Pipestone Creek Fecal Coliform Bacteria and Turbidity Total Maximum Daily Load Report

For Submission to:

U.S. Environmental Protection Agency
Region 5
Chicago, Illinois

Submitted by:

Minnesota Pollution Control Agency
May 2008

WQ-iw7-07b

Acknowledgements

The Minnesota Pollution Control Agency acknowledges the important contribution by the Pipestone County Conservation and Zoning Office for coordinating monitoring activities, providing watershed and related information and coordinating stakeholder and public involvement. We also are grateful to the staff of Pipestone National Monument for conducting much of the water quality monitoring in this study.

Project technical team:
Chris Zadak, Minnesota Pollution Control Agency
Kyle Krier, Pipestone County Conservation and Zoning Office

Contents

Appendices

Figures

Tables

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 water body 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 water body can receive and still meet water quality standards. It is the sum of the individual wasteload allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources and natural background, plus a margin of safety (MOS).

The Minnesota Pollution Control Agency (MPCA) listed three stream reaches in the Pipestone Creek watershed as impaired for both excess fecal coliform bacteria (a human health concern that limits recreational use of the water) and excess turbidity (a measure of cloudiness of water that affects aquatic life). Both categories of impairment are addressed in this study because it is believed that they share some common sources and, therefore, it will be more efficient to plan implementation efforts. It also requires less administration by the State if the impairments are combined into one study.

The Minnesota portion of the Pipestone Creek watershed is located in Pipestone County and encompasses 151 square miles (96,577 acres). The watershed is within the Northern Glaciated Plains ecoregion and is a subwatershed of the Big Sioux River watershed of the Missouri River basin. Pipestone Creek flows from Minnesota into South Dakota, and back into Minnesota before converging with Split Rock Creek. Split Rock Creek converges with the Big Sioux River in southeastern South Dakota. Land use is dominated by agricultural cropping and animal production. Pastureland makes up much of the riparian area.

This study used a flow duration curve approach to determine the pollutant loading capacity of the impaired reaches under varying flow regimes. The report focuses on pollutant loading capacity and general allocations necessary to meet water quality standards at three individual impaired stream reaches, rather than on precise loading reductions that may be required from specific sources. However, it is roughly estimated that the overall magnitude of reduction needed to meet water quality standards is approximately 77 percent and 26 percent for current fecal coliform bacteria and turbidity levels, respectively.

The primary contributing sources to fecal coliform bacteria are believed to be livestock on overgrazed riparian pasture, surface-applied manure on cropland and feedlots lacking adequate runoff controls. The primary contributing sources to the turbidity impairments appear to be soil erosion in the riparian zone from livestock, streambank erosion/slumping from livestock and increased flow related to land use, upland soil loss from row cropland and possibly nutrient additions leading to algae growth.

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/or designated uses.

A TMDL is a calculation of the maximum amount of pollutant that a water body can receive and still meet water quality standards and/or designated uses. It is the sum of the loads of a single pollutant from all contributing point and nonpoint sources. TMDLs 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 sources of the relevant pollutant;

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint 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 is an MPCA-required element, if applicable, for TMDLs.

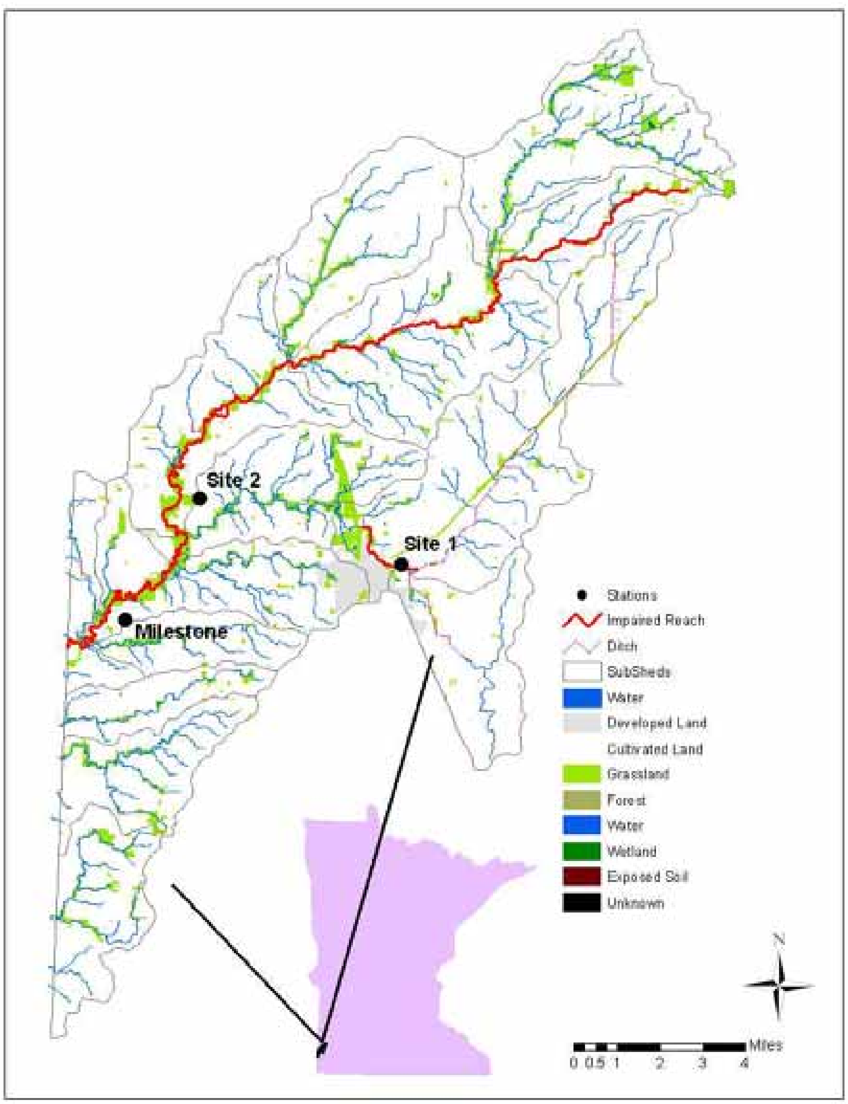
This TMDL report applies to three reaches that are impaired due to both fecal coliform bacteria and turbidity within the Pipestone Creek watershed in Minnesota. These impairments are currently on the 2006 303(d) list of impaired waters (see Sections 3.4

and 4.4 for the year each impairment was originally listed) and are shown in Table 1.1 and Figure 1.1.

TABLE 1.1. Pipestone Creek watershed 303(d) fecal coliform and turbidity impairments.

Reach name on 303(d) list	Assessment unit ID	Monitoring Station	Impairment
Main Ditch; CD A to Pipestone Cr	10170203-527	Site 1 (S000-646)	Fecal, Turbidity
Pipestone Creek, North Br; Headwaters to Pipestone Cr	10170203-514	Site 2 (S001-904)	Fecal, Turbidity
Pipestone Creek; N Br Pipestone Cr to MN/SD border	10170203-501	Milestone (S000-099)	Fecal, Turbidity

Figure 1.1. Pipestone Creek watershed 303(d) fecal coliform and turbidity impairments and land use.



All listed impairments are based on water quality monitoring conducted by Pipestone County Conservation and Zoning Office in cooperation with Pipestone National Monument staff (Sites 1 and 2) and the MPCA (Milestone Site). Sites 1 and 2 were monitored from 2002 through 2004 and the Milestone Site has a monitoring record that goes back to 1963 (at the time of the impairment assessment was done only the previous ten years of data were considered). Water analysis was done by the Minnesota Department of Health Laboratory.

The MPCA's projected schedule for TMDL completions, as indicated on Minnesota's 303(d) impaired waters list, implicitly reflects Minnesota's priority ranking of this TMDL. The project was scheduled to be completed in 2008. 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 waterbody; technical capability and willingness locally to assist with the TMDL; and appropriate sequencing of TMDLs within a watershed or basin.

In this report the background information relevant to both impairment categories (fecal coliform and turbidity) is provided in Section 2.0, followed by the TMDL technical elements of each impairment category provided separately in Sections 3.0 and 4.0. For follow-up monitoring, implementation, reasonable assurance and public participation both impairment categories are addressed together in Sections 5.0 through 8.0.

2.0 BACKGROUND INFORMATION

2.1 Applicable Water Quality Standards

This TMDL addresses exceedences of the state standard for fecal coliform bacteria and turbidity in the Pipestone Creek watershed of Minnesota. 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 TMDL.

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

According to Minn. Rules Ch. 7050.0470, the impaired reaches covered in this TMDL are classified as Class 2C, 3B, 3C, 4A, 4B, 5 and 6 water. The designated beneficial use for 2C waters is as follows:

> Aquatic life support and recreation, includes boating and other forms of recreation for which the water may be suitable (i.e., swimming). Class 2C waters may also support indigenous aquatic life, but not necessarily sport or commercial fish.

<u>Fecal coliform bacteria</u>

Fecal coliform bacteria are an indicator organism, meaning that not all the species of bacteria of this category are harmful but are usually associated with harmful organisms transmitted by fecal contamination. They are found in the intestines of warm-blooded animals, including humans. The presence of fecal coliform bacteria in water suggests the presence of fecal matter and associated harmful bacteria (e.g., some strains of *E. coli*), viruses and protozoa (e.g., *Giardia* and *Cryptosporidium*) that are pathogenic to humans when ingested (USEPA, 2001). While Minnesota currently uses fecal coliform bacteria as its standard the MPCA is proposing to change this to an *E. coli* standard (see Section 3.3 for further discussion).

Minn. Rules Ch. 7050.0222 subpart 5, fecal coliform water quality standard for Class 2C waters, states that fecal coliform concentrations shall "not exceed 200 organisms per 100 milliliters as a geometric mean[1] of not less than five samples in any calendar month, nor shall more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms per 100 milliliters. The standard applies only between April 1 and October 31." Impairment assessment is based on the procedures contained in The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment (MPCA, 2004).

<u>Turbidity</u>

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.

Minn. Rules Ch. 7050.0222 subpart 5, turbidity water quality standard for Class 2C waters, is 25 nephelometric turbidity units (NTUs). Impairment assessment procedures for turbidity are provided in the guidance manual cited above.

---

[1] Geometric means are used throughout this report. It is a type of average that is appropriate for summarizing the central tendency of environmental data that is not normally distributed (Helsel and Hirsch, 1991). Unlike arithmetic means, geometric means tend to dampen the effect of very high or very low values. They are calculated by taking the n^{th} root of the product of n numbers (or by taking the antilog of the arithmetic mean of log-transformed numbers).

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).

2.2 General Watershed Characteristics

The Minnesota portion of the Pipestone Creek watershed is located in Pipestone County and encompasses 151 square miles (96,577 acres). The watershed is within the Northern Glaciated Plains ecoregion and is a subwatershed of the Big Sioux River watershed of the Missouri River basin. Pipestone Creek flows from Minnesota into South Dakota, and back into Minnesota before converging with Split Rock Creek. Split Rock Creek converges with the Big Sioux River in southeastern South Dakota. Land use and cover is provided in Table 2.1 and shown in Figure 1.1.

TABLE 2.1. Land use / land cover for Pipestone Creek watershed.

Category	Area, acres	Percent
Cultivated land	84,333	87.3
Grassland	8131	8.4
Deciduous forest	1310	1.4
Farmsteads and rural residences	1229	1.3
Urban and industrial	1154	1.2
Other rural developments	151	0.2
Transitional agricultural land	99	0.1
Water	91	0.1
Other	79	0.1
Total	96,577	100

The watershed has mostly dark-colored, gently sloping soils that formed in medium-textured or moderately fine textured wind- or glacier-deposited material. The original vegetation was tall and medium prairie grasses. Upland cultivated land is dominated by corn and soybeans. Bottom lands along the creek are dominated by pasture, supporting numerous livestock operations.

Average annual precipitation in the watershed is about 26 inches.

The estimated population of the watershed is 5242 (based on US Census in 2000 and E911 database). The area has shown a declining population in recent years. From 1990 to 2000 the population of Pipestone County decreased 5.7 percent. Except for a small portion of the City of Holland, the only city in the watershed is Pipestone (population: 4280; US Census, 2000).

There is limited recreational use of Pipestone Creek in Minnesota due to its small size and lack of game fish. The most use the creek receives is at Pipestone National Monument, which is visited by over 100,000 people each year (Rothman and Holder, 1992). This is located on the north side of the City of Pipestone.

Pipestone Creek provides habitat to several nongame fish species, including the Topeka shiner, an endangered species of native prairie minnow.

3.0 FECAL COLIFORM BACTERIA

3.1 Surface Water Quality Conditions

Many factors affect the quantity of fecal coliform bacteria (and associated pathogens) in water bodies. The delivery of fecal matter to surface water is discussed later in this report. The factors affecting survivability of fecal coliform bacteria once they get into surface water include: sunlight, temperature, settling, and presence of nutrients and organic matter (USEPA, 2001).

A summary of the data used in this report is provided in Table 3.1 and Figures 3.1 through 3.4. The full dataset is provided in Appendix A. The data used was from 1994 through 2004, with the two project monitoring stations (Sites 1 and 2), which make up the bulk of the dataset, having data from the last three years of this record. To gain insight into seasonal differences data were separated into "spring" (April-May) and "summer" (June-October) on Table 3.1. To evaluate the effects of runoff-producing rainfall, data were also separated into "wet" and "dry" categories. Because many landscape, climatic and other site-specific factors affect the occurrence and degree of runoff, determining what is wet versus dry could be a very involved undertaking on its own. Because the goal of this analysis is only to gain some general insights, wet and dry are defined in a fairly simplistic way. Wet sample days are those in which either 0.5 inches or more of total rain fell within 24 hours prior to sampling or 1.0 inches or more of total rain fell within the previous 48 hours. Dry samples are those with less than these rainfall totals. (Some minor exceptions were made to these guidelines based on closer review of the data, i.e., some more intense rain events falling under these amounts were considered to be "wet".) In Table 3.1 exceedences of the 200 organisms/100 ml geometric mean standard are shown in gray.

Figures 3.2 through 3.4 are load duration curves. Load duration analysis as described by Cleland (2002) was used to integrate flow and the fecal coliform bacteria standard to provide loading capacity across the flow record as well as comparisons to the loading capacity using collected water quality data. A more complete explanation of load duration curves and how they were derived is provided in Appendix D. Samples highlighted in red represent samples that were taken at flows in which over 50 percent of the flow is due to a storm event, or flow primarily of relatively rapid surface runoff. Samples with a "+" were taken before July (in an attempt to distinguish pre-canopy from post-canopy samples). Note that the "moist" and "dry" conditions shown, which are describing flow levels or "zones", are not necessarily equated with the "wet" and "dry" samples of Table 3.1, which are describing previous rainfall events.

TABLE 3.1. Summary of fecal coliform data for Pipestone Creek watershed based on season and runoff conditions.*

* Shaded boxes are above the fecal coliform standard of 200 organisms/100 ml (geometric mean).

** Some observations for the Milestone Site have very few observations. Fewer than about five data points are not generally a reliable geometric mean.

Site	Spring						Summer						Spring Through Summer						
	Wet		Dry		All		Wet		Dry		All		Wet		Dry		All		% samples >2000
	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	Geom. mean	N	
Milestone Site (S000-099)**	2800	1	125	4	233	5	1900	1	1237	11	1282	12	2307	2	672	15	777	17	35
Site 1 (S000-646)	3600	8	22	15	128	23	4291	20	240	35	685	55	4081	28	116	50	417	78	27
Site 2 (S001-904)	1007	7	32	15	96	22	1679	20	634	35	903	55	1470	27	259	50	476	77	18
All sites	2029	16	33	34	120	50	2661	41	456	81	875	122	2466	57	207	115	471	172	24

Figure 3.1. Monthly geometric means for all monitoring sites in Pipestone Creek.

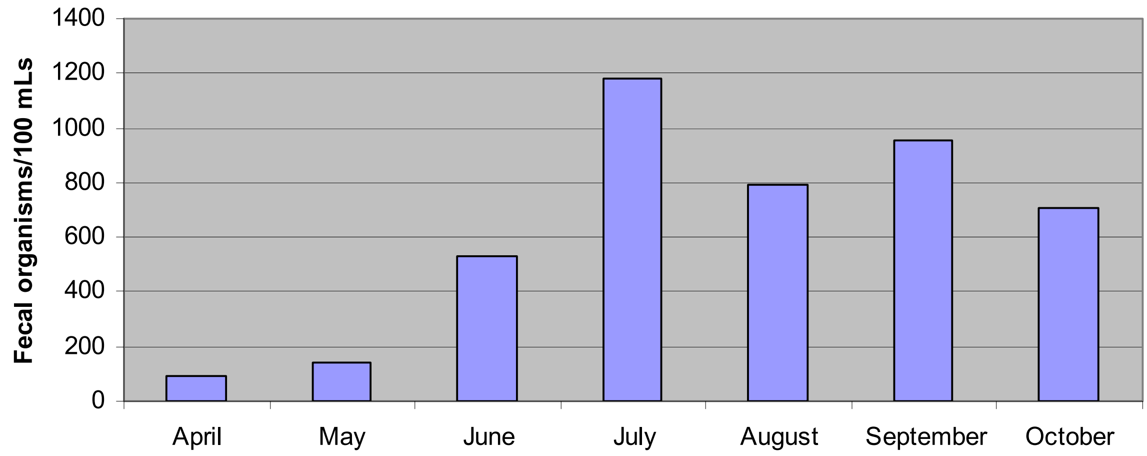


Figure 3.2. Load duration curve for fecal coliform bacteria for Milestone Site on Pipestone Creek.

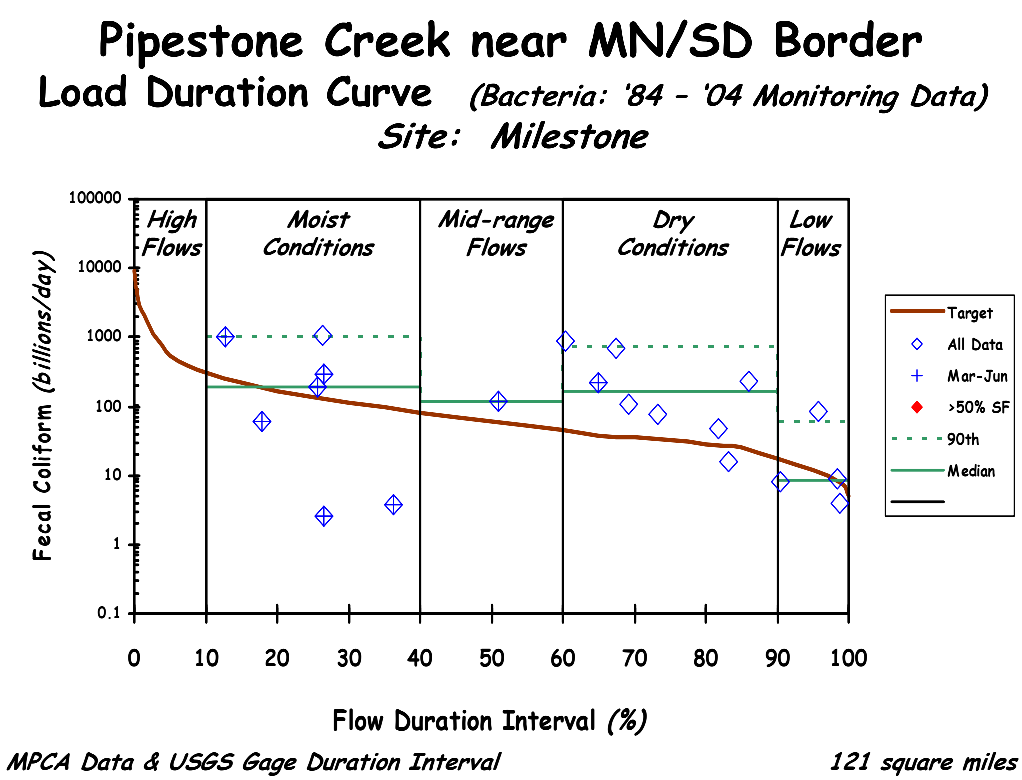


Figure 3.3. Load duration curve for fecal coliform bacteria for Site 1.

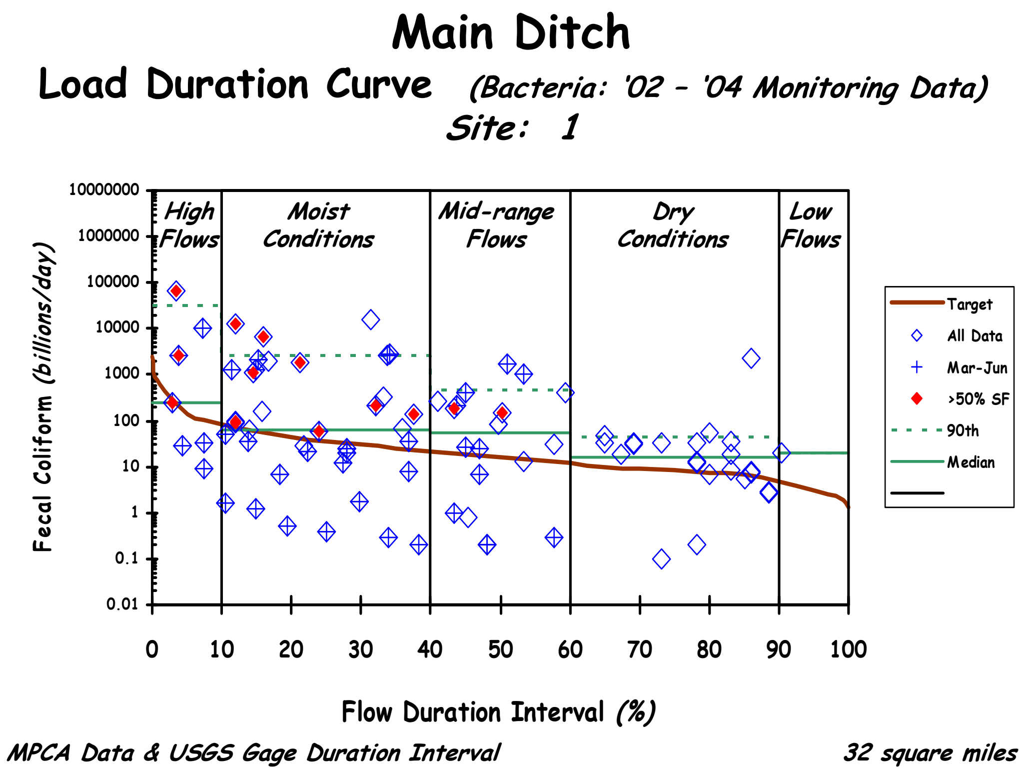
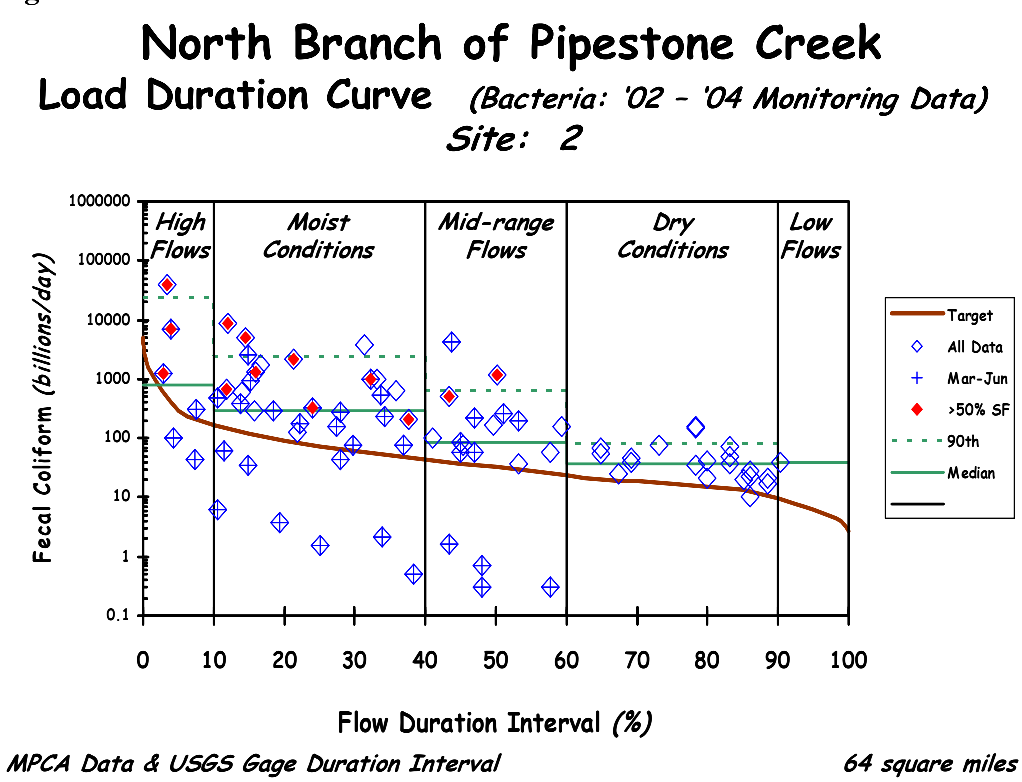


Figure 3.4. Load duration curve for fecal coliform bacteria for Site 2.



Some of the conclusions to be drawn from the data in Table 3.1 and Figures 3.1 through 3.4 are the following:

- The geometric mean of all samples collected at all of the sites for summer is relatively high—875 organisms/100 ml. A statistical analysis indicated no difference between Sites 1 and 2 for the entire season data set (Mann-Whitney rank-sum test; p-value of 0.53). Too few samples were collected at the Milestone Site to draw comparisons with it.
- The dominant factor for higher fecal coliform is rainfall. Overall, wet sampling events are about 12 times higher than dry sampling events. Factors responsible for this may include: 1) runoff from fields, riparian areas and impervious surfaces, and 2) storm runoff increasing the stream flow causing resuspension of sediments that are high in fecal coliform bacteria concentration. A study conducted in southern Minnesota, found that physical raking of streambed sediments at grazed sites resulted in water column bacteria concentrations several times higher than before resuspension (Jason Ewert, MPCA, personal communication, 2006).
- The summer geometric mean is roughly seven times higher than the spring geometric mean, although the spring and summer *wet* geometric means are of similar magnitude. Overall, the spring geometric mean is low and falls below the 200 organisms/100 ml standard. All summer months show high geometric means. Overall, the "season × runoff" situation geometric means fall out as follows: summer-wet ≥ spring-wet >> summer-dry > spring-dry. In general, all season × runoff situation geometric means exceed the standard except spring-dry.
- The percent of samples greater than the 2000 organisms/100 ml portion of the fecal standard varied among the sites, although all exceeded that level more than 10 percent of the time.
- An estimate for an overall load reduction percentage using the summer all-sites geometric mean (875 organisms/100 ml) and the standard (200 organisms/100 ml) is as follows:

  $$(875 - 200) / 875 = 77\%$$

  This reduction percentage is only intended as a rough approximation, as it does not account for flow, and is not a required element of a TMDL. It 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. This reduction percentage does not supersede the allocations provided in Section 3.3.

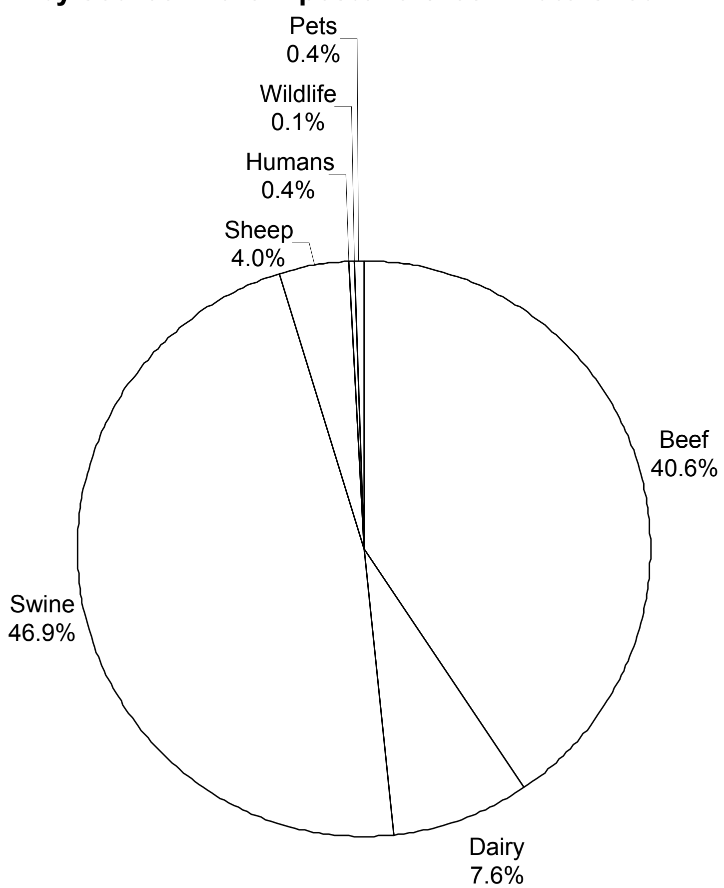
3.2 Fecal Coliform Sources and Current Contribution

Conclusions regarding fecal coliform sources and estimates of current loading are based on: 1) interpreting the water quality data presented in the previous section and other

MPCA information, 2) simple modeling via inventorying sources and estimating delivery of bacteria to the water (see Appendix C: Fecal Coliform Current Loading by Source: Methodology and Estimates of Relative Contribution), and 3) conducting a watershed survey (see Appendix B). The modeling in Appendix C is adapted from the 2002 version of the "Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (MPCA, 2002) and represents a means to roughly approximate the magnitude of the current loadings of the various fecal coliform source categories and subcategories.

The fecal coliform producers of this watershed are livestock (beef and dairy cattle, swine, and sheep), humans, wildlife and pets. Based on an inventory of these sources the breakdown of total fecal coliform production in the watershed is shown in Figure 3.5 (data based on Table C-1 from Appendix C).

Figure 3.5. Estimated fecal coliform produced by source in the Pipestone Creek Watershed



The following sections provide estimates of relative contribution and further discussion of these sources.

Livestock

In Pipestone County it is estimated that over 90 percent of the swine are confined and have below-barn manure pits. Manure is primarily injected and is done mainly in the fall. Of the dairy facilities about half are mostly confined with manure storage in earthen basins and the remainder with free stall barn and open lots using a daily scrape and haul system. Most dairy cattle are confined; the amount of time on pasture is minimal. Regarding beef cattle, cows and calves are grazed, approximately half the heifers are grazed and half are confined, and feeder cattle are primarily confined. Grazing occurs year-round, but only about half of those that graze in the summer will graze in the winter (which occurs primarily in corn fields rather than pasture).

From Figure 3.5 it is clear that the dominant producer of fecal coliform in the watershed is livestock. The magnitude of fecal coliform contribution from feedlots/stockpiles, pastures and manure-applied fields was estimated and presented in Appendix C. In summary, *overgrazed pasture near streams or waterways* appears to provide a high relative fecal coliform contribution across the various season x wet/dry settings, *surface-applied manure* appears to provide a high and moderate contribution under spring and summer wet conditions seasons, respectively, and *feedlots or stockpiles without runoff controls* appear to provide a moderate contribution during spring and summer wet conditions. Also, *incorporated/injected manure* was estimated to provide a low contribution under wet spring conditions. The high late season fecal coliform numbers as described in Section 3.1 are consistent with the conclusion that overgrazed areas may be a significant source, since it is those summer months when overgrazing may be most likely to occur (also this is when cattle use the stream to cool off).

Humans

The human-derived sources of fecal coliform are from inadequate individual sewage treatment systems (ISTSs) and the one wastewater treatment facility in the watershed—the City of Pipestone.

The watershed survey (Appendix B) briefly summarized the status of ISTSs. 385 households are served by ISTSs and a survey of 38 of them showed only 15 percent in compliance. Of the remaining households 48 percent surface-discharged on the property and 32 percent discharged into road ditches. Five percent outlet to streams or tile lines. The modeling exercise assumed 80 percent were noncompliant and showed a low contribution during dry conditions and very low contribution during wet conditions. The fact that they did not show a higher contribution is likely due to the relatively small amount of fecal production from this source compared to livestock.

The City of Pipestone wastewater treatment facility in the watershed utilizes stabilization ponds and is permitted to discharge from April 1 through June 15 and September 15 through December 15. Its outfall is below both monitoring Sites 1 and 2 and their associated reaches. According to state rule, a discharger is required to meet a discharge limit of 200 organisms/100 ml concentration. This is accomplished through disinfection of the wastewater at the final treatment stage, through chlorination or equivalent processes. A review of MPCA records since 2001 reveals six exceedances of the monthly geometric mean for fecal coliform.

Emergency bypasses at wastewater treatment facilities are an occasional source of bacteria and other pollutants. Wastewater treatment plants and sanitary sewer systems are designed to handle at least 100 gallons of water per person per day as well as the additional flow generated by commercial and industrial establishments. If the amount of water entering a system exceeds the design capacity of the system, some of the untreated wastewater is discharged to the environment. This event is called a bypass, because the wastewater has bypassed part or all of the treatment process.

Bypasses may occur during certain weather conditions, such as heavy rain events or flooding or in case of emergency because of equipment failure or when a pipe breaks. These diversions of wastewater are necessary in order to protect public health by preventing sewage from backing up into the streets and basements of homes and businesses. They are also necessary at times to prevent serious property damage that could result in the costly losses of equipment and the systems' ability to provide adequate treatment.

The MPCA considers all bypass events to be serious and expects treatment system operators to employ all reasonable measures to avoid bypassing. When that is not possible, the MPCA requires the operators to take whatever steps necessary to protect the public health and to minimize impacts on the environment. Additionally, operators are required to notify state and local governments within one hour of the onset of a bypass event, to sample and monitor the bypass discharge and to submit a detailed written report concerning the bypass. Intentional unreported bypasses are regarded as serious violations of Minnesota statute and rule and can result in the imposition of civil or criminal penalties. In cases where frequent bypasses have occurred, the MPCA imposes Schedules of Compliance requiring the system operator to correct the problem within a specified period of time. In such cases, the MPCA also places a moratorium on the issuance of sewer extension permits to prevent the introduction of additional flow to the system until the system has adequate capacity.

A review of MPCA records from 2000 to 2004 for the Pipestone wastewater treatment facility indicates five bypass events. The city currently has a compliance schedule in its permit pertaining to reduction of infiltration and inflow, which when implemented will reduce the frequency of bypasses. According to MPCA records, the city has been following the schedule and has been showing progress in implementing corrective actions.

Although the modeling exercise of Appendix C did not show the wastewater treatment facility to be a problem it is important to note that the modeling used an average fecal coliform discharge value and did not look at days with violations or bypasses. Nonetheless it appears that this source is much smaller than the nonpoint sources in the watershed.

Wildlife and Pets

The methodology for estimating the contributions from wildlife (which provides natural background levels) and pets is described in Appendix C. The modeling exercise indicated that the contribution from these sources is very low.

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

The TMDLs developed for the three reaches in this report consist of three main components: WLA, LA, and MOS as defined in Section 1.0. The WLA includes three sub-categories: Permitted wastewater treatment facilities, livestock facilities requiring NPDES permits, and "straight pipe" septic systems. (There are no communities subject to Stormwater MS4 NPDES permit requirements in this watershed.) The LA, reported as a single category, includes manure runoff from farm fields, pastures, and smaller non-NPDES permitted feedlots; stormwater runoff from the City of Pipestone and other nonpermitted areas with impervious surfaces; and fecal coliform contributions from wildlife. The LA includes land-applied manure from livestock facilities requiring NPDES permits, provided the manure is applied in accordance with the permit. The third component, MOS, is the part of the allocation that accounts for uncertainty that the allocations will result in attainment of water quality standards.

The three components (WLA, LA, and MOS) were calculated as average total daily load of fecal organisms (with the average being met over a calendar month). The methodology to derive and express these load components is referred to as the duration curve approach. It was used in the "Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (Jan 2006) and is described in Appendix D.

Allocations in the duration curve approach for each impaired stream reach are developed for the full range of flows in the watershed using the daily flow records at the US Geological Survey (USGS) gage station #06482610 below Pipestone Creek on Split Rock Creek in Corson, South Dakota from 1984-2005. This flow record contains 3561 average daily flow values. (Note: This flow record does not have data from 1990-2000.) It was decided to limit flow data to within this time period in order to have a closer reflection of hydrologic conditions occurring under "recent" land use. To estimate flow at the ends of the three listed reaches it was assumed that the flow at those reaches was proportional to the Corson site based on respective drainage areas represented. The project did have one year of flow data at Sites 1 and 2, but it was decided that for a duration curve approach a much longer record representing a greater range of flows is needed. (Calculated flows were then checked against the available flow data for Sites 1 and 2. This check showed that the magnitudes were generally similar between the actual vs. proportionally-calculated flows; however, there were some discrepancies in timing of peak flows following significant rain events.)

For each impaired reach and flow condition, the total loading capacity (TMDL) was divided into its component WLA, LA, and MOS. The process was as follows:

Wasteload Allocation

- For the City of Pipestone wastewater treatment facility the WLA was determined based on their permitted discharge volume from their pond (based on six inches per day drawdown) and their permitted concentration limit (200 organisms/100 ml). Although a daily WLA is assigned to this facility, it is important to note that discharge occurs only during specified days during the year (April 1 through June 15 and September 15 through December 15).
- Straight-pipe septic systems are illegal and unpermitted, and as such are assigned a zero WLA.
- Livestock facilities that have been issued NPDES permits are assigned a zero WLA. This is consistent with the conditions of the permits, which allow no pollutant discharge from the livestock housing facilities and associated sites. Discharge of fecal coliform from fields where manure has been land-applied may occur at times. Such discharges are covered under the LA portion of the TMDLs, provided the manure is applied in accordance with the permit.
- The total daily loading capacities in the dry and low flow zone are very small due to the occurrence of very low flows in the long-term flow records. Consequently, for one of the impaired reaches (Pipestone Creek; N Br Pipestone Cr to MN/SD border), the permitted wastewater treatment facility design flows exceed the stream flow at the low flow zone. Of course actual treatment facility flow can never exceed stream flow as it is a component of stream flow. For the dry flow zone the calculated MOS would take up all of the remaining allocation capacity. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

  Allocation = (flow contribution from a given source) x (200 organisms/100 ml)

  In essence, this amounts to assigning a concentration-based limit to the nonpoint LA sources for the dry and low flow zone. The WLAs for straight pipe septic systems and NPDES-permitted livestock operations remain at zero. (This is the same procedure employed for three reaches with similar situations in the "Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (Jan 2006)).

Margin of Safety

- The purpose of the MOS is to account for uncertainty that the allocations will result in attainment of water quality standards. Because the allocations are a direct function of daily flows, accounting for potential flow variability is an appropriate way to address the MOS. This is done within each of the five flow zones. Basically, the margins of safety were calculated as the difference between the loads corresponding to the median flow and minimum flow in each zone.
- For the impaired reach in which the allocations under low flow conditions required use of an alternative method of calculation, i.e., a concentration-based

Load Allocations

- Once the WLA and MOS were determined for a given reach and flow zone, the remaining loading capacity was considered LA. The LA includes nonpoint pollution sources that are not subject to NPDES permit requirements, as well as "natural background" sources such as wildlife. The nonpoint pollution sources are largely related to livestock production, inadequate human wastewater treatment (non-straight-pipes), and city stormwater runoff.

Additional Daily Loading Capacity and Allocations

- The TMDLs and allocations are "average daily loading values calculated within a calendar month" based on the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml. For the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml an additional allocation requirement is made. Specifically, the loading capacity and allocations must also meet a maximum single day load that is no more than ten times the listed average daily loading values. (This relates to the 2000 numerical standard being a factor of 10 times the 200 numerical standard.)

Change of Standard to E. coli

- Presently, changes to some of the water quality standards in Minn. Rules Ch. 7050 are being proposed. Among those changes are shifting from fecal coliform to *E. coli*, which is being set at an equivalent level to provide an equivalent level of protection. Specifically, the change takes into account water analysis studies that show an average of 63 percent of fecal coliform bacteria to be *E. coli* and, thereby, sets *E. coli* standards, for most situations, at that percentage of the current fecal coliform standard (e.g., monthly geometric mean of 126 *E. coli* bacteria/100 ml). Therefore, to adapt the fecal coliform TMDL allocations in this section to the future *E. coli* standards we will simply multiply those values by 0.63.

3.4 TMDL Allocations for Individual Impaired Reaches

In the sections below TMDL allocations are provided for the individual impaired reaches. Calculations for the TMDL, LA, WLA and MOS consider the total drainage area represented by the end of the listed reach. (Note: due to rounding the WLA, LA, and MOS may not exactly add up to the loading capacities provided in the tables below for some flow zones.)

3.4.1 Pipestone Creek; N Br Pipestone Cr to MN/SD Border (AUID: 10170203-501)

This reach of Pipestone Creek was added to the Section 303(d) Clean Water Act impaired waters list in 1994. The primary source of data that led to this listing was the MPCA Milestone long-term monitoring program.

The drainage area to the downstream end of this impaired reach is about 121 square miles, which represents 80 percent of the Pipestone Creek watershed in Minnesota. Previous sections provided land use information and watershed characteristics.
The City of Pipestone wastewater treatment facility contributes to this reach (NPDES Permit #MN0054801). This TMDL does not supersede the requirements of this permit.

There are three livestock facilities with NPDES permits located within the subwatershed for this listed reach (Table 3.2). They are all confined swine operations.

Table 3.3 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. The loading capacities for the five flow zones were developed using flow data from the USGS gage site #06482610 on Split Rock Creek at Corson, SD, as described in Appendix D.

TABLE 3.2. Livestock facilities with NPDES permits (AUID: 10170203-501).

FACILITY	NPDES PERMIT #
BMB Pork LLP	MNG440291
Sweet Finishers LLP	MNG440818
Ihlen Finishers LLP Farm	MNG440864

TABLE 3.3. Fecal coliform loading capacities and allocations—Pipestone Creek; N Br Pipestone Cr to MN/SD border (AUID: 10170203-501).

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	541	139	61	32	12
Wasteload Allocation					
Pipestone Wastewater Treatment Facility	25	25	25	25	*
Livestock Facilities Requiring NPDES Permits**	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	286	57	20	7	*
Margin of Safety	231	57	17	Implicit	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Pipestone Wastewater Treatment Facility	5%	18%	40%	78%	*
Livestock Facilities Requiring NPDES Permits**	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	53%	41%	33%	22%	*
Margin of Safety	43%	41%	27%	Implicit	Implicit

* See Section 3.3 for allocations for these specific categories in these flow zones.
** The individual facilities are listed in Table 3.2.

3.4.2 Pipestone Creek, North Br; Headwaters to Pipestone Cr (AUID: 10170203-514)

This reach of Pipestone Creek was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted by Pipestone County Conservation and Zoning Office in cooperation with Pipestone National Monument staff.

The drainage area to the downstream end of this impaired reach is about 64 square miles, which represents 43 percent of the Pipestone Creek watershed in Minnesota. The land use and watershed characteristics are similar to those of the larger watershed except that this subwatershed has no urban area. The North Branch of Pipestone Creek is nearly all a natural channel with very limited straightened ditch portions.

There are no wastewater treatment facilities that contribute to this reach.

There are six livestock facilities with NPDES permits located within the subwatershed for this listed reach (Table 3.4). They are all confined swine operations.

Table 3.5 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. The loading capacities for the five flow zones were developed using flow data from the USGS gage site #06482610 on Split Rock Creek at Corson, SD, as described in Appendix D.

TABLE 3.4. Livestock facilities with NPDES permits (AUID: 10170203-514).

FACILITY	NPDES PERMIT #
Calumet Gilts - Site II	MNG440288
Hiawatha Gilts	MNG440289
Troy Farms Inc	MNG440292
New Horizon Farms - Research Facilities	MNG440299
New Horizon Farms Prairie Finishers	MNG440805
Nokomis Pork Inc - Winnewissa Pork Inc	MNG920281

TABLE 3.5. Fecal coliform loading capacities and allocations—Pipestone Creek, North Br; Headwaters to Pipestone Cr (AUID: 10170203-514).

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	287	74	33	17	6
Wasteload Allocation					
Livestock Facilities Requiring NPDES Permits*	0	0	0	0	0
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	165	43	24	9	3
Margin of Safety	123	30	9	7	4
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Livestock Facilities Requiring NPDES Permits*	0%	0%	0%	0%	0%
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	57%	59%	73%	56%	43%
Margin of Safety	43%	41%	27%	44%	57%

* The individual facilities are listed in Table 3.4.

3.4.3 Main Ditch; CD A to Pipestone Cr (AUID: 10170203-527)

This reach of Pipestone Creek was added to the Section 303(d) Clean Water Act impaired waters list in 2004. The primary source of data that led to this listing was monitoring conducted by Pipestone County Conservation and Zoning Office in cooperation with Pipestone National Monument staff.

The drainage area to the downstream end of this impaired reach is about 32 square miles, which represents 21 percent of the Pipestone Creek watershed in Minnesota. The land use is primarily cultivated land, with only limited grassland/pasture on tributaries. The main stem of this reach is a straightened ditch with smaller ditches and natural small streams feeding it.

There are no wastewater treatment facilities or livestock facilities with NPDES permits that contribute to this reach.

Table 3.6 provides the average daily fecal coliform loading capacities for this reach to meet the portion of the water quality standard dictating a monthly geometric mean below 200 organisms/100 ml, as well as the component WLAs, LAs and MOS. To meet the portion of the standard that requires that no more than ten percent of all samples taken during any calendar month individually exceed 2000 organisms/100 ml the maximum single day loading capacity and allocations are set at ten times the listed average daily loading values in this table. The loading capacities for the five flow zones were developed using flow data from the USGS gage site #06482610 on Split Rock Creek at Corson, SD, as described in Appendix D.

TABLE 3.6. Fecal coliform loading capacities and allocations—Main Ditch; CD A to Pipestone Cr (AUID: 10170203-527)

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Billion organisms per day				
Average Total Daily Loading Capacity	142	37	16	8	3
Wasteload Allocation					
"Straight Pipe" Septic Systems	0	0	0	0	0
Load Allocation	81	21	12	5	1
Margin of Safety	61	15	4	4	2
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
"Straight Pipe" Septic Systems	0%	0%	0%	0%	0%
Load Allocation	57%	59%	73%	56%	43%
Margin of Safety	43%	41%	27%	44%	57%

3.5 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). Fecal coliform levels are generally at their worst following significant storm events during the summer months, as described in Section 3.1. This section further spelled out overall seasonal variation, indicating that the fecal coliform levels appear to be below standard in April and May and above the standard from June through October. Such conditions and variation are fully captured in the duration curve methodology used in this TMDL.

3.6 Consideration of Growth on TMDL

With regard to point sources, the only potential for considering the impact of growth would be the City of Pipestone wastewater treatment facility. As indicated previously, the population in Pipestone has declined in recent years. Should it increase in the future a revised permit may be sought, but is likely not to have a significant impact on Pipestone Creek provided discharge limits are met. This is because increased flows add to the overall loading capacity of the system.

The allocations for nonpoint sources are for all current *and* future sources. This means that any expansion of nonpoint sources will need to comply with the LA provided in this report. Additional nonpoint sources (e.g., livestock) could very well make meeting the TMDL more difficult over time. Therefore, continued efforts over time to prevent fecal delivery to the stream will be critical.

4.0 TURBIDITY

4.1 Surface Water Quality Conditions

The components of turbidity in streams include 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 for this waterbody. In order to evaluate and set loads the surrogate measure total suspended solids (TSS) is used. This is possible because most water samples taken for this project were analyzed for both turbidity and TSS. It should be noted that the turbidity measurements used in this project were all done using a Hach 2100AN turbidimeter, which reads in Nephelometric Turbidity Ratio Units, NTRUs, rather than a Hach 2100A turbidimeter, which reads in NTUs. The two meters do not provide the same results, but they can be related by the equation:

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

In essence, NTU values are approximately 65 percent of NTRU values. Because the turbidity standard is based on NTUs the data used for this report have been converted from NTRUs to NTUs (and those data are referred to as “NTU equivalent”). For a complete explanation of this see Appendix F.

A simple regression of TSS and “NTU equivalent” was done and shows a good correlation (R-squared = 0.85; Figure 4.1). This analysis indicates that the turbidity standard of 25 NTU corresponds to a TSS concentration of 54 mg/L for this dataset.

A summary of the data used in this report is provided in Table 4.1. The full dataset is provided in Appendix A. Figures 4.2 through 4.7 illustrate various aspects of the data in terms of timing, relation to flow and other relationships. The turbidity dataset used was from 1998 to 2001 at the Milestone Site and from 2002 to 2004 at the two project monitoring stations (Sites 1 and 2). The two project monitoring stations make up the bulk of the overall project dataset. However, TSS data at the Milestone Site goes back to 1963 and, thus, provides an opportunity for a long-term view (Figure 4.2).

Figures 4.3 through 4.5 are load duration curves which integrate flow and the TSS equivalent to the turbidity standard to provide loading capacity across the flow record as well as comparisons to the loading capacity using collected water quality data (see previous explanation in Section 3.1 and also Appendix D).

Figure 4.1. Relationship of turbidity to total suspended solids (TSS) for Pipestone Creek monitoring data.

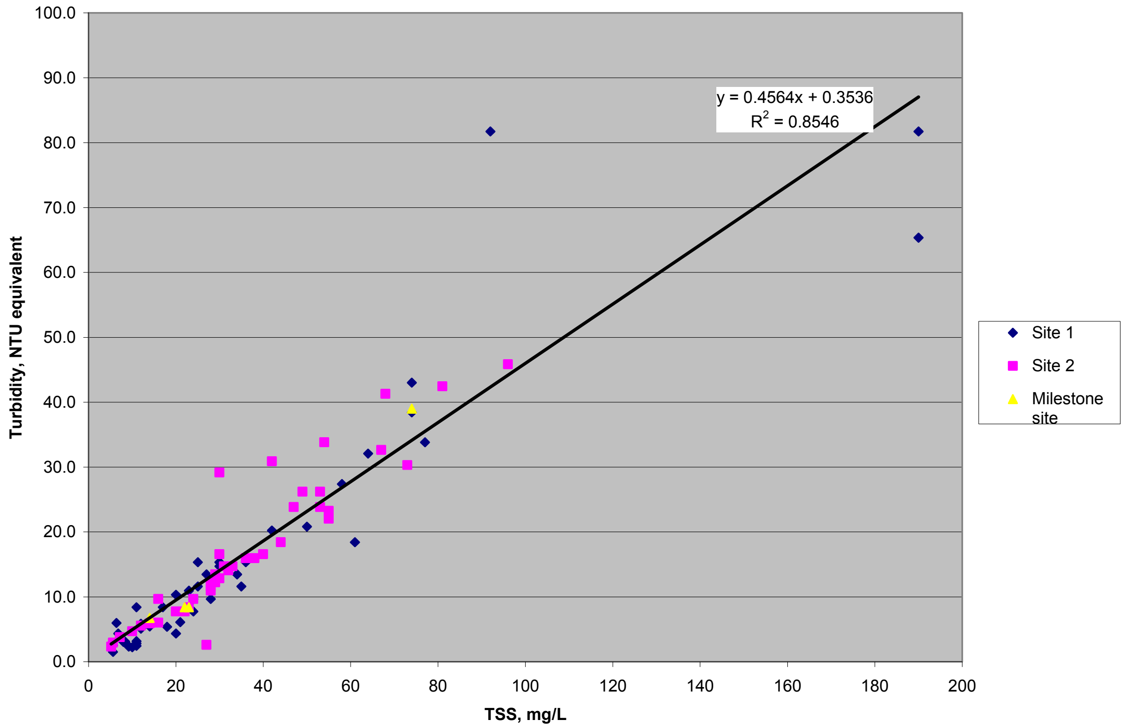


TABLE 4.1. Summary of turbidity data for Pipestone Creek watershed

	Milestone (S000-099)	Site 1 (S000-646)	Site 2 (S001-904)
Years sampled	1998 – 2001	2002 – 2004	2002 – 2004
Number of observations	10	46	45
Percent observations > 25 NTU equivalent (i.e., state standard)	20	17	24
Range, NTU equivalent	3 - 39	2 - 82	2 - 52
Mean, NTU equivalent	13	16	18
Median, NTU equivalent	8	10	14
90th percentile, NTU equivalent	29	36	33

Figure 4.2. Long term total suspended solids (TSS) results at Pipestone Creek Milestone Site. (The corresponding TSS value for the 25 NTU standard is shown.)

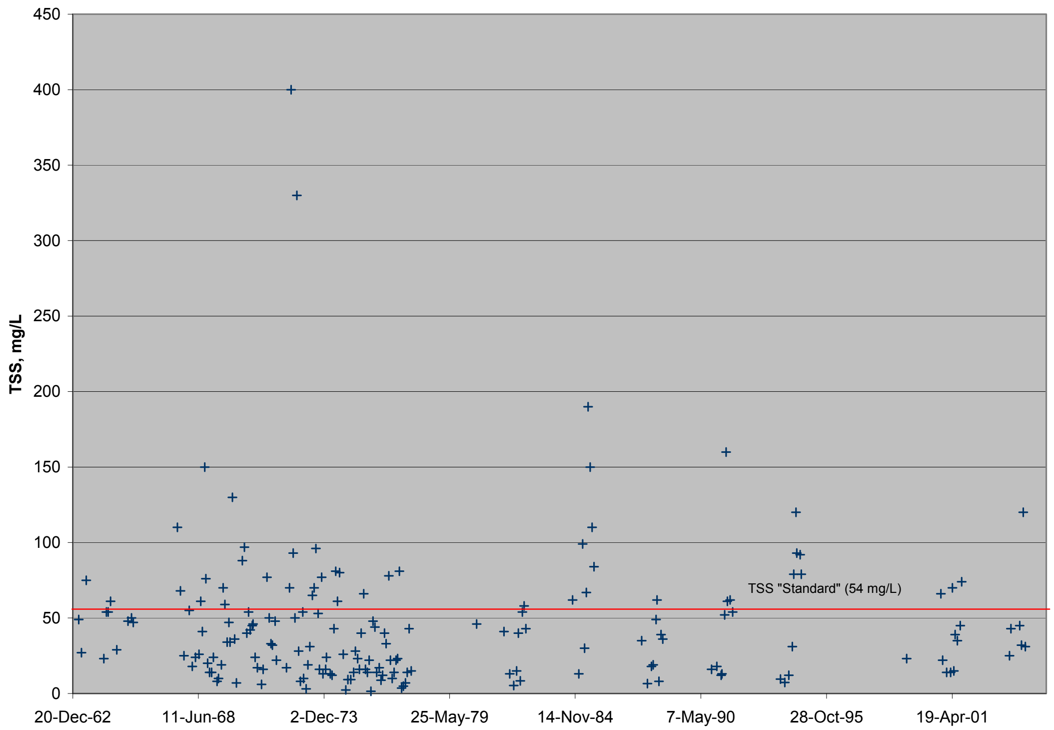


Figure 4.3. Load duration curve for total suspended solids for Milestone Site.

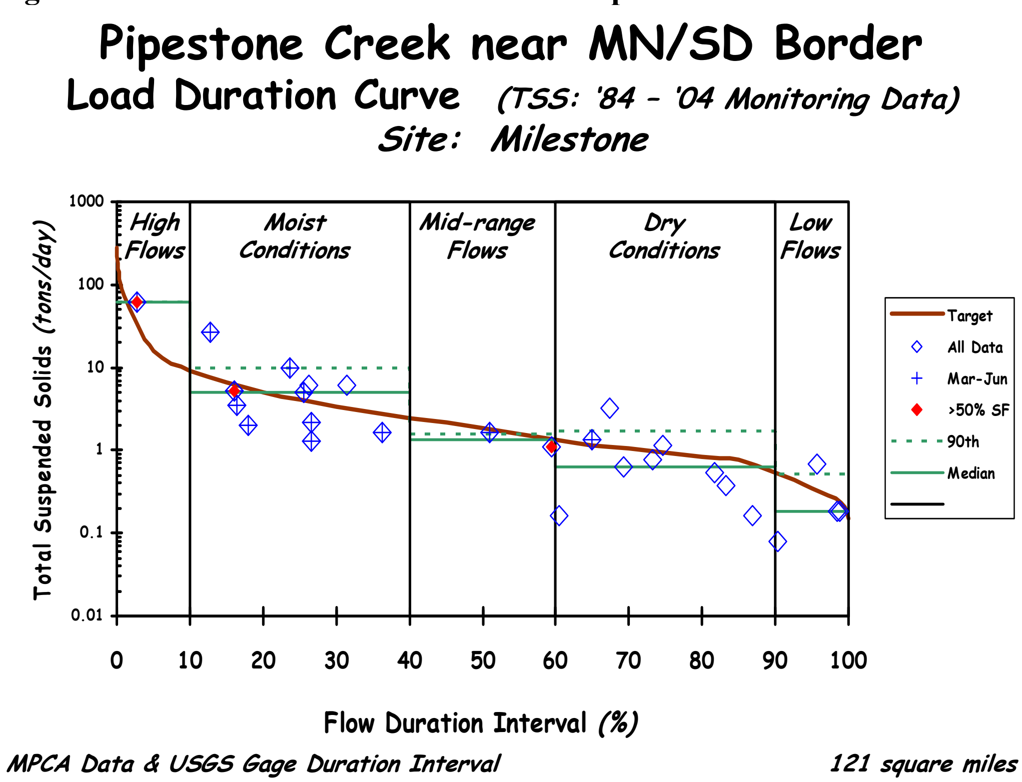


Figure 4.4. Load duration curve for total suspended solids for Site 1.

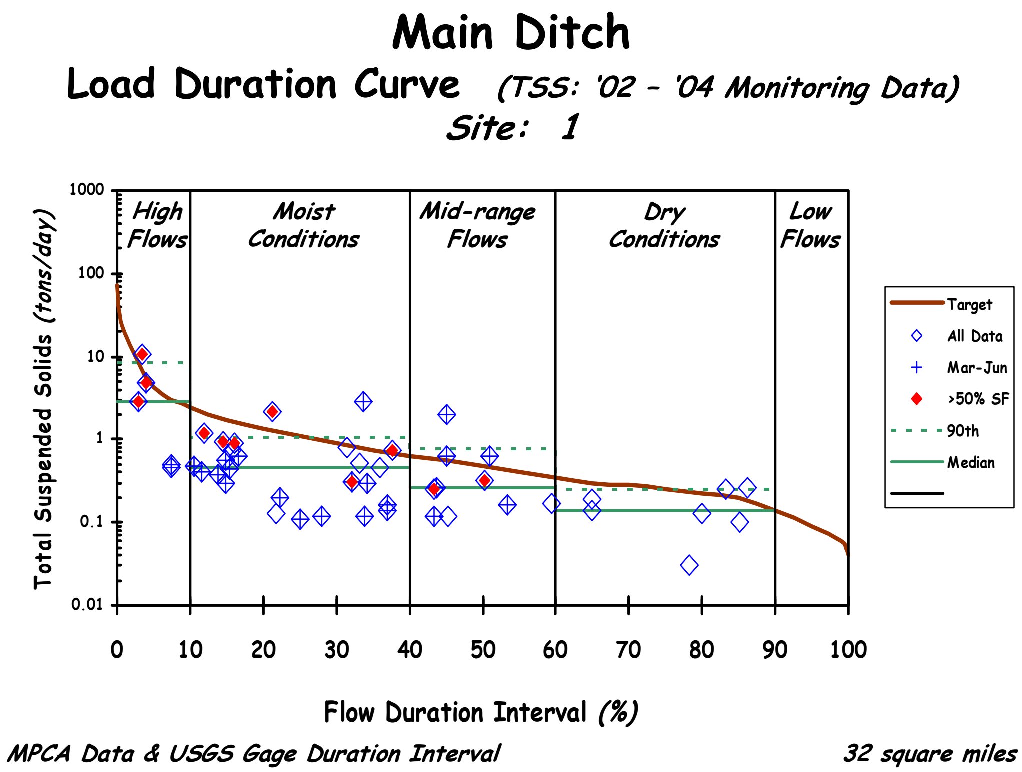


Figure 4.5. Load duration curve for total suspended solids for Site 2.

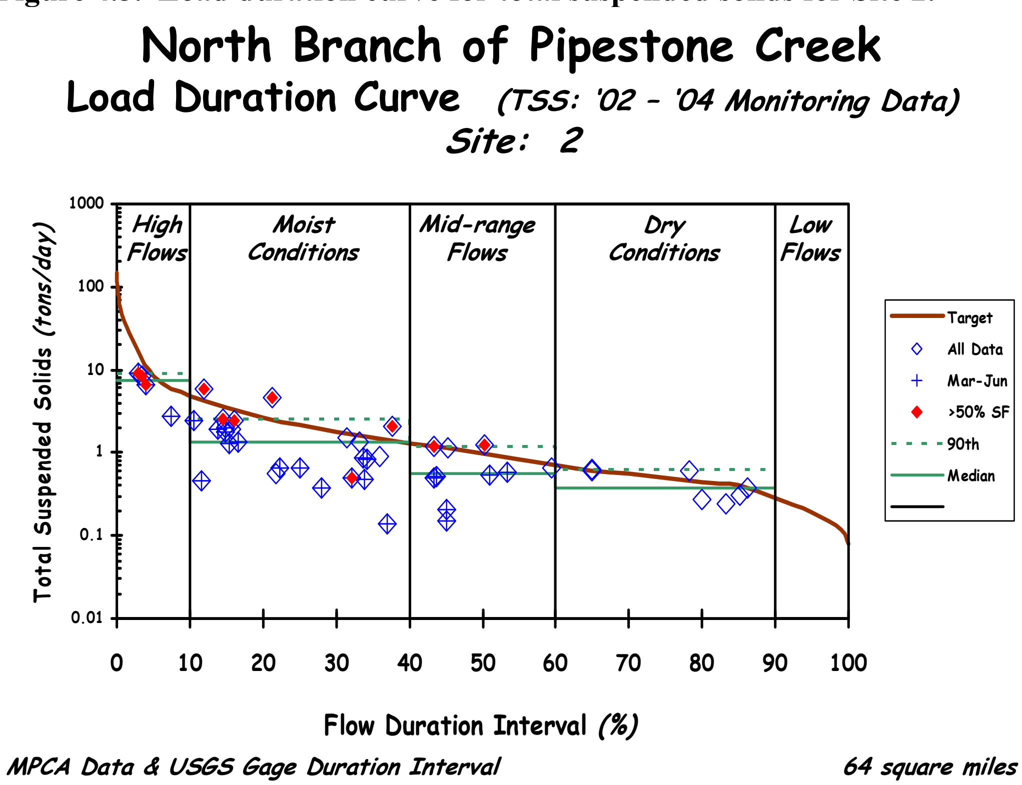


Figure 4.6. Ratio of total volatile solids (TVS) to total suspended solids (TSS) for Site 2, May-September data for 2004.

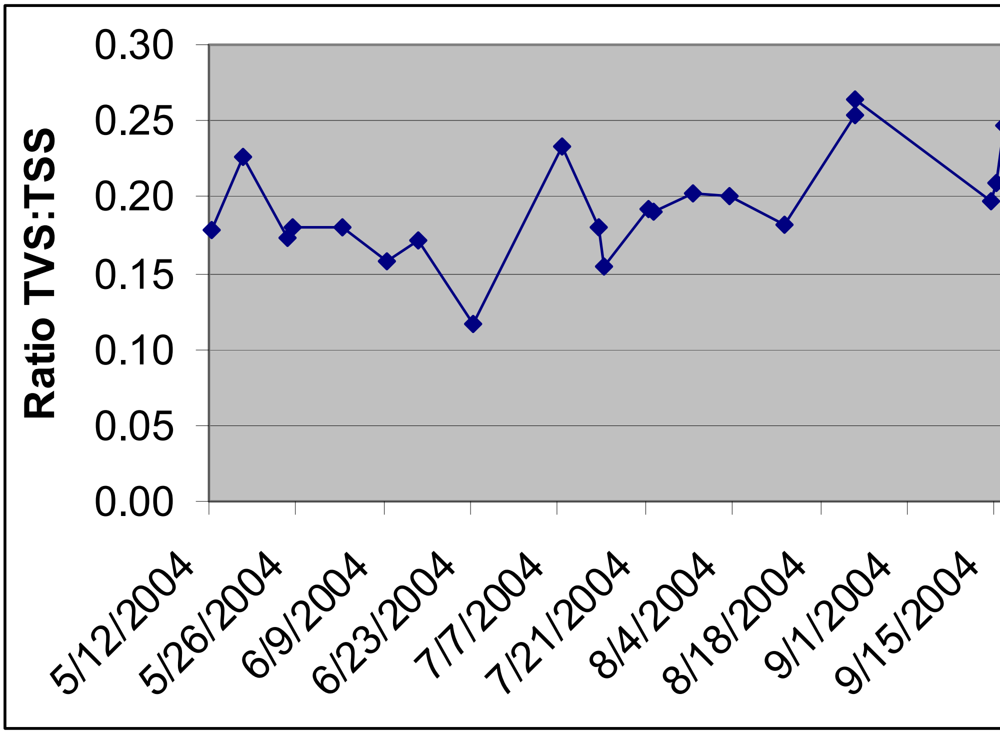
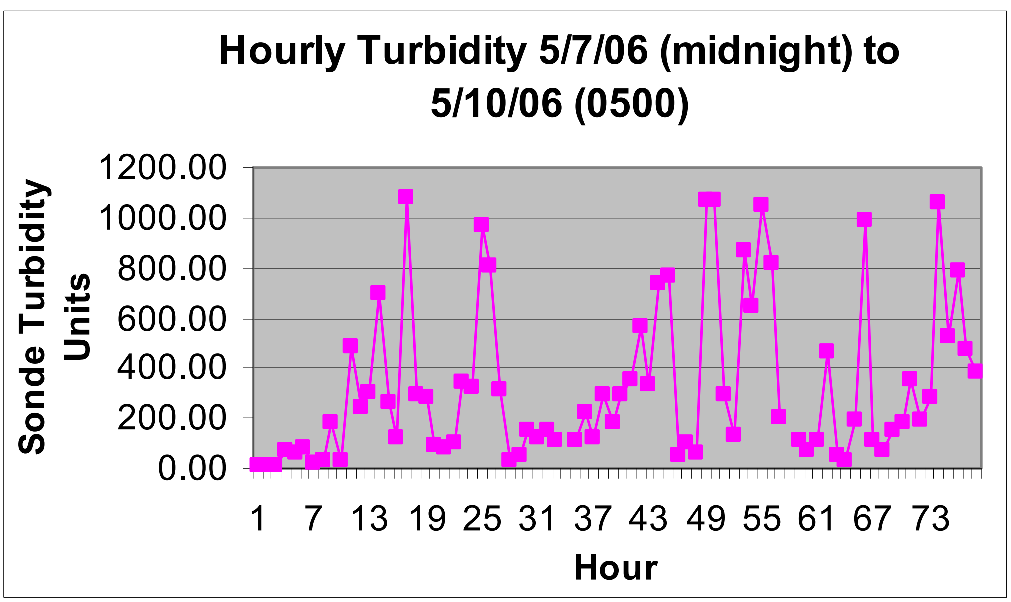


Figure 4.7. Hourly turbidity levels for Pipestone Creek at Pipestone National Monument, May 2006.



Some of the conclusions to be drawn from the data in Table 4.1 and Figures 4.2 through 4.7 and project monitoring experience are the following:

- Based on the available data the turbidity impairment in the watershed appears to be "minor" to "moderate" when viewed across the entire sampling season. A majority of the time turbidity readings are below the standard. Some site differences do exist, however.
- Site 2 appears to exhibit statistically higher results than Site 1 (using a Mann-Whitney rank-sum test; p-value of 0.059). The actual differences in turbidity across the two sites for the entire sampling season data set appear to be relatively minor. However, when looking at only the later season data (post-canopy) the differences are more pronounced between the two sites.
- The higher late season turbidity levels (at Site 2 in particular), which is similar to fecal coliform seasonal data, raise the possibility of related sources and/or pathways (e.g., overgrazing and associated erosion). Loading via runoff is suggested by storm event samples at Site 2 (Figure 4.5), which consistently shows high late season loading contributions. Some of the increased late-season turbidity could also be due to increased algae growth in the heat of the summer. Some evidence of this is in Figure 4.6, which shows the ratio of the total volatile solids (an indicator of suspended organic material, which includes algae) to total suspended solids. This graph appears to show a greater frequency of a higher organic fraction in August and September than earlier in the year.
- The long-term dataset for total suspended solids for the Milestone Site indicates no apparent increasing or decreasing trend.
- Flow data indicates very flashy hydrology in the watershed—flow rises sharply following significant rain and then decreases rapidly. In general, because of this, routine water quality sampling was not able to catch some of the more significant rain events. However, limited continuous monitoring data in spring of 2006 on Pipestone Creek at the Pipestone National Monument (Figure 4.7) does show high turbidity levels concurrent with spring runoff. (Note: it has not been determined how the turbidity units for the sonde used for this monitoring equate to laboratory generated data for the rest of the monitoring dataset, so definitive conclusions on spring turbidity concentrations cannot be made.)
- An estimate for an overall load reduction percentage can be made using the existing dataset. To do so it makes sense to consider the listing/delisting criteria for turbidity, which is based on whether or not 10 percent of the data points within a dataset exceed the 25 NTU standard. Therefore, to meet the standard 90 percent of the time would mean reducing the 90th percentile value from the dataset down to 25 NTU. The watershed-wide 90th percentile for turbidity is 34 "NTU equivalent" and to reduce that to 25 "NTU equivalent" would mean a reduction of:

  $$(34 - 25)/34 = 26\%$$

  This reduction percentage is only intended as a rough approximation, as it does not account for flow, and is not a required element of a TMDL. It 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. This reduction percentage does not supersede the allocations provided in Section 4.3.

4.2 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 stream survey conducted by Pipestone County Conservation and Zoning Office staff.

A simplified turbidity conceptual model is presented in Figure 4.8 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. Both "external" and "internal" sources are illustrated in this figure. Most point and nonpoint sources are typically considered external in that they are located in the watershed outside of a waterway, stream, or river yet contribute TSS and turbidity in some manner. Internal sources typically encompass processes that occur within the channel (including the bed and banks) or the floodplain of a waterway, stream, or river. Such processes include channel and floodplain erosion or scour, and bank slumping. 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.

Feedlots with pollution hazards

Feedlots near streams and waterways with pollution hazards can contribute to excess turbidity via soil and phosphorus runoff. According to the Watershed Survey (Appendix B) Pipestone County staff have inspected most of the 164 feedlots located in the watershed and determined that approximately 15 sites within the watershed have a runoff problem and will need corrective measures to minimize runoff.

Livestock in riparian zone

Livestock overgrazing in riparian areas can contribute to excess turbidity via soil and phosphorus runoff directly from de-vegetated areas, resuspending of sediments by walking in the stream, and by destabilizing the banks leading to increased bank erosion or slumping. While it does not appear that overgrazing in riparian pastures is a widespread chronic problem in the watershed, there is evidence to suggest this source is a concern and should be further identified and addressed. The fact that much of the watershed riparian area is in pasture and that much is relatively well managed is an overall positive thing in terms of stream turbidity and may be a reason that turbidity levels are relatively modest.

Row cropland

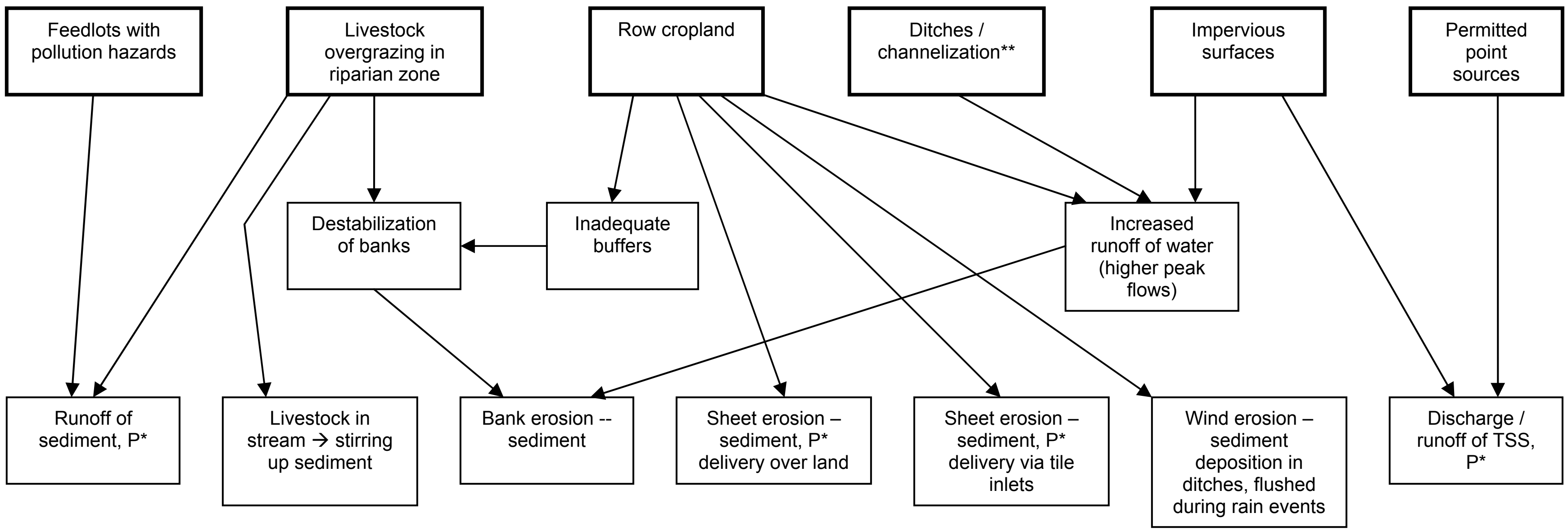
Row cropland can contribute to excess turbidity via sheet/rill erosion of soil either overland or via surface tile intakes, wind-eroded soil settling in ditches that are then flushed during rain events, destabilization of banks (if inadequate buffers) leading to increased bank erosion, and also drainage alterations on cropped land can lead to increased flows which can then cause bank/bed erosion.

Average annual soil loss estimates from sheet and rill erosion were done for cultivated and grasslands within the watershed using the Revised Universal Soil Loss Equation (RUSLE). Inputs for the Rainfall and Runoff Factor (R), Soil Erodibility Factor (adjusted K) and Slope Length and Steepness Factor (LS) were based on the Technical Guide by USDA-NRCS-MN (1996) and the University of Minnesota's Soil Survey Information System (SSIS) database. For the Support Practice Factor (P) no practice adjustment was made (i.e., a factor of 1.0 was used). For the Cover and Management Factor (C) the factor for cultivated land assumes equal portions corn and soybean acreage and uses an average C factor of 0.14 (based on a C factor = 0.18 for corn with assumed yield of 150 bu/acre and C factor = 0.10 for soybeans with assumed yield of 45 bu/acre). For grassland a C factor for continuous hay (0.005) was used. A summary of results is shown in Figures 4.9 and 4.10. While there is a range of potential soil loss and, therefore, potential delivery of soil to the creek, the RUSLE analysis primarily shows low levels of potential soil loss for the vast majority of upland areas, with the exception of an upper subwatershed with higher slopes. Intermittent streams within cropped areas that lack adequate buffers could be providing excess sediment delivery and, therefore, these should continue to be identified and addressed.

Wind-eroded soil (settling in ditches) does not appear to be a likely pathway/source for turbidity in this setting, based on knowledge of local staff. Also, open tile intakes are believed to be uncommon in the watershed.

As indicated in the watershed survey (Appendix B) there are portions of the north branch that have significant bank erosion. While some eroding banks were associated with overgrazed areas, many were not. It was concluded that much of the problem appears to be due to drainage alterations across the watershed.

Figure 4.8. Simplified turbidity conceptual model



* 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:

- channel eroding banks as streams revert to original meandering
- steeper gradient can cause headward erosion and downcutting (nickpoints may form; channel erodes nickpoint resulting in upstream scour)
- ditch cleaning / dredging

Figure 4.9. RUSLE output for Pipestone Creek watershed.

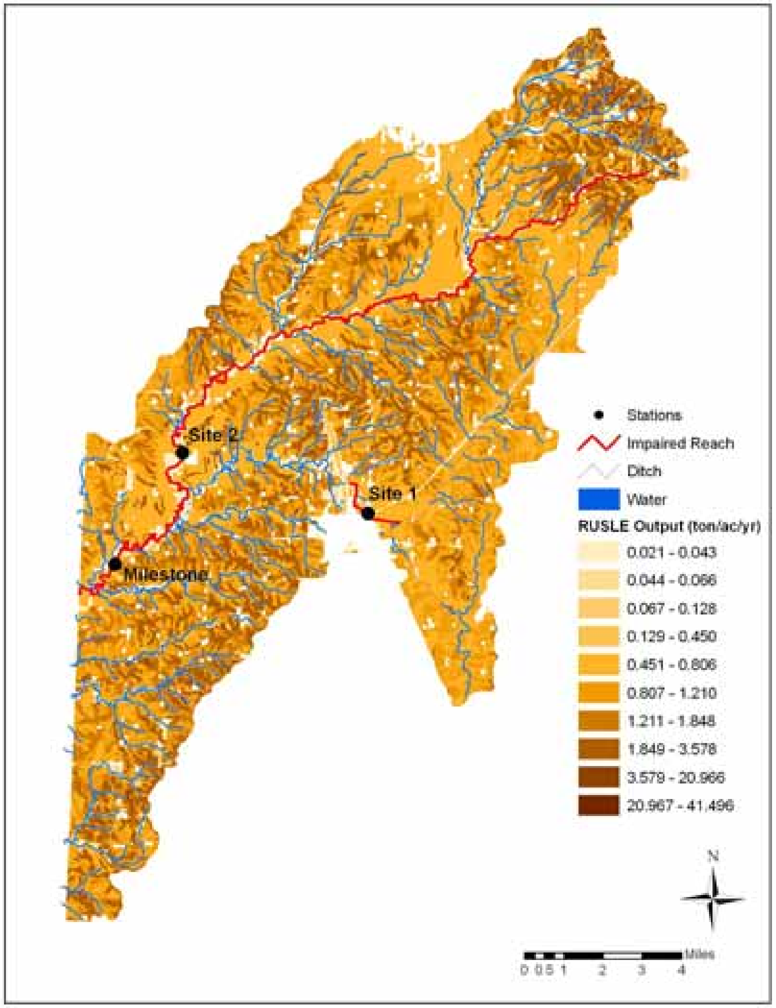
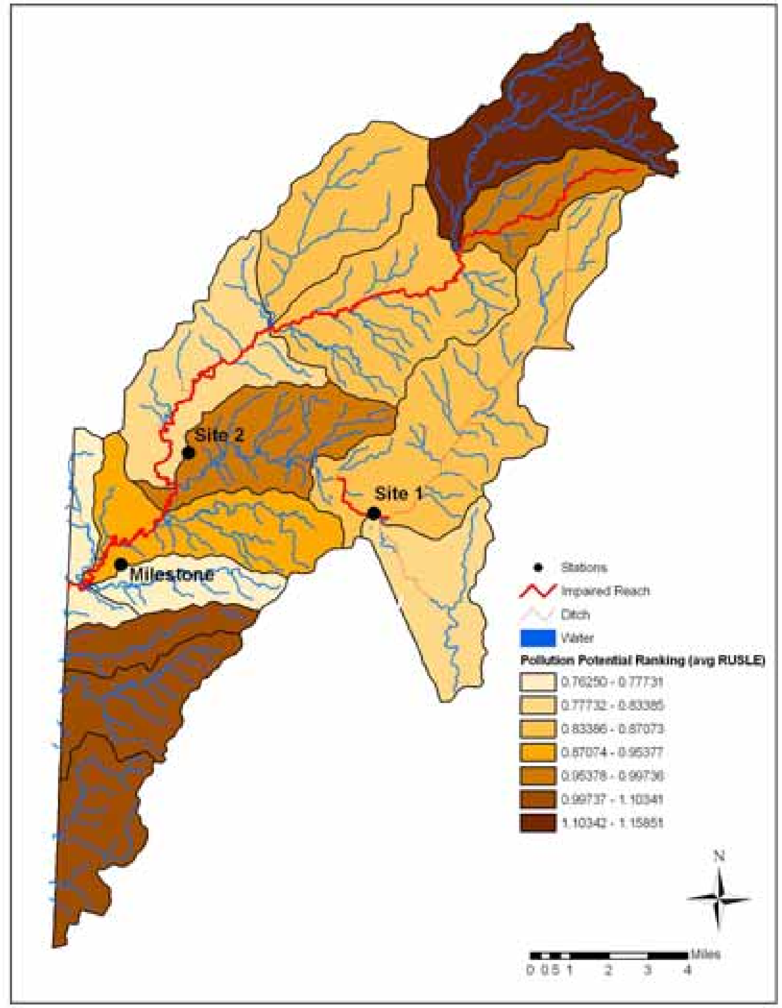


Figure 4.10. Average RUSLE output by subwatershed for Pipestone Creek watershed.



Ditches/channelization

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. Such waterways 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 access to the floodplain is limited. Therefore, the energy of the water is confined to the channel. Straightened channels also exhibit a continuous tendency to try to revert to a meandering condition. The net result is increased potential for bank erosion. Release of sediments also occurs during ditch cleaning/dredging.

A full assessment of the influence of ditches/channelization in terms of turbidity is difficult. As indicated previously, the difficulty of capturing storm events during routine sampling reduced the ability to evaluate some high flow conditions (when turbidity levels can be high). The limited continuous monitoring data (Figure 4.7), which was taken downstream of the main ditch, did show elevated spring turbidity levels. However, it is not clear what the breakdown of contributions is for upland erosion versus these in-channel sources.

Impervious surfaces (no permit required)

Impervious surfaces (roads, parking lots, roofs, etc.) can contribute to excess turbidity directly via sediment and phosphorus delivery and indirectly via increased runoff of water leading to increased bank/bed erosion. In 1987 the federal Clean Water Act was amended to include provisions for a two-phase program to address stormwater runoff. The City of Pipestone is the main source of urban stormwater in the watershed, but due to its small population does not fall under the requirements of this program to obtain a stormwater permit. (However, the MPCA has authority under Minn. Stat. § 103E.411, subd. 2 (2006) to review and approve plans for municipalities to connect their municipal drainage systems to the existing drainage systems.) Stormwater-related turbidity concerns do exist for the city. The watershed survey points out an example of stormwater discharge on the western edge of the city with significant erosion problems.

Point sources

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 water quality permit from the MPCA. In this watershed the potential point source categories are: municipal and industrial wastewater facilities, construction activities, and industrial stormwater sources.

The operation, location and other related information regarding the City of Pipestone wastewater treatment facility was described in Section 3.0. Relative to turbidity the facility's NPDES permit has a discharge limit of 45 mg/L TSS as well as average and maximum daily loading limits per calendar week and month. A review of MPCA records since 2001 reveals 23 TSS-related violations. These violations appear to represent a small to perhaps moderate contribution to Pipestone Creek (the lower reach represented by the Milestone Site) during the facility's discharge windows (spring and fall). Ongoing efforts by the city as well as continued regulatory oversight by MPCA are needed and should minimize this contribution.

The Lincoln Pipestone Rural Water Holland Well (NPDES permit #MN0064351) discharges water treatment effluent to the North Branch of Pipestone Creek during the spring and fall. Its permit has a discharge limit of 30 mg/L TSS for both sand filter backwash and membrane filter effluent. A review of MPCA records since 2001 reveals no TSS-related violations.

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), MPCA records show that the number of projects per year in this predominantly rural watershed is relatively small. Therefore, this source appears to be a very minor turbidity source.

Regarding industrial stormwater sources, there are four permit holders in the watershed according to the MPCA's DELTA database. None have TSS limits or otherwise appear to represent a TSS loading concern in this watershed.

Other

One other potential turbidity contributor worth noting is carp and other benthic feeders that stir up fine sediments. It is difficult to gage the relative impact of this internal source, but limited fish monitoring by MPCA in August of 2004 does show significant biomass of carp where sampling was conducted. For example, in a 500 meter reach on Pipestone Creek above the confluence with the north branch 25 carp were observed (ranging in size from 1.5 to 24 inches).

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

The TMDLs developed for the three reaches in this report consist of three main components: WLA, LA, and MOS as defined in Section 1.0. The WLA includes four sub-categories: two permitted facilities with TSS limits (the City of Pipestone wastewater treatment facility and the Lincoln Pipestone Rural Water Holland Well water treatment facility) and two permitted stormwater source categories (construction and industrial facilities). (There are no communities subject to Stormwater MS4 NPDES permit requirements in this watershed.) The LA, reported as a single category, includes the nonpoint sources described in the previous section, namely row cropland, overgrazed pastures, feedlots with pollution hazards, streambank/bed erosion, and stormwater runoff from impervious surfaces (in which no permit is required). The third component, MOS, is the part of the allocation that accounts for uncertainty that the allocations 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 4.1 this parameter is used as a surrogate for turbidity based on a good correlation between the two, with the turbidity standard of 25 NTU corresponding to 54 mg/L TSS. 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.

As with the fecal coliform impairments (Section 3.0), the methodology to derive and express the TSS load components is the duration curve approach and is described in Appendix D. The same flow gage (USGS #06482610) and flow records as with Section 3.0 were used here.

For each impaired reach and flow condition, the total loading capacity (TMDL) was divided into its component WLA, LA, and MOS. The process was as follows:

Wasteload Allocation

- For the City of Pipestone wastewater treatment facility and the Lincoln Pipestone Rural Water Holland Well water treatment facility their WLAs were determined based on their permitted discharge volumes from their ponds and their permitted TSS concentration limits. Although a daily WLA is assigned to these facilities, it is important to note that discharge occurs only during specified days during the year (April 1 through June 15 and September 15 through December 15).
- The WLA for construction and industrial stormwater is less than one percent of the TMDL and a load that is difficult to quantify. Construction storm water activities are considered in compliance with provisions of the TMDL if they obtain a Construction General Permit under the NPDES program and properly select, install and maintain all BMPs required under the permit, or meet local construction stormwater requirements if they are more restrictive than requirements of the State General Permit. Industrial storm water activities are considered in compliance with provisions of the TMDL if they obtain an industrial stormwater general permit or General Sand and Gravel general permit (MNG49) under the NPDES program and properly select, install and maintain all BMPs required under the permit.
- As occurred in the calculations for the fecal coliform section (Section 3.0), the total daily loading capacities in the dry and low flow zone are very small due to the occurrence of very low flows in the long-term flow records. Consequently, for one of the impaired reaches (Pipestone Creek; N Br Pipestone Cr to MN/SD border), the permitted wastewater treatment facility design flows exceed the stream flow at the low flow zone. Of course actual treatment facility flow can

never exceed stream flow as it is a component of stream flow. For the dry flow zone the calculated MOS would take up all of the remaining allocation capacity. To account for these unique situations only, the WLAs and LAs are expressed as an equation rather than an absolute number. That equation is simply:

Allocation = (flow contribution from a given source) x (*X* mg/L TSS), where *X* equals 45 for the City of Pipestone wastewater treatment facility, 30 for the Lincoln Pipestone Rural Water Holland Well water treatment facility, and 54 for all other sources

In essence, this amounts to assigning a concentration-based limit to the sources for the dry and low flow zone.

Margin of Safety

- The purpose of the MOS is to account for uncertainty that the allocations will result in attainment of water quality standards. Because the allocations are a direct function of daily flows, accounting for potential flow variability is an appropriate way to address the MOS. This is done within each of the five flow zones. Basically, the margins of safety were calculated as the difference between the loads corresponding to the median flow and minimum flow in each zone.
- For the impaired reach in which the allocation for the dry and low flow zones required use of an alternative method of calculation, i.e., a concentration-based limit, an implicit MOS was used. An implicit MOS means that conservative assumptions were built in to the TMDL and/or allocations. In this instance the creek is expected to meet the TMDL because the permitted point source dischargers are limited to discharge concentrations below the TSS target, thereby providing additional capacity. In addition, the creek flow itself is primarily being fed by ground water at these low flows, which is believed to convey very little TSS.

Load Allocations

- Once the WLA and MOS were determined for a given reach and flow zone, the remaining loading capacity was considered LA. 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 the other sources.

4.4 TMDL Allocations for Individual Impaired Reaches

In the sections below TMDL allocations are provided for the individual impaired reaches. Calculations for the TMDL, LA, WLA and MOS consider the total drainage area represented by the end of the listed reach. (Note: due to rounding the WLA, LA, and MOS may not exactly add up to the loading capacities provided in the tables below for some flow zones.)

4.4.1 Pipestone Creek; N Br Pipestone Cr to MN/SD Border (AUID: 10170203-501)

This reach of Pipestone Creek was added to the Section 303(d) Clean Water Act impaired waters list in 2002. The primary source of data that led to this listing was the MPCA Milestone long-term monitoring program.

The drainage area to the downstream end of this impaired reach is about 121 square miles, which represents 80 percent of the Pipestone Creek watershed in Minnesota. Previous sections provided land use information and watershed characteristics.

The City of Pipestone wastewater treatment facility (NPDES Permit #MN0054801) and the Lincoln Pipestone Rural Water Holland Well water treatment facility (NPDES permit #MN0064351) contribute to this reach. For the City of Pipestone wastewater treatment facility the WLA was determined based on their permitted discharge volume from their pond (based on six inches per day drawdown) and their permitted TSS concentration limit (45 mg/L), which is a technology-based limit. The effluent concentration limit for the Lincoln Pipestone Rural Water Holland Well water treatment facility is 30 mg/L TSS. This TMDL does not supersede the requirements of these facilities' permits.

Table 4.2 provides the daily TSS loading capacities for this reach, as well as the component WLAs, LAs and MOS. The loading capacities for the five flow zones were developed using flow data from the USGS gage site #06482610 on Split Rock Creek at Corson, SD, as described in Appendix D.

TABLE 4.2. TSS loading capacities and allocations—Pipestone Creek; N Br Pipestone Cr to MN/SD border (AUID: 10170203-501)

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Tons TSS per day				
Total Daily Loading Capacity	16.1	4.1	1.8	0.9	0.3
Wasteload Allocation					
Pipestone Wastewater Treatment Facility	0.6	0.6	0.6	*	*
Lincoln Pipestone Holland Well Water Trt Fac	0.02	0.02	0.02	*	*
Load Allocation	8.6	1.8	0.7	*	*
Margin of Safety	6.9	1.7	0.5	Implicit	Implicit
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Pipestone Wastewater Treatment Facility	4%	15%	33%	*	*
Lincoln Pipestone Holland Well Water Trt Fac	0.1%	1%	1%	*	*
Load Allocation	53%	43%	38%	*	*
Margin of Safety	43%	41%	27%	Implicit	Implicit

* See Section 4.3 for allocations for these specific categories in these flow zones.

4.4.2 Pipestone Creek, North Br; Headwaters to Pipestone Cr (AUID: 10170203-514)

This reach of Pipestone Creek was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted by Pipestone County Conservation and Zoning Office in cooperation with Pipestone National Monument staff.

The drainage area to the downstream end of this impaired reach is about 64 square miles, which represents 43 percent of the Pipestone Creek watershed in Minnesota. The land use and watershed characteristics are similar to those of the larger watershed except that this subwatershed has no urban area. The North Branch of Pipestone Creek is nearly all a natural channel with very limited straightened ditch portions.

The Lincoln Pipestone Rural Water Holland Well water treatment facility (NPDES permit #MN0064351) contributes to this reach. Its effluent concentration limit is 30 mg/L TSS.

Table 4.3 provides the daily TSS loading capacities for this reach, as well as the component WLAs, LAs and MOS. The loading capacities for the five flow zones were developed using flow data from the USGS gage site #06482610 on Split Rock Creek at Corson, SD, as described in Appendix D.

TABLE 4.3. TSS loading capacities and allocations—Pipestone Creek, North Br; Headwaters to Pipestone Cr (AUID: 10170203-514)

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Tons TSS per day				
Total Daily Loading Capacity	8.5	2.2	1.0	0.5	0.2
Wasteload Allocation					
Lincoln Pipestone Holland Well Water Trt Fac	0.02	0.02	0.02	0.02	0.02
Load Allocation	4.9	1.3	0.7	0.3	0.06
Margin of Safety	3.6	0.9	0.3	0.2	0.1
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Lincoln Pipestone Holland Well Water Trt Fac	0.3%	1%	2%	5%	12%
Load Allocation	57%	58%	71%	51%	31%
Margin of Safety	43%	41%	27%	44%	57%

4.4.3 Main Ditch; CD A to Pipestone Cr (AUID: 10170203-527)

This reach of Pipestone Creek was added to the Section 303(d) Clean Water Act impaired waters list in 2006. The primary source of data that led to this listing was monitoring conducted by Pipestone County Conservation and Zoning Office in cooperation with Pipestone National Monument staff.

The drainage area to the downstream end of this impaired reach is about 32 square miles, which represents 21 percent of the Pipestone Creek watershed in Minnesota. The land use is primarily cultivated land, with only limited grassland/pasture on tributaries. The main stem of this reach is a straightened ditch with smaller ditches and natural small streams feeding it.

There are no wastewater treatment facilities that contribute to this reach.

Table 4.4 provides the daily TSS loading capacities for this reach, as well as the component WLAs, LAs and MOS. The loading capacities for the five flow zones were developed using flow data from the USGS gage site #06482610 on Split Rock Creek at Corson, SD, as described in Appendix D.

TABLE 4.4. TSS loading capacities and allocations—Main Ditch; CD A to Pipestone Cr (AUID: 10170203-527)

	FLOW ZONE				
	High	**Moist**	**Mid**	**Dry**	**Low**
	Tons TSS per day				
Total Daily Loading Capacity	4.2	1.1	0.5	0.2	0.09
Wasteload Allocation					
Load Allocation	2.4	0.6	0.3	0.1	0.04
Margin of Safety	1.8	0.4	0.1	0.1	0.05
	Percent of total daily loading capacity				
Average Total Daily Loading Capacity	100%	100%	100%	100%	100%
Wasteload Allocation					
Load Allocation	57%	59%	73%	56%	43%
Margin of Safety	43%	41%	27%	44%	57%

4.5 Critical Conditions and Seasonal Variation

The EPA definition of "critical conditions" was provided in Section 3.5. Turbidity levels are generally at their worst following significant storm events during the spring and summer months, as described in Section 4.1. This section also addressed seasonal variation, which was 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.

4.6 Consideration of Growth on TMDL

With regard to point sources, the primary potential for considering the impact of growth would be the City of Pipestone wastewater treatment facility and the Lincoln Pipestone Rural Water Holland Well water treatment facility. As indicated previously, the population in Pipestone has declined in recent years. Should it increase in the future revised permits may be sought, but is likely not to have a significant impact on Pipestone Creek provided discharge limits are met. This is because increased flows add to the overall loading capacity of the system.

The allocations for nonpoint sources are for all current *and* future sources. This means that any expansion of nonpoint sources will need to comply with the LA provided in this report. Additional nonpoint sources (e.g., shifting grassland to row cropland) could very well make meeting the TMDL more difficult over time. Therefore, continued efforts over time to prevent soil/sediment delivery to the stream will be critical.

5.0 MONITORING PLAN

The goal of this monitoring plan is to assess the effectiveness of source reduction efforts for attaining water quality standards and designated uses. The impaired reaches will remain listed until water quality standards are met.

Monitoring of *E. coli* (assuming the proposed rule change shift from fecal coliform to *E. coli* occurs) will be done at the same sites that were monitored for assessment/study purposes and will be done five times per month from April 1 through October 31. A similar schedule will be done for turbidity. This monitoring will be done for a minimum of two seasons and will begin after a period of time that substantial implementation has taken place, approximately five to seven years from now (assuming funding for implementation and monitoring is available). The monitoring data will dictate the need for additional implementation and follow-up monitoring.

Monitoring will be conducted by Pipestone County Conservation and Zoning Office and it is expected that funding for analysis will be through the MPCA.

6.0 IMPLEMENTATION

This section provides an overview of implementation options and considerations to address the fecal coliform bacteria and turbidity TMDLs. A more detailed implementation plan will be developed following approval of this TMDL study. Because fecal coliform bacteria and turbidity have several sources and delivery pathways in common it will make sense to address implementation efforts together. Furthermore, most agricultural best management practices (BMPs) address a range of pollutants.

A BMP matrix that offers a range of appropriate implementation options is provided in Appendix E. It was developed by David Mulla of the Department of Soil, Water, and Climate of the University of Minnesota and was designed to provide options on an agroecoregion basis and is focused on turbidity impairments, though appears to have applicability to other runoff-driven pollutants. The Pipestone Creek watershed is predominantly in the Inner Coteau agroecoregion. In the narrative discussing this agroecoregion Mulla provides the following summary of appropriate BMPs for the range of agricultural-related water quality impacts that occur there:

> *Good animal and manure management practices include livestock exclusion from streams, improved pasture management, and limiting manure applications to frozen ground. Liquid manure waste holding facilities should be properly sited and designed to minimize seepage and overflow. The Manure Application Planner is recommended for nutrient management. Conservation tillage, and conservation crop rotations are recommended to reduce soil erosion. Protection of ground water quality from nitrate contamination is a high priority in this agroecoregion. Nitrogen fertilizer applications should be based on realistic crop yield goals, nitrogen credits from legumes and manure, and an N soil test.*

Specific to improved pasture management the use of rotational grazing is an appropriate practice to be used in this watershed. With rotational grazing, only one portion of the pasture is grazed at a time. This is accomplished by dividing the pasture into paddocks and by moving livestock from one paddock to another before the forage is overgrazed. Rotationally grazed pastures have several environmental advantages to tilled land or to continuously grazed pastures: they dramatically decrease soil erosion potential, require minimal pesticides and fertilizers, and decrease the amount of fecal coliform and nutrient runoff. Grazing management that encourages tall, vigorous growing vegetation will result in higher water infiltration into the soil, thus reducing runoff losses. When grazing along streams, rotational grazing can be used as a tool to manage livestock activity for maintaining healthy stream bank vegetative cover while controlling unwanted plant species.

Additional actions to specifically address the fecal coliform impact include upgrading of noncompliant septic systems and correction of feedlots with runoff problems.

Streambank erosion was identified as an important contributing source to the turbidity problem. It is not clear to what extent streambank restoration will be pursued in this watershed. Due to potential high cost any streambank restoration projects should be prioritized based on magnitude of apparent contribution.

As indicated in the watershed survey (Appendix B) the Pipestone County Conservation and Zoning Office staff is currently promoting existing program and cost-share assistance to interested producers within the watershed to resolve issues. Some of these programs include Environmental Quality Improvement Program, State Cost-share, Ag BMP loan program, Conservation Reserve Enhancement Program and Conservation Reserve Program. Also, staff is trying to work with counterparts in South Dakota to coordinate implementation efforts. Upon approval of this TMDL additional state and federal funding sources will be sought. A specific cost estimate to address the impairments identified in this report has not yet been done. However, restoration cost estimates for similarly-sized watersheds in Minnesota with primarily nonpoint source implementation needs indicate overall costs to be in the $4-6 million range.

7.0 REASONABLE ASSURANCE

The following should be considered as reasonable assurance that implementation will occur and result in fecal coliform and sediment load reductions in the reaches of Pipestone Creek to meet their designated uses.

- The BMPs and other actions outlined in Section 6.0 have all been demonstrated to be effective in reducing transport of pollutants to surface water. Also, many of these actions are currently being promoted by local resource managers.
- The advisory committee formed to provide feedback and input into the project had broad representation from government, citizens, and agricultural experts.
- The Pipestone County Water Plan (2004) includes several goals, objectives and guidelines related to the impairments addressed in this report and indicates the intent to "proactively participate in getting waters off the MPCA's impaired waters list."
- TMDL studies and implementation plans have been done downstream of these impaired reaches in South Dakota. This will contribute to raising awareness of the problems and a sense that all landowners in the area will need to play a role.
- Monitoring will be conducted to track progress and suggest adjustment in the implementation approach.

8.0 PUBLIC PARTICIPATION

An advisory group was assembled and included representation from federal and state agencies, local governments and landowners. Two meetings were held. The first meeting focused on the purpose of the project, monitoring results and data and information needs. The second meeting focused on preliminary conclusions with regard to sources and implementation options.

A public meeting was held in December 2006 to present key findings, outline future actions and address questions and concerns. An opportunity for further public comment was provided via a public notice in the State Register and the MPCA website that announced a 30-day comment period.

References

Cleland, B.R. November 2002. *TMDL Development From the "Bottom Up" – Part II: Using Duration Curves to Connect the Pieces*. National TMDL Science and Policy – WEF Specialty Conference. Phoenix, AZ.

Helsel, D.R. and R.M. Hirsh. 1991. *Statistical Methods in Water Resources.* Techniques of Water-Resources Investigations of the USGS Book 4.

Minnesota Pollution Control Agency. 2002. *Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota.*
Minnesota Pollution Control Agency. 2004. *The Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment.* http://www.pca.state.mn.us/publications/manuals/tmdl-guidancemanual04.pdf

Minnesota Pollution Control Agency. 2006. *Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota.*

Minnesota Pollution Control Agency. 2006. *Stormwater Program for Construction Activity* web page http://www.pca.state.mn.us/water/stormwater/stormwater-c.html

Pipestone County Water Plan. 2004. http://www.pipestone-county.com/documents/Pipestone_County_Comprehensive_Plan.pdf

Rothman, H. K. and D. J. Holder. 1992. *Managing the Sacred and the Secular: An Administrative History of Pipestone National Monument.* National Park Service, Midwest Region. MWR-1-0015-002.

US Department of Agriculture – Natural Resource Conservation Service – Minnesota. 1996. Technical Guide (Section I-C). Predicting Rainfall Erosion Losses: Revised Universal Soil Loss Equation (RUSLE).

US Environmental Protection Agency. 1999. *Protocol for Developing Sediment TMDLs, First Edition* EPA 841-B-99-004. Washington, D.C.

US Environmental Protection Agency. 2001. *Protocol for Developing Pathogen TMDLs.* EPA 841-R-00-002. Office of Water (4503F). United States Environmental Protection Agency, Washington, DC.

APPENDICES

Appendix A. Water Quality Dataset

Milestone Site (S000-099)

Date	Turbidity NTRU	TSS mg/L	FC #/100ml
26-Mar-63		49	
7-May-63		27	
22-Jul-63		75	
28-Apr-64		23	
8-Jun-64		54	
6-Jul-64		54	
13-Aug-64		61	
17-Nov-64		29	
18-May-65		48	
12-Jul-65		50	
9-Aug-65		47	
12-Jul-67		110	
30-Aug-67		68	
25-Oct-67		25	
17-Jan-68		55	
6-Mar-68		18	
24-Apr-68		24	
19-Jun-68		26	
18-Jul-68		61	
14-Aug-68		41	
18-Sep-68		150	
9-Oct-68		76	
6-Nov-68		20	
4-Dec-68		14	
8-Jan-69		14	
5-Feb-69		24	
2-Apr-69		8	
29-Apr-69		10	
12-Jun-69		19	
9-Jul-69		70	
6-Aug-69		59	
9-Sep-69		34	
8-Oct-69		47	
29-Oct-69		34	
3-Dec-69		130	
7-Jan-70		36	
4-Feb-70		7	
12-May-70		88	
16-Jun-70		97	
21-Jul-70		40	
18-Aug-70		54	
15-Sep-70		42	
14-Oct-70		45	
28-Oct-70		46	
1-Dec-70		24	
6-Jan-71		17	
11-Mar-71		6	
7-Apr-71		16	
8-Jun-71		77	
13-Jul-71		50	
10-Aug-71		33	
2-Sep-71		32	
14-Oct-71		48	
5-Nov-71		22	
13-Apr-72		17	
31-May-72		70	
27-Jun-72		400	
27-Jul-72		93	
25-Aug-72		50	
27-Sep-72		330	
25-Oct-72		28	
21-Nov-72		8	
28-Dec-72		54	
10-Jan-73		10	
21-Feb-73		3	
22-Mar-73		19	
19-Apr-73		31	
30-May-73		65	
28-Jun-73		70	
26-Jul-73		96	
30-Aug-73		53	
19-Sep-73		16	
24-Oct-73		77	
16-Nov-73		13	
28-Dec-73		16	
9-Jan-74		24	
13-Mar-74		13	
10-Apr-74		12	
7-May-74		43	
4-Jun-74		81	
2-Jul-74		61	
6-Aug-74		80	
2-Oct-74		26	
13-Nov-74		2.4	
17-Dec-74		9.2	
29-Jan-75		9.2	
20-Mar-75		14	
15-Apr-75		28	
20-May-75		23	
17-Jun-75		16	
15-Jul-75		40	
26-Aug-75		66	
23-Sep-75		16	
21-Oct-75		14	
19-Nov-75		22	
17-Dec-75		1.5	

Milestone Site (S000-099), cont'd

Date	Turbidity NTRU	TSS mg/L	FC #/100ml	Date	Turbidity NTRU	TSS mg/L	FC #/100ml
21-Jan-76		48		10-Aug-88		39	99
19-Feb-76		44		7-Sep-88		36	200
18-Mar-76		14		23-Oct-90		16	200
27-Apr-76		17		15-Jan-91		18	110
25-May-76		8.8		26-Mar-91		12	4
22-Jun-76		12		9-Apr-91		13	64
21-Jul-76		40		22-May-91		52	1100
17-Aug-76		33		11-Jun-91		160	6800
28-Sep-76		78		2-Jul-91		61	560
26-Oct-76		22		13-Aug-91		62	460
22-Nov-76		10		25-Sep-91		54	400
20-Dec-76		14		27-Oct-93		9.6	290
20-Jan-77		22		4-Jan-94		7.4	360
15-Feb-77		23		8-Mar-94		12	250
14-Mar-77		81		2-May-94		31	260
19-Apr-77		3.6		23-May-94		79	440
17-May-77		4.8		28-Jun-94		120	2100
21-Jun-77		7		12-Jul-94		93	6400
19-Jul-77		14		1-Sep-94		92	1200
16-Aug-77		43		20-Sep-94		79	1700
20-Sep-77		15		21-Oct-98	12.2		
29-Jul-80				17-Nov-98	5		
30-Jul-80		46		2-Feb-99	3.5		
6-Oct-81		41		25-Mar-99	9.1		
6-Jan-82		13		28-Apr-99	12	23	
10-Mar-82		5.2		8-Jun-99	44		
27-Apr-82		15		13-Sep-99	35		
25-May-82		40		24-Oct-00		66	3300
22-Jun-82		8.4		20-Nov-00	12	22	
27-Jul-82		54		23-Jan-01		14	
24-Aug-82		58		27-Mar-01	9.5	14	
21-Sep-82		43		24-Apr-01		70	2800
4-Oct-84		62		14-May-01		15	270
9-Jan-85		13		5-Jun-01		39	2700
11-Mar-85		99		10-Jul-01		35	670
10-Apr-85		30	< 9	27-Aug-01		45	320
8-May-85		67	280	18-Sep-01	63	74	2800
5-Jun-85		190	800	28-Aug-03			1900
10-Jul-85		150	3600	21-Oct-03		25	120
7-Aug-85		110	1500	11-Nov-03		43	
9-Sep-85		84	1600	28-Mar-04		45	
7-Oct-87		35	340	26-Apr-04		32	8
6-Jan-88		6.6	3900	23-May-04		120	
9-Mar-88		18	460	27-Jun-04		31	
6-Apr-88		19	63	21-Jul-04		100	
25-May-88		49	400	25-Aug-04		31	590
8-Jun-88		62	1100	8-Sep-04		41	450
7-Jul-88		8	90				

Site 1 (S000-646)

Date	Turbidity NTRU	TVS mg/L	TSS mg/L	FC #/100ml
6-May-02	1.9		5.6	2
8-May-02	8.3		6.4	150
13-May-02				2
21-May-02				2
29-May-02				270
3-Jun-02	62		74	21000
11-Jun-02				120
18-Jun-02				78
24-Jun-02				310
1-Jul-02				1000
8-Jul-02	5.9		6.8	830
15-Jul-02				540
22-Jul-02				110
29-Jul-02				850
5-Aug-02				1400
6-Aug-02	51		64	1000
12-Aug-02	16		23	1800
19-Aug-02				240
21-Aug-02	54		77	51000
26-Aug-02				260
3-Sep-02				180
10-Sep-02				740
16-Sep-02				300
24-Sep-02	22		30	170
1-Oct-02				330
19-Mar-03	12		11	
2-Apr-03				4
9-Apr-03				2
16-Apr-03	140		190	19000
23-Apr-03				32
30-Apr-03	2.9		10	3600
7-May-03				4
14-May-03				20000
22-May-03	3		9.2	4
29-May-03				72
4-Jun-03				12
11-Jun-03				28
17-Jun-03	8.5		21	21000
24-Jun-03	12		17	4300
2-Jul-03				200
9-Jul-03				7400

Date	Turbidity NTRU	TVS mg/L	TSS mg/L	FC #/100ml
16-Jul-03				2500
24-Jul-03				490
31-Jul-03				700
7-Aug-03				620
14-Aug-03				250
21-Aug-03				360
27-Aug-03	20		27	170
28-Aug-03	70		74	72000
3-Sep-03				100
10-Sep-03	23		36	1800
18-Sep-03	23		25	6900
7-Apr-04	4.1	1.2	8.4	2
20-Apr-04	110	29	190	270
20-Apr-04	28	10	61	4200
21-Apr-04	8.1	5.6	12	290
21-Apr-04	3.7	2	11	64
12-May-04	15	4.8	20	14000
17-May-04	14	5.6	24	2100
18-May-04	5.9	2.4	20	1500
24-May-04		4.8	22	
25-May-04	7.5	3.2	14	7300
2-Jun-04	7.4	2.8	18	170
9-Jun-04	3.2	2	11	110
14-Jun-04	4.2	2	11	130
17-Jun-04	31	6	42	2600
23-Jun-04	4	<1	8	18
30-Jun-04	3.5	<1	8.8	100
7-Jul-04	3.3	<1	5.6	140
13-Jul-04	23	4.2	30	25000
14-Jul-04	11	3.6	24	570
21-Jul-04	32	8	50	110000
22-Jul-04	17	4	35	2400
28-Jul-04	20	4.8	34	550
3-Aug-04	14	5.2	28	3600
12-Aug-04	7	2	12	9
23-Aug-04	20	6	34	880
23-Aug-04	17	5.3	25	640
14-Sep-04	43	10	58	1200
15-Sep-04	140	18	92	8400
16-Sep-04	23	4.8	30	36000

Site 2 (S001-904)

Date	Turbidity NTRU	TVS mg/L	TSS mg/L	FC #/100ml
6-May-02	11		16	4
8-May-02	8.3		10	130
13-May-02				8
21-May-02				2
29-May-02				320
3-Jun-02	21		30	1600
11-Jun-02				810
18-Jun-02				1200
24-Jun-02				850
1-Jul-02				1000
8-Jul-02	52		67	1800
15-Jul-02				680
22-Jul-02				310
29-Jul-02				820
5-Aug-02				270
6-Aug-02	46		30	1000
12-Aug-02	41		53	2500
19-Aug-02				520
21-Aug-02	25		30	16000
26-Aug-02				960
3-Sep-02				250
10-Sep-02				820
16-Sep-02				420
24-Sep-02	21		32	540
1-Oct-02				1900
19-Mar-03	11		22	
2-Apr-03				2
9-Apr-03				2
16-Apr-03	20		29	2000
23-Apr-03				55
30-Apr-03	3.9		5.6	84
7-May-03				8
14-May-03				42
22-May-03	3.4		27	58
29-May-03				460
4-Jun-03				250
11-Jun-03				600
17-Jun-03	18		28	880
24-Jun-03	19		30	4400
2-Jul-03				980
9-Jul-03				3300
16-Jul-03				470
24-Jul-03				460
31-Jul-03				470
7-Aug-03				390
14-Aug-03				160
21-Aug-03				250
27-Aug-03	49		42	300
28-Aug-03	54		54	440
3-Sep-03				380
10-Sep-03	67		68	7100
18-Sep-03	41		49	1300
7-Apr-04	8.4	3.2	16	8
20-Apr-04	6.4	2.4	10	440
20-Apr-04	5.1	3.2	7.2	300
21-Apr-04				
21-Apr-04	3	2.8	5.2	310
12-May-04	24	6.4	36	1300
17-May-04	12	5.2	23	21000
18-May-04	14	<1	16	3400
24-May-04		4	23	
25-May-04	11	3.6	20	1600
2-Jun-04	18	5.2	29	430
9-Jun-04	16	4.4	28	610
14-Jun-04	17	4.8	28	590
17-Jun-04	86	5	29	3400
23-Jun-04	14	2.8	24	290
30-Jun-04	8.2	<1	14	420
7-Jul-04	7.7	2.8	12	300
13-Jul-04	25	7.2	40	2400
14-Jul-04	22	4.8	31	510
21-Jul-04	37	9	47	13000
22-Jul-04	28	8.4	44	3600
28-Jul-04	22	6.7	33	2500
3-Aug-04	24	7.6	38	8300
12-Aug-04	34	10	55	400
23-Aug-04	36	14	55	650
23-Aug-04	37	14	53	510
14-Sep-04	69	16	81	900
15-Sep-04	75	20	96	5100
16-Sep-04	48	18	73	12000

Appendix B. Watershed Survey

During the summer and fall of 2005 staff from the Pipestone County Soil and Water Conservation District conducted a watershed survey of Pipestone Creek to determine the source of pollutants that is causing the water quality to exceed total maximum daily load amounts. The survey was conducted by driving the watershed and identifying any possible contributing sources of fecal coliform or sediments. Staff then reviewed permitting, inventories and inspections of feedlots, septics and other various land use data that was available.

The watershed can be divided into two primary sections, one being the east branch which consists primarily of corn and bean production and contains the County Ditch system. The Ditch also feeds the Winnewissa Falls which is part of the Pipestone National Monument. While the north branch is also predominantly corn and beans, it also contains pasture throughout most all the riparian and floodplain portions of the watershed. The north branch also contains one of the regions most productive municipal water supply well fields. Lincoln Pipestone Rural Water has nine wells which they draw from to supply this region with water. A reverse osmosis plant operates on-site to treat the surficial aquifer water quality issues (nitrates, manganese, and iron).

Exhibit A

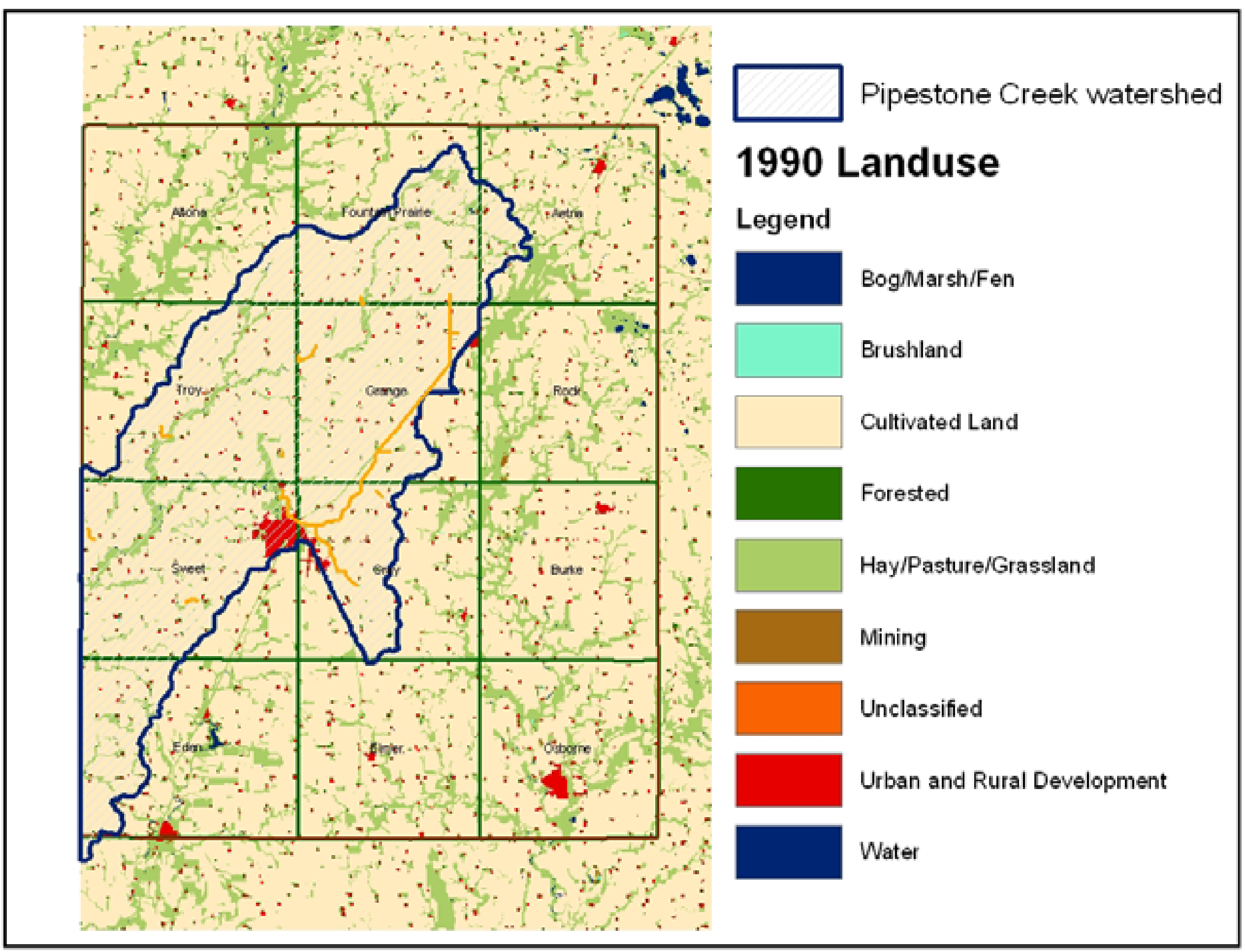
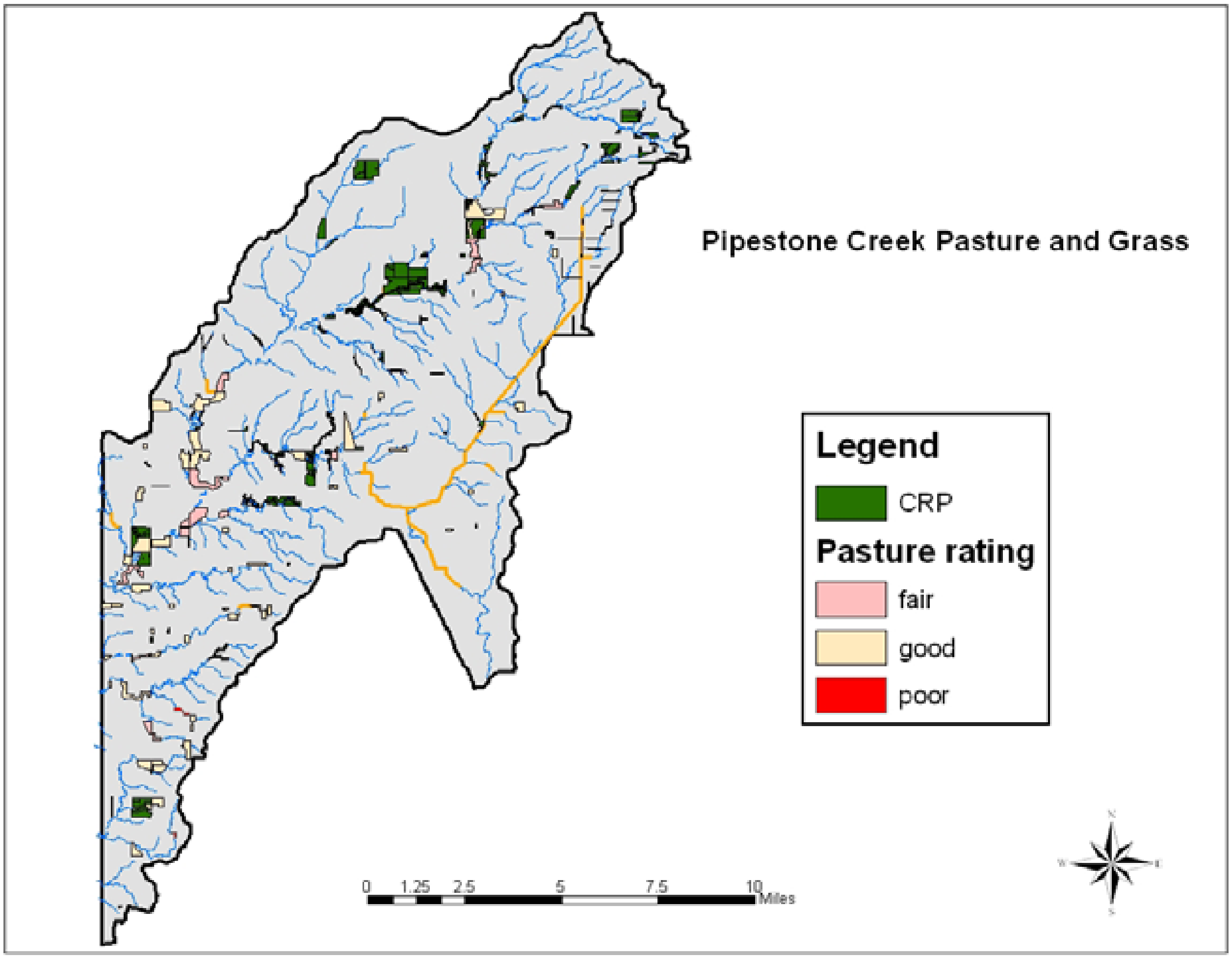


Exhibit B



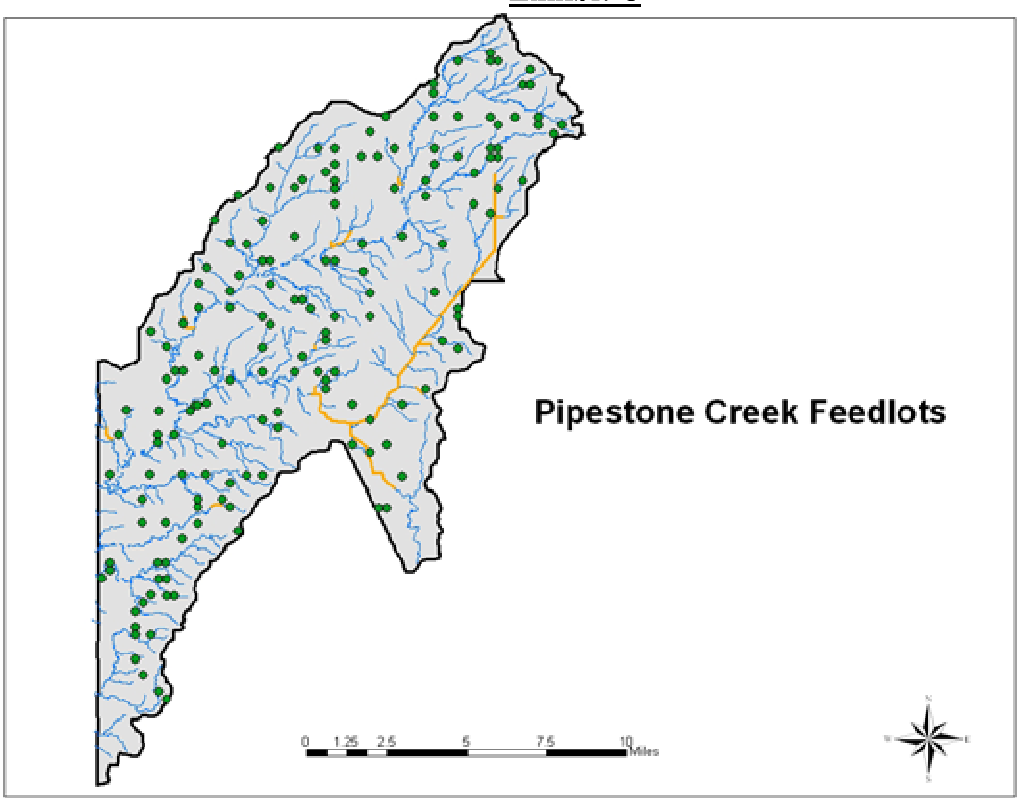
Land Use: Land use throughout the watershed is predominantly Ag with a minor portion of urban as shown in (Exhibit A). It is estimated that 91 percent of ag land within the watershed is utilized for corn and bean production, 2 percent small grains, 2 percent hay, 2.5 percent Conservation Reserve Program (CRP), and 2.5 percent pasture. According to the Pipestone County residue transect survey data from 2004 in which crop, tillage, and residue amounts are documented at specific locations throughout the county, results showed that conservation tillage is being utilized on 43 percent of the land, reduced-till residue amounts of 15 – 30 percent are maintained on 38 percent, and conventional-till with residue amounts of 0 – 15 were identified on 19 percent of the ground (data found at ctic.pudue.edu). Nutrient management is also a major concern within this watershed. In the late 1990s, a Minnesota Department of Ag nutrient application study was conducted within the Lincoln Pipestone Rural Water Wellhead Area. This study showed that there was an over application of nitrogen on corn ground. Since this time the University of Minnesota conducted field studies through an LCMR grant to confirm that U of M fertilizer recommendations held true to this area of the state as well. Findings confirmed that U of M fertilizer recommendations are indeed adequate for the SW part of the state. Funds were also received though 319 Clean Water Funds to provided incentives to producers within the watershed to develop and maintain a nutrient and residue management plan on sensitive land within the watershed. Nutrient management plan were developed on approximately 3,500 acres.

Riparian

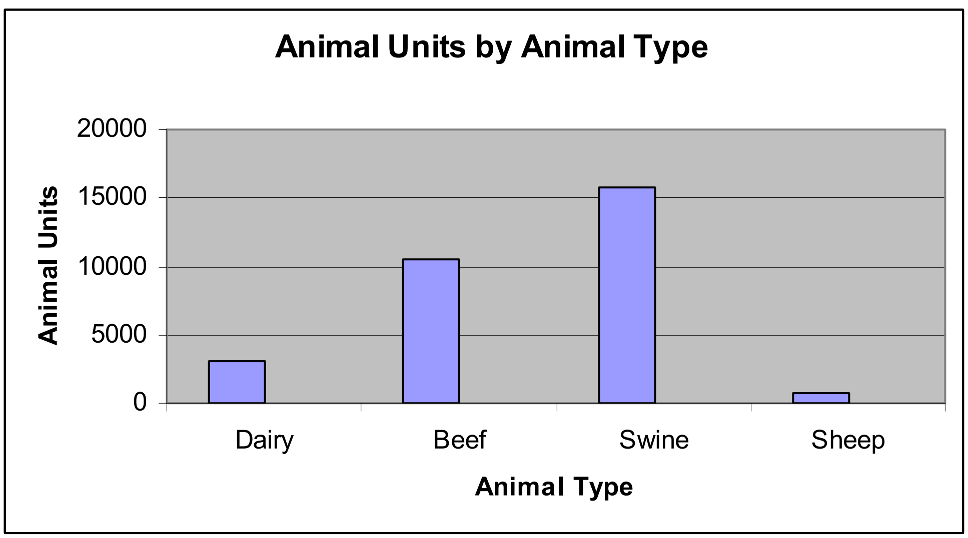
Within the watershed the majority of the riparian areas are pasture land. These pastures were surveyed in mid to late August 2005 and were given a rating from good to poor, depending on their appearance at that time. (Exhibit B). A good rating meant that the pastures had no black areas and the grass had not been eaten down to ground level. A fair rating meant that there may have been a few black areas around the feeding areas or that the grass was getting a little short. Poor ratings meant that black areas were spread beyond the feeding areas, and water access areas, grasses were very short, and there may have been some bank erosion. Animal numbers per pasture were also estimated. The county ditch system was another riparian area investigated. Buffers of a rod (16.5') or greater were identified on both sides of the ditch for a distance of 9.2 miles, buffers on one side are being maintained for 3.8 miles and no buffer is being maintained on approximately 2 miles. Therefore buffer promotion should take place on 7.8 miles of ditch. Buffer promotional efforts continue to protect intermittent creeks and streams through the Continuous Conservation Reserve and Conservation Reserve Enhancement Programs. CRP filter strips areas are also identified in Exhibit B.

Feedlots

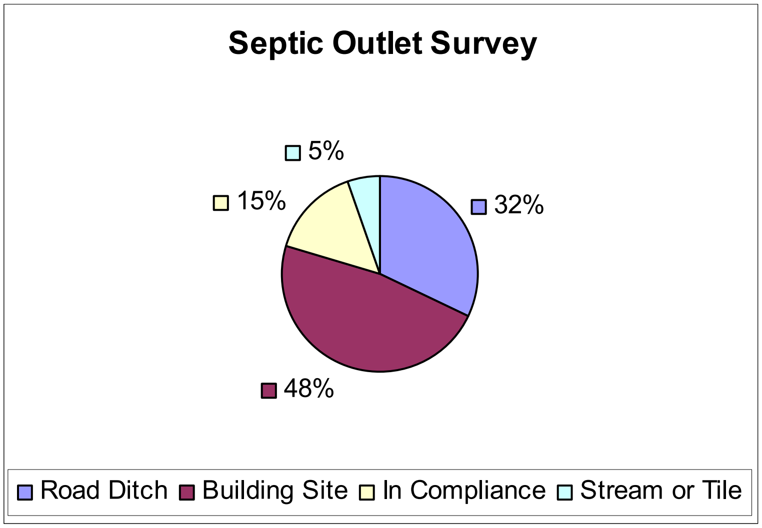
Exhibit C



According to the Pipestone County Feedlot Inventory there are 164 feedlots located in the watershed (Exhibit C). Site inspections have been conducted on most of the sites to identify if a pollution potential exists or not. Site data was collected on sites that had potential for runoff, and the Feedlot Evaluation Model (FLEVAL) was utilized to provide a rating. It is estimated that approximately 15 sites within the watershed do have a runoff problem and will need corrective measures to minimize runoff. Dairy facilities and milkhouse waste is another issue that has high water quality impacts, most facilities surface discharge milkhouse waste. Technical assistance and development of best management practices need to be implemented. Management of animal manure is another major concern with the high volume of livestock. Most producers need assistance in the development and implementation of a manure management plan and identification of sensitive features. See the following graph for animal unit information by type of animal.



Individual Sewage Treatment Systems (ISTS)
The watershed has 385 households, each served by an ISTS. A survey of ISTS was completed at 38 households within the watershed during feedlot compliance inspections. Residents were asked the type of system, the date it was installed, number of tanks, and where it outlets.



Pipestone County adopted an ISTS ordinance in 1998 and in 2006 updated the ordinance to require inspection and/or upgrades on land transfers. On an average there are about 40 systems getting updated county wide per year.

Urban Storm Water and Waste Water

The City of Pipestone discharges its storm water into the County Ditch system in several locations, while another portion of town surface discharges into a waterway west of town. Loading rates from the city are unknown, but future storm water management planning would greatly benefit the city and water quality.

Bank Erosion

Throughout the north branch of the Pipestone Creek there are areas that have major bank erosion. These areas of bank erosion are not only present within pastures. It appears that much of the problem has been caused by drainage alterations and increased flows due to drainage. One area of significant concern is located on the western edge of the City of Pipestone where storm water discharges. Major erosion has and continues to occur as shown in the picture below.

Conclusion
Pipestone Creek is a non complex watershed. Although it's difficult to identify one major non-point TMDL contributing source, it is evident that many small or individual contributors would have the ability to be a major contributor when combined. It's also evident that through the development and implementation of best management practices all identified contributing sources can be controlled with the exception of possibly stream bank erosion. Currently the Pipestone County Conservation and Zoning Office staff are promoting existing program and cost-share assistance to interested producers within the watershed to resolve issues, but with the limited staff and funding available major improvements are difficult. Some of these programs include Environmental Quality Improvement Program, State Cost-share, Ag BMP loan program, Conservation Reserve Enhancement Program, and Conservation Reserve Program. Pipestone County is confident that the promotion and implementation of best management practices such as nutrient management planning, upgrading of direct discharging ISTS, correction of feedlots with runoff problems, buffers, and promotion of proper pasture management, Pipestone Creek will be de-listed as a TMDL.

Appendix C. Fecal Coliform Current Loading by Source: Methodology and Estimates of Relative Contribution

The methodology outlined here is adapted from the 2002 version of the "Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (MPCA, 2002). It represents a means to estimate the current loadings of the various fecal coliform source categories and subcategories. It is only a very rough approximation for several reasons including: 1) flow is not accounted for, 2) the dynamics of fecal coliform growth/die-off in the environment and such factors as resuspension in the stream are not rigorously factored in, and 3) very general percentages for availability and delivery based largely on professional judgment rather than research-derived estimates are used. Because of these factors the relative contributions of the various sources are ultimately expressed in more of a qualitative manner (i.e., low, moderate, high) rather than precise percentages or loads. Despite the shortcomings, this method can help to understand delivery mechanisms and indicate the general magnitude of the various contributing sources.

Step 1. Estimating fecal coliform produced per animal per day.

For use in subsequent steps it is necessary to start with estimates of fecal production by animal type. Table C-1 provides numbers obtained from the literature.

TABLE C-1. Fecal coliform produced per animal and animal unit per day.

	FC orgs/animal/day			Weight, lbs.	FC orgs / AU / day
	Source 1*	Source 2*	Average		
Dairy		1.00E+11	1.00E+11	1400	7.14E+10
Beef		1.00E+11	1.00E+11	1000	1.00E+11
Swine	8.90E+09	1.10E+10	9.95E+09	140	7.11E+10
Chickens	2.40E+08	1.40E+08	1.90E+08	4	4.75E+10
Turkeys	1.30E+08	9.50E+07	1.13E+08	18	6.25E+09
Horses		4.20E+08	4.20E+08	1000	4.20E+08
Sheep	1.80E+10	1.20E+10	1.50E+10	100	1.50E+11
Deer**	5.00E+08		5.00E+08		
Geese***	1.04E+07		1.04E+07		
People	2.00E+09		2.00E+09		
Dogs/cats****	5.00E+09		5.00E+09		

* Source 1: Metcalf and Eddy, 1991; source 2: ASAE, 1998

** interpolated from Metcalf and Eddy, 1991 (in Dry Creek Watershed TMDL, Alabama, 2001)

*** from Alderisio, K.A. and N. DeLuca, 1999. Applied and Env. Microb. (assumes 1.5 lbs. waste/goose/day)

**** from Horsley and Witten, 1996

Table C-2 summarizes the total fecal coliform production by all animal types in the watershed. Livestock numbers were determined using a level II feedlot inventory by Pipestone County Conservation and Zoning staff (per Feedlot Inventory Guidebook, Minnesota Board of Water and Soil Resources, June 1991). The number of people using septic systems is based on households in the county's E911 database and assumes 2.5 people per household. Adequate vs. inadequate was estimated by identifying the systems in the county septic database that have been updated and are in compliance, and then

assuming that the remaining households are inadequate. Known inadequate systems are described in Appendix B. The wastewater treatment plant population served is based on year 2000 census data for the City of Pipestone. Deer numbers are based on the DNR Slayton Office estimates of five deer per square mile in this area. In the absence of reliable data for other wildlife an equivalency to deer is assumed. The estimated number of dogs and cats are based on American Veterinary Medicine Association data that indicates 0.58 dogs and 0.66 cats per household.
(see: http://www.avma.org/membshp/marketstats/formulas.asp#households1) and the assumption of 2.5 people per household. For dogs and cats in the city it is assumed that 10 percent of the pets' waste is not properly managed, i.e., not collected and disposed of. It is assumed that the waste of rural pets is not collected.

TABLE C-2. Total FC produced per animal type in the watershed.

	Subcategory	AUs or #s	FC/unit/day	Total FC/day	% of total
Livestock	Beef, AUs	12,063	1.00E+11	1.21E+15	99.2
	Dairy, AUs	3,159	7.14E+10	2.26E+14	
	Swine, AUs	19,588	7.11E+10	1.39E+15	
	Sheep, AUs	793	1.50E+11	1.19E+14	
Humans	Popn w/ inadeq septic	817	2.00E+09	1.63E+12	0.4
	Popn w/ adeq septic	145	2.00E+09	2.90E+11	
	Popn served by WWTF	4280	2.00E+09	8.56E+12	
Wildlife	Deer	755	5.00E+08	3.78E+11	0.1
	Other wildlife	Unknown	Unknown	3.78E+11	
	Total wildlife			7.55E+11	
Pets	Dogs+cats in city--uncollected	212	5.00E+09	1.06E+12	0.4
	Dogs+cats in city--collected	1911	5.00E+09	9.55E+12	
	Dogs+cats outside city	477	5.00E+09	2.39E+12	
Total				2.97E+15	100

Step 2. Estimating fecal coliform produced within livestock subcategories that is available for potential runoff.

In order to assess potential contributions of fecal coliform from livestock a number of assumptions were made regarding where the fecal coliform bacteria "start out", i.e., where they are deposited or otherwise reside on the landscape, and would subsequently be available to some degree of runoff. The possibilities considered for where manure (and, therefore, fecal coliform) exists during various times during the year in this watershed are as follows:

- Feedlots or stockpiles without runoff controls
- Overgrazed pasture near streams or waterways
- Other pasture
- Surface-applied manure to fields
- Incorporated / injected manure in fields

Estimates of the percent of feedlots/stockpiles with and without runoff controls for the different livestock types are provided in Table C-3. Estimates of the percent of manure that is applied/deposited in pasture settings and fields are provided in Table C-4. These estimates are based on the professional judgment of Pipestone County Conservation and Zoning staff.

TABLE C-3. Estimates of the percent of feedlots/stockpiles with and without runoff controls.

	Beef	**Dairy**	**Swine**	**Sheep**
Feedlots or stockpiles <u>without</u> runoff controls	10%	2%	1%	1%
Feedlots or stockpiles <u>with</u> runoff controls	90%	98%	99%	99%
Total	100%	100%	100%	100%

TABLE C-4. Estimates of the percent of manure that is applied/deposited in pastures and fields.

	Beef	**Dairy**	**Swine**	**Sheep**
Overgrazed pasture near streams or waterways	25%	5%		
Other pasture	10%	5%		20%
Surface-applied*	60%	45%	10%	70%
Incorporated/injected**	5%	45%	90%	10%
Total	100%	100%	100%	100%

* It is estimated that 90% of this manure is surface-applied in the fall through spring and 10% is applied during the summer
** It is estimated that 95% of this manure is incorporated/injected in the fall through spring and 5% is incorporated/injected during the summer

Combining the information in the above tables results in Table C-5, which provides estimates of fecal coliform available for potential runoff for the various “sources” or settings in which manures exist during various times during the year.

TABLE C-5. Fecal coliform produced by livestock by potentially available for runoff broken out by setting/location. (The "proportion available" column is from Tables C-3 and C-4 expressed in decimal percent.)

Source	Animal type	Total FC/d	proportion available	Total FC avail/d	Source total FC avail/d
Feedlots or stockpiles without runoff controls	Beef	1.21E+15	0.1	1.21E+14	1.40E+14
	Dairy	2.26E+14	0.02	4.51E+12	
	Swine	1.39E+15	0.01	1.39E+13	
	Sheep	1.19E+14	0.01	1.19E+12	
Overgrazed pasture near streams or waterways	Beef	1.21E+15	0.25	3.02E+14	3.13E+14
	Dairy	2.26E+14	0.05	1.13E+13	
Other pasture	Beef	1.21E+15	0.1	1.21E+14	1.56E+14
	Dairy	2.26E+14	0.05	1.13E+13	
	Sheep	1.19E+14	0.2	2.38E+13	
Surface-applied	Beef	1.21E+15	0.6	7.24E+14	1.05E+15
	Dairy	2.26E+14	0.45	1.02E+14	
	Swine	1.39E+15	0.1	1.39E+14	
	Sheep	1.19E+14	0.7	8.33E+13	
Incorporated / injected	Beef	1.21E+15	0.05	6.03E+13	1.43E+15
	Dairy	2.26E+14	0.45	1.02E+14	
	Swine	1.39E+15	0.9	1.25E+15	
	Sheep	1.19E+14	0.1	1.19E+13	

Step 3. Estimating fecal coliform produced by wastewater treatment facilities.

There is one wastewater treatment facility in the watershed—the City of Pipestone, which uses stabilization ponds (NPDES Permit #MN0054801). The plant is permitted to discharge from April 1 through June 15 and September 15 through December 15. Discharge records from the MPCA's DELTA database were reviewed for the period from 2000-2004 and fecal coliform concentration and flow data were used to determine fecal coliform discharged per day that discharge occurred. An overall geometric mean of the daily loading values was calculated for use in subsequent calculations.

TABLE C-6. Fecal coliform daily discharge from City of Pipestone WWTF for 2000-2004.

Month/year	FC/100 ml geomean	Avg flow, mgd	Total flow MG	FC/day	# days discharge
04/00	10	3.4	21	1.30E+09	6
04/01	4931	2.9	47	5.47E+11	16
04/02	76	3.4	24	9.80E+09	7
04/03	4	2.9	47	4.62E+08	16
04/04	157	3.2	48	1.88E+10	15
05/00	32	3.4	34	4.10E+09	10
05/01	315	3.6	87	4.33E+10	24
05/02	12	2.7	43	1.21E+09	16
05/03	1	2.7	48	1.33E+08	18
05/04	35	3.3	23	4.30E+09	7
06/00	10	3.4	55	1.30E+09	16
06/01	140	3.4	72	1.82E+10	21
06/02	192	2.7	30	1.99E+10	11
06/03	3	2.6	36	2.94E+08	14
06/04	102	3.3	50	1.28E+10	15
09/02	32	2.7	19	3.22E+09	7
09/03	38	2.8	25	4.00E+09	9
09/04	1338	3.3	30	1.68E+11	9
10/00	31	3.4	48	3.96E+09	14
10/01	116	3.4	51	1.51E+10	15
10/02	8	2.7	49	7.75E+08	18
Geomean	45			5.25E+09	

Step 4. Estimating fecal coliform delivery potential

To estimate actual delivery from the various sources to the surface water of the watershed, a second set of assumptions needs to be applied.

Table C-7 shows estimated fecal coliform "delivery potential" expressed in both a qualitative and quantitative fashion. Sources of fecal coliform and delivery potential vary both with season and weather. In the table this variability is reflected by different values for spring and summer as well as wet and dry conditions. While this is a bit of an oversimplification, it does recognize that certain sources are not "active" under dry conditions (i.e., no surface runoff).

TABLE C-7. Estimated fecal coliform delivery potential.

SOURCE	ESTIMATED DELIVERY POTENTIAL			
	Spring (wet)	**Spring (dry)**	**Summer (wet)**	**Summer (dry)**
Feedlots or stockpiles without runoff controls	High (4%)		Moderate (2%)	
Overgrazed pasture near streams or waterways	High (4%)	Low (1%)	High (4%)	Low (1%)
Other pasture	Very low (0.1%)		Very low (0.1%)	
Surface-applied manure	Low (1%)		Low (1%)	
Incorporated / injected manure	Very low (0.1%)		Very low (0.1%)	
Failing / inadequate septic systems	High (4%)	High (4%)	High (4%)	High (4%)
Municipal wastewater treatment facility (excluding bypasses)	Contribution estimated directly based on discharge reports			
Deer and other wildlife	Low (1%)	Low (1%)	Low (1%)	Low (1%)
Dogs and cats in city—waste not collected	High (4%)		High (4%)	
Dogs and cats outside city	Very low (0.1%)		Very low (0.1%)	

The concept for the qualitative and quantitative fecal coliform delivery potential shown in this table came from Mulla et al. (Mulla, D.J., A.S. Birr, G. Randall, J. Moncrief, M. Schmitt, A. Sekely & E. Kerre. Technical Work Paper: Impacts of Animal Agriculture on Water Quality. University of Minnesota Department of Soil, Water and Climate. April 3, 2001), which describes water quality risk associated with different types of livestock, animal housing operations, and land application practices on a 1-5 scale (1 = very low risk, 5 = very high risk). Following the methodology of the 2002 version of the "Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (MPCA, 2002) a similar scale (very low to high) was used to describe fecal coliform delivery potential and takes into account in a general way the various physical, microbiological, climatic and other factors at play. These qualitative rankings were translated into delivery percentages. One percent is considered a low delivery percentage and the percentage is doubled for each step up the scale (moderate = 2%, high = 4%). The exception to this is that for some sources a delivery of 0.1% was assigned, an order of magnitude below 1%, to reflect the very low delivery expected with those (see source-specific discussion below). Discussion of the estimated delivery and the likely delivery mechanisms associated with each of the sources is provided below.

Livestock

Runoff from feedlots and pastures has the potential to be a significant source of fecal coliform bacteria and other pollutants. Owing largely to the close proximity of many feedlots to the creek and waterways, runoff from "feedlots or stockpiles without runoff controls" under wet conditions is estimated as high during the spring. The summertime wet estimate is reduced to moderate to account for the filtering effect of vegetation growth. A high delivery potential is assumed during wet conditions for “overgrazed pasture near streams or waterways” due to proximity as well as limited protective cover, or even bare soil, that results from overgrazing. Under dry conditions a low level of delivery is assumed to occur by direct deposit of manure from livestock standing in the water. For “other pasture” (i.e., further upland or otherwise properly managed pasture) very little delivery under wet conditions is expected to occur due to the effects of vegetative cover and no delivery is expected under dry conditions.

Land application of manure can also be a significant source of nonpoint pollution runoff. Much depends on how the manure application is managed – the rate, timing and method of application; observance of setbacks from surface water; timely incorporation to avoid major runoff following a major rain; use of riparian buffer strips; residue management to retard surface runoff and other practices. Runoff of applied manure only occurs during wet conditions. Unlike some feedlots and overgrazed pasture areas, there is generally some separation between manured fields and streams and waterways. Also, the soils of much of this watershed, particularly in the bottomlands, are of very low slope. As such, delivery potential is considered low relative to the other manure sources. Compared to surface-applied manure, the delivery potential of injected or incorporated manure is considered very low.

<u>Humans</u>

Failing or inadequate septic systems are estimated to have a high delivery potential during wet and dry conditions. These estimates assume waste delivery primarily via runoff and relatively few that are direct-to-tile systems. The contribution from the wastewater treatment plant are estimated directly from discharge reports (as shown in Table C-6).

<u>Wildlife</u>

The estimated delivery potential of deer and other wildlife is believed to be low during all conditions. It is assumed that deer waste is deposited mainly in well-vegetated areas, but that they also spend time near the creek and waterways, as those are their water source.

<u>Pets</u>

The delivery of pet waste is assumed only to occur during wet conditions. For “dogs and cats in city-waste not collected” a high delivery is estimated due to storm water runoff via impervious surfaces and storm sewers. Outside the city the delivery potential is consider very low as it assumed the waste is deposited mainly in well-vegetated areas.

Step 5. Estimating fecal coliform current loading

Table C-8 is a summary of the amounts of fecal coliform that are available daily for potential runoff and were taken from the above tables. The “surface-applied” and “incorporated/injected” categories have been multiplied by the percentages in the footnotes of Table C-4 to reflect the actual amounts of fecal coliform (i.e., manure) available during the spring and summer seasons. Also, for the purposes of simplifying the calculations it is assumed that the wastewater treatment plant, like other listed sources, discharges every day. However, discharge actually only occurs during some days from April 1 through June 15 and September 15 through December 15.

TABLE C-8. Summary of the amounts of fecal coliform that are available daily for potential runoff

SOURCE	ESTIMATED TOTAL FC AVAILABLE			
	Spring (wet)	**Spring (dry)**	**Summer (wet)**	**Summer (dry)**
Feedlots or stockpiles without runoff controls	1.40E+14		1.40E+14	
Overgrazed pasture near streams or waterways	3.13E+14	3.13E+14	3.13E+14	3.13E+14
Other pasture	1.56E+14		1.56E+14	
Surface-applied manure	9.43E+14		1.05E+14	
Incorporated / injected manure	1.36E+15		7.13E+13	
Failing / inadequate septic systems	1.63E+12	1.63E+12	1.63E+12	1.63E+12
Municipal wastewater treatment facility (excluding bypasses)	5.25E+09	5.25E+09	5.25E+09	5.25E+09
Deer and other wildlife	7.55E+11	7.55E+11	7.55E+11	7.55E+11
Dogs and cats in city—waste not collected	1.06E+12		1.06E+12	
Dogs and cats outside city	2.39E+12		2.39E+12	

To determine actual estimated load delivered to water the amounts available shown in Table C-8 are multiplied by the delivery percentages in Table C-7. The result is shown in Table C-9.

TABLE C-9. Estimated current daily FC load (number of bacteria) delivered by source.

SOURCE	ESTIMATED FC DELIVERED, # OF BACTERIA			
	Spring (wet)	**Spring (dry)**	**Summer (wet)**	**Summer (dry)**
Feedlots or stockpiles without runoff controls	5.61E+12		2.81E+12	
Overgrazed pasture near streams or waterways	1.25E+13	3.13E+12	1.25E+13	3.13E+12
Other pasture	1.56E+11		1.56E+11	
Surface-applied manure	9.43E+12		1.05E+12	
Incorporated / injected manure	1.36E+12		7.13E+10	
Failing / inadequate septic systems	6.54E+10	6.54E+10	6.54E+10	6.54E+10
Municipal wastewater treatment facility (excluding bypasses)	5.25E+09	5.25E+09	5.25E+09	5.25E+09
Deer and other wildlife	7.55E+09	7.55E+09	7.55E+09	7.55E+09
Dogs and cats in city—waste not collected	4.25E+10		4.25E+10	
Dogs and cats outside city	2.39E+09		2.39E+09	

To translate this information into a simpler format we can convert the numbers in Table C-9 to percentages of the total load and then express the results in terms the categories below. The result is shown in Table C-10.

"very low to none" (less than 1%)	
"low" (1-5%)	
"moderate" (5-20%)	
"high" (greater than 20%)	

TABLE C-10. Estimated current daily FC load delivered by source.

SOURCE	ESTIMATED FC DELIVERED			
	Spring (wet)	Spring (dry)	Summer (wet)	Summer (dry)
Feedlots or stockpiles without runoff controls				
Overgrazed pasture near streams or waterways				
Other pasture				
Surface-applied manure				
Incorporated / injected manure				
Failing / inadequate septic systems				
Municipal wastewater treatment facility (excluding bypasses)				
Deer and other wildlife				
Dogs and cats in city—waste not collected				
Dogs and cats outside city				

Appendix D. Methodology for TMDL Equations and Load Duration Curves

The loading capacity determination used for this report is based on the process developed for the "Revised Regional Total Maximum Daily Load Evaluation of Fecal Coliform Bacteria Impairments in the Lower Mississippi River Basin in Minnesota" (Jan 2006). This process is known as the "Duration Curve" method.

Loading capacities for specific pollutants are related directly to flow volume. As flows increase, the loading capacity of the stream will also increase. Thus, it is necessary to determine loading capacities for a variety of flow zones.

For this approach daily flow values for each site are sorted by flow volume, from highest to lowest and a percentile scale is then created (where a flow at the X^{th} percentile means X% of all measured flows equal or exceed that flow). Five flow zones are used in this approach: "high" (0-10^{th} percentile), "moist" (10^{th}- 40^{th} percentile), "mid-range" (40^{th}-60^{th} percentile), "dry" (60^{th}-90^{th} percentile) and "low" (90^{th}-100^{th} percentile). The flows at the mid-points of each of these zones (i.e., 5^{th}, 25^{th}, 50^{th}, 75^{th} and 95^{th} percentiles) are multiplied by the water quality standard concentration and a conversion factor to yield the allowable loading capacity or TMDL. For example, if the "mid-range" (50^{th} percentile) flow is 100 cubic feet/sec the loading capacity for fecal coliform bacteria would be:

100 cu ft/sec x 200 organisms/100 ml x 28,312 ml/cu ft x 86,400 sec/day ÷ 1 billion =
489 billion fecal coliform bacteria per day

For turbidity the total suspended solids (TSS) equivalent to the turbidity standard is used. For Pipestone Creek the equivalent to 25 NTU was determined to be 54 mg/L TSS using a regression of the available data. Thus, for the flow zone example above the TMDL for TSS would be:

100 cubic feet/sec x 54 mg/L TSS x 28.31 l/cubic ft x 86,400 s/day ÷ 907,184,740 mg/ton
= 14.6 tons TSS/day

The flow monitoring data used in this project was from 1984-2005 at the downstream U.S. Geological Survey gage station #06482610 on Split Rock Creek at Corson, SD. This flow record contains 3561 average daily flow values. (Note: This flow record does not have data from 1990-2000.) It was decided to limit flow data to within the last 20 years in order to have a closer reflection of hydrologic conditions occurring under "recent" land use. To estimate flow at the ends of the three listed reaches it was assumed that the flow at those reaches was proportional to the Corson site based on respective drainage areas represented. The project did have one year of flow data at Sites 1 and 2, but it was decided that for a duration curve approach a much longer record representing a greater range of flows is needed. (Calculated flows were then checked against the available flow data for Sites 1 and 2. This check showed that the magnitudes were generally similar between the actual vs. proportionally-calculated flows; however, there were some discrepancies in timing of peak flows following significant rain events.)

TMDLs were calculated for all the flow zones for each listed reach of the project. The TMDLs were then divided into a Margin of Safety (MOS), Wasteload Allocations (WLAs) and a Load Allocation (LA).

The MOS accounts for uncertainty in the TMDL allocation process. The MOS was established not to exceed the load associated with the minimum flow for each zone. Each zone MOS is the difference between the central and lowest flow value for each zone. For example, to determine the MOS for the high flow zone, the 10^{th} percentile flow value was subtracted from the 5^{th} percentile flow value. The resulting value was converted to a load and used as the MOS.

The next step in the process was determining the WLAs for point sources with specific discharge limits.

The wastewater dischargers with specific discharge limits in this watershed both are facilities with pond systems. The maximum daily flow from these facilities was either taken from the facility's permit or was calculated based on six inches per day drawdown from their secondary pond. The resulting daily volumes of effluent were converted to daily loads using the permitted concentration limits and a conversion factor. Example calculations for the WLA for a wastewater treatment facility discharging 3,000,000 gallons of effluent per day with a 200 organisms/100 ml and a 45 mg/L TSS concentration limit are as follows:

3,000,000 gallons/day x 200 organisms/100 ml x 3785 ml/gallon ÷ 1 billion
= 23 billion fecal coliform bacteria per day

3,000,000 gallons/day x 45 mg/L TSS x 3.785 l/gallon ÷ 907,184,740 mg/ton
= 0.56 tons TSS/day

The WLA for a given wastewater treatment facility will be the same under all flow zones since its allocation is based on the volume it is permitted to discharge.

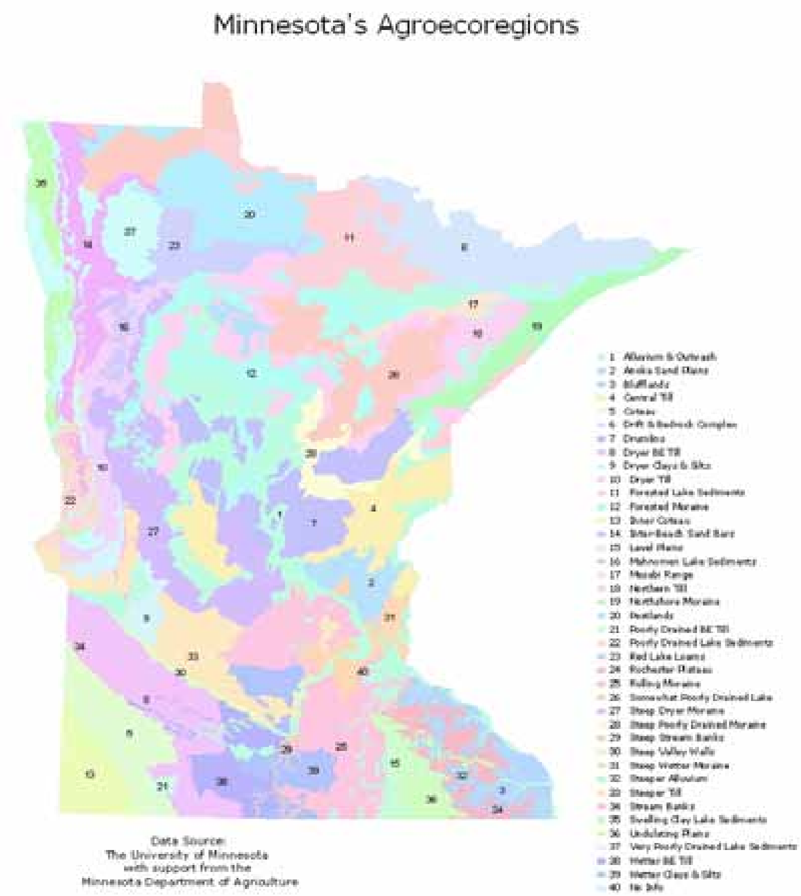
The WLAs for these dischargers with specific discharge limits and the MOS were subtracted from the total available loading capacity. The remaining capacity was then given to all nonpoint sources, i.e., the LA category

Load duration curves shown in the report display the allowable load across the range of flows in the timeframe selected. The loads represented by grab samples were calculated and plotted. The samples representing greater than 50 percent storm flow were calculated using the methodology described in "HYSEP: A Computer Program for Streamflow Hydrograph Separation and Analysis," US Geological Survey, Water-Resources Investigations Report 96-4040.

Appendix E. Agroecoregion BMP Matrix

The matrix below was developed by David Mulla of the Department of Soil, Water, and Climate of the University of Minnesota and provides Best Management Practice (BMP) options based on agroecoregion. These agroecoregions for Minnesota are shown in the figure to the right.

Ratings in the table that follows are High (H), Medium (M) and Low (L). High means a practice that will be very effective over a large area. Low means a practice that will be very effective, but is suitable only for small portions of the agroecoregion.



NRCS #	Conservation Practices	Alluvium & Outwash	Anoka Sand Plains	Bluffands	Central Till	Coteau	Drumlins	Dryer Blue Earth Till	Dryer Clays & Silts	Dryer Till	Inner Coteau	Inter-Beach Sand Bars	Level Plains	Mahnomen Lake Sediments	Poorly Drained Blue Earth Till	Poorly Drained Lake Sediments	Rochester Plateau	Rolling Moraine	Somewhat Poorly Drained Lake	Steep Dryer Moraine	Steep Stream Banks	Steep Valley Walls	Steep Wetter Moraine	Steeper Alluvium	Steeper Till	Stream Banks	Swelling Clay Lake Sediments	Undulating Plains	Very Poorly Drained Lake Sediments	Wetter Blue Earth Till	Wetter Clays & Silts
	Riparian																														
393	**Grass Filter Strip**[1]	M	L	M-H		M	L	M-H		H	L	M	H	L	L	L	M	H	L	H	H	M	H	H	M	H	M	M	L	H	L
391	**Riparian Forest Buffer**	M	L	M-H		L	L			L		M	M			L	M	L	H	M	M	H	H		L	L		M	L	L	
580	**Streambank & Shoreline Protection**	L		H		H		L-M					L			M	M	M	L	H	H	H	H	M	M	H	M	L	L	M	M
657	**Wetland Restoration**[2] *	L	L				M	H				L	L	L	M	H		L	H	M		M	M		L		M		M	H	M
659	**Wetland Enhancement**						M	H								M			H												M
	Upland																														
328	**Conservation Crop Rotation**[3]	M	L	H		H	M	M	M	H	M	L	M	L	M	M	H	H	L	M	H	M	H	M	L	L		L	M	L	L
329	**Conservation Tillage**[4]	M	L	H		H	M	H	M	M	M	M	M	L	M		H	H	L	H	H	L	H	M	H	H		M		H	M
	Primary Crop																										L		L		
	Secondary Crop																										M		M		
332	**Contour Buffer Strip**					H				M	L		M				M	M		H			L					M		L	
330	**Contour Farming**		L	H		H	M	L		H	M		M				H	**H**	**L**	**H**			**H**	**M**	**L**			**M**		**M**	
340	**Cover Crop**	M	M	L		L		L-M			M											L	L		L			L		L	L
342	**Critical Area Planting**	M	M	L		L		L				M			L		L	M		M	H	H	M	H	L	H		L		M	
643	**Declining Habitat Restoration & Mgt**[5]*							M-H			M			L	M	L			H	M		M					M		M		L
362	**Diversion**					H											M	L			M									M	

NRCS #	Conservation Practices	Alluvium & Outwash	Anoka Sand Plains	Blufflands	Central Till	Coteau	Drumlins	Dryer Blue Earth Till	Dryer Clays & Silts	Dryer Till	Inner Coteau	Inter-Beach Sand Bars	Level Plains	Mahnomen Lake Sediments	Poorly Drained Blue Earth Till	Poorly Drained Lake Sediments	Rochester Plateau	Rolling Moraine	Somewhat Poorly Drained Lake	Steep Dryer Moraine	Steep Stream Banks	Steep Valley Walls	Steep Wetter Moraine	Steeper Alluvium	Steeper Till	Stream Banks	Swelling Clay Lake Sediments	Undulating Plains	Very Poorly Drained Lake Sediments	Wetter Blue Earth Till	Wetter Clays & Silts
554	**Drainage Water Mgnt**[6]							M-H					M	M	M-H	H		M	M						M		H	L	M	M	H
	Field Border																														L
655	**Forest Harvest Trails & Landings**						M												H	M									M		
666	**Forest Stand Improvement**						M												H	M									M		
	Gully Erosion	L		H		H		L									H	H		M	H	H	M		M	M		L		M	L
410	**Grade Stabilization**			H		H											H					M	M		L			L		M	L
412	**Grass Waterway**			M		H		L		M	M						H	M		M	H		M		L			L		M	L
600	**Terrace**			M		H				L	M						H	M					L		L			M		L	
638	**Water and Sediment Control Basin**			H		H		L		L							H	H		M	H		H		M			L		M	L
	Grass Cover (CRP only) [7]*	M	L	H		H	L	L		H	L	M					H	H		H	M	H	H	L	M	M	M	L	L	H	L
512	**Pasture & Hayland Planting**	M	M	H		H	H	L-M		M	M						H	H	M	H			M		L	M		L		L	L
528A	**Prescribed Grazing**	M	L	M-H		H	H	L-M			L						M	M	M	M			M		L	M		L		L	L
350	**Sediment Basin**	M	L	M		M	L	L									M	H		M	H		H		M			L		M	
725	**Sinkhole Treatment**[8]			M													H											L			
585	**Stripcropping**[9]			H		M					M		M				H			M								L		L	
612	**Tree/Shrub Planting** *						M									L			M	M		M	M	L		M			M		
472/ 382	**Use Exclusion / Fencing**	M	L	L		H	H	L			H		L				M	L	M	M		L	M		L	H		M	M	L	
645	**Upland Wildlife Habitat Management**[10]*			M		M		M-H		H	M				M	L	M		M	M		M	L				L		M		L
658	**Wetland Creation**							H								L			H												
657	**Wetland Restoration**[11]	L	L				M	H				L	M	M	M	H		L	H	M		L	M		L		M	L	H	M	H
	Wind Erosion																														

NRCS #	Conservation Practices	Alluvium & Outwash	Anoka Sand Plains	Blufflands	Central Till	Coteau	Drumlins	Dryer Blue Earth Till	Dryer Clays & Silts	Dryer Till	Inner Coteau	Inter-Beach Sand Bars	Level Plains	Mahnomen Lake Sediments	Poorly Drained Blue Earth Till	Poorly Drained Lake Sediments	Rochester Plateau	Rolling Moraine	Somewhat Poorly Drained Lake	Steep Dryer Moraine	Steep Stream Banks	Steep Valley Walls	Steep Wetter Moraine	Steeper Alluvium	Steeper Till	Stream Banks	Swelling Clay Lake Sediments	Undulating Plains	Very Poorly Drained Lake Sediments	Wetter Blue Earth Till	Wetter Clays & Silts
589	**Cross-Wind Ridges / X-Wind Stripcropping / X-Wind Trap Strips**	L	M					M	H	L		H		M	L-M	M			M	L							H		M		
422	**Hedgerow/ Herbaceous Wind Barrier**	L	M						H	L		H		M	L-M	M			M	L							H		M		
380/ 650	**Windbreak / Shelterbelt / Living Snow Fence** *	L	M						H	L		H		M	L-M	M			M	L							H		M		

* A common CRP cover type in Minnesota

[1] Effectiveness depends on complementary upland practices (which may be true for several other practices in this table as well)
[2] In riparian zones, this means floodplain wetlands
[3] Refers to the addition of at least a third crop—one that is resource-conserving and regionally appropriate—to an existing 2-crop rotation.
[4] Refers to NRCS Standards 329A-329C (Residue Management) which encompass No-Till, Strip-Till, Mulch-Till and Ridge-Till
[5] When the habitat being restored is native prairie, this is effectively an enhanced version of a typical CRP grass stand.
[6] Refers to a range of "conservation drainage" practices, some currently in Mn-NRCS Standard 554 Drainage Water Management and many not; examples include blind inlets, rock inlets, and tile spacing and depth.
[7] Some CRP grass stands are planted with special attention to use of native species, while others are not (need to specify if there is a significant difference in terms of water quality).
[8] Treatment is typically with filter strips and/or diversions
[9] Includes contour stripcropping as well as stripcropping on flatter land
[10] In the Northern Tallgrass Prairie region, this often consists of grassland restoration
[11] In uplands (esp. in the Northern Tallgrass Prairie region), depressional "prairie potholes" are often the type of wetlands being restored.

Appendix F: Evaluation of "Paired" Turbidity Measurements from Two Turbidimeters for Use in Two TMDL Projects

December 13, 2007

Greg Johnson
Minnesota Pollution Control Agency
Regional Division
Watershed Section – Technical Assistance Unit

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 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 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 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.

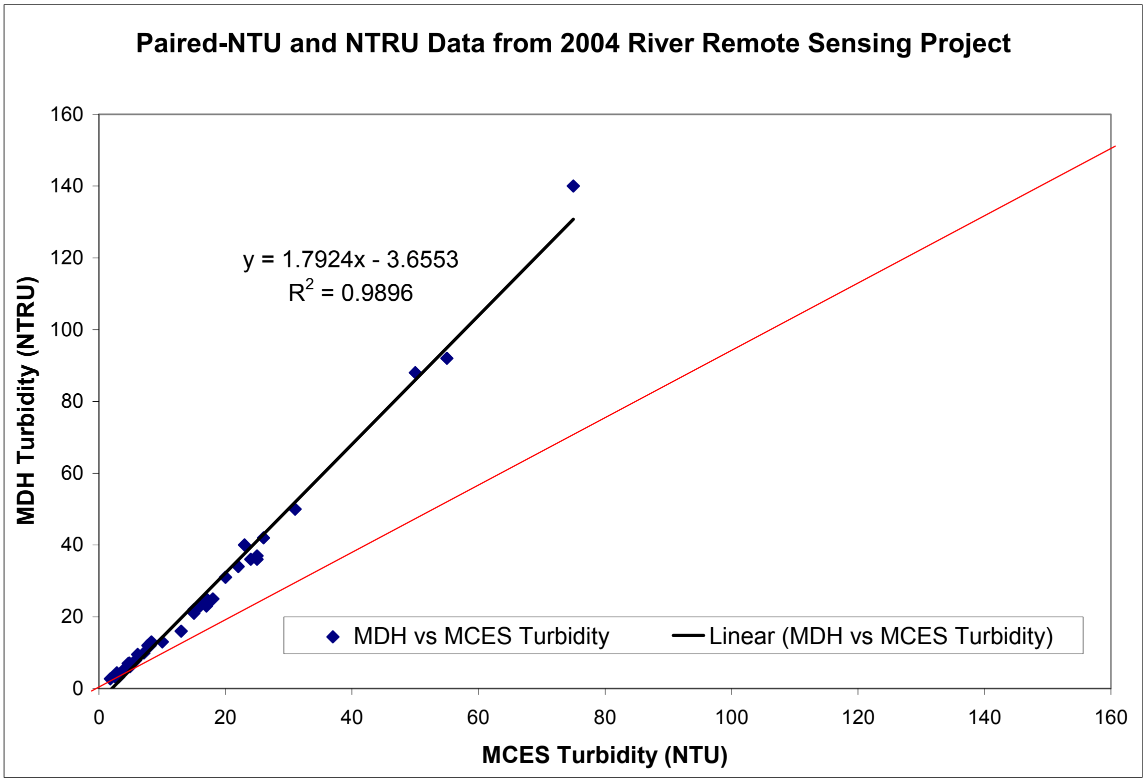
Excel and Minitab were used to analyze the paired laboratory turbidity data. The goal of the analysis was to use appropriate statistical methods to provide a "conversion" factor for estimating NTU values from measured NTRU values for use in the West Fork Des Moines River and Pipestone Creek Turbidity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

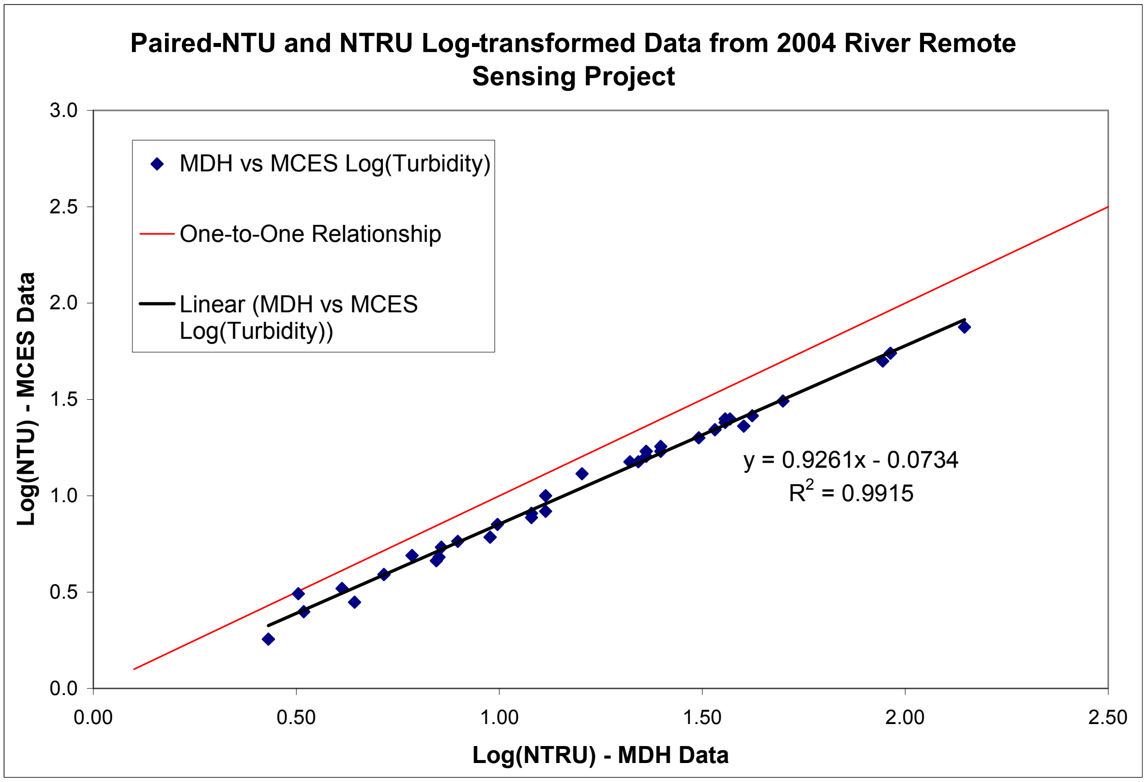
Figure 1.



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 10 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 affect 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" 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.

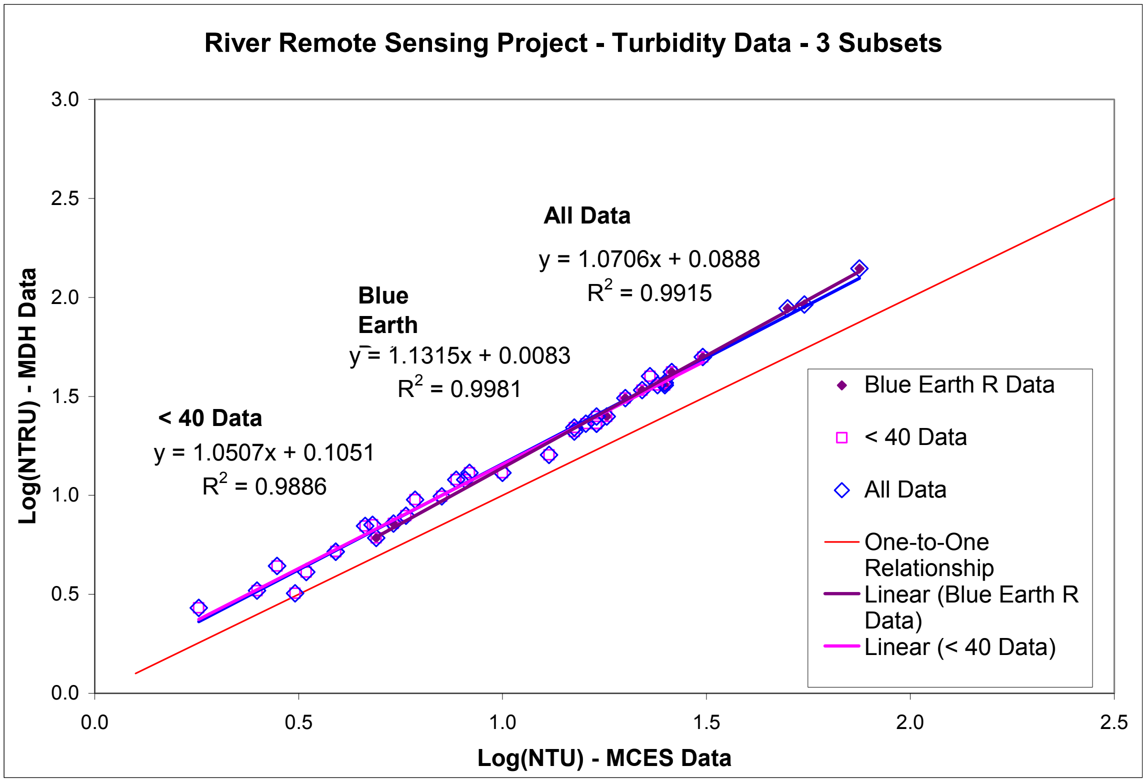
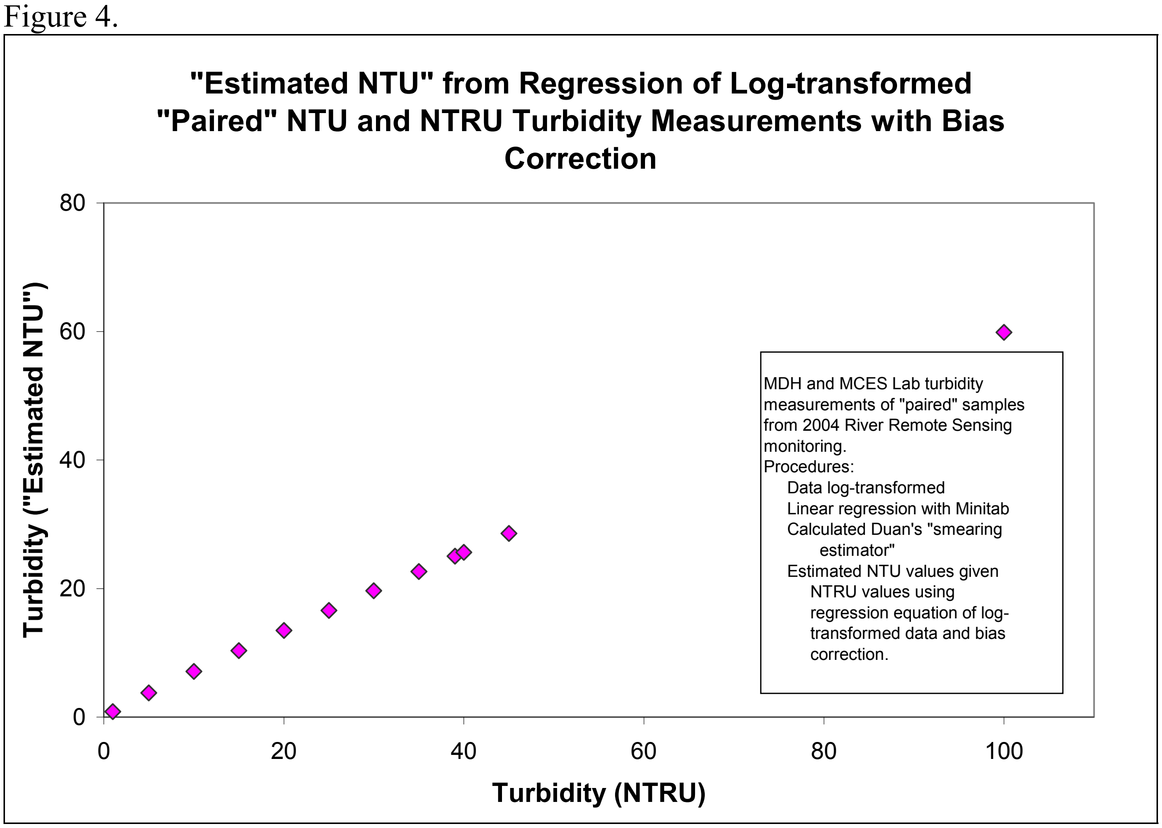


Figure 4.



References

Anderson, C.W., September 2005, Turbidity (version 2.1): U.S. Geological Survey Techniques of Water-Resources Investigations, book 9, chap. A6., section 6.7, accessed Dec. 13, 2007 from http://pubs.water.usgs.gov/twri9A6/.

Ankcorn, P.D. 2003. Clarifying Turbidity – The Potential and Limitations of Turbidity as a Surrogate for Water-Quality Monitoring. Proceedings of the 2003 Georgia Water Resources Conference, held April 23–24, 2003, at the University of Georgia. Kathryn J. Hatcher, editor, Institute of Ecology, The University of Georgia, Athens, Georgia.

Federal Water Pollution Control Administration. 1968. Water Quality Criteria: Report of the National Technical Advisory Committee to the Secretary of the Interior.

Miller, T.L. 2004. Revision of National Field Manual Chapter 6, Section 6.7--USGS Water-Quality Technical Memorandum 2004.03 http://water.usgs.gov/admin/memo/QW/qw04.03.html

MPCA. 2007. Turbidity TMDL Protocols and Submittal Requirements. Accessed December 13, 2007 at http://www.pca.state.mn.us/publications/wq-iw1-07.pdf.

Pavelich, P. 2002. Turbidity Studies at the National Water Quality Laboratory. Proceedings of the Federal Interagency Workshop on Turbidity and other Sediment Surrogates, April 30-May 2, 2002, Reno, Nevada. J.R. Gray and G.D. Glysson, editors. U.S. Geological Survey Circular 1250. [http://pubs.water.usgs.gov/circ1250]

USGS. Undated. Bias Correction Factor. Suspended-Sediment Database – Daily Values of Suspended Sediment and Ancillary Data. Accessed December 13, 2007 at http://co.water.usgs.gov/sediment/bias.frame.html.

River Remote Sensing Project

MCES and MDH Laboratory Analytical Data for Turbidity

All samples were collected on August 19, 2004

Site Description	Basin ID	Time	NTU	NTRU
LeSueur River at Hwy 66 Bridge in South Bend Twp.	LESUEUR	9:15	75	140
Minnesota River at Co Rd 42 Bridge in Judson	MINNESOTA	8:45	50	88
Blue Earth River at Hwy 169 Bridge in Mankato	BLUEEARTH	14:30	55	92
Blue Earth River Upstream of the Confluence with the LeSueur	BLUEEARTH	10:00	26	42
LeSueur River (Gravel Pit) Upstream of the Confluence with the Blue Earth	LESUEUR	9:30	4.9	6.1
Blue Earth River at Rapidan Dam	BLUEEARTH	8:25	22	34
Blue Earth River Upstream of the Confluence with Watonwan	BLUEEARTH	11:30	31	50
Watonwan River Upstream of Confluence with Blue Earth	WANTONWAN	11:40	5.4	7.2
Blue Earth River Upstream of the Pool Created by the Rapidan Dam	BLUEEARTH	12:00	18	25
Center of the Pool on the Blue Earth River Upstream of the Rapidan Dam	BLUEEARTH	12:50	20	31
Crow River at Hwy 55 Bridge in Rockford	CROW_R	8:30	15	22
North Fork of Crow River at Farmington Ave Bridge	CROW_R	9:00	17	23
South Fork of Crow River at Farmington Ave Bridge	CROW_R	9:25	7.1	9.9
Rum River at Main Street Bridge in Anoka	RUM	7:15	5.8	7.9
Mississippi River at Hwy 169 Bridge near Anoka	MISSISSIPPI	10:20	3.1	3.2
Mississippi River 250m Upstream of Confluence with the Crow River	MISSISSIPPI	13:20	2.5	3.3
Crow River at River Road Bridge near the Confluence with the Mississippi River	CROW_R	13:45	6.1	9.5
Mississippi River Downstream of Goodin Island - Right Descending Bank	MISSISSIPPI	14:45	3.9	5.2
Mississippi River Downstream of Goodin Island - Left Descending Bank	MISSISSIPPI	15:00	2.8	4.4
Mississippi River Downstream of Cloquet Island - Center Channel	MISSISSIPPI	10:50	3.3	4.1
Mississippi River at Hwy 5 Bridge	MISSISSIPPI	12:43	4.6	7
Mississippi River side of Pike Island	MISSISSIPPI	13:10	4.8	7.1
Minnesota River side of Pike Island	MINNESOTA	13:50	25	37
Minnesota River at Fort Snelling between I494 and Hwy 55	MINNESOTA	13:35	24	36
Mississippi River at I35E Bridge - Right Descending Bank	MISSISSIPPI	14:54	7.7	12
Mississippi River at I35E Bridge - Left Descending Bank	MISSISSIPPI	14:42	23	40
Mississippi River at Smith Ave High Bridge in St. Paul - Right Descending	MISSISSIPPI	14:15	15	21

Bank				
Mississippi River at Smith Ave High Bridge in St. Paul - Left Descending Bank	MISSISSIPPI	14:25	17	23
Mississippi River at Lock and Dam No. 2	MISSISSIPPI	9:00	16	23
Mississippi River downstream of Hwy 61 Bridge near Hastings	MISSISSIPPI	8:47	17	25
St. Croix River at Hwy 10 Bridge near Prescott	ST_CROIX	9:15	1.8	2.7
Mississippi River One-Half Mile Downstream of Prescott Island - Right Descending Bank	MISSISSIPPI	9:41	10	13
Mississippi River One-Half Mile Downstream of Prescott Island - Left Descending Bank	MISSISSIPPI	9:55	13	16
Mississippi River Three Miles Downstream from Prescott Island - Right Descending Bank	MISSISSIPPI	10:11	8.1	12
Mississippi River Three Miles Downstream from Prescott Island - Left Descending Bank	MISSISSIPPI	10:21	8.3	13
Minnesota River at Sibley Park	MINNESOTA	14:45	25	36
Mississippi River at Hayden Creek Confluence	MISSISSIPPI	9:50	3.9	5.2