between 0.08 percent and 0.70 percent, and the creek is moderately to fully entrenched for most of its course. The watershed land uses comprise a mix of agricultural, developed area and undeveloped forested upland and meadow areas. 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. The lower reach of the creek has steep valley walls, is highly sinuous, and lined with trees. About 85 percent of the catchment is covered by high-relief, hummocky glacial deposits of loamy till, with some localized organic deposits of muck.

The turbidity impairment of Bluff Creek was analyzed using a load duration curve methodology. Two sampling stations were used for the analysis: Pioneer Trail Sampling Station, located at Pioneer Trail road (2.25 miles upstream from Rice Lake), with a drainage area of 4.6 square miles was a temporary monitoring station setup to sample during the summer of 2008; WOMP station (BL 3.5), located south of Old Highway 212 (0.75 miles upstream of Rice Lake), with a drainage area of 5.7 square miles is a permanent monitoring station operated by the Metropolitan Council Environmental Services (MCES).

In 2008 the median TSS load for high flow events (0-10% flow duration) at Pioneer trail was 0.18 tons/day. At the Bluff Creek WOMP station the median TSS load was 5.36 tons/day for high flow events for an increase of 5.18 tons/day with only 1.1 square miles of added watershed area. 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.

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). Primary sources contributing TSS within this watershed are stream bank 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.

An inventory and assessment of the Bluff Creek lower valley was completed to identify sites contributing inordinate amounts of sediment to Bluff Creek and to determine feasible options for addressing sources of excess sediment delivery to the stream. Implementation of feasible options for minimizing excess sediment delivery to the stream and design and construction of a ramp to allow fish passage at the regional crossing trail culvert to meet both the turbidity and fish biota impairment in Bluff Creek is estimated to cost between approximately $2.0 million and $4.5 million, not including the cost required to mitigate the impacts of future development in the watershed.

1.0 Introduction

Section 303(d) of the Clean Water Act provides authority for completing Total Maximum Daily Loads (TMDLs) to achieve state water quality standards and designated uses.

A TMDL is a calculation of the maximum amount of pollutant that a waterbody can receive and still meet water quality standards and designated uses. It is the sum of the loads of a single pollutant from all contributing point and nonpoint sources. TMDLs are approved by the U.S. Environmental Protection Agency (EPA) based on the following elements:

1. They are designed to implement applicable water quality criteria;
2. Include a total allowable load as well as individual waste load allocations;
3. Consider the impacts of background pollutant contributions;
4. Consider critical environmental conditions;
5. Consider seasonal environmental variations;
6. Include a margin of safety;
7. Provide opportunity for public participation; and
8. Have a reasonable assurance that the TMDL can be met.

In general, the TMDL is developed according to the following relationship:

$$TMDL = WLA + LA + MOS + RC$$

Where:

WLA = wasteload allocation; the portion of the TMDL allocated to existing or future point (permitted) sources of the relevant pollutant;

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint (non-permitted) sources of the relevant pollutant. The load allocation may also encompass “natural background” contributions;

MOS = margin of safety, or an accounting of uncertainty about the relationship between pollutant loads and receiving water quality. The margin of safety can be provided implicitly through analytical assumptions or explicitly by reserving a portion of loading capacity (USEPA, 1999); and

RC = reserve capacity, an allocation for future growth.

This TMDL report applies to Bluff Creek which is impaired for excess turbidity and fish bioassessments. 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. 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 Index of Biological Integrity (IBI) scores. For the Minnesota River Basin, biological impairment for fish is defined as failing to meet the Minnesota River Assessment Project (MRAP) 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. Both impairments are addressed in this report and displayed in Table 1.1.

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

Reach	Description	Year listed	Assessment Unit ID	Affected Use	Pollutant or Impairment
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

The MPCA projected schedule for Total Maximum Daily Load (TMDL) report completion, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of these TMDLs. The Bluff Creek Watershed TMDL study was scheduled to begin in 2008 and be complete in 2011. Ranking criteria for scheduling TMDL projects include, but are not limited to: impairment impacts on public health and aquatic life; public value of the impaired water resource; likelihood of completing the TMDL in an expedient manner, including a strong base of existing data and restorability of the water body; technical capability and willingness locally to assist with each TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

In this report, the background information relevant to all impairments is provided in Section 2.0, followed by the TMDL technical elements provided in Section 3.0. For follow-up monitoring, implementation, reasonable assurance and public participation all impairments are addressed together in Sections 4.0, 5.0, 7.0 and 8.0. Section 6.0 details a water quality modeling analysis of the Bluff Creek watershed. Appendix A details an analysis using the possible water quality standard change from the current 25 nephelometric turbidity units (NTU) turbidity standard to a 30 mg/L TSS standard.

2.0 Background Information

2.1 Applicable Water Quality Standards

A discussion of water classes in Minnesota and the standards for those classes is provided below in order to define the regulatory context and environmental endpoint of the TMDLs addressed in this report.

All waters of Minnesota are assigned classes based on their suitability for the following beneficial uses:

1. Domestic consumption
2. Aquatic life and recreation
3. Industrial consumption
4. Agriculture and wildlife
5. Aesthetic enjoyment and navigation
6. Other uses
7. Limited resource value

Bluff Creek is not listed in the Minn. Rules Ch. 7050.0470 classification therefore it follows the Minn. Rules Ch. 7050.0430 Unlisted Waters as a classification 2B, 3C, 4A, 5, 6 water. Class 2B waters are defined as:

> **Class 2B waters**. The quality of Class 2B surface waters shall be such as to permit the propagation and maintenance of a healthy community of cool or warm water sport or commercial fish and associated aquatic life and their habitats. These waters shall be suitable for aquatic recreation of all kinds, including bathing, for which the waters may be usable. This class of surface waters is also protected as a source of drinking water.

Turbidity

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. The turbidity standard for Class 2B waters is defined as:

<u>Minn. Rules Ch. 7050.0222, turbidity water quality standard for Class 2B waters</u> is 25 nephelometric turbidity units (NTUs). The designated use that this standard protects is aquatic life. Impairment assessment procedures for turbidity are provided in the guidance manual for determination of impairment (MPCA, 2007a). Essentially, listings occur when greater than ten percent of data points collected within the previous ten-year period exceed the 25 NTU standard (or equivalent values for total suspended solids or transparency tube data).

Fish Bioassessments

Bluff Creek was placed on the list of impaired waters for impaired biota due to low fish Index of Biological Integrity (IBI) scores. For the Minnesota River Basin, biological impairment for fish is defined as failing to meet the MRAP 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. Bluff Creek fish data collected by the Minnesota Department of Natural Resources (MDNR) and the Riley-Purgatory-Bluff Creek Watershed District (RPBCWD) were evaluated to determine the reaches of Bluff Creek that are considered to have impaired fish assemblages. Data were collected by the Minnesota Department of Natural Resources (MDNR) from two locations on July 22, 2000 as a part of a survey to characterize Twin Cities Metro Area streams. Figure 2.1 shows that Station 00MN009 had an IBI score of 21.6 and Station 00MN008 had an IBI score of 31.2, which is above the impairment threshold of 30 or greater (MDNR, 2000), indicating the stream was impaired at the upstream location (00MN009), but was not impaired at the downstream location (00MN008). Data were annually collected by RPBCWD from Station B-1 (Figure 2.1) during 1997 through 2006 to determine the stream's fish assemblage and also to determine whether the District's ecological use goals for the stream had been attained. No fish were observed or collected during the 1997 and 1998 monitoring events, indicating severe impairment. During 1999 through 2006, IBI scores at B-1 were consistently 16.8 (Figure 2.1) and were below the impairment threshold during all 8 sampling years (Barr, 1998, 1999, 2000, 2001, 2002, 2003, 2004, 2005, 2006a, and 2006b). The consistent scores occurred at B-1 because only one or two species of fish were present each year. Brook stickleback was consistently present and northern fathead minnow co-occurred during about half of the events.

The IBI was disaggregated and macroinvertebrate data were assessed to identify more specific effects that appeared to indicate distinctive impairment mechanisms. Specific effects associated with the impairment observed at Stations B-1 and 00MN009 include a low number of native fish species, a high relative abundance of the two most dominant invertebrate taxa, an absence of intolerant invertebrates, and an absence of darters, insectivores, and simple lithophilic spawners. The data indicate environmental degradation has occurred in the impaired reach. The absence of darters and simple lithophilic spawners indicate the impaired stream reach may have habitat deficiencies due to siltation of coarse substrates and excessive sedimentation or due to cold water temperatures. The absence of darters may also indicate a loss of channel complexity from channelization. Because the downstream unimpaired location noted darters, the data either indicate siltation of coarse substrates is not problematic at the downstream location, the downstream channel is more complex, or that another stressor (e.g., habitat fragmentation between the two locations) is the driving force in the fish assemblage.

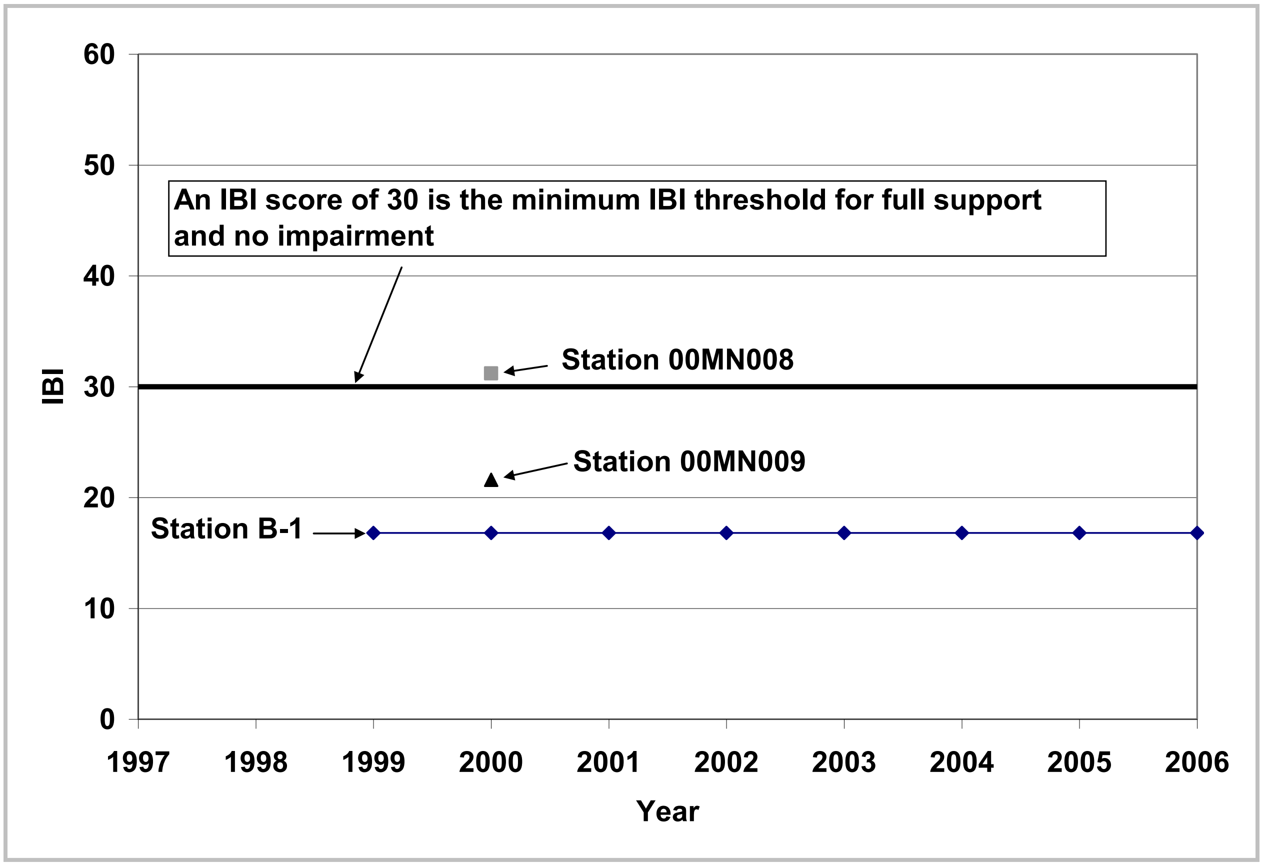

Figure 2.1 1999-2006 Bluff Creek IBI Summary—Stations B-1, 00MN008, and 00MN009

2.2 General Watershed Characteristics

Bluff Creek is a small tributary of the Lower Minnesota River. 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 2.2). 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 comprised of a mix 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. 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, 2007). 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.

Three historic periods can be distinguished based on land use in the Bluff Creek watershed. The first corresponds to pre-European settlement, until the 1850s. Big woods of maple-basswood forest and oak savanna extended across the watershed, and native prairie plants composed the understory vegetation. Magner and Steffen (2001) argue that some stable degree of morphologic equilibrium had been reached in the Minnesota River and tributaries prior to plowing of the prairie. The second period was dominated by the introduction and intensification of agricultural practices, beginning in the 1900s. Consistent with Zimmerman et al. (2003), it is reasonable to hypothesize that as more water and sediment reached the stream, the channel morphology evolved toward a new equilibrium configuration, which may or may not have been attained; cultivation patterns have been switching from field to row crops. The last period corresponds to urban sprawl, beginning in the 1980s. A preliminary analysis of LandSat imagery indicates that the mean percent imperviousness in the Bluff Creek watershed has jumped from 3 percent in 1986 to 15 percent in 2002, with the highest percentage increase between 1991 and 1998. This urban development, which is expected to continue progressing at a rapid pace in the next twenty years, has likely generated another change in the hydrologic and sediment supply boundary conditions of the stream; hence the channel has again begun working toward a new morphologic equilibrium.

With the introduction of agricultural practices at the turn of the last century and later intensification in the Bluff Creek watershed, more sediment and more water reached the stream. The United States Army Corps of Engineers (2004) point out that the prairie and forest vegetation helped to hold soils in place. Moreover, larger evapotranspiration losses and a lower drainage density predicts less volume runoff and smaller peak flows before than after plowing of the prairie. The increase in sediment supply from the upland areas to the stream must have been particularly important after row crop cultivation became more dominant in the watershed, beginning in the 1950s. It is not clear whether the longitudinal profile of Bluff Creek was subject to overall bed aggradation; the increase in sediment supply may or may not have been compensated by the increase in frequency, magnitude, and duration of water discharges above the threshold for fluvial motion of bed material. It is reasonable to expect, however, that the increase in sediment supply caused localized bed aggradation, probably more pronounced in the middle reaches of the creek where the streamwise bed slope is less steep and therefore the sediment transport capacity is smaller, as well as an increase in stream sinuosity, especially in the downstream reach of the creek (Barr Engineering Company, 2007).

It can be assumed that urban development has produced an even bigger increase in frequency, magnitude, and duration of flows, so the positive trend continues. But contrary to what happened until the 1980s, the amount of sediment delivered from the upland areas of the watershed to the stream must have decreased; there is less surface area in the watershed that can be eroded. Put simply, urban sprawl generates more water and less bare soil. Nonetheless, ravine erosion in the highly erodible watershed has increased causing the conveyance of substantial loads of sediment to the stream. The anticipated morphodynamic response to the additional water from urbanization is the overall promotion of channel incision combined with a bigger probability of streambank erosion due to mass-wasting failures, rather than increased fluvial erosion of the channel banks or greater channel migration rates; the ratio of floodprone width to bankfull width is about two for most of the water course. It is not clear whether this in-stream sediment contribution results in an increased sediment transport conveyance along the creek, or if the sediment is deposited within a few feet downstream from its source. Lauer et al. (2006) indicate that eroding banks usually do not contribute sediment such that a net increase in sediment results from the eroding banks on most single-thread rivers, because the channel usually rebuilds a new bank on the opposite side of the channel from the eroding bank. In this regard, point bars are observed in Bluff Creek (Barr Engineering Company, 2007).

A 2007 inventory of Bluff Creek indicated ravine erosion contributes significant quantities of sediment to Bluff Creek annually. Ravine erosion, for the most part, is occurring independently of Bluff Creek, and is due to overland stormwater runoff and/or groundwater seepage. The majority of the ravines with severe or moderate erosion are located after the Pioneer Trail sampling location (Figure 2.2). Much of the stream itself was observed to be stable, although some reaches of downcutting and bank erosion were observed. Nonetheless, ravine erosion within the watershed results in sediment delivery to Bluff Creek and a corresponding degradation of biological habitat.

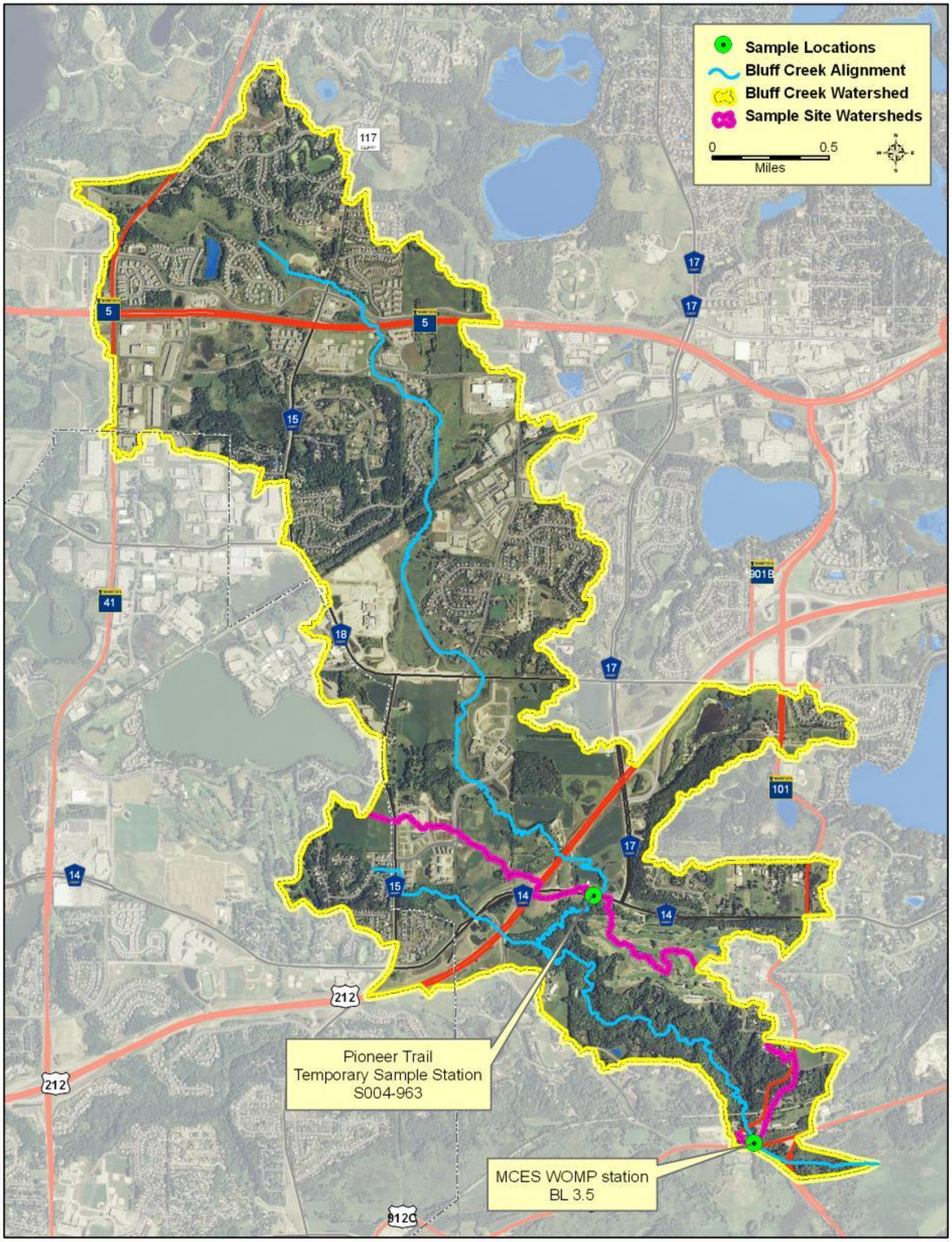

Figure 2.2 Bluff Creek watershed overview

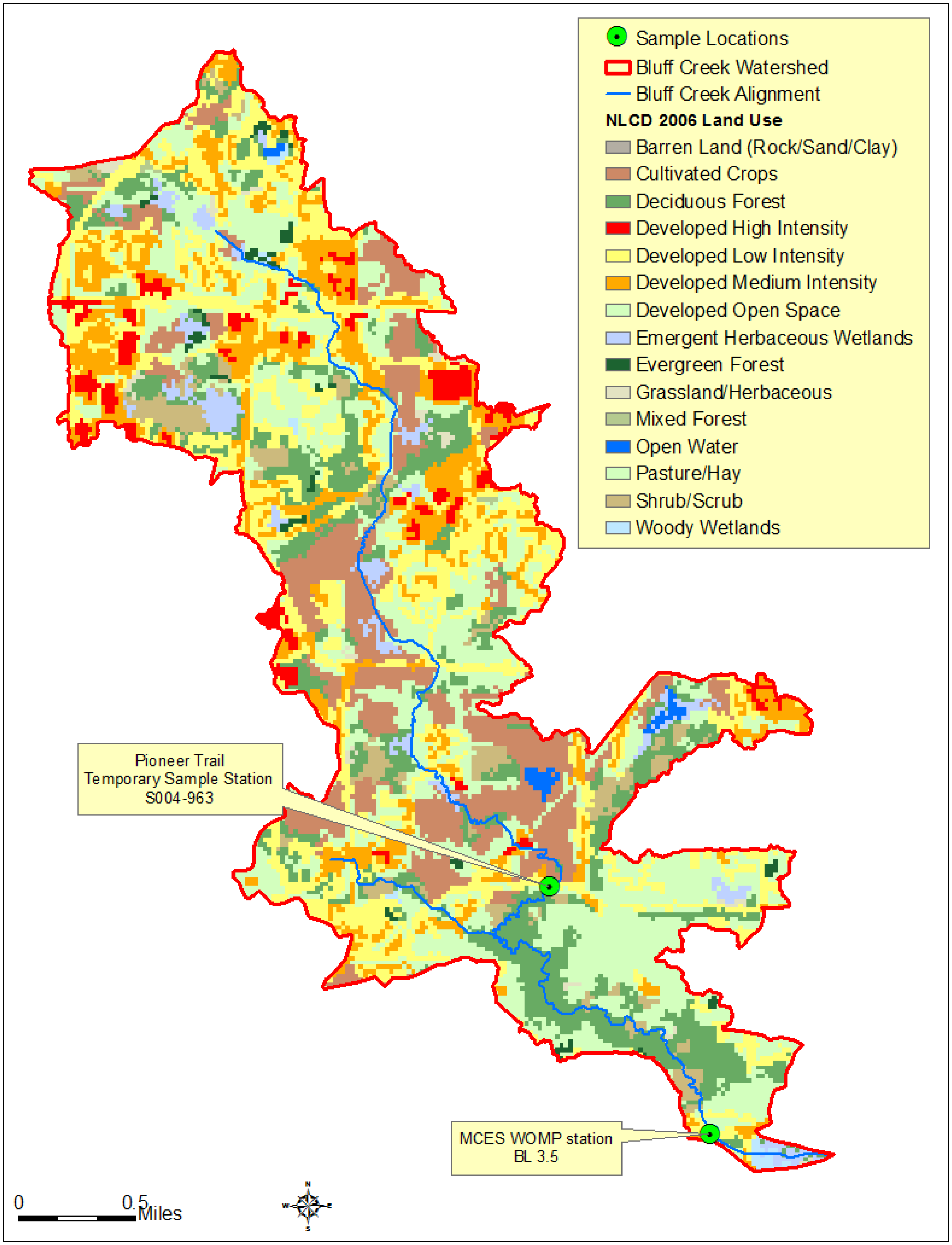

Figure 2.3 Bluff Creek 2006 NLCD Land Use Data

3.0 Turbidity

3.1 Surface Water Quality Conditions

Turbidity in streams is derived from suspended sediments, organic material, dissolved salts and stains. This analysis will focus 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) is used. This parameter shows a good correlation with turbidity, based on regressions done on the monitoring data.

Turbidity is a parameter that has a significant amount of variability associated with the measurement values reported. Unlike many water quality parameters which are a measurement of mass of constituents in a volume of water, turbidity is a measure of the optical properties of a water sample which causes light to be scattered and absorbed (Federal Water Pollution Control Administration, 1968). Differences in the constituents' response to light contribute to the variability in turbidity readings. Adding to this variability, differences between turbidity meter types can result in different turbidity values being measured for the same water samples.

The MPCA's Turbidity TMDL Protocol (MPCA, 2007b) identified the need to use the turbidity reporting units/categories adopted by the United States Geological Survey (USGS) to differentiate data sets by type of turbidity meter. The MPCA began using the reporting categories for data being entered into the EPAs STORET data warehouse in 2005. The protocol identified a list of options/recommendations to use/follow when a project has one or more types of turbidity data. The difficulty of selecting a "method" from this list of options became apparent fairly quickly for various reasons in developing the TMDLs in Minnesota. In the past, water samples had been analyzed by laboratories measuring turbidity as NTU, while more recent samples collected within the Bluff Creek watershed have been analyzed by the Minnesota Department of Health (MDH) Lab measuring turbidity as nephelometric turbidity ratio units (NTRU). Fortunately, both turbidimeters had previously been used to test some of the same samples as part of the Minnesota River Turbidity TMDL project. Appendix B describes and fully documents the statistical relationship between the paired data to provide a "conversion" factor for estimating NTU values from measured NTRU values for use in this project given the absence of paired measurements with each meter.

Water quality duration curves were developed based on continuous turbidity probe measurements at the two stations: Pioneer Trail station, a temporary station only installed in the summer of 2008; and

Bluff Creek WOMP station, a permanent station operated by the MCES. Lab turbidity samples were typically collected at stream monitoring sites coincidental with the continuous turbidity measurements. FTS DTS-12 turbidity probes installed in Bluff Creek recorded turbidity data (in formazin nephelometric units (FNU) units) and stream flow at 15 minute intervals. To compare this turbidity data to the target of 25 NTU, two conversions were used. The pairs of turbidity data where the date and time of an automated, 'continuous' measurement matched the date and time of a sample sent to a laboratory were used to construct a linear FNU – NTU relationship for each of the two sites. When NTRU was measured instead of NTU the relationship detailed in Appendix B was used to convert the measurement to NTU. Individual relationships were developed for both the Pioneer Trail (Figure 3.1) and WOMP station (Figure 3.2) sample locations.

Laboratory TSS measurement were used to create a NTU to TSS relationship. At the WOMP site, grab sample data were available for years 1991 to 2010. At the Pioneer Trail site, grab samples were available only for year 2008. A quadratic log-log equation was developed for both the Pioneer Trail (Figure 3.3) and WOMP (Figure 3.4) sites. Statistical research has shown that a bias is introduced when the retransformation is computed to get TSS from the log-log relationship. Therefore the Duan's Smearing Estimator (Duan, 1983) was calculated for both locations matching the method detailed in Appendix B for the NTRU to NTU conversion. The smearing factor for the Pioneer Trail and WOMP locations were calculated as 1.014 and 1.041 respectively. The final equations used to convert turbidity (NTU) to a TSS concentration (mg/L) are detailed in Equations 3.1 and 3.2 for the Pioneer Trail and WOMP sampling location respectively.

$$TSS\left(\frac{mg}{l}\right) = 10^{-0.885*\log(NTU)^2+3.0632*\log(NTU)-0.6814} * 1.014 \; Eq\ 3.1$$

$$TSS\left(\frac{mg}{l}\right) = 10^{-0.2298*\log(NTU)^2+1.8554*\log(NTU)-0.0832} * 1.041 \; Eq\ 3.2$$

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 converted to a TSS concentration of 75 mg/L. At the WOMP sampling location a concentration of 120 mg/L TSS represents the 25 NTU standard.

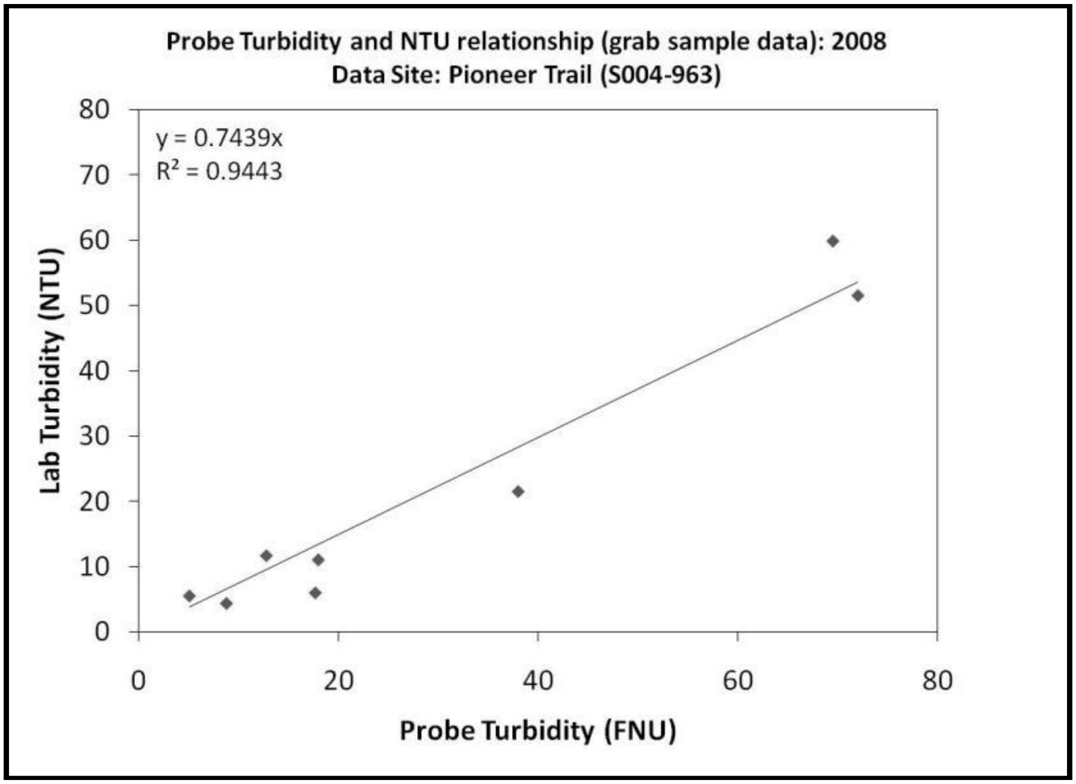

Figure 3.1 Pioneer Trail FNU to NTU relationship

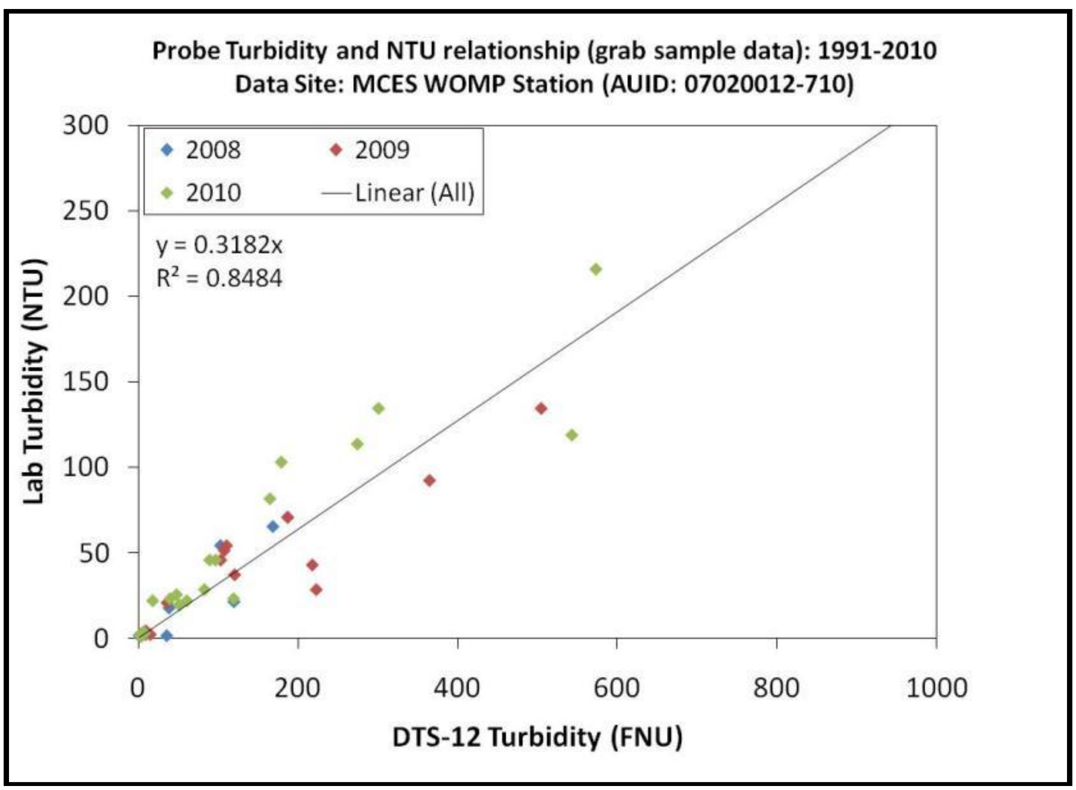

Figure 3.2 Bluff Creek WOMP (MCES BL 3.5) FNU to NTU relationship

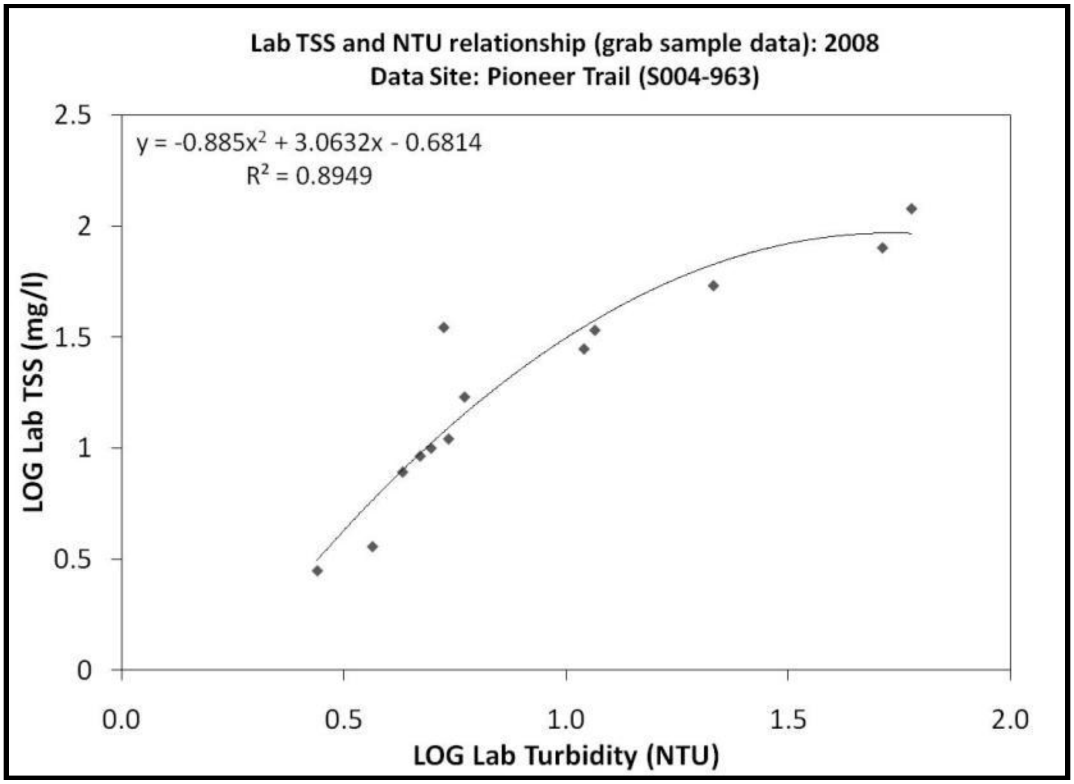

Figure 3.3 Pioneer Trail NTU to TSS relationship

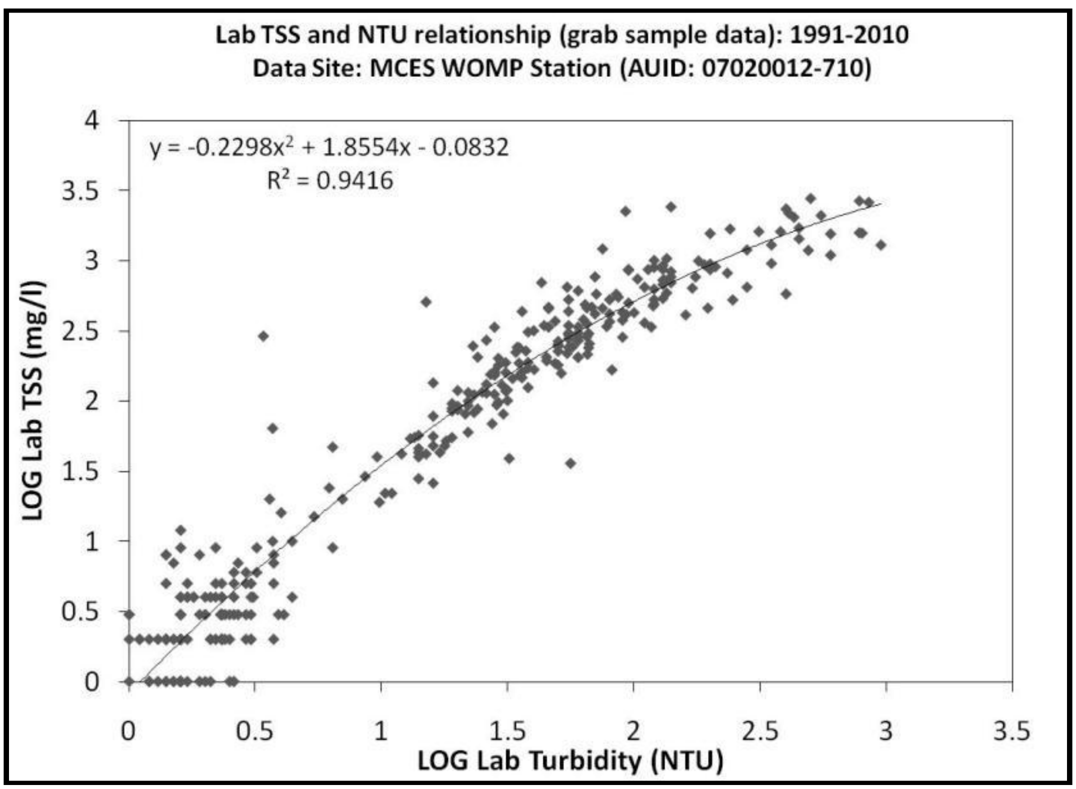

Figure 3.4 Bluff Creek WOMP (MCES BL 3.5) NTU to TSS relationship

3.2 Turbidity Sources and Current Contribution

Conclusions regarding turbidity sources and current loading are based largely on analysis/interpretation of the available data and information. Various sources of information are used in the analysis including water quality data collected and other MPCA information, soil and land use information, and a memorandum that details the results of watershed stream surveys (pertinent details included in Implementation section).

A simplified turbidity conceptual model is presented in Figure 3.5 that shows several possible candidate sources. This figure illustrates both potential sources and pathways for sediment and phosphorus. Phosphorus is included since it can contribute to turbidity through production of algae during lower flow periods or in low-gradient/low-velocity portions of the stream or in ponds and wetlands. Both “external” and “internal” sources are illustrated in this figure. Most concentrated and diffuse runoff sources are typically considered external in that they are located in the watershed outside of the stream or river channel yet contribute TSS. TSS contribution from concentrated sources of runoff is more easily quantified, while the effects due to diffuse sources are harder to define and measure. Internal sources typically encompass processes that occur within the channel (including the bed, banks and bluffs) or the floodplain of a waterway or stream. Such processes include channel and floodplain erosion or scour, and bank slumping. Figure 3.5 also indicates that higher peak flow and runoff volume contribute to bank erosion. This is because increases in runoff volume and peak flow lead to a shift in the flow duration characteristics, which in turn, correspond with higher rates of sediment delivery capacity in the stream. Algae growth and decay could be considered an internal process though the phosphorus that drives its production is generally from external sources. The components of this conceptual model, as they pertain to this watershed, are evaluated below.

Livestock in Riparian Zone

Livestock overgrazing in riparian areas can contribute to excess turbidity via soil and phosphorus runoff directly from unvegetated areas, re-suspension of sediments by walking in the stream, and by destabilizing the banks leading to increased bank erosion or slumping. While this may have been a problem in the past, it no longer appears as though overgrazing in riparian pastures is a problem in the watershed, but should be further identified and addressed where it occurs.

Row Cropland

Row cropland can contribute to excess turbidity via sheet/rill erosion of soil either overland or via surface tile intakes, wind-eroded soil settling in ditches that are then flushed during rain events, destabilization of banks (if inadequate buffers) leading to increased bank erosion, and also drainage alterations on cropped land can lead to increased flows which can then cause bank/bed erosion. Based on the land use data from 2006, agricultural land represents less than 30% of the watershed, with cultivated crops occupying less than 15% of the watershed. The most recent crop survey statistics indicate corn and soybeans are grown on much of the harvested cropland in the county.

Poorly Vegetated Ravines, Streambanks, Bluffs and Gullies

Lane (1955) completed some of the early work of defining how alluvial channels become unstable and adjust to changes in order to re-establish equilibrium and offset the effects of the imposed changes. The general expression, presented by Lane (1955), shows that the product of the bed material sediment load and median grain size (also referred to as erosional resistance) should balance the product of the water discharge and channel slope (referred to as stream power) for channels that are in equilibrium. If any of these four variables are altered, it indicates that proportional changes in one or more of the other variables must take place to re-establish equilibrium in the stream. For example, increases in water discharge (or slope) will result in increased sediment loadings until changes to grain size distribution or slope allow a channel to re-establish a new equilibrium. Simon (1994) indicates that stream systems may take up to a hundred or more years to reach equilibrium following significant disturbances that alter any of the four aforementioned variables in the Lane (1955) expression. A channel evolution model developed by Simon and Hupp (1986) indicates that channel erosion and mass-wasting associated with bank failures would be expected to follow these types of channel disturbances.

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 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.

An inventory was performed of the erosion sites in the lower valley of Bluff Creek as part of the Bluff Creek Corridor Feasibility Study in 1997 (Barr Engineering Company, 1999), focusing on the stream channel and adjacent areas. In 2007, the lower valley was visited again to perform a detailed inventory of stream erosion and, particularly, erosion of the contributing ravines and valley walls. The inventory included a reconnaissance walk of the stream channel and visits to all of the contributing ravines. Significant bank erosion on the creek was noted, as well as large slope failures in the valley that were not necessarily associated with a ravine. During the visits, erosion sites were photographed, soil and vegetation conditions were noted, storm sewer inlets documented, and erosion dimensions estimated. Ground photographs were geo-referenced to aerial photography using ArcMap software. A total of 22 erosion sites in the lower valley were documented, in addition to observed streambank erosion. These included contributing ravine erosion, mass slope failures, and erosion associated with storm sewer inlets (Barr Engineering Company, 2007). All of the inventoried erosion sites are downstream of the Pioneer Trail road crossing and upstream of the WOMP station.

Ravine erosion, for the most part, is occurring independently of Bluff Creek, and is due to overland runoff and/or groundwater seepage. Some of the sites appear to be influenced by irrigation practices and runoff from the Bluff Creek golf course.

Ditches/Channelization

A full assessment of the influence of ditches/channelization in terms of turbidity is difficult. There is no specific monitoring data that provides a breakdown of contributions for upland erosion versus these near-channel sources. Ditches and/or straightened portions of the stream are not turbidity sources per se, but are important factors to consider when evaluating excess stream turbidity and flow rates. Such watercourses are shorter than the natural channel and, thus, steeper in gradient. As such they generally exhibit higher velocities and higher peak flows. Also, their geometry is such that there is limited access to the floodplain. Therefore, the energy of the stream is confined to the channel. Straightened channels also exhibit a continuous tendency to revert to a meandering condition. The net result is increased potential for bank erosion. Temporary release of sediments also occurs during ditch and pond cleaning/dredging.

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. All of the impervious surfaces in the Bluff Creek watershed are subject to NPDES permit requirements.

Permitted Point Sources

Permitted point sources, for the purpose of this TMDL, are those facilities/entities that discharge or potentially discharge solids to surface water or otherwise contribute to excess turbidity and require a

NPDES permit from the MPCA. Typical point source categories are: wastewater treatment facilities, construction activities, and municipal and industrial stormwater sources.

The only point sources that apply to this watershed are municipal, construction, and industrial stormwater sources. No industrial or wastewater treatment plants discharge into Bluff Creek, therefore these categories are not considered in the analysis.

Regarding construction, the MPCA issues construction permits for any construction activities disturbing: one acre or more of soil; less than one acre of soil if that activity is part of a "larger common plan of development or sale" that is greater than one acre; or less than one acre of soil, but the MPCA determines that the activity poses a risk to water resources. Although stormwater runoff at construction sites that do not have adequate runoff controls can be significant on a per acre basis (MPCA Stormwater web page, 2006), the source appears to be a minor turbidity source in the Bluff Creek watershed.

Regarding industrial stormwater sources, for the purpose of the TMDL this source is lumped with construction stormwater into a categorical WLA. The remaining sources of sediment in the Bluff Creek watershed are addressed by MS4-permitted stormwater runoff. MS4 discharges to Bluff Creek will meet the MS4 wasteload allocations as long as the TSS concentration in the stormwater runoff from the MS4 area remains at or below the TSS surrogates concentrations determined in Equations 3.1 and 3.2, while maintaining the flow duration characteristics that correspond with each flow zone for the impaired reach in the Bluff Creek watershed.

Figure 3.6 provides a conceptual model of how the various sources of sediment are expected to represent a stressor to aquatic life in Bluff Creek and a probable cause of biological impairment. This diagram is further discussed in the Bluff Creek Stressor Identification report (Barr Engineering Company, 2010).

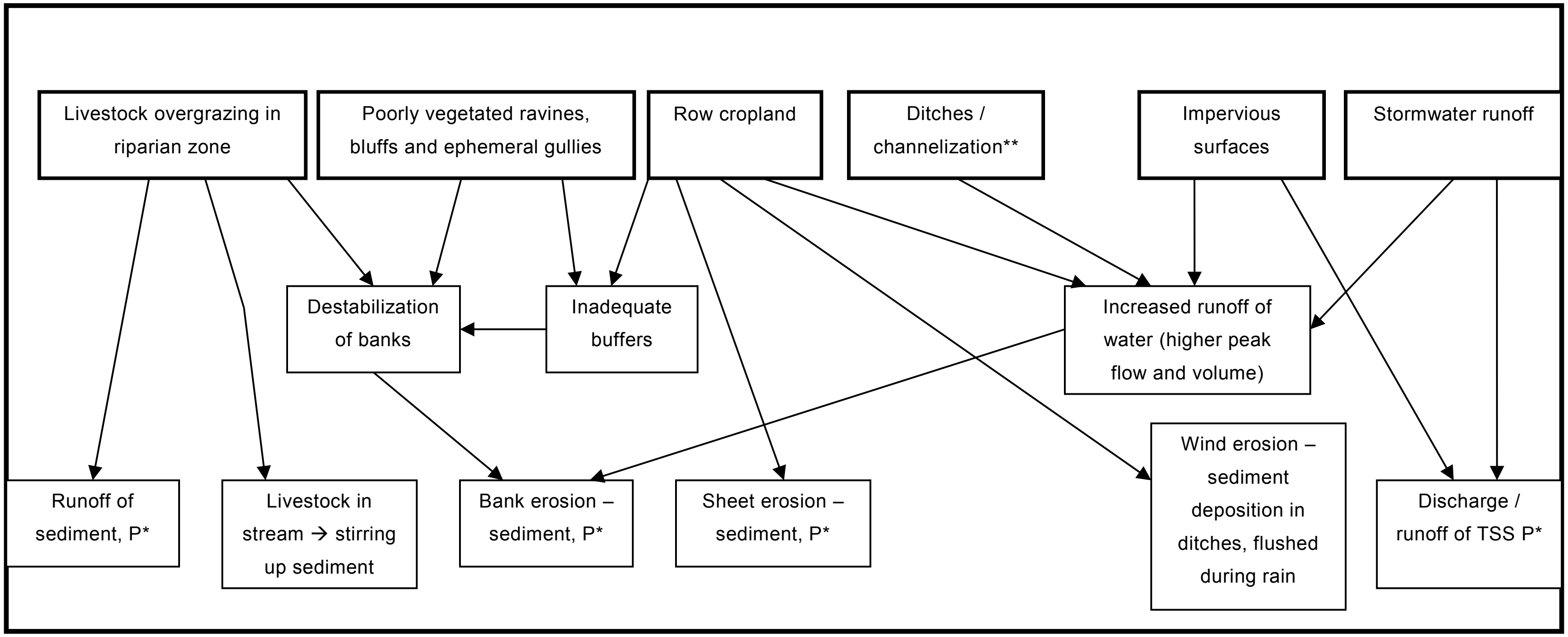

Figure 3.5 Simplified turbidity conceptual model of candidate sources and potential pathways

* Phosphorus (P) can contribute to turbidity through production of algal blooms during lower flow periods or in low-gradient/low-velocity portions of stream.

** Ditches / channelization also can cause sediment delivery via:

- bank erosion as watercourses revert to original meandering
- scour erosion at side-inlets
- steeper gradient can cause headward erosion and downcutting (nickpoints may form; channel erodes nickpoint resulting in upstream scour)
- ditch cleaning / dredging

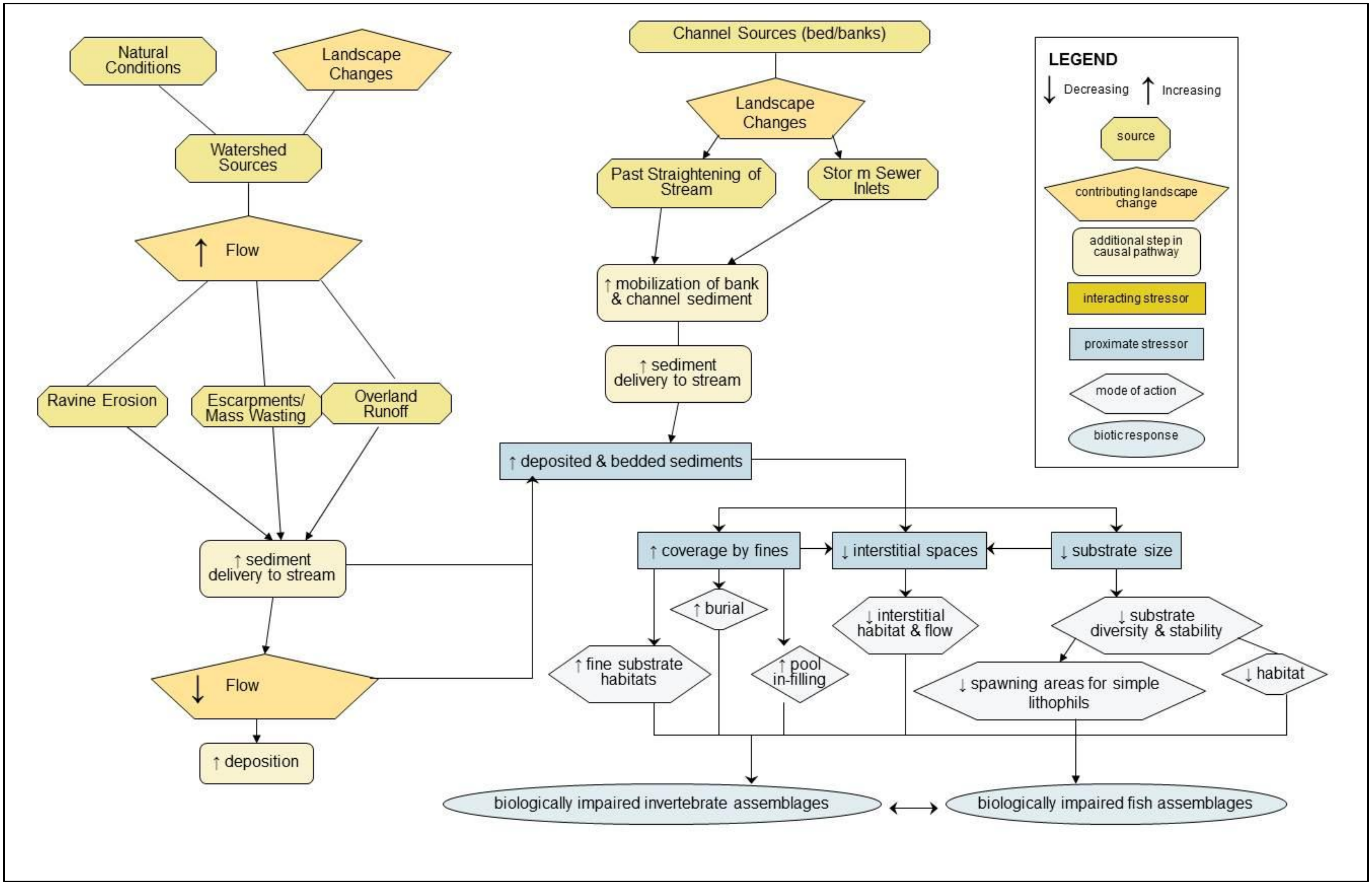

Figure 3.6 Simplified conceptual model of sediment as a candidate cause of biological impairment

3.3 Methodology for Load Allocations, Wasteload Allocations and Margins of Safety

The TMDLs consist of three main components: WLA, LA, and MOS as defined in Section 1.0. The WLA includes three sub-categories: permitted wastewater facilities with TSS limits, the MS4 permitted stormwater source category, and a construction plus industrial permitted stormwater category. The LA, reported as a single category, includes the nonpoint sources described in the previous section. The third component, MOS, is the part of the allocation that accounts for uncertainty that will result in attainment of water quality standards.

The three components (WLA, LA, and MOS) were calculated as total daily load of TSS. As described in Section 3.1 this parameter is used as a surrogate for turbidity based on a good correlation between the two. While it was noted that 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 to derive and express the TSS load components is 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. It should be noted that this method implicitly assumes that observed stream flows and flow regimes must remain constant over time. The process for computing each component of the TMDL is described below.

3.3.1 Wasteload Allocation

Watershed scale pollutant load modeling was conducted (Section 6.0 and Appendix C) and load duration curves were developed to establish TMDLs at levels necessary to attain and maintain applicable water quality standards. Federal regulation 40 CFR 130.3 states that *TMDLs can be expressed in terms of either mass per time, toxicity, or other appropriate measure*. All municipal and industrial NPDES wastewater permits in the watersheds of the turbidity impaired reaches contain effluent Total Suspended Solids concentration limits that are more restrictive than applicable water quality standards. Permitted effluent concentration limits ensure that these sources do not have a reasonable potential to cause or contribute TSS above the applicable water quality standard. Effluent concentrations are therefore appropriate expressions of the applicable wasteload allocations. Thus, according to the nature of the NPDES permits written for the various sub-categories of point source dischargers, appropriate measures for achieving compliance with the TSS wasteload allocation are described as follows.

Industrial & Municipal Wastewater Treatment Facilities: Individual WLAs

No industrial or municipal wastewater treatment facilities are actively discharging into Bluff Creek.

Construction Stormwater: Categorical WLA

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.

Industrial Stormwater: Categorical WLA

The wasteload allocation for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES industrial stormwater permit coverage is 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.

Municipal Separate Storm Sewer Systems (MS4s): Individual WLAs

MS4s are separate from the preceding three categories of point source dischargers in that they have the potential to encompass large land areas and thus generate significant runoff to surface waters during high flow conditions; thus they have the potential to change over time the flow duration characteristics of a given stream reach. They have no design flows or loading limits. Their compliance with the TMDL provisions of the MS4 permit should be somewhat akin to that for the nonpoint source load: demonstration of a load reduction to meet their allocation, or implementation of performance measures as part of a phased approach in pursuit of the load reduction goal and/or improvements to the flow duration characteristics of the stream, as part of the NPDES stormwater permit process.

3.3.2 Margin of Safety

The purpose of the MOS in the TMDL is to provide capacity to allow for uncertainty. The federal guidance for TMDLs states that the MOS may be implicit, that is incorporated into the calculations by using conservative assumptions, or explicit, expressed as loadings set aside for the MOS in the TMDL (MPCA, 2007b).

The MOS for the Bluff Creek TMDL is an explicit ten percent of the total loading capacity at each of the flow zones. The MOS is expected to provide an adequate accounting of uncertainty since, according to Metropolitan Council and Carver County comprehensive plans and growth estimates, little change in land use is expected over the next 20 years. Also, the mechanisms for soil loss from urban and agricultural sources and the factors that affect this have been extensively studied over the decades and are well understood. Follow-up effectiveness monitoring will provide a means to evaluate installed BMPs in terms of compliance with WLAs and progress or achievement of the TMDL.

3.3.3 Load Allocations

The LA includes nonpoint pollution sources that are not subject to NPDES permit requirements, as well as “natural background” sources such as low levels of soil/sediment erosion from both upland areas and the stream channel. The nonpoint pollution sources were described previously and include upland and riparian erosion and bank/bed erosion, as well as agricultural lands. Agricultural and natural 2006 National Land Cover Database (2006 NLCD, Fry et al, 2011) land use classifications were used to define LA areas.

3.3.4 Calculation Methodology

The methodology for developing the WLAs and LAs was as follows:

- Industrial and municipal wastewater treatment facilities WLA was set to 0.

- Construction stormwater and industrial stormwater are lumped together into a categorical WLA based on an approximation of the land area covered by those activities. To account for industrial stormwater, which the MPCA does not have readily accessible acreage data (but is likely much smaller than construction), as well as reserve capacity (to allow for the potential of higher rates of construction and additional industrial facilities), this TMDL assumes 0.1 percent of the land area for a combined construction and industrial stormwater category. The allocation to this category is made after the MOS is subtracted from the total loading capacity. That remaining capacity is divided up between construction and industrial stormwater, permitted MS4s and all of the nonpoint sources (the LA) based on the percent land area covered.

- The allocation for communities subject to MS4 NPDES stormwater permit requirements and LAs representing agricultural and natural lands are made after the WLA for wastewater treatment facilities and the MOS are subtracted from the total loading capacity. Subtracting the 0.1 percent allocated to construction and industrial stormwater and 10% for MOS results in the other 89.9% of TSS allocated to MS4 permit requirements and LAs. Four organizations are permitted for stormwater discharge within the Bluff Creek watershed: Minnesota Department of Transportation (Mn/DOT) for discharge from state operated road rights-of-way, Carver County for discharge from county operated road rights-of-way, and the municipalities of Chaska and Chanhassen. The MS4 wasteload allocations and LAs were divided between the four entities based on respective drainage areas. Land use data and municipal boundaries were used to differentiate between WLAs and LAs. Areas operated by the state or county were calculated first. Next, areas designated as agricultural or natural by the 2006 NLCD (Fry et al, 2011) were calculated. The remaining areas were divided based on municipal boundaries. The allocation areas for each entity are shown in Figure 3.7.

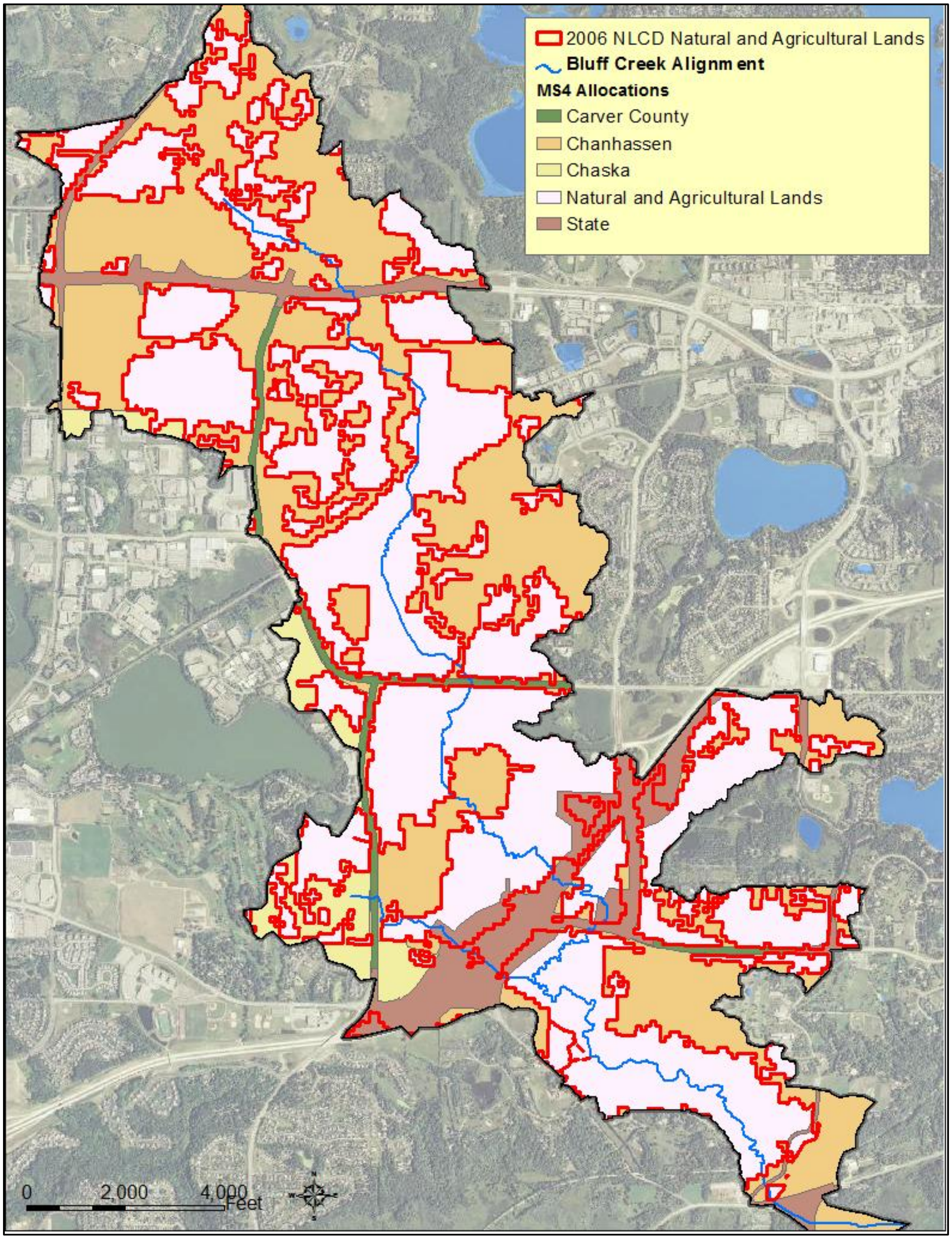

Figure 3.7 MS4 load allocation areas

3.4 TMDL Allocations

This section details the TMDL allocation process and results as well as the reduction percentages needed in the creek to meet the TMDL requirements. Data from the Metropolitan Council Environmental Services (MCES) watershed outlet monitoring program (WOMP) was used for years 2008-2010. The Bluff Creek WOMP station (BL 3.5) is located 3.5 miles upstream from where Bluff Creek joins the Minnesota River (Figure 2.1). A second monitoring station was installed at the Pioneer Trail crossing for the year 2008 (Figure 2.1). Both stations measured continuous turbidity and flow giving an average output every 15 minutes. This data was used to conduct the Bluff Creek TMDL.

3.4.1 Flow Duration Curves

Flow duration curves were developed at the WOMP station (BL 3.5) for the last three years (2008, 2009 and 2010) along with a combined data set representing all three years (2008-2010). The flow duration curves rank each flow based on its percent rank. A flow duration interval of 10% represents a value where only 10% of the flow rates are higher. A 90% interval represents a low flow rate where 90% of measurements are higher. The results show 2008 as a low flow year when compared to both 2009 and 2010 (Figure 3.8). A further comparison looking at daily average flow rates for 2008, 2009 and 2010 and comparing them to historical values for the past 9 years (2002-2010) shows the same results (Figure 3.9) with 2008 having lower flow rates throughout the flow regime.

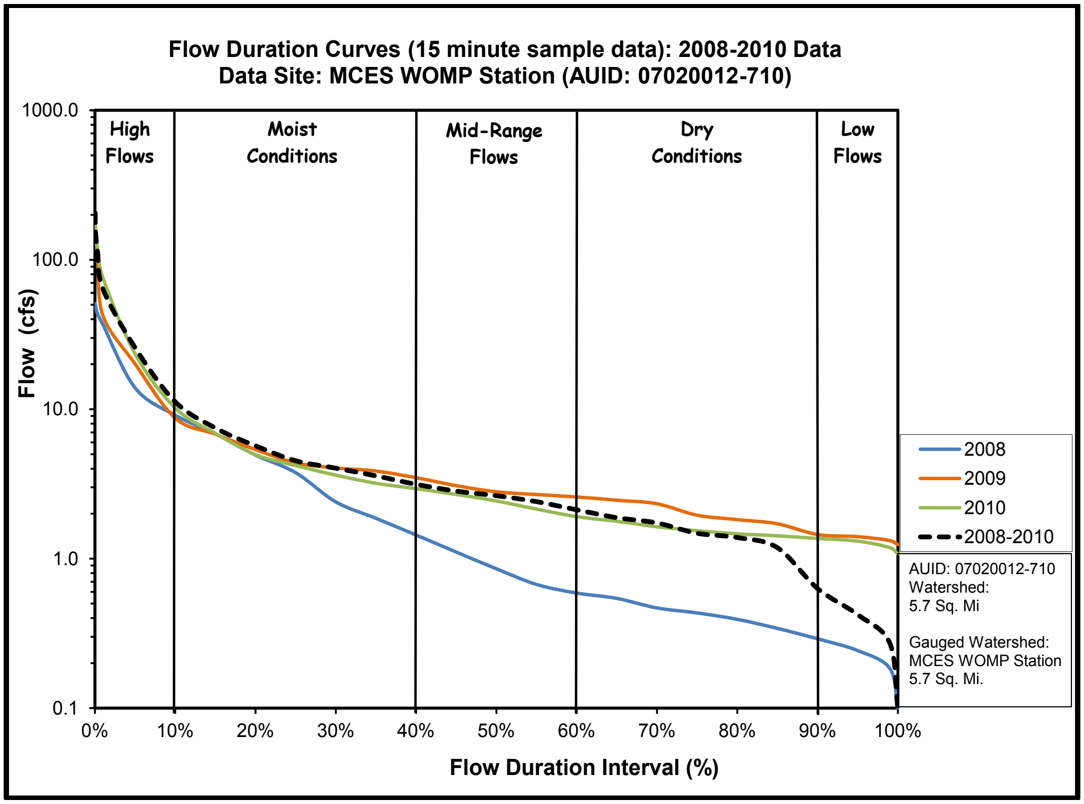

Figure 3.8 Flow duration curve 2008-2010 using 15 minutes flow data (AUID: 07020012-710)

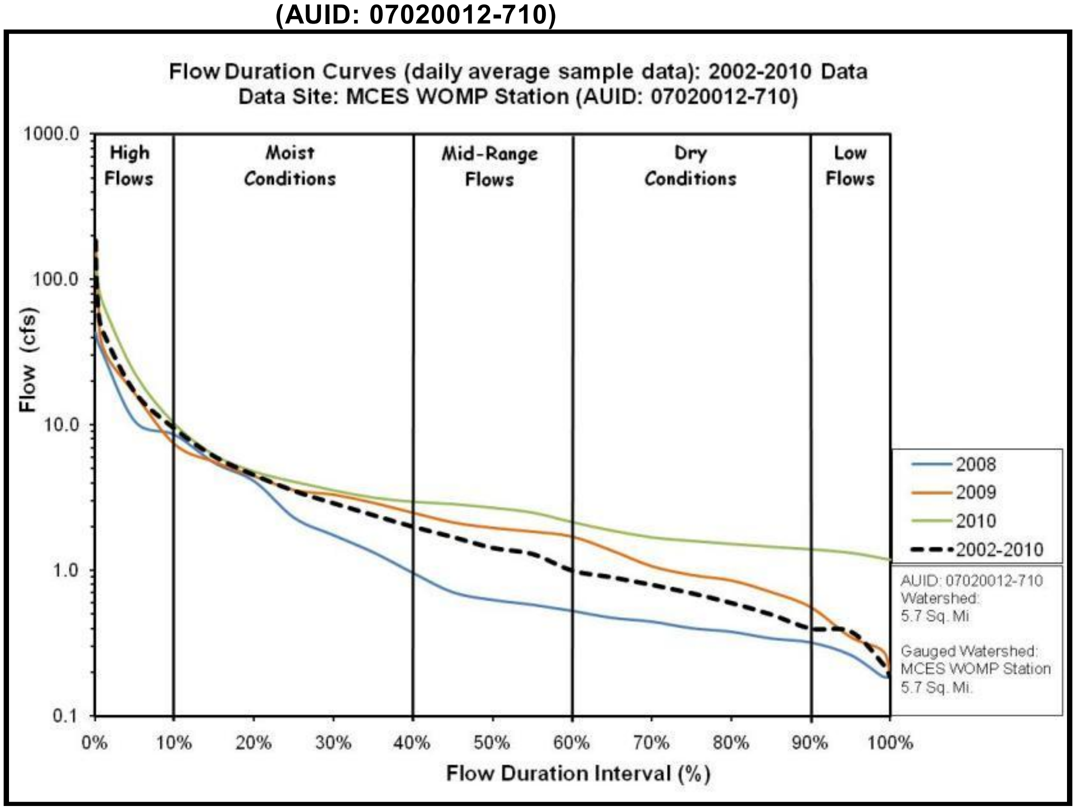

Figure 3.9 Flow duration curve 2002-2010 using daily average flow data (AUID: 07020012-710)

3.4.2 TSS Daily Loading Capacity

The Bluff Creek WOMP station flow rates measured from 2008 through 2010 were divided into five flow zones: high flows (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 3.1). 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 impaired reach of Bluff Creek extends downstream of the WOMP station (to Rice Lake) therefore the load capacities were adjusted based on the total watershed area at the confluence with Rice Lake in proportion to the watershed area at the WOMP station. Following this adjustment the total daily load capacities for the impaired reach of Bluff Creek 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. In this analysis MOS, MS4 NPDES requirements, construction and industrial stormwater requirements and LAs from natural and agricultural lands are apportioned. 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 3.1 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 MS4 NPDES	0.68	0.12	0.07	0.04	0.01
Carver County MS4 NPDES	0.13	0.02	0.01	0.01	0.002
Chaska MS4 NPDES	0.27	0.05	0.03	0.02	0.004
Chanhassen MS4 NPDES	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

	Flow Zone				
	High (5%)	Moist (25%)	Mid (50%)	Dry (75%)	Low (95%)
	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 MS4 NPDES	8.3%	8.3%	8.3%	8.3%	8.3%
Carver County MS4 NPDES	1.6%	1.6%	1.6%	1.6%	1.6%
Chaska MS4 NPDES	3.3%	4.2%	4.2%	4.2%	4.2%
Chanhassen MS4 NPDES	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%

The MS4 NPDES wasteload allocations were split between the permitted organizations based on drainage area. Right of way information was obtained from Mn/DOT and Carver County and combined with municipal boundaries from the cities of Chaska and Chanhassen. These drainage areas were used to estimate wasteload allocations for each organization (expressed in Table 3.1).

3.4.3 Load and Water Quality Duration Curves Bluff Creek WOMP

Load duration curves were created for each of the three years individually and all three years combined (2008-2010) at the Bluff Creek WOMP station (Figures 3.10 through 3.13). 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 percent rank (%) 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 3.13) 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. The higher loads occurring under high and moist flow conditions is a result of combining the higher flows with the highest TSS concentrations observed within the high and moist flow zones due to poorly vegetated ravines, bluffs, gullies and stream channels (Figure 3.14). 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.

For each year, 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 3.10 through 3.13. Also present on Figures 3.10 through 3.13 are 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. The mid-range, dry and low flows are below the standard in all years. Moist conditions are above the standard in 2008 and below the standard in 2009 and 2010.

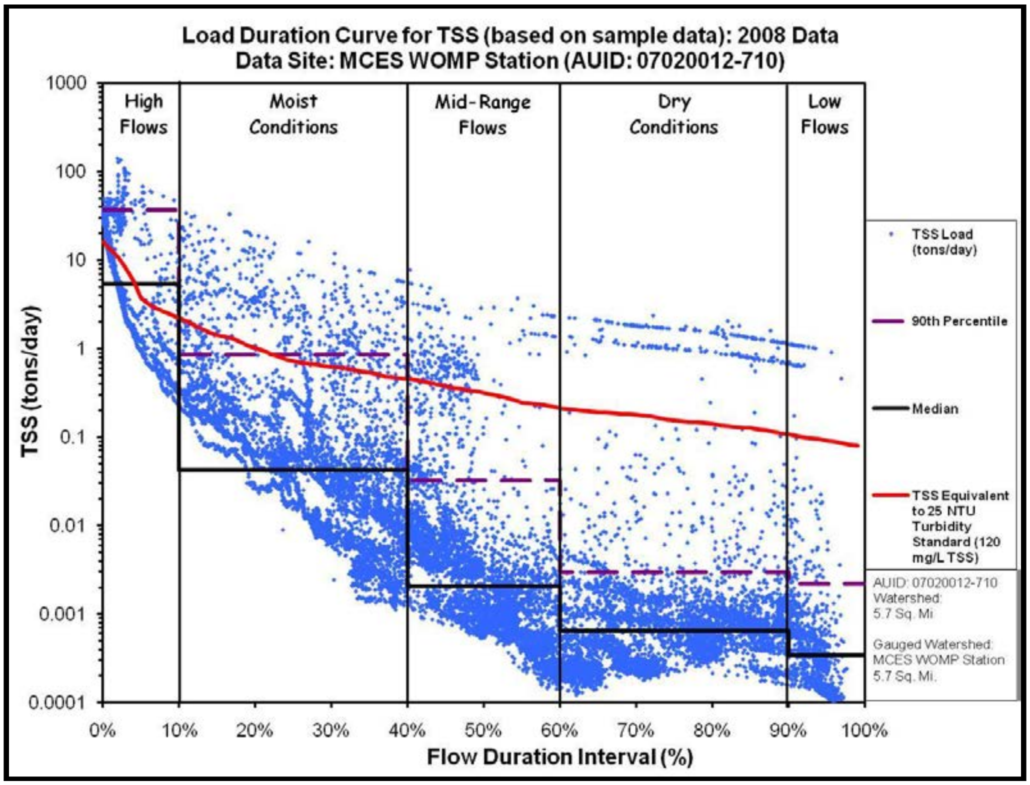

Figure 3.10 Load duration curve 2008 (AUID: 07020012-710)

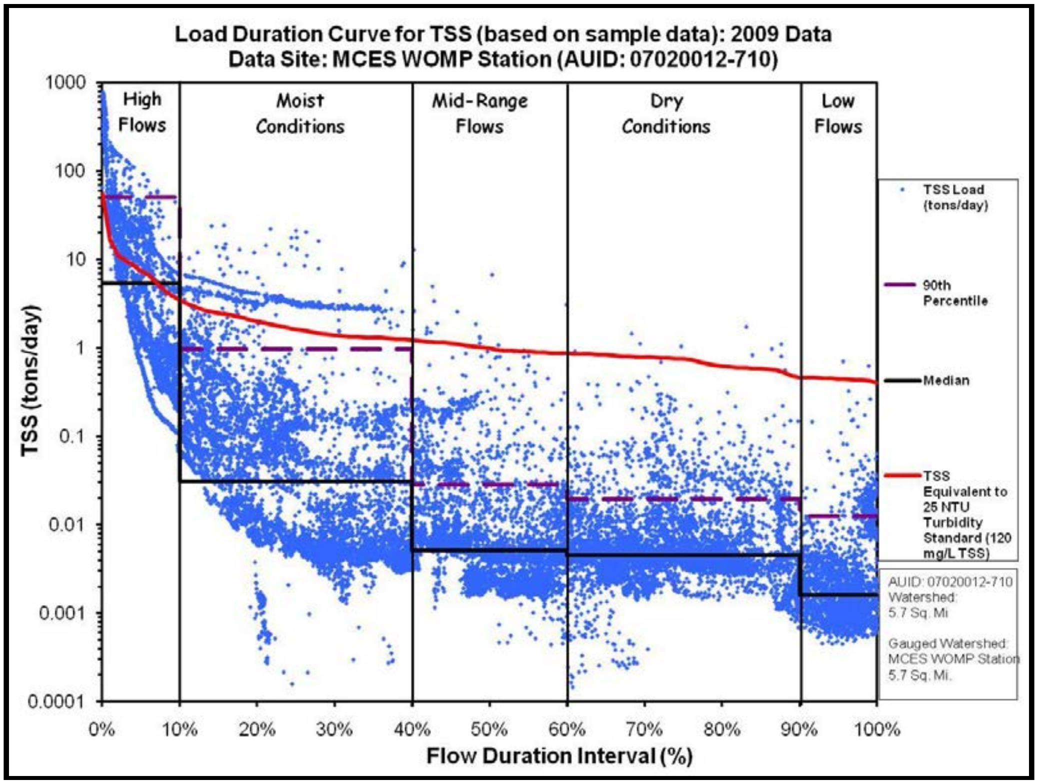

Figure 3.11 Load duration curve 2009 (AUID: 07020012-710)

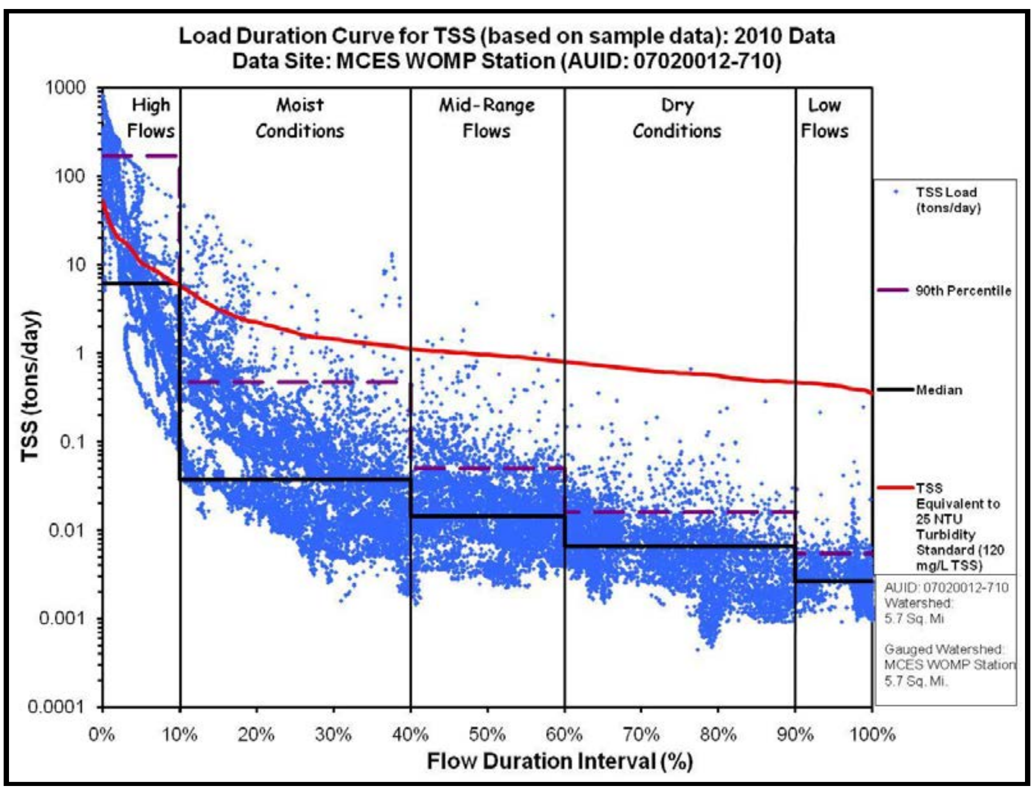

Figure 3.12 Load duration curve 2010 (AUID: 07020012-710)

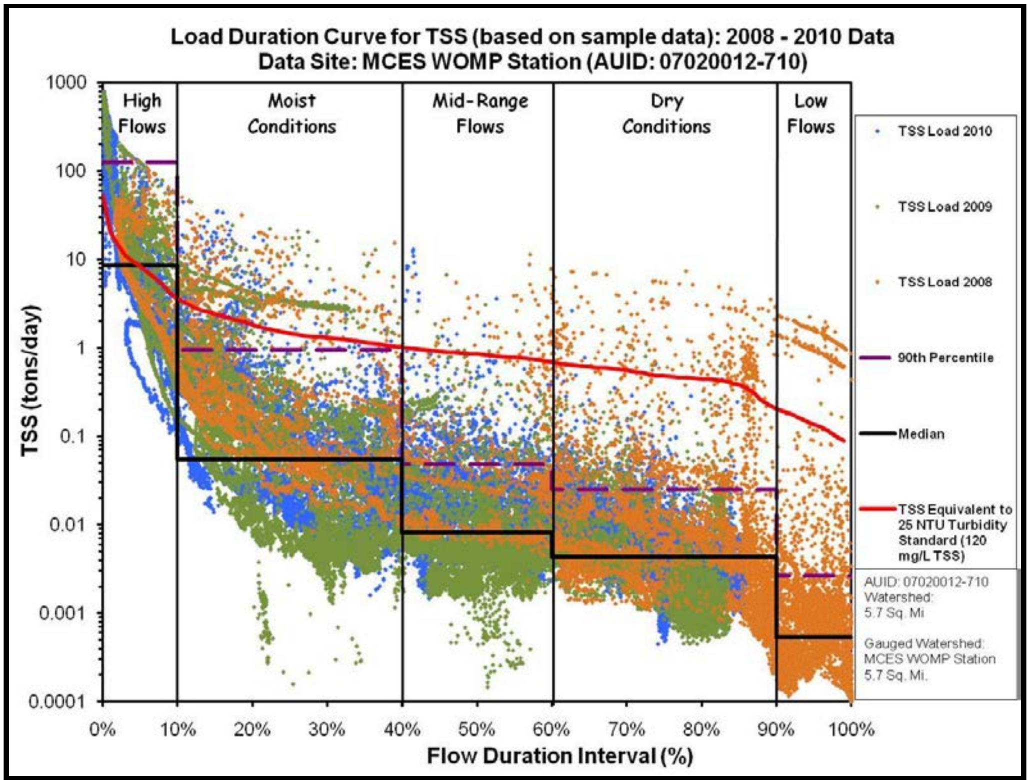

Figure 3.13 Load duration curve 2008-2010 (AUID: 07020012-710)

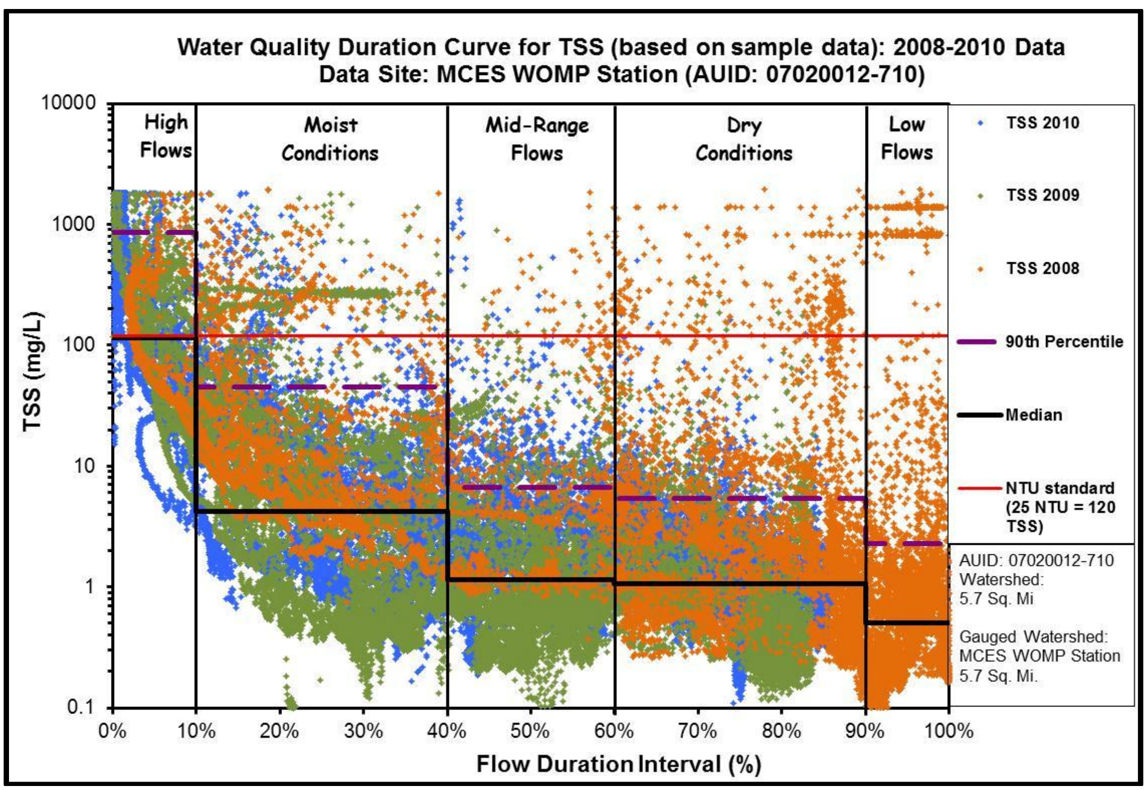

Figure 3.14 Water quality duration curve 2008-2010 (AUID: 07020012-710)

3.4.4 Pioneer Trail TSS Data Analysis

TSS concentrations and loads were also calculated at the upstream Pioneer Trail temporary sampling station (Figures 3.15 and 3.16). The station was set up for the year 2008 only. Samples were collected every 15 minutes. During low to mid-range flow levels the water level in the stream receded below the bottom of the DTS-12 turbidity probe. During late summer no flow was present at this station. In order to compensate for the lack of data, flow percentages were calculated for the entire year, but only the corresponding loads with a corresponding NTU measurement were plotted. 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. The data shown in Figure 3.15 was not used in setting the TMDL, but was compared with the data collected at the WOMP station (see Figure 3.10) to evaluate the relative importance of the gullies/ravines, bluffs and streambank erosion sources of turbidity that enter the stream in the lower valley of the watershed between Pioneer Trail and the WOMP monitoring stations. The results of this data comparison indicate that the TSS load measured at the WOMP station was one to two orders of magnitude higher than the load observed at Pioneer Trail during high flow conditions in 2008.

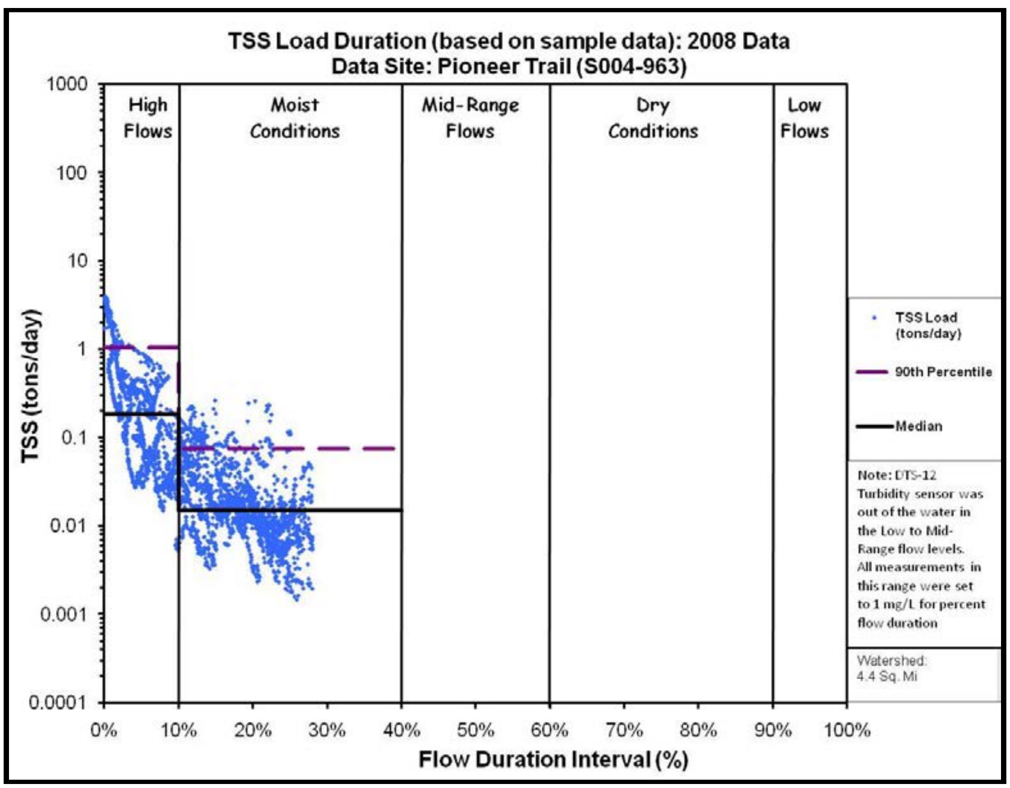

Figure 3.15 Load duration curve 2008 (Pioneer Trail)

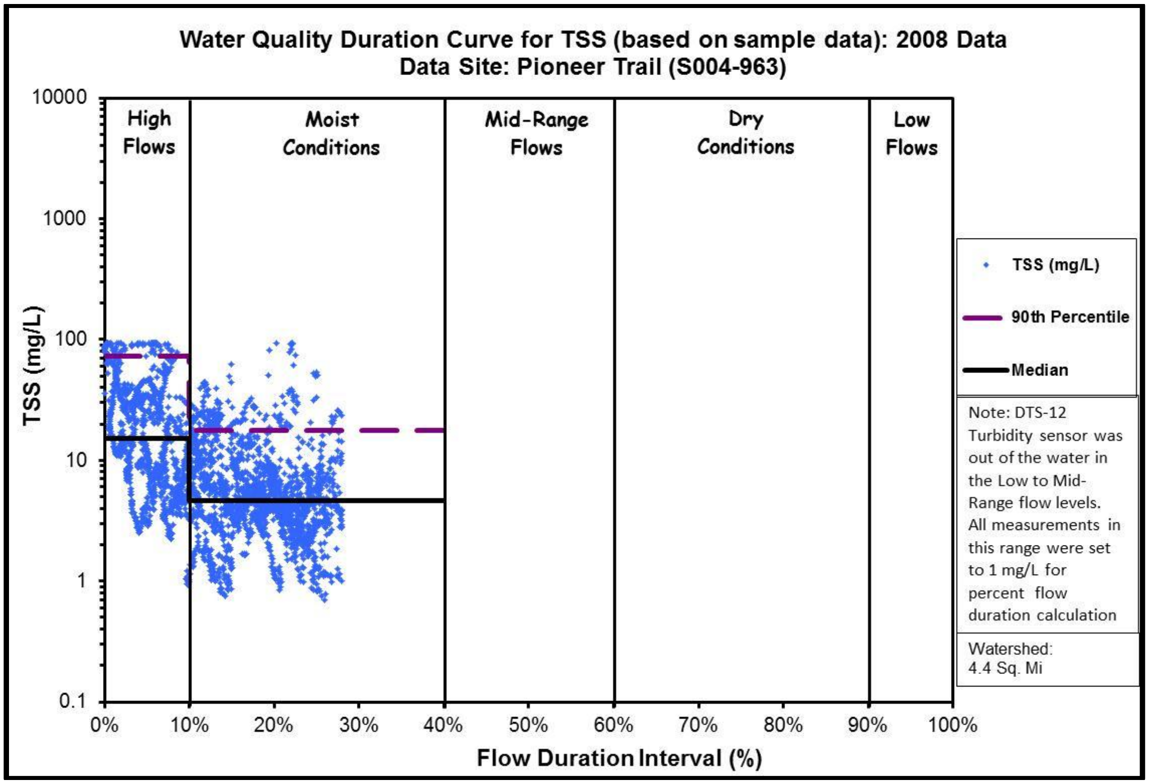

Figure 3.16 Water quality duration curve 2008 (Pioneer Trail)

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

Some of the conclusions to be drawn from the project monitoring experience, data and assessments discussed in Sections 3.1, 3.2 and 3.4 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. More discussion of these results is located in Sections 3.2, 3.4 and 6.4.

- Primary sources contributing TSS within this watershed are stream bank 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).

3.6 Critical Conditions and Seasonal Variation

EPA states that the critical condition *"…can be thought of as the "worst case" scenario of environmental conditions in the waterbody in which the loading expressed in the TMDL for the pollutant of concern will continue to meet water quality standards. Critical conditions are the combination of environmental factors (e.g., flow, temperature, etc.) that results in attaining and maintaining the water quality criterion and has an acceptably low frequency of occurrence"* (USEPA, 1999). Turbidity levels are generally at their worst following significant storm events during the spring and summer months. Seasonal variation is somewhat more difficult to generalize given reach-specific differences. Regardless, such conditions and variation are fully captured in the duration curve methodology used in this TMDL, as allocations have been developed for five separate segments of the overall flow-duration regime.

3.7 Impacts of Future Growth on TMDL Allocations

The increase in impervious areas in the form of roads, parking lots, buildings, and landscape changes due to development will contribute additional runoff and TSS loading to the system. All WLAs are based on 2008-2010 stream flow rates and the allowable loadings implicitly assume that flow rates and flow regimes will stay the same in the future. 99.8% of the WLA for this TMDL are for communities subject to MS4 NPDES requirements. The MPCA's MS4 General Permit requires MS4s to provide reasonable assurances that if an EPA-approved TMDL has been developed, they must review the adequacy of their Storm Water Pollution Prevention Program required by the MS4 to meet the TMDL's WLA set for stormwater sources. If the Storm Water Pollution Prevention Program is not consistent with achieving the applicable requirements, schedules and objectives of the TMDL, they must modify their Storm Water Pollution Prevention Program, as appropriate, within 18 months after the TMDL is approved. Any future development would also have to meet the MS4 permit requirements as it pertains to this TMDL.

Future transfer of loads in this TMDL may be necessary if any of the following scenarios occur within the Bluff Creek watershed:

1. New development occurs within a regulated MS4. Newly developed areas that are not already included in the WLA must be given additional WLA to accommodate the growth.
2. One regulated MS4 acquires land from another regulated MS4. Examples include annexation or highway expansions. In these cases, the transfer is WLA to WLA.
3. One or more non-regulated MS4s become regulated. If this has not been accounted for in the WLA, then a transfer must occur from the LA.
4. Expansion of an urban area encompasses new regulated areas for existing permittees. An example is existing state highways that were outside an Urban Area at the time the TMDL was completed, but are now inside a newly expanded urban area. This will require either a WLA to WLA transfer or a LA to WLA transfer.
5. A new MS4 or other stormwater-related point source is identified and is covered under a NPDES permit. In this situation, a transfer must occur from the LA.

Load transfers will be based on methods consistent with those used in setting the allocations in this TMDL. In cases where WLA is transferred from or to a regulated MS4, the permittees will be notified of the transfer.

4.0 Biological Stressors

The Bluff Creek Biological Stressor Identification report (http://www.pca.state.mn.us/index.php/view-document.html?gid=13751) determined the stressors causing the stream's biological impairment. Four primary stressors affecting biotic integrity in Bluff Creek were identified: sediment, metals, flow, and habitat fragmentation. One of those stressors – sediment – would be addressed by achieving TMDL wasteload and load reductions through this TMDL.

A second stressor - metals – may also 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 (Figures 4.1 through 4.6). Hence, sediment load reductions will also reduce metal loads to Bluff Creek. Although metals contamination appears to be a stressor, additional monitoring is needed for verification because "clean hands/dirty hands" methodology was not employed during collection and analyses of metals samples. This sampling methodology separates field duties and dedicates one individual as "clean hands" to tasks related to direct contact with the sample while another individual takes care of all operations involving contact with potential sources of contamination.

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 4.7) interrupts the connectivity of Bluff Creek. This interruption of connectivity prevents passage of fish between upstream and downstream reaches of Bluff Creek. High flows were identified as a stressor to the stream's biological community because of its interaction with sediment, metals, and habitat fragmentation. Sediment input from bank and ravine erosion was evident at high flows and this sediment stressed the biological community. The data indicate metals are entering Bluff Creek with sediment during periods of high flow (Figure 4.1 through Figure 4.6). 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. Because flow is only a problem when high flows interact with these other stressors (e.g. sediment, metals, habitat fragmentation), removal of these stressors could also eliminate problems associated with high flows in Bluff Creek. Again, this TMDL only addresses sediment although all the known stressors (sediment, metals, habitat fragmentation, and flow) to fish biota are related in some context (Appendix D).

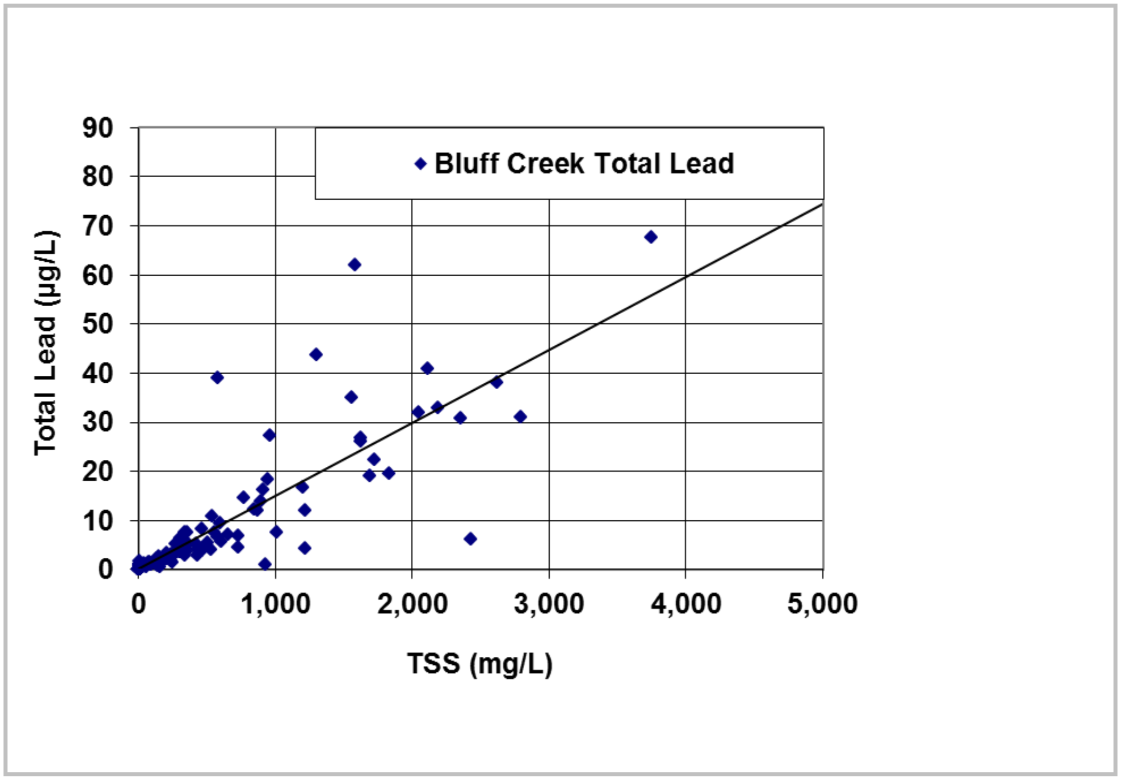

Figure 4.1 Lead versus suspended solids for Bluff Creek WOMP site

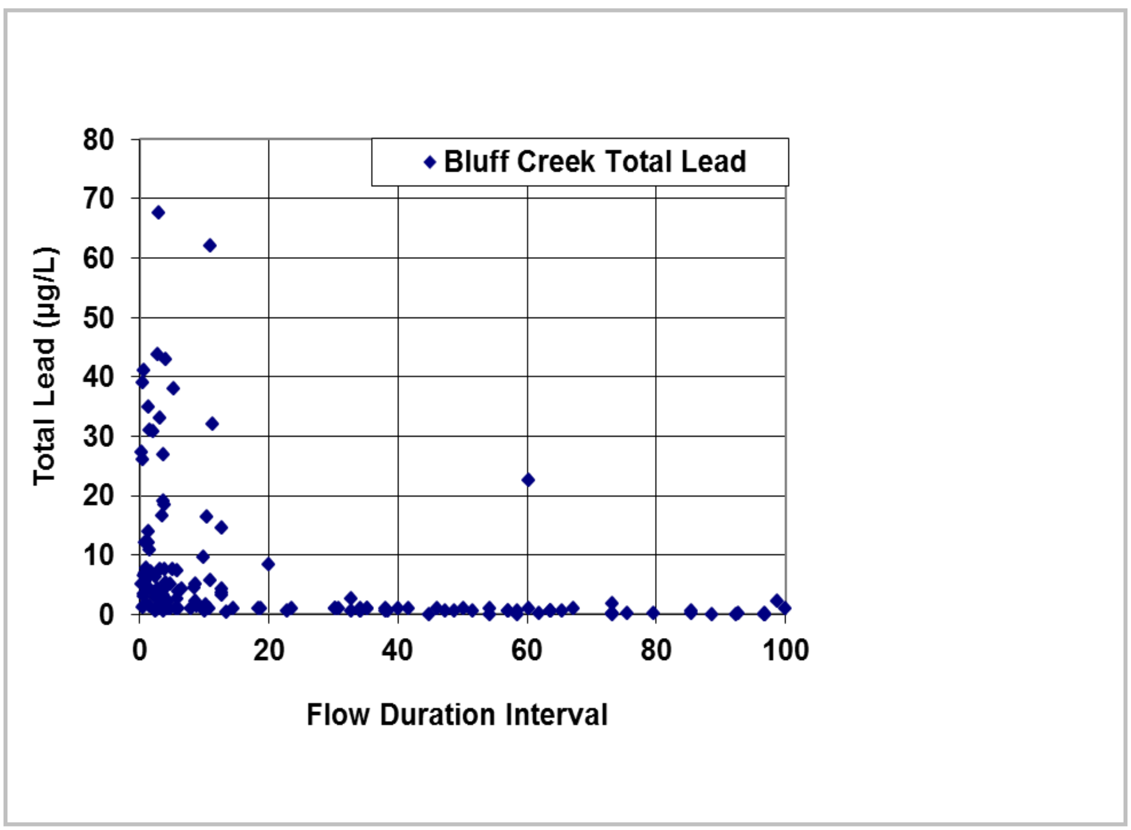

Figure 4.2 Lead water quality duration curve for Bluff Creek WOMP site

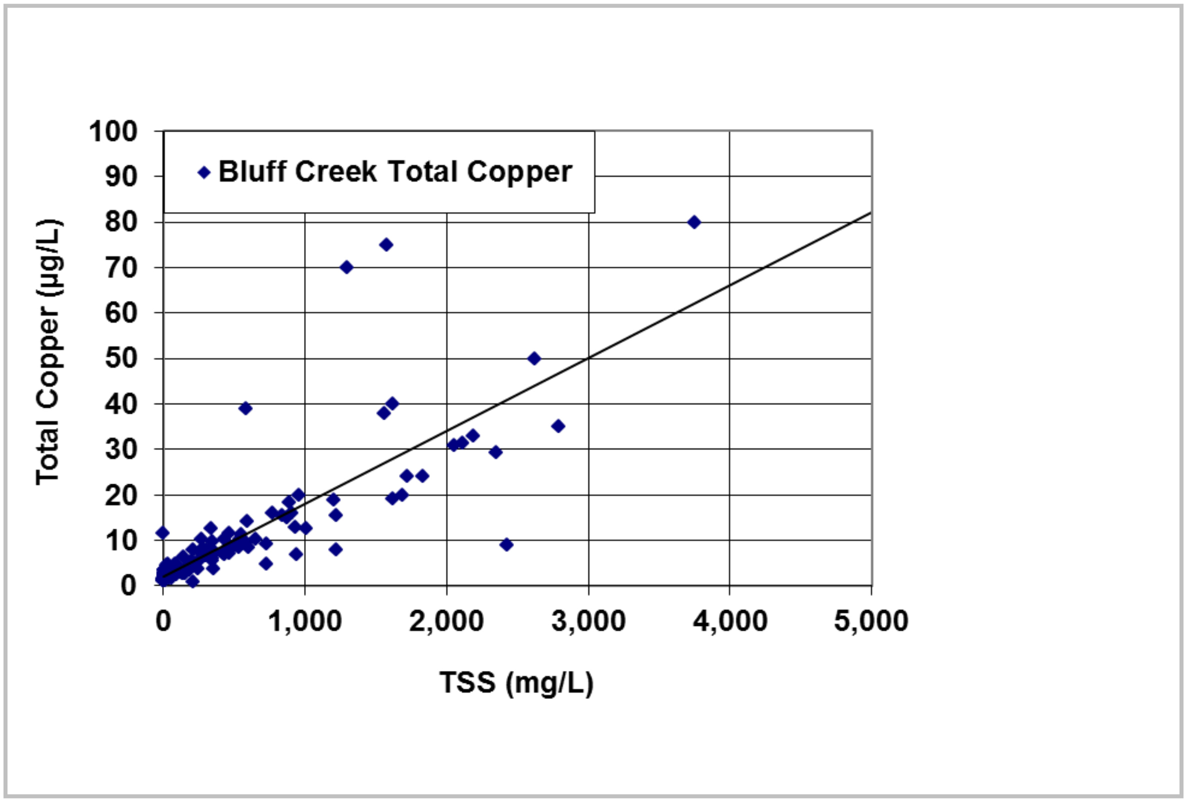

Figure 4.3 Copper versus suspended solids for Bluff Creek WOMP site

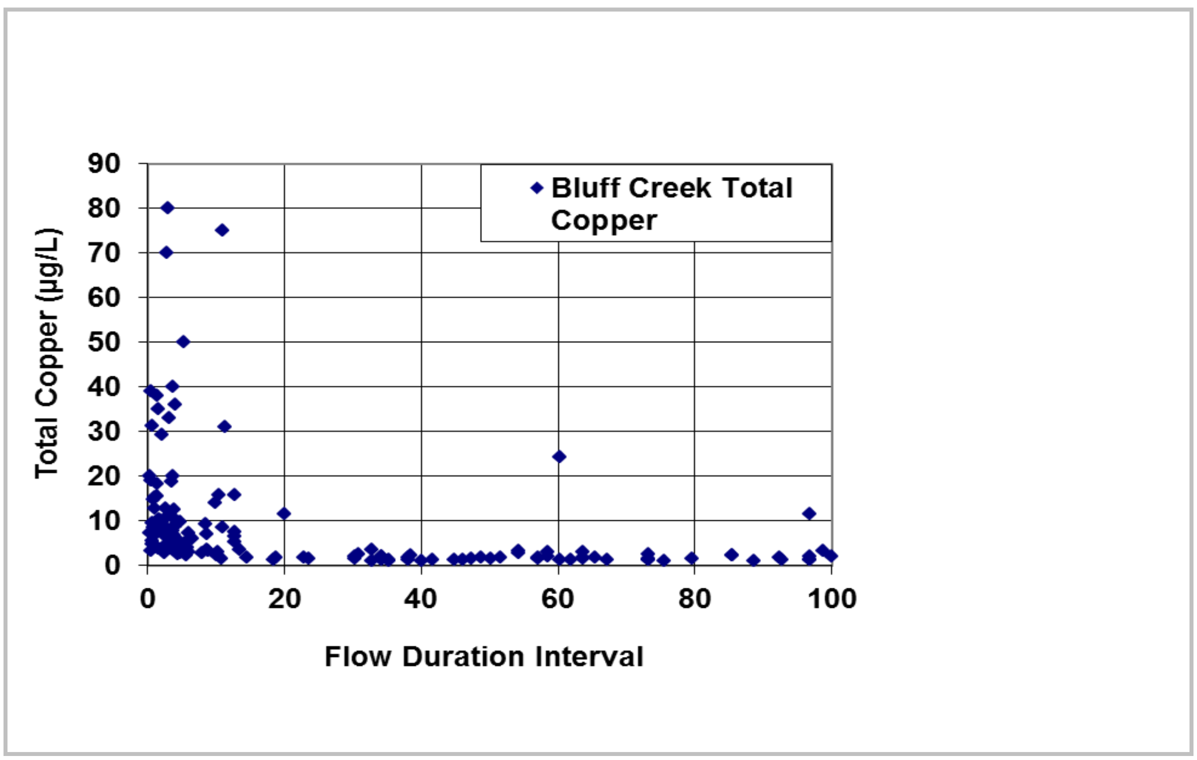

Figure 4.4 Copper water quality duration curve for bluff creek WOMP site

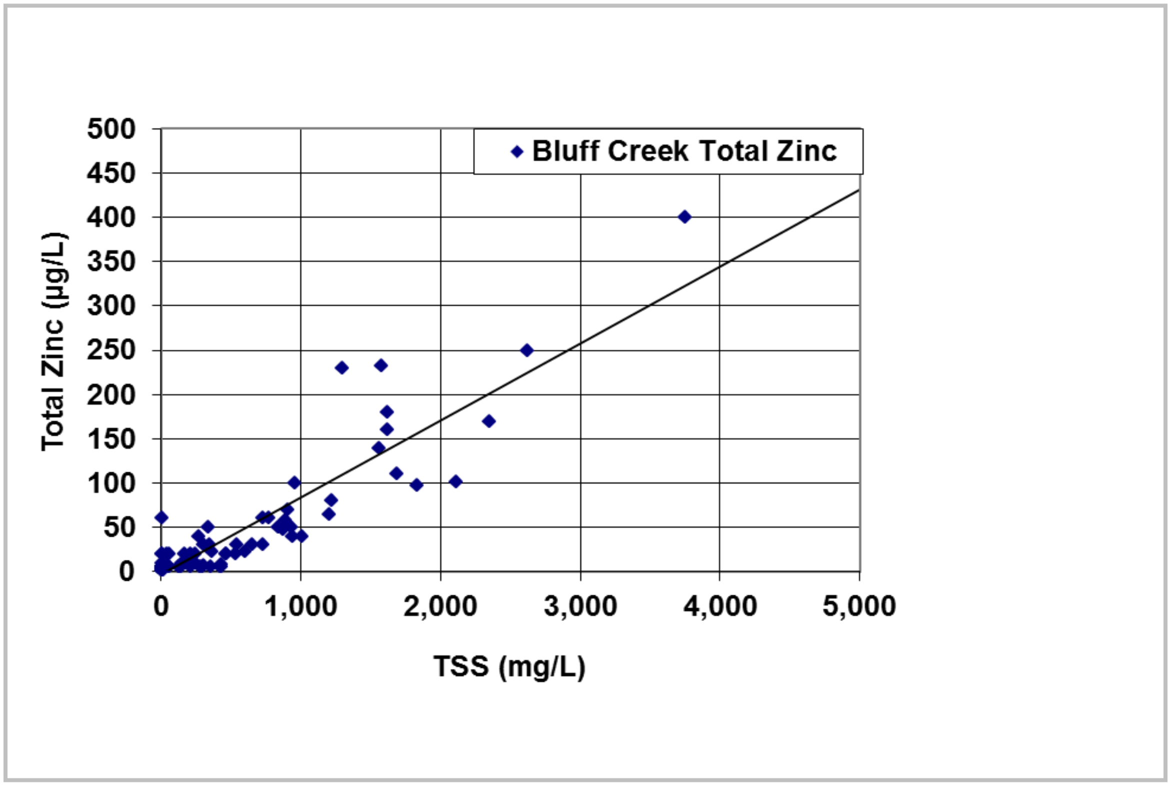

Figure 4.5 Zinc versus suspended solids for Bluff Creek WOMP site

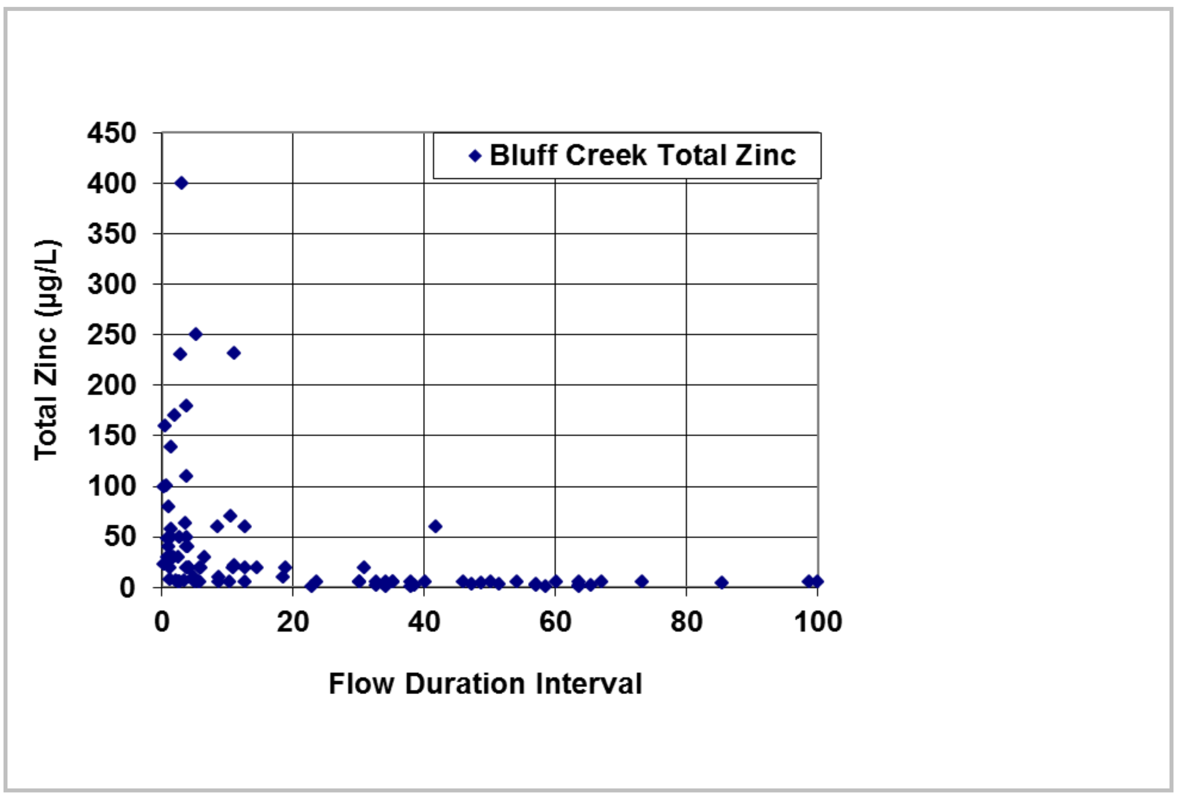

Figure 4.6 Zinc water quality duration curve for Bluff Creek WOMP site

Figure 4.7 Large drop at downstream end of regional trail culvert (looking upstream)

5.0 Monitoring

The goals of follow-up monitoring are generally to both evaluate progress toward the water quality targets provided in the TMDL and to inform and guide implementation activities. More specific monitoring plan(s) will be developed as part of implementation efforts. The impaired water body will remain listed until water quality standards are met. Monitoring will primarily be conducted by local and regional staff.

5.1 Turbidity

At a minimum, the current monitoring program should 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 (15 minutes) 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 continue to be analyzed in grab samples to evaluate mineral versus algal sources of suspended solids in order to better target implementation efforts.

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. If metal sample results exceed the water quality standards, 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.

5.3 Geomorphology

The Barr Engineering Company (2007) report (discussed in Section 3.2), detailing streambank and ravine erosion, recommended that the severe and moderate erosion sites be stabilized and revegetated, with the role of groundwater evaluated and addressed at each site as necessary.

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 the erosion sites, which would be difficult to survey using traditional methods. The survey should be repeated every 2 to 3 years and following severe runoff events. Monitoring the sites over a period of years will provide a better picture of which erosion sites are most active. 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 sources of runoff to the ravines should be performed to determine if upland best management practices can be implemented to reduce the rate and volume of runoff, as well as the likelihood of erosion in the ravines.

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 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.

6.0 Water Quality Modeling

6.1 Overview

A water quality model was developed using the P8 water quality model 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. A 2009 HydroCad Model provided by the City of Chanhassen was used as a starting point for the development of the model. The information in the HydroCad model was updated using current 2010 topological information, 2006 NLCD land use data, pond information provided by the city and the inclusion of the new 4 lane Highway 212 that runs through the watersheds.

6.2 Watershed Characteristics

Watershed delineations were determined for the P8 model. The previous drainage areas from the 2009 HydroCad model were used as a starting point for the development of the new model. The new 2010 topological information obtained from the city of Chanhassen was used with aerial photography to adjust the existing watershed boundaries. Further delineation of the lower reach of Bluff Creek leading up to the WOMP station (MCES BL3.5) was applied to separate various ravines from the main stem. The boundaries for each of the watersheds in the P8 model are displayed in Figure 6.1. Overall 96 watersheds were delineated. Each of the subwatersheds were grouped together into six watershed divisions representing various drainage areas of Bluff Creek. The six divisions display the water flowpath in Bluff Creek from the head waters of division A1 down to the WOMP station at the end of A6. Division A2 enters the Creek by intersection with division A3. Watershed Divisions A1-A5 all drain to the Pioneer Trail sampling station. The only addition to Bluff Creek before the WOMP station is watershed division A6.

Land use data and impervious surface percentages from the 2006 USGS NLCD data was used to determine land use characteristic for each of the watersheds (Fry et al, 2011). Land use data is shown in Figure 2.3 and impervious data is displayed in Figure 6.2. Land use data, in conjunction with soil data provided by Carver County, were used to calculate a SCS curve number for each watershed. Highway 212 was digitized individually and included as impervious area in the analysis. The landuses and associated CNs are displayed in Table 6.1. In Bluff Creek the largest land use is developed low intensity (21%) followed by pasture/hay (17%), deciduous forest (14%), developed medium intensity (13%), cultivated crops (13%) and developed open space (12%). These six land uses cover 89 percent of the Bluff Creek watershed. P8 model inputs and watershed parameters used are shown in Appendix C.

Table 6.1 Land use information and associated curve numbers (CNs) used in P8 model

Land Use	Percent of watershed	CNs by Hydrologic Soil Group (HSG)			
		A/D	B	B/D	C
Open Water	0.4%				
Developed Open Space	11.9%	59.5	61	70.5	74
Developed Low Intensity	20.5%	66.5	69	76.5	79
Developed Medium Intensity	13.0%	66.5	69	76.5	79
Developed High Intensity	2.8%	78.5	79	84	86
Deciduous Forest	13.9%	55.5	58	68.5	72
Evergreen Forest	0.7%	55.5	58	68.5	72
Mixed Forest	0.1%	55.5	58	68.5	72
Shrub/Scrub	4.2%	59.5	61	70.5	74
Grassland/Herbaceous	0.7%	59.5	61	70.5	74
Pasture/Hay	16.7%	59.5	61	70.5	74
Cultivated Crops	12.7%	78	78	83.5	85
Woody Wetlands	0.2%	75.5	71	75.5	80
Emergent Herbaceous Wetlands	2.2%	75.5	71	75.5	80

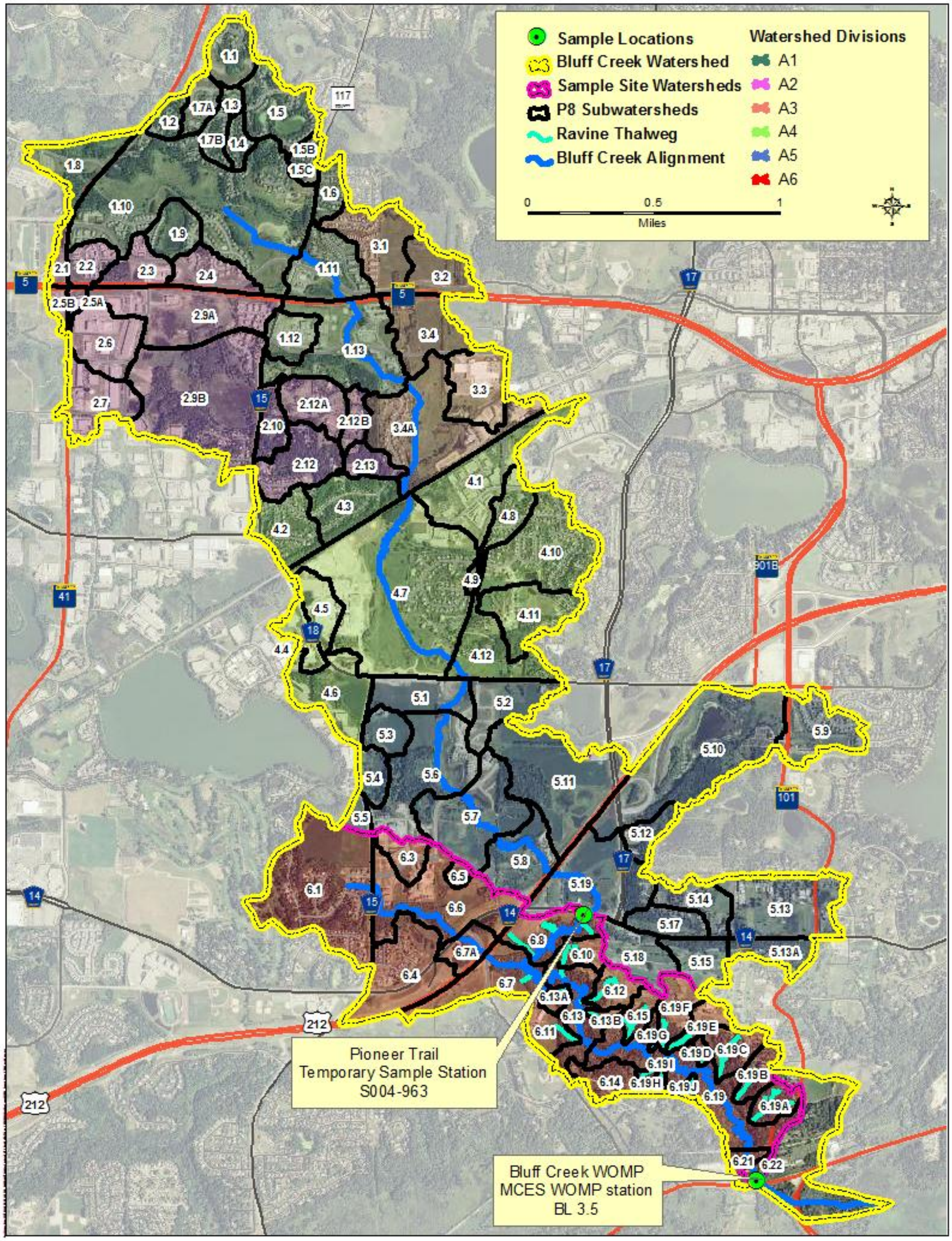

Figure 6.1 Bluff Creek P8 watersheds

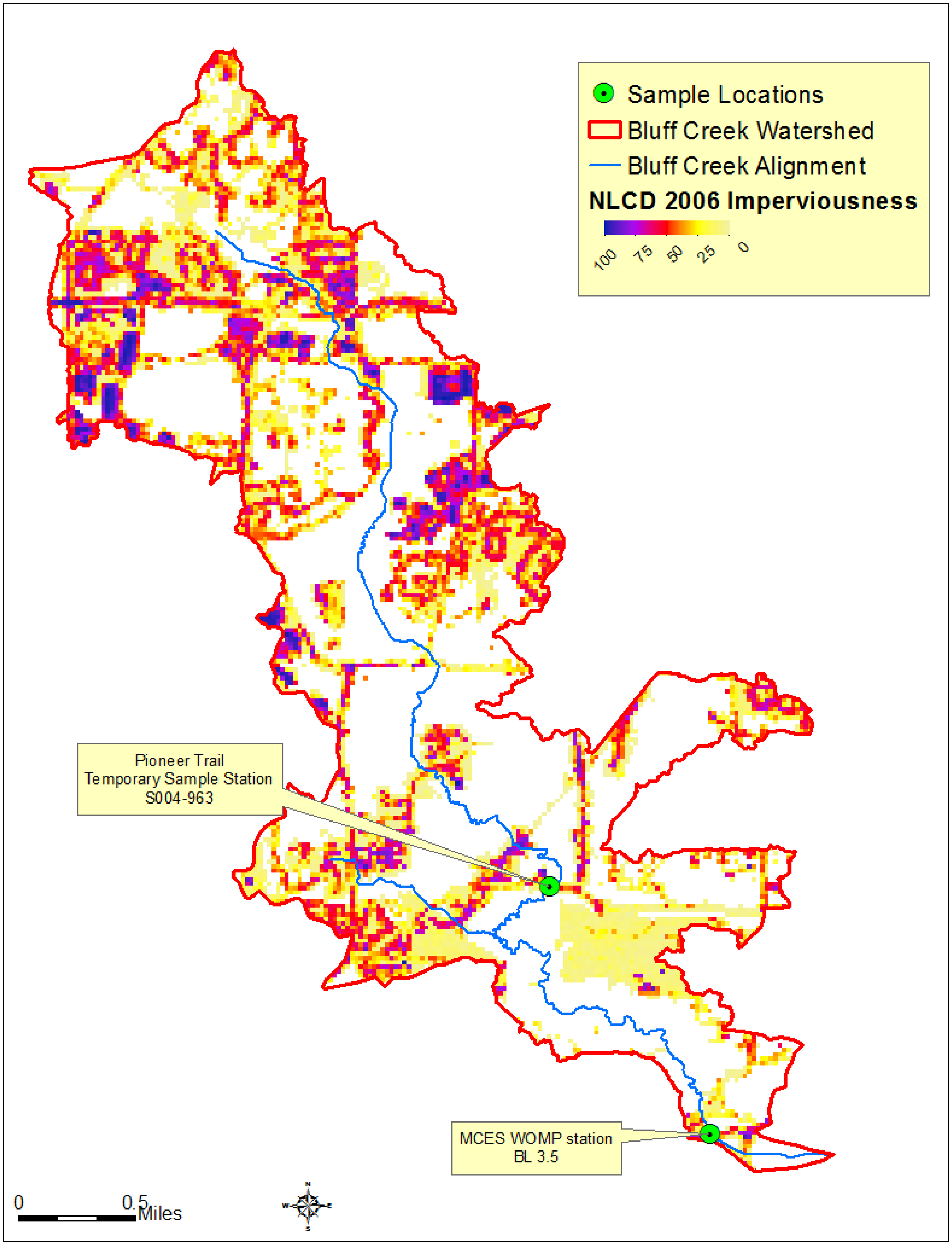

Figure 6.2 Bluff Creek 2006 NLCD Percent Impervious Area

6.3 Pollutant Removal Device Information

The P8 water quality model can predict pollutant removal efficiency for a variety of treatment practices such as detention ponds and infiltration basins. The model can also be used to simulate pollutant removal from alternative BMPs such as underground treatment devices. The modeled treatment practices are referred to in the P8 model as pollutant removal 'devices'. Stormwater ponds are the primary structural BMPs that currently exist within the Bluff Creek watershed, and as such, were the only pollutant removal devices included in the P8 model for this study. The TMDL Implementation Plan will include recommendations for infiltration practices (rainwater gardens, infiltration basins, swales, etc.) that can also be captured with future P8 modeling efforts.

Ponds

Water quality ponds (also called detention ponds, stormwater ponds) were the only BMP modeled with TSS removal capabilities. The "dead" storage volume (storage below the normal water level) is an important factor in the pollutant removal efficiency of water quality ponds. As such, it is important to represent this volume as accurately as possible. Dead storage information was available for a small number of ponds through a 2009 HydroCad model provided by the city of Chanhassen. Information on pond depths and areas were used to determine the dead storage and flood storage for each of the ponds. Ponds without a dead storage values were calculated assuming a 2-foot depth.

6.4 Results

Results were recorded for three model runs. The first model run calibrated the model using the combined precipitation record collected at the Bluff Creek and the nearby Riley Creek WOMP stations for a portion of 2008. The second model run used the entire Bluff and Riley Creek dataset for all of 2008. Ten passes of the precipitation record were run through each of the 2008 models to allow the detention ponds to attain steady-state pollutant levels before results were recorded. The third model used precipitation data from the Minneapolis/ St Paul International Airport for years 1949 to 2008. The model was run for the entire precipitation record but results were only recorded between 1990 and 2008.

The P8 model was calibrated for total runoff volume during 2008 at both the Pioneer Trail and WOMP sites along with the 2008 TSS load at the Pioneer Trail site (see Figure 6.1). A calibration for TSS at the WOMP site was not conducted due to the high TSS load contributions from bluff and ravine erosion that are not captured by the P8 model. Depression storage and watershed runoff coefficients were used to calibrate total runoff volume while the particle removal scale factors for the stormwater ponds were adjusted to calibrate TSS loads. The model simulation was run using a combined precipitation dataset obtained from the Bluff Creek and Riley Creek WOMP stations for 2008. The model was run from 6/25/2008 to 11/17/2008 matching the flow sampling period of the Pioneer Trail station. This time period also limits the influence of snowmelt runoff on the creek and calibrated the model to monitored rainfall events only. Total TSS load and total runoff volume for this time period were estimated for the sampling period. Flow monitoring at the Pioneer Trail station indicated that the creek ran dry over multiple periods in 2008. Average TSS concentrations and flow rates taken at the two stations were used to calculate measured TSS load and runoff volume.

The model was able to accurately predict total runoff volume at both sites as well as TSS loads at the Pioneer Trail station (Table 6.2). Peak flow rates over the time period also compare well with measured results. Both the modeling and monitoring data show increased TSS concentration in the lower reach of the Creek over the calibration period. The monitoring data show an addition of ~30,000 lbs of TSS to the creek downstream of the Pioneer Trail station with the addition of only 60 acre-ft of runoff. 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.

Table 6.2 Modeling and monitoring data comparison for 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

Comparing the modeling and monitoring data indicate that a large increase in TSS concentration downstream of the Pioneer Trail station is likely due to erosion from ravines and stream banks and bluffs located in the lower reach of the creek. Model results were analyzed for the ravines (included in the inventory of erosion sites described in Section 3.2) to help assess erosion capabilities (Table 6.3). Peak flow rates and annual runoff volumes for each of the ravines were calculated for the 2008 model run using the Riley Creek precipitation record and also average annual values using the MSP airport precipitation record. The Riley Creek precipitation record only includes rainfall events while the MSP dataset includes both rainfall and snowmelt events. Use of the P8 model results in assessing the severity of channel erosion is further discussed in the Implementation section (Section 7.0).

Table 6.3 P8 model results for ravine subwatersheds

P8 Watershed	Peak Flow 1990-2008[a] (cfs)	Peak Flow 2008[b] (cfs)	Annual Runoff Volume 1990-2008[a] (acre-ft)	Annual Runoff Volume 2008[b] (acre-ft)
6.19A	6.94	0.38	1.55	0.60
6.19B	8.06	0.61	2.37	0.97
6.19C	11.30	0.90	3.41	1.43
6.19D[c]	1.71	0.00	0.18	0.01
6.19E	10.97	1.39	4.24	2.19
6.19F	13.16	1.77	5.50	2.80
6.19G	1.55	0.02	0.22	0.04
6.19H	2.04	0.03	0.26	0.04
6.19I	1.01	0.01	0.12	0.02
6.19J	1.35	0.04	0.21	0.06
6.12	7.97	0.84	2.80	1.36
6.13A	2.61	0.02	0.30	0.04
6.13B	2.15	0.12	0.51	0.19
6.11	10.30	1.47	4.49	2.32
6.10	6.80	0.21	1.29	0.33
6.15	6.16	0.45	1.66	0.71

[a] Modeled using precipitation data at Minneapolis/St. Paul International airport. (MSP4908.PCP)
[b] Modeled using combined precipitation data from Riley Creek and Bluff Creek WOMP stations. (Riley08.PCP)
[c] Modeled runoff estimates indicate that no significant runoff volume was produced for 2008 monitoring period.

7.0 Implementation

7.1 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. From the modeling it appears that a major component to this increased TSS load is erosion of ravines and stream banks and bluffs in the lower reach of Bluff Creek. A more detailed analysis of the ravines and stream banks/bluffs was completed to determine erosion severity and also implementation costs needed for remediation.

7.1.1 Erosion Survey

An inventory and assessment of the Bluff Creek Lower Valley completed in 2007 (Barr Engineering Company, 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 qualitatively assessed by a geomorphologist based on the relative volumes of erosion observed at each site and 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 culvert crossing of the Hennepin County Regional Trail Corridor was inspected to determine fish passage options to address habitat fragmentation caused by significant erosion immediately downstream of the culvert. A more detailed analysis of the 22 sites identified in the survey, recommended management measures to reduce sediment loading to Bluff Creek, and a conceptual cost estimate and given in the implementation report. Numbered site locations are shown on Figure 7.1.

7.1.2 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 soils type 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 7.2 along with the peak SPI value and location for each of the ravine watersheds.

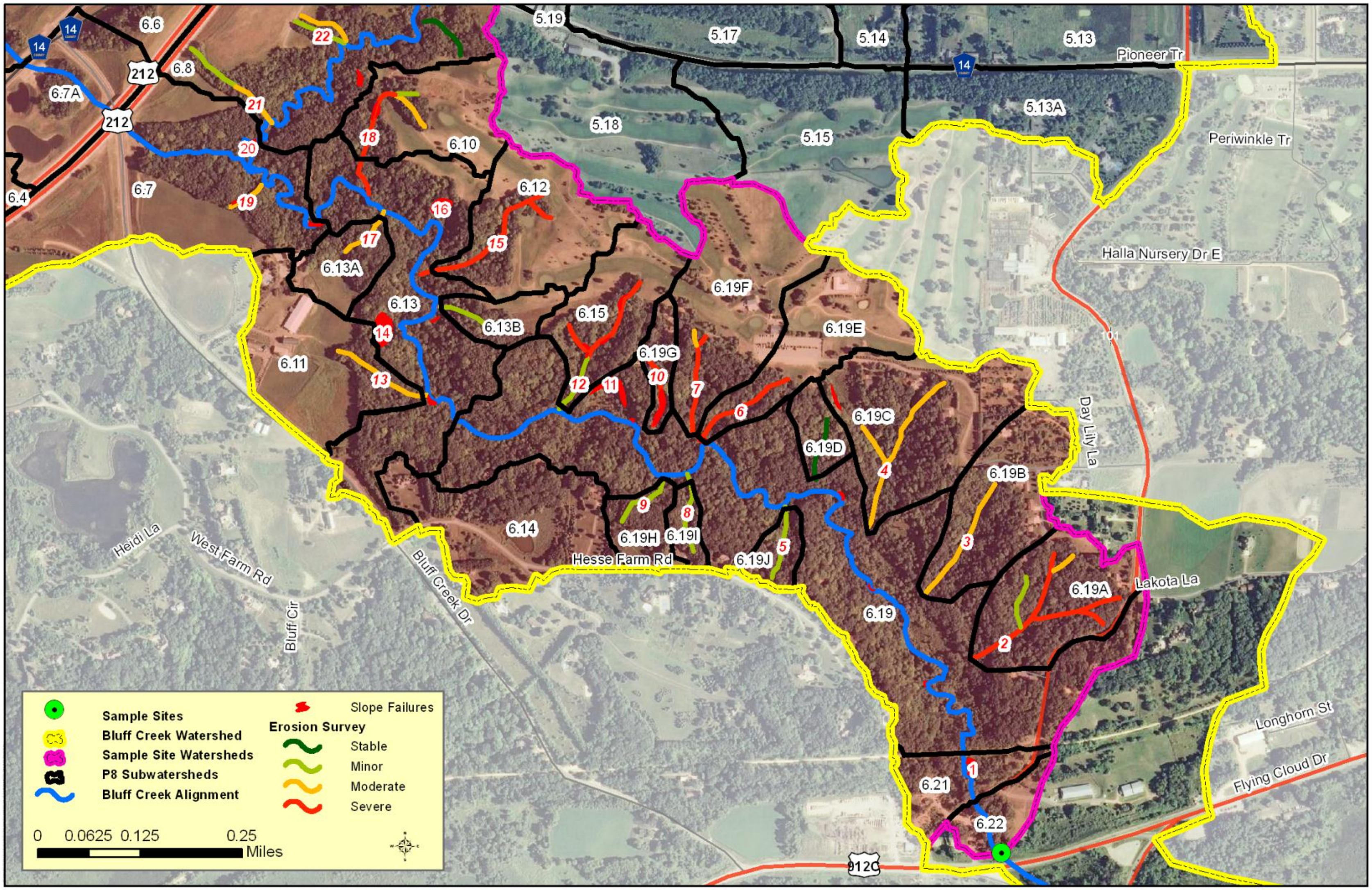

Figure 7.1 Bluff Creek channel survey

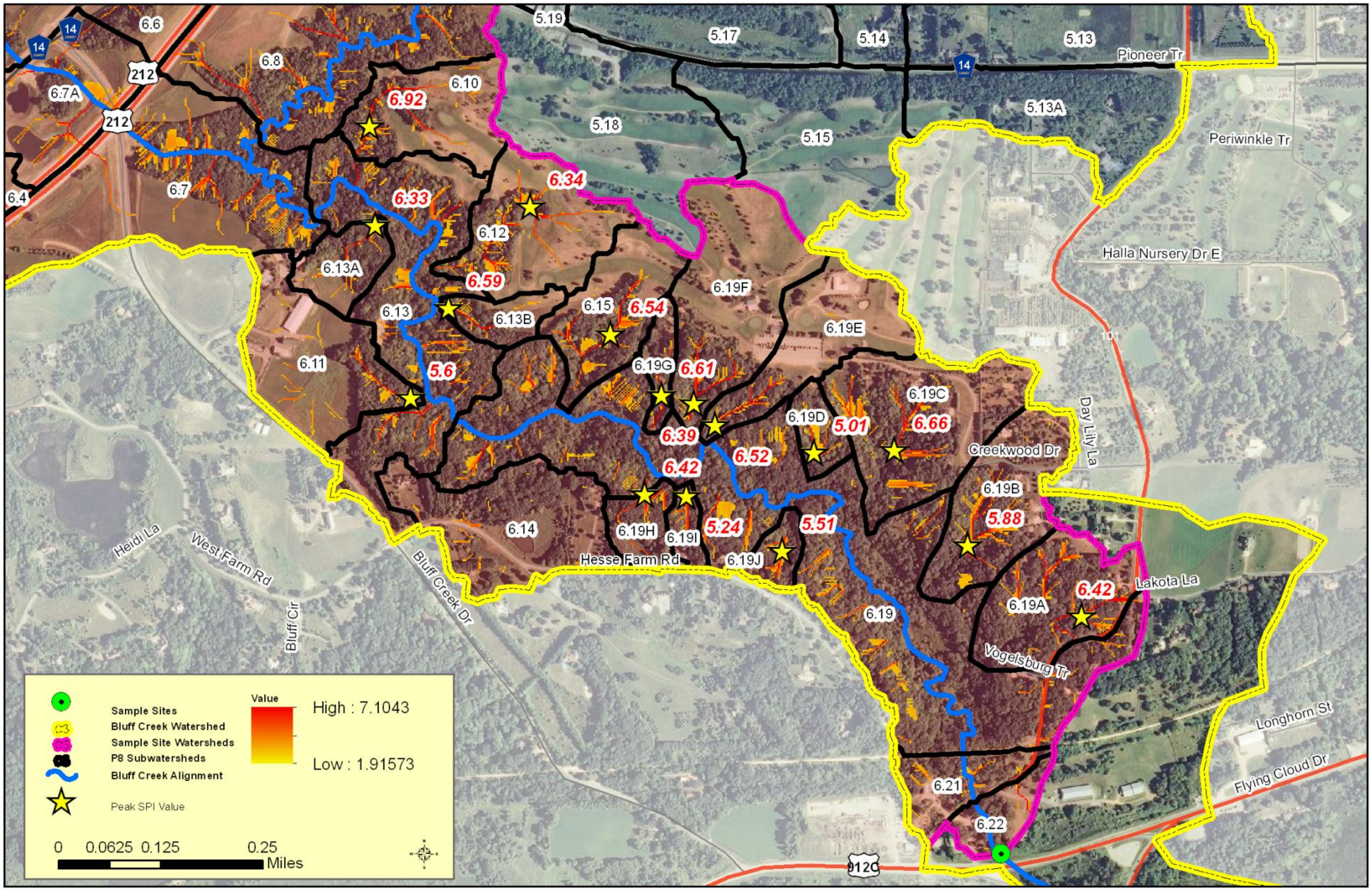

Figure 7.2 Bluff Creek terrain analysis

7.1.3 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 7.1 shows the results including: the ravine erosion classification displayed in Figure 7.1; 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 6.0; and the max SPI value and average of the top 5 % SPI values (Figure 7.2) for each of the ravine watersheds obtained through the terrain analysis.

Table 7.1 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	1.71	0.18	1	5.01	2.69
6.19H	9	Minor	2.04	0.26	1	6.42	3.38
6.19I	8	Minor	1.01	0.12	1	5.24	3.52
6.19J	5	Minor	1.35	0.21	1	5.51	3.28
6.13B	--*	Minor	2.15	0.51	6	6.59	3.29
6.19B	3	Moderate	8.06	2.37	21	5.88	2.98
6.19C	4	Moderate	11.3	3.41	24	6.66	3.05
6.13A	17	Moderate	2.61	0.3	1	6.33	3.21
6.11	13	Moderate	10.3	4.49	27	5.6	2.87
6.15	12	Severe/Minor	6.16	1.66	18	6.54	3.2
6.19A	2	Severe	6.94	1.55	17	6.42	3.49
6.19E	6	Severe	10.97	4.24	26	6.52	3.55
6.19F	7	Severe	13.16	5.5	27	6.39	3.43
6.19G	10	Severe	1.55	0.22	1	6.61	4.03
6.12	15	Severe	7.97	2.8	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 7.3. Figure 7.3 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.

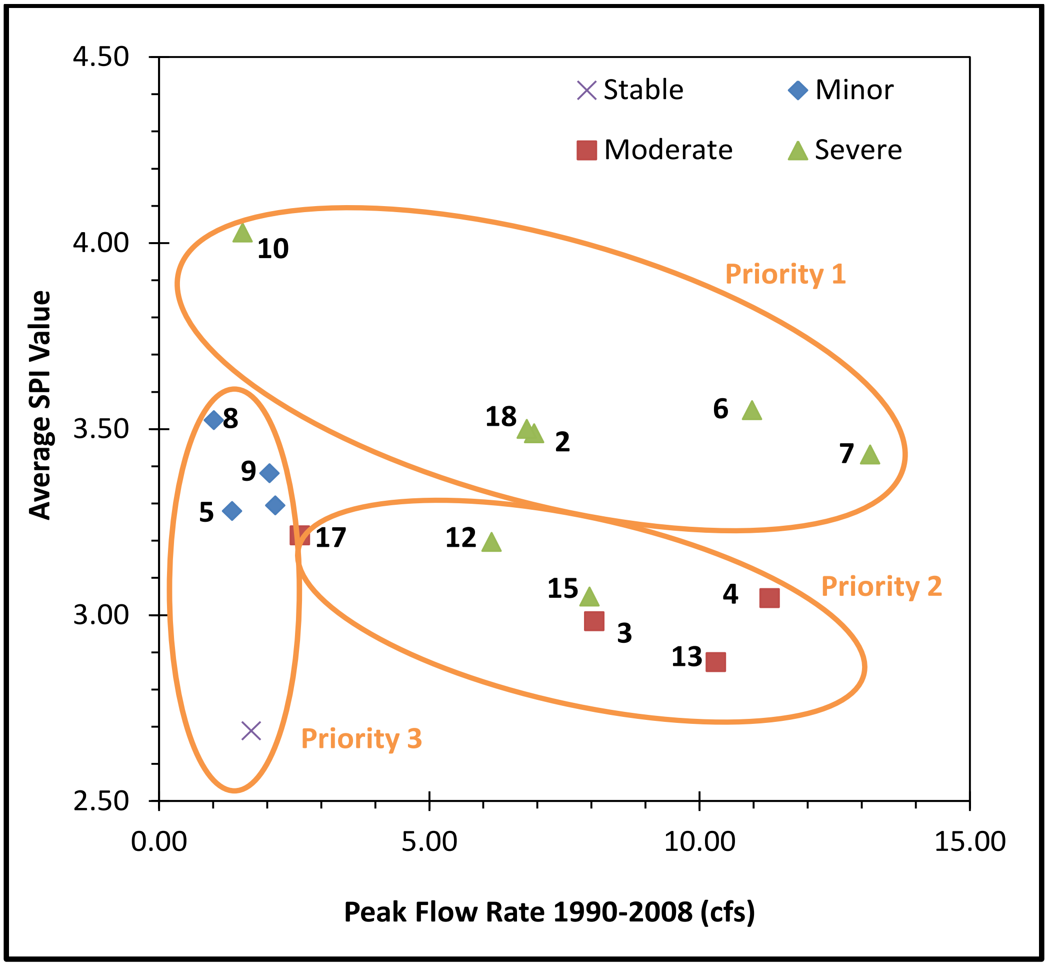

Figure 7.3 Ravine stability comparison

7.1.4 Implementation Prioritization and Costs to Address Erosion Sources

Using the results from Figure 7.3 and the severity rankings from the erosion survey implementation sites were group into three priority rankings. Priority 1 sites include the five ravines located in the severe grouping in Figure 7.3 plus a site with severe slope failure and the bank erosion downstream of the Bluff Creek culvert crossing of the Hennepin County Regional Trail Corridor. Priority 2 sites include four moderate erosion ravines and two severe erosion ravines located in the moderate grouping in Figure 7.3, as well as the three moderate erosion slope failure and bank erosion sites listed along with stream stabilization measures along with entire lower reach. The remaining sites listed as having minor erosion were listed as priority 3. Table 7.2 lists all of the erosion sites grouped by priority and includes cost information in 2007 dollars for each sites. 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 trail culvert crossing is estimated to cost approximately $4.5 million. The implementation of only priority 1 sites would cost $2.0 million, priority 2 sites would cost $2.35 million and priority 3 sites would cost $110,000.

7.1.5 BMP Implementation for Habitat Fragmentation

As discussed in Section 4, long-term erosion downstream of the Bluff Creek culvert crossing of the Hennepin County Regional Trail Corridor has resulted in habitat fragmentation for most of the watershed of Bluff Creek. The stream channel has downcut significantly below the culvert, and the culvert is being undermined. Left unchecked, the culvert may begin to fail. As discussed in Section 7.1.4, an implementation project at Site 1 is proposed as a high priority to both address the erosion and ultimately restore fish passage at this site.

Assuming that the culvert is not in need of replacement, fish passage could be provided by building a ramp structure at the culvert outlet. The ramp would provide a series of pools that fish could navigate in the upstream direction. 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 eroding bank should be stabilized at the time of construction, likely with vegetated reinforced soil slope (VRSS), which is a bio-engineering approach that is well suited to steep banks.

7.1.6 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 cities. Each city's 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. When MS4s discharge to an impaired water with an approved TMDL, the permittee must review the adequacy of the SWPPP to meet the

WLAs set for storm water sources and make appropriate modifications to the SWPPP within 18 months after the TMDL is approved.

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. 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.

Chapter 7 of the Minnesota Stormwater Manual (MPCA, 2008) provides guidance on nine key factors to consider in the selection of the appropriate BMPs for implementation within the urbanized areas of the basin and Chapter 4 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. The TMDL Implementation Plan will include recommendations for infiltration practices (rainwater gardens, infiltration basins, swales, etc.) and improved site design that can be used to mitigate the impacts of future watershed development.

7.2 Construction Stormwater Implementation

The wasteload allocation for stormwater discharges from sites where there is construction activities reflects the number of construction sites $\geq$ 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.

Table 7.2 **Estimating project cost bluff creek lower valley stabilization.**

Erosion Site Number	Type	Grade	Priority	Estimated Cost	Mobilization 10%	Engineering & Design 30%	Contingency 20%	Total[1,2]
1	Culvert/Bank Erosion/Fragmentation	Severe	1	$81,250	$8,125	$24,375	$16,250	$130,000
2	Ravine	Severe	1	$200,467	$20,047	$66,154	$44,103	$330,000
6	Ravine	Severe	1	$114,300	$11,430	$37,719	$25,146	$190,000
7	Ravine	Severe	1	$140,767	$14,077	$46,453	$30,969	$230,000
10	Ravine	Severe	1	$118,760	$11,876	$39,191	$26,127	$200,000
14	Slope Failure	Severe	1	$280,000	$28,000	$92,400	$61,600	$460,000
18	Ravine	Severe	1	$280,800	$28,080	$92,664	$61,776	$460,000
15	Ravine	Severe	2	$252,200	$25,220	$83,226	$55,484	$420,000
12	Ravine	Severe	2	$172,000	$17,200	$56,760	$37,840	$280,000
3	Ravine	Moderate	2	$98,767	$9,877	$32,593	$21,729	$160,000
4	Ravine	Moderate	2	$107,000	$10,700	$35,310	$23,540	$180,000
11	Slope Failure	Moderate	2	$175,000	$17,500	$57,750	$38,500	$290,000
13	Ravine	Moderate	2	$10,000	$1,000	$3,300	$2,200	$20,000
16	Slope Failure	Moderate	2	$243,333	$24,333	$80,300	$53,533	$400,000
17	Ravine	Moderate	2	$31,000	$3,100	$10,230	$6,820	$50,000
19	Ravine	Moderate	2	$16,567	$1,657	$5,467	$3,645	$30,000
20	Bank Erosion	Moderate	2	$10,000	$1,000	$3,300	$2,200	$20,000
Various	Stream Stabilization	Minor to Severe	2	$300,000	$30,000	$99,000	$66,000	$500,000
21	Ravine	Moderate/Minor	3	$10,000	$1,000	$3,300	$2,200	$20,000
22	Ravine	Moderate/Minor	3	$15,000	$1,500	$4,950	$3,300	$20,000
5	Ravine	Minor	3	$18,000	$1,800	$5,940	$3,960	$30,000
8	Ravine	Minor	3	$10,000	$1,000	$3,300	$2,200	$20,000
9	Ravine	Minor	3	$10,000	$1,000	$3,300	$2,200	$20,000
							GRAND TOTAL	**$4,460,000**

Notes:
[1]All costs are in 2007 dollars
[2]Total costs do not include the costs of construction easements or permanent easements

7.3 Industrial Stormwater Implementation

The wasteload allocation for stormwater discharges from sites where there is industrial activity reflects the number of sites in the watershed for which NPDES industrial stormwater permit coverage is 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.

7.4 Implementation Summary

As indicated in Figure 3.13, 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. This indicates that loading reductions are only needed under the high flow condition to meet the turbidity standard and no reductions are necessary under the other four flow conditions. As discussed in Sections 3.4.2 and 3.4.3, 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 3.1. Since the 90th percentile TSS concentration over the three year monitoring period (Figure 3.14) 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 7.3. Table 7.3 also shows the estimated TSS loadings under existing 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 7.3 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	--

The Clean Water Legacy Act requires that a TMDL include an overall approximation ("…a range of estimates") of the cost to implement a TMDL [Minn. Statutes 2007, section 114D.25]. Based on the costs estimated for implementing the individual improvement options (see Table 7.2) intended to meet the Bluff Creek Turbidity TMDL, an expected range of overall possible project costs is estimated between $2.0 million and $4.5 million. This estimate will be refined when the detailed implementation plan is developed, following approval of the TMDL study.

8.0 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.

Within one year of the approval of the Turbidity TMDL by the USEPA, a Final Implementation Plan will be released. This Implementation Plan will identify the responsible entities and actions that it will take to incorporate TMDL results into local management activities. 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 Riley-Purgatory-Bluff Creek Watershed District's Watershed Management Plan, the Carver County Water Plan, and the City of Chaska's Comprehensive Plan.

- The MPCA's MS4 General Permit requires MS4s to provide reasonable assurances that if an EPA-approved TMDL has been developed, they must review the adequacy of their Storm Water Pollution Prevention Program required by the MS4 to meet the TMDL's WLA set for stormwater sources. If the Storm Water Pollution Prevention Program is not consistent with achieving the applicable requirements, schedules and objectives of the TMDL, they must modify their Storm Water Pollution Prevention Program, as appropriate, within 18 months after the TMDL is approved.

- 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.

9.0 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

An opportunity for public comment on the draft TMDL report was provided between November 5 and December 5, 2012. Approximately 42 comments were received from five organizations.

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Appendices

Appendix A

Analysis of Proposed Change to Turbidity Standard

Overview of New Turbidity Standard

The MPCA is considering a change in the turbidity standard from the current 25 NTU standard to a new standard where TSS concentrations cannot exceed 30 mg/L more than 10% of the time. This appendix outlines one potential approach to computing the TMDL for the new standard. The standard is still being developed and approaches to apply the standard are in flux.

A probable change in the turbidity standard from 25 NTU to 30 mg/L TSS would influence the results of this TMDL study. This appendix details the TMDL components described in section 3.4 using the possible new 30 mg/L standard. Application of the new standard to this TMDL would involve a shift in the calculation of the TMDL from the current standard's TSS surrogate of 120 mg/L to a TSS concentration of 30 mg/L not to be exceeded more than 10% of the time.

TSS Daily Loading Capacity

A methodology for calculating the TSS total daily loading capacities with the proposed TSS standard has not been developed by the MPCA yet to account for the introduction of a percent exceedance into the numeric standard. In lieu of such a procedure, the daily loading capacities for the proposed standard were calculated for the Bluff Creek WOMP station (MCES 3.5) the same way the current TMDL was calculated. The flow duration curves and flow zone values using data for years 2008-2010 are equivalent to the values discussed in section 3.4. In this manner, the target TSS concentration was changed from 120 mg/L to 30 mg/L with no adjustment to account for the 10% exceedance that would be present in the new standard. The reduction reduced the total daily loading capacities from 8.22 to 2.06 tons/day; 1.44 to 0.38 tons/day; 0.84 to 0.21 tons/day; 0.47 to 0.12 tons/day; and 0.13 to 0.03 tons/day for the high, moist, mid, dry and low flow zones respectively (Table A.1).

Table A.1 Total Suspended Solids Loading Capacities and Allocations Using 30 mg/L TSS Standard (AUID: 07020012-710)

	Flow Zone				
	High	Moist	Mid	Dry	Low
	Tons/day				
TOTAL DAILY LOADING CAPACITY	2.14	0.38	0.21	0.12	0.03
Wasteload Allocation					
Communities Subject to MS4 NPDES Requirements					
Mn/DOT MS4 NPDES	0.18	0.03	0.02	0.01	0.002
Carver County MS4 NPDES	0.03	0.01	0.003	0.002	<0.001
Chaska MS4 NPDES	0.07	0.01	0.01	0.004	0.001
Chanhassen MS4 NPDES	0.73	0.13	0.07	0.04	0.01
Construction Stormwater	0.001	<0.001	<0.001	<0.001	<0.001
Industrial Stormwater	0.001	<0.001	<0.001	<0.001	<0.001
Load Allocation	0.91	0.16	0.09	0.05	0.01
Margin of Safety	0.21	0.04	0.02	0.01	0.00
	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 MS4 NPDES	8.3%	8.3%	8.3%	8.3%	8.3%
Carver County MS4 NPDES	1.6%	1.6%	1.6%	1.6%	1.6%
Chaska MS4 NPDES	3.3%	4.2%	4.2%	4.2%	4.2%
Chanhassen MS4 NPDES	34.1%	52.3%	52.3%	52.3%	52.3%
Construction Stormwater	0.05%	0.05%	0.05%	0.05%	0.05%
Industrial Stormwater	0.05%	0.05%	0.05%	0.05%	0.05%
Load Allocation	42.6%	23.6%	23.6%	23.6%	23.6%
Margin of Safety	10%	10%	10%	10%	10%

Load and Water Quality Duration Curves Bluff Creek WOMP

Load duration curves were developed showing the existing 25 NTU standard and the proposed 30 mg/L TSS standard for the three sample years (Figure A.1-A.3) and all three years combined (Figure A.4). The 90th percentile and mean values for each flow zone are also shown and are discussed in section 3.4 of the report. The 90th percentile value for both the high flow and moist conditions zones are above the 30 mg/L standard for all years and do not meet the standard requirements. The midrange flows, dry conditions and low flows all meet the standard requirements.

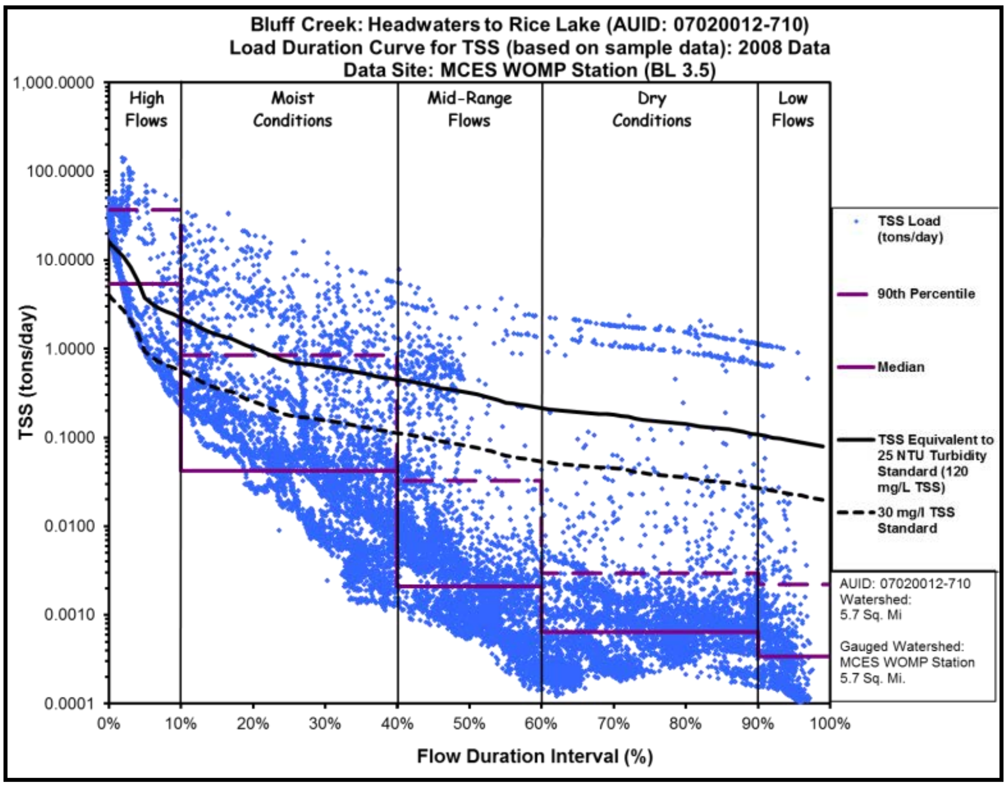

Figure A.1 Load Duration Curve 2008 (Bluff Creek WOMP)

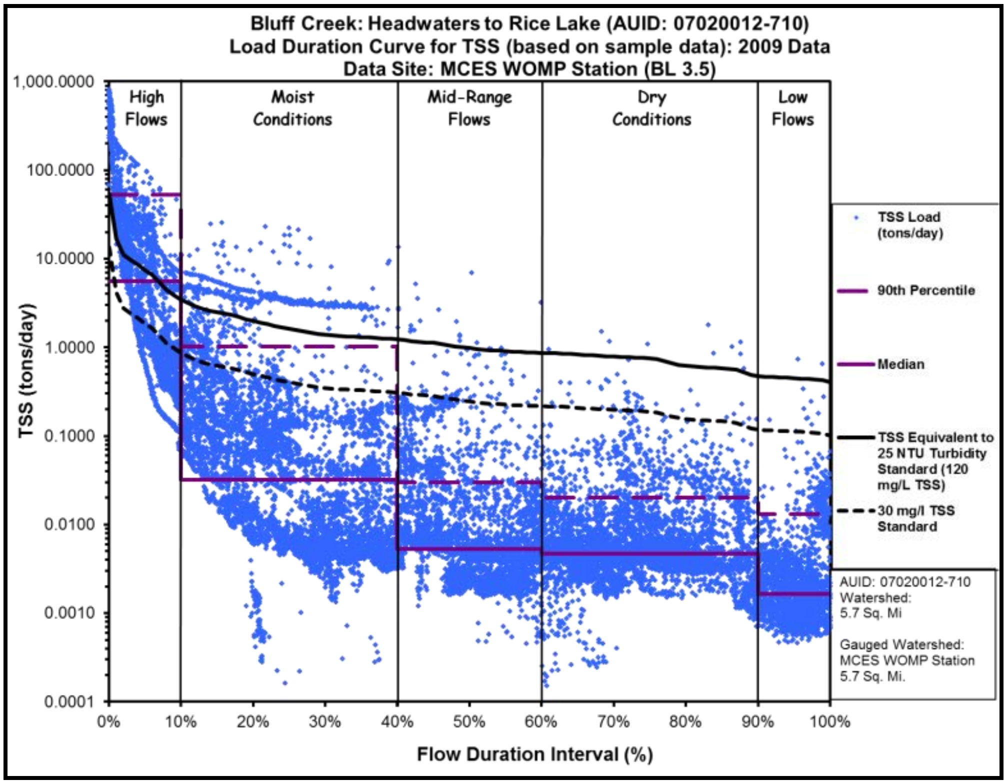

Figure A.2 Load Duration Curve 2009 (Bluff Creek WOMP)

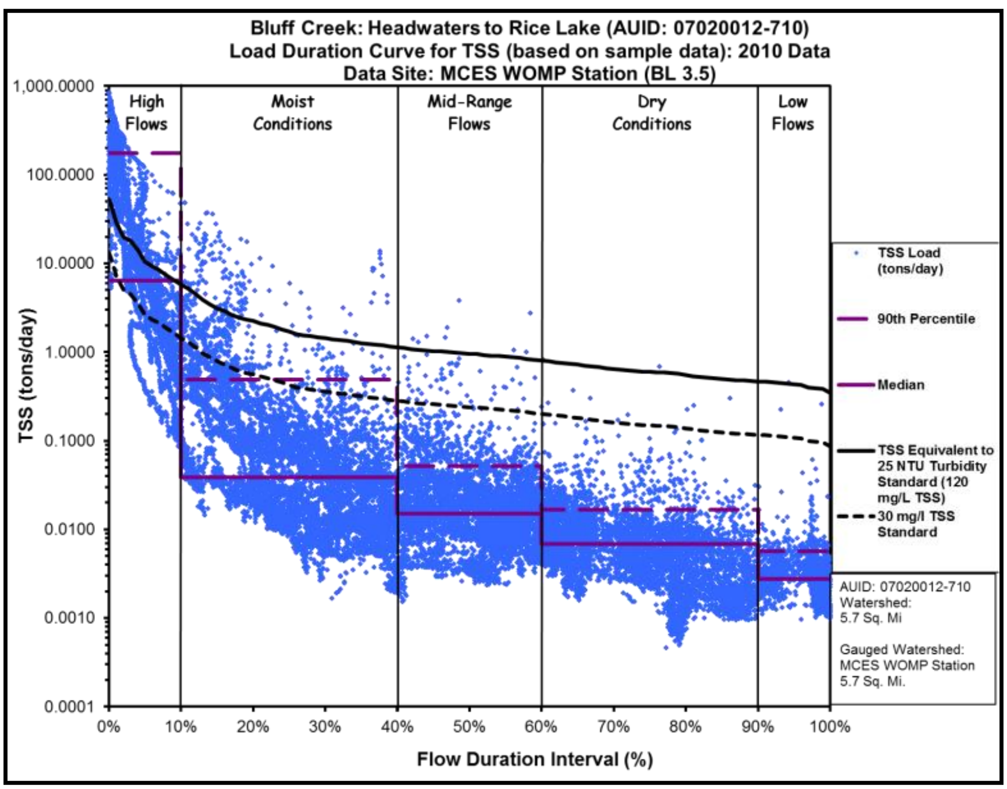

Figure A.3. Load Duration Curve 2010 (Bluff Creek WOMP)

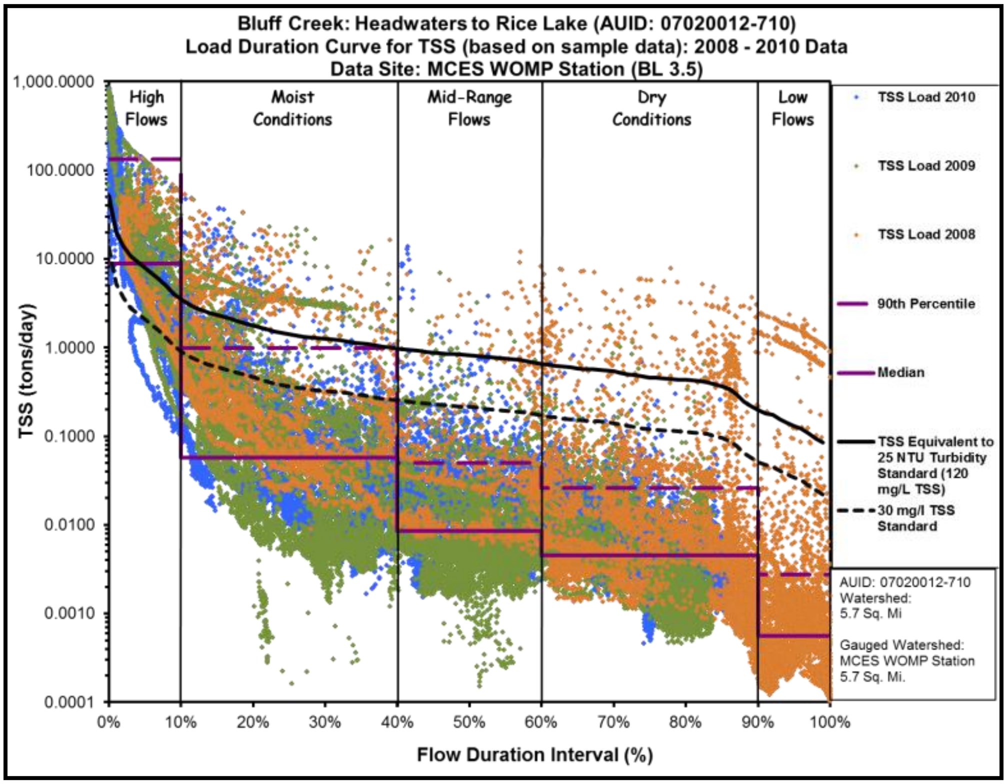

Figure A.4. Load Duration Curve 2008-2010 (Bluff Creek WOMP)

Load Duration Curve Pioneer Trail

A load duration curve was developed showing the existing 25 NTU standard and the proposed 30 mg/L TSS standard for 2008 at the Pioneer Trail sample site (Figure A.5). The 90th percentile and mean values for each flow zone are also shown and are discussed in section 3.4 of the report. The 90th percentile value for both the High flow and moist conditions zones are above the 30 mg/L standard for all years and do not meet the standard requirements. The midrange flows, dry conditions and low flow data were not available for analysis.

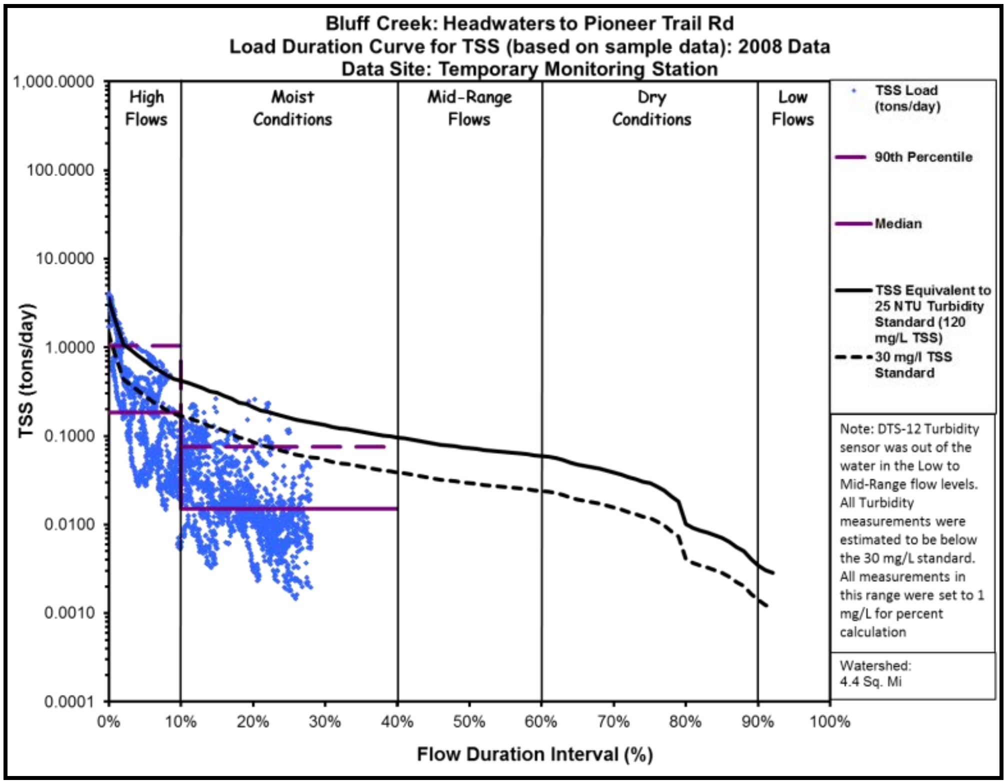

Figure A.5 Load Duration Curve 2008 (Pioneer Trail)

Overall Conclusions

In order to meet the proposed standard the Bluff Creek WOMP (07020012-710) would have to be below 30 mg/L 90% of the time. Figure B.6 shows how the existing data at the WOMP station compares to this standard. The TSS concentrations were ranked based on the percent exceedance. The red line represents the TSS water quality standard crossing at 10% and 30 mg/L. In order to meet the standard the percent rank lines would have to cross through or below the intersection of the two standard lines. In all three years the TSS concentrations exceed the new standard. For 2010 14.7% of the TSS measurements exceed 30 mg/L. In 2009 this number was 13.6%, 2008 it was also 13.6% and the combined 2008-2010 record exceeded 30 mg/L 14.1% of the time. The 10% exceedance concentrations were 65, 67, 70 and 67 mg/L for the 2010, 2009, 2008, and the combined (2008-2010) data sets. This is more than double the 30 mg/L standard.

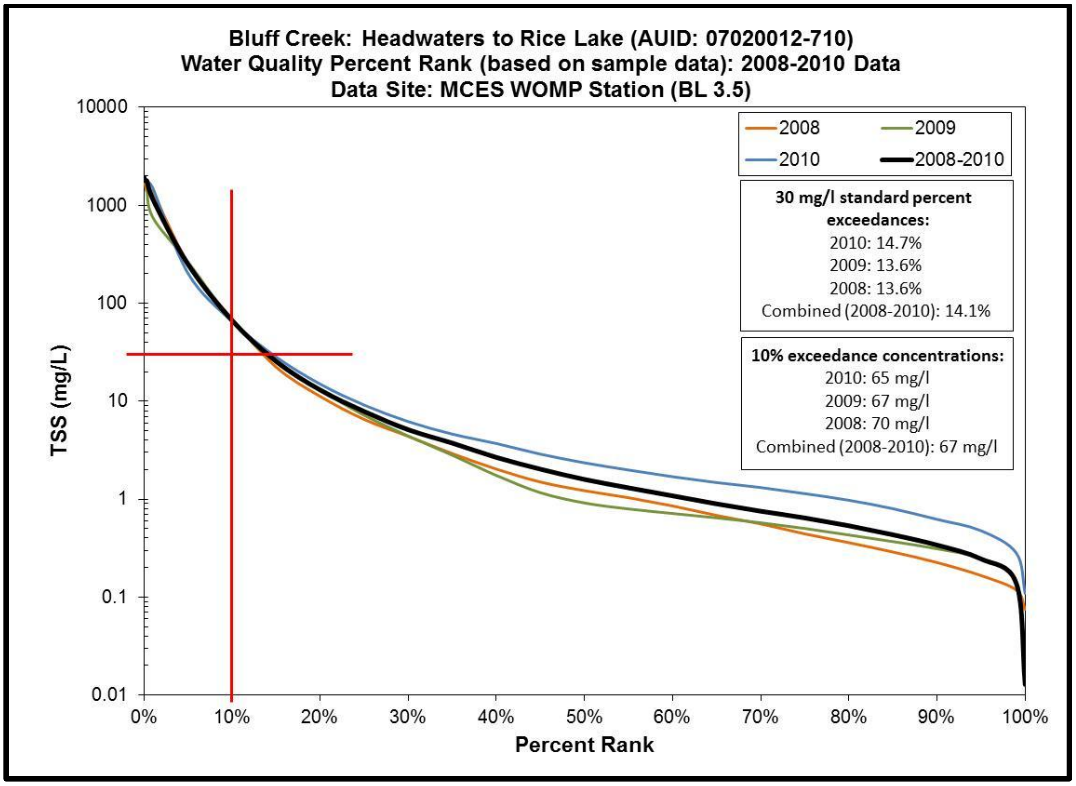

Figure A.5 Water Quality Percent Rank (Bluff Creek WOMP)

The calculated Total Maximum Daily Load (TMDL) of TSS that serves as the loading capacity for each reach is based on the 30 mg/L TSS standard, but an approximation for an overall load reduction percentage can be made by comparing the existing dataset to the assessment criteria. The standard states that 30 mg/L cannot be exceeded more than 10% of the time, therefore, to meet the standard 90 percent of the time would mean reducing the 90th percentile value from the dataset down to 30 mg/L. Based on the monitoring data, it is estimated that the overall magnitude of reduction needed to the meet the turbidity standard for the Bluff Creek WOMP is between 97 and 99% for high flows (0-10% flow duration), and between 13 and 79 % for moist conditions (10-40% flow duration) with mid-range flows (40-60% flow duration), dry conditions (60-90% flow duration intervals), and low flows (90-100% flow duration) meeting the turbidity standard throughout the study area under current conditions (Table A.2). At the Pioneer Trail station the reduction needed to meet the standard is 72 % for high flow and 14% for moist conditions. Data was not available for the three other flow conditions, but it is assumed that they currently meet the standard. These reduction percentages are intended as a rough approximation, as it does not account for any changes in flow, but serves to provide a starting point based on available water quality data for assessing the magnitude of the effort needed in the watershed to achieve the standard.

Under the existing 25 NTU standard these reduction percentages would be much lower (Table A.3). To meet this standard at the Bluff creek WOMP station high flow concentrations would need to be reduced by 86-94 percent and moist conditions only exceeded the standard during the year 2008. At the Pioneer Trail station, concentrations would only need to be reduced by 32% during high flow events. These reductions are based on the assumption that the 25 NTU standard can be exceeded 10 percent of the time and delisted. However the language of the standard does not state this assumption. In the new 30 mg/L standard this assumption is clearly stated.

Table A.2 Percent Decrease by Flow Regime for Bluff Creek using 30 mg/L TSS Standard

AUID	Description	Percent Decrease by Flow Regime				
		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
	Headwaters to Pioneer Trail (2008)	72.3%	13.5%	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2008)	97.4%	78.9%	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2009)	96.5%	59.9%	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2010)	98.5%	13.5%	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2008-2010)	98.4%	62.7%	N/A	N/A	N/A

Table A.3 Percent Decrease by Flow Regime for Bluff Creek using 25 NTU Turbidity Standard

AUID	Description	Percent Decrease by Flow Regime				
		High Flows	Moist Conditions	Mid-Range Flows	Dry Conditions	Low Flows
	Headwaters to Pioneer Trail (2008)	31.7%	N/A	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2008)	89.8%	15.6%	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2009)	85.9%	N/A	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2010)	94.0%	N/A	N/A	N/A	N/A
07020012-710	Headwaters to WOMP (2008-2010)	93.9%	N/A	N/A	N/A	N/A

Appendix B

Evaluation of “Paired” Turbidity Measurements from Two Turbidimeters for Use in Two TMDL Projects

December 13, 2007

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Background

Turbidity is a parameter that has a significant amount of variability associated with the measurement values reported. Unlike many water quality parameters which are a measurement of a mass of constituents in a volume of water, turbidity is a measure of the optical properties of a water sample which causes light to be scattered and absorbed (Federal Water Pollution Control Administration, 1968). The optical properties are affected by the biological, physical and chemical components in the water. Differences in the constituents' response to light contribute to this variability. Adding to this variability, differences between turbidity meter types can result in different turbidity values being measured for the same water samples. The USGS and others have published papers documenting the variation in turbidity measurements that can occur due to different sensor configurations, detector angle, and light wavelength used (Pavelich, 2002; Ankcorn, 2003; Anderson, 2005). While the manufactured meters comply with standard method requirements of the EPA, different results may occur when using different types of turbidity meters and sensors. The variation occurs across different manufacturing company sensors and even within different generations of the same model sensor within a company. To address this issue, the United States Geological Survey (USGS) developed a reporting unit/category system to distinguish between the different sensor groups (Miller 2004, Anderson 2005).

Differences in turbidity values between meters have been observed in Minnesota through various monitoring efforts.

With the development of turbidity (and other variables) TMDLs well under way in Minnesota, the Minnesota Pollution Control Agency (MPCA) developed a Turbidity TMDL Protocol (MPCA, 2007) as guidance to assist projects in completing the work needed for a turbidity TMDL. The issue of differences in measurements of turbidity between different meters was addressed in two ways. First, the protocol identified the need to use the turbidity reporting units/categories adopted by the USGS to differentiate data sets by type of turbidity meter. The MPCA began using the reporting categories for data being entered into STORET in 2005.

Secondly, the protocol identified a list of options/recommendations to use/follow when a project has one or more types of turbidity data. At the time of the protocol development, it was envisioned that use of this list would be sufficient in the short term as paired measurements of the data types were made and compared. The list of options assumed that the type of data present in a project would largely determine which reporting unit would be used in evaluating the data against the turbidity standards of 10 or 25 NTU. This, in essence, is what has been done for the turbidity TMDLs that have been approved by EPA prior to 2008.

The difficulty of selecting a "method" from this list of options became apparent fairly quickly for various reasons in three projects. In the Minnesota River Turbidity TMDL project, a difference in turbidity values between the MPCA and Metropolitan Council Environmental Services (MCES) monitoring programs had been recognized and discussed prior to and following the completion of the protocol. The primary differences are likely due to the use of different turbidimeters in the two labs. The MCES lab used a Hach 2100A meter to measure turbidity (J. Klang, personal communication, 2006). This meter measures turbidity via a single white light source and a single light detector located at 90 degrees to the light source. The USGS unit reporting category for this meter is NTU. The MDH lab used a Hach 2100AN meter to measure turbidity. This meter is set to measure turbidity utilizing a single white light source and two (multiple) light detectors. One detector is located at 90 degrees to the light source and the second light detector is located at a wider angle with a "ratio" compensation being made between the two (J. Klang, personal communication, 2006). The USGS unit reporting category for this meter is NTRU.

The protocol includes a description of the differences. The impact of the difference was thought to be important, but a decision on which to use in evaluating the standard was not made until the project timeline required a decision be made to identify a target for the HSPF modeling of the basin. The MPCA technical team for the project decided to use the NTU reporting category and, hence, the MCES turbidity data in the targeting work. The difference between the data sets was shown in a small set of paired (same water samples) turbidity measurements made by the MCES and Minnesota Department of Health (MDH) Laboratories where a "difference factor" of 0.55 was estimated in some way, but not formally documented.

The next turbidity project to face a decision on what and/or how to deal with turbidity data with different reporting units was the West Fork Des Moines River Turbidity TMDL project. In this case, the initial analysis and evaluation of the turbidity data combined together resulted in an apparent difference in the sediment reduction needed between two watersheds in the project. In working to document this unexpected difference, it was determined that the water samples from two watershed projects were analyzed by different laboratories – one being the MDH Lab measuring turbidity as NTRU and the other being the Minnesota Valley Testing Laboratory (MVTL) measuring turbidity as NTU. In discussing a means in which to "correct" the data, the project team decided to make the assumption that the difference between the two measurement types was the same as for the paired-data set of MCES and MDH turbidity measurements completed as part of a river remote sensing and monitoring project conducted in 2004. Subsequent estimates of load reductions needed in the two watersheds were very similar, as expected given the similarity of the watersheds. However, the relationship between the paired data had not been fully completed and documented, so MPCA staff began completing the data analysis with this document describing the results of the work.

A third turbidity TMDL project to encounter a problem related to a difference between reporting unit values was the Pipestone Creek Turbidity TMDL. In this project, the TMDL was originally developed with a lower TSS target. During the TMDL review, MPCA reviewed the calculation of the TMDL target for TSS. By going back to the water quality data documentation for the monitoring done in the project, it was determined that all of the turbidity data was measured as NTRU by the MDH Lab rather than as NTU, resulting in an overly stringent TSS target. Subsequent use of the initial ratio between NTRU and NTU in the paired data set provided a "better" / "more representative" evaluation of the current conditions to the turbidity standard.

Methods

With these issues and situations at the forefront of needs in completing turbidity TMDLs, this document presents a statistical evaluation of the paired data set for application in the Minnesota River, West Fork Des Moines River, and Pipestone Creek Turbidity TMDLs. The paired data are from water quality monitoring conducted as part of a river remote sensing study in 2004 by MPCA staff.

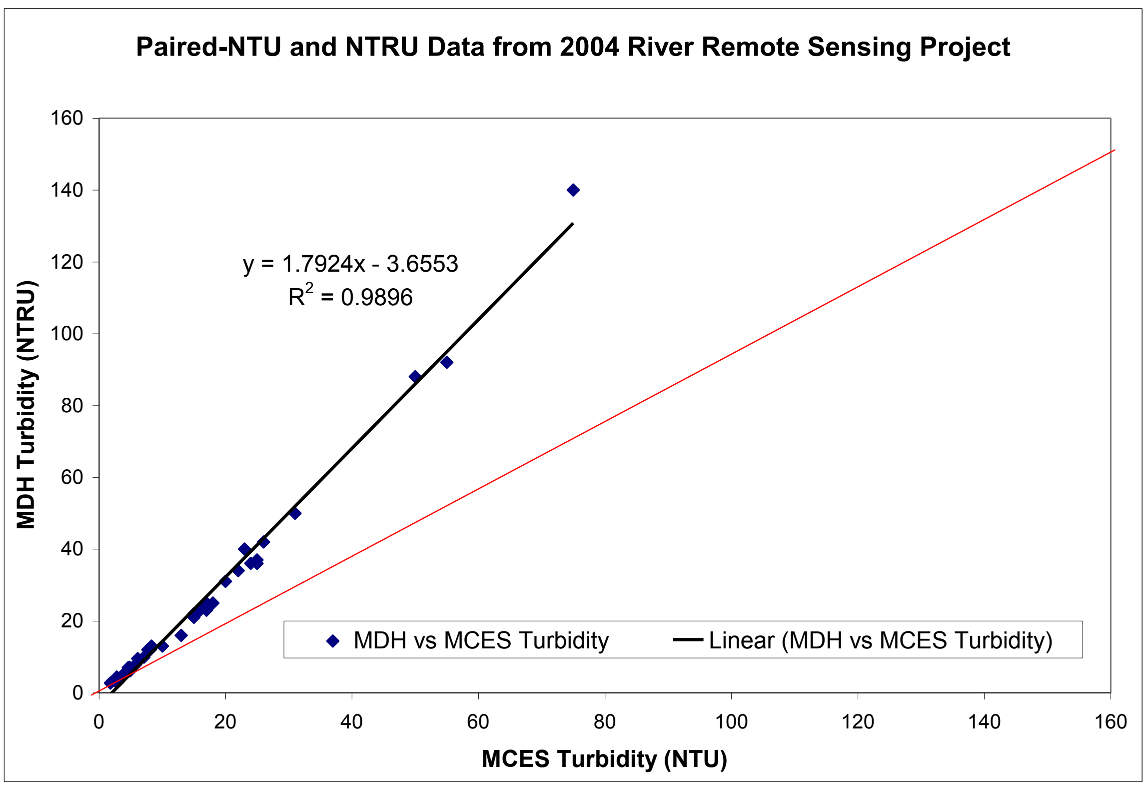
Excel and Minitab were used to analyze the paired laboratory turbidity data. The goal of the analysis was to use appropriate statistical methods to provide a "conversion" factor for estimating NTU values from measured NTRU values for use in the West Fork Des Moines River and Pipestone Creek Turbidity TMDLs given the absence of paired measurements from those project areas.

Summary statistics, tests for normality, linear regression, and paired-t tests and a nonparametric test parallel to a t-test were used for the analyses. The data and selected analyses are included at the end of this appendix.

Results

Linear regression of the raw data was initially completed to check if the initial difference factor of 0.55 was determined in this way (Figure 1). The results appear to indicate that this is the means in which the initial number was determined. However, summary statistics and histograms in Excel and tests for normality in Minitab indicate that the data is not normally distributed; such that parametric statistics (i.e., linear regression) should not be used on the raw data.

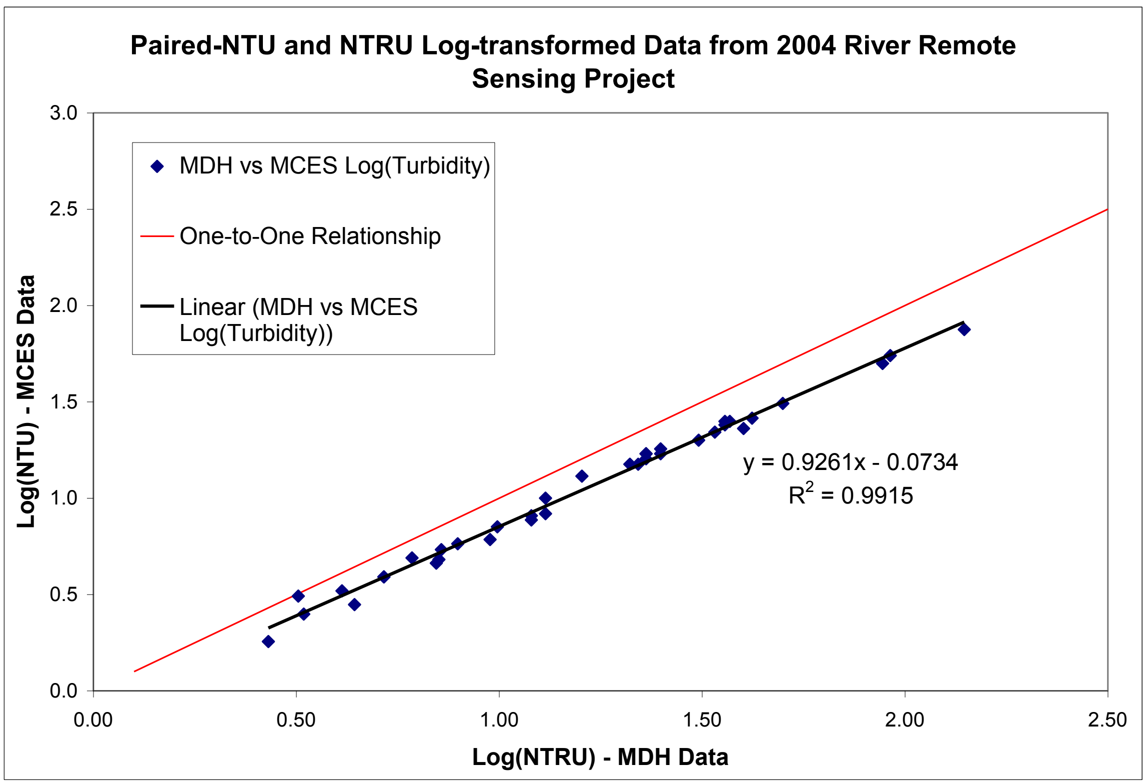
Figure 1.



The data were then log-transformed and evaluated to see if the log-transformed data were normally distributed. Summary statistics and histograms in Excel and tests for normality in Minitab indicate that the transformed data are nearly and acceptably normally distributed, respectively.

Linear regression analyses were then completed on the log-transformed data. The Excel regressions were done assigning the NTU data as the independent variable and the NTRU data as the dependent variable. The resulting regression equation resulted in the predicted y-variable being NTRU rather than NTU; therefore, the equation had to mathematically be solved for NTU. To reduce the chance of making a mistake in solving the equation for NTU, the Minitab regressions were run with the independent variable as NTRU and dependent variables as NTU. The resulting equation provided the predicted y-variable directly as NTU values. The switch to this approach occurred when a mistake in the math was found in the intermediate analysis work.

Figure 2.



Converting the predicted log-transformed value back to standard units (NTU) is done by taking the anti-log of the predicted number. Statistical analyses are often stopped at this point, especially in the natural sciences. However, statistical research has demonstrated that doing so results in a biased retransformation estimate. To correct this bias, there are various bias-correction factor procedures available for use. For this data, the Duan's Smearing Estimator (USGS, undated) was used. The effect of the bias-correction in this data was minimal; however, it is still the method of choice in this evaluation to complete the analyses following formal statistical procedures.

The final regression analysis and retransformation of the predicted variable in units of NTU resulted in the equation:

NTU = 10^(-0.0734+0.926*LOG(NTRU))/1.003635.

It is important to note when using this approach to "convert" NTRU to NTU values that the variability in measurements and characteristics of the water is probably much greater than the "accuracy" inferred by the significant digits used in this analysis. The estimated NTU turbidity values are best reported as integers, except for values less than ten where a single decimal place is adequate.

Table 1 provides a comparison of NTRU values to the predicted NTU values along with the ratio between the predicted NTU and observed NTRU values. Given the log-transformation and retransformation, the ratio between the values varies from low to high values with the difference between predicted NTU and measured NTRU being the least (highest ratio) at lower turbidity levels and greatest (lowest ratio) at higher turbidity levels. The ratio ranges from 0.6 to 0.65 for estimated turbidities (NTU) between 100 and 20, respectively. The ratio between the predicted and measured values at 25 NTU is 0.64.

Table 1

NTRU and "Estimated NTU" values based on regression of paired turbidity data from the 2004 River Remote Sensing Project

NTRU	"Estimated NTU"	Ratio
1	0.84	0.84
5	3.74	0.75
10	7.1	0.71
15	10.33	0.70
20	13.48	0.67
25	16.58	0.66
30	19.63	0.65
35	22.64	0.65
39	**25.02**	**0.64**
40	25.62	0.64
45	28.57	0.64
100	59.84	0.60

Given the differences in the standard procedures for the two meters and the relatively wide geographic range of the remote sensing study rivers, a visual check of regressions using two subsets of the paired data was performed. A subset of data less than 40 NTU was selected to check for a possible effect on the relationship due to dilution of samples for turbidities greater than 40 when using Standard Methods with a Hach 2100A turbidimeter. The second subset to be checked was data from the Blue Earth River Basin assuming that its location was "most similar" to that of the Des Moines River and Pipestone Creek. Figure 3 plots these with the "all data" regression. They show little difference between them, so the "all data" regression equation was used in calculating NTU values from the measured NTRU values in the turbidity TMDLs for the West Fork Des Moines River and Pipestone Creek.

Figure 4 plots the estimated NTU values versus a range of NTRU values based on the final regression analysis of the paired data set.

Figure 3.

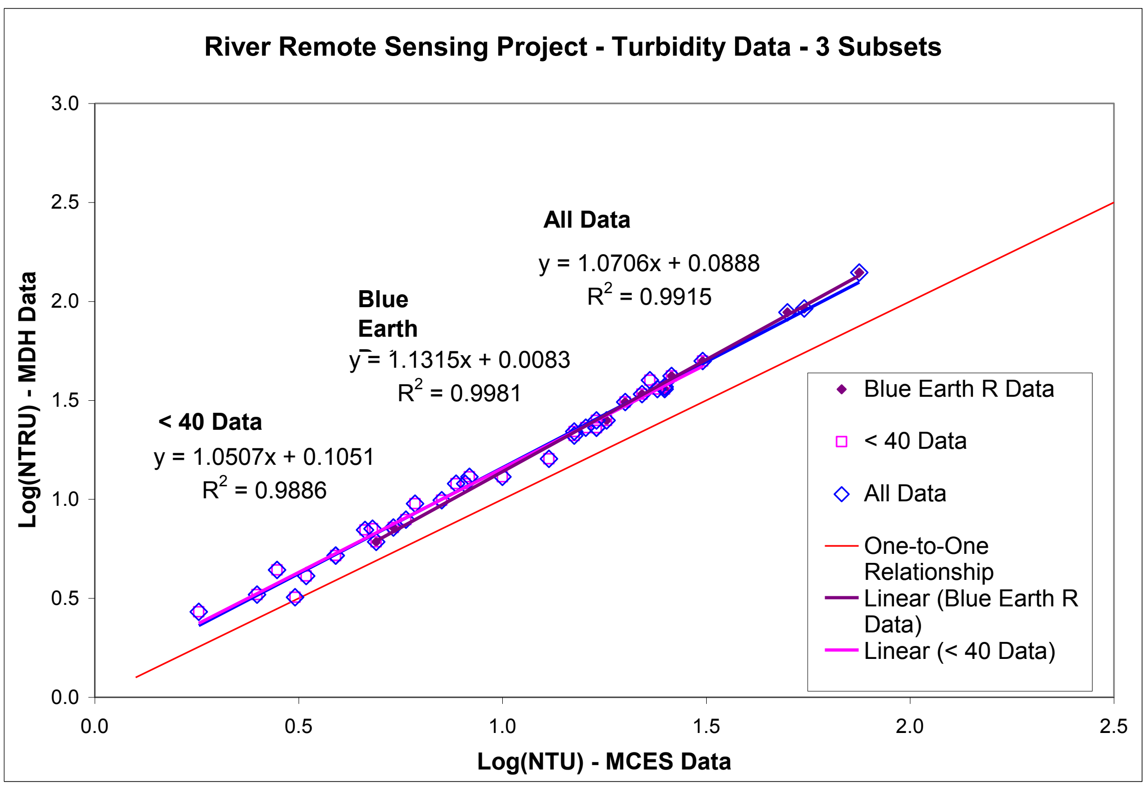
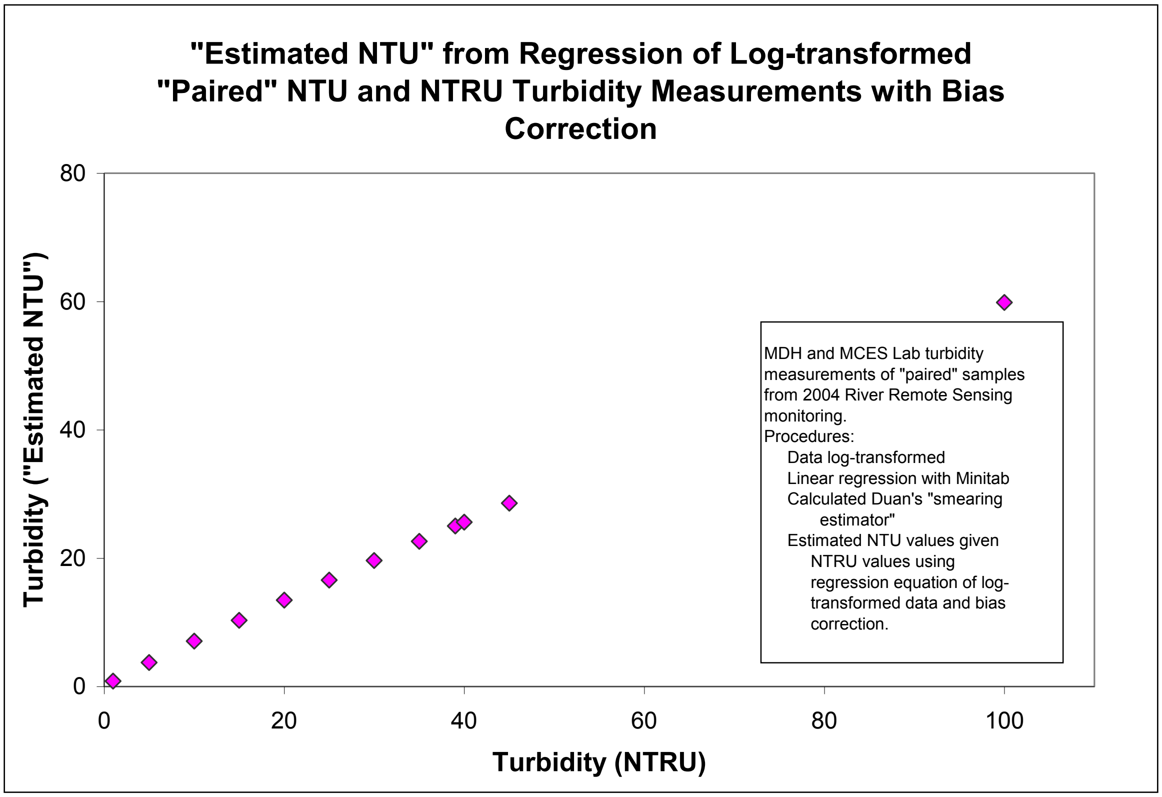


Figure 4.



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Appendix C

P8 Water Quality Modeling Parameters

P8 Model Parameters

Precipitation and Temperature Data

P8 reads hourly precipitation and daily average temperature data from a data file for a continuous simulation of watershed hydrology and the buildup/washoff of water quality constituents. Two hourly rainfall data sets were developed and used with a single temperature record.

- **Riley08.PCP**. The precipitation file Riley08 is comprised of precipitation data collected at the nearby Riley Creek WOMP station for year 2008. Precipitation was added from the Bluff Creek WOMP station when available. Bluff Creek precipitation data was used for periods 8/29/2008 – 9/6/2008 and 10/11/2008 – 12/9/2008. The data was converted from 15 minute intervals to hourly values. Snowmelt data is not included in this dataset. Only rainfall events were recorded.
- **MSP4908.PCP.** The precipitation file MSP4908 is comprised of precipitation data obtained from the National Weather Service Station at the Minneapolis-St. Paul International Airport during the period from 1949 through 2008. Hourly precipitation data were collected. Both rainfall and snowmelt events are included in this dataset.
- **MSP4908.tmp.** The temperature file was comprised of daily average temperature data from the National Weather Service Station at the Minneapolis–St. Paul International Airport during the period from 1949 through 2008.

Particle File Selection

- **NURP50.PAR**. The NURP50 particle file was used for the updated P8 model, which is consistent with the previous P8 model developed for the ASDD. The NURP50 particle file was developed as part of the Nationwide Urban Runoff Program (NURP); a research program conducted by the U.S. Environmental Protection Agency, and provides default parameters for several water quality components, based upon calibration to median, event-mean concentrations reported by NURP (Athayede et al., 1983).

Devices Parameter Selection

Three types of devices were used in this model: detention ponds, swales, and pipes. Detention ponds were used in watersheds were stormwater detention ponds were present or for reaches of the creek where ponding might occur. Swales were used to represent the parts of the stream channel and pipes were used at outflow points. Overall, 69 devices were created including 9 swale devices and 40 detention pond devices, and 20 pipe devices. The following are the various parameters used in each of the devices:

* **Detention Pond — Permanent Pool — Area and Volume —** The surface area and dead storage volume of each detention pond were determined. If limited information was supplied, an average depth of 2 feet was assumed and estimated the surface area (based on digital two-foot topography) to determine the pond permanent pool volume.

* **Detention Pond — Flood Pool — Area and Volume** — The surface area and storage volume under flood conditions (i.e., the storage volume between the normal level and flood elevation) were determined. The areas and volumes were obtained from the 2009 HydroCAD model. Where information was not present estimations were made based on digital two-foot topography, as built development plans, or field survey.

* **Infiltration Rate (in/hr)** — Infiltration rates were not used for detention ponds or swales.

* **Detention Pond — Orifice Diameter and Weir Length**— The orifice diameter or weir length was determined from the HydroCAD model.

* **Particle Removal Scale Factor —** A particle removal factor of 0.6 was selected for all ponds. A factor of 0.6 was used for all swales.

* **Swale – Flow Path Length** – The total channel length was measured in ArcGIS.

* **Swale – Flow Path Slope** – The percent slope was calculated using 2-ft contours provided by the city.

* **Swale – Bottom Width** – The bottom width was transferred from the HydroCad Model provided by the city.

* **Swale – Manning's n** – Manning's n was set to 0.03 for all channels.

* **Pipe – Time of Concentration (hrs)** – The time of concentration for various watersheds was calculated using a watershed CN and flow path length.

Watersheds Parameter Selection

* **Pervious Curve Number**— An overall composite pervious curve number was determined by weighting the areas for the given soil groups for each landuse type within

each P8 drainage basin. Soil information was provided by Carver County and land use information was provided by the 2006 NLCD land use dataset.

* **Indirectly Connected Impervious Fraction** – The parameter is a new addition to P8 Version 3.4. This value was set to 0 for all P8 drainage basins.

* **Connected Impervious Fraction** — A conservative estimate was used by assuming all impervious area is connected impervious.

* **Swept/Not Swept —** An "Unswept" assumption was made for the entire impervious watershed area. A Sweeping Frequency of 0 was selected.

* **Depression Storage —** 0.08 inches for all P8 drainage basins.

* **Impervious Runoff Coefficient** — 0.90 for all P8 drainage basins.

Watershed	Watershed Area (acres)	SCS Curve Number (Pervious)	Percent Impervious
BC-A1.1	27.19	68.9	15.7
BC-A1.10	222.55	68.5	16.9
BC-A1.11	47.21	71.5	39.1
BC-A1.12	21.91	72.4	41.4
BC-A1.13	89.85	69.2	21.9
BC-A1.2	11.99	70.1	24.4
BC-A1.3	5.73	64.7	7.5
BC-A1.4	11.01	68.8	26.0
BC-A1.5	46.23	65.1	27.7
BC-A1.5B	4.03	69.9	38.8
BC-A1.5C	8.43	67.3	27.1
BC-A1.6	15.82	74.8	28.6
BC-A1.7A	16.80	68.6	14.8
BC-A1.7B	13.00	70.8	30.7
BC-A1.8	38.39	68.5	9.6
BC-A1.9	24.15	65.4	21.6
BC-A2.1	9.38	72.6	22.7
BC-A2.10	18.54	65.4	20.4
BC-A2.12	43.29	68.1	14.2
BC-A2.12A	31.86	69.2	7.7
BC-A2.12B	12.29	68.2	11.1
BC-A2.13	15.28	63.3	7.2
BC-A2.2	17.73	70.5	53.3
BC-A2.3	23.92	72.0	46.8
BC-A2.4	27.41	68.3	37.0
BC-A2.5A	5.27	76.1	51.5
BC-A2.5B	7.17	68.8	23.9
BC-A2.6	41.52	72.8	46.2
BC-A2.7	40.52	74.2	53.5
BC-A2.9A	80.11	70.7	22.8
BC-A2.9B	140.33	67.7	14.9
BC-A3.1	50.66	73.8	26.6
BC-A3.2	31.44	75.5	14.6
BC-A3.3	42.58	70.7	42.0
BC-A3.4	45.72	73.1	9.2
BC-A3.4A	103.19	70.4	11.4
BC-A4.1	69.65	73.5	42.2
BC-A4.10	77.77	70.9	30.8
BC-A4.11	43.66	69.5	10.3
BC-A4.12	44.73	69.1	5.9
BC-A4.2	38.47	73.4	25.5
BC-A4.3	41.90	71.1	13.2
BC-A4.4	16.40	73.5	54.5
BC-A4.5	22.59	78.4	7.5
BC-A4.6	49.22	69.4	26.9
BC-A4.7	214.33	72.7	12.3
BC-A4.8	24.82	74.5	39.5
BC-A4.9	2.92	78.7	37.8

Watershed	Watershed Area (acres)	SCS Curve Number (Pervious)	Percent Impervious
BC-A5.1	36.39	73.6	8.0
BC-A5.10	140.80	64.7	12.4
BC-A5.11	97.83	69.7	5.9
BC-A5.12	15.95	63.8	4.2
BC-A5.13	71.65	67.0	11.3
BC-A5.13A	21.15	66.2	10.7
BC-A5.14	26.52	64.4	7.3
BC-A5.15	25.49	67.5	8.8
BC-A5.17	21.40	66.1	7.9
BC-A5.18	32.22	62.2	12.2
BC-A5.19	74.76	72.1	17.6
BC-A5.2	36.69	67.4	4.0
BC-A5.3	18.44	71.5	2.8
BC-A5.4	16.10	65.0	9.2
BC-A5.5	7.94	81.9	13.6
BC-A5.6	78.21	67.6	8.6
BC-A5.7	72.37	71.7	10.0
BC-A5.8	42.52	69.9	10.9
BC-A5.9	42.71	70.1	29.0
BC-A6.1	124.15	74.4	17.6
BC-A6.10	13.31	64.2	2.1
BC-A6.11	17.97	64.0	10.7
BC-A6.12	16.84	60.6	6.7
BC-A6.13	35.20	60.7	0.9
BC-A6.13A	5.77	59.0	0.5
BC-A6.13B	4.34	61.7	3.7
BC-A6.14	20.09	62.8	2.6
BC-A6.15	12.66	61.1	4.6
BC-A6.19	76.67	59.5	1.6
BC-A6.19A	15.37	59.2	3.2
BC-A6.19B	15.55	64.1	5.2
BC-A6.19C	21.80	64.0	5.4
BC-A6.19D	3.63	60.5	0.1
BC-A6.19E	14.76	66.3	12.3
BC-A6.19F	21.99	64.7	10.6
BC-A6.19G	3.09	62.7	0.9
BC-A6.19H	4.48	59.3	0.8
BC-A6.19I	2.27	58.7	0.6
BC-A6.19J	2.95	59.2	1.6
BC-A6.21	7.09	63.3	13.1
BC-A6.22	4.71	64.5	16.2
BC-A6.3	16.94	72.3	35.6
BC-A6.4	64.39	69.1	33.2
BC-A6.5	5.12	71.8	0.0
BC-A6.6	84.89	68.8	19.0
BC-A6.7	44.16	63.0	17.8
BC-A6.7A	17.47	66.2	36.7
BC-A6.8	33.28	63.0	10.1

Appendix D

Detailed Discussion of Biological Stressors

The Bluff Creek Biological Stressor Identification report (http://www.pca.state.mn.us/index.php/view-document.html?gid=13751) determined the stressors causing the stream's biological impairment. Four primary stressors affecting biotic integrity in Bluff Creek were identified: sediment, metals, flow, and habitat fragmentation. One of those stressors – sediment – would be addressed by achieving TMDL wasteload and load reductions through this TMDL.

A second stressor - metals – may also 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 (Figures D.1 through D.6). Hence, sediment load reductions will also reduce metal loads to Bluff Creek.

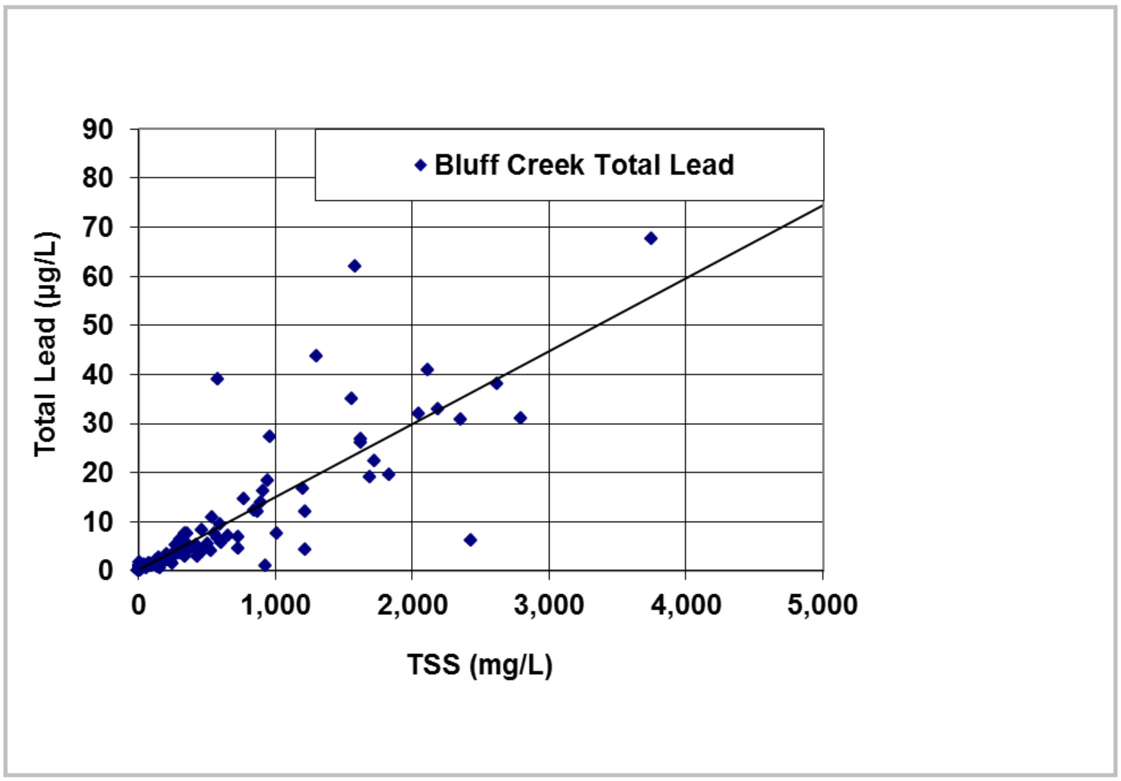

Figure D.1 Lead versus suspended solids for Bluff Creek WOMP site

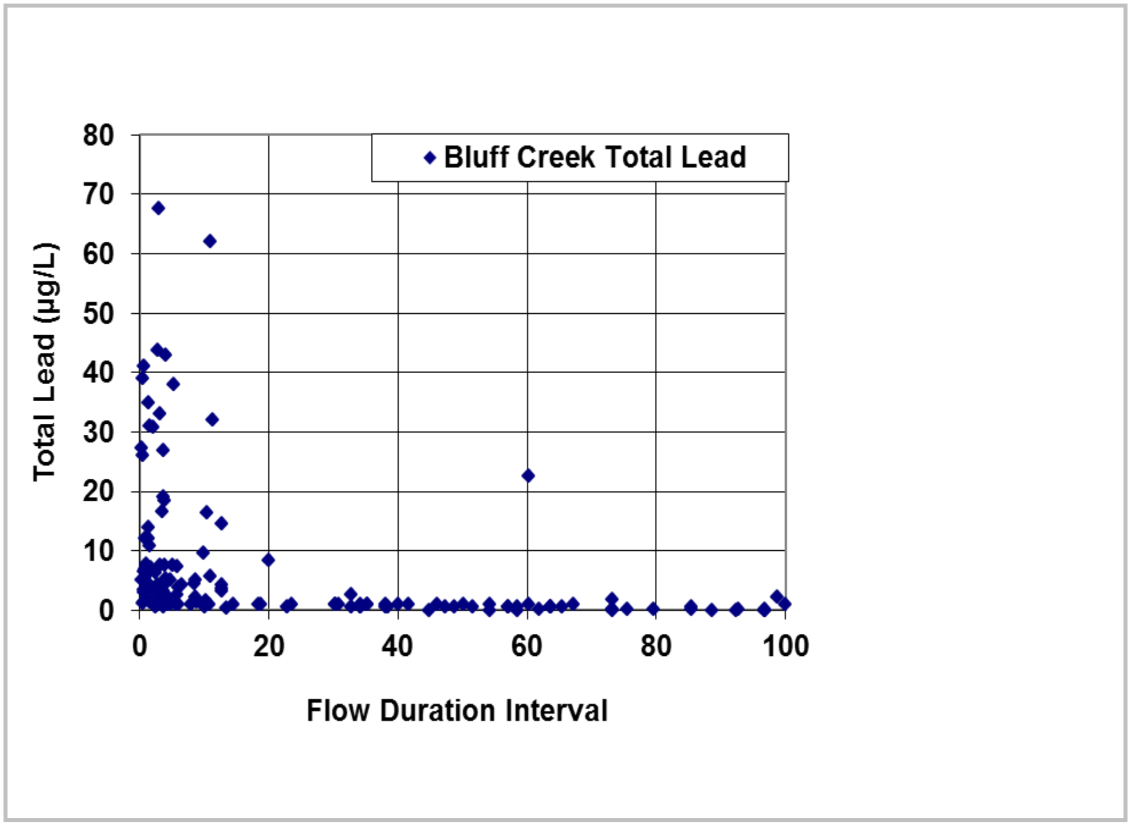

Figure D.2 Lead water quality duration curve for Bluff Creek WOMP site

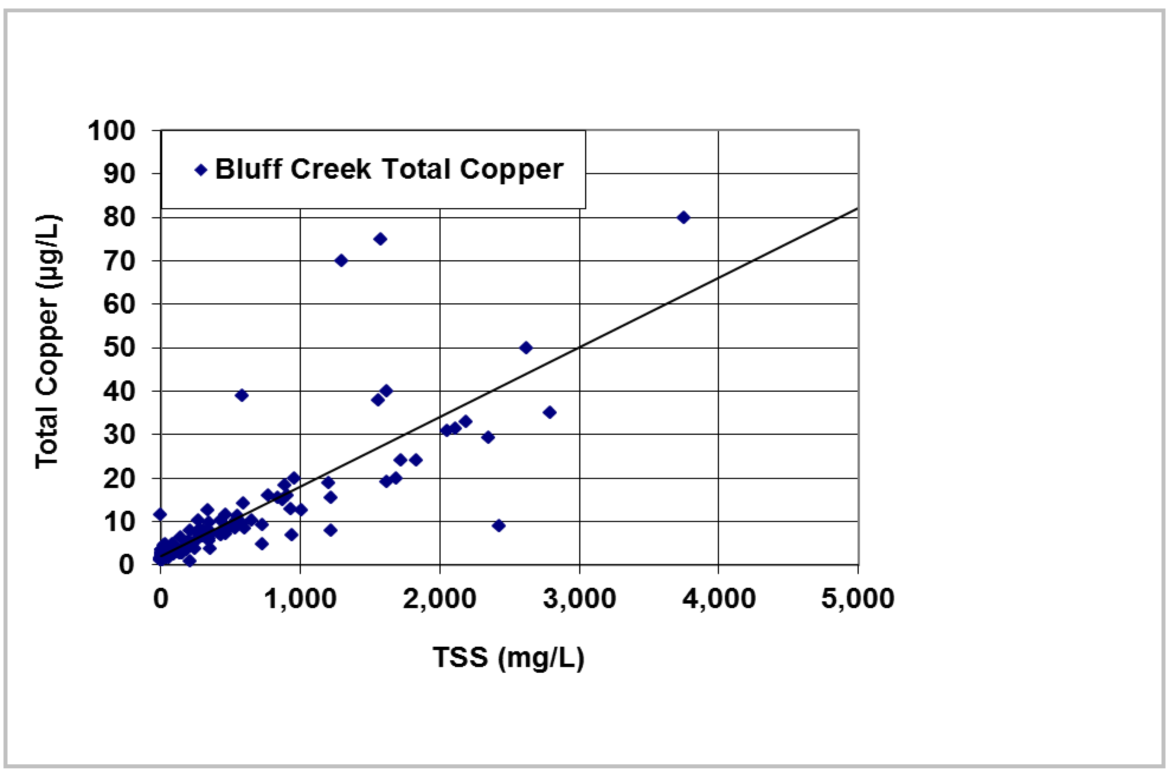

Figure D.3 Copper versus suspended solids for Bluff Creek WOMP site

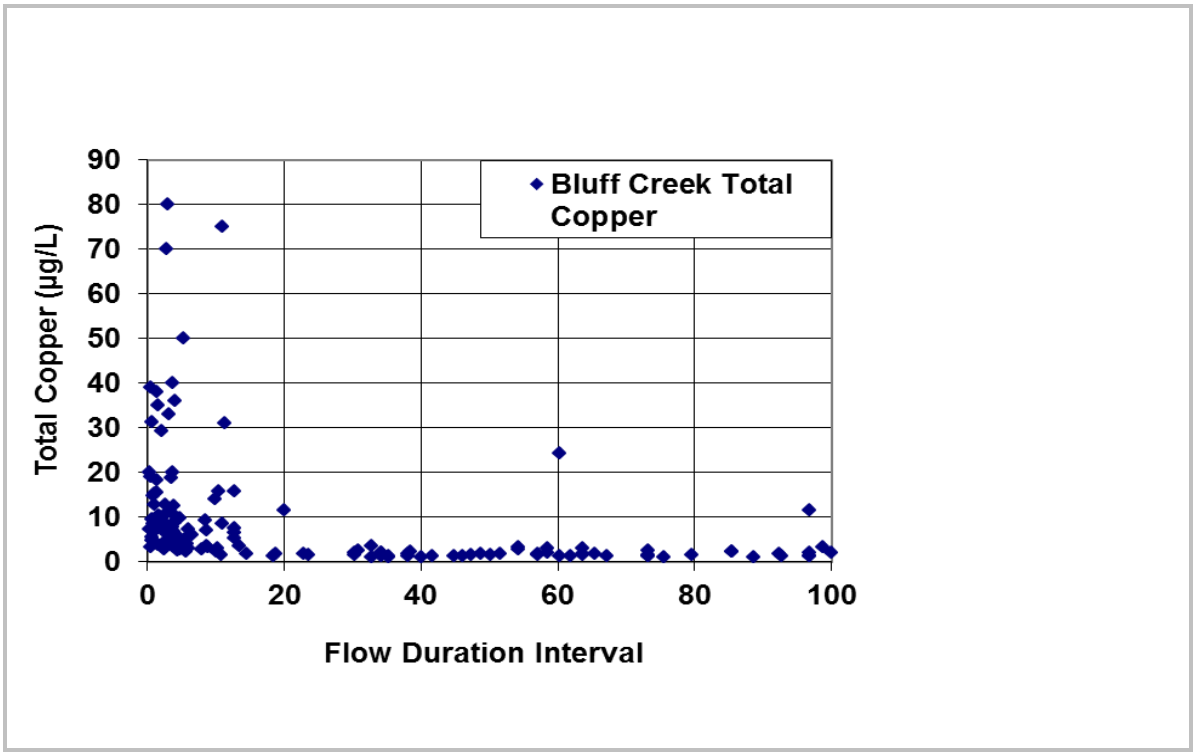

Figure D.4 Copper water quality duration curve for bluff creek WOMP site

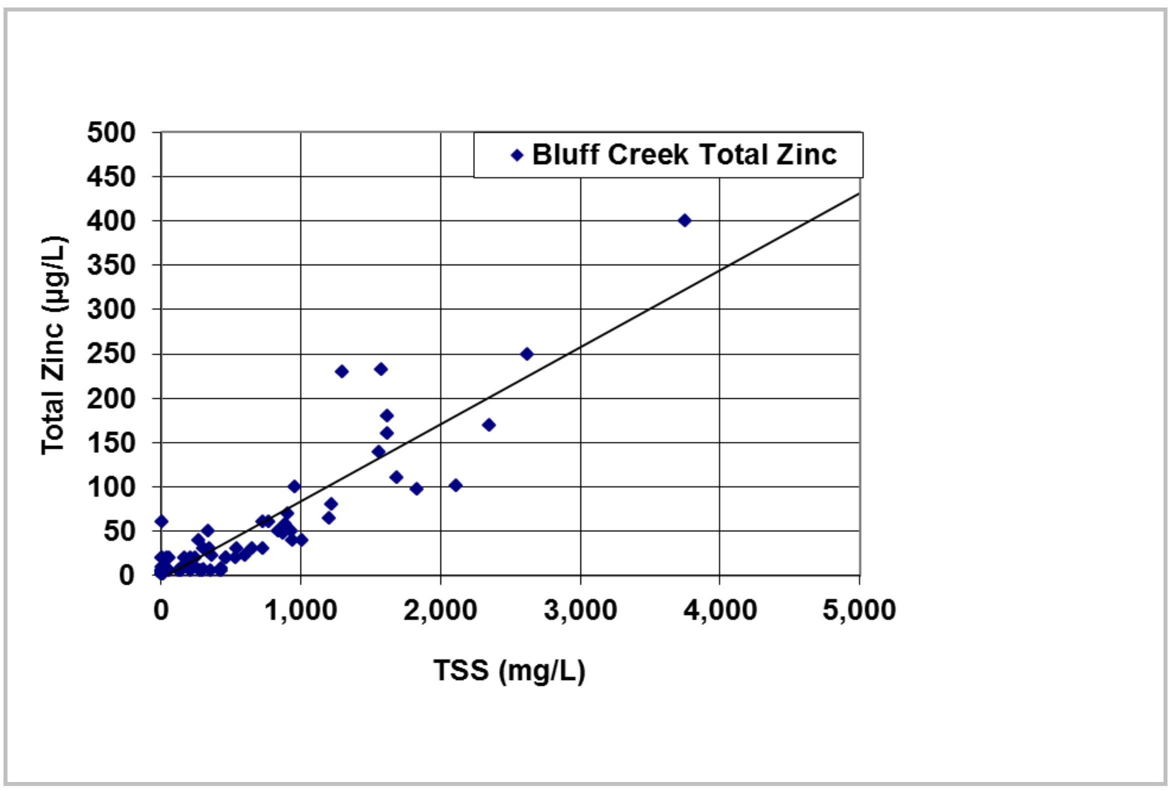

Figure D.5 Zinc versus suspended solids for Bluff Creek WOMP site

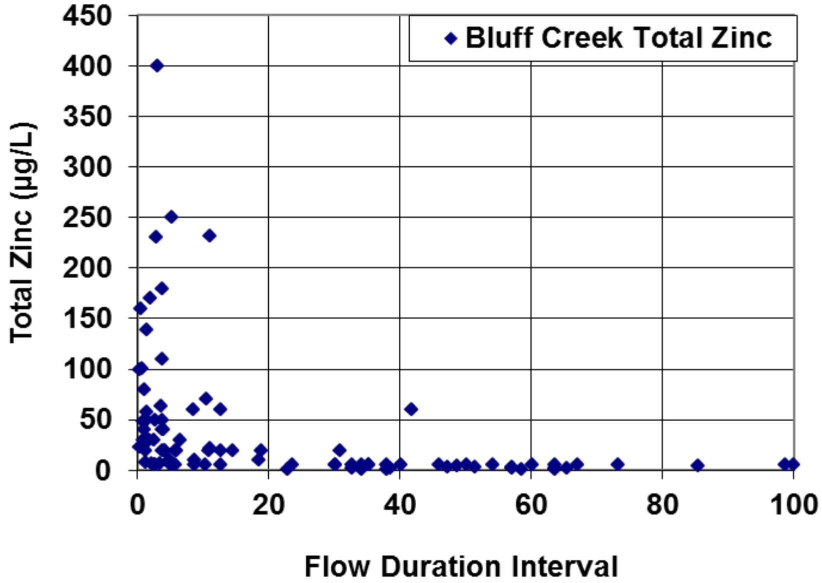

Figure D.6 Zinc water quality duration curve for Bluff Creek WOMP site

Although metals contamination appears to be a stressor, additional monitoring is needed for verification because "clean hands/dirty hands" methodology was not employed during collection and analyses of metals samples. The potential for contamination is acknowledged. For this reason, paired biological and metals monitoring using "clean hands/dirty hands" methodology for sampling and analysis is needed to confirm metals contamination as well as adverse impacts of metals contamination on Bluff Creek biota. The monitoring results would confirm whether metals contamination is a biological stressor and, whether additional management measures are needed to reduce metals concentrations in Bluff Creek. It is recommended that the monitoring occur following completion of the Implementation Plan.

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 D.7) 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 D.7 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. 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 eroding left stream bank (looking downstream) immediately downstream of the culvert outlet (Figure D.8) should be stabilized at the time of ramp construction, likely with vegetated reinforced soil slope (VRSS), which is a bio-engineering approach that is well suited to steep banks. In addition, the culvert should be inspected to identify needed repairs and any repairs identified during inspection should be made. 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.

Figure D.8 Eroding left stream bank immediately downstream of culvert outlet

High flows were identified as a stressor to the stream's biological community because of its interaction with sediment, metals, and habitat fragmentation. Sediment input from bank and ravine erosion was evident at high flows and this sediment stressed the biological community. The data indicate metals are entering Bluff Creek with sediment during periods of high flow (Figure D.1 through Figure D.6). 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).

Problems with high flow would be addressed by achieving sediment TMDL wasteload and load reductions through this TMDL and designing and constructing a ramp structure at the culvert outlet. Sediment load reduction is expected to address both sediment and metals as stressors in 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.

Finally, due to the cold temperatures found in Bluff Creek, 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 suitable. Tiered Aquatic Life Use should address stream Use Classes when developed for Minnesota. This work may help guide future management of appropriate Bluff Creek fish populations. Until that time, the recommendations in this document and in the forthcoming TMDL Implementation Plan are based on the Class 2B designation to protect aquatic life. Similar to all TMDL Projects, the TMDL Report and Implementation Plan for Bluff Creek can be reevaluated and revised as needed to reflect new policies, standards, classifications, and additional monitoring.