Turbidity TMDL Assessment for Stony, Un-named and Getchell Creek

Wenck File #0019-66

Prepared for:

SAUK RIVER WATERSHED DISTRICT

Prepared by:

WENCK ASSOCIATES, INC.
1800 Pioneer Creek Center
P.O. Box 249
Maple Plain, Minnesota 55359-0249
(763) 479-4200

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Wenck
Engineers • Scientists

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<tr><td>303(d) Listing Information</td><td colspan="6">Un-named Creek 07010202-542
Un-named Creek was added to the 303(d) list in 2008 because of excess turbidity impairing aquatic life. This TMDL is prioritized to start in 2009 and be completed by 2012. Getchell and Stony Creek are currently not on the 303(d) list but were assessed for turbidity and included in this document.</td><td>1-2</td></tr>
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<tr><td>Getchell</td><td>29.42</td><td>7.68</td><td>2.77</td><td>1.69</td><td>0.45</td></tr>
<tr><td>Un-named</td><td>2.42</td><td>1.08</td><td>0.75</td><td>0.68</td><td>0.66</td></tr>
<tr><td>Stony</td><td>6.58</td><td>1.77</td><td>1.12</td><td>0.41</td><td>0.00</td></tr>
</table>

TMDL Summary

<table>
<tr><th colspan="8">TMDL Summary Table</th></tr>
<tr><th>EPA/MPCA Required Elements</th><th colspan="6">Summary</th><th>TMDL Page #</th></tr>
<tr><td rowspan="6">Wasteload Allocation</td><td colspan="6">Portion of the loading capacity allocated to existing and future permitted sources for each flow condition</td><td rowspan="6">3-5</td></tr>
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<tr><td>Very High</td><td>High</td><td>Mid</td><td>Low</td><td>Dry</td></tr>
<tr><td>Getchell
Freeport WWTF MNG580019
Construction Stormwater
Industrial Stormwater</td><td>0.473</td><td>0.147</td><td>0.074</td><td>0.05</td><td>0.038</td></tr>
<tr><td>Un-named
permitted point sources
Construction Stormwater
Industrial Stormwater</td><td>0.036</td><td>0.016</td><td>0.012</td><td>0.01</td><td>0.01</td></tr>
<tr><td>Stony
permitted point source
Construction Stormwater
Industrial Stormwater</td><td>0.099</td><td>0.027</td><td>0.017</td><td>0.006</td><td>0</td></tr>
<tr><td rowspan="6">Load Allocation</td><td colspan="6">The portion of the loading capacity allocated to existing and future non-permitted sources for each flow condition</td><td rowspan="6">3-5</td></tr>
<tr><td rowspan="2">Source</td><td colspan="5">Load Allocation (tons/day) per flow category</td></tr>
<tr><td>Very High</td><td>High</td><td>Mid</td><td>Low</td><td>Dry</td></tr>
<tr><td>Getchell non-point source and channel</td><td>27.48</td><td>7.25</td><td>2.54</td><td>1.08</td><td>0.39</td></tr>
<tr><td>Un-named non-point source and channel</td><td>2.32</td><td>1.05</td><td>0.73</td><td>0.67</td><td>0.65</td></tr>
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</table>

TMDL Summary

<table>
<tr><th colspan="8">TMDL Summary Table</th></tr>
<tr><td rowspan="6">Margin of Safety</td><td colspan="6">The margin of safety is intended to account for uncertainty that the allocations will result in attainment of water quality standards. The margin of safety was calculated for each flow category as the difference between the median flow of each flow regime and the 45th percentile flow in each zone.</td><td rowspan="6">3-5</td></tr>
<tr><td rowspan="2">Stream</td><td colspan="5">Margin of Safety (tons/day) per flow category</td></tr>
<tr><td>Very High</td><td>High</td><td>Mid</td><td>Low</td><td>Dry</td></tr>
<tr><td>Getchell</td><td>1.46</td><td>0.28</td><td>0.16</td><td>0.04</td><td>0.02</td></tr>
<tr><td>Un-named</td><td>0.07</td><td>0.01</td><td><0.01</td><td><0.01</td><td><0.01</td></tr>
<tr><td>Stony</td><td>0.16</td><td>0.07</td><td>0.03</td><td>0.07</td><td>0.00</td></tr>
<tr><td>Seasonal Variation</td><td colspan="6">Seasonal variation is accounted for by developing load duration curves based on average daily flow data to assimilate flow and TSS data across stream flow regimes.</td><td>3-1</td></tr>
<tr><td>Reasonable Assurance</td><td colspan="6">Reasonable assurance is provided by implementing the TMDL through the Sauk River Watershed District Watershed Management Plan and the Stearns County Comprehensive Local Water Management Plan</td><td>6-1</td></tr>
<tr><td>Monitoring</td><td colspan="6">The Sauk River Watershed District currently performs physical and chemical monitoring of these streams and will continue to do so throughout the implementation period. The district will also track the implementation of Best Management Practices and capital projects throughout these watershed on an annual basis.</td><td>6-3</td></tr>
<tr><td>Implementation</td><td colspan="6">This TMDL sets forth an implementation framework and general load reduction strategies that will be expanded and refined through the development of an Implementation Plan. Implementation costs will range between $500,000 and $5 Million.</td><td>6-1</td></tr>
<tr><td>Public Participation</td><td colspan="6">The Sauk River Watershed District held a public meeting December, 2008 and will conduct two future stakeholder meetings upon completion of this report to update stakeholders. The District has also kept stakeholders updated through their annual newsletter, monthly District meetings, and website.</td><td>7-1</td></tr>
</table>

Executive Summary

This report includes a turbidity TMDL for Un-named, Stony and Getchell Creek, three stream tributaries in the Sauk River Watershed River in Central Minnesota. The Sauk River Watershed lies in the heart of the North Central Hardwood Forest Ecoregion and discharges to the Upper Mississippi River. Land use in the watershed is primarily agriculture with the majority of land in corn/soybean rotations and pasture land. Un-named Creek was included on Minnesota's 2008 303(d) Total Maximum Daily Load (TMDL) list for excess turbidity. Neither Stony nor Getchell Creeks are currently on this list but were included in this document for turbidity assessment due to the significant proportion of loading into the Sauk River from these two watersheds.

Turbidity is a measure of the cloudiness or haziness of water caused by suspended and dissolved substances in the water column. Turbidity can be caused by increased suspended soil or sediment particles, phytoplankton growth, and dissolved substances in the water column. Since turbidity is a measure of light scatter and adsorption, loads need to be developed for a surrogate parameter. Total suspended solids (TSS) is a measurement of the amount of sediment and organic matter suspended in water and is often used as a turbidity surrogate to define allocations and capacities in terms of daily mass loads.

At this time, there are no paired turbidity and TSS sampling data available for Un-named, Stony and Getchell Creeks. However, over 100 readings of paired turbidity-TSS data were collected in the North Fork Crow/Crow River watershed from Mill Creek to its outflow to the Mississippi River. The Sauk and North Fork Crow/Crow are adjacent watersheds located in the Upper Mississippi River Basin and North Central Hardwood Forest ecoregion with similar land-use and soil types. Thus, the turbidity surrogate developed for the North Fork Crow River Turbidity TMDL (79 mg/L) was adopted as the surrogate value for Un-named, Stony and Getchel Creek for the purpose of this TMDL study. Upon approval, the 79 mg/L surrogate will be used as a benchmark concentration for discharges in these watersheds which permitted activities should not exceed.

Total Maximum Daily Loads were established for Un-named, Stony and Getchell Creek using the load duration curve approach (Cleland 2002). It was estimated that a 35% to 95% reduction in total suspended solids is required for Un-named and Stony Creek during the higher flows and 7% to 66% reduction during the lower flows to meet current state standards. The only load reduction required for Getchell Creek is during the high flow category, where a 26% reduction is needed to comply with state standards.

A source assessment was conducted for each basin to qualitatively assess potential sediment sources to the channel. The potential contribution of sediment to the stream channel from field erosion out-weighed estimated in-channel sediment delivery by almost 10 to 1 suggesting that field erosion is likely a more important source of sediment in the Stony, Un-named and Getchell

Creek watersheds. However, serious signs of bank failure and erosion suggest that active bank erosion is occurring in all three stream systems. Both of these potential sources should be addressed however, field erosion warrants greater attention because of the magnitude of sediment potentially delivered to the stream. Neither point sources nor stormwater are important contributors of suspended particles to either stream. No data are available to assess algal productivity in the stream systems, but this source was assumed to be not as significant since the majority of violations occur during high flow which is associated with erosion.

1.0 Introduction

1.1 PURPOSE

Section 303(d) of the Clean Water Act (40 C.F.R. 130.7) requires states to identify waters that do not meet applicable water quality standards and to establish Total Maximum Daily Loads (TMDL) for those pollutants exceeding water quality standards. A TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still meet established water quality standards. The TMDL allocates pollutant quantity to the various sources and establishes the allowable loadings of pollutants based on the relationship between the pollution sources and the receiving water. TMDLs provide states a basis for determining the pollutant reductions necessary from both point and non-point sources to restore and maintain the quality of their water resources.

A TMDL includes separating the acceptable load among the Load Allocation (LA) and Wasteload Allocation (WLA). A TMDL must also account for seasonal variation and include a margin of safety (MOS). The MOS accounts for uncertainty in the relationship between effluent limitations and water quality in the receiving water. The total of all the allocations, including the wasteload allocations for permitted discharges, the load allocations for non-permitted sources and the MOS (if explicitly defined) cannot exceed the maximum allowable pollutant load. The following TMDL equation summarizes these requirements:

$$\text{TMDL} = \sum \text{WLAs} + \sum \text{LAs} + \text{MOS}$$

These components are described in more detail below:

WLA = Waste Load Allocation, which is the sum of all permitted sources, including wastewater treatment facilities, construction stormwater sources, industrial stormwater sources, and municipal stormwater sources, all of which are permitted under the NPDES program.

LA = Load Allocation, which is the sum of all non-permitted sources, including runoff from cropland, non-permitted feedlots, livestock in riparian pastures, and in-stream sources.

MOS = Margin of Safety, which may be implicit due to conservative assumptions used in the analysis to derive the allocations, or explicit, where an additional load is subtracted from the available load prior to allocation among the sources or the load is based on achieving a better condition than the standard in the receiving water.

RC = Reserve Capacity, which is an allocation of loading for future growth that keeps the overall load to the receiving water at or below what it needs to be to meet water quality standards in the future.

1.2 CRITERIA USED FOR LISTING

The criteria used for determining stream reach impairments are outlined in the MPCA document Guidance Manual for Assessing the Quality of Minnesota Surface Waters for Determination of Impairment – 305(b) Report and 303(d) List, January 2004. The applicable water body classifications and water quality standards are specified in Minnesota Rules Chapter 7050. Minnesota Rules Chapter 7050.0407 lists water body classifications and Chapter 7050.2222 (subp. 5) lists applicable water quality standards for the impaired reaches.

Turbidity assessment protocol includes pooling of data over a ten-year period and requires a minimum of ten samples. The surface water standard for each of the impaired reaches covered in this report is 25 nephelometric turbidity units (NTUs). For assessment purposes, a stream is listed as impaired if at least three observations and 10% of the observations exceed 25 NTUs. Transparency (>20 cm clarity) and total suspended solids (North Central Hardwood Forest Ecoregion standard is 100 mg/L) samples may also be used as a surrogate for the turbidity standard. If there are two or more parameters observed in a single day, the hierarchy of consideration for impairment assessment purposes is turbidity, then transparency, then total suspended solids.

2.0 Watershed Description and Impairments

2.1 DESCRIPTION OF TURBIDITY

Turbidity is a measure of water clarity typically determined using a meter that measures the scatter of a beam of light passed through a water sample. Turbidity is caused by suspended soil particles, algae, dissolved salts, and other organic materials that scatter light in the water column, making the water appear cloudy. Excessive levels of turbidity can harm aquatic life by making it more difficult for sight-feeding organisms to find food, adversely affecting gill function, and smothering food organisms as well as spawning habitat.

2.2 APPLICABLE MINNESOTA WATER QUALITY STANDARDS

The numeric criteria for turbidity, based on stream use classification, are provided in Table 2.1 (Minnesota Rules Chapter 7050.0220). Both Stony and Getchell Creek and the impaired reach of Un-named Creek addressed in this study are classified as Class 2B streams and have a turbidity standard of 25 NTU.

Table 2.1 Minnesota Turbidity Standards by Stream Classification

Class	Description	Turbidity (NTUs)
1B	Drinking water	10
2A	Cold water fishery, all recreation	10
2B	Cool and warm water fishery, all recreation	25
2C	Indigenous fish, most recreation	25

2.3 TMDL IMPAIRED REACH

This report includes a TMDL for one turbidity impaired stream reach in the Sauk River Watershed: Un-named Creek (Figure 2.1). The watershed for this stream is contiguous and lies within central Minnesota. Figure 2.1 highlights the Un-named, Stony and Getchel Creek watersheds and their location within the Sauk River Watershed. The Sauk River, to which all three tributaries discharge, is a tributary within the upper Mississippi River basin.

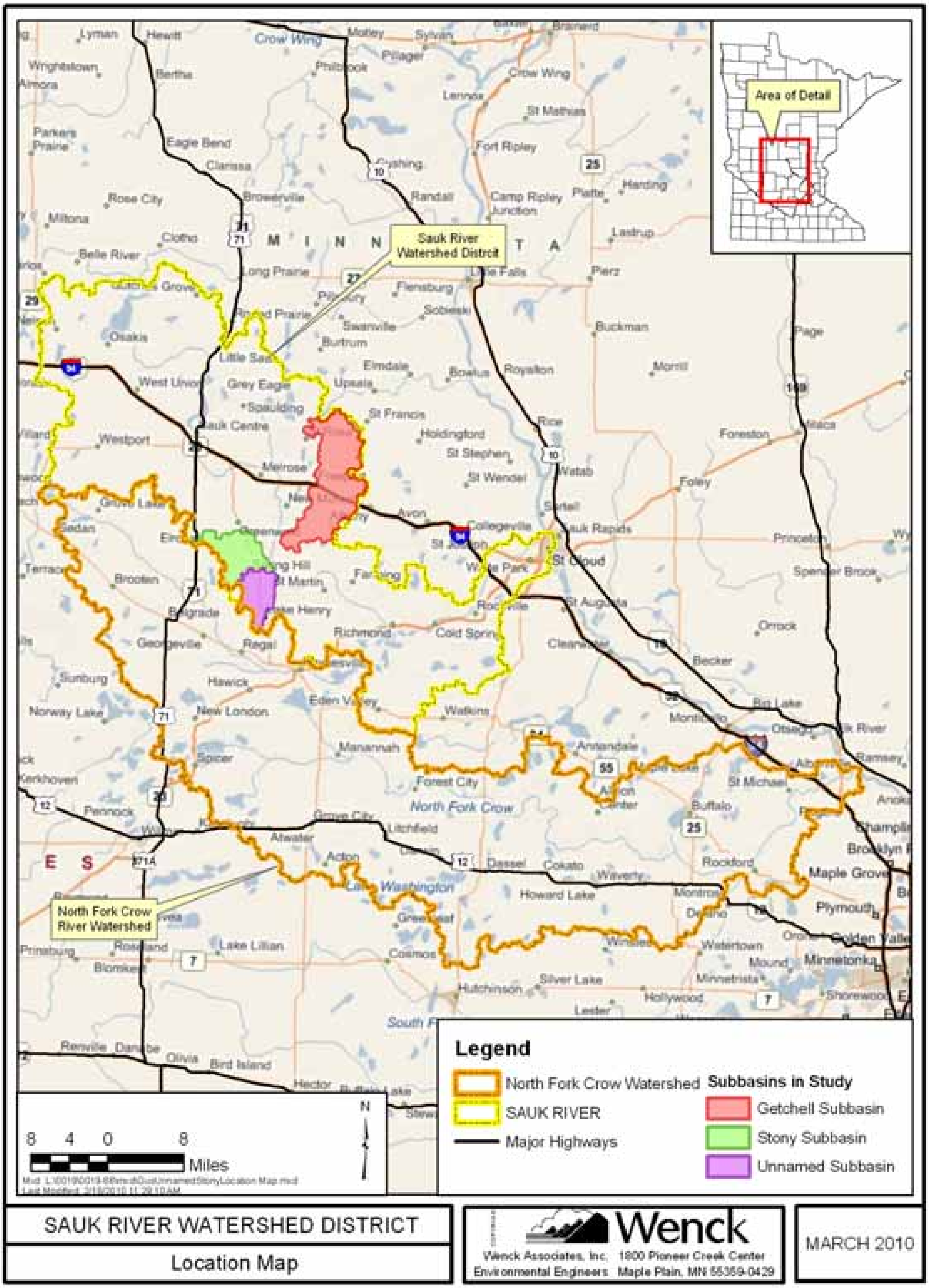


Figure 2.1 Location of the Sauk and North Fork Crow River Watersheds.

Un-named Creek is located within the larger Getchell, Un-named and Stony (GUS) subwatershed of the Sauk River. Though they are not listed as impaired for turbidity, Stony and Getchell Creek have displayed high concentrations of total suspended sediment. Thus, all three tributary reaches will be evaluated for turbidity in this report (Table 2.2). Locations of all three reaches and their contributing watersheds are shown in Figure 2.2 along with gauging station locations for which flow data was generated to support the TMDLs for each stream reach.

Table 2.2 Impaired Stream Reaches

Stream Name	Description	MPCA River Assessment ID	Turbidity Impairment	Year Listed
Un-named Creek (Un-named Creek to Sauk River)	Unnamed creek to Sauk River	07010202-542	Yes	2008
Getchell Creek	Unnamed creek to Sauk River	07010202-562	No	---
Stony Creek	Headwaters to Sauk River	07010202-541	No	---

All three watersheds are dominated by fine, deep loamy soils formed in calcareous glacial till. Getchell Creek soils drain slightly better than those found in Stony and Un-named Creek. Slopes are less than 3% throughout a majority of the watersheds for all three creeks. Getchell and Un-named Creek watersheds contain more high-sloped areas (26% and 25% of their respective watershed greater than 3% slope) compared to Stony (17% greater than 3% slope).

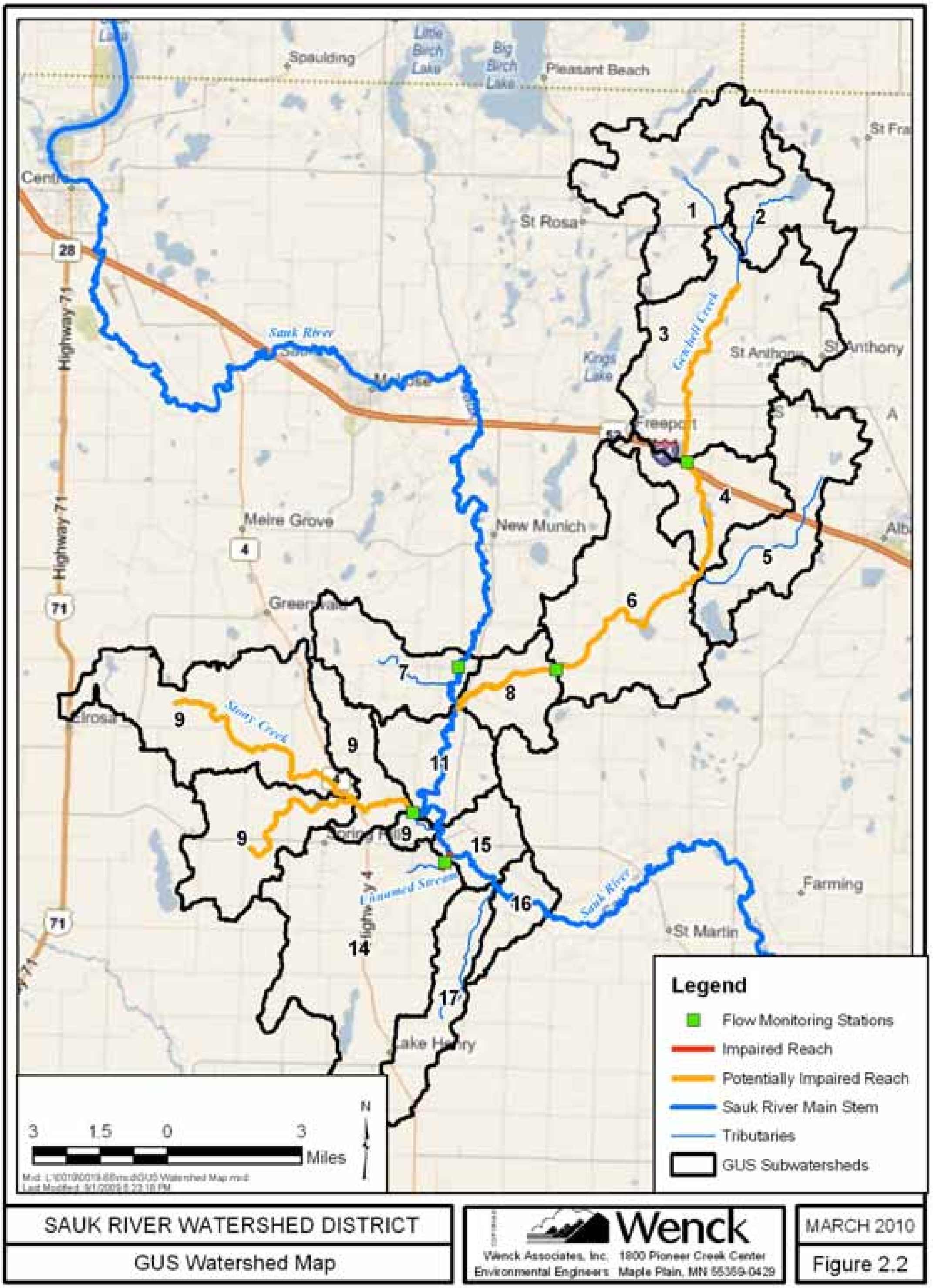


Figure 2.2 Location and contributing watersheds of impaired reaches

2.4 SELECTION OF TURBIDITY SURROGATES

Turbidity is a measure of the cloudiness or haziness of water caused by suspended and dissolved substances in the water column. Turbidity can be caused by increased suspended soil or sediment particles, phytoplankton growth, and dissolved substances in the water column. Since turbidity is a measure of light scatter and adsorption, loads need to be developed for a surrogate parameter. Total suspended solids (TSS) is a measurement of the amount of sediment and organic matter suspended in water and is often used as a turbidity surrogate to define allocations and capacities in terms of daily mass loads.

The relationship between turbidity and TSS varies in streams across Minnesota and depends on local soil types, geology, and water quality. To account for this variability, MPCA recommends that stream-specific relationships between turbidity and TSS be developed for each stream when adequate data exists. An adequate data set usually consists of several years of data in the last 10 years with paired samples of turbidity and TSS over all seasons and flow regimes. Table 2.3 presents some relationships developed for streams in Minnesota using site specific data.

Table 2.3 Turbidity surrogates developed for other watersheds and regions in Minnesota

Location	TSS (mg/L) Value for 25 NTU	Source
North Central Hardwood Forest Ecoregion	100	MPCA listing protocol 2010 list
Western Cornbelt Plains/Northern Glaciated Plains Ecoregion	60	MPCA listing protocol 2010 list
North Fork Crow River Turbidity TMDL	79	Wenck (2009)
Chippewa River	51	MPCA memo 2008
Redwood River	72	
Cottonwood River	64	
Watonwan River	85	
Blue Earth River	90	
Le Sueur River	89	
Minnesota River at Jordan	105	

At this time, there are no paired turbidity and TSS sampling data available for Stony, Un-named and Getchell Creek. However, over 100 readings of paired turbidity-TSS data were collected in the North Fork Crow/Crow River watershed from Mill Creek to its outflow to the Mississippi River (Table 2.3 Appendix A). The Sauk and North Fork Crow/Crow are adjacent watersheds located in the Upper Mississippi River Basin and North Central Hardwood Forest ecoregion with similar land-use and soil types. Thus, the turbidity surrogate developed for the North Fork Crow River Turbidity TMDL (79 mg/L) was adopted as the surrogate value for Stony, Un-named and Getchell Creek for the purpose of this TMDL study. The State has also developed ecoregion TSS surrogates to evaluate TSS data for potential impacts on turbidity. The North Central

Hardwood Forest ecoregion TSS target is 100 mg/L. The North Fork Crow surrogate was selected as a conservative assumption since it is less than the ecoregion value. Furthermore, since the Sauk River and North Fork Crow are adjacent watersheds, the North Fork Crow developed surrogate was assumed to be more reflective of site specific conditions.

2.5 LAND USE AND COVER

Land use was developed using the National Agriculture Statistical Survey (NASS) data layers available from the NRCS. The NASS data layer uses satellite imagery to develop land cover. The data sets are developed annually with Minnesota data available starting in 1997. Each years' data were combined to root out any errors in the cover associated with seasonal changes in standing water when the image was taken. The data set is then further updated with the National Wetlands Inventory (NWI) to identify wetland areas in the watershed.

The watersheds of each of the reach are dominated by cultivated land with 41%, 38% and 53% of the land in Un-named, Getchell and Stony in a corn/soybean rotation, respectively (Figure 2.3; Table 2.4). Pasture is also a significant land use with 17 to 32% of the watersheds used for pasture, hay and alfalfa production. Less than 1% of the watersheds are developed representing a low density road network and farm buildings.

Table 2.4 Land cover for the Un-named, Getchell and Stony Creek subwatersheds

NASS Land Cover Category	Area (acres)	Percent
Un-named Creek		
Pasture/Hay	3,495	32.0
Corn	3,314	30.4
Soybeans	1,119	10.3
Alfalfa	705	6.5
Spring Wheat	688	6.3
Open Space	627	5.7
Deciduous Forest	373	3.4
Open Water	203	1.9
Herbaceous Wetlands	152	1.4
Grass Pasture	68	0.6
Developed/Low-Med Intensity	35	0.3
Other	134	1.2
TOTAL	10,912	100%
Getchell Creek		
Corn	12,586	32%
Alfalfa	6,705	17%
Wetlands	5,717	15%
Roads	3,005	7%
Range Grasses	2,574	7%
Soybeans	2,498	6%
Deciduous Forest	2,177	6%
Kentucky Bluegrass	2,150	5%
Oats	563	2%
Wheat	459	1%
Urban/Residential	414	1%
Other	470	1%
TOTAL	39,483	100%
Stony Creek		
Corn	5,442	35.2
Pasture/Hay	3,753	24.3
Soybeans	2,786	18.0
Open Space	1,010	6.5
Alfalfa	786	5.1
Deciduous Forest	600	3.9
Herbaceous Wetlands	398	2.6
Spring Wheat	335	2.2
Grass Pasture	94	0.9
Open Water	84	0.5
Developed/Low-Med Intensity	45	0.3
Other	140	0.9
TOTAL	15,474	100%

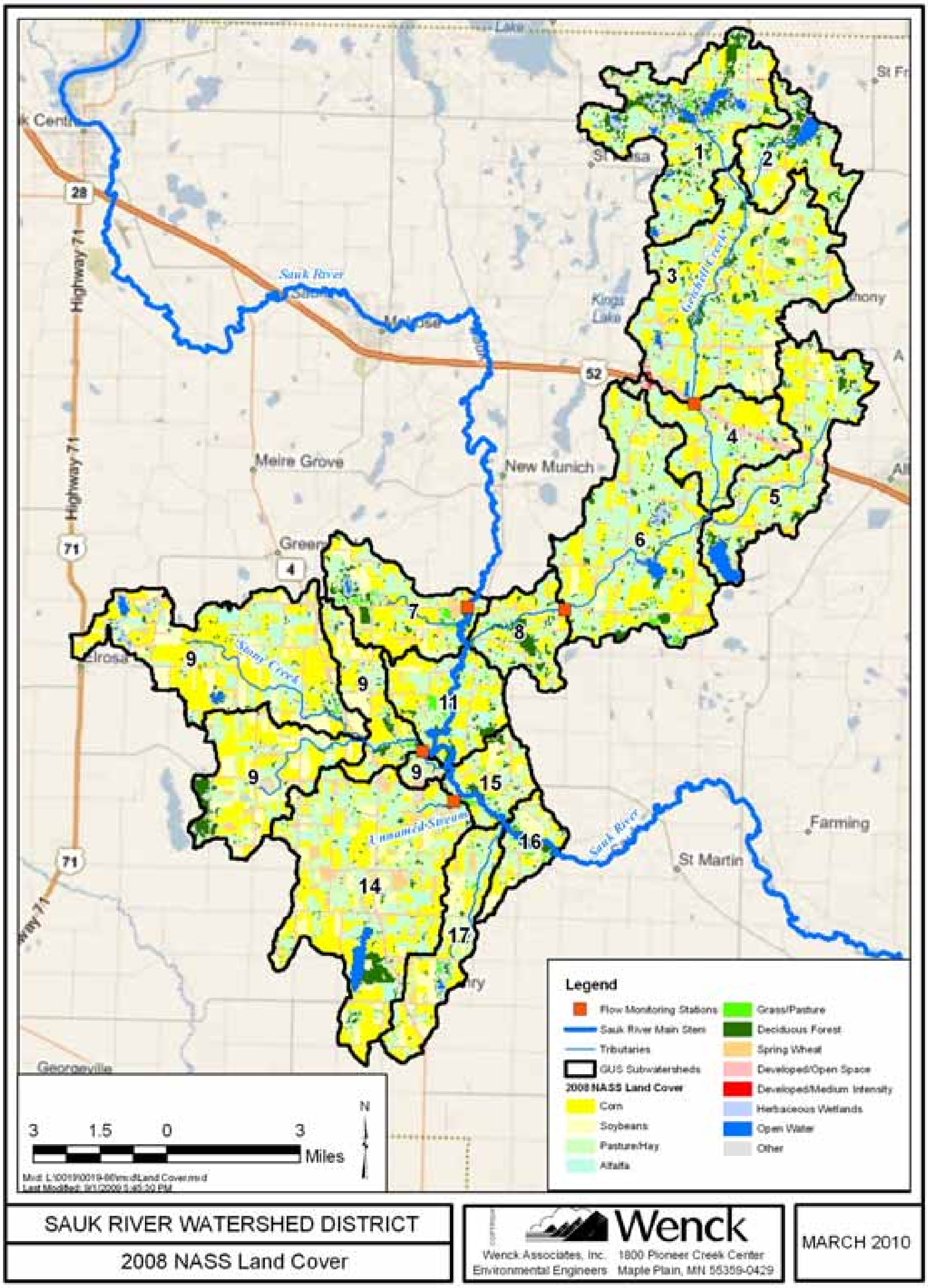


Figure 2.3 Land Use within GUS Project Watershed

2.6 IMPAIRMENT ASSESSMENT

2.6.1 Flow

The Sauk River Watershed District has collected both continuous and gauged flow data near the outlets of Getchell, Stony and Un-named Creek since 1994 (Figure 2.2). Mean daily flow data was collected for 2,044 total days between 1994-2008 for Getchell Creek, 701 days from 1994-2002 at the Un-named Creek monitoring site and for 1,381 days between 1994-2007 at the Stony Creek station. There was also 88 and 56 instantaneous gauged flow measurements recorded from 1995-2008 at the Stony and Un-named Creek stations, respectively. These measurements were taken when continuous flow measurements were not recorded.

Mean daily flow records for Getchell, Un-named and Stony Creek's cover approximately 47%, 18% and 32% of the total non-winter (March through November) portion of the hydrograph during these time periods. Filling of hydrograph data gaps was explored by looking at regressions to nearby long-term continuous USGS flow stations. However, because of the small size of the study watersheds compared to the long-term continuous flow stations, no reasonable relationships existed. Consequently, gaps in the flow data record were not filled. However, the entire 15 year monitoring period was used to generate the flow duration curves for the watersheds.

2.6.2 Turbidity and TSS

The Sauk River Watershed District has collected TSS samples at stations near the outlets of Getchell, Un-named and Stony Creeks since 1994. Total suspended solids samples were collected twice a month with some targeted runoff events. The goal of the effort was to collect a total of fifteen samples with the majority of the samples prior to July 1st when the majority of runoff occurs. 158, 67 and 150 TSS samples have been collected at the Getchell, Un-named and Stony sites between 1994-2008, respectively (Figures 2.4 – 2.7). Less than 50% of the Getchell (8%) and Stony (27%) exceed the TSS surrogate standard of 79 mg/L TSS adopted from the North Fork Crow/Crow River turbidity TMDL. A majority of these violations occurred from 1994-2002. Un-named Creek had 37 samples (~55%) exceeding the TSS standard all of which were collected prior to 2003.

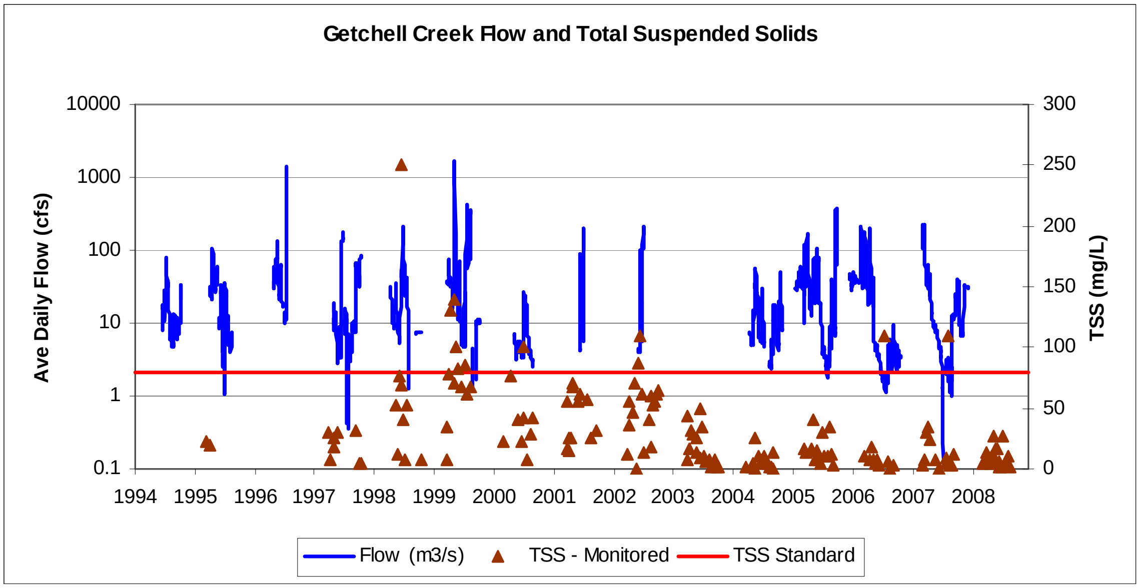


Figure 2.4 Flow and total suspended solids for Getchell Creek (1994 through 2008)

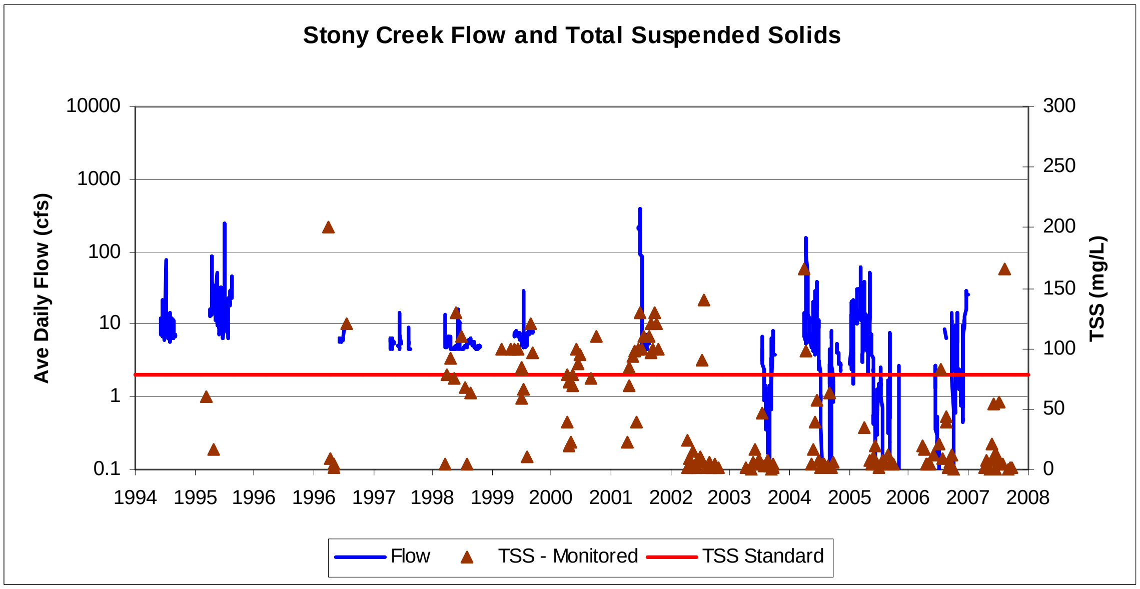


Figure 2.5 Flow and total suspended solids for Stony Creek (1994 through 2008)

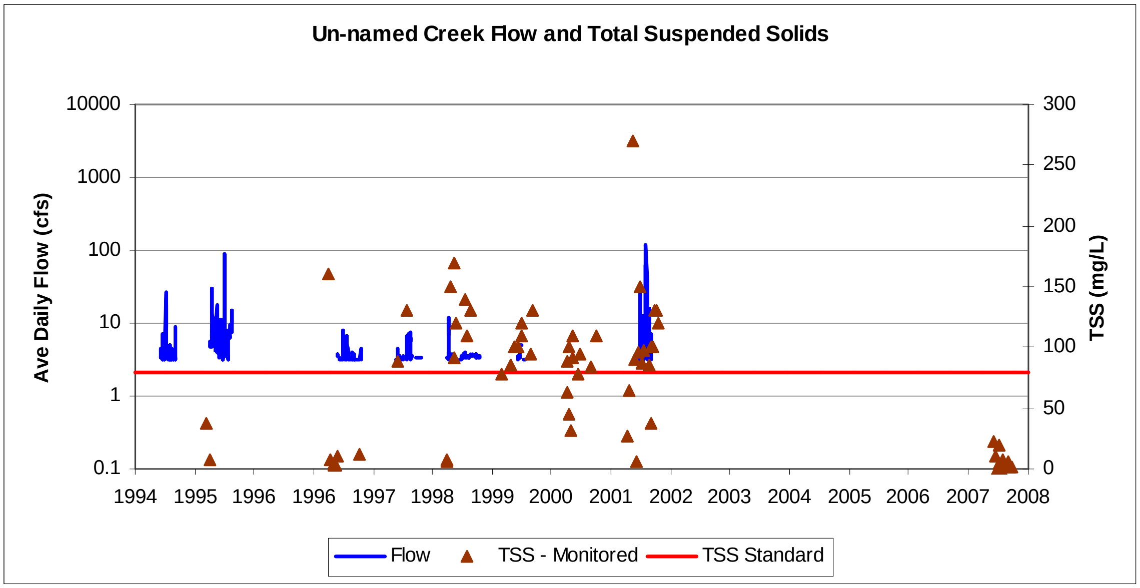


Figure 2.6 Flow and total suspended solids for Un-named Creek (1994 through 2008)

3.0 Turbidity TMDL Development

3.1 ALLOCATION APPROACH

Assimilative capacities for the streams were developed from load duration curves (Cleland 2002). Load duration curves assimilate flow and TSS data across stream flow regimes and provide assimilative capacities and necessary load reductions necessary to meet water quality standards.

Flow duration curves were developed using flow collected by the Sauk River Watershed District between 1994 and 2007 (Figure 3.1). Data was not available for every year during that period, so all available data were used to develop the flow duration curves. The curved line relates mean daily flow to the percent of time those values have been met or exceeded. For example, at the 50% exceedance value for Stony Creek, the stream was at 5 cubic feet per second or greater 50% of the time. The 50% exceedance is also the midpoint or median flow value. The curve is then divided into flow zones including very high (0-10%), high (10-40%), mid (40-60%), low (60-90%) and dry (90 to 100%) flow conditions.

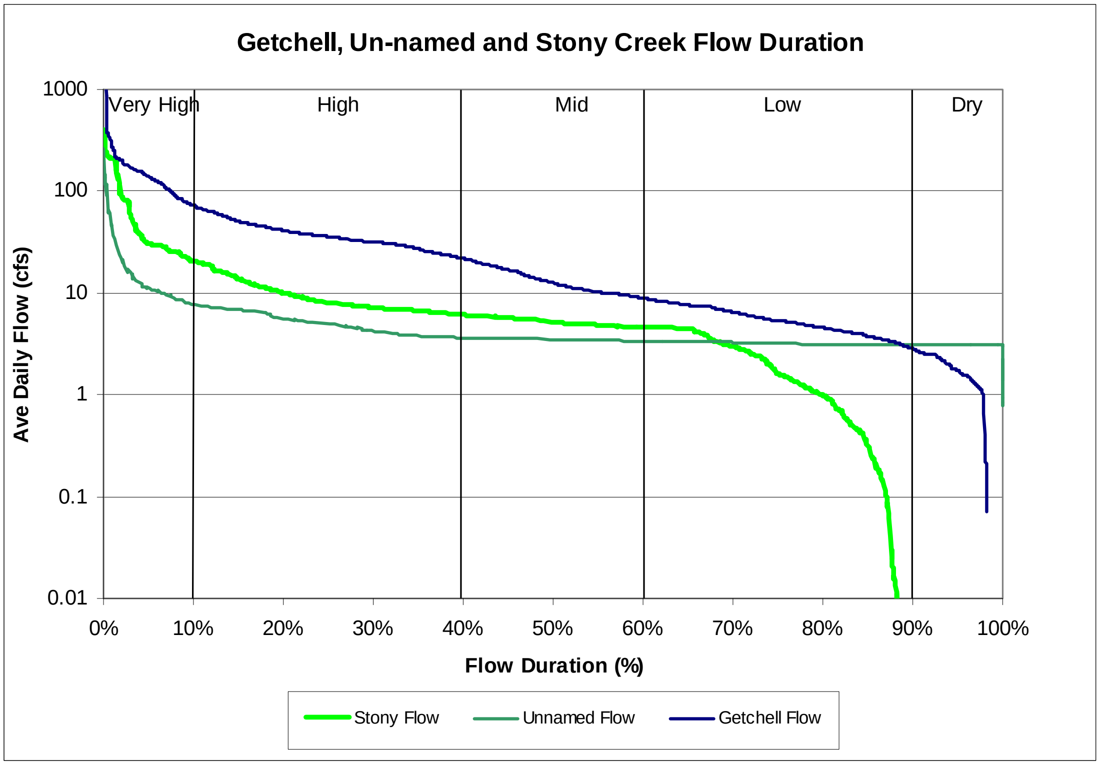


Figure 3.1 Flow duration for Getchell, Un-named and Stony Creek.

To develop a load duration curve, all average daily flow values were multiplied by the TSS-surrogate (79 mg/L) and converted to a daily load to create “continuous” load duration curves (Figure 3.2). Now the line represents the assimilative capacity of the stream for each daily flow. To develop the TMDL, the median load of each flow zone is used to represent the total daily loading capacity (TDLC) for that flow zone. The TDLC can also be compared to current conditions by plotting the measured load by exceedance for each water quality sampling event (Figure 3.2). Each value that is above the TDLC line represents an exceedance of the water quality standard while those below the line are below the water quality standard. Necessary reductions to meet current state water quality standards are further explored in Section 4.

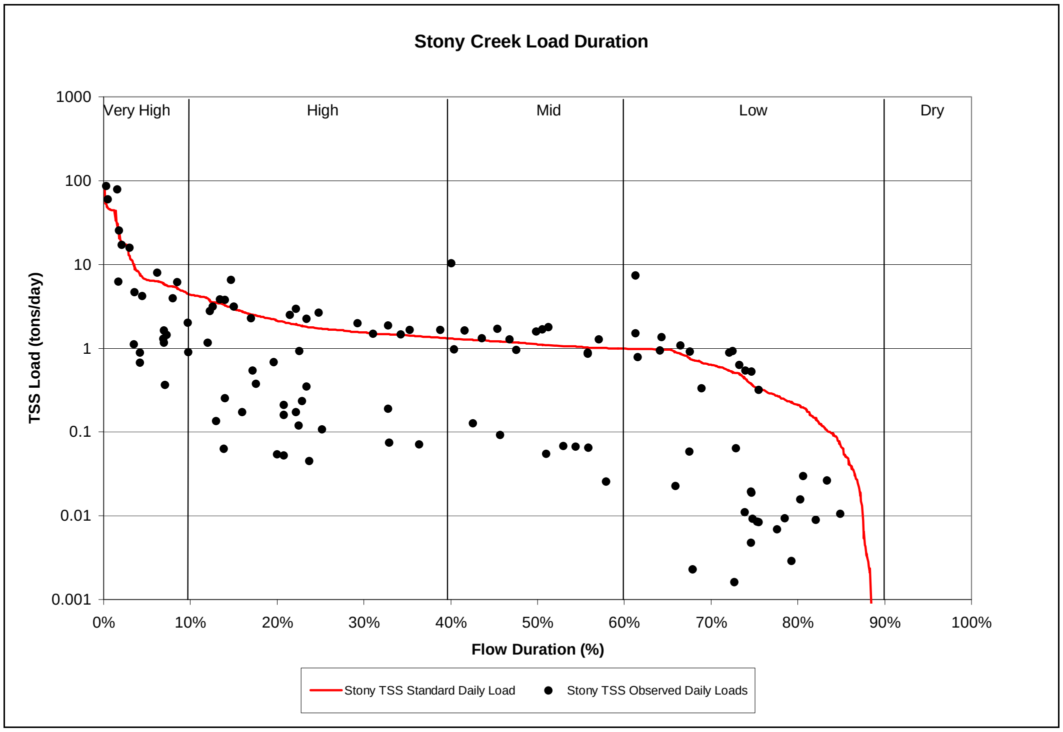


Figure 3.2 Load duration curves for Stony Creek

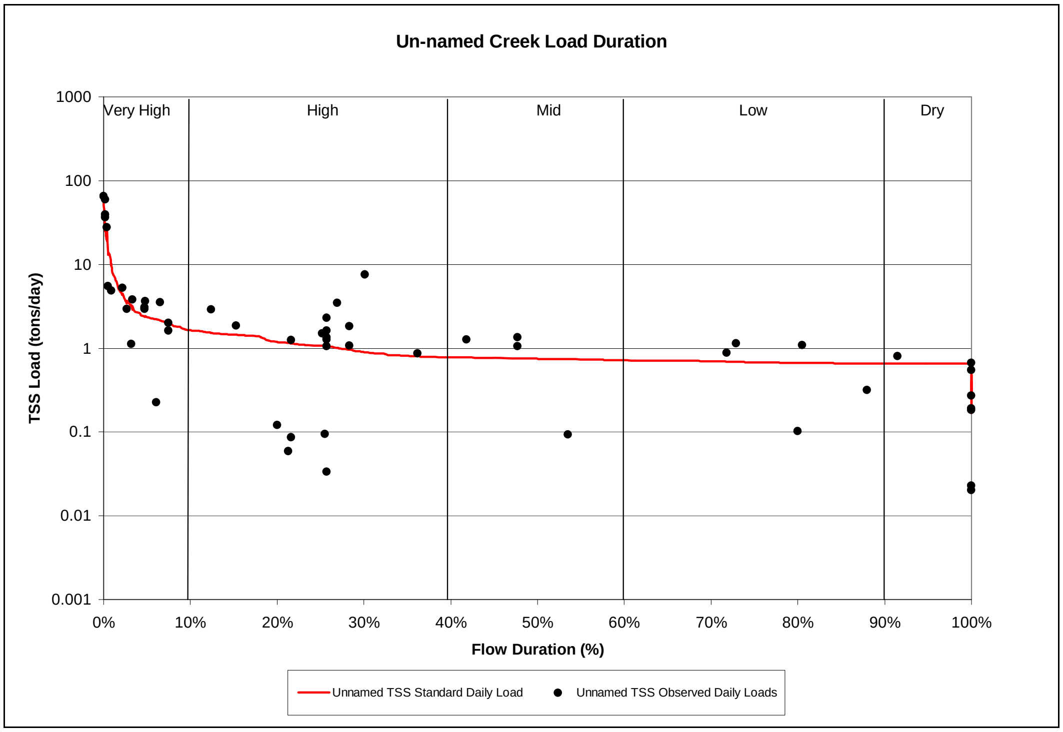


Figure 3.3 Load duration curves for Un-named Creek

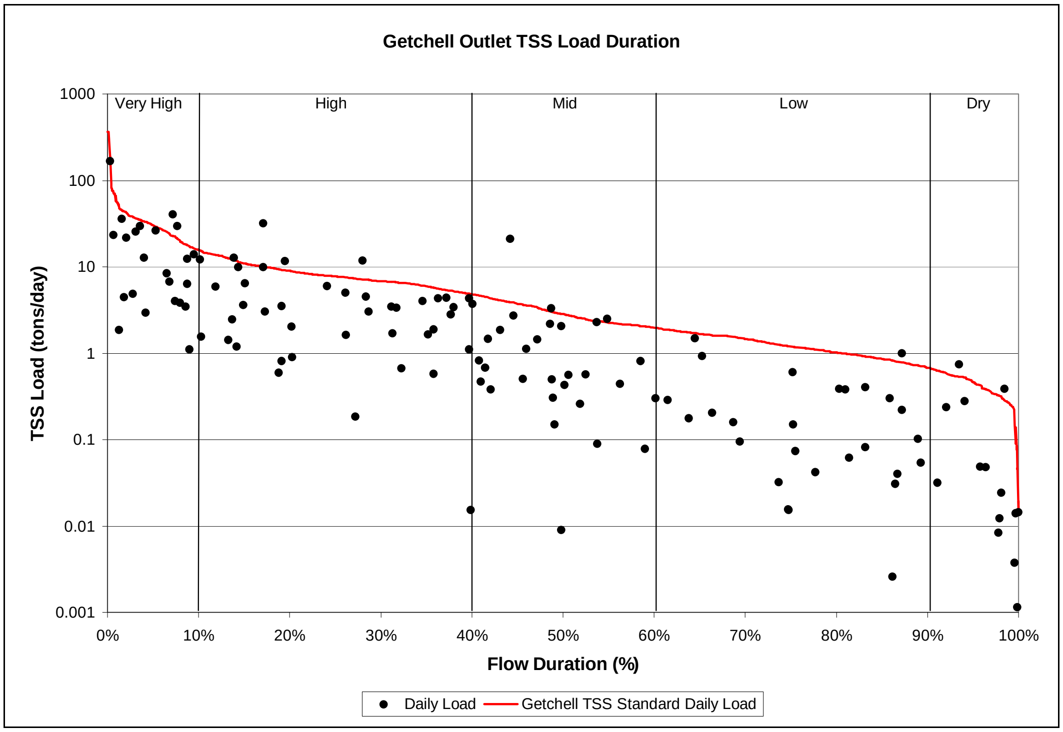


Figure 3.4 Load duration curve for Getchell Creek

3.2 WASTELOAD AND LOAD ALLOCATIONS

3.2.1 Wasteload Allocations

The wasteload allocations were divided into three primary categories including permitted point source dischargers, construction stormwater and industrial stormwater. Typically an allocation would also be included for MS4 stormwater. However, there are no MS4 permitted communities in the study watersheds. Following is a description of how each of these loads was estimated.

The Freeport Waste Water Treatment Plant (MNG580019), located on Getchell Creek, is the only permitted point source discharger located in the GUS watershed. Load allocations for this point source were estimated by calculating the load generated from the facilities designed wet weather flow and the TSS surrogate concentration. According to the Discharge Monitoring Reports (DMRs), this facility has only once exceeded the 79 mg/L TSS surrogate standard.

The review of National Pollutant Discharge Elimination System (NPEDS) construction permits in the watersheds showed minimal construction activities in the watersheds (<0.1% of the watershed area). The wasteload allocation was determined based on estimated percentage of land in the impaired reach watersheds. To account for future growth (reserve capacity), allocations in the TMDL were rounded to one percent. 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.

There are currently no industrial stormwater permits in the Getchell, Un-named or Stony Creek watersheds. Although there are no permitted industrial facilities, to account for future growth (reserve capacity), allocations for industrial stormwater in the TMDL are set at a half percent. Under all flow regimes, industrial stormwater is allocated less than one percent of the total loading capacity. 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.

3.2.2 Margin of Safety

The purpose of the margin of safety (MOS) is to account for uncertainty that the allocations will result in attainment of water quality standards. The MOS was determined as the difference between the median flow of each flow regime and the 45th percentile flow in each zone. The resulting value was converted to a daily load by multiplying by the TSS standard and set as the MOS for each flow category. Essentially, the MOS moves the target load in each category so that only 5% of the values would be allowed to exceed the standard as compared to the current state standard of less than 10%. This methodology accounts for variability in the data set without over protecting the high end of the flow zone and under-protecting the low end of the flow zone. The data in each flow zone are treated as a distribution and assumes any reduction efforts will affect the entire distribution.

3.2.3 Load Allocation

Once wasteload allocations (point sources, construction and industrial stormwater) and MOS were determined for each watershed and flow regime, the remaining loading capacity was considered the load allocation. The load allocation includes nonpoint pollution sources that are not subject to NPDES permit requirements, as well as soil erosion from stream channel and upland areas. The load allocation also includes runoff from agricultural lands and non-NPDES stormwater runoff.

3.2.4 Total Maximum Daily Loads

Tables 3.1 through 3.3 present the wasteload and load allocations as well as the margin of safety for Getchell, Un-named and Stony Creek. Getchell is the only watershed with a permitted point source discharger as allocations are set at zero for Stony and Un-named Creeks. Any new permitted point source dischargers would meet Wasteload allocations as long as discharged concentrations remained below the established TSS surrogate of 79 mg/L. The tables also present the load allocations as the percentages of the total allowable load in each flow category.

Table 3.1 Getchell Creek TSS total daily loading capacities and allocations

		Flow Zones				
		Very High	High	Mid-Range	Low	Dry
Getchell Creek		TSS Load (tons/day)				
Wasteload Allocation	Permitted Point Source Dischargers/ Construction Stormwater/ Industrial Stormwater	0.473	0.147	0.074	0.05	0.038
Load Allocation	Nonpoint source and channel	27.484	7.253	2.541	1.075	0.388
Margin of Safety (MOS)		1.462	0.278	0.159	0.044	0.021
Total Daily Loading Capacity		**29.419**	**7.678**	**2.774**	**1.169**	**0.447**
Value expressed as percentage of total daily loading capacity						
Total Daily Loading Capacity		100%	100%	100%	100%	100%
Wasteload Allocation	Permitted Point Source Dischargers/ Construction Stormwater/ Industrial Stormwater	1.60%	1.90%	2.70%	4.20%	8.70%
Load Allocation	Nonpoint source and channel	93.4%	94.5%	91.6%	92.0%	86.7%
Margin of Safety (MOS)		5.0%	3.6%	5.7%	3.7%	4.6%

Table 3.2 Un-named Creek TSS total daily loading capacities and allocations

Un-named Creek		Very High	High	Mid-Range	Low	Dry
		TSS Load (tons/day)				
Wasteload Allocation	Permitted Point Source Dischargers/ Construction Stormwater/ Industrial Stormwater	0.036	0.016	0.012	0.01	0.01
Load Allocation	Nonpoint source and channel	2.317	1.048	0.731	0.670	0.647
Margin of Safety (MOS)		0.069	0.012	0.008	0.002	0.000
Total Daily Loading Capacity		**2.422**	**1.076**	**0.751**	**0.682**	**0.657**
Value expressed as percentage of total daily loading capacity						
Total Daily Loading Capacity		100%	100%	100%	100%	100%
Wasteload Allocation	Permitted Point Source Dischargers/ Construction Stormwater/ Industrial Stormwater	1.5%	1.5%	1.5%	1.5%	1.5%
Load Allocation	Nonpoint source and channel	95.7%	97.4%	97.5%	98.2%	98.5%
Margin of Safety (MOS)		2.8%	1.1%	1.0%	0.3%	0.0%

Table 3.3 Stony Creek TSS total daily loading capacities and allocations

		Flow Zones				
		Very High	High	Mid-Range	Low	Dry
Stony Creek		TSS Load (tons/day)				
Wasteload Allocation	Permitted Point Source Dischargers/ Construction Stormwater/ Industrial Stormwater	0.099	0.027	0.017	0.006	0
Load Allocation	Nonpoint source and channel	6.319	1.675	1.075	0.331	0.000
Margin of Safety (MOS)		0.162	0.070	0.030	0.074	0.000
Total Daily Loading Capacity		**6.580**	**1.772**	**1.122**	**0.411**	**0.000**
Value expressed as percentage of total daily loading capacity						
Total Daily Loading Capacity		100%	100%	100%	100%	0%
Wasteload Allocation	Permitted Point Source Dischargers/ Construction Stormwater/ Industrial Stormwater	1.5%	1.5%	1.5%	1.5%	0.0%
Load Allocation	Nonpoint source and channel	96.0%	94.5%	95.8%	80.5%	0.0%
Margin of Safety (MOS)		2.5%	4.0%	2.7%	18.0%	0.0%

3.3 IMPACT OF GROWTH ON ALLOCATIONS

3.3.1 Point Sources

The current TSS surrogate for meeting the state turbidity standard in the Sauk River watershed is 79 mg/L. It is assumed that future dischargers will meet this watershed standard for TSS. If the future dischargers meet this standard, the additional load will be offset by the additional flow associated with the discharge adding to the overall capacity of the receiving water. Consequently, as long as dischargers are required to discharge below 79 mg/L as a daily average, future dischargers will not impact attainment of the water quality standards.

3.3.2 Municipal Separate Storm Sewer Systems

There are currently no MS4 communities in the watersheds although there are several small communities. There are no current plans to expand or develop MS4 communities in the watershed for the foreseeable future. Because there is no way to estimate the potential stormwater contributions from future MS4 communities and there are no current plans that suggest such development will occur, no future allocation has been established for MS4 stormwater. However, it is safe to assume that any development in the watershed will need to provide appropriate treatment to meet the established load allocations.

3.3.3 Agricultural Practices

The amount of land in agricultural land use in the three stream watersheds is likely to remain fairly constant over the next several decades. The watersheds are comprised mainly of row crops (corn and soybeans) and pasture and hay land. While the majority of the landscape is likely to remain in an agricultural land use, it is possible a modest shift from pasture/hay to row crops could occur. Any such shift would likely not affect the loading capacity of the streams, since that capacity is based on long-term flow values that incorporate land use variability, and slight shifts in land use should not appreciably change the magnitude of the land use-driven flow variability that the period of record already reflects.

4.0 Source Assessment

4.1 TSS LOAD REDUCTIONS

Reduction targets were developed for Getchell, Un-named, and Stony Creeks using statistical expressions of loads in each of the flow zones. It is important to note that these expressions do not represent the necessary reductions to meet state water quality standards on a daily basis. Rather, the expressed reductions demonstrate the necessary reductions to reduce turbidity below the 10% exceedance threshold for listing. These reductions would result in the streams meeting required state standards and ultimately lead to de-listing.

Figures 4.1 through 4.3 present TSS samples for Getchell, Un-named and Stony Creeks plotted on a load duration curve using the continuous and gauged flow data from each monitoring station. The figure shows all TSS samples collected at each station from 1994-2008 as well as the daily loading capacity over the entire flow record. Values that lie above the load duration curve represent samples that exceed the 79 mg/L TSS-surrogate. The data for Stony and Un-named Creek indicate that a majority of samples exceeding the TSS standard (53% and 67%, respectively) occur during the very high and high flow regimes. Data for Getchell show that a 26% reduction in TSS concentrations is required for the “high” flow category as this flow regime has the highest incidence of TSS violations. However, all three streams have TSS concentrations that exceed the 79 mg/L TSS standard across all flow regimes. Approximately 28% of Stony Creek and 25% of Un-named Creek samples are above the TSS standard occurred under low and dry conditions.

Figures 4.1 through 4.3 also compare the 90th percentile TSS load for each flow regime to the loading capacity at the 45th percentile (Median minus MOS). The difference between the loading capacity and the 90th percentile of sampled loads produced an estimated percent reduction in TSS that will be needed to remove Un-named Creek from the impaired waters list and ensure Getchell and Stony Creek do not become listed. The data indicate that the greatest reductions in TSS load will need to occur during the very high and high flow regimes. These would be the periods when overland flow and stream water velocity would be greatest and most likely to cause sediment re-suspension and in-channel erosion.

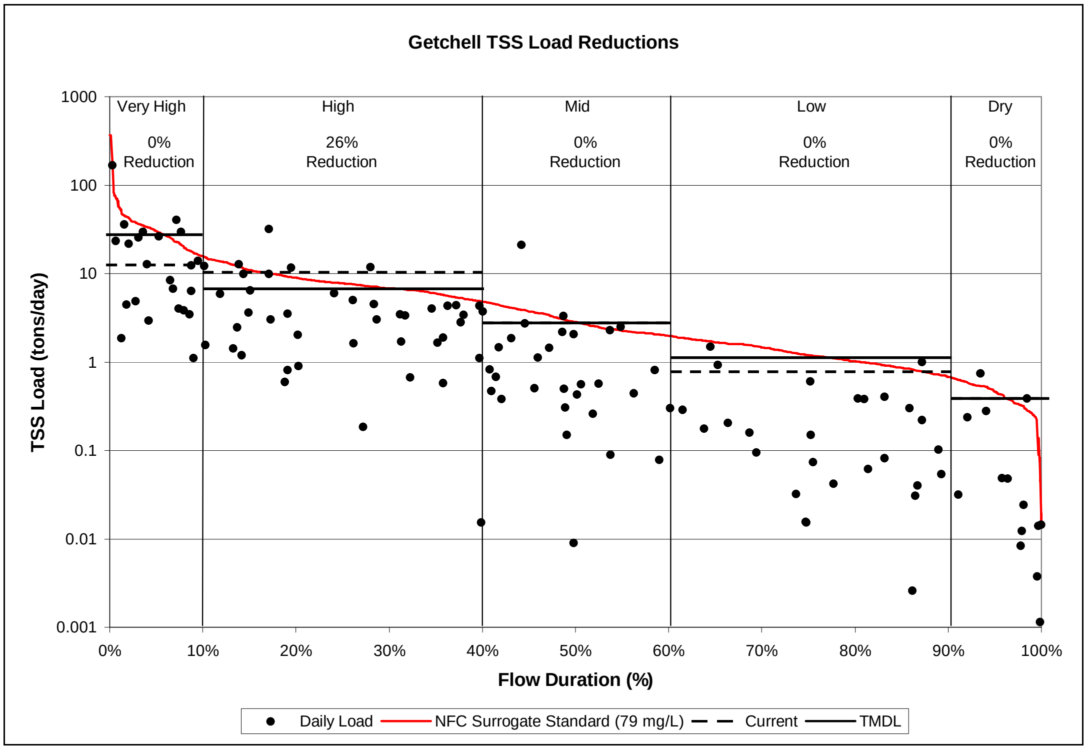


Figure 4.1 Getchell Creek necessary load reductions by flow category. Current loads (dashed line) for the mid and dry flow zones are not visible because they are approximately the same.

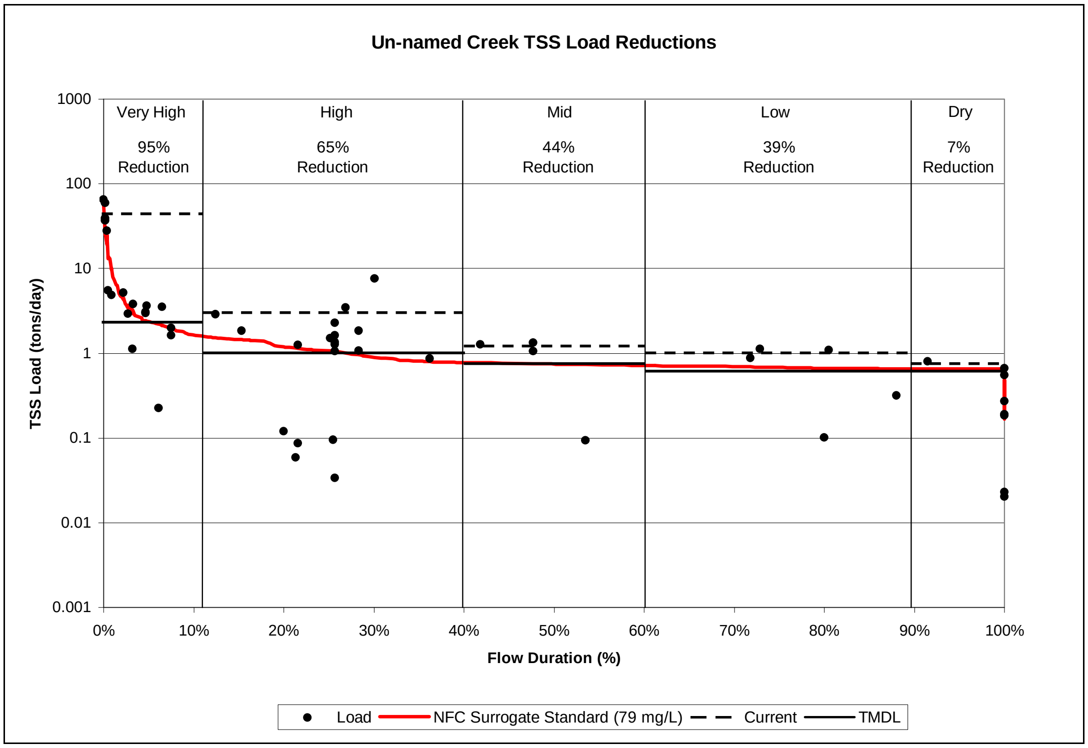


Figure 4.2 Un-named Creek necessary load reductions by flow category.

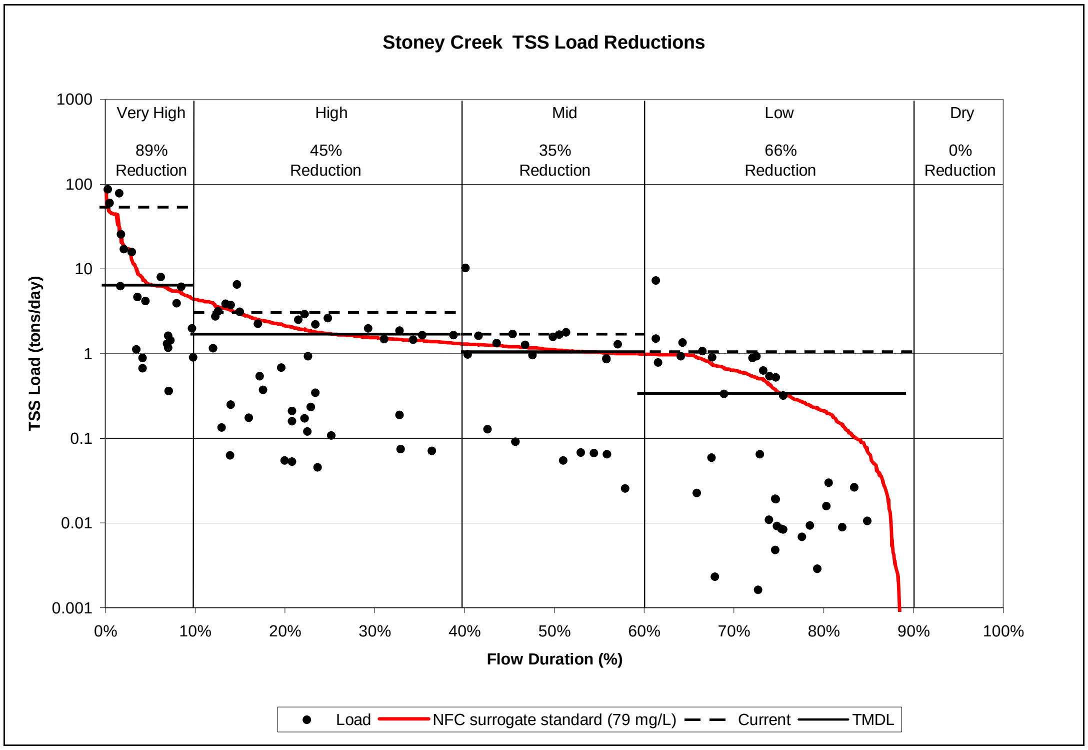


Figure 4.3 Stony Creek necessary load reductions by flow category

4.2 POTENTIAL SOURCES OF TSS

When assessing sources of turbidity and ultimately TSS in streams, the first step is to determine the relative proportions of external and internal sources. External sources include those sources outside of the stream channel and include point sources, field and gully erosion, livestock grazing and stormwater from construction sites and impervious surfaces. Internal sources of sediment includes sediment resuspension, bank erosion and failure, and in-channel algal production. The following is a description of potential sediment sources in Getchell, Un-named and Stony Creek.

Identifying the sources of turbidity in a stream system is difficult because of the complex nature of stream systems and their interaction with the watershed. However, a general sense of the timing, magnitude and sources of TSS can be developed using available data to provide a weight of evidence for the sources. The following is a description of some methods used to develop a better understanding of potential sources in the system to provide evidence for potential sources. It is important to note that these estimates of sources do not affect the established TMDL allocations which is based off of the load duration curves and flow developed for each of the streams.

4.2.1 Field Erosion

The potential for field erosion was assessed using the Soil Water Assessment Tool (SWAT) interface. The SWAT interface was used to develop Hydrologic Response Units (HRU) which combines land cover, soils, and slope into unique classes or HRUs. The model then runs the Modified Universal Soils Loss Equation (MULSE) to determine the mass of soil loss from fields. MULSE estimates gross soil erosion as a function of precipitation intensity (peak runoff rate), soil erodibility, cover type, management practices, and topography. SWAT accounts for crop growth to assess the stability of soils based on crop cover. SWAT also accounts for conservation practices implemented in the watershed. It is important to note that only the SWAT interface was used to develop potential field erosion sources. The intent of the model is not to explicitly model source loads for allocations. Rather the model is intended to provide some understanding of sources in the watershed.

Based on MULSE, estimated sediment yield from field erosion was 52,095, 8,291 and 6,453 tons from Getchell, Un-named and Stony Creek watersheds respectively (Table 4.1). However, this estimate does not account for potential settling in depressional storage and wetlands in the watershed. SWAT estimated sediment removal by wetlands of approximately 40%, 52% and 64% for Getchell, Un-named and Stony Creek respectively. SWAT estimates sediment settling based on median particle size and residence time. The wetland areas receiving drainage were based on visual estimation of the percent of the watershed draining through wetlands (NWI data). The estimated sediment yield after wetland removal represents the sediment mass that may ultimately be delivered to the channel and provides a reasonable comparison to estimated mass loads from stream bank erosion (Section 4.2.2). Based on this assessment, field erosion is likely a large contributor to suspended solids in the streams and ultimately stream turbidity.

Table 4.1 Estimated watershed sediment yield using MULSE and depressional settling

Subwatershed	Sediment Yield (tons/ha)	Sediment Yield (tons/year)	% Wetland	Sediment Yield after wetland removal (tons/year)
Getchell Creek				
1	4.0	10,607	80%	2,280
2	3.5	18,444	40%	11,195
3	3.2	15,453	20%	12,416
4	2.2	4,906	40%	2,992
5	2.8	2,687	10%	2,424
	Total	**52,095**		**31,305**
Stony Creek				
1	0.7	2,401	75%	675
2	1.8	1,769	75%	904
3	1.5	228	50%	207
4	1.1	2,055	10%	564
	Total	**6,453**		**2,350**
Un-named Creek				
1	1.4	3,522	25%	2,666
2	2.6	4,769	75%	1,335
	Total	**8,291**		**4,001**

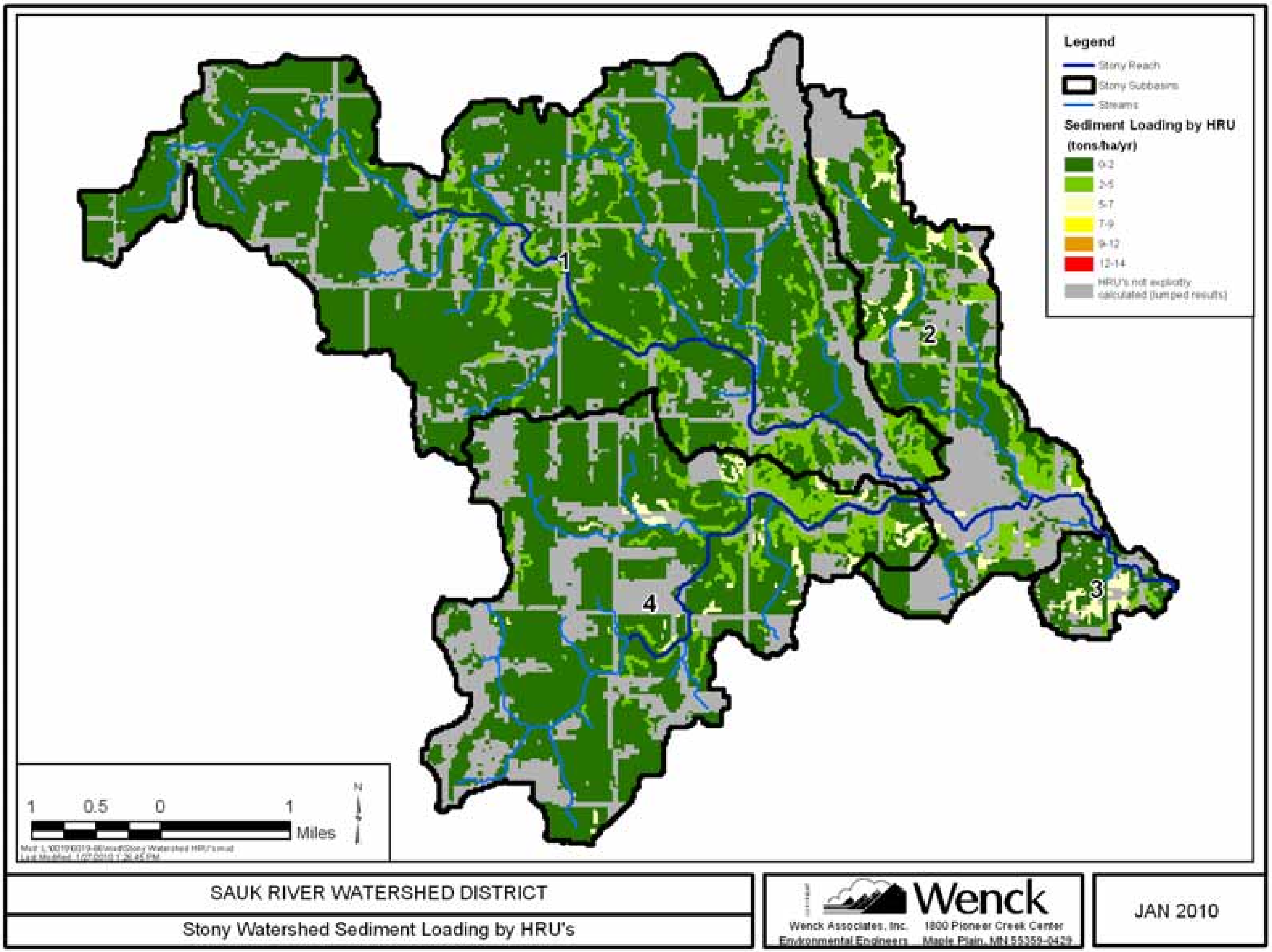


Figure 4.4 Stony Watershed Sediment Loading by HRUs

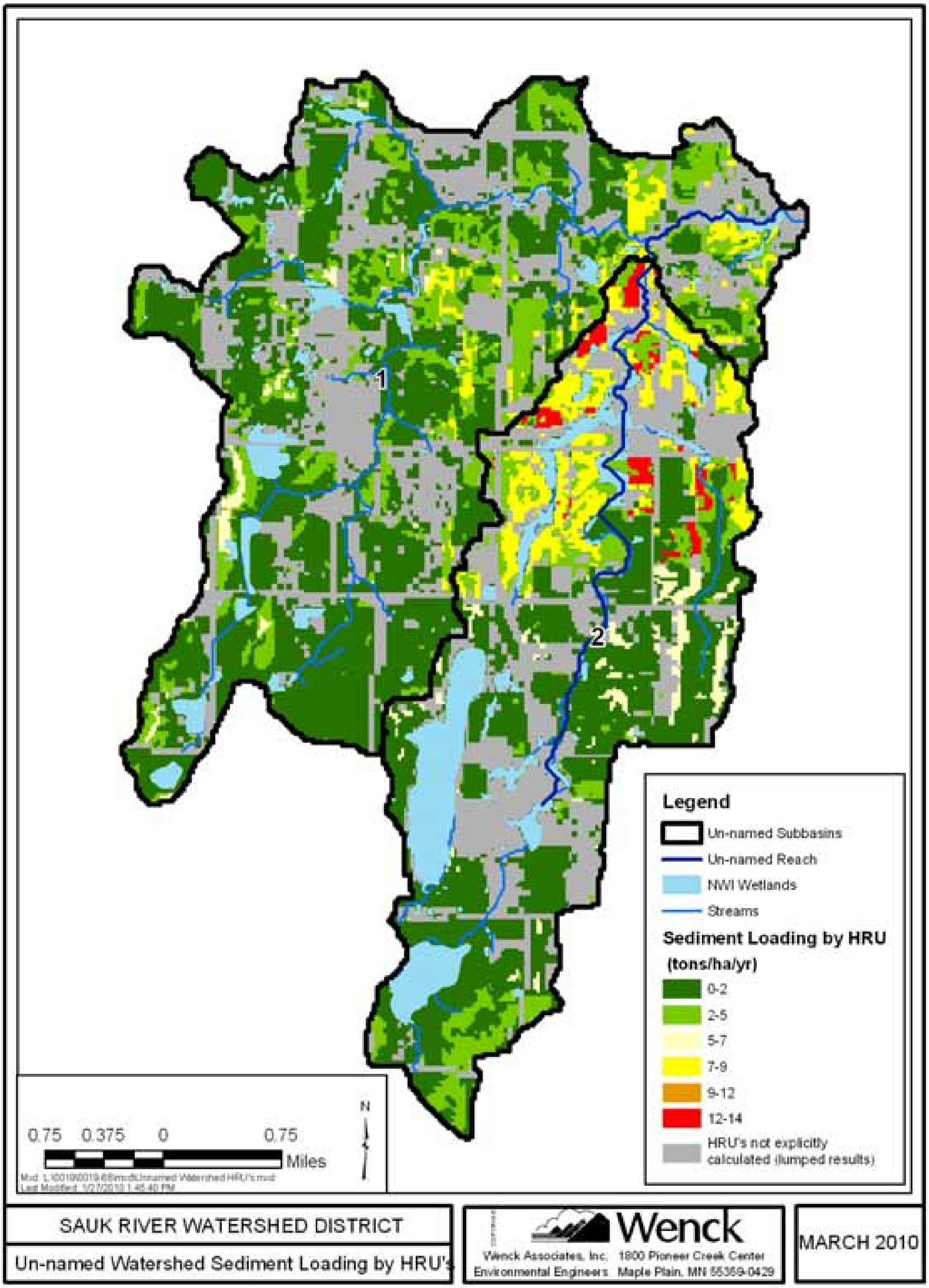


Figure 4.5 Un-named Watershed Sediment Loading by HRUs

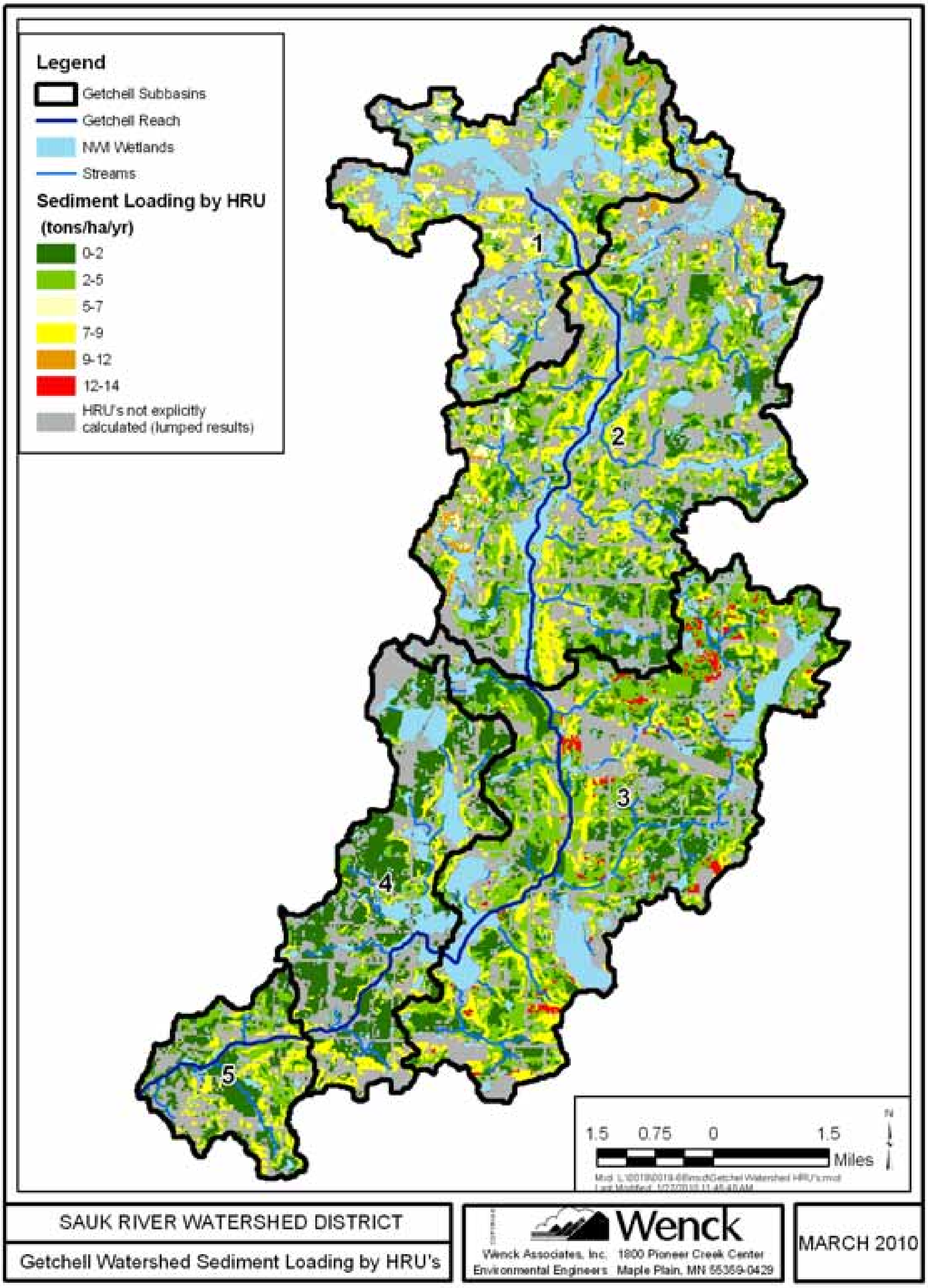


Figure 4.6 Getchell Watershed Sediment Loading by HRUs

4.2.2 Stream Bank Erosion

The primary sources of sediment in streams are sediment conveyed from the landscape and soil particles detached from the streambank. The amount of sediment conveyed from the landscape will vary based on general soil erodibility, land cover, slope, and conveyances to the stream. Streambank erosion is a natural process that can be accelerated significantly as a result of change in the watershed or to the stream itself.

To evaluate whether soil loss from streambank erosion may be contributing significantly to suspended sediment load, a random sampling of stream reaches on Getchell, Un-named and Stony Creek were evaluated for stability and amount of observed soil loss by severity. The annual soil loss by mile by stream order was estimated, and the results extrapolated to all streams in the watershed. Streambank soil samples were analyzed to estimate the fraction that would likely remain suspended rather than contribute to bed load.

The annual soil loss by mile was estimated using field collected data and a method developed by the Natural Resources Conservation Service referred to as the "NRCS Direct Volume Method," or the "Wisconsin method," (Wisconsin NRCS 2003). Soil loss is calculated by:

1. measuring the amount of exposed streambank in a known length of stream;
2. multiplying that by a rate of loss per year;
3. multiplying that volume by soil density to obtain the annual mass for that stream length; and then
4. converting that mass into a mass per stream mile.

The Direct Volume Method is summarized in the following equation:

$$\frac{\text{(eroding area) (lateral recession rate) (density)}}{\text{2000 lbs/ton}} = \text{erosion in tons/year}$$

The eroding area is in square feet, the lateral recession rate is in feet/year, and density is in pounds/cubic feet (pcf).

4.2.2.1 Streambank Conditions

The stream network used for this analysis was the Minnesota DNR Stream Order shapefile dated April 2008. This network was derived by the DNR from the 24K stream network. As a first step, GIS analysis identified each quarter section of land in the watershed that contained a segment of stream on the stream order network. Each identified quarter section was assigned a unique number, and a random number generator was used to select quarter sections for evaluation so that a representative number of quarter sections by stream order were selected.

Streams within these randomly selected quarter sections were walked and field evaluated for bank condition and potential risk for and severity of erosion. Not all of the randomly selected quarter sections were evaluated. Some were not accessible, and for others landowner permission was not able to be obtained. A total of 72 quarter sections were selected. Data were available for

41 of those sites. The evaluated sites were geographically dispersed, and included stream segments for stream orders one through four.

The following sections describe how each of the parameters in the Direct Volume equation was estimated for these streams.

Eroding Area

The eroding area is defined as that part of the streambank that is bare, rilled, or gullied, and showing signs of active erosion such as sloughed soil at the base. The length and width of the eroding face of the streambank is multiplied to get an eroded area.

As the evaluators walked each of the randomly-selected quarter sections, each area of significant erosion on either side of the streambank was measured and recorded on a field sheet. Professional judgment was used to determine which areas were significant.

Lateral Recession Rate

The lateral recession rate is the thickness of soil eroded from a streambank face in a given year. Soil loss may occur at an even rate every year, but more often occurs unevenly as a result of large storm events, or significant land cover change in the upstream watershed. Historic aerial or other photographs, maps, construction records, or other information sources may be available to estimate the total recession over a known period of time, which can be converted into an average rate per year. However, these records are often not available, so the recession rate is estimated based on streambank characteristics that evaluate risk potential. Table 4.2 presents the categories of bank condition that are evaluated and the varying levels of condition and associated risk severity score.

Table 4.2 Bank condition severity rating

Category	Observed Condition	Score
Bank Stability	Do not appear to be eroding	0
	Erosion evident	1
	Erosion and cracking present	2
	Slumps and clumps sloughing off	3
Bank Condition	Some bare bank, few rills, no vegetative overhang	0
	Predominantly bare, some rills, moderate vegetative overhang	1
	Bare, rills, severe vegetative overhang, exposed roots	2
	Bare, rills and gullies, severe vegetative overhang, falling trees	3
Vegetation / Cover on Banks	Predominantly perennials or rock	0
	Annuals / perennials mixed or about 40% bare	1
	Annuals or about 70% bare	2
	Predominantly bare	3
Bank / Channel Slope	V-shaped channel, sloped banks	0
	Steep V- shaped channel, near vertical banks	1
	Vertical Banks, U-shaped channel	2
	U-shaped channel, undercut banks, meandering channel	3
Channel Bottom	Channel in bedrock / non-eroding	0
	Soil bottom, gravels or cobbles, minor erosion	1
	Silt bottom, evidence of active down cutting	2
Deposition	No evidence of recent deposition	1
	Evidence of recent deposits, silt bars	0

A Cumulative Rating score of 0-4 indicates a streambank at slight risk of erosion. A score of 5-8 indicates a moderate risk, and 9 or greater a severe risk. The Wisconsin NRCS used its field data from streams in Wisconsin to assign a lateral recession rate for each category (Table 4.3). Professional judgment is necessary to select a reasonable rate within the category.

Table 4.3 Estimated annual lateral recession rates per severity risk category

Lateral Recession Rate (ft/yr)	Category	Description
0.01 - 0.05 feet per year	Slight	Some bare bank but active erosion not readily apparent. Some rills but no vegetative overhang. No exposed tree roots.
0.06 - 0.15 feet per year	Moderate	Bank is predominantly bare with some rills and vegetative overhang. Some exposed tree roots but no slumps or slips.
0.16 - 0.3 feet per year	Severe	Bank is bare with rills and severe vegetative overhang. Many exposed tree roots and some fallen trees and slumps or slips. Some changes in cultural features such as fence corners missing and realignment of roads or trails. Channel cross section becomes U-shaped as opposed to V-shaped.
0.5+ feet per year	Very Severe	Bank is bare with gullies and severe vegetative overhang. Many fallen trees, drains and culverts eroding out and changes in cultural features as above. Massive slips or washouts common. Channel cross section is U-shaped and stream course may be meandering.

At each of the measured erosion areas in the randomly selected quarter sections, evaluators performed the above severity assessment, recorded on the field sheet the score for each of the condition categories above, and commented on features or unusual conditions that would help in selecting an appropriate recession rate. If possible from local conditions, evaluators suggested an estimated observed annual recession rate.

Density

Fourteen streambank soil samples were taken at various locations on Getchell Creek, and the samples analyzed for bulk density, sand/silt/clay fraction, and texture. In addition, at many of the other evaluated locations, soil texture was field evaluated and noted on the field sheet.

4.2.2.2 Annual Streambank Soil Loss

Data were compiled into a spreadsheet database that summarized for each selected quarter section stream length, total eroding area, Bank Condition Severity Rating, and soil texture. Unless a field-observed recession rate was recorded, the selected recession rates in Table 4.4 were applied.

Table 4.4 Assumed recession rate based on bank condition

Bank Condition Severity Rating	Assumed Recession Rate (ft/yr)
≤7	0.1
8-10	0.25
≥11	0.5

The assumed recession rate was multiplied by the total eroding area to obtain the estimated total annual volume of soil loss (Table 4.5). To convert this soil loss to mass, soil texture or actual measured bulk dry density was used to establish a volume weight for the soil. At four locations on Getchell Creek, two to four soil cores were taken from the top of the streambank and sent to a soils lab for analysis. The soil analysis lab report indicated that the bulk density of these samples were lower than was typical. The following volume weights by texture were assumed:

Table 4.5 Assumed recession rates for various soil textures

Soil Texture	Volume-Weight Based On Measured Bulk Density (lbs/cu-ft) (pcf)	Wisconsin NRCS Average Range (lbs/cu-ft) (pcf)	Assumed Volume Weight (lbs/cu-ft) (pcf)
Clay	49-62	60-70	60
Silt		75-90	N/A
Silty Clay			60
Sand	77	90-110	N/A
Sandy Clay			70
Sandy Clay Loam	39-61		N/A
Loam	44	80-100	N/A
Sandy Loam	60-96	90-110	80
Silty Loam			75
No Texture Recorded			70

N/A = No field-identified soil textures of this type.

The total estimated volume of soil per quarter section was multiplied by the assumed volume weight and converted into annual tons. As a final step, the mass was divided by the quarter sections' stream length in miles to obtain an estimated annual soil loss in tons per mile. These data were used to establish a range of annual soil loss by stream order. Some of the evaluated sites with the most severe erosion were estimated to experience annual soil loss at a rate significantly outside the ranges shown below (Table 4.6).

Table 4.6 Estimated range of annual soil loss by stream order based on field evaluation

Stream Order	Soil Loss Range (Tons/Mile/Year)	
	Low Rate	High Rate
1st order	1	3
2nd order	2	10
3rd order	4	7
4th order	5	30

As a final step in the estimation of soil loss from streambank erosion, these rates were applied to all streams in the watershed. Stream length by order was summed for each of the stream basins – Getchell, Un-named and Stony, and the rates applied to estimate the total mass of soil loss (Table 4.7).

Table 4.7 Estimated annual and monthly soil loss in Getchell, Un-named and Stony Creeks

Subbasin and Stream Order	Stream Miles	Estimate Rates (tons/mi/yr)		Annual Soil Loss (ton/yr)		Monthly Soil Loss (ton/yr)	
		Low Rate	High Rate	Low Rate	High Rate	Low Rate	High Rate
Getchell (basins 1-6, 8)							
1st order	52	1	3	52	156	4	13
2nd order	31	2	10	62	310	5	26
3rd order	13	4	7	50	88	4	7
4th order	22	5	30	110	661	9	55
Subtotal	118			275	1,216	23	101
Un-named (basin 14)							
1st order	15	1	3	15	46	1	4
2nd order	5	2	10	10	50	1	4
3rd order	11	4	7	45	78	4	7
4th order	1	5	30	6	37	1	3
Subtotal	33			76	212	6	18
Stony (basins 9,10,12,13)							
1st order	25	1	3	25	76	2	6
2nd order	14	2	10	29	143	2	12
3rd order	8	4	7	30	53	3	4
4th order	4	5	30	19	112	2	9
Subtotal	51			103	383	9	32

In many watersheds with primarily agricultural land use, first order streams tend to be relatively stable grassed swales that function mainly to convey snowmelt and large events. This stream analysis found the first and most of the second order sites to be generally stable, with only a few areas with significant erosion. The streams with the most evidence of erosion and annual soil loss were primarily fourth order stream segments.

4.2.3 Algal and Plant Production

In channel plant and algal production can contribute to turbidity in streams by increasing the amount of in-stream suspended organic particles. However, no volatile suspended solids or chlorophyll-a data are available for the streams. If algal productivity contributed to turbidity violations in the streams, violations would be expected to occur during low and extremely low flows. Although some violations do occur during these flow conditions (Figure 5.1), the majority of exceedances occur during higher flows suggesting that runoff plays a more critical role in turbidity exceedances in Getchell, Un-named and Stony Creek.

4.2.4 Stormwater

Stormwater is another potential source of suspended solids to streams and includes runoff from impervious surfaces, construction activities, and industrial sites. Land use is dominated by agricultural uses and there are no permitted MS4 communities in the watershed. Additionally, there are no industrial sites in the watershed. The only impervious surfaces in the watershed include a low density road network and the few farm buildings that currently exist. Consequently, stormwater is unlikely to be a large source of suspended solids in the watershed.

Interstate 94 does cross the Getchell Creek subwatershed and may contribute sediment to the stream. However, no data are available to assess this potential source. The National Urban Runoff Program measured runoff quality from urban areas had a median value of 100 mg/L TSS which would exceed the established surrogate value for the watershed. However, it is unlikely that this is a significant source to the stream since little or no sand is used on the highway for snow and ice control. Furthermore, it is unclear if drainage from the highway goes directly to the streams or through ponds and wetlands.

4.2.5 Point Sources

Freeport Wastewater Treatment Facility is currently the only point source discharger in the Getchell Creek watershed. Growth of this facility or new facilities would need to discharge at or below the TSS surrogate of 79 mg/L TSS. There are no permitted point source dischargers in the Stony or Un-named Creek watersheds. Similar to Getchell, future point sources would need to discharge at or below the TSS surrogate of 79 mg/L TSS. Because expansions and future discharges also include flow, meeting the designated TSS surrogate would also add to the required assimilative capacity of these streams to meet state standards.

4.3 SOURCE SUMMARY

The potential contribution of sediment to the stream channel from field erosion out-weighed estimated in-channel sediment delivery by almost 10 to 1 suggesting that field erosion is likely a more important source of sediment in Getchell, Un-named and Stony Creek watersheds. However, serious signs of bank failure and erosion suggest that active bank erosion is occurring in all three stream systems. The stream analysis found the first and most of the second order sites to be generally stable, with only a few areas with significant erosion. The streams with the most evidence of erosion and annual soil loss were primarily fourth order stream segments.

Both of these potential sources should be addressed however, field erosion warrants greater attention because of the magnitude of sediment potentially delivered to the stream. Neither point sources nor stormwater are important contributors of suspended particles to either stream. No data is available to assess algal productivity in the stream system, so the importance of algal production is unknown. However, field observations during stream bank stability surveys conducted during the summer low flow season do not suggest that algal productivity is a problem in these streams. Furthermore, few violations occur during the low flow periods in these streams.

5.0 Implementation Activities

This section provides general implementation strategies targeted towards reduction of turbidity in the impaired reach (Un-named Creek) and other non-impaired reaches (Getchell and Stony Creek) of the GUS watershed. Implementation measures are likely to be needed to control erosion and sediment transport from upland areas, stabilize key riparian areas, and perhaps to make adjustments in in-channel processes to control scour and sediment conveyance. Following approval of this TMDL, a more detailed implementation plan will be developed that will result in a customized combination of BMPs to address these components for the TMDL project area.

5.1 BMP GUIDANCE BASED ON AGROECOREGION

Minnesota has 39 agroecoregions. Each agroecoregion is associated with a specific combination of soil types, landscape and climatic features, and land use. Agroecoregions are units having relatively homogeneous climate, soil and landscapes, and land use/land cover. Agroecoregions can be associated with a specific set of soil and water resource concerns, and with a specific set of management practices to minimize the impact of land use activities on soil and water resource quality. Figure 5.1 is a map that shows the agroecoregions that comprise the GUS TMDL project area.

A matrix has been developed by Dr. David Mulla of the University of Minnesota to provide general planning-level guidance on the application of Best Management Practices (BMPs) within each agroecoregion in the state. The BMPs were developed through a focus group process that included experts from the University of Minnesota, Minnesota Pollution Control Agency, Minnesota Department of Agriculture, and the Minnesota Board of Water and Soil Resources. Four broad categories of management practices discussed include nutrient management, vegetative practices, tillage practices, and structural practices. Selection of appropriate management practices for the pollutant(s) of concern depends on site-specific conditions, stakeholder attitudes and knowledge, and on economic factors. This information is intended to be used as a starting point in the development of a custom set of BMPs to reduce sediment generation and transport through improved management of uplands and riparian land within the GUS TMDL project area.

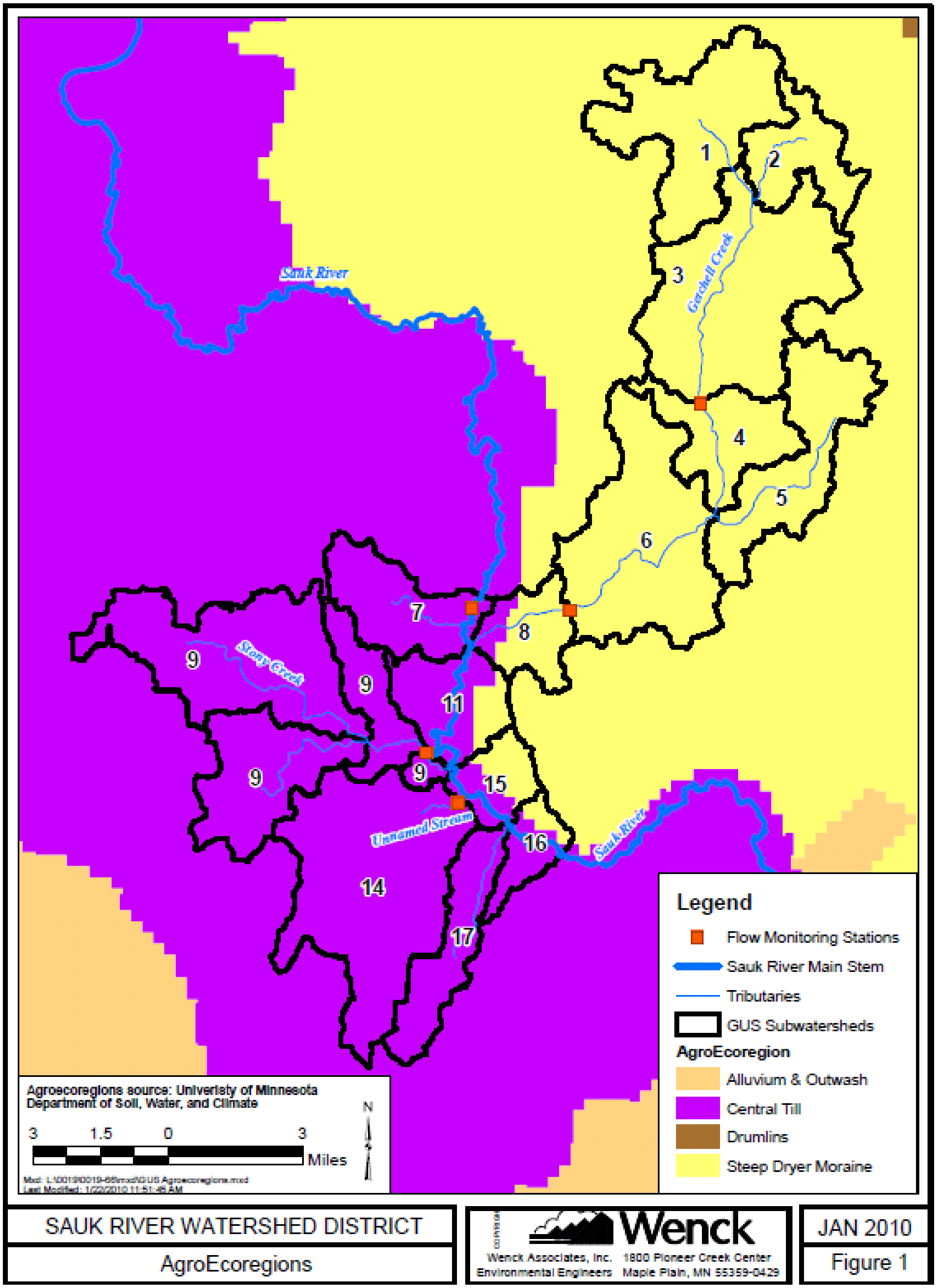


Figure 5.1 Agroecoregions in the GUS TMDL project area

The focus group identified a list of riparian and upland management practices that appear especially appropriate for both the Steep Dryer Moraine and Central Till agroecoregions within which the GUS project area watershed falls. For the purposes of controlling sediment generation and transport to address the turbidity issue, those BMPs noted under the Vegetative, Primary Tillage, and Structural Practices categories apply most directly to the turbidity TMDL including:

Vegetative Practices

- Contour farming
- Strip cropping
- Grassed waterways
- Grass filter strip for feedlot runoff
- Forest management practices
- Alternative crop in rotation
- Field windbreak
- Pasture management (IRG)
- CRP or CREP

Primary Tillage Practices

- Chisel Plow
- One pass tillage
- Ridge till
- Sustain surface roughness

Structural Practices

- Wetland restoration
- Livestock exclusion
- Liquid manure waste facilities

A brief summary of each type of practice as it applies to the GUS TMDL watershed follows.

5.1.1 Vegetative management practices

Vegetative practices include those focusing on the establishment and protection of crop and non-crop vegetation to minimize sediment mobilization from agricultural lands and decrease sediment transport to receiving waters. The recommended cropping practices are designed in part to slow the speed of runoff over bare soil to minimize its ability to entrain sediment. Grassed waterways and grass filter strips provide settling of entrained sediment which gets incorporated into both the soil and vegetation. Other practices, such as alternative crop rotations, forest management, and field windbreaks are designed to minimize exposure of bare soils to wind and water which can transport soil off-site. Pasture management often emphasizes rotational grazing techniques, where pastures are divided into paddocks, and the livestock moved from one paddock to another before forage is over-grazed. As livestock are moved frequently, forage is able to survive. Maintaining the vegetation, as opposed to bare soil, allows for greater water infiltration, reducing runoff and associated sediment transport.

There are a number of programs available to compensate land owners for moving environmentally sensitive cropland out of production for varying periods of time. These include the Conservation Reserve Program (CRP), Re-Invest in Minnesota (RIM) Reserve Program, and the Conservation Reserve Enhancement Program-Minnesota II (CREP-II). Anticipated benefits in reducing soil erosion and improving water quality are key considerations in deciding what lands can be enrolled in each program.

5.1.2 Primary Tillage Practices

Certain kinds of tillage practices can significantly reduce the generation and transport of soil from fields. Conservation tillage techniques emphasize the practice of leaving at least some vegetation cover or crop residue on fields as a means of reducing the exposure of the underlying soil to wind and water which leads to erosion. If it is managed properly, conservation tillage can reduce soil erosion on active fields by up to two-thirds (Randall et. al. 2002).

5.1.3 Structural Practices

Structural practices emphasize elements that generally require a higher level of site-specific planning and engineering design. Most structural practices focus on watershed improvements to decrease sediment loading to the receiving water. For example, restoration of wetlands can create a natural method of slowing overland runoff and storing runoff water, which can both reduce channel instability and flooding downstream. In addition, the quiescent conditions of a wetland mean that they can be effective at settling out sediment particles in the runoff that reaches them, although accumulation of too much sediment too rapidly can compromise other important functions of the wetland. Livestock exclusion involves fencing or creating other structural barriers to limit or eliminate access to stream by livestock, and may involve directing livestock to an area that is better designed to provide limited access with minimal impact.

5.1.4 Stream and Channel Restoration

Other practices which may be considered for the GUS project area involve making improvements to the structure of the receiving water to improve stability and decrease in-stream sources of sediment. In-stream structures need to be carefully designed to direct flow where appropriate under a wide range of discharge conditions and make sure that solution of one channel stability problem doesn’t create another elsewhere. Also important is, where possible, making sure that the main stream channel can overflow into its floodplain at high flows to allow the stream to temporarily store water outside the streambank, reducing flow velocity and excessive scouring of the channel. Intact natural vegetation in the floodplain also acts to slow flow velocities and encourages deposition and permanent capture of sediment.

5.2 ADAPTIVE MANAGEMENT

This list of implementation elements and the more detailed implementation plan that will be prepared following this TMDL assessment focuses on adaptive management (Figure 5.2). As the sediment dynamics within the watershed are better understood, management activities will be changed or refined to efficiently meet the TMDL and lay the groundwork for de-listing the impaired reaches. Because there are no known point sources in the project area watershed, the implementation elements will focus exclusively on non-point source controls.

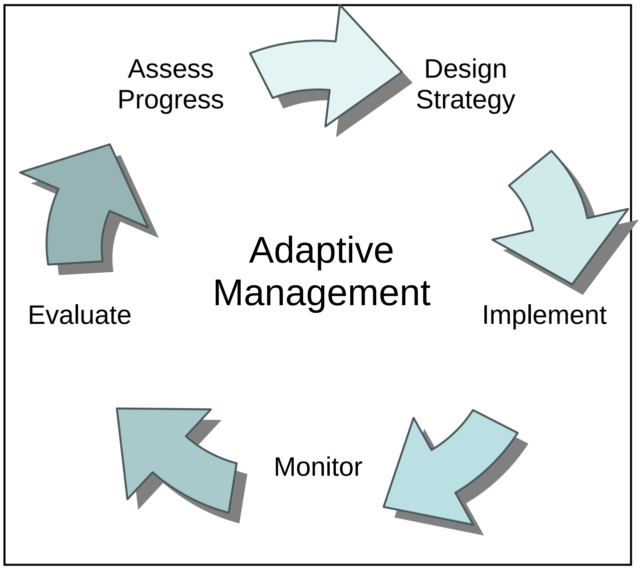


Figure 5.2 Adaptive management.

6.0 Reasonable Assurance

Introduction

As a requirement of TMDL studies, reasonable assurance must be provided demonstrating the ability to reach and maintain water quality endpoints. The source reduction strategies detailed in Section 5 have been shown to be effective in reducing turbidity in receiving waters. It is reasonable to expect that these measures will be widely adopted by landowners and resource managers, in part because they have already been implemented in some parts of the watershed over the last 20 years.

Many of the goals outlined in this TMDL study are consistent with objectives outlined in the Stearns County Comprehensive Local Water Management Plan and the Sauk River Watershed District Watershed Management Plan. These plans have the same objective of developing and implementing strategies to bring impaired waters into compliance with appropriate water quality standards and thereby establish the basis for removing those impaired waters from the 303(d) Impaired Waters List. These plans provide the watershed management framework for addressing water quality issues. In addition, the stakeholder processes associated with both this TMDL effort as well as the broader planning efforts mentioned previously have generated commitment and support from the local government units affected by this TMDL and will help ensure that this TMDL project is carried successfully through implementation.

Various technical and funding sources will be used to execute measures detailed in the implementation plan that will be developed within one year of approval of this TMDL. Technical resources include the Sauk River Watershed District and Stearns County Soil and Water Conservation District as well as the Minnesota Department of Natural Resources. Funding resources include a mixture of state and federal programs, including (but not limited to) the following:

- Conservation Reserve Program
- Federal Section 319 program for watershed improvements
- Funds ear-marked to support TMDL implementation from the Clean Water, Land, and Legacy constitutional amendment, approved by the state's citizens in November 2008.
- Sauk River Watershed District program funds
- Local government cost-share funds

Finally, it is a reasonable expectation that existing regulatory programs such as those under NDPES will continue to be administered to control discharges from industrial, municipal, and construction sources as well as large animal feedlots that meet the thresholds identified in those regulations.

Following is a discussion of the key agencies at the local level that will help assure that implementation activities proposed under this TMDL will be executed.

6.1 SAUK RIVER WATERSHED DISTRICT

The Sauk River Watershed District (SRWD) has been active in water resources management and protection since it was formed in 1986. The SRWD current watershed management plan identifies the following major roles for the District:

1. Collection of monitoring data, with an emphasis on collection of a comprehensive set of surface water quality data to support diagnostic studies.
2. Development and implementation of a regulatory program that requires a permit from the SRWD for:
   a. The development or redevelopment of properties which create greater than one acre of impervious.
   b. Land disturbance within 500 feet of water bodies or wetlands.
   c. Work in the ROW of any legal drainage system
   d. Construction, installation or alteration of certain water control structures
   e. Diversion of water into a different sub-watershed or county drainage system
3. Providing technical assistance to landowners, farmers, businesses, lake associations, cities, townships, counties, state agencies, and school districts. Much of this technical assistance pertains to planning and installing best management practices for water quality protection and improvement.
4. Implementation of capital improvements.
5. Public education.

In March of 2010, the SRWD concluded the process of updating its rules, including addition of new requirements for stormwater runoff management, erosion control, drainage and water use. The SRWD will also begin working on updating its existing watershed management plan, the term for which currently extends from 2003-2012. This will provide the opportunity to more closely link SRWD policies, programs and projects with implementation of TMDLs affecting its jurisdiction, including the GUS TMDL.

6.2 STEARNS COUNTY COMPREHENSIVE LOCAL WATER MANAGEMENT PLAN

Stearns County, within which the project area watershed lies, has adopted a county water plan that articulates goals and objectives for water and land-related resource management initiatives. The adopted plan is for the time period 2008-2017. Completion of TMDL assessments of impaired waters within the county was identified as one of the top three priorities in the plan. In addition, the implementation section of the plan focuses on a number of areas important in restoring impaired waters to a non-impaired status, including:

1. Support and cooperate with watershed districts and the Minnesota Pollution Control Agency on on-going TMDL projects.
2. Educate feedlot owners on proper feedlot management, including manure storage and application, for the purpose of meeting regulatory requirements.
3. Provide information, technical and/or financial assistance to County landowners implementing agricultural BMPs on working lands to reduce soil erosion, protect streambanks, and improve water resources.
4. Actively promote and market federal/state/local conservation programs to targeted landowners and help prepare them for eligibility in program such as CSP and EQIP.
5. Promote and market conservation programs that provide cost-share and assistance to livestock producers for the adoption of comprehensive nutrient management plans.
6. Ensure the proper use and abandonment of manure pits.
7. Continue to inspect feedlots and work with owner/operators to bring their facilities into compliance, with those feedlots that are within identified TMDL watersheds having priority.
8. Promote and establish buffers on public and private ditches
9. Establish and maintain vegetative buffers in accordance with existing Stearns County Land Use and Zoning Ordinance #209 and MN Rules 61.20.3300 Subpart 7.

6.3 STEARNS COUNTY SOIL AND WATER CONSERVATION DISTRICT

The purpose of the Stearns County Soil and Water Conservation District (SWCD) is to plan and execute policies, programs, and projects which conserve the soil and water resources within its jurisdictions. It is particularly concerned with erosion of soil due to wind and water. The SWCD is heavily involved in the implementation of practices that effectively reduce or prevent erosion, sedimentation, siltation, and agricultural-related pollution in order to preserve water and soil as resources. The District frequently acts as local sponsor for many types of projects, including grassed waterways, on-farm terracing, erosion control structures, and flow control structures. The SRWD has established close working relationships with the SWCD on a variety of projects. One example is the conservation buffer strip cash incentives program that provides cash incentives to create permanent grass buffer strips adjacent to water bodies and water course on land in agricultural use. The SRWD currently participates in the program by providing matching grants and will work to target such practices in the GUS TMDL watershed so that the practices are implemented as cost effectively as possible to achieve the load reduction required in the TMDL.

6.4 MONITORING

Two types of monitoring are necessary to track progress toward achieving the load reduction required in the TMDL and the attainment of water quality standards. The first type of monitoring is tracking implementation of Best Management Practices and capital projects. The Sauk River Watershed District and the Stearns County Soil and Water Conservation District will track the implementation of these projects annually. The second type of monitoring is physical and chemical monitoring of the resource. The Sauk River Watershed District plans to monitor the affected resources routinely.

This type of effectiveness monitoring is critical in the adaptive management approach. Results of the monitoring identify progress toward benchmarks as well as shape the next course of action for implementation. Adaptive management combined with obtainable benchmark goals and monitoring is the best approach for implementing TMDLs.

7.0 Public Participation

As part of the strategy to achieve implementation of the necessary allocations, the Sauk River Watershed District (SRWD) held a public meeting in December, 2008. The purpose of this meeting was to inform the general public and stakeholders about the TMDL process, preliminary results of the Un-named Creek TMDL study, and turbidity assessments of Getchell and Stony Creeks. The SRWD will be conducting stakeholder meetings following the draft TMDL to update residents on the results and the approval process. In addition to the public meetings the SRWD intends to publish these results and project updates in their annual newsletter as they have done on past TMDL studies in addition to their website (www.srwdmn.org). The SRWD's Board of managers and Stearns County Soil and Water Conservation District staff have also made efforts to discuss the TMDL process and findings with their constituents and local landowners.

8.0 References

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

MPCA. 2008. Development of Total Suspended Solids (TSS) Surrogates for Turbidity in the Minnesota River Basin. Technical Memorandum.

Randall, G. 2002. Tillage Best Management Practices for Water Quality Protection in Southeastern Minnesota. University of Minnesota Extension Service.

Wenck 2009. North Fork Crow River Bacteria and Turbidity TMDLs – Summary of Preliminary Findings. Technical Memorandum to the Crow River Organization of Water.

Wisconsin NRCS. 2003. Field Office Technical Guide: Stream Erosion. <<http://www.dnr.wi.gov/runoff/pdf/grants/mso341_streambank.pdf>>

Appendix A

North Fork Crow River TSS Surrogate Analysis

Wenck Engineers • Scientists

Wenck Associates, Inc.
1800 Pioneer Creek Center
Maple Plain, MN 55359
(763) 479-4200
Fax (763) 4242
E-mail: wenckmp@wenck.com

Wenck Associates, Inc.
1802 Wooddale Drive, Suite 100
Woodbury, MN 55125
(651) 294-4580
Fax (651) 228-1969

TECHNICAL MEMORANDUM

TO: Diane Sander, CROW Watershed Coordinator

FROM: Rich Brasch
Jeff Strom
Joe Bischoff

DATE: June 11, 2009

SUBJECT: North Fork Crow River Bacteria and Turbidity TMDLs – Summary of Preliminary Findings

CC:

The purpose of this memo is to summarize information and data gathered for the North Fork Crow River bacteria and turbidity TMDL project. The information is intentionally presented in a format suitable for incorporation into the draft TMDL report.

1.0 Background Information

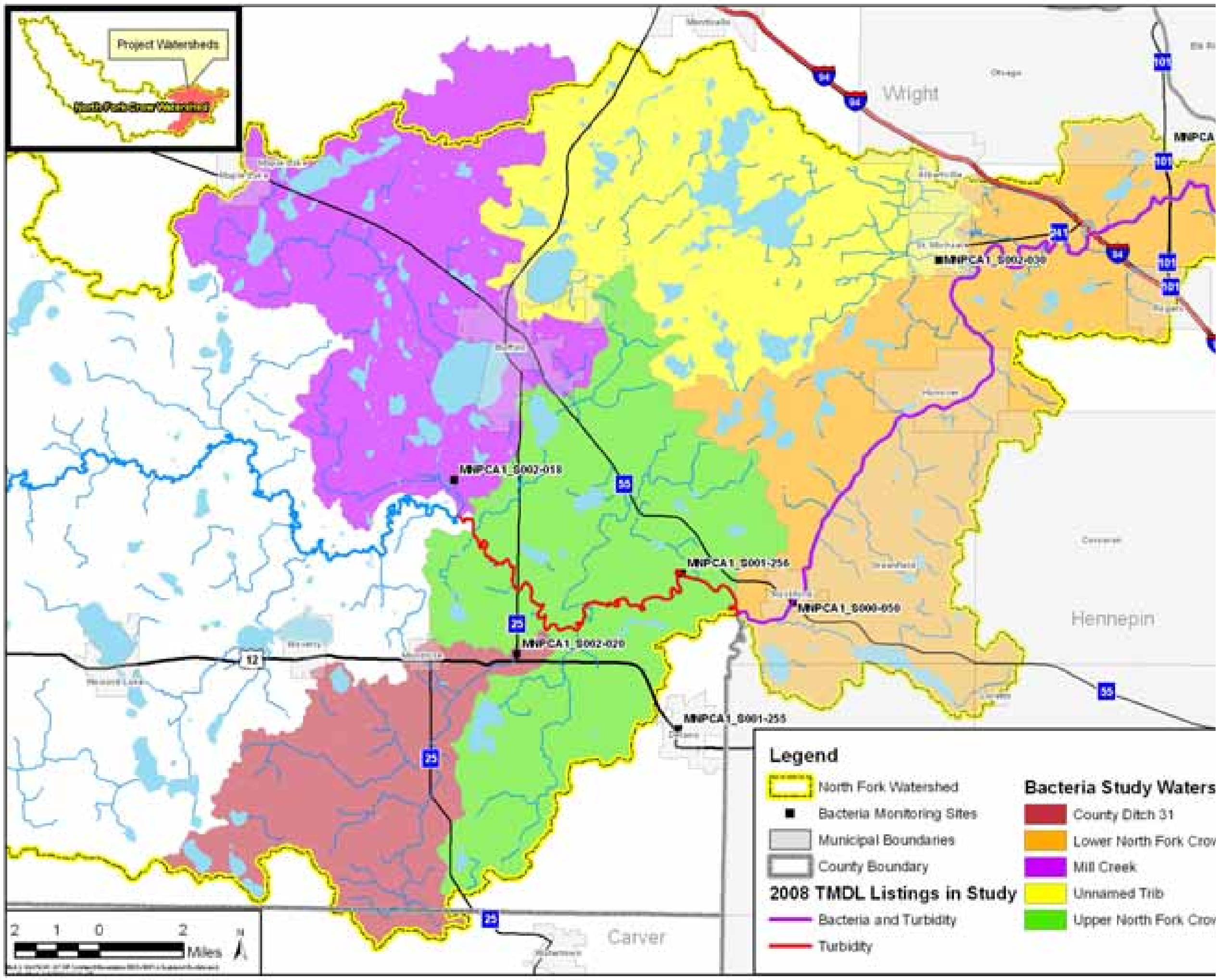
This TMDL effort applies to the turbidity impairment for the North Fork of the Crow River watershed from Mill Creek to the South Fork of the Crow River and both bacteria and turbidity impairments in the River from its junction with the South Fork of the Crow River to the Mississippi River (Table 1).

Table 1 – N. Fork Crow River Watershed Bacteria and Turbidity Impairments

Reach Name on 303(d) List/Description	Yr[12]	Assessment Unit ID[10]	Affected use	Pollutant or stressor[3]	Target start// completion[7]
Crow River, South Fk Crow R to Mississippi R	04	07010204-502	Aquatic recreation	Fecal coliform/E. coli	2006//2012
Crow River; South Fk Crow R to Mississippi R	02	07010204-502	Aquatic life	Turbidity	2006//2012
Crow River, North Fk; Mill Cr to South Fk Crow R	04	07010204-503	Aquatic life	Turbidity	2006//2012

Figure 1 shows the impaired reaches in the watershed along with the locations of key monitoring sites. The data from these sites served as the basis of the impairment determination and will be used to provide information to support the development of the TMDL.

Figure 1- Impaired Reaches and Key Monitoring Sites – N. Fork Crow River Project Area



2.0 Applicable Water Quality Standards

This TMDL addresses exceedances of the state standard for fecal coliform bacteria and turbidity in the North Fork Crow River watershed of Minnesota. A discussion of water classes in Minnesota and the standards for those classes is provided 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 resources value

According to Minn. Rules Ch. 7050.0470, the impaired reaches covered in this TMDL are assigned use classifications of 2B, 3B, 4A, 5 and 6 as unlisted water. These classifications include consideration for aquatic life and recreation, industrial consumption, agriculture and wildlife, aesthetic enjoyment and navigation, and other beneficial uses not specifically listed. Chapter 7050 contains general provisions, definitions of water use classes, specific standards of quality and purity for classified waters of the state, and the general and specific standards for point source dischargers to waters of the state.

The designated beneficial use for 2B waters (the most protective use class) is as follows:

> **Class 2 waters, aquatic life and recreation**. Aquatic life includes all waters of the state which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes, and where quality control is or may be necessary to protect aquatic or terrestrial life or their habitats, or the public health, safety, or welfare.

2.1 Fecal Coliform Bacteria and E. coli

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 bacteria in water suggests the presence of fecal matter and associated bacteria (i.e. some strains of *E. coli*), viruses, and protozoa (i.e. Giardia and Cryptosporidium) that are pathogenic to humans when ingested (USEPA 2001). The decision to list the reaches identified was originally based on a fecal coliform standard, which was in effect prior to the most recent rule revision in 2008. The fecal coliform standard contained in Minn. Rules Ch. 7050.0222 subpart 5, fecal coliform water quality standard for Class 2B waters, stated that fecal coliform concentrations shall "not exceed 200 organisms per 100 milliliters as a geometric mean 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 2005). With the revisions of Minnesota's water quality rules in 2008, the state has changed to an *E. coli* standard because *E. coli* is a superior indicator of potential illness and the costs for lab analysis to detect *E. coli* can be substantially less than for fecal coliform (MPCA 2007). The state standard for *E. coli* of 126 cfu/100 ml was adopted and was considered reasonably equivalent to the fecal coliform standard of 200 cfu/100 ml from a public health protection standpoint. Further, the SONAR (Statement of Need and Reasonableness) section that supports the rationale for the change in the standard contains a log plot of paired fecal coliform and *E.coli* data that was cited as being a reasonable basis to convert fecal coliform concentrations into *E. coli* concentrations (MPCA 2007). The relationship has an R^2 of 0.6887 and the equation generated by the regression is $y = 1.7993x^{0.8057}$ where y is the *E. coli* concentration and x is the fecal coliform concentration. Where fecal coliform data is converted to *E. coli* data in this memo, this is the equation used to make that conversion.

2.2 Turbidity

Turbidity in water is caused by suspended sediment, organic material, dissolved salts, and stains that scatter light in the water column, making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, increase the cost of treatment for drinking water or food processing uses, and harm aquatic life. Adverse ecological impacts caused by excessive turbidity include hampering the ability of aquatic organisms to visually locate food, negatively affecting gill function, and smothering of spawning beds and benthic organism habitat

The turbidity standard found in Minn. R. 7050.0222 subpart 5 for 2B and 3B water is 25 nephalometric turbidity units (NTUs). Impairment assessment procedures for turbidity are provided in the guidance manual cited above. The water body is added to the impaired waters list when greater than ten percent of the 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). This TMDL is written for Class 2 waters as this is the more protective class

3.0 North Fork Crow River Watershed Geographic Location and Project Area Boundaries

The headwaters for the North Fork Crow River are located in Pope County, at Grove Lake. The North and South Forks of the Crow River converge in Rockford, Minnesota to become the Crow River. The Crow River flows northeast along the borders of Wright and Hennepin Counties until it empties in to the Mississippi River near Dayton, Minnesota. This area of the River is locally referred to as the North Fork - Lower Crow. However, the United States Geological Service includes the North Fork - Lower Crow River as part of the North Fork Watershed. For the purposes of this memo, we will refer to the river from it's headwaters to its junction with the Mississippi River as the North Fork Crow River.

The total watershed area of the North Fork Crow River watershed at its junction with the Mississippi River is approximately 1.77 million acres in area. The project area is comprised of the watershed area that discharges to the North Fork Crow River in the impaired reach of the River between its junction with Mill Creek to the its mouth at the Mississippi River. This area is approximately 185,000 acres. All of the project area is located within the North Central Hardwood Forest (NCHF), where the topography ranges from nearly flat to rolling to steep sloped.

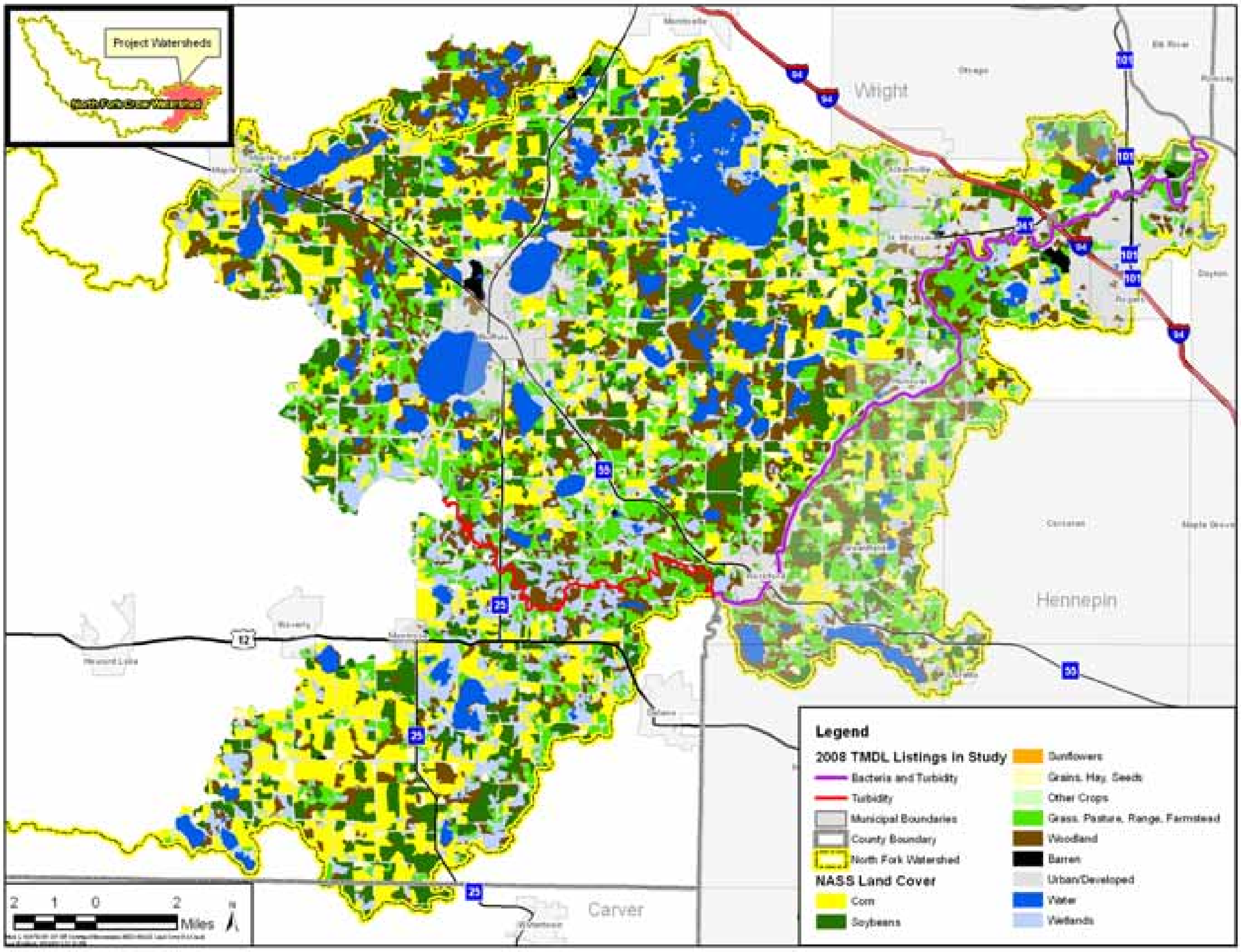
3.1 Land Cover

The land cover of the North Fork Crow River project area watershed as provided by the National Agricultural Statistics Service (NASS) is shown in Figure 2. Table 2 presents the number of acres of each land cover type within the project area watershed in 2007.

Table 2-Watershed Land Cover by Type

Land Cover Category	***Area (acres)***	***Percent***
Corn	26,805	14.5
Soybeans	21,897	11.8
Other cropland	10,228	5.5
Grass Pasture (non-ag)	5,156	2.8
Woodland/Forest	30,550	16.5
Barren and shrubland	2,944	1.6
Developed Urban	25,228	13.6
Water	16,585	9.0
Wetlands	36,963	20.0
Other	8,789	4.7
TOTAL	185,145	100%

Figure 2-Land Cover in the North Fork Crow River Project Area



4.0 Data Sources

All sample data supporting the analyses presented in the following sections was secured from the STORET data base. Table 3 summarizes the bacteria data by monitoring site in upstream to downstream order and Table 4 does the same for the turbidity data.

Table 3 - Bacteria Data by Monitoring Site

STORET ID/Station Description	Parameter	Years	N	Paired
S002-019-N. Fk. Crow above Mill Creek	Fecal Coliform	01	3	None
	E. Coli	08	15	
S002-018-Mill Creek (trib. To N. Fk. Crow)	Fecal Coliform	03	1	None
	E. Coli	07-08	26	
S002-020- Un-named Creek (trib. To N. Fk. Crow)	Fecal Coliform	03	2	None
	E. Coli	07-08	31	
S001-256-N. Fk. Crow above S. Fk. Crow	Fecal Coliform	01-03	12	7
	E. Coli	02,07-08	44	
S000-050-N. Fk. Crow at Rockford	Fecal Coliform	01,03	5	8
	E. Coli	07-08	26	
S002-030- Un-named Creek (trib. To N. Fk. Crow)	Fecal Coliform	03	1	None
	E. Coli	07-08	31	
S000-004-N. Fk. Crow near junction with Mississippi River	Fecal Coliform	00-02,04	12	10
	E. Coli	00-02,04-07	29	

Table 4 - Turbidity Data by Monitoring Site

STORET ID/Station Description	Turbidity Method	Year(s)	N
S002-018-Mill Creek (trib. To N. Fk. Crow)	NTU	01,03	8
	NTRU	--	--
	Field (FNU)	07-08	11
S002-020- Un-named Creek (trib. To N. Fk. Crow	NTU	03	2
	NTRU	--	--
	Field (FNU)	07-08	10
S001-256-N. Fk. Crow above S. Fk. Crow	NTU	01,03	19
	NTRU	98,01,02,06	10
	Field (FNU)	02,07-08	26
S000-050-M. Fk. Crow	NTU	01,03	20

at Rockford	NTRU	99-02,06	23
	Field (FNU)	00,02	9
S002-030- Un-named Creek (trib. To N. Fk. Crow)	NTU	01,03	5
	NTRU	--	--
	Field (FNU)	07-08	10
S000-004-N. Fk. Crow near junction with Mississippi River	NTU	--	--
	NTRU	98-02	25
	Field (FNU)	01,02,04,05,07	18

A summary of flow data available by site is also presented in Table 5.

Table 5 - Discharge Data by Monitoring Site

STORET ID	Location	DNR ID	USGS ID	Provider	Years of Operation	Flow Record Length (days)	Notes
S000-050	N. Fork Crow River at Rockford	18087001	05280000	USGS	1906 - Present	39373	
S001-256	N. Fork Crow River west of Rockford, Farmington Ave	18088001	05278400	DNR/PCA	02, 04-06, 08	708	08 data only Sep-Oct
S001-517	N. Fork Crow River near Cokato, CSAH 4	18083001	--	DNR/PCA	08	295	Outside of listed area
S001-255	S. Fork Crow River at Delano, Bridge St	19001001	05279400	DNR/PCA	03, 05, 06, 08	1083	Outside of listed area

5.0 Fecal Coliform Bacteria

5.1 Surface Water Quality Conditions

As mentioned previously in this report, the reach of the North Fork Crow River from its junction with the South Fork to its junction with the Mississippi River has been listed as impaired for fecal coliform bacteria. Table 6 summarizes the fecal coliform and *E. coli* bacteria available for the project area, showing the total number of samples and the total number of exceedances for each type of bacteria by station.

Table 6- Bacteria Data Summary by Monitoring Station

Monitoring Site	Parameter	# Samples	# Samples Showing Exceedances
S002-019 – N. Fk Crow above Mill Creek	Fecal coliform	3	1
	E. coli	15	3
S002-018 – Mill Creek	Fecal coliform	1	0
	E. coli	26	6
S002-020 – Un-named Creek (trib to N. Fk Crow)	Fecal coliform	1	0
	E. coli	32	21
S001-256 – N. Fk. Crow above	Fecal coliform	5	3

S. Fork, Rockford	*E. coli*	44	10
S001-255 – S. Fk. Crow at Delano	Fecal coliform	5	2
	E. coli	26	12
S000-050 – N. Fk. Crow at Rockford	Fecal coliform	6	2
	E. coli	8	4
S002-030 – Un-named Creek (trib to N. Fk. Crow)	Fecal coliform	1	1
	E. coli	31	21
S000-004 – N. Fk. Crow near junction with Mississippi R.	Fecal coliform	2	0
	E. coli	29	4
TOTAL		235	90

Data were analyzed by season to see if seasonal patterns exist. Table 7 presents the number and geometric mean of data points collected at each of the above monitoring sites by season by type of bacteria.

Table 7 - Seasonal Bacteria Concentrations by Monitoring Station

Site	Parameter	Spring (April-May)		Summer (June-Aug)		Fall (Sept-October)		Total	
		N	Geomean	N	Geomean	N	Geomean	N	Geomean
S002-019 – N. Fk Crow above Mill Creek	Fecal coliform	0	-	3	114	0	-	3	114
	E. coli	6	13	7	140	2	94	15	51
S002-018 – Mill Creek (trib to N. Fk. Crow	Fecal coliform	0	-	1	140	0	-	1	140
	E. coli	9	6	12	84	4	312	25	42
S002-020 – Un-named Creek (trib to N. Fk Crow)	Fecal coliform	0	-	1	130	0	-	1	130
	E. coli	11	31	18	424	3	349	32	169
S001-256 – N. Fk. Crow above S. Fork, Rockford	Fecal coliform	0	-	5	258	0	-	5	258
	E. coli	11	18	26	91	7	98	44	61
S001-255 – S. Fk. Crow at Delano	Fecal coliform	0	-	5	497	0	-	5	497
	E. coli	8	20	15	169	3	84	26	81
S000-050 – N. Fk. Crow at Rockford	Fecal coliform	2	14	4	290	0	-	6	106
	E. coli	0	-	6	160	2	69	8	130
S002-030 – Un-named Creek (trib to N. Fk. Crow)	Fecal coliform	0	-	1	1100	0	-	1	1100
	E. coli	11	62	15	445	5	349	32	169
S000-004 – N. Fk. Crow near junction with Mississippi R.	Fecal coliform	0	-	2	76	0	-	2	76
	E. coli	7	16	12	61	9	38	29	32

A preliminary analysis of the bacterial data was conducted to try to characterize the potential sources of the bacteria loadings causing the impairments. For this analysis, we used both raw *E. coli* data as well as fecal coliform data converted to *E. coli* equivalents. We considered using project area specific relationships between *E. coli* and fecal coliform to make this conversion. There were 25 samples-virtually all of them collected between May and September 2002- that were analyzed for both fecal coliform and *E. coli* in the project area data set. Log plots of the paired *E. coli*/fecal coliform data for the project area yielded an excellent fit (R-squared of 0.93), but generated an *E. coli* equivalent of 184 CFU/100 ml for the 200 cfu/100 ml fecal coliform standard, apparently due to the influence of several high values. Thus, we elected to use the regression equation provided in the SONAR supporting the state standard of 126 cfu/100 ml *E. coli* (see Section 2.1 of this memo) to make the conversions.

Figures 3 through 10 show bacteria concentration data (raw *E. coli* data as well as fecal coliform data converted to *E. coli* equivalents using the SONAR regression relationship) plotted by flow frequency regime for the above monitoring stations. Flow regimes were established using flow records between April 2001 and October 2008 at monitoring station S001-050 in Rockford. The bacteria concentration data for each of the stations was collected between June 2000 and September 2008.

Figure 3 - Station S002-019 (N. Fk Crow above Mill Creek) *E. coli* Concentrations by Flow Regime

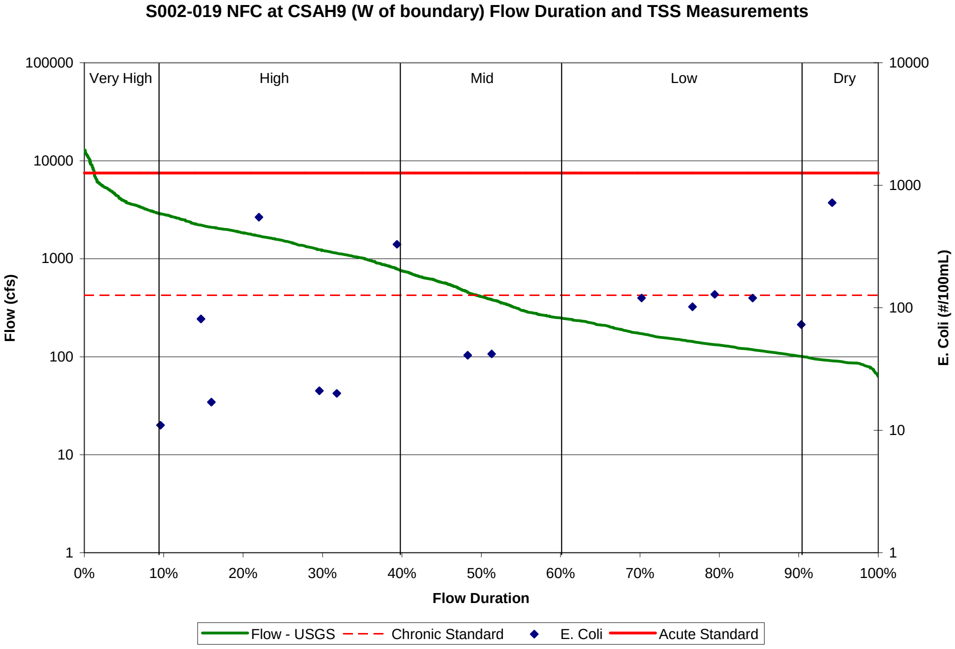


Figure 4 - S002-018 (Mill Creek) *E. coli* Concentrations by Flow Regime

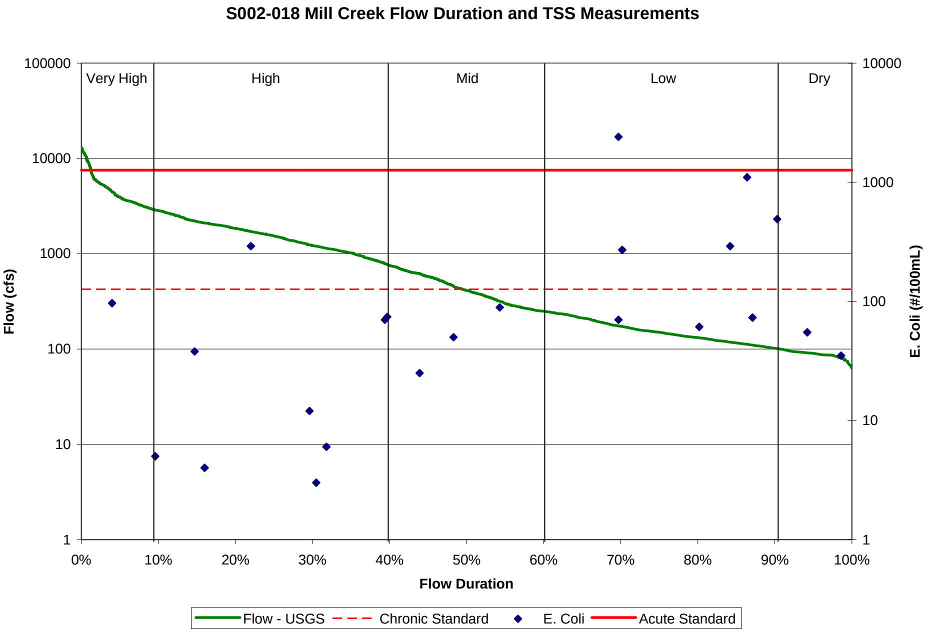


Figure 5 - S002-020 (Un-named Creek) *E. coli* Concentrations by Flow Regime

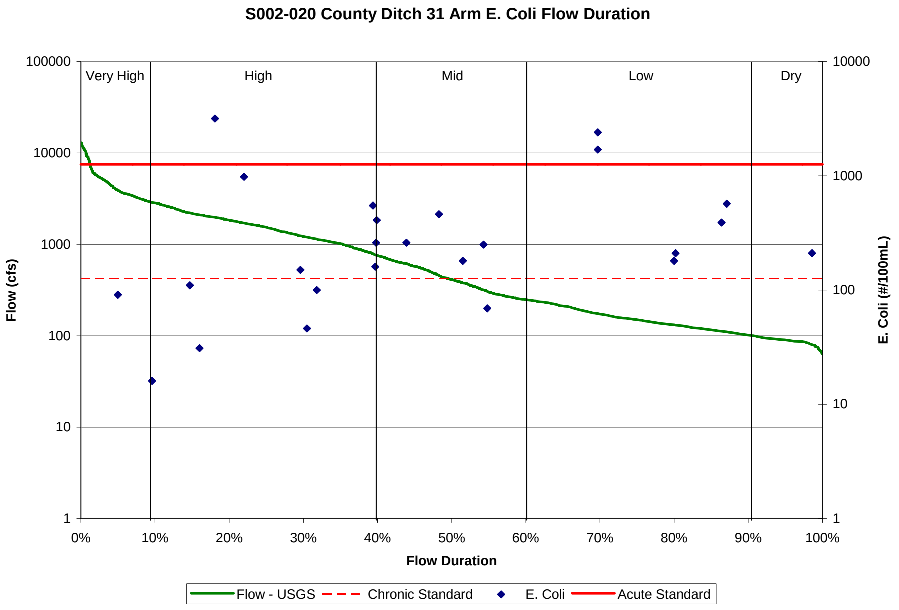


Figure 6 - S001-256 – (N.Fk. Crow above S. Fork, Rockford) *E. coli* Concentrations by Flow Regime

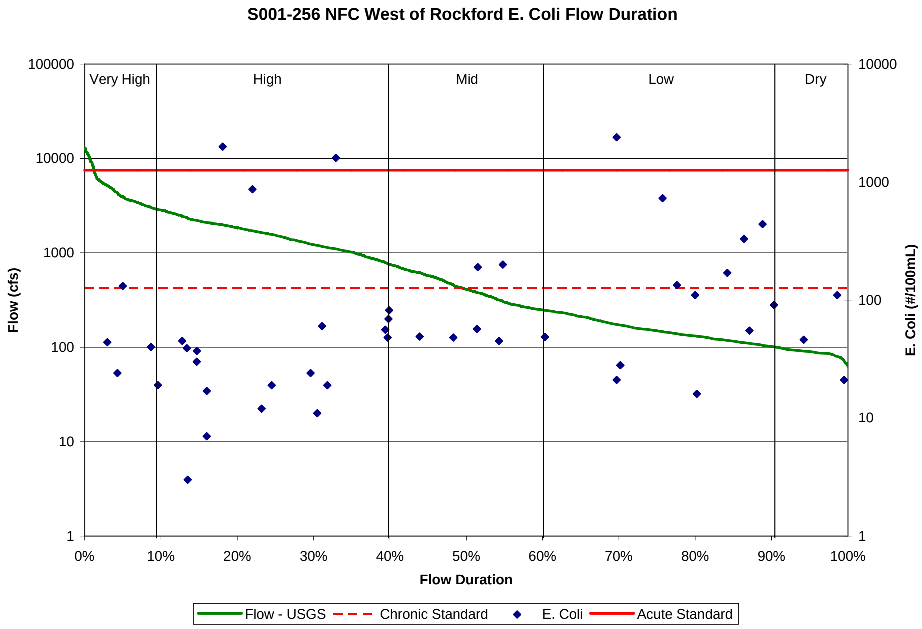


Figure 7 - S001-255 (S. Fk. Crow at Delano) *E. coli* Concentrations by Flow Regime

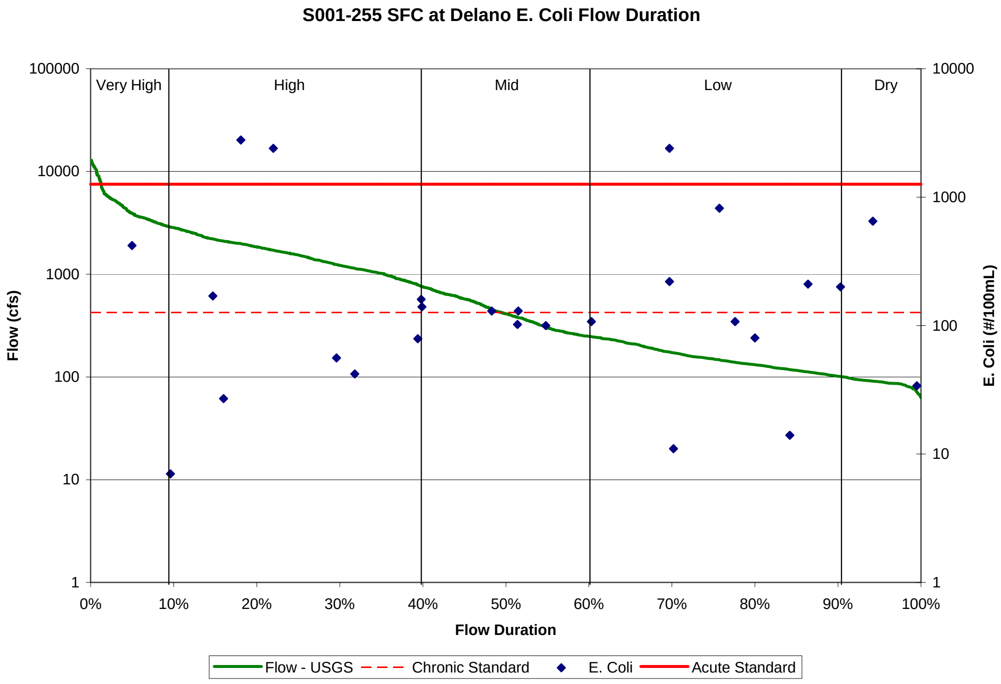


Figure 8 - S000-050 (N. Fk. Crow at Rockford) *E. coli* Concentrations by Flow Regime

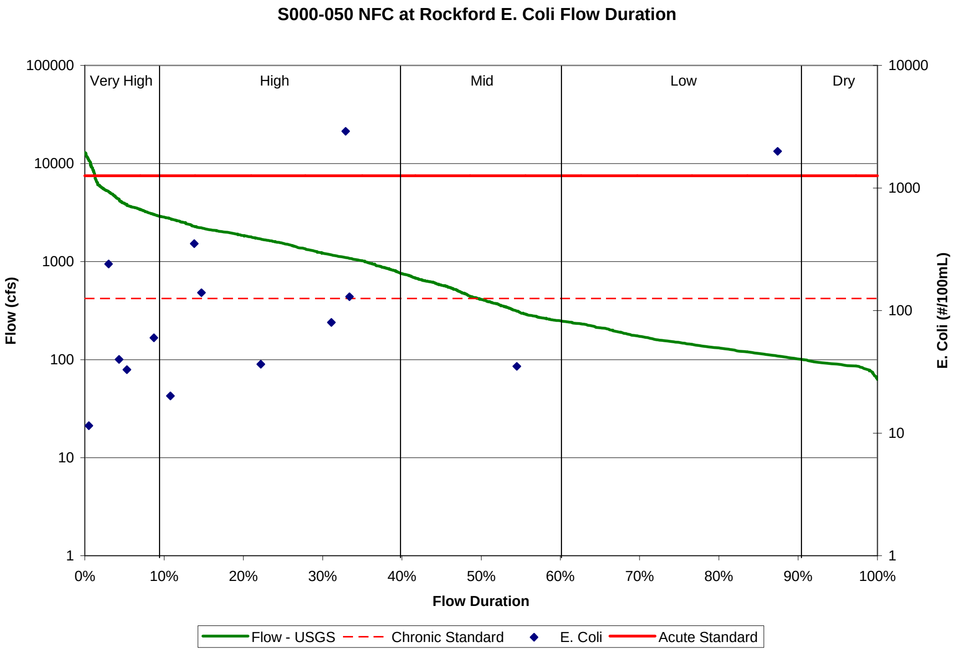


Figure 9 - S002-030 (Un-named Creek) *E. coli* Concentrations by Flow Regime

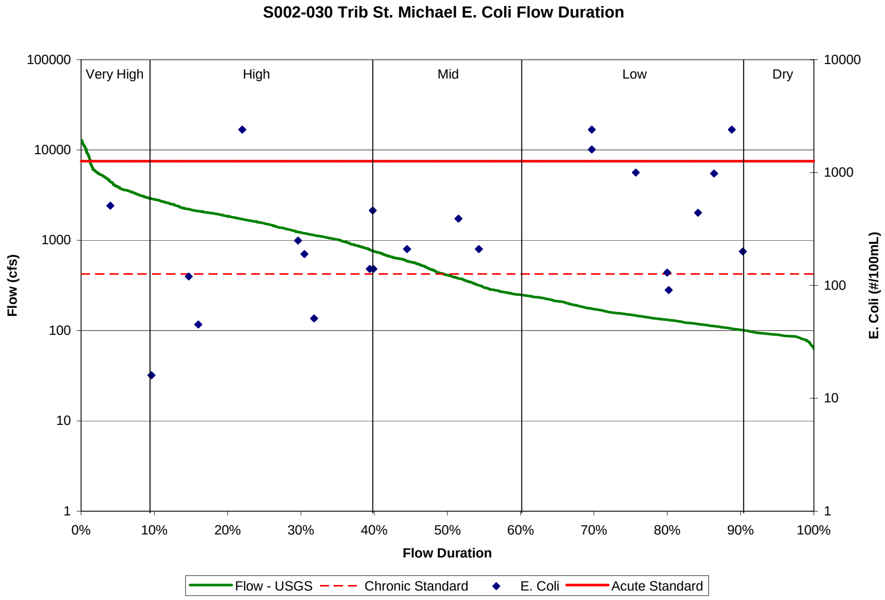
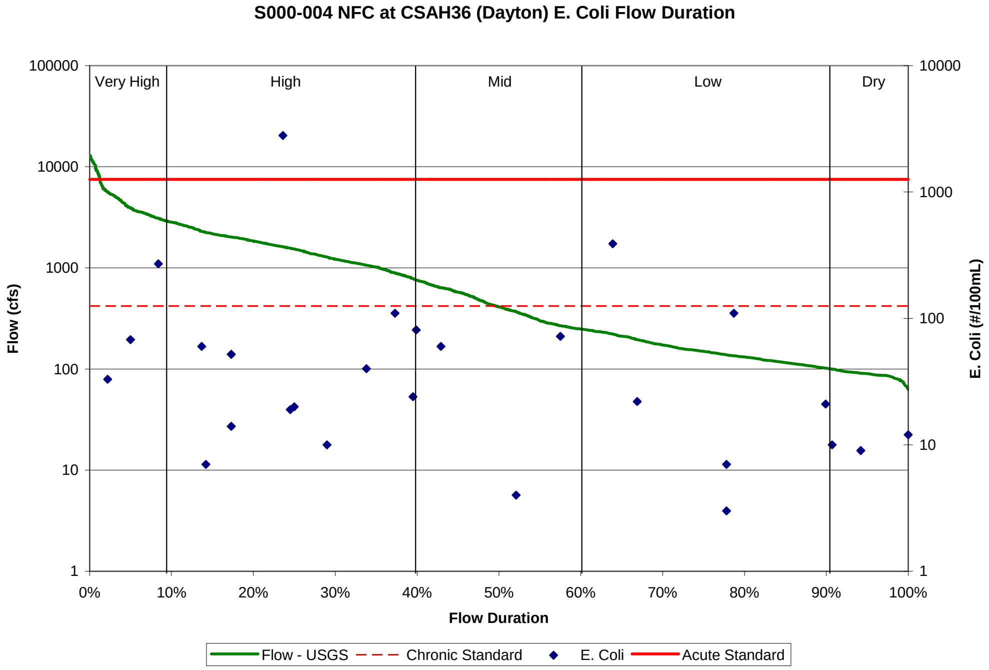


Figure 10 - S000-004 (N. Fk. Crow near junction with Mississippi R.) *E. coli* Concentrations by Flow Regime



These analyses suggest the following:

- Five of the six exceedances that were recorded within the impaired reach of the North Fork Crow River at Rockford occurred at high or very high flows during the summer period, indicating runoff driven processes as a prime suspect in delivery of bacteria loads to the system.
- The plots of *E. coli* concentrations by flow regime indicate many exceedances of the 126 CFU/100 ml standard occur during low flow conditions for most of the monitoring sites located on small tributaries, as well as the South Fork at Delano, and the N. Fk. Crow River above the impaired reach. Most of these data were collected after 2002, the latest year for which data is available for the N. Fork Crow River site at Rockford. High bacteria concentrations during low flow conditions suggest sources such as septic systems, overgrazed pastures with direct access to streams, and/or wildlife as probable sources.
- Concentrations for the listed reach of the North Fork vary somewhat across the seasons, with geometric mean values usually highest for the summer season. This reflects the probable role of summer precipitation events generating runoff episodes that cause delivery of bacterial loads to the receiving water.
- A lack of major differences in seasonal geomeans for both summer and fall from several of the small tributaries suggest a diversity of sources are contributing to the loads.

5.2 Bacteria Pollutant Source Inventory

A bacteria source assessment is intended to estimate the mass of bacteria produced in the watershed from various sources over a period of time based on knowledge of the numbers and basic characteristics of bacteria producers in the watershed. This information can be used to obtain information on the largest potential sources of bacteria to focus on for load estimation purposes. The calculation methodologies focus on fecal coliform bacteria, so the bacteria mass information in this section will generally be expressed as fecal coliform Fecal coliform will be converted to *E. coli* when the source assessment information is presented in the TMDL to match the requirements of the standard.

It is important to note that while there has been much work done in Minnesota to characterize the bacteria generation as well as delivery characteristics from specific sources, it is common for these numbers to be adjusted based on local knowledge. Much of the information prepared for this initial source assessment was taken from recent bacteria analyses conducted for a bacteria TMDL in Carver County, located just south of the Lower North Fork Crow River subwatershed. Thus, the information contained in this section may be subject to further adjustments prior to the time the TMDL is developed.

The analysis in this section focuses on those features of the watershed that drain directly to the impaired reach, based on boundary conditions agreed to during scoping of this project. The assumption was made that the majority of inputs causing the impairment are likely entering the impaired reach between the monitoring stations near the upper and lower bound of that reach (Station S000-050 at Rockford on the upper end and Station S000-004 at the mouth of the N. Fork Crow River on the lower end). In this case, that means that inputs were characterized for the watershed draining to the River between these two points, including the un-named tributary near St. Michael (Station S002-030). These subwatersheds are called Lower North Fork Crow River and Un-named Tributary.

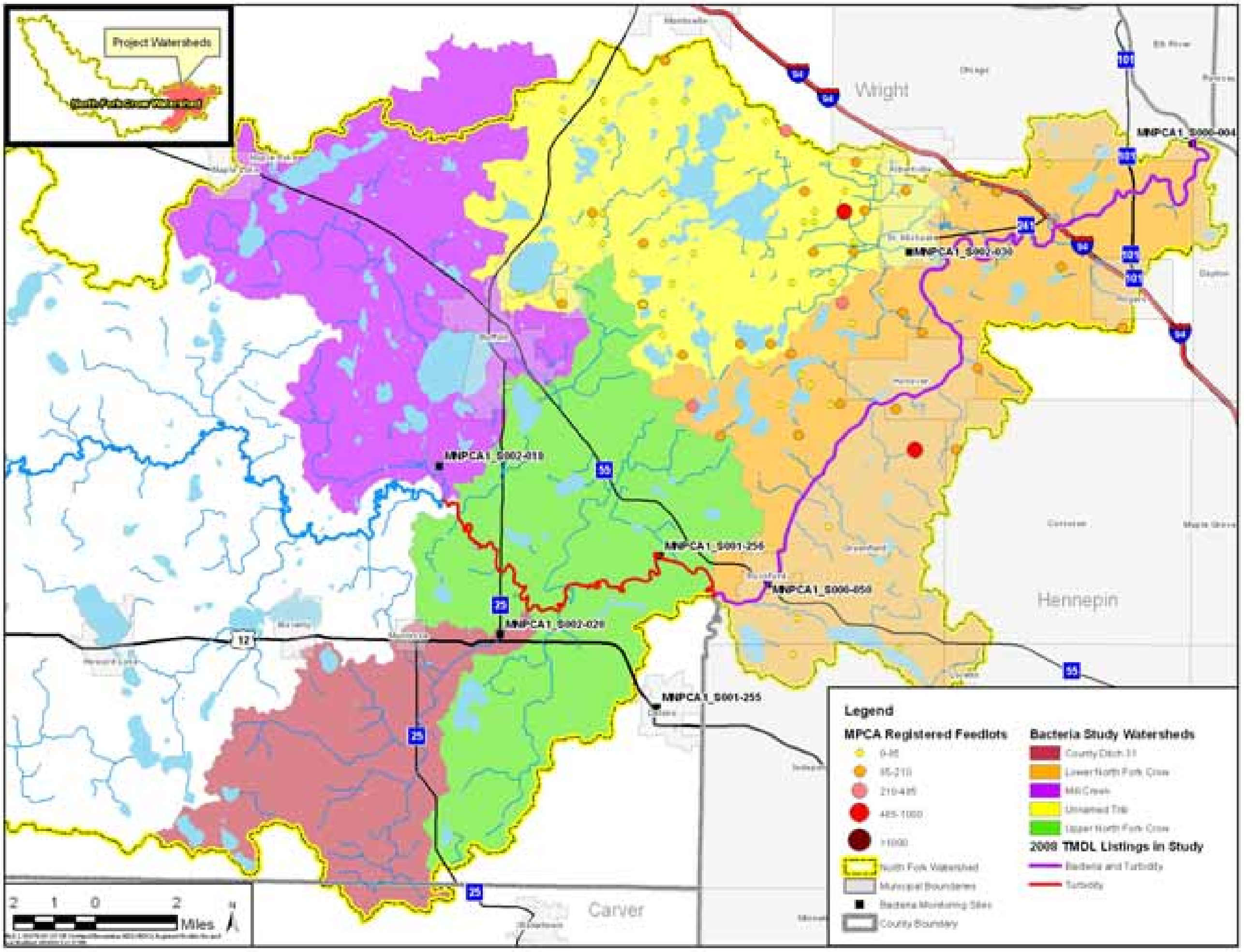
5.2.1 Livestock

Livestock sources include several categories such as feedlots, overgrazed pastures, surface application of manure and incorporated manure. Following is a description of these sources.

5.2.1.1 Feedlots and Over-grazed Pastures Near Streams

An area is considered a feedlot if it is a lot or building or combination of lots and buildings intended for the confined feeding, breeding, raising or holding of animals and specifically designed as a confinement area in which manure may accumulate or where the concentration of animals is such that vegetative cover cannot be maintained within the enclosure. Open lots used for the feeding and rearing of poultry (poultry ranges) are considered animal feedlots. There are a total of 72 feedlots in the two subwatersheds (44 in Un-named Tributary and 28 in the North Fork) feedlots and an estimated 7,038 animal units in the two sub-watersheds. The majority of the animal units are dairy (4,378 units) followed by beef (1,756 units) and swine (654 units). A map of the location of the confined animal feedlot operations (CAFOs) in the sub-watersheds of interest is shown in Figure 11. CAFOs are regulated under the NPDES permit system.

Figure 11 - Confined Animal Feeding Operations (CAFOs) in Subwatersheds of the Bacteria Impaired Reach-North Fork Crow River



GIS data showing the exact location and boundaries of pastures in the watershed was limited, however all feedlots and open lot cattle and dairy facilities within 300ft of a stream would have a higher likelihood of animal access to the stream and therefore higher likelihood of delivering bacterial loads to the receiving water. In the North Fork Crow River subwatershed, there are four feedlots within 300 feet of the River with about 370 animal units, including one within 100 feet of the River with 165 animal units. For the Un-named Tributary watershed near St. Michael, 5 feedlots with almost 720 animal units are within 300 feet of the tributary, including 1 within 100 feet housing just over 20 animal units.

5.2.1.2 Surface Manure Application

Manure application rates were estimated for the Carver County bacteria TMDL (Mike Wanous, Director – Carver SWCD and Tom Kalahar with Renville County). Based on that information, we assumed that approximately 1/3 of the cropland in the two subwatersheds receive some sort of manure application. The application rates vary depending on the nutrient content but reasonable estimates would be 12,000 gallons per acre for liquid and 15 tons for solid. Most liquid manure is injected into the ground or incorporated within 24 hours. Solid manure is spread on the soil surface, and in most cases is not immediately incorporated into the ground.

Most hog manure is applied as a liquid. Most beef and poultry manure is applied as a solid. Dairy manure is applied as both liquid and solid manure. In most cases the larger dairy operations have liquid ag-waste pits, and the smaller dairies haul manure as a solid.

A large portion of manure applications occur in the fall when animal waste pits are emptied out. However, some farmers (especially small dairy farmers) spread manure year round. To account for the varied application periods, it was assumed that 20% of surface applied manure occurred in the spring, 20% in the summer, and 60% in the fall (WENR Technical Sub-Committee, 2004).

All estimates in this sub-section should be reviewed by local resource managers to determine if they are appropriate for use in this project area.

5.2.1.3 Incorporated Manure

Liquid manure is often injected directly into the topsoil, or incorporated into the soil after surface spreading with agriculture tillage equipment. Application of incorporated manure typically occurs in the fall when waste pits are full and crops have been removed, however some pits will be emptied earlier in the year if needed. When this happens, it is often done before June 1 (before crops are planted in the spring). Most farmers find it difficult to rely on spring applications because the soil is often too wet in the spring months. To account for the varied application, it was assumed that 20% of incorporated manure spreading occurred in the spring with the remaining 80% occurring in the fall. Again, all estimates in this sub-section should be reviewed by local resource managers to determine if they are appropriate for use in this project area

5.2.2 Industrial Dischargers

There is only one industrial discharger in the Lower North Fork Crow River sub-watershed. That discharger is Great River Energy (MN00049077-SD-1), which discharges non-contact cooling water There was no monitoring data for bacteria for this discharge in 2008. In the Un-named Tributary sub-watershed, Dale's 66 is the only listed industrial discharger, but this permit may now be terminated and there is neither flow nor quality data available for the discharge in 2008. Barring unique circumstances, however, neither is expected to contribute much of a bacterial load to adjacent receiving waters.

5.2.3 Human Sources

Septic Systems (ISTS)

Failing or nonconforming septic systems can be an important source of bacteria especially during dry periods when these sources continue to discharge and runoff driven sources are not active. The MPCA estimated a failure rate of 44% for ISTSs for the Southeast Minnesota Regional (MPCA 2002), and Carver County estimated a failure rate of 43% for the entire County (Mary West, pers. comm.). A non-compliance rate for ISTSs of about 65% has been estimated for Wright County, though it should be noted that this figure does not necessarily represent system failures (Sean Riley-Wright County Planning and Zoning, personal communication).

Based on data from the 2000 census and assuming 2.8 people per household, the rural population and number of rural households in the Lower North Fork Crow River subwatershed and the Un-named Tributary subwatershed is 3,530/1,261 and 967/345, respectively. (Rural populations were defined as those populations outside the boundaries of incorporated jurisdictions). Thus over 1,600 households, comprising about 20 percent of the total population in the two subwatersheds, dispose of wastewater through on-site disposal systems, also known as septic systems or individual sewage treatment systems (ISTS). Unless on-site disposal systems are functioning properly, groundwater and surface water contamination can occur. Wastewater from septic systems may include many types of contaminants such as nitrates, harmful bacteria and viruses, and other toxic substances, which can be hazardous to both groundwater and surface water. Properly sited, designed and operated ISTS do not pose any risk of contamination to surface water or groundwater. Summary information on the total number of septic systems and the estimated number of failing systems, based on a 44% failure rate for the two subwatersheds, is presented in Table 8. The failure rate assumption should be reviewed with local government staff to determine if it is appropriate for use in the project area.

Table 8. Septic Systems in the Lower North Fork Crow River and Un-Named Tributary Subwatersheds.

Watershed	**Estimated Number of Septic Systems**	**Estimated Number of Failing Septic Systems**
Lower North Fork of Crow River	1261	555
Un-named Tributary	345	152

Municipal Wastewater Treatment Facilities

The Lower North Fork Crow and Un-named Tributary subwatersheds have a total of five wastewater treatment plants. About 81% and 91% of the human population in the Lower North Fork Crow River and the Un-named Tributary subwatersheds, respectively, discharge to municipal wastewater treatment facilities. Table 9 summarizes the discharge characteristics of the facilities.

Table 9. WWTP Loads for Dischargers in the N. Fork Crow River and Un-named Tributary Subwatersheds.

WWTP	Receving Water	Maximum Monitored Fecal Coliform Concentration (CFU/ 100 ml) (2008)
Otsego Wastewater Treatment Plant (MN0064190-SD-1)	N. Fork Crow River	2
St. Michael Wastewater Treatment Plant (MN0020222—SD-1)	Un-Named Tributary to the N. Fork Crow River	<3
Rogers Wastewater Treatment Plant (MN0029629-SD-1)	Un-named tributary to N. Fork Crow River	95
Rockford Wastewater Treatment Plant (MN002467-SD-1)	N. Fork Crow River	104
Greenfield Commercial/Industrial Park (MN0063762-SD-1)	N. Fork Crow River	87

By rule, these dischargers must maintain discharge fecal coliform concentrations below 200 cfu/100ml, which can be accomplished through additional treatment such as chlorination. Additionally, these dischargers must monitor effluent to ensure compliance with these rules. Note that 2008 monitoring data show that all facilities are discharging at well below the fecal coliform standard of 200 CFU/100 ml.

5.2.4 Wildlife

Wildlife in the watershed encompasses a broad group of animals. For the purposes on this assessment, we focused on deer and geese because they are known contributors of bacteria and considered good estimates of wildlife densities in general. Other wildlife was lumped into a single category.

The Minnesota Department of Natural Resources (MnDNR) modeled deer population densities for several areas in adjacent Carver County. MnDNR staff provided estimates of about 5 deer/mi^2 for most of the watershed, with up to 15 deer per mi^2 closer to the river valleys (Jeff Miller-MnDNR Wildlife Division in Wilmar, personal communication). We assumed that the overall deer density for the entire project area was 6 deer per square mile.

Goose densities were estimated using the Southeast Minnesota Regional TMDL where they assumed a goose population of 20,000 individuals. Based on the land area in that watershed, the density would be approximately 2.8 geese per square mile. These estimates will be reviewed by the MnDNR to determine whether they are reasonable for this project area.

5.2.5 Urban Stormwater Runoff

Untreated urban stormwater has demonstrated bacteria concentrations as high or higher than grazed pasture runoff, cropland runoff, and feedlot runoff (USEPA 2001, Bannerman et al. 1993, 1996). There is a moderate amount of urban area in the Lower North Fork Crow River and Un-named Tributary subwatersheds (19% and 12.5% respectively). Consistent with the methodology outlined in the Southeast Minnesota Regional Bacteria TMDL (MPCA 2002), urban bacteria contributions were assumed to come exclusively from improperly managed waste from dogs and cats. Using the approach in that study, it was assumed that there were 0.58 dogs/household and 0.73 cats/household in the urban areas.

Local bacteria loads in some of the cities will need to be addressed under NPDES Phase II, which would require surface water receiving stormwater to meet the State standards. EPA guidance states that MS4 stormwater allocations in a TMDL must now be included in the TMDL as a Wasteload Allocation. NPDES Phase II MS4 permit requirements, which regulates urban stormwater discharges, currently apply to the City of St. Michael and the City of Otsego, both of which are designated MS4s because their population is over 5,000 and because of their close proximity to an impaired water.

5.3 North Fork Crow River Watershed Bacteria Producers

The previous sections detail how the gross numbers of bacteria producers was quantified for this preliminary analysis. However, not all bacteria produced are necessarily available for transport. Thus, another important assumption for each source is the percentage of bacteria produced that is *potentially* available for transport away from where it is produced. Table 10 shows the percentages for each bacteria production category that were assumed for this preliminary analysis. These assumptions are based in part on work completed for the Southeast Minnesota Regional Bacteria TMDL (MPCA 2002; and Mulla et. al 2001), then adjusted for a bacteria TMDL conducted for Carver County and located within 10 miles of the impaired reach of the North Fork Crow River. As always, these numbers should be reviewed and adjusted as appropriate to reflect conditions in the project area.

Table 10. Assumptions Used to Estimate the Amount of Daily Fecal Coliform Production Available for Potential Runoff or Discharge into the Streams and Rivers of the Project Area

Category	**Source**	**Assumption**
Livestock	Overgrazed Pasture near Streams or Waterways	1% of Dairy Manure 1% of Beef Manure
	Feedlots or Stockpiles without Runoff Controls	1% of Dairy 5% of Beef Manure 1% Poultry Manure
	Surface Applied Manure	64% of Dairy Manure 94% of Beef Manure 99% of Poultry Manure 10% Swine Manure; 20% of this manure applied in Spring 20% of this manure applied in Summer 60% of this manure applied in Fall
	Incorporated Manure	34% of Dairy Manure 90% of Swine Manure; 20% of this manure applied in the Spring 80% of this manure applied in Fall
Human	Failing Septic Systems and Unsewered Communities	All waste from failing septic systems and unsewered communities
	Municipal Wastewater Treatment Facilities (excluding bypasses)	Calculated directly from WWTP discharge (April through October) and the geometric mean fecal coliform concentration (2004 data)
Wildlife	Deer	All fecal matter produced by deer in basin
	Geese	All fecal matter produced by geese in basin
	Other Wildlife	The equivalent of all fecal matter produced by deer and geese in basin
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	10% of waste produced by estimated number of dogs and cats in basin

Tables 11 and 12 present for the Lower North Fork Crow River and Un-named Tributary subwatersheds, respectively, the estimated daily fecal coliform bacteria load potentially available for delivery to the receiving water from the major identified sources.

Table 11 - Estimated Daily Fecal Coliform Available for Potential Delivery to Crow River from Lower North Fork Crow River Subwatershed

Category	**Source**	**Animal Units or Individuals**	**Animal Type**	**Fecal Coliform Organisms Produced Per Unit Per Day** (10^9)**	**Total Fecal Coliform Available(10^9)**	**Total Fecal Coliform Available by Source(10^9) (% of total for subwatershed)**
Livestock	Overgrazed Pasture near Streams or Waterways	22	Dairy Animal Units	58	1,301	1,938 (0.8%)
		7	Beef Animal Units	89	637	
	Feedlots or Stockpiles without Runoff Controls	22	Dairy Animal Units	58	1,301	4,485 (1.9%)
		36	Beef Animal Units	89	3,184	
		0	Poultry Animal Units	21	0	
	Surface Applied Manure***	1,430	Dairy Animal Units	58	83,249	143,670 (60.2%)
		672	Beef Animal Units	89	59,867	
		17	Swine Units	33	543	
		0	Poultry Animal Units	21	10	
	Incorporated Manure	760	Dairy Animal Units	58	44,226	49,112 (20.6%)
		0	Beef Animal Units	89	0	
		149	Swine Units	33	4,885	
		0	Poultry Animal Units	21	0	
Human	Failing Septic Systems and Unsewered Communities	1,553	People	2.0	3,106	35,273 (14.8%)
	Municipal Wastewater Treatment Facilities	16,083	People	2.0	32,167	
Wildlife	Deer	482	Deer	0.5	241	661 (0.3%)
	Geese	225	Geese	0.4	90	
	Other Wildlife	0	Equivalent of deer plus dogs and cats		331	
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	752	Dogs and Cats	4.5	3,386	3,386 (1.4%)
Total						238,525

Table 12 - Estimated Daily Fecal Coliform Available for Potential Delivery to North Fork Crow River from Un-named Tributary Subwatershed

Category	Source	Animal Units or Individuals	Animal Type	Fecal Coliform Organisms Produced Per Unit Per Day** (10^9)	Total Fecal Coliform Available(10^9)	Total Fecal Coliform Available by Source(10^9) (% of total for subwatershed)
Livestock	Overgrazed Pasture near Streams or Waterways	21	Dairy Animal Units	58	1,247	2,175 (0.8%)
		10	Beef Animal Units	89	928	
	Feedlots or Stockpiles without Runoff Controls	21	Dairy Animal Units	58	1,247	5,887 (2.3%)
		52	Beef Animal Units	89	4,640	
		0	Poultry Animal Units	21	0	
	Surface Applied Manure***	1,372	Dairy Animal Units	58	79,837	168,663 (65.6%)
		979	Beef Animal Units	89	87,230	
		49	Swine Units	33	1,596	
		0	Poultry Animal Units	21	1	
	Incorporated Manure	729	Dairy Animal Units	58	42,414	56,775 (22.1%)
		0	Beef Animal Units	89	0	
		439	Swine Units	33	14,362	
		0	Poultry Animal Units	21	0	
Human	Failing Septic Systems and Unsewered Communities	425	People	2.0	851	20,885 (8.1%)
	Municipal Wastewater Treatment Facilities	10,017	People	2.0	20,034	
Wildlife	Deer	343	Deer	0.5	172	472 (0.2%)
	Geese	160	Geese	0.4	64	
	Other Wildlife	0	Equivalent of deer plus dogs and cats		236	
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	469	Dogs and Cats	4.5	2,109	2,109 (0.8%)
Total						256,967

While this preliminary analysis does not take into account estimated delivery to the receiving water, there are several items to note:

1. Surface applied manure is by far the most significant potential source of bacterial loading, comprising over 60% of the bacteria load potentially available for transport in both subwatersheds.
2. Incorporated manure comprises the second highest source of bacteria at over 20% of the potentially available load for both subwatersheds.
3. Delivery of the bacterial load from both surface applied manure and incorporated manure are largely dependent on runoff processes to reach receiving waters. This has not been taken into account yet in the analysis.
4. Potential bacterial loading from human sources is ranked third, comprising over 15% and 8% of potential loads in the Lower N. Fork Crow River and Un-named Tributary subwatersheds, respectively. These figures do not take into account the effect of wastewater treatment plants in attenuating bacterial loads from their service areas.
5. Human sources can still be significant during certain flow conditions, since they are one of the few sources that discharge regardless of runoff conditions.
6. Other potential sources appear minor, with potential load contributions of less than 3% each. Again, however, overgrazed pastures near streams and waterways can be significant sources of bacteria loadings to streams if the animals have direct access to the stream, regardless of runoff conditions.

It is also important to note that there are uncertainties associated with the estimates in the table. Estimates of the population with inadequate wastewater treatment are based on an assumed septic failure rate in the county. Additionally, pet numbers are derived from a national survey and may not directly reflect conditions in these specific subwatersheds. Deer populations are from model estimates and geese population estimates are based on densities used in the Southeast Regional TMDL. This summary does, however, provide a reasonable estimate of bacteria producers in the watershed as well as the comparative densities in each category.

6.0 Turbidity

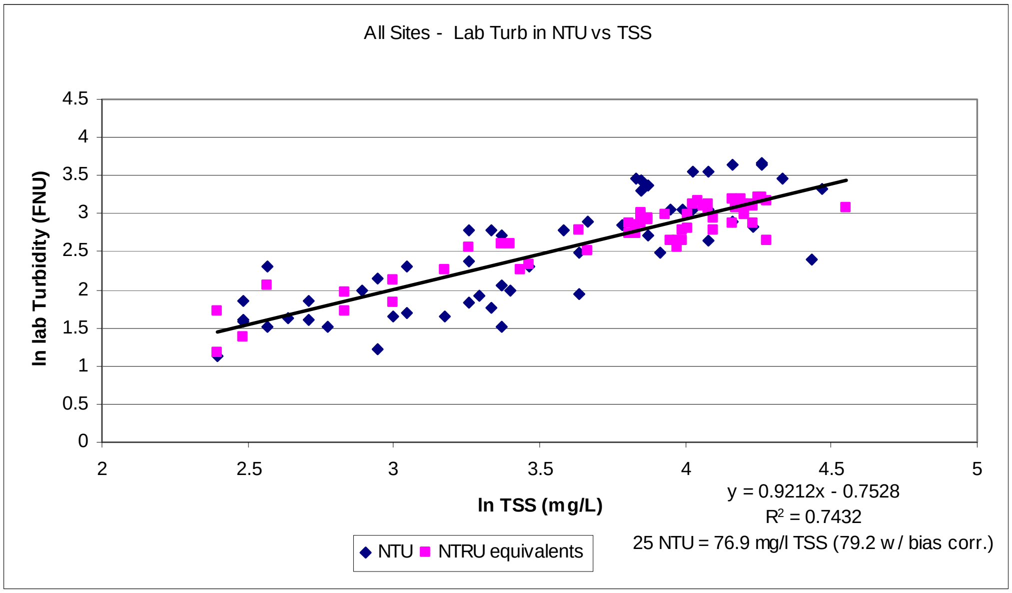
In order to evaluate and set loads affecting turbidity, total suspended solids is used as a surrogate measure. Paired readings of turbidity and total suspended solids are used as the basis for developing this relationship. In the case of the North Fork of the Crow, over 100 readings of paired data were used to define this relationship. About half the paired data points were based on measurements taken with a meter that read turbidity in Nephalometric Turbidity Ratio Units (NTRUs), while the remainder were taken with a meter that read turbidity in Nephalometric Turbidity Units (NTUs). These two units are not the same, but can be related by the following 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 in developing the TSS surrogate value and also presented in the remainder of this report have been converted from NTRUs to NTUs (those data will be referred to as “NTU equivalents”).

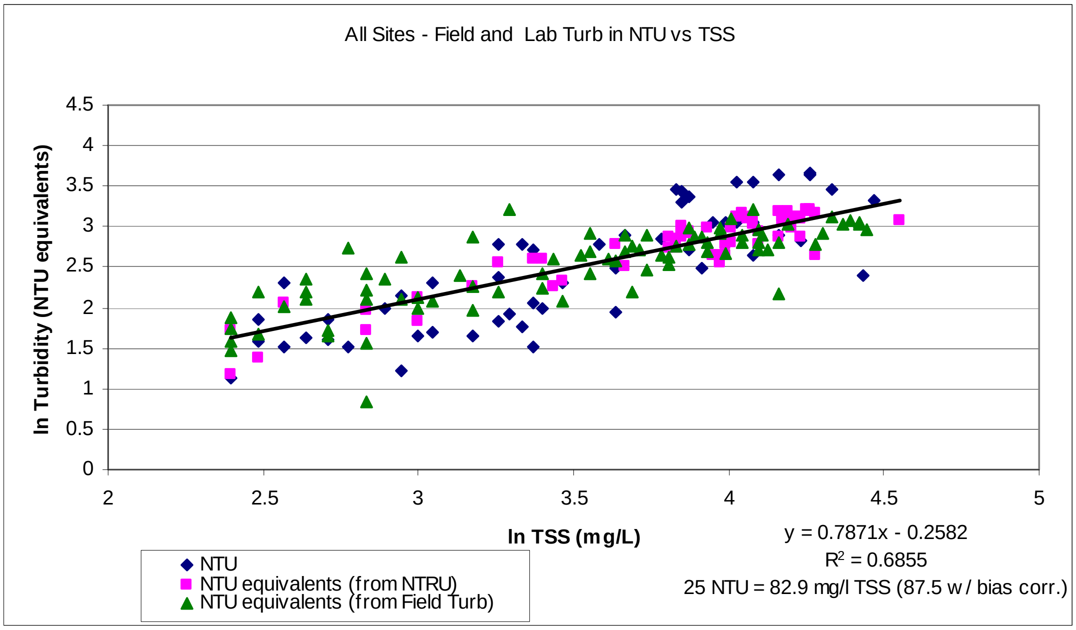
A simple regression of the natural logarithm of TSS and NTU as well as “NTU equivalents” from the NTRU data was completed using the available paired data from all monitoring sites in the project area for the North Fork Crow River. As per the methodology recommended by MPCA, only data associated with turbidities of 40 NTUs or less and TSS values greater than 10 mg/l were used to derive the relationship (MPCA 2008). The regression is shown in Figure 12 and shows a good correlation (R-squared = 0.74). The analysis indicates that the turbidity standard of 25 NTU corresponds to a surrogate TSS concentration of 76.9 mg/l for this data set. However, informal guidance provided by MPCA suggests that “retransforming log-transformed regression estimates to provide ‘raw’ data value estimates results in a retransformation bias given that the logarithmic transformation is nonlinear” (MPCA unpublished 2008) Because the resulting TSS estimates are biased on the low side, the reference document recommends using a bias correction method known as Duan’s smearing. After applying this bias correction method to the data set, the corrected TSS surrogate value for the 25 NTU standard is 79.2 mg/l.

Figure 12 - Turbidity/Total Suspended Solids Relationship-Lab Turbidity Data Only (N. Fork Crow River)



We also evaluated using paired field turbidity/total suspended solids data as well to help define the TSS surrogate value. Combining the field turbidity data with the lab turbidity data presented in Figure 12 generated a regression relationship with a lower R-squared value (0.6855 vs. 0.7432 for the lab data only) and a TSS surrogate of 87.5 mg/l with bias correction. The relationship is shown in Figure 13.

Figure 13 - Turbidity/Total Suspended Solids Relationship-Field and Lab Turbidity Data (N. Fork Crow River)



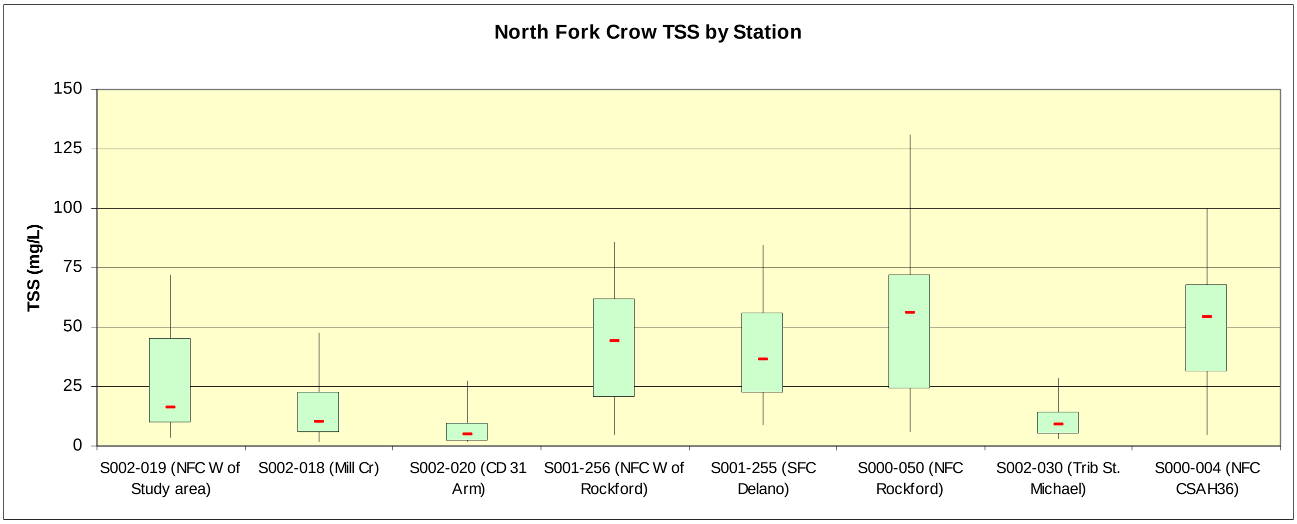
We elected to use the TSS surrogate based only on the lab data because of the tighter relationship between turbidity and TSS values.

6.1 Surface Water Quality Conditions

In an effort to further define the conditions under which exceedances of the turbidity standards occurs and start to identify possible causes of the exceedances, several graphical analyses were conducted. These analyses are presented and briefly described below.

Figure 14 shows box plots of all TSS data available for a number of important monitoring stations in and adjacent to the North Fork Crow River project area. The box plots are presented left to right in upstream to downstream order. Tributary data in the sequence is presented based on where the tributary enters the North Fork relative to the North Fork mainstem monitoring stations. This data presentation format is of value in evaluating spatial patterns that may exist for turbidity exceedances in the system.

Figure 14 - Box Plots of All TSS Concentration Data by Station



Figures 15 - 17 show flow duration curves along with TSS concentration data for three stations on the mainstem of the N. Fork Crow River within the reach identified as impaired for turbidity. Station S001-256 is on the mainstem above its junction with the South Fork, Station S001-050 is below the junction with the South Fork, and Station S001-004 is at the mouth just upstream from the Mississippi River. This data presentation format is of value for evaluating whether exceedances of the turbidity standard at a particular station are associated consistently with any particular flow regime. The surrogate TSS concentration standard of 79.2 mg/l is shown in red on each graph.

Figure 15 - TSS Concentration Data by Flow Interval for Site S001-256 (N. Fork Crow River above Rockford)

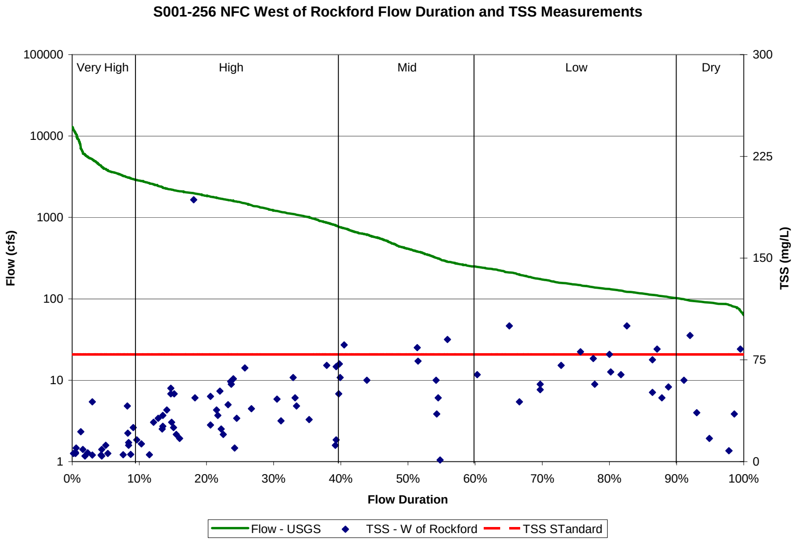


Figure 16 - TSS Concentration Data by Flow Interval for Site S001-050 (N. Fork Crow River at Rockford below junction with South Fork Crow River)

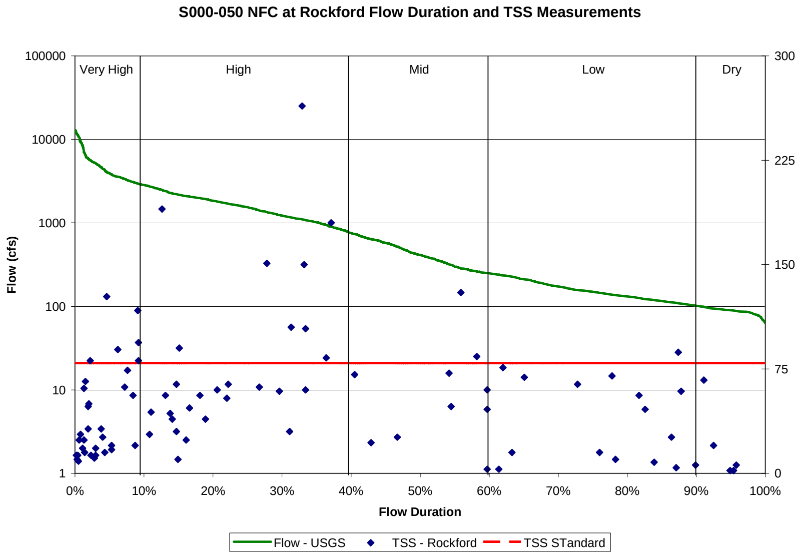
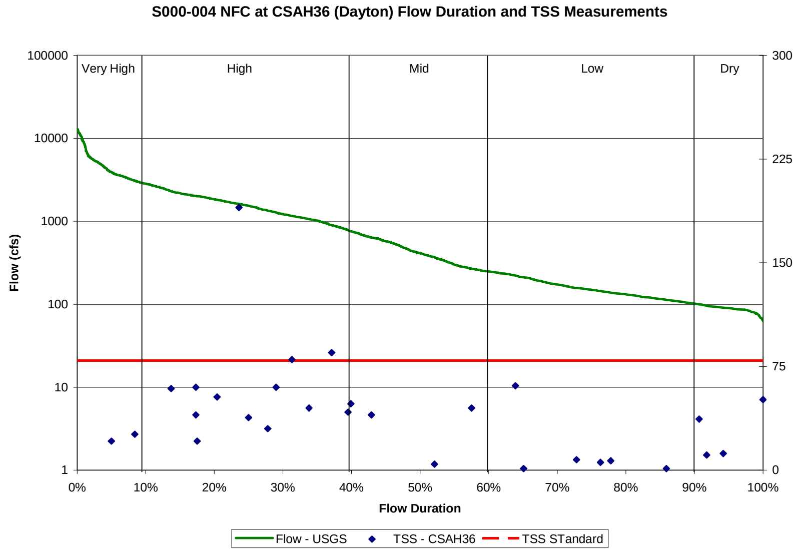


Figure 17 - TSS Concentration Data by Flow Interval for Site S001-004 (N. Fork Crow River at just above junction with Mississippi River)



Finally, Figures 18 - 20 show graphs of the ratio of volatile suspended solids to total suspended solids along with chlorophyll a data by flow regime for various stations. This data presentation format is intended to help detect the connection that organic constituents such as algal blooms or non-algal organic-rich sources might have in causing turbidity exceedances. VSS/TSS fraction and chlorophyll-a data taken during conditions where the turbidity standard was exceeded are shown as large asterisks.

Figure 18 – Station S001-256 NFC West of Rockford – VSS Fraction and Chlorophyll a by Flow Regime

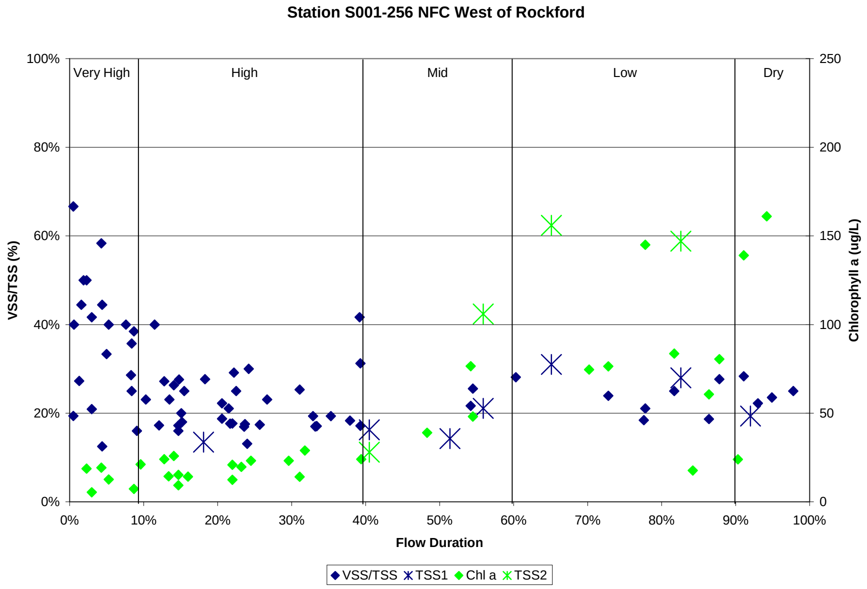


Figure 19 – Station S000-050 NFC at Rockford – VSS Fraction and Chlorophyll a by Flow Regime

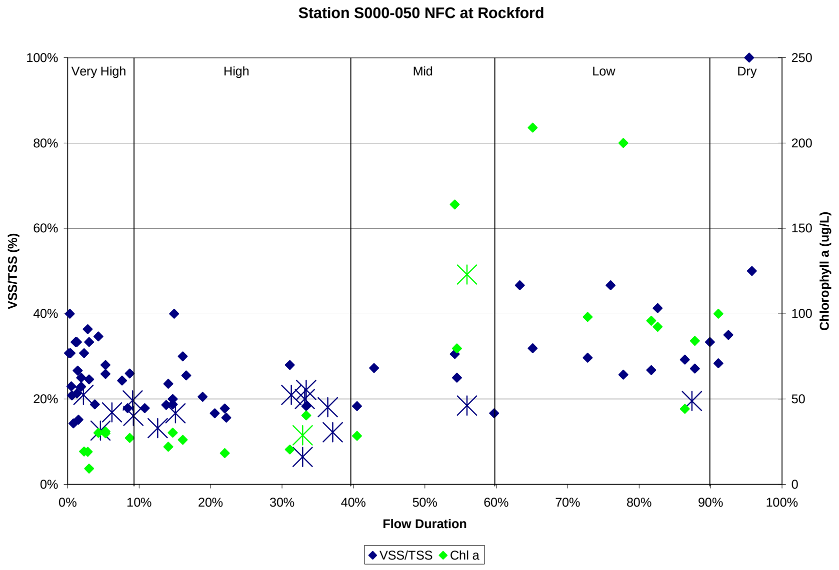
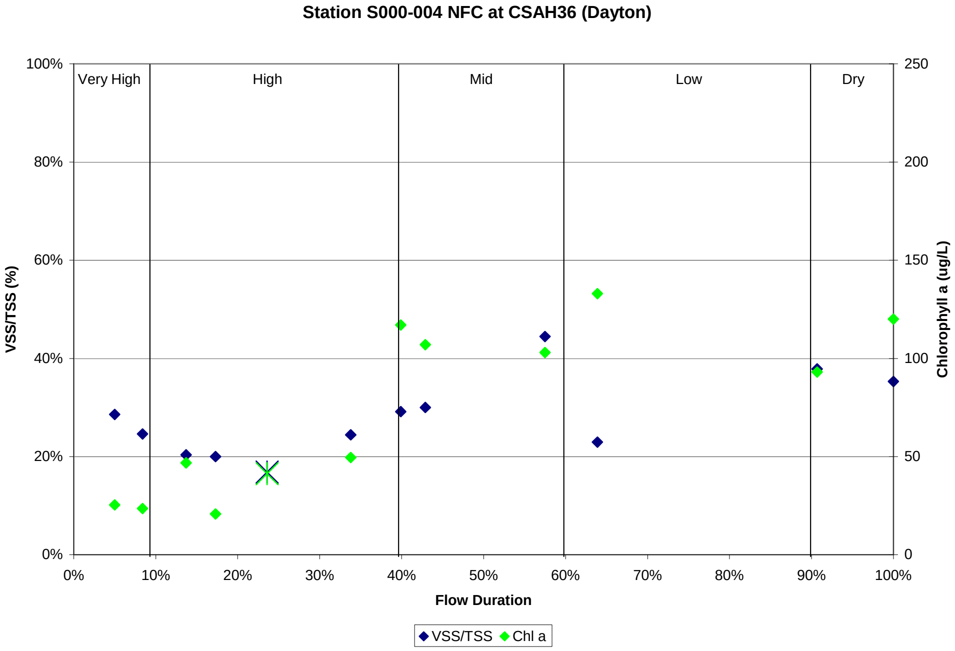


Figure 20 – Station S000-004 NFC at CSAH 36 (Dayton)– VSS Fraction and Chlorophyll a by Flow Regime



Preliminary conclusions that can be drawn from the data presented previously are as follows:

- The box plots (Figure 14) suggest that the primary cause of the turbidity impairment arises between Stations S002-019 on the mainstem of the North Fork above the junction with Mill Creek and Station S001-256 above Rockford and upstream of where the South Fork joins the North Fork. Further, the impairment conditions appear to worsen between Station S001-256 and the Rockford station (S000-050). It also appears that TSS loads from the four monitored tributaries are not big contributing factors to the exceedances in the mainstem North Fork, since the measured TSS concentrations from these tributaries are almost always well below the standard. Even the maximum TSS concentration in the South Fork data set is less than 85 mg/l. compared to the TSS surrogate of 79.2 mg/l.
- The flow duration curves (Figures 15-17) suggest that the majority of exceedances at Station S001-256 above Rockford occur during moderate to low flow regimes. This points to potential causes such as algal blooms and/or disturbances/discharges to the stream channel or near stream environment that occur during lower flow conditions, possibly associated with point source discharges and/or breakdown of streambanks or re-suspension of bottom sediments due to animal activity. At the Rockford monitoring station (S001-256), the majority of exceedances occur during high to very high flow periods, suggesting runoff driven processes that discharge sediment between the two stations. Presumably, these loadings could come from non-urban as well as urban sources.
- The VSS/TSS ratios and chlorophyll a concentrations for Station S001-256 show that many of the turbidity exceedances occur in the moderate to low flow regimes and show high chlorophyll a levels (> 100 ug/l); a number exhibit elevated VSS fractions (>20%) as well. This pattern disappears at Station S000-050 where most exceedances occur at high to very high flow regimes and are generally accompanied by *neither* high chlorophyll-a or elevated

VSS fractions. This could suggest, as stated above, that the primary cause of the turbidity impairments changes from algal blooms or some other organic-based turbidity at low flows in the upper segment of the impaired reach to inorganic particles like mineral sediments that are transported and suspended during runoff events and/or high flows in the lower reaches of the impaired River segment. It should be noted, however, that the database on which these observations are based is not very robust due to the relatively low number of VSS fraction and chlorophyll a data points for turbidity exceedance episodes.

- Overall, based on the available data the turbidity impairment in the listed reach appears to be minor to moderate. Over a significant majority of the time, the TSS readings are below the surrogate standard.

6.2 Pollutant Source Inventory

The following is a discussion of the potential contributors to the turbidity impairment for the listed reaches of the N. Fork Crow River.

6.2.1 Point Sources

National Pollutant Discharge Elimination System (NPDES) permits are issued by the Minnesota Pollution Control Agency (MPCA) under a delegation agreement from the U.S. Environmental Protection Agency (USEPA). These permits are issued to a wide range of facilities or industries, most, but not all, of which have point source discharges. The permits define the conditions that a facility must meet in order to discharge to surface or groundwater. Effluent limits are set on pollutant discharges based on water quality standards and the receiving water's designated use (MPCA 2002). The effluent limit most relevant to this report is for total suspended solids (TSS), although phosphorus is also of interest because of its potential impact on algal-related turbidity.

6.2.1.1 NPDES Municipal and Industrial Wastewater Permit Holders

There are a number of municipal wastewater treatment facilities (WWTFs) located within the North Fork Crow River project area watershed. Those serving the cities of Montrose, Rockford, St. Michael, Rogers, and Otsego discharge effluent to the impaired segment of the North Fork Crow River. The facilities serving Rockford, St. Michael, and Otsego discharge effluent directly to the River, while those serving Montrose and Rogers discharge to ditches/creeks that are tributary to the impaired reach. All together, the sum of the permitted maximum calendar week average TSS loads for these facilities is approximately 2,400 pounds/day based on a maximum calendar week average concentration of 45 mg/l TSS. A summary of these discharge permits will be included in the appendix of the TMDL document.

There is only one permitted industrial facility that discharges to the impaired reach of the North Fork Crow River. It is a substation facility owned and operated by Great River Energy. The permitted discharge is for just over 4 gallons/minute for cooling water blowdown and stormwater runoff. The discharge is to an un-named ditch that is tributary to the North Fork Crow River near the upper end of the impaired reach. The discharge has a TSS limit of 30 mg/l and a requirement to monitor for phosphorus. A summary of this permit will be presented in the appendix of the TMDL report.

6.2.1.2 NPDES Stormwater Permit Holders

Municipal. In the North Fork Crow River project area watershed, approximately 15.8% of the land use is urban/developed. Stormwater runoff-generated pollutant loads generated in developed areas are often a function of the impervious coverage and the extent to which urban Best Management Practices (such as detention ponds and infiltration features) are incorporated into the storm drainage system. The cities of Otsego and St. Michael are both designated MS4s that discharge stormwater to the impaired reach of the North Fork Crow River and are required to obtain Municipal Separate Storm Sewer System (MS4) permit under the MPCA's MS4 stormwater regulations. As part of the permit requirements, these municipalities are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP).

Construction Permits. The watershed contains some of the fastest growing areas on the outer edge of the Twin Cities metro area. Based on data to be obtained from MPCA, we will include in the TMDL information on the number of acres in the North Fork Crow River watershed that have been under regulated development-related activity for the time period of interest, the number of construction permits issued in areas that discharge to the impaired reach of the North Fork Crow River, and the range in the sizes of the construction sites that have been permitted.

Industrial. There are several facilities with Industrial Stormwater permits that discharge to the impaired reach of the North Fork Crow River watershed. A summary of the permits and a characterization of the discharges will be presented in the final TMDL report.

6.2.1.3 Concentrated Animal Feeding Operations

There are 178 Concentrated Animal Feedlot Operations (CAFOs) located within the project area sub-watersheds. Both CAFOs have NPDES/SDS permit coverage under the State of Minnesota General Livestock Production Permit. The conditions associated with each of these permits allows no discharge of pollutants from the production area of the CAFOs.

6.2.2 Non-Point Sources

Non-point sources can include both background sources, such as natural soil erosion from stream channel processes and upland areas as well as human-caused disturbances. I n a watershed with mixed urban and non-urban land uses like that of the North Fork of the Crow River watershed, non-point sediment related turbidity sources typically fall into one of the following categories:

- Approximately 32% of the land use in the North Fork Crow River project area is agricultural row crop, primarily corn and soybeans. Soil loss is due in part to these areas being left without much vegetative cover for portions of the year between crop harvest and the emergence of the following year's crop. Slope length and steepness, soil type, and cropping practices can all influence soil erosion rates. Agricultural best management practices (BMPs) such as reduced tillage, terracing, etc. can reduce soil erosion dramatically where they are used.
- Livestock grazing can cause erosion by leaving over-grazed land without sufficient vegetative cover to hold soil and other particles in place. The problem may be more serious if over-grazing occurs along streams or waterways, as eroded material is delivered to the water more easily. Roughly 3% of land over in the North Fork Crow River subwatershed is grassland, a portion of which is pastured.

- Over 13% of the project area is developed, and contains some of the fastest growing communities in the Metropolitan area. Erosion from construction sites can export many tons of soil from exposed graded areas in a matter of hours as a result of runoff events if those areas are not properly stabilized. In addition, un-paved roads contribute sediment directly from their surfaces or indirectly through increased volume or velocity of runoff. Gravel roads are only slightly more pervious than asphalt or concrete roads.
- Channel sources include accelerated channel erosion caused by increases in stream channel instability due to hydraulic over-loading. Hydraulic over-loading in turn can be caused by ditching and drain-tiling which delivers runoff to the channel much more rapidly than would occur without those drainage features. Uncontrolled discharge of runoff from impervious surfaces can also be a major contributor in areas where developed land uses dominate. The result is often entrainment of streambank and stream bed material during periods of high stream flow. Mechanical failure of stream banks can also be a contributor, especially where soils are erodible and riparian land uses remove vegetation that would otherwise help anchor the soils along the bank. Finally, high phosphorus concentrations in a slow moving stream system can contribute to blooms of planktonic algae during the growing season that can contribute to turbidity. Enriched runoff from agricultural cropland (either through surface runoff or through drain tile systems), high nutrient discharges from CAFOs, or phosphorus discharged from wastewater treatment plants or industrial or municipal sources can each be of significance.

7.0 References

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U.S. Environmental Pollution Control Agency. 2001. Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002

Appendix A

North Fork Crow River TSS Surrogate Analysis

Wenck Associates, Inc.
1800 Pioneer Creek Center
Maple Plain, MN 55359
(763) 479-4200
Fax (763) 4242
E-mail: wenckmp@wenck.com

Wenck Associates, Inc.
1802 Wooddale Drive, Suite 100
Woodbury, MN 55125
(651) 294-4580
Fax (651) 228-1969

TECHNICAL MEMORANDUM

TO: Diane Sander, CROW Watershed Coordinator

FROM: Rich Brasch
Jeff Strom
Joe Bischoff

DATE: June 11, 2009

SUBJECT: North Fork Crow River Bacteria and Turbidity TMDLs – Summary of Preliminary Findings

CC:

The purpose of this memo is to summarize information and data gathered for the North Fork Crow River bacteria and turbidity TMDL project. The information is intentionally presented in a format suitable for incorporation into the draft TMDL report.

1.0 Background Information

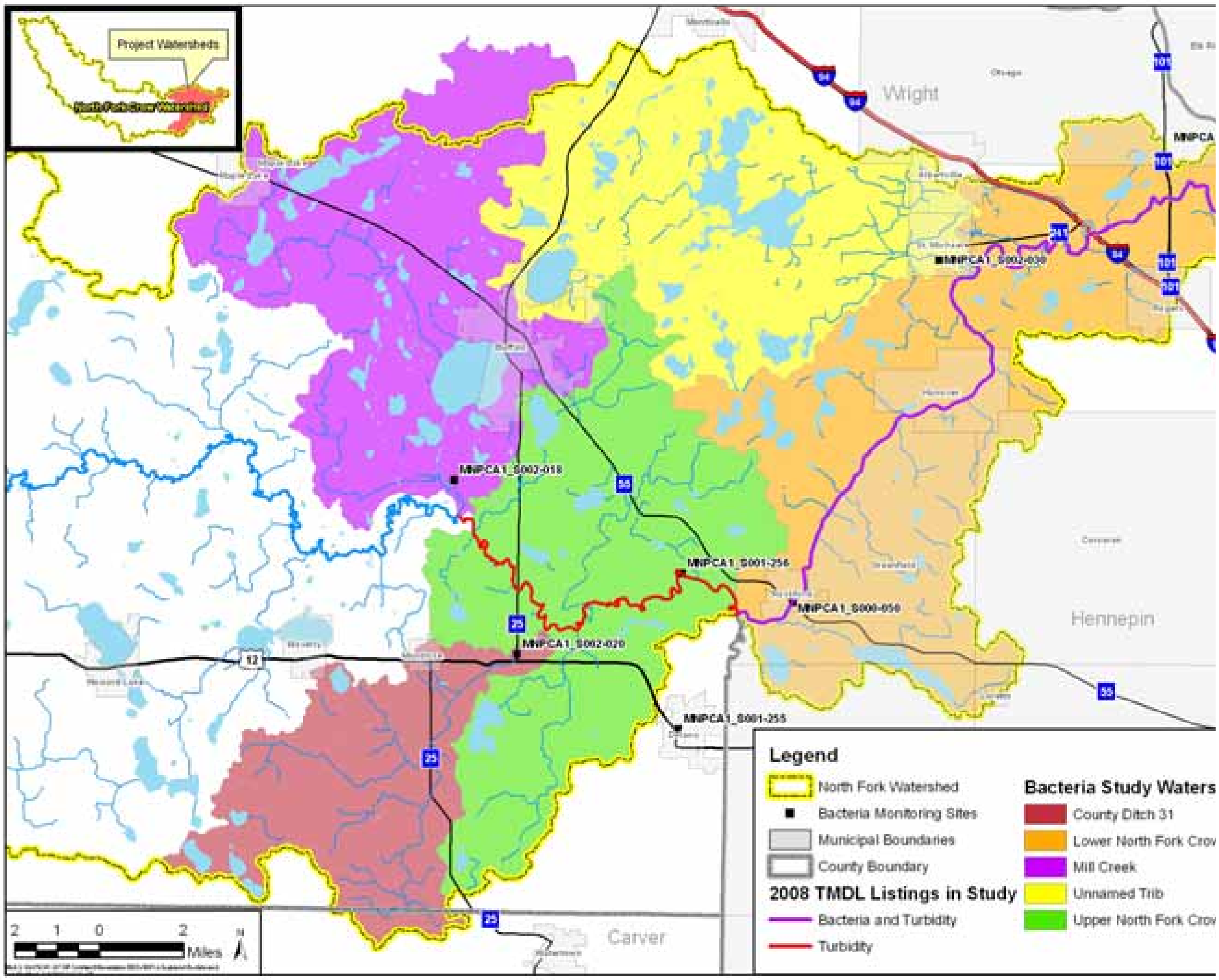
This TMDL effort applies to the turbidity impairment for the North Fork of the Crow River watershed from Mill Creek to the South Fork of the Crow River and both bacteria and turbidity impairments in the River from its junction with the South Fork of the Crow River to the Mississippi River (Table 1).

Table 1 – N. Fork Crow River Watershed Bacteria and Turbidity Impairments

Reach Name on 303(d) List/Description	Yr[12]	Assessment Unit ID[10]	Affected use	Pollutant or stressor[3]	Target start// completion[7]
Crow River, South Fk Crow R to Mississippi R	04	07010204-502	Aquatic recreation	Fecal coliform/E. coli	2006//2012
Crow River; South Fk Crow R to Mississippi R	02	07010204-502	Aquatic life	Turbidity	2006//2012
Crow River, North Fk; Mill Cr to South Fk Crow R	04	07010204-503	Aquatic life	Turbidity	2006//2012

Figure 1 shows the impaired reaches in the watershed along with the locations of key monitoring sites. The data from these sites served as the basis of the impairment determination and will be used to provide information to support the development of the TMDL.

Figure 1- Impaired Reaches and Key Monitoring Sites – N. Fork Crow River Project Area



2.0 Applicable Water Quality Standards

This TMDL addresses exceedances of the state standard for fecal coliform bacteria and turbidity in the North Fork Crow River watershed of Minnesota. A discussion of water classes in Minnesota and the standards for those classes is provided 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 resources value

According to Minn. Rules Ch. 7050.0470, the impaired reaches covered in this TMDL are assigned use classifications of 2B, 3B, 4A, 5 and 6 as unlisted water. These classifications include consideration for aquatic life and recreation, industrial consumption, agriculture and wildlife, aesthetic enjoyment and navigation, and other beneficial uses not specifically listed. Chapter 7050 contains general provisions, definitions of water use classes, specific standards of quality and purity for classified waters of the state, and the general and specific standards for point source dischargers to waters of the state.

The designated beneficial use for 2B waters (the most protective use class) is as follows:

> **Class 2 waters, aquatic life and recreation**. Aquatic life includes all waters of the state which do or may support fish, other aquatic life, bathing, boating, or other recreational purposes, and where quality control is or may be necessary to protect aquatic or terrestrial life or their habitats, or the public health, safety, or welfare.

2.1 Fecal Coliform Bacteria and E. coli

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 bacteria in water suggests the presence of fecal matter and associated bacteria (i.e. some strains of *E. coli*), viruses, and protozoa (i.e. Giardia and Cryptosporidium) that are pathogenic to humans when ingested (USEPA 2001). The decision to list the reaches identified was originally based on a fecal coliform standard, which was in effect prior to the most recent rule revision in 2008. The fecal coliform standard contained in Minn. Rules Ch. 7050.0222 subpart 5, fecal coliform water quality standard for Class 2B waters, stated that fecal coliform concentrations shall "not exceed 200 organisms per 100 milliliters as a geometric mean 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 2005). With the revisions of Minnesota's water quality rules in 2008, the state has changed to an *E. coli* standard because *E. coli* is a superior indicator of potential illness and the costs for lab analysis to detect *E. coli* can be substantially less than for fecal coliform (MPCA 2007). The state standard for *E. coli* of 126 cfu/100 ml was adopted and was considered reasonably equivalent to the fecal coliform standard of 200 cfu/100 ml from a public health protection standpoint. Further, the SONAR (Statement of Need and Reasonableness) section that supports the rationale for the change in the standard contains a log plot of paired fecal coliform and *E.coli* data that was cited as being a reasonable basis to convert fecal coliform concentrations into *E. coli* concentrations (MPCA 2007). The relationship has an R^2 of 0.6887 and the equation generated by the regression is $y = 1.7993x^{0.8057}$ where y is the *E. coli* concentration and x is the fecal coliform concentration. Where fecal coliform data is converted to *E. coli* data in this memo, this is the equation used to make that conversion.

2.2 Turbidity

Turbidity in water is caused by suspended sediment, organic material, dissolved salts, and stains that scatter light in the water column, making the water appear cloudy. Excess turbidity can degrade aesthetic qualities of water bodies, increase the cost of treatment for drinking water or food processing uses, and harm aquatic life. Adverse ecological impacts caused by excessive turbidity include hampering the ability of aquatic organisms to visually locate food, negatively affecting gill function, and smothering of spawning beds and benthic organism habitat

The turbidity standard found in Minn. R. 7050.0222 subpart 5 for 2B and 3B water is 25 nephalometric turbidity units (NTUs). Impairment assessment procedures for turbidity are provided in the guidance manual cited above. The water body is added to the impaired waters list when greater than ten percent of the 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). This TMDL is written for Class 2 waters as this is the more protective class

3.0 North Fork Crow River Watershed Geographic Location and Project Area Boundaries

The headwaters for the North Fork Crow River are located in Pope County, at Grove Lake. The North and South Forks of the Crow River converge in Rockford, Minnesota to become the Crow River. The Crow River flows northeast along the borders of Wright and Hennepin Counties until it empties in to the Mississippi River near Dayton, Minnesota. This area of the River is locally referred to as the North Fork - Lower Crow. However, the United States Geological Service includes the North Fork - Lower Crow River as part of the North Fork Watershed. For the purposes of this memo, we will refer to the river from it's headwaters to its junction with the Mississippi River as the North Fork Crow River.

The total watershed area of the North Fork Crow River watershed at its junction with the Mississippi River is approximately 1.77 million acres in area. The project area is comprised of the watershed area that discharges to the North Fork Crow River in the impaired reach of the River between its junction with Mill Creek to the its mouth at the Mississippi River. This area is approximately 185,000 acres. All of the project area is located within the North Central Hardwood Forest (NCHF), where the topography ranges from nearly flat to rolling to steep sloped.

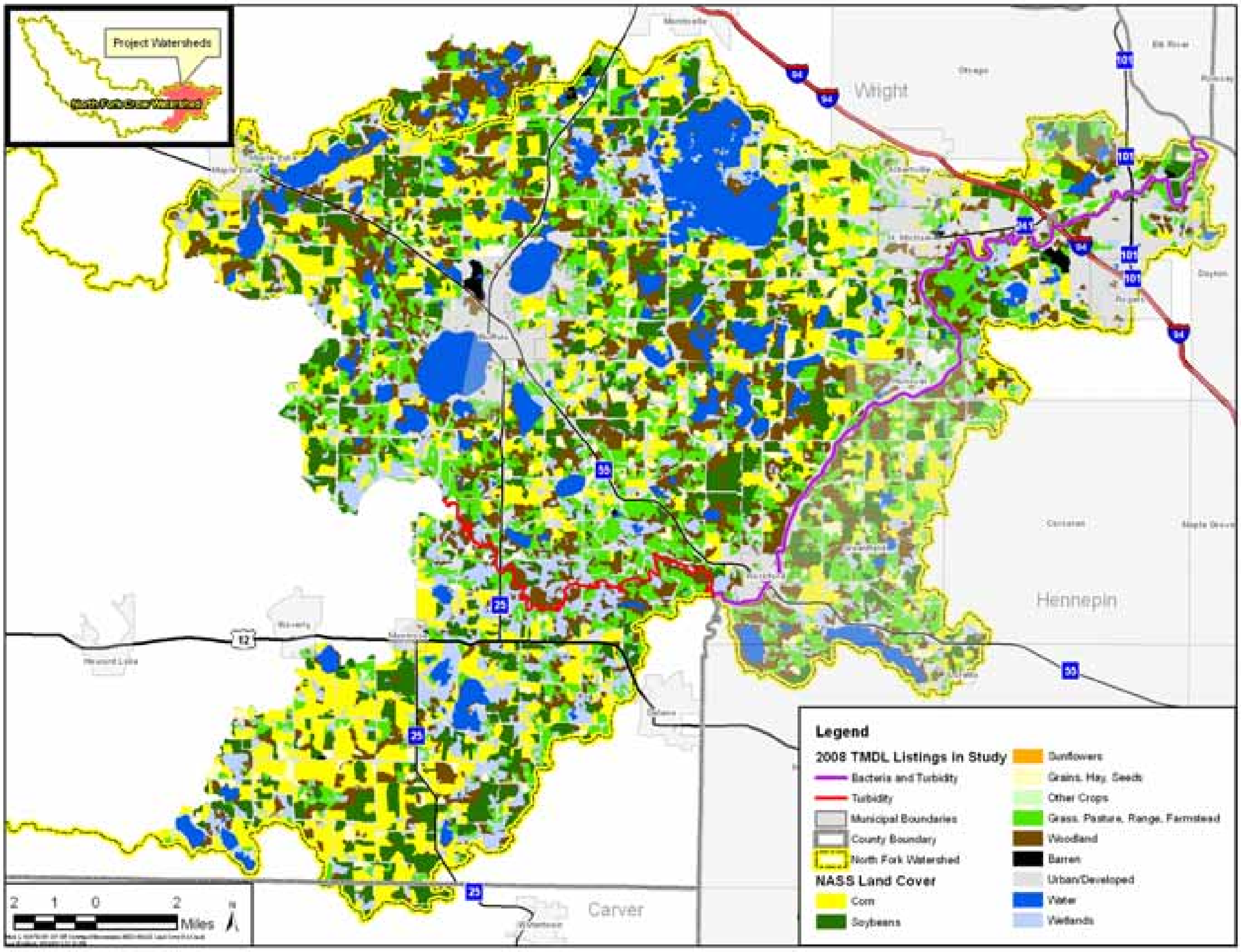
3.1 Land Cover

The land cover of the North Fork Crow River project area watershed as provided by the National Agricultural Statistics Service (NASS) is shown in Figure 2. Table 2 presents the number of acres of each land cover type within the project area watershed in 2007.

Table 2-Watershed Land Cover by Type

Land Cover Category	***Area (acres)***	***Percent***
Corn	26,805	14.5
Soybeans	21,897	11.8
Other cropland	10,228	5.5
Grass Pasture (non-ag)	5,156	2.8
Woodland/Forest	30,550	16.5
Barren and shrubland	2,944	1.6
Developed Urban	25,228	13.6
Water	16,585	9.0
Wetlands	36,963	20.0
Other	8,789	4.7
TOTAL	185,145	100%

Figure 2-Land Cover in the North Fork Crow River Project Area



4.0 Data Sources

All sample data supporting the analyses presented in the following sections was secured from the STORET data base. Table 3 summarizes the bacteria data by monitoring site in upstream to downstream order and Table 4 does the same for the turbidity data.

Table 3 - Bacteria Data by Monitoring Site

STORET ID/Station Description	Parameter	Years	N	Paired
S002-019-N. Fk. Crow above Mill Creek	Fecal Coliform	01	3	None
	E. Coli	08	15	
S002-018-Mill Creek (trib. To N. Fk. Crow)	Fecal Coliform	03	1	None
	E. Coli	07-08	26	
S002-020- Un-named Creek (trib. To N. Fk. Crow)	Fecal Coliform	03	2	None
	E. Coli	07-08	31	
S001-256-N. Fk. Crow above S. Fk. Crow	Fecal Coliform	01-03	12	7
	E. Coli	02,07-08	44	
S000-050-N. Fk. Crow at Rockford	Fecal Coliform	01,03	5	8
	E. Coli	07-08	26	
S002-030- Un-named Creek (trib. To N. Fk. Crow)	Fecal Coliform	03	1	None
	E. Coli	07-08	31	
S000-004-N. Fk. Crow near junction with Mississippi River	Fecal Coliform	00-02,04	12	10
	E. Coli	00-02,04-07	29	

Table 4 - Turbidity Data by Monitoring Site

STORET ID/Station Description	Turbidity Method	Year(s)	N
S002-018-Mill Creek (trib. To N. Fk. Crow)	NTU	01,03	8
	NTRU	--	--
	Field (FNU)	07-08	11
S002-020- Un-named Creek (trib. To N. Fk. Crow	NTU	03	2
	NTRU	--	--
	Field (FNU)	07-08	10
S001-256-N. Fk. Crow above S. Fk. Crow	NTU	01,03	19
	NTRU	98,01,02,06	10
	Field (FNU)	02,07-08	26
S000-050-M. Fk. Crow	NTU	01,03	20

at Rockford	NTRU	99-02,06	23
	Field (FNU)	00,02	9
S002-030- Un-named Creek (trib. To N. Fk. Crow)	NTU	01,03	5
	NTRU	--	--
	Field (FNU)	07-08	10
S000-004-N. Fk. Crow near junction with Mississippi River	NTU	--	--
	NTRU	98-02	25
	Field (FNU)	01,02,04,05,07	18

A summary of flow data available by site is also presented in Table 5.

Table 5 - Discharge Data by Monitoring Site

STORET ID	Location	DNR ID	USGS ID	Provider	Years of Operation	Flow Record Length (days)	Notes
S000-050	N. Fork Crow River at Rockford	18087001	05280000	USGS	1906 - Present	39373	
S001-256	N. Fork Crow River west of Rockford, Farmington Ave	18088001	05278400	DNR/PCA	02, 04-06, 08	708	08 data only Sep-Oct
S001-517	N. Fork Crow River near Cokato, CSAH 4	18083001	--	DNR/PCA	08	295	Outside of listed area
S001-255	S. Fork Crow River at Delano, Bridge St	19001001	05279400	DNR/PCA	03, 05, 06, 08	1083	Outside of listed area

5.0 Fecal Coliform Bacteria

5.1 Surface Water Quality Conditions

As mentioned previously in this report, the reach of the North Fork Crow River from its junction with the South Fork to its junction with the Mississippi River has been listed as impaired for fecal coliform bacteria. Table 6 summarizes the fecal coliform and *E. coli* bacteria available for the project area, showing the total number of samples and the total number of exceedances for each type of bacteria by station.

Table 6- Bacteria Data Summary by Monitoring Station

Monitoring Site	Parameter	# Samples	# Samples Showing Exceedances
S002-019 – N. Fk Crow above Mill Creek	Fecal coliform	3	1
	E. coli	15	3
S002-018 – Mill Creek	Fecal coliform	1	0
	E. coli	26	6
S002-020 – Un-named Creek (trib to N. Fk Crow)	Fecal coliform	1	0
	E. coli	32	21
S001-256 – N. Fk. Crow above	Fecal coliform	5	3

S. Fork, Rockford	*E. coli*	44	10
S001-255 – S. Fk. Crow at Delano	Fecal coliform	5	2
	E. coli	26	12
S000-050 – N. Fk. Crow at Rockford	Fecal coliform	6	2
	E. coli	8	4
S002-030 – Un-named Creek (trib to N. Fk. Crow)	Fecal coliform	1	1
	E. coli	31	21
S000-004 – N. Fk. Crow near junction with Mississippi R.	Fecal coliform	2	0
	E. coli	29	4
TOTAL		235	90

Data were analyzed by season to see if seasonal patterns exist. Table 7 presents the number and geometric mean of data points collected at each of the above monitoring sites by season by type of bacteria.

Table 7 - Seasonal Bacteria Concentrations by Monitoring Station

Site	Parameter	Spring (April-May)		Summer (June-Aug)		Fall (Sept-October)		Total	
		N	Geomean	N	Geomean	N	Geomean	N	Geomean
S002-019 – N. Fk Crow above Mill Creek	Fecal coliform	0	-	3	114	0	-	3	114
	E. coli	6	13	7	140	2	94	15	51
S002-018 – Mill Creek (trib to N. Fk. Crow	Fecal coliform	0	-	1	140	0	-	1	140
	E. coli	9	6	12	84	4	312	25	42
S002-020 – Un-named Creek (trib to N. Fk Crow)	Fecal coliform	0	-	1	130	0	-	1	130
	E. coli	11	31	18	424	3	349	32	169
S001-256 – N. Fk. Crow above S. Fork, Rockford	Fecal coliform	0	-	5	258	0	-	5	258
	E. coli	11	18	26	91	7	98	44	61
S001-255 – S. Fk. Crow at Delano	Fecal coliform	0	-	5	497	0	-	5	497
	E. coli	8	20	15	169	3	84	26	81
S000-050 – N. Fk. Crow at Rockford	Fecal coliform	2	14	4	290	0	-	6	106
	E. coli	0	-	6	160	2	69	8	130
S002-030 – Un-named Creek (trib to N. Fk. Crow)	Fecal coliform	0	-	1	1100	0	-	1	1100
	E. coli	11	62	15	445	5	349	32	169
S000-004 – N. Fk. Crow near junction with Mississippi R.	Fecal coliform	0	-	2	76	0	-	2	76
	E. coli	7	16	12	61	9	38	29	32

A preliminary analysis of the bacterial data was conducted to try to characterize the potential sources of the bacteria loadings causing the impairments. For this analysis, we used both raw *E. coli* data as well as fecal coliform data converted to *E. coli* equivalents. We considered using project area specific relationships between *E. coli* and fecal coliform to make this conversion. There were 25 samples-virtually all of them collected between May and September 2002- that were analyzed for both fecal coliform and *E. coli* in the project area data set. Log plots of the paired *E. coli*/fecal coliform data for the project area yielded an excellent fit (R-squared of 0.93), but generated an *E. coli* equivalent of 184 CFU/100 ml for the 200 cfu/100 ml fecal coliform standard, apparently due to the influence of several high values. Thus, we elected to use the regression equation provided in the SONAR supporting the state standard of 126 cfu/100 ml *E. coli* (see Section 2.1 of this memo) to make the conversions.

Figures 3 through 10 show bacteria concentration data (raw *E. coli* data as well as fecal coliform data converted to *E. coli* equivalents using the SONAR regression relationship) plotted by flow frequency regime for the above monitoring stations. Flow regimes were established using flow records between April 2001 and October 2008 at monitoring station S001-050 in Rockford. The bacteria concentration data for each of the stations was collected between June 2000 and September 2008.

Figure 3 - Station S002-019 (N. Fk Crow above Mill Creek) *E. coli* Concentrations by Flow Regime

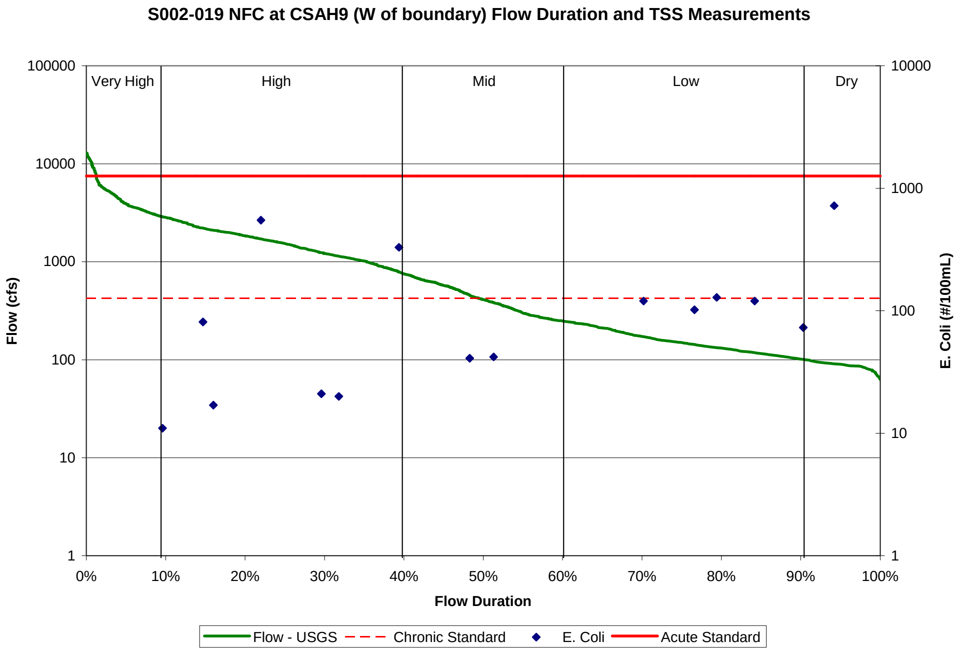


Figure 4 - S002-018 (Mill Creek) *E. coli* Concentrations by Flow Regime

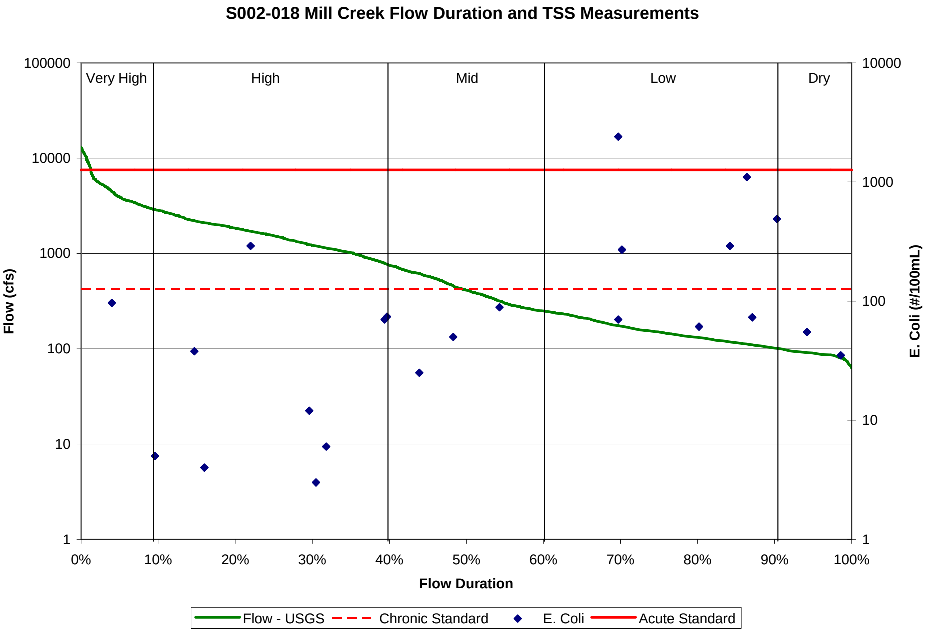


Figure 5 - S002-020 (Un-named Creek) *E. coli* Concentrations by Flow Regime

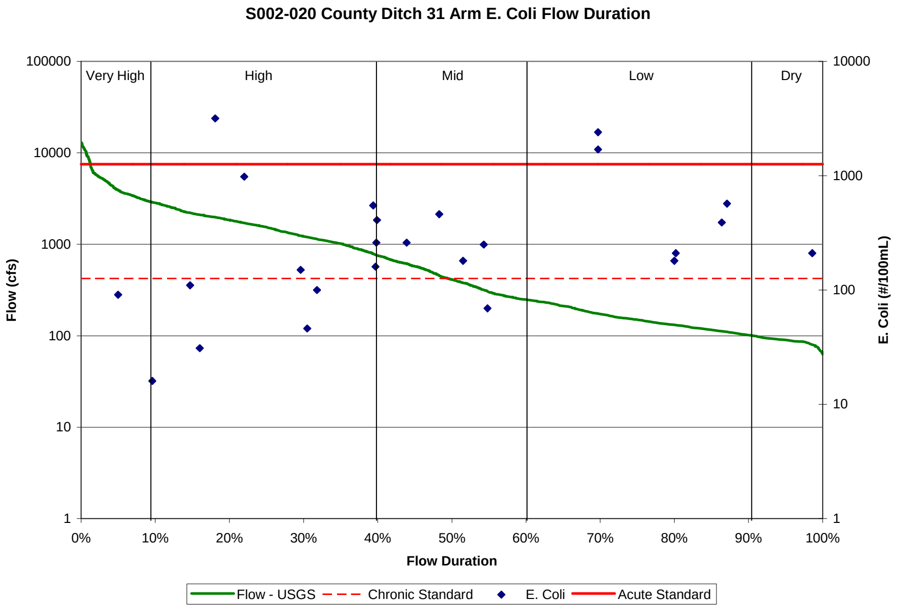


Figure 6 - S001-256 – (N.Fk. Crow above S. Fork, Rockford) *E. coli* Concentrations by Flow Regime

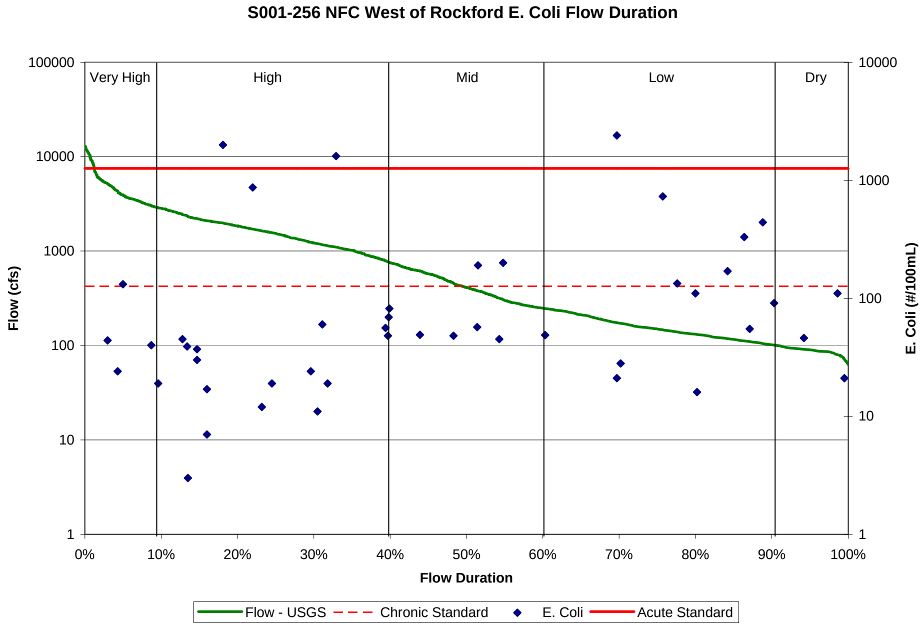


Figure 7 - S001-255 (S. Fk. Crow at Delano) *E. coli* Concentrations by Flow Regime

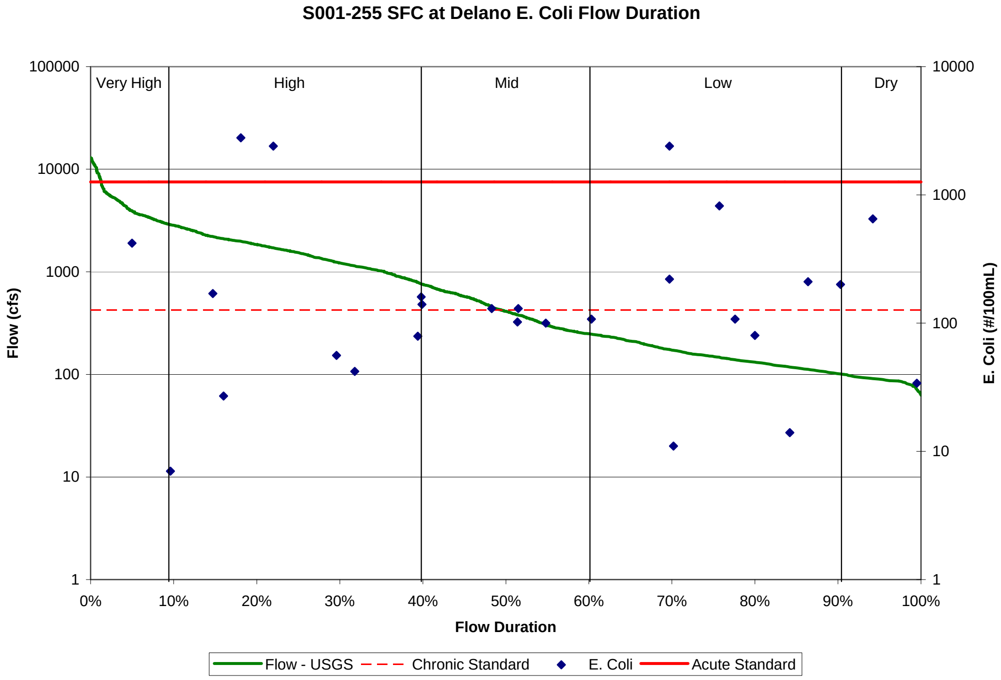


Figure 8 - S000-050 (N. Fk. Crow at Rockford) *E. coli* Concentrations by Flow Regime

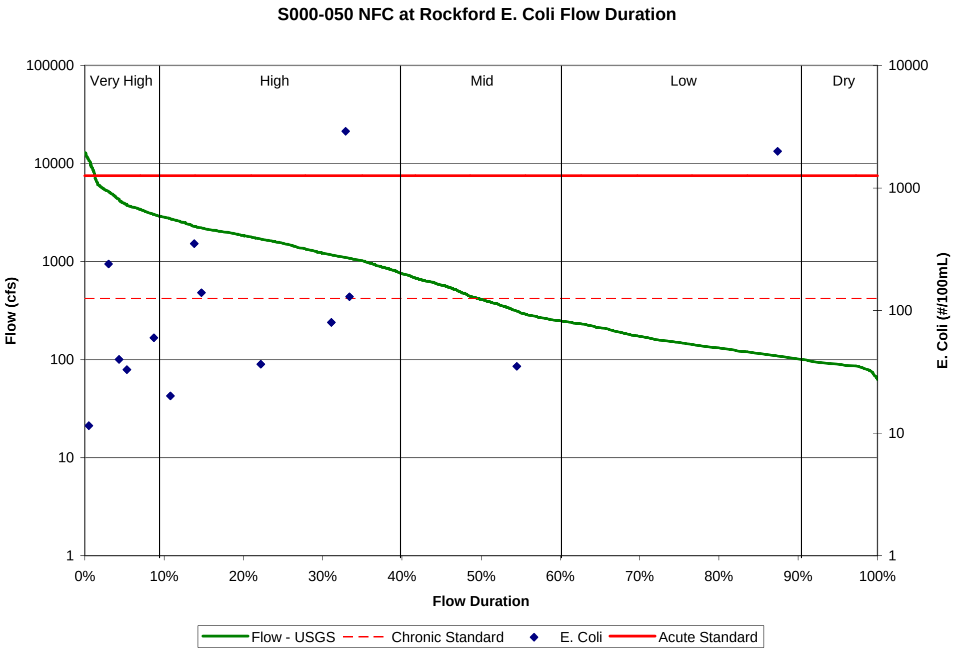


Figure 9 - S002-030 (Un-named Creek) *E. coli* Concentrations by Flow Regime

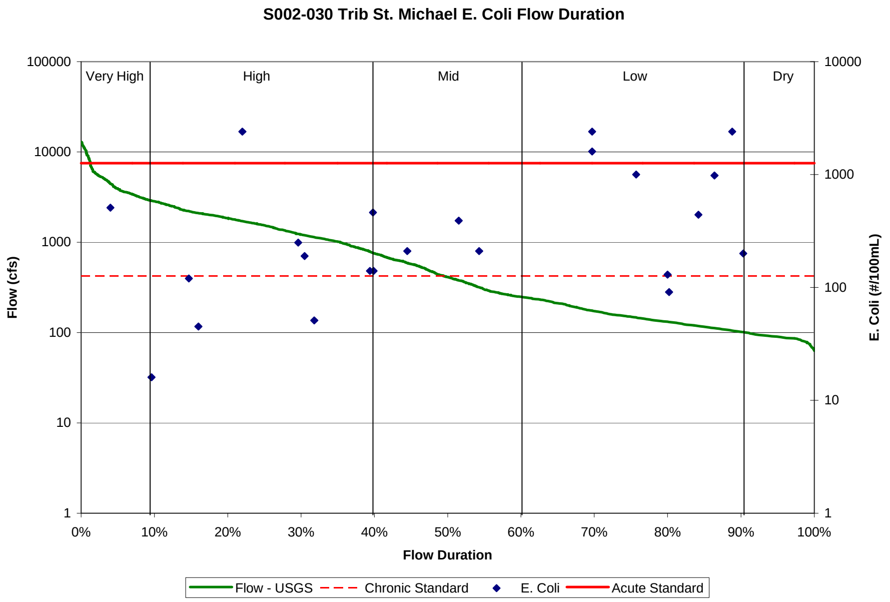
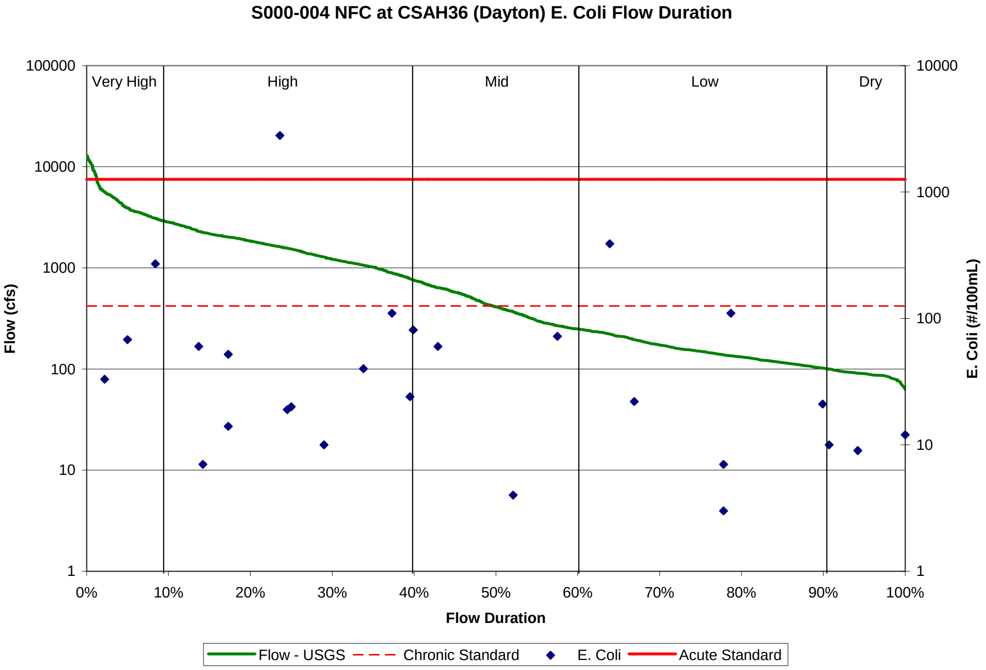


Figure 10 - S000-004 (N. Fk. Crow near junction with Mississippi R.) *E. coli* Concentrations by Flow Regime



These analyses suggest the following:

- Five of the six exceedances that were recorded within the impaired reach of the North Fork Crow River at Rockford occurred at high or very high flows during the summer period, indicating runoff driven processes as a prime suspect in delivery of bacteria loads to the system.
- The plots of *E. coli* concentrations by flow regime indicate many exceedances of the 126 CFU/100 ml standard occur during low flow conditions for most of the monitoring sites located on small tributaries, as well as the South Fork at Delano, and the N. Fk. Crow River above the impaired reach. Most of these data were collected after 2002, the latest year for which data is available for the N. Fork Crow River site at Rockford. High bacteria concentrations during low flow conditions suggest sources such as septic systems, overgrazed pastures with direct access to streams, and/or wildlife as probable sources.
- Concentrations for the listed reach of the North Fork vary somewhat across the seasons, with geometric mean values usually highest for the summer season. This reflects the probable role of summer precipitation events generating runoff episodes that cause delivery of bacterial loads to the receiving water.
- A lack of major differences in seasonal geomeans for both summer and fall from several of the small tributaries suggest a diversity of sources are contributing to the loads.

5.2 Bacteria Pollutant Source Inventory

A bacteria source assessment is intended to estimate the mass of bacteria produced in the watershed from various sources over a period of time based on knowledge of the numbers and basic characteristics of bacteria producers in the watershed. This information can be used to obtain information on the largest potential sources of bacteria to focus on for load estimation purposes. The calculation methodologies focus on fecal coliform bacteria, so the bacteria mass information in this section will generally be expressed as fecal coliform Fecal coliform will be converted to *E. coli* when the source assessment information is presented in the TMDL to match the requirements of the standard.

It is important to note that while there has been much work done in Minnesota to characterize the bacteria generation as well as delivery characteristics from specific sources, it is common for these numbers to be adjusted based on local knowledge. Much of the information prepared for this initial source assessment was taken from recent bacteria analyses conducted for a bacteria TMDL in Carver County, located just south of the Lower North Fork Crow River subwatershed. Thus, the information contained in this section may be subject to further adjustments prior to the time the TMDL is developed.

The analysis in this section focuses on those features of the watershed that drain directly to the impaired reach, based on boundary conditions agreed to during scoping of this project. The assumption was made that the majority of inputs causing the impairment are likely entering the impaired reach between the monitoring stations near the upper and lower bound of that reach (Station S000-050 at Rockford on the upper end and Station S000-004 at the mouth of the N. Fork Crow River on the lower end). In this case, that means that inputs were characterized for the watershed draining to the River between these two points, including the un-named tributary near St. Michael (Station S002-030). These subwatersheds are called Lower North Fork Crow River and Un-named Tributary.

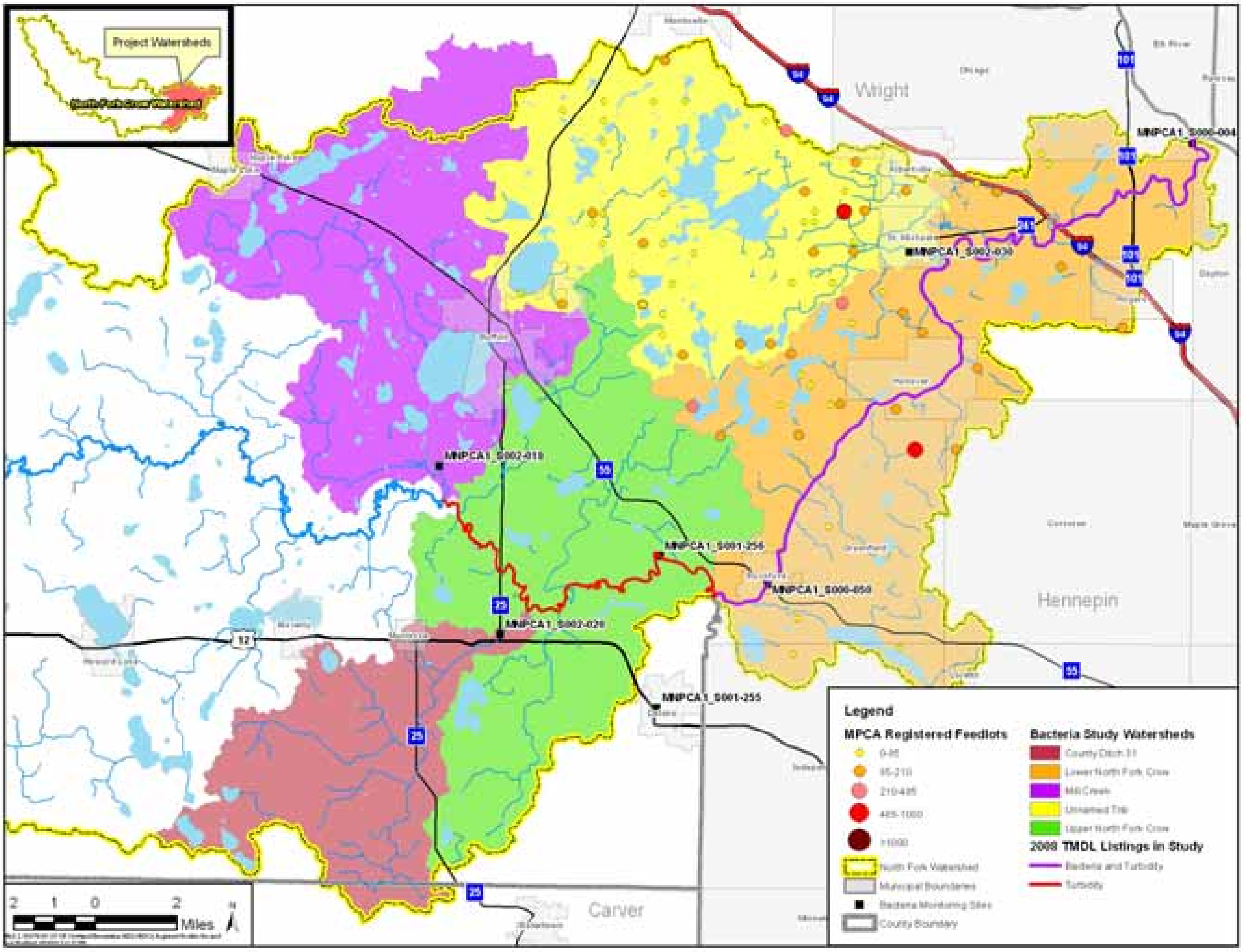
5.2.1 Livestock

Livestock sources include several categories such as feedlots, overgrazed pastures, surface application of manure and incorporated manure. Following is a description of these sources.

5.2.1.1 Feedlots and Over-grazed Pastures Near Streams

An area is considered a feedlot if it is a lot or building or combination of lots and buildings intended for the confined feeding, breeding, raising or holding of animals and specifically designed as a confinement area in which manure may accumulate or where the concentration of animals is such that vegetative cover cannot be maintained within the enclosure. Open lots used for the feeding and rearing of poultry (poultry ranges) are considered animal feedlots. There are a total of 72 feedlots in the two subwatersheds (44 in Un-named Tributary and 28 in the North Fork) feedlots and an estimated 7,038 animal units in the two sub-watersheds. The majority of the animal units are dairy (4,378 units) followed by beef (1,756 units) and swine (654 units). A map of the location of the confined animal feedlot operations (CAFOs) in the sub-watersheds of interest is shown in Figure 11. CAFOs are regulated under the NPDES permit system.

Figure 11 - Confined Animal Feeding Operations (CAFOs) in Subwatersheds of the Bacteria Impaired Reach-North Fork Crow River



GIS data showing the exact location and boundaries of pastures in the watershed was limited, however all feedlots and open lot cattle and dairy facilities within 300ft of a stream would have a higher likelihood of animal access to the stream and therefore higher likelihood of delivering bacterial loads to the receiving water. In the North Fork Crow River subwatershed, there are four feedlots within 300 feet of the River with about 370 animal units, including one within 100 feet of the River with 165 animal units. For the Un-named Tributary watershed near St. Michael, 5 feedlots with almost 720 animal units are within 300 feet of the tributary, including 1 within 100 feet housing just over 20 animal units.

5.2.1.2 Surface Manure Application

Manure application rates were estimated for the Carver County bacteria TMDL (Mike Wanous, Director – Carver SWCD and Tom Kalahar with Renville County). Based on that information, we assumed that approximately 1/3 of the cropland in the two subwatersheds receive some sort of manure application. The application rates vary depending on the nutrient content but reasonable estimates would be 12,000 gallons per acre for liquid and 15 tons for solid. Most liquid manure is injected into the ground or incorporated within 24 hours. Solid manure is spread on the soil surface, and in most cases is not immediately incorporated into the ground.

Most hog manure is applied as a liquid. Most beef and poultry manure is applied as a solid. Dairy manure is applied as both liquid and solid manure. In most cases the larger dairy operations have liquid ag-waste pits, and the smaller dairies haul manure as a solid.

A large portion of manure applications occur in the fall when animal waste pits are emptied out. However, some farmers (especially small dairy farmers) spread manure year round. To account for the varied application periods, it was assumed that 20% of surface applied manure occurred in the spring, 20% in the summer, and 60% in the fall (WENR Technical Sub-Committee, 2004).

All estimates in this sub-section should be reviewed by local resource managers to determine if they are appropriate for use in this project area.

5.2.1.3 Incorporated Manure

Liquid manure is often injected directly into the topsoil, or incorporated into the soil after surface spreading with agriculture tillage equipment. Application of incorporated manure typically occurs in the fall when waste pits are full and crops have been removed, however some pits will be emptied earlier in the year if needed. When this happens, it is often done before June 1 (before crops are planted in the spring). Most farmers find it difficult to rely on spring applications because the soil is often too wet in the spring months. To account for the varied application, it was assumed that 20% of incorporated manure spreading occurred in the spring with the remaining 80% occurring in the fall. Again, all estimates in this sub-section should be reviewed by local resource managers to determine if they are appropriate for use in this project area

5.2.2 Industrial Dischargers

There is only one industrial discharger in the Lower North Fork Crow River sub-watershed. That discharger is Great River Energy (MN00049077-SD-1), which discharges non-contact cooling water There was no monitoring data for bacteria for this discharge in 2008. In the Un-named Tributary sub-watershed, Dale's 66 is the only listed industrial discharger, but this permit may now be terminated and there is neither flow nor quality data available for the discharge in 2008. Barring unique circumstances, however, neither is expected to contribute much of a bacterial load to adjacent receiving waters.

5.2.3 Human Sources

Septic Systems (ISTS)

Failing or nonconforming septic systems can be an important source of bacteria especially during dry periods when these sources continue to discharge and runoff driven sources are not active. The MPCA estimated a failure rate of 44% for ISTSs for the Southeast Minnesota Regional (MPCA 2002), and Carver County estimated a failure rate of 43% for the entire County (Mary West, pers. comm.). A non-compliance rate for ISTSs of about 65% has been estimated for Wright County, though it should be noted that this figure does not necessarily represent system failures (Sean Riley-Wright County Planning and Zoning, personal communication).

Based on data from the 2000 census and assuming 2.8 people per household, the rural population and number of rural households in the Lower North Fork Crow River subwatershed and the Un-named Tributary subwatershed is 3,530/1,261 and 967/345, respectively. (Rural populations were defined as those populations outside the boundaries of incorporated jurisdictions). Thus over 1,600 households, comprising about 20 percent of the total population in the two subwatersheds, dispose of wastewater through on-site disposal systems, also known as septic systems or individual sewage treatment systems (ISTS). Unless on-site disposal systems are functioning properly, groundwater and surface water contamination can occur. Wastewater from septic systems may include many types of contaminants such as nitrates, harmful bacteria and viruses, and other toxic substances, which can be hazardous to both groundwater and surface water. Properly sited, designed and operated ISTS do not pose any risk of contamination to surface water or groundwater. Summary information on the total number of septic systems and the estimated number of failing systems, based on a 44% failure rate for the two subwatersheds, is presented in Table 8. The failure rate assumption should be reviewed with local government staff to determine if it is appropriate for use in the project area.

Table 8. Septic Systems in the Lower North Fork Crow River and Un-Named Tributary Subwatersheds.

Watershed	**Estimated Number of Septic Systems**	**Estimated Number of Failing Septic Systems**
Lower North Fork of Crow River	1261	555
Un-named Tributary	345	152

Municipal Wastewater Treatment Facilities

The Lower North Fork Crow and Un-named Tributary subwatersheds have a total of five wastewater treatment plants. About 81% and 91% of the human population in the Lower North Fork Crow River and the Un-named Tributary subwatersheds, respectively, discharge to municipal wastewater treatment facilities. Table 9 summarizes the discharge characteristics of the facilities.

Table 9. WWTP Loads for Dischargers in the N. Fork Crow River and Un-named Tributary Subwatersheds.

WWTP	**Receving Water**	**Maximum Monitored Fecal Coliform Concentration (CFU/ 100 ml) (2008)**
Otsego Wastewater Treatment Plant (MN0064190-SD-1)	N. Fork Crow River	2
St. Michael Wastewater Treatment Plant (MN0020222—SD-1)	Un-Named Tributary to the N. Fork Crow River	<3
Rogers Wastewater Treatment Plant (MN0029629-SD-1)	Un-named tributary to N. Fork Crow River	95
Rockford Wastewater Treatment Plant (MN002467-SD-1)	N. Fork Crow River	104
Greenfield Commercial/Industrial Park (MN0063762-SD-1)	N. Fork Crow River	87

By rule, these dischargers must maintain discharge fecal coliform concentrations below 200 cfu/100ml, which can be accomplished through additional treatment such as chlorination. Additionally, these dischargers must monitor effluent to ensure compliance with these rules. Note that 2008 monitoring data show that all facilities are discharging at well below the fecal coliform standard of 200 CFU/100 ml.

5.2.4 Wildlife

Wildlife in the watershed encompasses a broad group of animals. For the purposes on this assessment, we focused on deer and geese because they are known contributors of bacteria and considered good estimates of wildlife densities in general. Other wildlife was lumped into a single category.

The Minnesota Department of Natural Resources (MnDNR) modeled deer population densities for several areas in adjacent Carver County. MnDNR staff provided estimates of about 5 deer/mi^2 for most of the watershed, with up to 15 deer per mi^2 closer to the river valleys (Jeff Miller-MnDNR Wildlife Division in Wilmar, personal communication). We assumed that the overall deer density for the entire project area was 6 deer per square mile.

Goose densities were estimated using the Southeast Minnesota Regional TMDL where they assumed a goose population of 20,000 individuals. Based on the land area in that watershed, the density would be approximately 2.8 geese per square mile. These estimates will be reviewed by the MnDNR to determine whether they are reasonable for this project area.

5.2.5 Urban Stormwater Runoff

Untreated urban stormwater has demonstrated bacteria concentrations as high or higher than grazed pasture runoff, cropland runoff, and feedlot runoff (USEPA 2001, Bannerman et al. 1993, 1996). There is a moderate amount of urban area in the Lower North Fork Crow River and Un-named Tributary subwatersheds (19% and 12.5% respectively). Consistent with the methodology outlined in the Southeast Minnesota Regional Bacteria TMDL (MPCA 2002), urban bacteria contributions were assumed to come exclusively from improperly managed waste from dogs and cats. Using the approach in that study, it was assumed that there were 0.58 dogs/household and 0.73 cats/household in the urban areas.

Local bacteria loads in some of the cities will need to be addressed under NPDES Phase II, which would require surface water receiving stormwater to meet the State standards. EPA guidance states that MS4 stormwater allocations in a TMDL must now be included in the TMDL as a Wasteload Allocation. NPDES Phase II MS4 permit requirements, which regulates urban stormwater discharges, currently apply to the City of St. Michael and the City of Otsego, both of which are designated MS4s because their population is over 5,000 and because of their close proximity to an impaired water.

5.3 North Fork Crow River Watershed Bacteria Producers

The previous sections detail how the gross numbers of bacteria producers was quantified for this preliminary analysis. However, not all bacteria produced are necessarily available for transport. Thus, another important assumption for each source is the percentage of bacteria produced that is *potentially* available for transport away from where it is produced. Table 10 shows the percentages for each bacteria production category that were assumed for this preliminary analysis. These assumptions are based in part on work completed for the Southeast Minnesota Regional Bacteria TMDL (MPCA 2002; and Mulla et. al 2001), then adjusted for a bacteria TMDL conducted for Carver County and located within 10 miles of the impaired reach of the North Fork Crow River. As always, these numbers should be reviewed and adjusted as appropriate to reflect conditions in the project area.

Table 10. Assumptions Used to Estimate the Amount of Daily Fecal Coliform Production Available for Potential Runoff or Discharge into the Streams and Rivers of the Project Area

Category	**Source**	**Assumption**
Livestock	Overgrazed Pasture near Streams or Waterways	1% of Dairy Manure 1% of Beef Manure
	Feedlots or Stockpiles without Runoff Controls	1% of Dairy 5% of Beef Manure 1% Poultry Manure
	Surface Applied Manure	64% of Dairy Manure 94% of Beef Manure 99% of Poultry Manure 10% Swine Manure; 20% of this manure applied in Spring 20% of this manure applied in Summer 60% of this manure applied in Fall
	Incorporated Manure	34% of Dairy Manure 90% of Swine Manure; 20% of this manure applied in the Spring 80% of this manure applied in Fall
Human	Failing Septic Systems and Unsewered Communities	All waste from failing septic systems and unsewered communities
	Municipal Wastewater Treatment Facilities (excluding bypasses)	Calculated directly from WWTP discharge (April through October) and the geometric mean fecal coliform concentration (2004 data)
Wildlife	Deer	All fecal matter produced by deer in basin
	Geese	All fecal matter produced by geese in basin
	Other Wildlife	The equivalent of all fecal matter produced by deer and geese in basin
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	10% of waste produced by estimated number of dogs and cats in basin

Tables 11 and 12 present for the Lower North Fork Crow River and Un-named Tributary subwatersheds, respectively, the estimated daily fecal coliform bacteria load potentially available for delivery to the receiving water from the major identified sources.

Table 11 - Estimated Daily Fecal Coliform Available for Potential Delivery to Crow River from Lower North Fork Crow River Subwatershed

Category	**Source**	**Animal Units or Individuals**	**Animal Type**	**Fecal Coliform Organisms Produced Per Unit Per Day** (10^9)**	**Total Fecal Coliform Available(10^9)**	**Total Fecal Coliform Available by Source(10^9) (% of total for subwatershed)**
Livestock	Overgrazed Pasture near Streams or Waterways	22	Dairy Animal Units	58	1,301	1,938 (0.8%)
		7	Beef Animal Units	89	637	
	Feedlots or Stockpiles without Runoff Controls	22	Dairy Animal Units	58	1,301	4,485 (1.9%)
		36	Beef Animal Units	89	3,184	
		0	Poultry Animal Units	21	0	
	Surface Applied Manure***	1,430	Dairy Animal Units	58	83,249	143,670 (60.2%)
		672	Beef Animal Units	89	59,867	
		17	Swine Units	33	543	
		0	Poultry Animal Units	21	10	
	Incorporated Manure	760	Dairy Animal Units	58	44,226	49,112 (20.6%)
		0	Beef Animal Units	89	0	
		149	Swine Units	33	4,885	
		0	Poultry Animal Units	21	0	
Human	Failing Septic Systems and Unsewered Communities	1,553	People	2.0	3,106	35,273 (14.8%)
	Municipal Wastewater Treatment Facilities	16,083	People	2.0	32,167	
Wildlife	Deer	482	Deer	0.5	241	661 (0.3%)
	Geese	225	Geese	0.4	90	
	Other Wildlife	0	Equivalent of deer plus dogs and cats		331	
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	752	Dogs and Cats	4.5	3,386	3,386 (1.4%)
Total						238,525

Table 12 - Estimated Daily Fecal Coliform Available for Potential Delivery to North Fork Crow River from Un-named Tributary Subwatershed

Category	Source	Animal Units or Individuals	Animal Type	Fecal Coliform Organisms Produced Per Unit Per Day** (10^9)	Total Fecal Coliform Available(10^9)	Total Fecal Coliform Available by Source(10^9) (% of total for subwatershed)
Livestock	Overgrazed Pasture near Streams or Waterways	21	Dairy Animal Units	58	1,247	2,175 (0.8%)
		10	Beef Animal Units	89	928	
	Feedlots or Stockpiles without Runoff Controls	21	Dairy Animal Units	58	1,247	5,887 (2.3%)
		52	Beef Animal Units	89	4,640	
		0	Poultry Animal Units	21	0	
	Surface Applied Manure***	1,372	Dairy Animal Units	58	79,837	168,663 (65.6%)
		979	Beef Animal Units	89	87,230	
		49	Swine Units	33	1,596	
		0	Poultry Animal Units	21	1	
	Incorporated Manure	729	Dairy Animal Units	58	42,414	56,775 (22.1%)
		0	Beef Animal Units	89	0	
		439	Swine Units	33	14,362	
		0	Poultry Animal Units	21	0	
Human	Failing Septic Systems and Unsewered Communities	425	People	2.0	851	20,885 (8.1%)
	Municipal Wastewater Treatment Facilities	10,017	People	2.0	20,034	
Wildlife	Deer	343	Deer	0.5	172	472 (0.2%)
	Geese	160	Geese	0.4	64	
	Other Wildlife	0	Equivalent of deer plus dogs and cats		236	
Urban Stormwater Runoff	Improperly Managed Waste from Dogs and Cats	469	Dogs and Cats	4.5	2,109	2,109 (0.8%)
Total						256,967

While this preliminary analysis does not take into account estimated delivery to the receiving water, there are several items to note:

1. Surface applied manure is by far the most significant potential source of bacterial loading, comprising over 60% of the bacteria load potentially available for transport in both subwatersheds.
2. Incorporated manure comprises the second highest source of bacteria at over 20% of the potentially available load for both subwatersheds.
3. Delivery of the bacterial load from both surface applied manure and incorporated manure are largely dependent on runoff processes to reach receiving waters. This has not been taken into account yet in the analysis.
4. Potential bacterial loading from human sources is ranked third, comprising over 15% and 8% of potential loads in the Lower N. Fork Crow River and Un-named Tributary subwatersheds, respectively. These figures do not take into account the effect of wastewater treatment plants in attenuating bacterial loads from their service areas.
5. Human sources can still be significant during certain flow conditions, since they are one of the few sources that discharge regardless of runoff conditions.
6. Other potential sources appear minor, with potential load contributions of less than 3% each. Again, however, overgrazed pastures near streams and waterways can be significant sources of bacteria loadings to streams if the animals have direct access to the stream, regardless of runoff conditions.

It is also important to note that there are uncertainties associated with the estimates in the table. Estimates of the population with inadequate wastewater treatment are based on an assumed septic failure rate in the county. Additionally, pet numbers are derived from a national survey and may not directly reflect conditions in these specific subwatersheds. Deer populations are from model estimates and geese population estimates are based on densities used in the Southeast Regional TMDL. This summary does, however, provide a reasonable estimate of bacteria producers in the watershed as well as the comparative densities in each category.

6.0 Turbidity

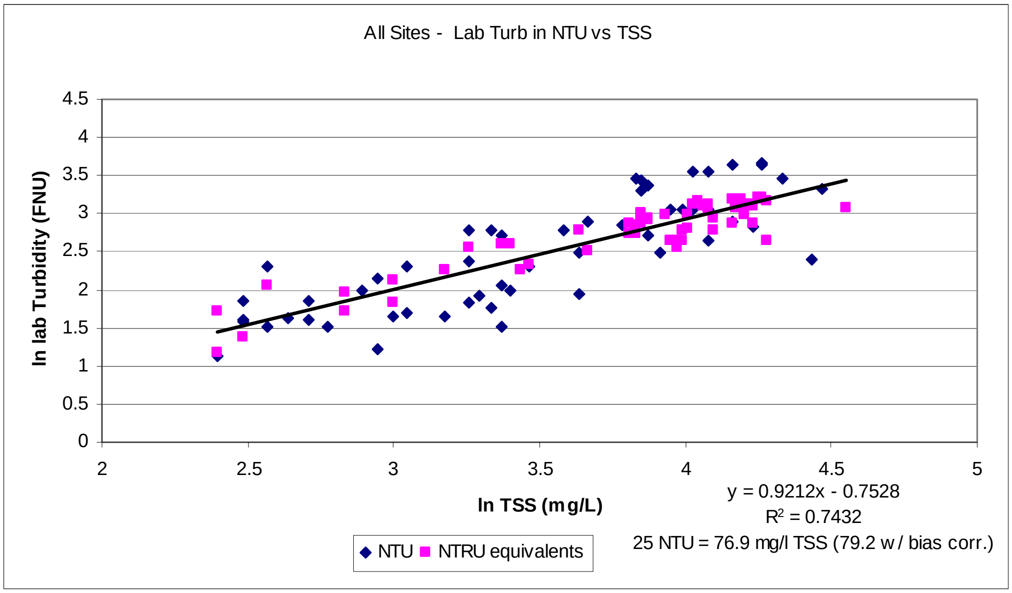
In order to evaluate and set loads affecting turbidity, total suspended solids is used as a surrogate measure. Paired readings of turbidity and total suspended solids are used as the basis for developing this relationship. In the case of the North Fork of the Crow, over 100 readings of paired data were used to define this relationship. About half the paired data points were based on measurements taken with a meter that read turbidity in Nephalometric Turbidity Ratio Units (NTRUs), while the remainder were taken with a meter that read turbidity in Nephalometric Turbidity Units (NTUs). These two units are not the same, but can be related by the following 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 in developing the TSS surrogate value and also presented in the remainder of this report have been converted from NTRUs to NTUs (those data will be referred to as “NTU equivalents”).

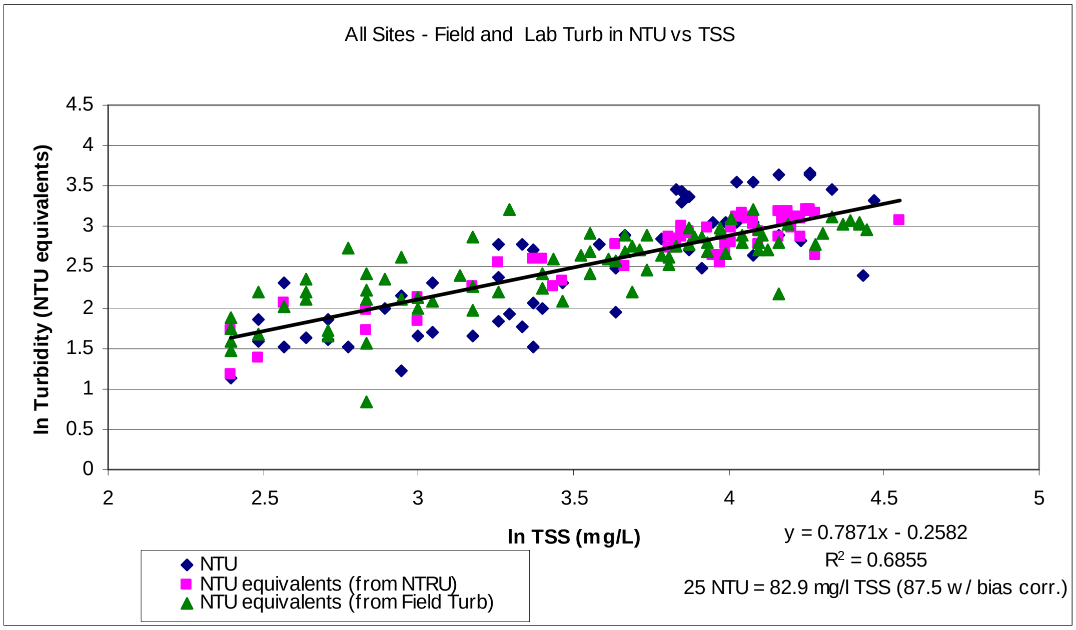
A simple regression of the natural logarithm of TSS and NTU as well as “NTU equivalents” from the NTRU data was completed using the available paired data from all monitoring sites in the project area for the North Fork Crow River. As per the methodology recommended by MPCA, only data associated with turbidities of 40 NTUs or less and TSS values greater than 10 mg/l were used to derive the relationship (MPCA 2008). The regression is shown in Figure 12 and shows a good correlation (R-squared = 0.74). The analysis indicates that the turbidity standard of 25 NTU corresponds to a surrogate TSS concentration of 76.9 mg/l for this data set. However, informal guidance provided by MPCA suggests that “retransforming log-transformed regression estimates to provide ‘raw’ data value estimates results in a retransformation bias given that the logarithmic transformation is nonlinear” (MPCA unpublished 2008) Because the resulting TSS estimates are biased on the low side, the reference document recommends using a bias correction method known as Duan’s smearing. After applying this bias correction method to the data set, the corrected TSS surrogate value for the 25 NTU standard is 79.2 mg/l.

Figure 12 - Turbidity/Total Suspended Solids Relationship-Lab Turbidity Data Only (N. Fork Crow River)



We also evaluated using paired field turbidity/total suspended solids data as well to help define the TSS surrogate value. Combining the field turbidity data with the lab turbidity data presented in Figure 12 generated a regression relationship with a lower R-squared value (0.6855 vs. 0.7432 for the lab data only) and a TSS surrogate of 87.5 mg/l with bias correction. The relationship is shown in Figure 13.

Figure 13 - Turbidity/Total Suspended Solids Relationship-Field and Lab Turbidity Data (N. Fork Crow River)



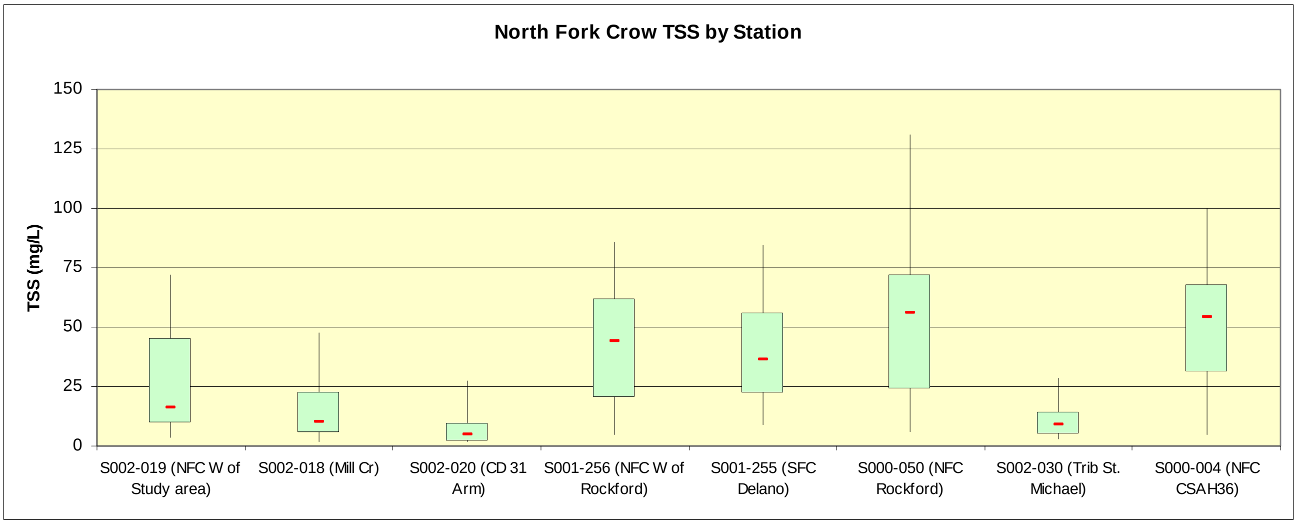
We elected to use the TSS surrogate based only on the lab data because of the tighter relationship between turbidity and TSS values.

6.1 Surface Water Quality Conditions

In an effort to further define the conditions under which exceedances of the turbidity standards occurs and start to identify possible causes of the exceedances, several graphical analyses were conducted. These analyses are presented and briefly described below.

Figure 14 shows box plots of all TSS data available for a number of important monitoring stations in and adjacent to the North Fork Crow River project area. The box plots are presented left to right in upstream to downstream order. Tributary data in the sequence is presented based on where the tributary enters the North Fork relative to the North Fork mainstem monitoring stations. This data presentation format is of value in evaluating spatial patterns that may exist for turbidity exceedances in the system.

Figure 14 - Box Plots of All TSS Concentration Data by Station



Figures 15 - 17 show flow duration curves along with TSS concentration data for three stations on the mainstem of the N. Fork Crow River within the reach identified as impaired for turbidity. Station S001-256 is on the mainstem above its junction with the South Fork, Station S001-050 is below the junction with the South Fork, and Station S001-004 is at the mouth just upstream from the Mississippi River. This data presentation format is of value for evaluating whether exceedances of the turbidity standard at a particular station are associated consistently with any particular flow regime. The surrogate TSS concentration standard of 79.2 mg/l is shown in red on each graph.

Figure 15 - TSS Concentration Data by Flow Interval for Site S001-256 (N. Fork Crow River above Rockford)

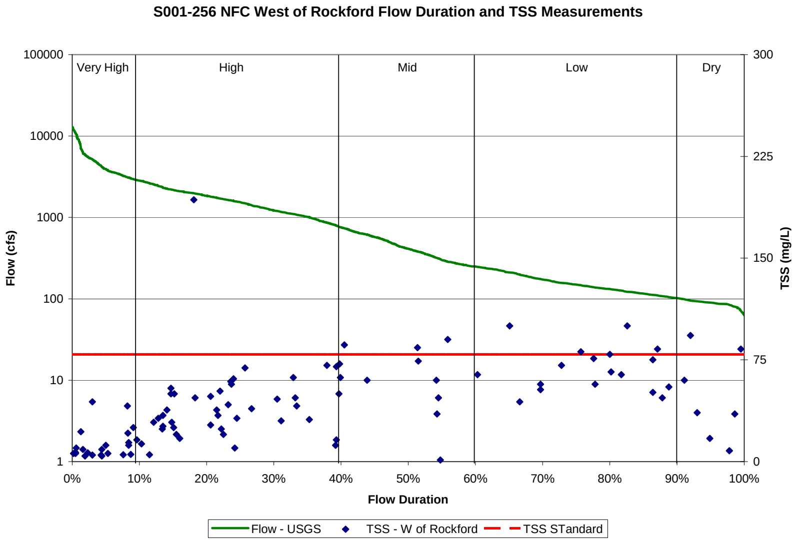


Figure 16 - TSS Concentration Data by Flow Interval for Site S001-050 (N. Fork Crow River at Rockford below junction with South Fork Crow River)

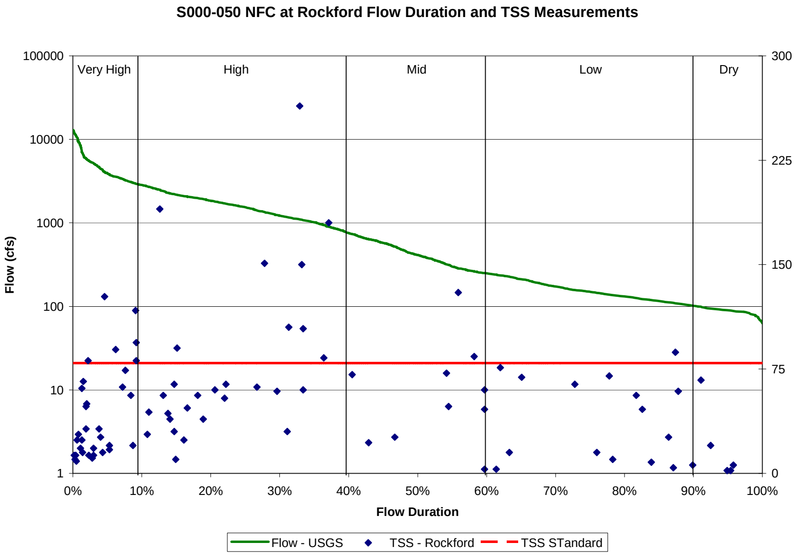
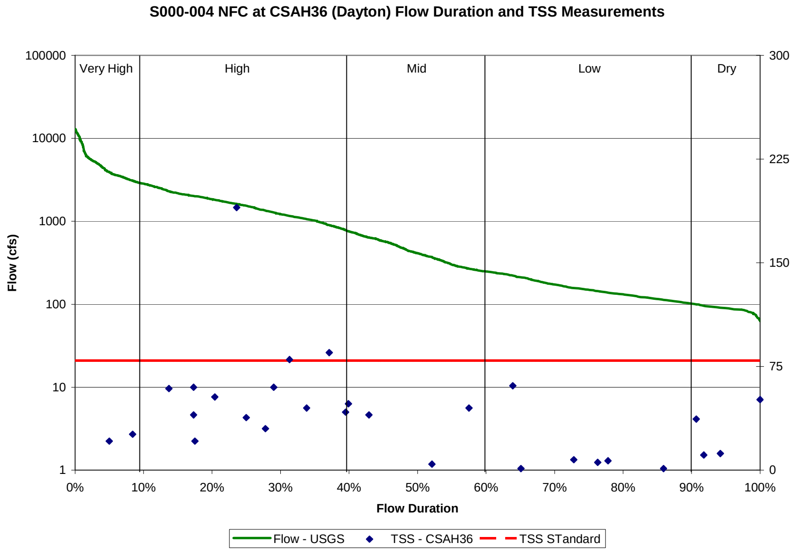


Figure 17 - TSS Concentration Data by Flow Interval for Site S001-004 (N. Fork Crow River at just above junction with Mississippi River)



Finally, Figures 18 - 20 show graphs of the ratio of volatile suspended solids to total suspended solids along with chlorophyll a data by flow regime for various stations. This data presentation format is intended to help detect the connection that organic constituents such as algal blooms or non-algal organic-rich sources might have in causing turbidity exceedances. VSS/TSS fraction and chlorophyll-a data taken during conditions where the turbidity standard was exceeded are shown as large asterisks.

Figure 18 – Station S001-256 NFC West of Rockford – VSS Fraction and Chlorophyll a by Flow Regime

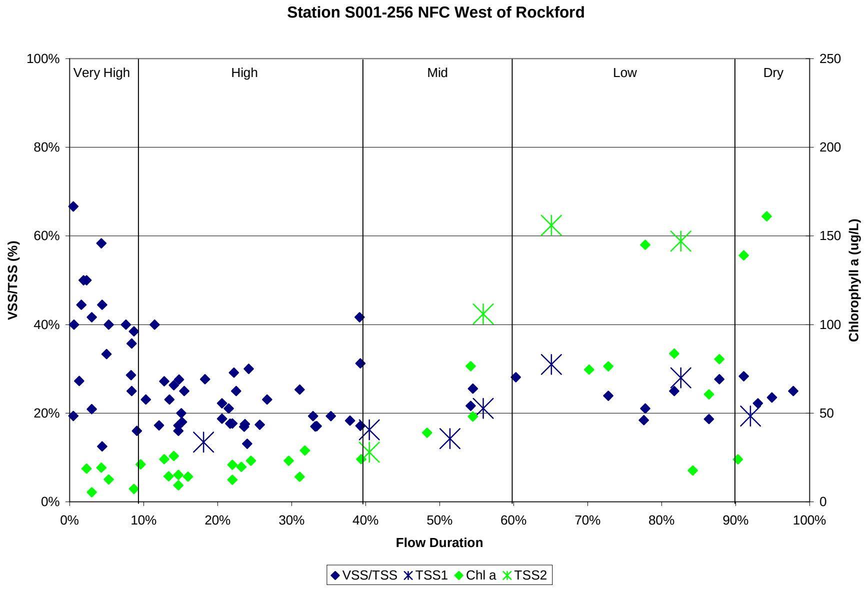


Figure 19 – Station S000-050 NFC at Rockford – VSS Fraction and Chlorophyll a by Flow Regime

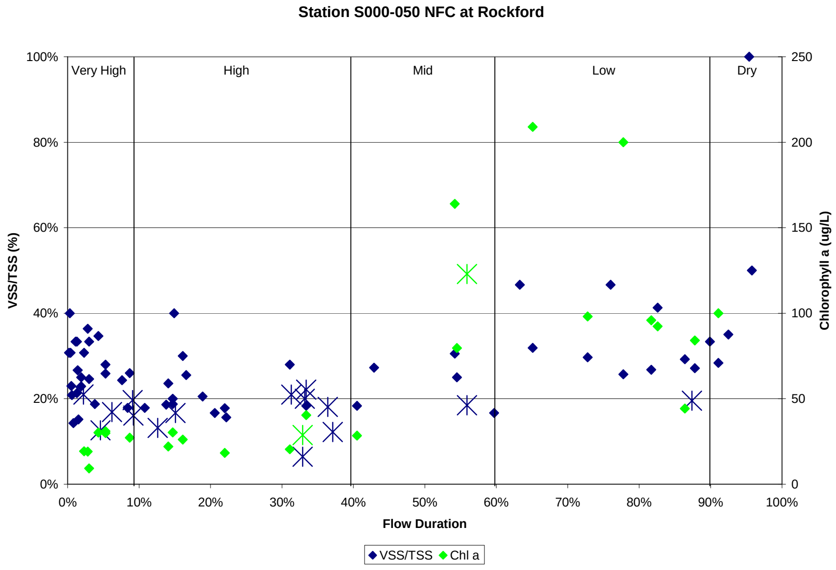
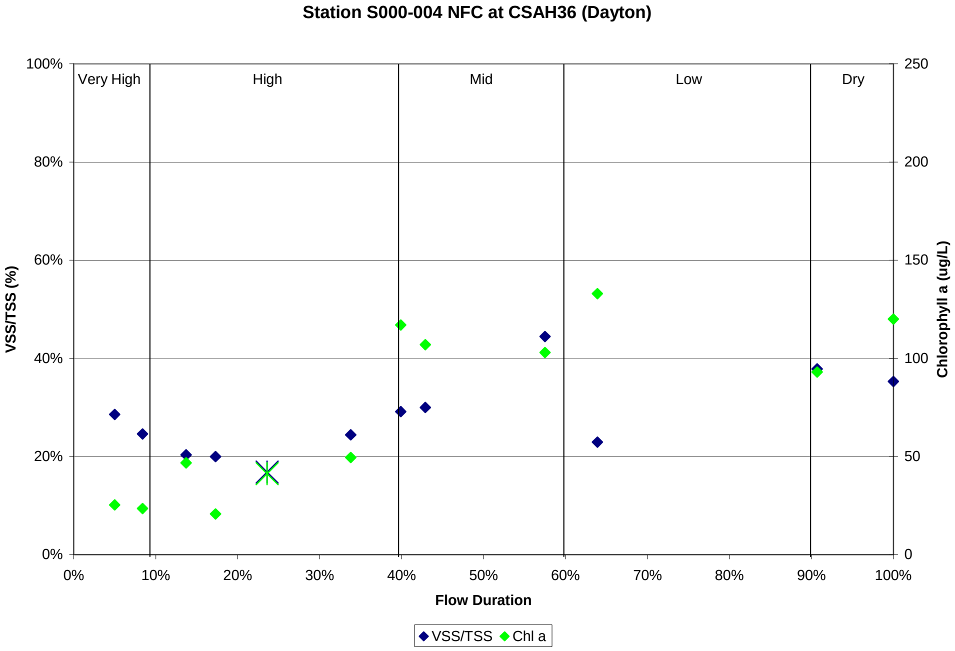


Figure 20 – Station S000-004 NFC at CSAH 36 (Dayton)– VSS Fraction and Chlorophyll a by Flow Regime



Preliminary conclusions that can be drawn from the data presented previously are as follows:

- The box plots (Figure 14) suggest that the primary cause of the turbidity impairment arises between Stations S002-019 on the mainstem of the North Fork above the junction with Mill Creek and Station S001-256 above Rockford and upstream of where the South Fork joins the North Fork. Further, the impairment conditions appear to worsen between Station S001-256 and the Rockford station (S000-050). It also appears that TSS loads from the four monitored tributaries are not big contributing factors to the exceedances in the mainstem North Fork, since the measured TSS concentrations from these tributaries are almost always well below the standard. Even the maximum TSS concentration in the South Fork data set is less than 85 mg/l. compared to the TSS surrogate of 79.2 mg/l.
- The flow duration curves (Figures 15-17) suggest that the majority of exceedances at Station S001-256 above Rockford occur during moderate to low flow regimes. This points to potential causes such as algal blooms and/or disturbances/discharges to the stream channel or near stream environment that occur during lower flow conditions, possibly associated with point source discharges and/or breakdown of streambanks or re-suspension of bottom sediments due to animal activity. At the Rockford monitoring station (S001-256), the majority of exceedances occur during high to very high flow periods, suggesting runoff driven processes that discharge sediment between the two stations. Presumably, these loadings could come from non-urban as well as urban sources.
- The VSS/TSS ratios and chlorophyll a concentrations for Station S001-256 show that many of the turbidity exceedances occur in the moderate to low flow regimes and show high chlorophyll a levels (> 100 ug/l); a number exhibit elevated VSS fractions (>20%) as well. This pattern disappears at Station S000-050 where most exceedances occur at high to very high flow regimes and are generally accompanied by *neither* high chlorophyll-a or elevated

VSS fractions. This could suggest, as stated above, that the primary cause of the turbidity impairments changes from algal blooms or some other organic-based turbidity at low flows in the upper segment of the impaired reach to inorganic particles like mineral sediments that are transported and suspended during runoff events and/or high flows in the lower reaches of the impaired River segment. It should be noted, however, that the database on which these observations are based is not very robust due to the relatively low number of VSS fraction and chlorophyll a data points for turbidity exceedance episodes.

- Overall, based on the available data the turbidity impairment in the listed reach appears to be minor to moderate. Over a significant majority of the time, the TSS readings are below the surrogate standard.

6.2 Pollutant Source Inventory

The following is a discussion of the potential contributors to the turbidity impairment for the listed reaches of the N. Fork Crow River.

6.2.1 Point Sources

National Pollutant Discharge Elimination System (NPDES) permits are issued by the Minnesota Pollution Control Agency (MPCA) under a delegation agreement from the U.S. Environmental Protection Agency (USEPA). These permits are issued to a wide range of facilities or industries, most, but not all, of which have point source discharges. The permits define the conditions that a facility must meet in order to discharge to surface or groundwater. Effluent limits are set on pollutant discharges based on water quality standards and the receiving water's designated use (MPCA 2002). The effluent limit most relevant to this report is for total suspended solids (TSS), although phosphorus is also of interest because of its potential impact on algal-related turbidity.

6.2.1.1 NPDES Municipal and Industrial Wastewater Permit Holders

There are a number of municipal wastewater treatment facilities (WWTFs) located within the North Fork Crow River project area watershed. Those serving the cities of Montrose, Rockford, St. Michael, Rogers, and Otsego discharge effluent to the impaired segment of the North Fork Crow River. The facilities serving Rockford, St. Michael, and Otsego discharge effluent directly to the River, while those serving Montrose and Rogers discharge to ditches/creeks that are tributary to the impaired reach. All together, the sum of the permitted maximum calendar week average TSS loads for these facilities is approximately 2,400 pounds/day based on a maximum calendar week average concentration of 45 mg/l TSS. A summary of these discharge permits will be included in the appendix of the TMDL document.

There is only one permitted industrial facility that discharges to the impaired reach of the North Fork Crow River. It is a substation facility owned and operated by Great River Energy. The permitted discharge is for just over 4 gallons/minute for cooling water blowdown and stormwater runoff. The discharge is to an un-named ditch that is tributary to the North Fork Crow River near the upper end of the impaired reach. The discharge has a TSS limit of 30 mg/l and a requirement to monitor for phosphorus. A summary of this permit will be presented in the appendix of the TMDL report.

6.2.1.2 NPDES Stormwater Permit Holders

Municipal. In the North Fork Crow River project area watershed, approximately 15.8% of the land use is urban/developed. Stormwater runoff-generated pollutant loads generated in developed areas are often a function of the impervious coverage and the extent to which urban Best Management Practices (such as detention ponds and infiltration features) are incorporated into the storm drainage system. The cities of Otsego and St. Michael are both designated MS4s that discharge stormwater to the impaired reach of the North Fork Crow River and are required to obtain Municipal Separate Storm Sewer System (MS4) permit under the MPCA's MS4 stormwater regulations. As part of the permit requirements, these municipalities are required to develop and implement a Stormwater Pollution Prevention Plan (SWPPP).

Construction Permits. The watershed contains some of the fastest growing areas on the outer edge of the Twin Cities metro area. Based on data to be obtained from MPCA, we will include in the TMDL information on the number of acres in the North Fork Crow River watershed that have been under regulated development-related activity for the time period of interest, the number of construction permits issued in areas that discharge to the impaired reach of the North Fork Crow River, and the range in the sizes of the construction sites that have been permitted.

Industrial. There are several facilities with Industrial Stormwater permits that discharge to the impaired reach of the North Fork Crow River watershed. A summary of the permits and a characterization of the discharges will be presented in the final TMDL report.

6.2.1.3 Concentrated Animal Feeding Operations

There are 178 Concentrated Animal Feedlot Operations (CAFOs) located within the project area sub-watersheds. Both CAFOs have NPDES/SDS permit coverage under the State of Minnesota General Livestock Production Permit. The conditions associated with each of these permits allows no discharge of pollutants from the production area of the CAFOs.

6.2.2 Non-Point Sources

Non-point sources can include both background sources, such as natural soil erosion from stream channel processes and upland areas as well as human-caused disturbances. I n a watershed with mixed urban and non-urban land uses like that of the North Fork of the Crow River watershed, non-point sediment related turbidity sources typically fall into one of the following categories:

- Approximately 32% of the land use in the North Fork Crow River project area is agricultural row crop, primarily corn and soybeans. Soil loss is due in part to these areas being left without much vegetative cover for portions of the year between crop harvest and the emergence of the following year's crop. Slope length and steepness, soil type, and cropping practices can all influence soil erosion rates. Agricultural best management practices (BMPs) such as reduced tillage, terracing, etc. can reduce soil erosion dramatically where they are used.
- Livestock grazing can cause erosion by leaving over-grazed land without sufficient vegetative cover to hold soil and other particles in place. The problem may be more serious if over-grazing occurs along streams or waterways, as eroded material is delivered to the water more easily. Roughly 3% of land over in the North Fork Crow River subwatershed is grassland, a portion of which is pastured.

- Over 13% of the project area is developed, and contains some of the fastest growing communities in the Metropolitan area. Erosion from construction sites can export many tons of soil from exposed graded areas in a matter of hours as a result of runoff events if those areas are not properly stabilized. In addition, un-paved roads contribute sediment directly from their surfaces or indirectly through increased volume or velocity of runoff. Gravel roads are only slightly more pervious than asphalt or concrete roads.
- Channel sources include accelerated channel erosion caused by increases in stream channel instability due to hydraulic over-loading. Hydraulic over-loading in turn can be caused by ditching and drain-tiling which delivers runoff to the channel much more rapidly than would occur without those drainage features. Uncontrolled discharge of runoff from impervious surfaces can also be a major contributor in areas where developed land uses dominate. The result is often entrainment of streambank and stream bed material during periods of high stream flow. Mechanical failure of stream banks can also be a contributor, especially where soils are erodible and riparian land uses remove vegetation that would otherwise help anchor the soils along the bank. Finally, high phosphorus concentrations in a slow moving stream system can contribute to blooms of planktonic algae during the growing season that can contribute to turbidity. Enriched runoff from agricultural cropland (either through surface runoff or through drain tile systems), high nutrient discharges from CAFOs, or phosphorus discharged from wastewater treatment plants or industrial or municipal sources can each be of significance.

7.0 References

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