PHASE I REPORT

NORTH FORK – LOWER CROW RIVER

Prepared for

Minnesota Pollution Control Agency

March 2008

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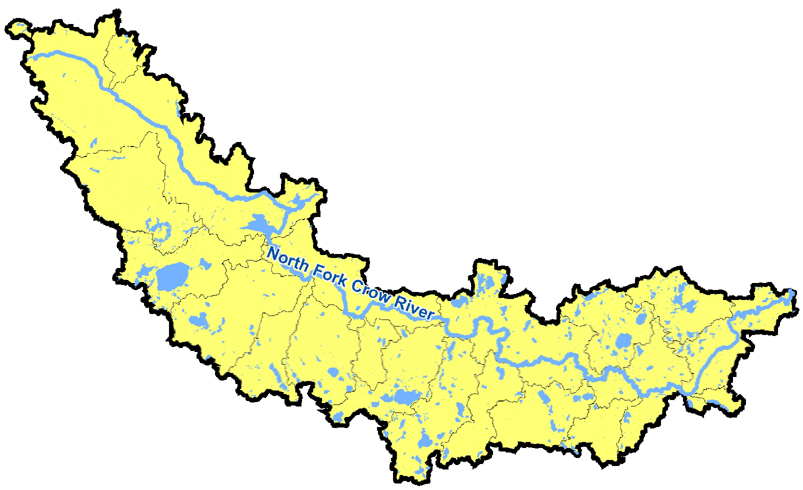

BROWN AND CALDWELL
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1. INTRODUCTION

The purpose of this project is to develop a TMDL for the impaired waters listings for the North Fork – Lower Crow River. The project is broken down into three phases:

- Phase I – Data review and recommendations
- Phase II – Monitoring and data analysis
- Phase III – TMDL Development

These phases are illustrated in Figure 1a.

This report addresses Phase I of the study and is outlined further in Figure 1b. It is important to note that Figure 1b illustrates the original intent of the work elements, however, due to data limitations some of the elements will require further development once additional data is collected. For example, only limited relationships have been identified for the causes of impairment at this time. This report addresses the elements in the Phase I outline.

The sheer size of this watershed makes developing this TMDL a challenge. Impairments that are geographically separated and yet inter-related over hundreds of thousands of acres are one of many issues that must be addressed throughout this process. It is important to note that this TMDL development will require refinement as the process unfolds. The known unknowns are significant and can't be wholly addressed in this initial development process. The strategy developed later in this report provides a relatively simple straightforward approach that will be necessary for this large project with a limited budget. This TMDL can be developed in terms of adaptive management which is a strategy for addressing pollutant load uncertainty that emphasizes taking near term actions to improve water quality. Adaptive management can be employed when data may only weakly quantify links between sources, allocations and in stream targets. Adaptive management identifies site-specific actions leading toward water quality standards attainment, future data collection and analysis, and reassessment of appropriate actions.

On August 2, 2007 a meeting of the watershed stakeholders was held to initiate the public participation element of the TMDL involvement. The meeting notes and supporting information are included in Appendix A.

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Project Phases

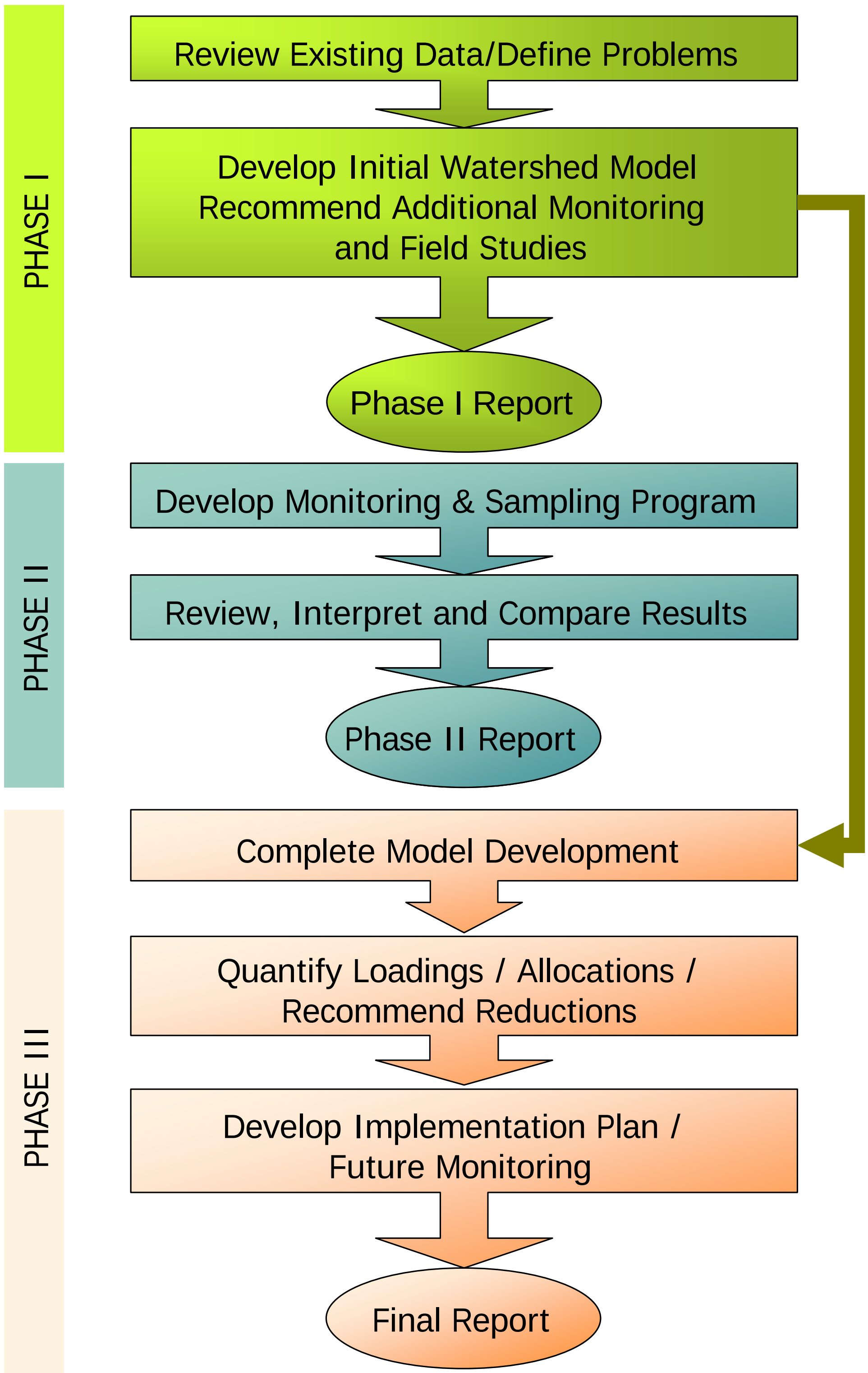
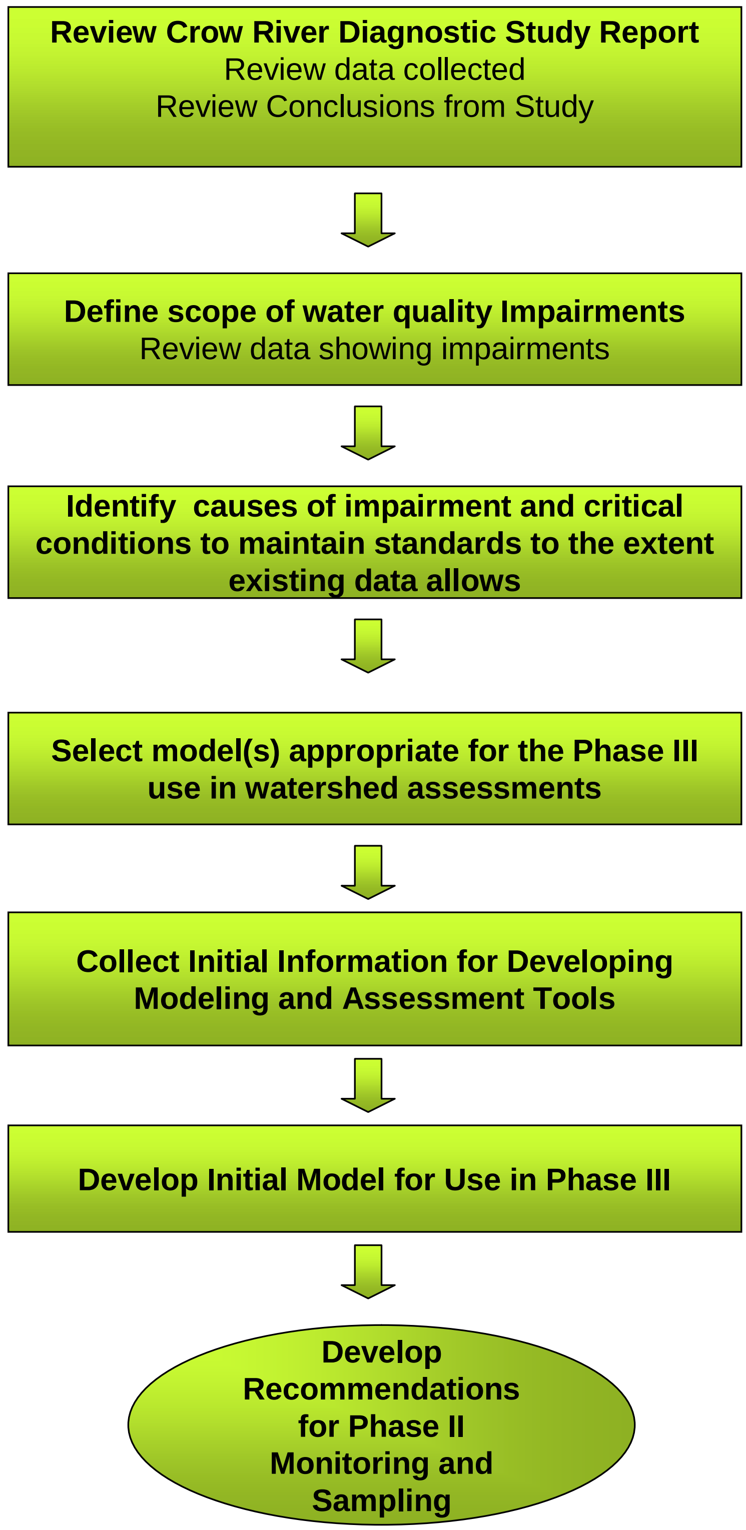


Figure 1b
North Fork - Lower Crow TMDL
Phase I Outline



2. WATERSHED CHARACTERISTICS

The North Fork of the Crow River originates in eastern Pope County and flows for approximately 152 miles to its confluence with the South Fork of the Crow River near Rockford, Minnesota. Together, the North and South Forks form the Lower Crow River, which flows another 26 miles to its confluence with the Mississippi River near Dayton, Minnesota.

The North Fork – Lower Crow River watershed covers approximately 950,000 acres and includes portions of eight counties (Carver, Hennepin, Kandiyohi, McLeod, Meeker, Pope, Stearns, and Wright). Surface elevations within the North Fork – Lower Crow River watershed range from 1411 feet above mean sea level near Green Lake in northern Kandiyohi County, to 841 feet above mean sea level at the confluence of the Lower Crow River and the Mississippi River at Dayton MN. Mean river gradient for the North Fork – Lower Crow River is approximately 2.7 feet of elevation change per mile of river. General topography varies from undulating and hummocky in the lower third of the watershed, to gently rolling in the middle third of the watershed, and finally to mostly flat in the upper third of the watershed. Steep areas are mainly adjacent to the stream bed. Figure 2 displays the geo-morphology of the watershed. Super-glacial drift complex predominates the lower two-thirds of the watershed. The upper third of the watershed is predominantly till plain and outwash.

Cultivated land is the predominant land use/land cover in the watershed, accounting for 61% of the total area. Hay/pasture/grassland and forested areas are next in land use/land cover, accounting for 15% and 9% of the total land area respectively. Figure 3 shows the land use map of the watershed.

The North Fork – Lower Crow River watershed contains 15 stream reaches and 37 lakes that are currently on MPCA's 2006 303(d) list of impaired waters. In addition, the Crow River Organization of Water (C.R.O.W) published the Crow River Diagnostic Study Report Summary, which identified water quality problem areas in the watershed and defined management areas to be targeted for pollutant reduction over the next 15 to 20 years. Table 1 lists the stream reaches that are the focus of this study:

Table 1. Impaired Reaches

Reach Name	AUID	Reach Description	Impairment
Crow River	07010204-502	South Fork Crow River to Mississippi River	Fecal Coliform, Turbidity
Crow River, North Fork	07010204-503	Mill Creek to South Fork Crow River	DO, Turbidity
Grove Creek	07010204-514	Unnamed Creek to North Fork Crow River	DO
Mill Creek	07010204-515	Buffalo Lake to North Fork Crow River	DO
Unnamed creek (County Ditch 31)	07010204-527	Unnamed Ditch to North Fork Crow River	DO
Unnamed creek (St. Michael)	07010204-542	Unnamed Creek to Crow River	DO
Jewitts Creek	07010204-585	Headwaters (Lake Ripley) to North Fork Crow River	DO

Five of these targeted stream reaches are tributary to the main stem of the North Fork – Lower Crow River. All five list low dissolved oxygen as the cause of impairment. The five sub-watersheds are primarily cultivated land, secondarily pasture/hay/grassland areas, with lesser amounts of urban/rural development, forested land, bog/marsh/fen area, brush land, and water bodies. Figure 4 illustrates some of the watershed the impairments.

Several physical features of the North Fork – Lower Crow River watershed, along with some of the local land use practices may contribute to the water quality problems that the watershed is currently experiencing, and that this study is designed to address. The effects of agricultural land uses, such as row crop farming practices, and farm field drainage improvements, have the potential for negative impact. Farms in the watershed are among the highest producers of cattle in the State of Minnesota. The total number of feedlots and the manure management practices of livestock producers have the potential to affect water quality.

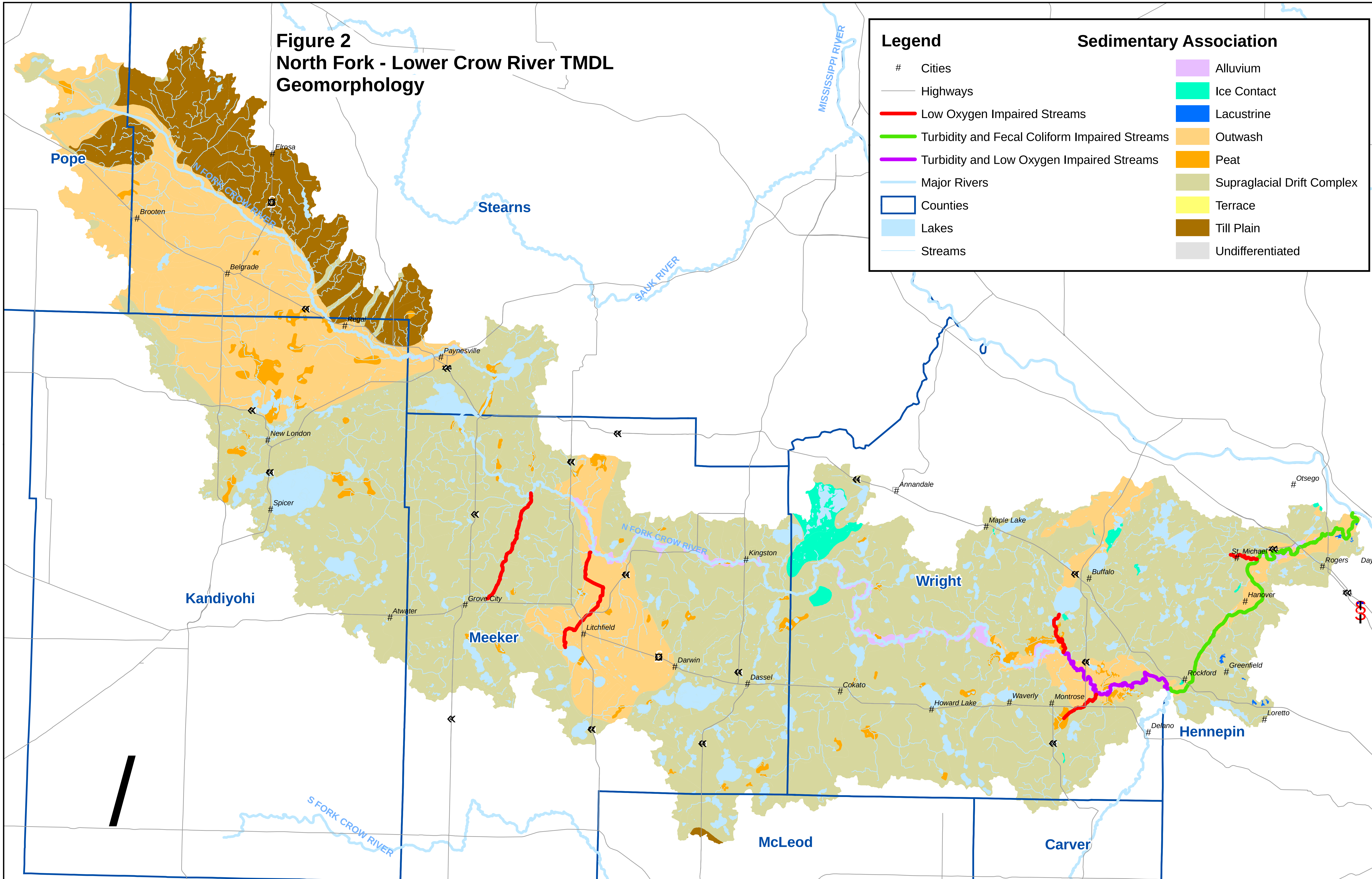


Figure 2
North Fork - Lower Crow River TMDL
Geomorphology
Legend
Cities
Highways
Low Oxygen Impaired Streams
Turbidity and Fecal Coliform Impaired Streams
Turbidity and Low Oxygen Impaired Streams
Major Rivers
Counties
Lakes
Streams
Sedimentary Association
Alluvium
Ice Contact
Lacustrine
Outwash
Peat
Supraglacial Drift Complex
Terrace
Till Plain
Undifferentiated
Pope
Stearns
Kandiyohi
Meeker
Wright
Hennepin
McLeod
Carver
MISSISSIPPI RIVER
SAUK RIVER
N FORK CROW RIVER
S FORK CROW RIVER
Elrosa
Brooten
Belgrade
Regal
Paynesville
New London
Spicer
Grove City
Atwater
Litchfield
Darwin
Dassel
Kingston
Cokato
Annandale
Maple Lake
Buffalo
Howard Lake
Waverly
Montrose
Delano
St. Michael
Hanover
Rockford
Greenfield
Loretto
Rogers
Dayton
Otsego

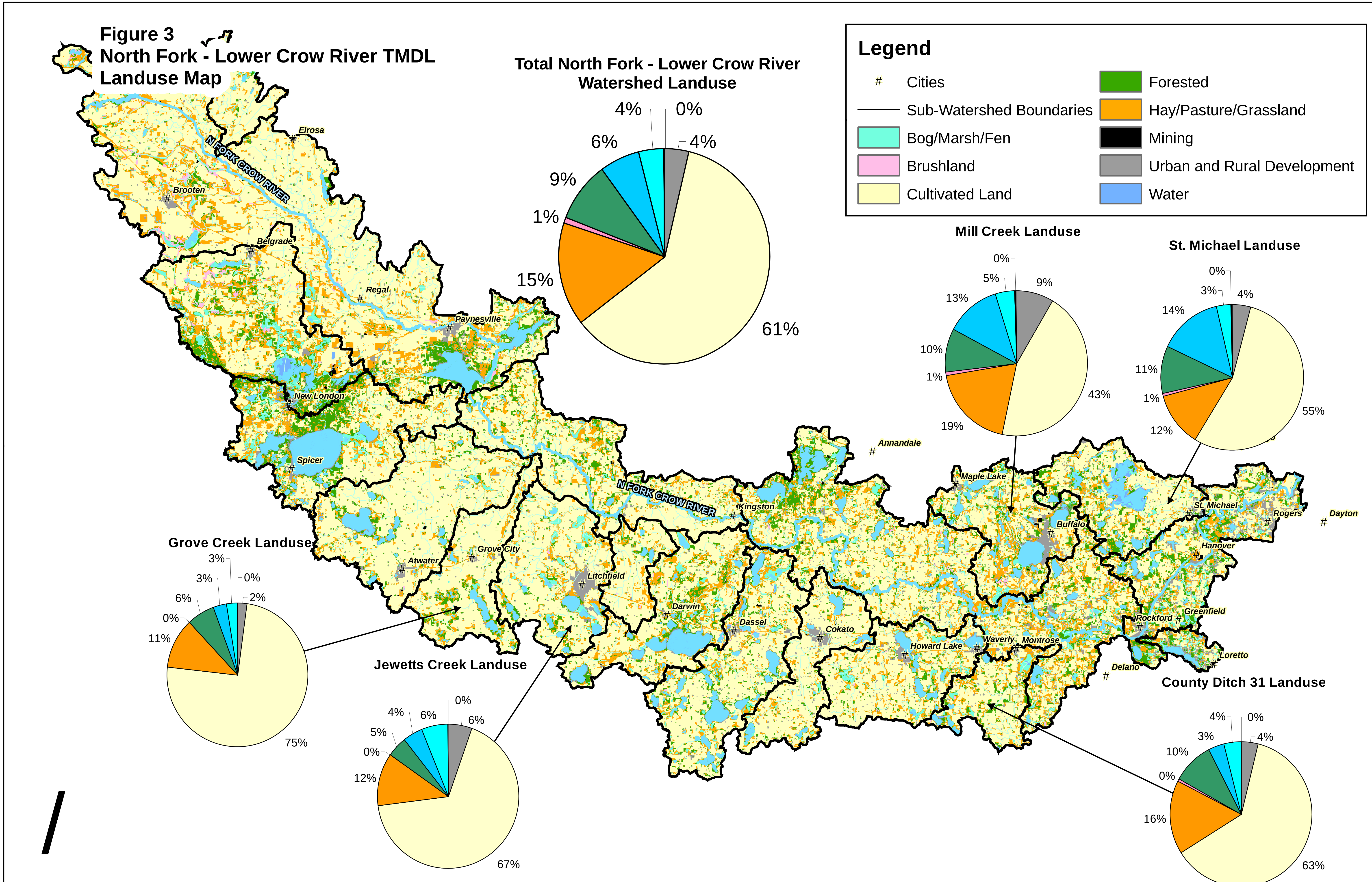


Figure 3
North Fork - Lower Crow River TMDL
Landuse Map
Total North Fork - Lower Crow River
Watershed Landuse
4%
0%
6%
4%
9%
1%
15%
61%
Legend
Cities
Sub-Watershed Boundaries
Bog/Marsh/Fen
Brushland
Cultivated Land
Forested
Hay/Pasture/Grassland
Mining
Urban and Rural Development
Water
Mill Creek Landuse
0%
5%
9%
13%
10%
1%
19%
43%
St. Michael Landuse
0%
3%
4%
14%
11%
1%
12%
55%
Grove Creek Landuse
3%
3%
0%
6%
2%
0%
11%
75%
Jewetts Creek Landuse
0%
4%
6%
6%
5%
0%
12%
67%
County Ditch 31 Landuse
4%
0%
3%
4%
10%
0%
16%
63%
N FORK CROW RIVER
Elrosa
Brooten
Belgrade
Regal
Paynesville
New London
Spicer
Atwater
Grove City
Litchfield
Darwin
Dassel
Cokato
Kingston
Annandale
Maple Lake
Buffalo
St. Michael
Rogers
Dayton
Hanover
Greenfield
Rockford
Loretto
Delano
Montrose
Waverly
Howard Lake

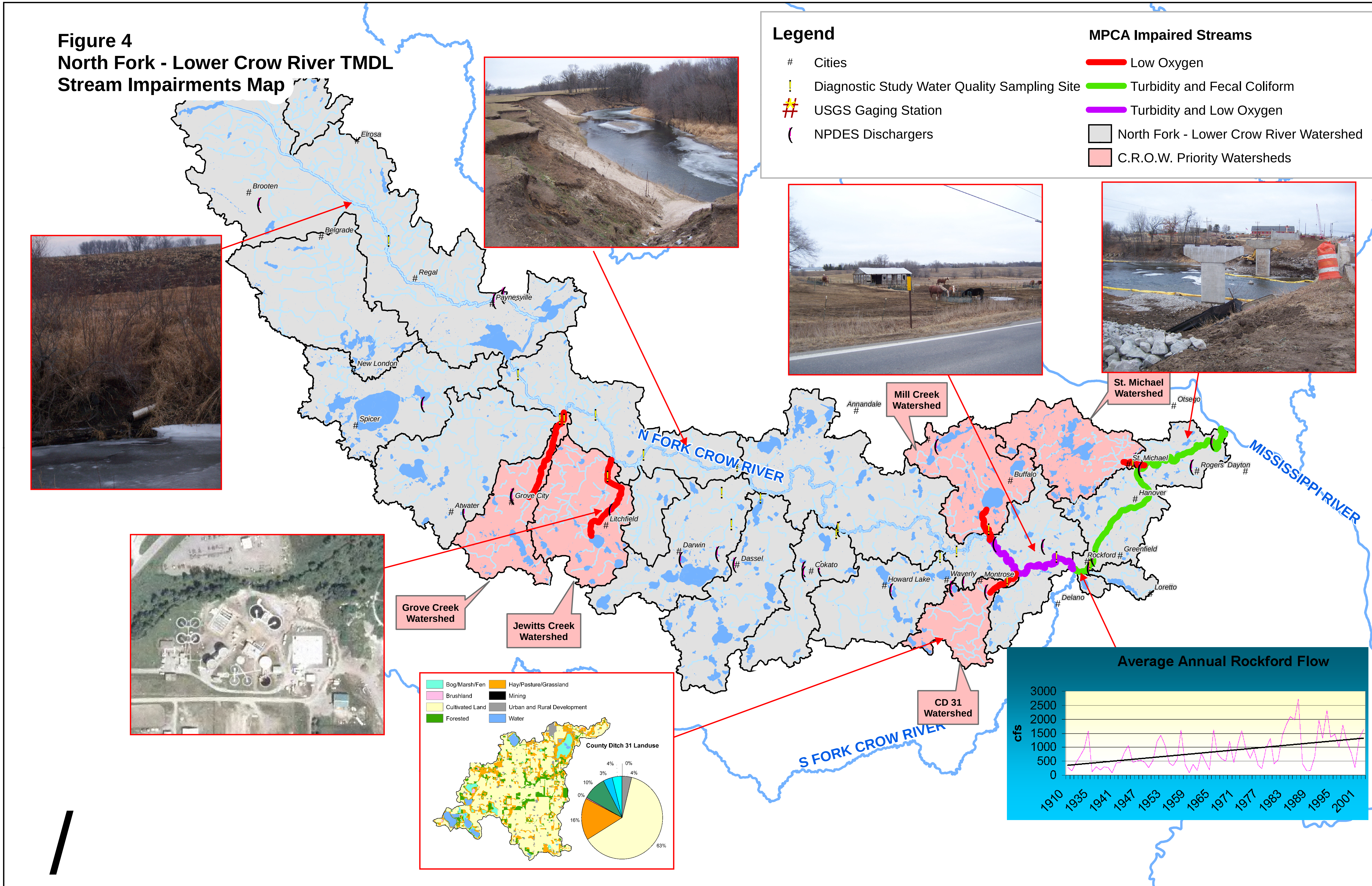


Figure 4
North Fork - Lower Crow River TMDL
Stream Impairments Map

In addition, the North Fork – Lower Crow River and its tributaries are the receiving waters for 25 NPDES permitted dischargers of treated industrial and municipal wastewater. Table 2 shows the list of NPDES discharges including the MPCA code, station name and water body associated with the discharger. The lower portion of the watershed is currently experiencing rapid residential and commercial development. The land use practices and construction activities associated with this development have the potential for impact.

Table 2. Permitted Dischargers in the North Fork Crow River Watershed

	MPCA ID Code	Station Name	Waterbody
1	MN0020168-SD-1	Paynesville WWTP: Retention Basin	
	MN0020168-SD-2	Paynesville WWTP: Tile Around The Aerated Pond Cell	
2	MN0020222-SD-1	St Michael WWTP: Total Facility Discharge Prior To Ponds	Crow River
	MN0020222-SD-2	St Michael WWTP: Effluent From Ponds To Surface Water	Crow River
3	MN0021326-SD-1	Waverly WWTP: 001A Treatment Facility Bypass	
	MN0021326-SD-2	Waverly WWTP: 001 Main Discharge	
4	MN0022659-SD-1	Atwater WWTP: 001 Total Facility Discharge - Monthly	County Ditch C-17
5	MN0023159-SD-1	Darwin WWTP: 001 Total Facility Discharge - Monthly	Lake Darwin
6	MN0023574-SD-1	Grove City WWTP: Treatment Facility Bypass	
	MN0023574-SD-2	Grove City WWTP: Main Facility Discharge	
7	MN0023973-SD-1	Litchfield WWTP: Total Facility Discharge	Jewitts Creek
	MNG640055-SD-1	Litchfield WTP: WTP #8 Discharge	
	MNG640055-SD-2	Litchfield WTP: WTP #9 Discharge	
	MNG640055-SD-3	Litchfield WTP: WTP #10 Discharge	
	MNG640055-SD-4	Litchfield WTP: WTP #12 Discharge	
8	MN0024082-SD-1	Maple Lake WWTP: 001 Total Facility Discharge	Mud Lake
9	MN0024228-SD-1	Montrose WWTP: Total Facility Discharge	Unnamed Creek
10	MN0024627-SD-1	Rockford WWTP: Total Facility Discharge	Crow River
11	MN0025909-SD-1	Brooten WWTP: 001 Total Facility Discharge - Monthly	
12	MN0029629-SD-1	Rogers WWTP: Facility Effluent	Unnamed Creek
13	MN0030635-SD-1	Faribault Foods - Cokato:	
	MN0030635-SD-2	Faribault Foods - Cokato: Contact Cooling Water Discharge	
14	MN0040649-SD-1	Buffalo WWTP: Total Facility Discharge	North Fork Of The Crow River
	MN0040649-SD-2	Buffalo WWTP: Ground Water Discharge	
15	MN0042277-SD-1	Montrose Investments - 12 Hi Estates: Controlled Discharge - Effluent	Unnamed Ditch
16	MN0044326-SD-1	Ampi - Paynesville: 20100 Combined Discharge	
	MN0044326-SD-2	Ampi - Paynesville: 20101 Barometric Condensr Water	
17	MN0049077-SD-1	Great River Energy Of Dickinson: Nc Cooling Water Discharge	Unnamed Ditch
	MN0049077-SD-2	Great River Energy Of Dickinson: Storm Water Runoff	Unnamed Ditch
18	MN0049204-SD-1	Cokato WWTP: Total Facility Discharge	North Fork Of Crow River
	MN0049204-SD-2	Cokato WWTP: Equalization Basin Overflow	North Fork Of Crow River
	MN0049204-SD-4	Cokato WWTP:	North Fork Of Crow River
19	MN0051381-SD-1	Belgrade WWTP: Monthly Monitoring & Pond Discharge	
20	MN0051926-SD-1	Howard Lake WWTP: Total Facility Discharge	
21	MN0052752-SD-1	Green Lake SSWD WWTP:	Unnamed Creek To Mud Lake
	MN0052752-SD-2	Green Lake SSWD WWTP:	Middle Fork Of The Crow River
22	MN0054127-SD-1	Dassel WWTP: Discharge To Wetland/ Washington Creek	Unnamed Wetland
	MN0054127-SD-2	Dassel WWTP: Tile Line - North And East Sides Of Pond	
23	MN0063762-SD-1	Greenfield Commercial/Industrial Park:	Crow River
24	MN0064190-SD-1	Otsego WWTP: Facility Discharge	Crow River
25	MNG790021-SD-1	Dale'S 66: Monthly GWP Monitoring	

** Source: MPCA EDA (6/23/2006)*

Finally, the geology of the watershed, the presence of highly erode-able soils, stream morphology, weather patterns, and various other natural phenomenon may have impacts on the river's water quality.

3. HISTORICAL FLOW AND WATER QUALITY DATA

Data collected in recent years provided by the Minnesota Pollution Control Agency (MPCA) were reviewed for this initial Phase of the Project. These data included flow and water quality data. These data were provided electronically in spreadsheet format and were compiled into a database format that will be added to as the project progresses. The database will be the repository for all data collected in later phases of this project. These data generally included two periods of monitoring, one during 2001 and 2002 and the other in 2006. The latter period was conducted at only a few locations. These are further discussed below.

3.1 Historical Data

The Crow River Organization of Water (CROW) collected data in 2001 and 2002 as part of the Crow River Diagnostic Study in 2001 and 2002. Additional data has been collected in 2006 at fewer locations but with a larger parameter list. The results of the Diagnostic Study are included in the CROW report dated October 15, 2003. Table 3 Lists the data collected for the Diagnostic Study (as well as the associated data termed Listing Data) as well as Bridge-Down data collected in 2006. The table includes the program name of the sampling effort, locations, parameters and the frequency of samples taken. The Listing Data was generally collected at the same time of the Diagnostic Study as illustrated in the table.

Data collected during the Diagnostic Study included flow and water quality. Flow data as well as water quality samples were collected at temporary flow monitoring sites throughout the watershed. The parameters that were measured included the following:

Total Phosphorus	TSS	chlorides
Ortho-phosphorus	TVS	Temperature
Nitrate/nitrite N	Alkalinity	BOD
NH3	pH	Conductivity
TKN	Hardness	Chlorophyll a
Turbidity	Color	Dissolved oxygen

A target sample number of 15-20 grab samples per year were collected in 2001 and 2002. An attempt was made at collecting some wet-weather data during storm events; however, the limited data do not show specific storm events and the impact on water quality.

Table 3. Sampling Matrix Summary

Continuous Flow Data Avail.
Daily Average Flow Data Avail.
Instantaneous Flow Data Avail.

Note: Number of samples provides a general guide to but may not be representative for all parameters where multiple parameters are listed.

Number of Samples by Month

Sampling Program	Location	Parameters	Jan-00	Feb-00	Mar-00	Apr-00	May-00	Jun-00	Jul-00	Aug-00	Sep-00	Oct-00	Nov-00	Dec-00
C.R.O.W Diagnostic Study	Lake Koronis Outlet	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	Middle Fork Crow	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	Jewetts Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	Grove Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	Mill Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	CD 31	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	St. Michael	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	CSAH 9 - Waverly	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	Rockford	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
	Rockford USGS	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
MPCA Impaired Stream Sampling (Listing Data)	Grove Creek	DO												
	Jewetts Creek	DO												
	Mill Creek	DO												
	CD 31	DO												
	St. Michael	DO												
	Rockford	DO												
	Rockford	Turbidity												
	Rockford USGS	Turbidity						2	1	2	3			
	Rockford USGS	FC												
	Dayton - Turb.	Turbidity		1	1	1	1	3	2	3	3			
	Dayton	FC						1	1	1	1			
C.R.O.W 2006 Bridge-Down Sampling	Rockford	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
	CSAH 9 - Waverly	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
	Mill Creek	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
	CD 31	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
	St. Michael	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Litchfield WWTP Instream Sampling	Jewitts Creek	DO	1	2	3	4	4		4	5	4	4	5	2

Location	Parameters	Jan-01	Feb-01	Mar-01	Apr-01	May-01	Jun-01	Jul-01	Aug-01	Sep-01	Oct-01	Nov-01	Dec-01
Lake Koronis Outlet	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	3	3	2	1	2		
Middle Fork Crow	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	3	3	2	1	2	1	
Jewetts Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	4	2			2	1	
Grove Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS					5	4	2	3	1	2	1	
Mill Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	4	2	3	1	2	1	
CD 31	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS					3	4	1					
St. Michael	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	4	1	1				
CSAH 9 - Waverly	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				1	5	5	2	3	1	4	1	
Rockford	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	5	4	4	3	2	1	
Rockford USGS	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS	1	1	2	10	3	5	2	3	2	1	2	1
Grove Creek	DO					4	4	2	2	1	2	1	
Jewetts Creek	DO					4	4	2			2	1	
Mill Creek	DO					4	4	2	3	1	2	1	
CD 31	DO					3	4	1					
St. Michael	DO					4	4	1	1				
Rockford	DO					4	5	4	4	3	2	1	
Rockford	Turbidity						2	2	2	2			
Rockford USGS	Turbidity						2	2	2	2			
Rockford USGS	FC												
Dayton - Turb.	Turbidity										1	1	
Dayton	FC										1		
Rockford	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CSAH 9 - Waverly	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Mill Creek	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CD 31	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
St. Michael	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Jewitts Creek	DO	2	2	3	4	5	4	4	5	4	5		

Location	Parameters	Jan-02	Feb-02	Mar-02	Apr-02	May-02	Jun-02	Jul-02	Aug-02	Sep-02	Oct-02	Nov-02	Dec-02
Lake Koronis Outlet	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				2	4	2	1	2	1	2		
Middle Fork Crow	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	4	5	2		3		
Jewetts Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	4	5	2		3		
Grove Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	4	5	2		3		
Mill Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				3	5	4	5	2	1	2		
CD 31	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				5	4	3	4	2	2	2		
St. Michael	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				4	4	4	5	2	2	2		
CSAH 9 - Waverly	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS				4	4	4	5	2	2	2		
Rockford USGS	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS			1	1	4	6	4	7	1	2		
Grove Creek	DO				3	5	4	4	2		3		
Jewetts Creek	DO				3	5	4	5	2		3		
Mill Creek	DO				3	5	4	5	2	1			
CD 31	DO				5	3	2	4	2	1			
St. Michael	DO				5	9	7	7	3	2			
Rockford	DO				4	3	4	6	5	3			
Rockford	Turbidity						1	1	4	2			
Rockford USGS	Turbidity						2	2	5	3			
Rockford USGS	FC						2	2	2	2			
Dayton - Turb.	Turbidity				1	1	1	1	1	1			
Dayton	FC				1	1	1	1	1	1			
Rockford	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CSAH 9 - Waverly	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Mill Creek	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CD 31	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
St. Michael	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Jewitts Creek	DO				4	5	4	4	5	4	5	4	

Location	Parameters	Jan-03	Feb-03	Mar-03	Apr-03	May-03	Jun-03	Jul-03	Aug-03	Sep-03	Oct-03	Nov-03	Dec-03
Lake Koronis Outlet	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Middle Fork Crow	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Jewetts Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Mill Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CD 31	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
St. Michael	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CSAH 9 - Waverly	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford USGS	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	DO			1	3	3	4	1					
Jewetts Creek	DO			1	3	3	4	1					
Mill Creek	DO												
CD 31	DO												
St. Michael	DO												
Rockford	DO												
Rockford	Turbidity												
Rockford USGS	Turbidity												
Rockford USGS	FC												
Dayton - Turb.	Turbidity												
Dayton	FC												
Rockford	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CSAH 9 - Waverly	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Mill Creek	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CD 31	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
St. Michael	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Jewitts Creek	DO				4	5	4	5	6	4	5		

Location	Parameters	Jan-04	Feb-04	Mar-04	Apr-04	May-04	Jun-04	Jul-04	Aug-04	Sep-04	Oct-04	Nov-04	Dec-04
Lake Koronis Outlet	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Middle Fork Crow	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Jewetts Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Mill Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CD 31	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
St. Michael	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CSAH 9 - Waverly	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford USGS	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	DO												
Jewetts Creek	DO												
Mill Creek	DO												
CD 31	DO												
St. Michael	DO												
Rockford	DO												
Rockford	Turbidity												
Rockford USGS	Turbidity												
Rockford USGS	FC												
Dayton - Turb.	Turbidity												
Dayton	FC												
Rockford	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CSAH 9 - Waverly	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Mill Creek	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CD 31	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
St. Michael	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Jewitts Creek	DO				5	4	4	5	4	5	4	4	

Location	Parameters	Jan-05	Feb-05	Mar-05	Apr-05	May-05	Jun-05	Jul-05	Aug-05	Sep-05	Oct-05	Nov-05	Dec-05
Lake Koronis Outlet	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Middle Fork Crow	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Jewetts Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Mill Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CD 31	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
St. Michael	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CSAH 9 - Waverly	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford USGS	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	DO												
Jewetts Creek	DO												
Mill Creek	DO												
CD 31	DO												
St. Michael	DO												
Rockford	DO												
Rockford	Turbidity												
Rockford USGS	Turbidity												
Rockford USGS	FC												
Dayton - Turb.	Turbidity												
Dayton	FC												
Rockford	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CSAH 9 - Waverly	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Mill Creek	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
CD 31	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
St. Michael	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO												
Jewitts Creek	DO				4	4	5	4	5	4	4	4	

Location	Parameters	Jan-06	Feb-06	Mar-06	Apr-06	May-06	Jun-06	Jul-06	Aug-06	Sep-06	Oct-06	Nov-06	Dec-06
Lake Koronis Outlet	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Middle Fork Crow	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Jewetts Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Mill Creek	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CD 31	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
St. Michael	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
CSAH 9 - Waverly	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Rockford USGS	TP, OP, TKN, N23, NH3, Chloride, VSS, TSS												
Grove Creek	DO												
Jewetts Creek	DO												
Mill Creek	DO												
CD 31	DO												
St. Michael	DO												
Rockford	DO												
Rockford	Turbidity												
Rockford USGS	Turbidity												
Rockford USGS	FC												
Dayton - Turb.	Turbidity												
Dayton	FC												
Rockford	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO				3	2	3	3	4		1		
CSAH 9 - Waverly	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO				3	2	3	3	4		1		
Mill Creek	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO				3	2	1		3		1		
CD 31	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO				3	2	3	1	4		1		
St. Michael	Alk, Cl, Chlphy, TSS, VSS, Hard, BOD, NO3, TKN, OP, TP, E Coli, Temp, pH, Turb, Cond, DO				3	2	3	2	3		1		
Jewitts Creek	DO				4	5	4		5	4	4	5	

The purpose of the Diagnostic Study was to identify nutrients and sediment loads for each of the major tributaries and along the reaches of the Crow River. Based on the monitoring and sampling, the study accomplished the following:

- Assessed watershed characteristics by basin area
- Measured flow and water quality parameters (to estimate flow weighted mean concentration data at each sampling site)
- Estimated relative loadings for each sampling site for phosphorus and TSS
- Estimated the significance of point source phosphorus loadings relative to non-point source loadings
- Identified sub-watersheds deemed to have a high significance of point source phosphorous loading
- Predicted the impact of flow-weighted mean concentration of phosphorous in the Crow River based on assumed point source reductions at wastewater treatment facilities

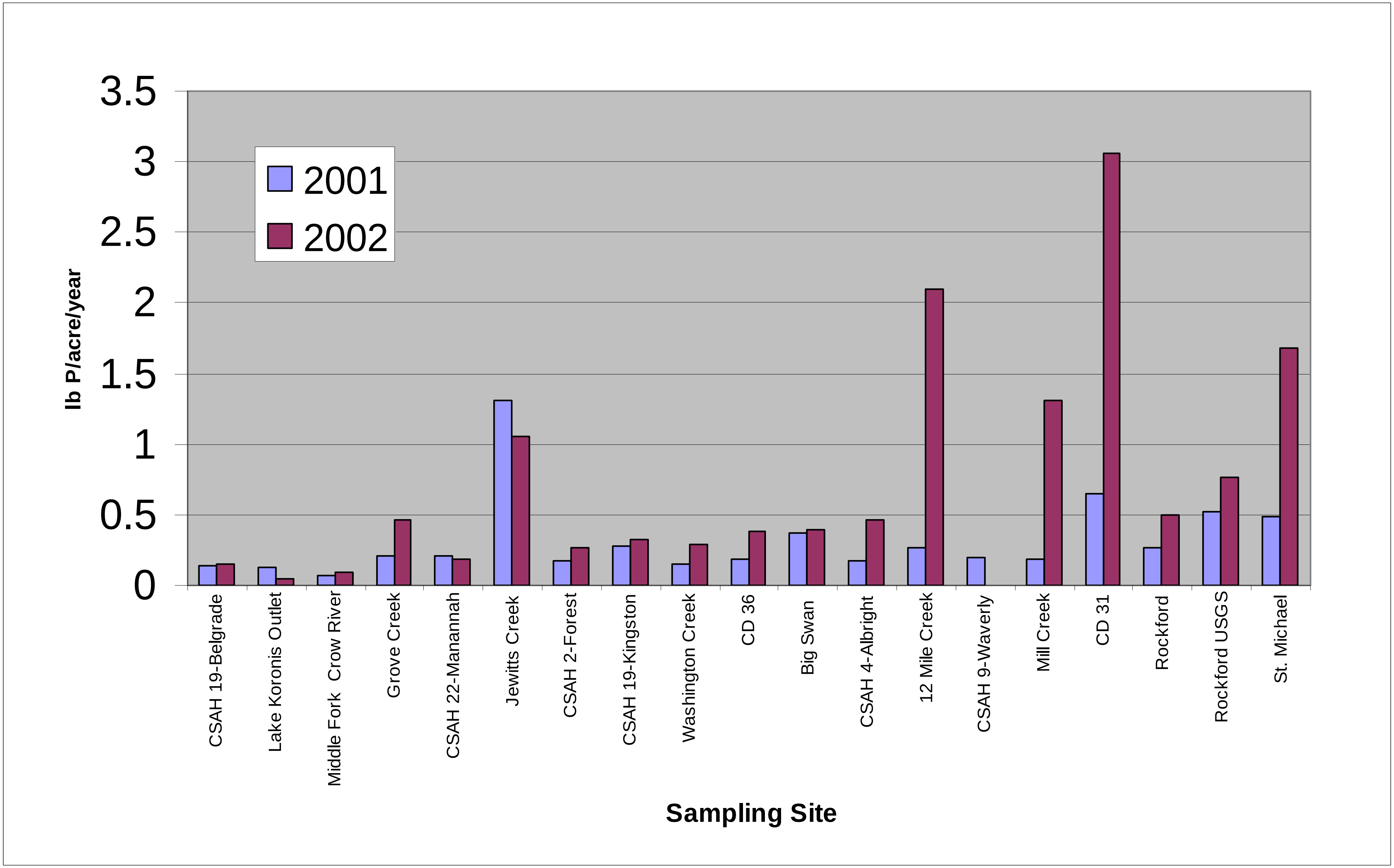
An example of information provided from this study is shown in Figure 5, which illustrates pollutant yields that allow comparisons to be made by sub-watershed. Those watersheds that have been identified as impaired based on dissolved oxygen are generally exhibiting high phosphorous yields as illustrated in Figure 5. Figure 6 provides the same data shown geographically. Table 4, taken from the Diagnostic Report, presents the significance of point source loads in the watersheds sampled. Jewitts Creek, Forest, and Mill Creek located in the North Fork watershed were identified as having a high point source significance. The Forest (CSAH22) location is showing a high significance, in part, due to Jewitts Creek historical high contribution of phosphorus. This may change as a result of improvements that have been made at the Litchfield treatment plant reducing phosphorus loadings to Jewitts Creek. Future monitoring will be necessary to verify these improvements in water quality in the stream segments impaired in this subwatershed and downstream on the main stem. Related to the Litchfield improvements, long-term DO monitoring was conducted as a separate study in Jewitts Creek and appears to show signs of improvement in DO in 2006 as shown in Figure 7. These data show dissolved oxygen measurements from 2000 through most of 2006at a number of locations along Jewitts Creek. It is interesting to note that the data collected upstream of the Litchfield treatment plant show the Creek is impacted by low dissolved oxygen. The data shown in 2004 and later show some improvement with the greatest improvement exhibited in 2006. Additional monitoring should be continued to confirm improvement in the creek and river segments. One of the potential reasons for slow recovery in these segments is the creeks response to long-term historical loading of nutrients and other parameters which contribute to low DO.

Table 4. Point Source Significance from Diagnostic Study

Stream or Crow River Reach	Average % TP	Point Source Significance
	2001/2002	
KORONIS Outlet	3%	Low
Middle Fork	31%	Moderate
GROVE Ck.	4%	Low
JEWITTS Ck	100%+	VERY HIGH
CSAH22	4%	Low
FOREST	53%	HIGH
KINGSTON	35%	Moderate
Washington Creek	1%	Low
BigSwan Ck.	0.1%	Very Low
Cokato Lake Oultet	82%	VERY HIGH
NFCR4	35%	Moderate
Twelve Mile	13%	Low
NFCR9	40%	HIGH
MILL CK	100% +	VERY HIGH
CD31	6%	Low
Rockford	27%	Moderate

Source: Table 19, page 58, Crow River Diagnostic Study Final Report.

Figure 5
North Fork - Lower Crow TMDL
C.R.O.W. Diagnostic Study Total Phosphorus Yields (lbs. P/acre/year)



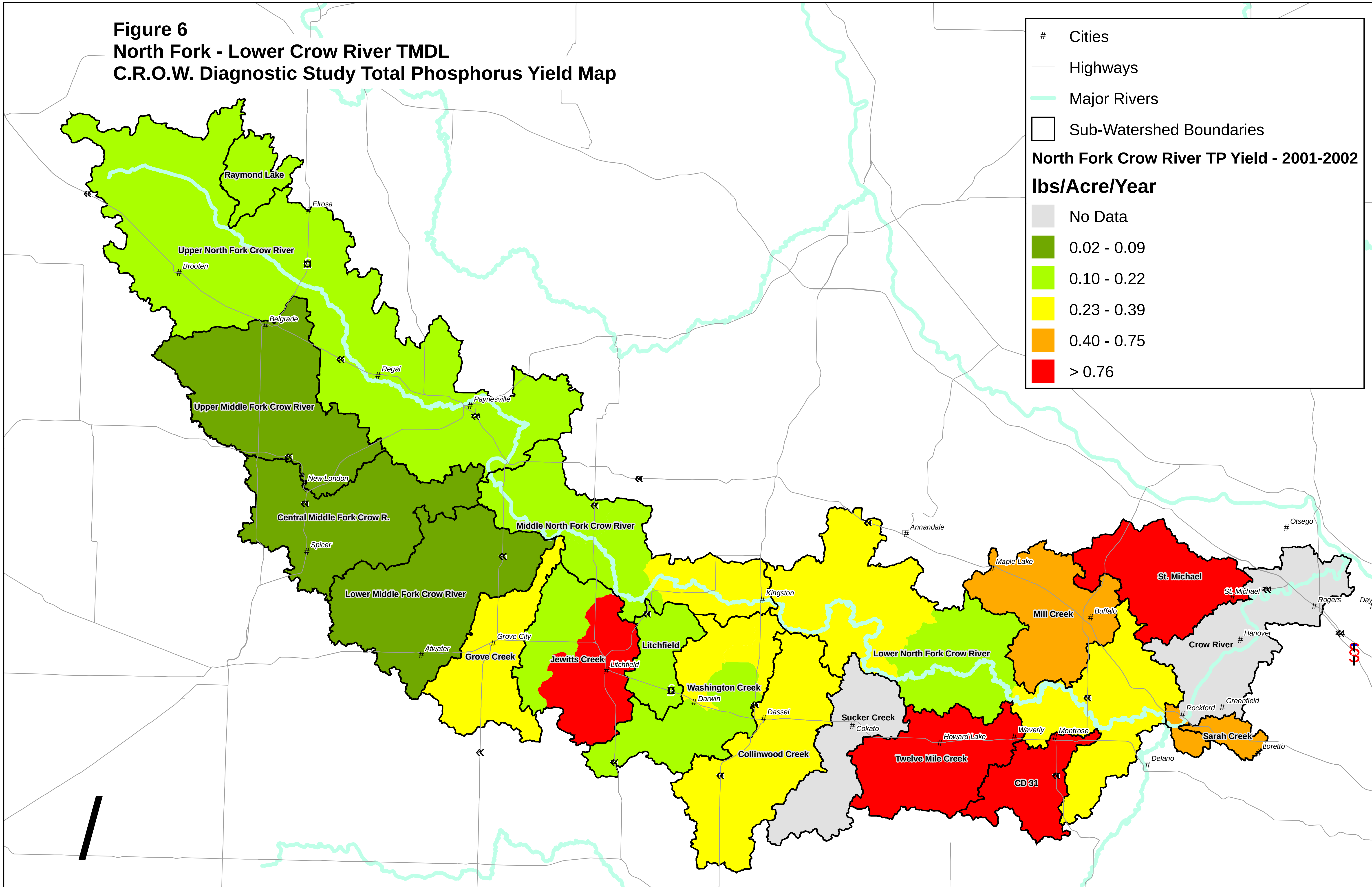
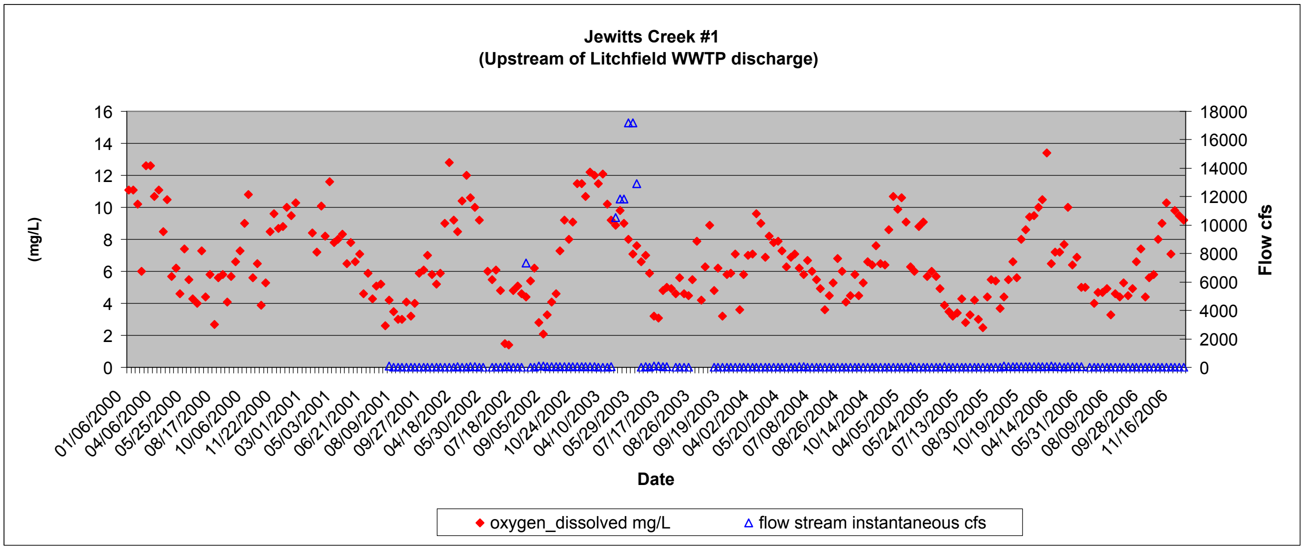
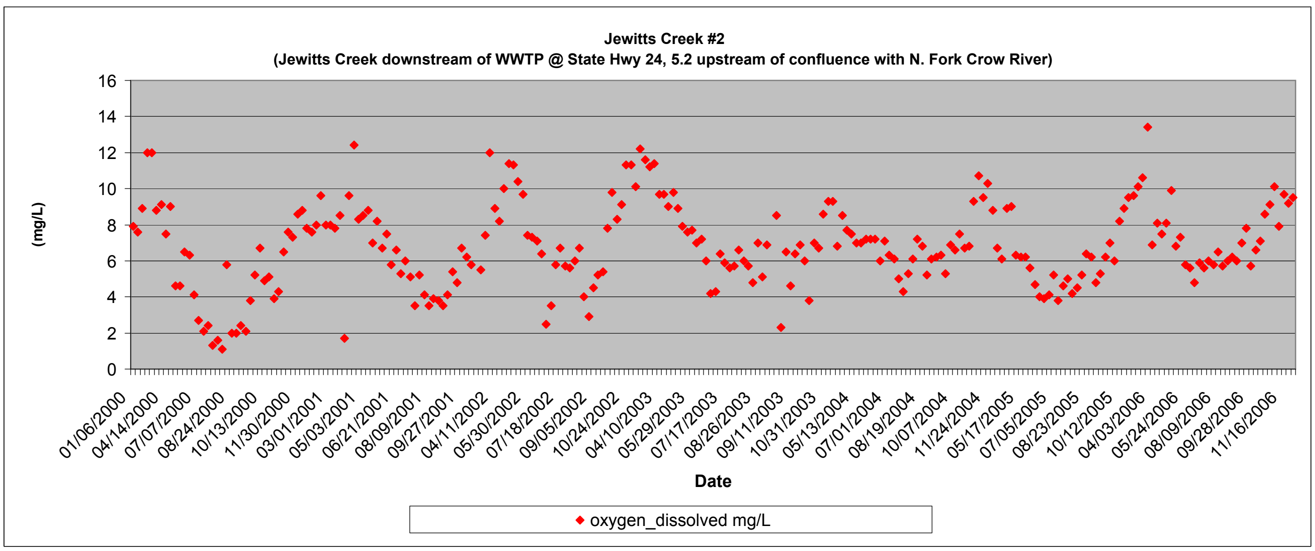
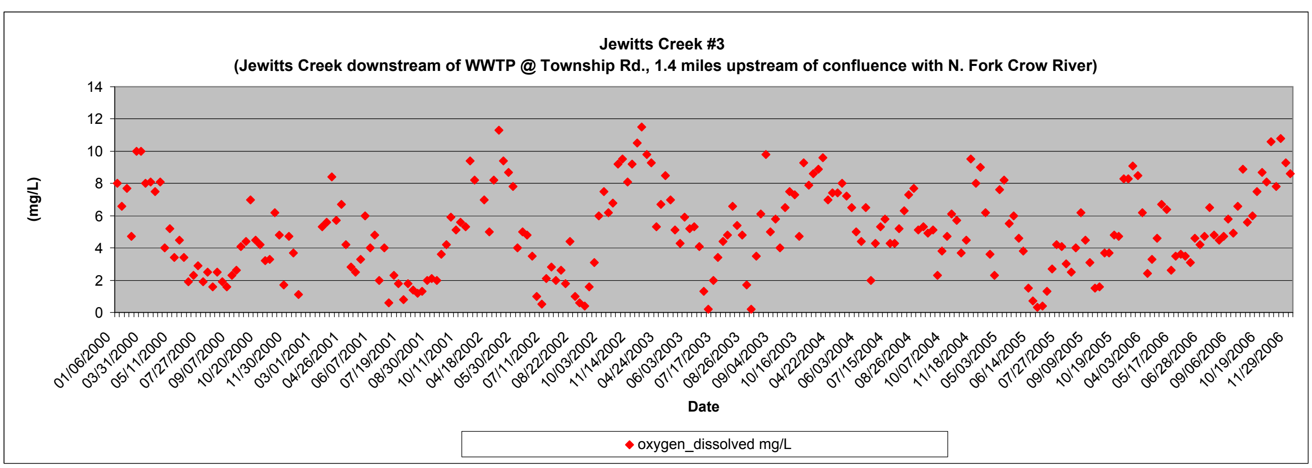


Figure 6
North Fork - Lower Crow River TMDL
C.R.O.W. Diagnostic Study Total Phosphorus Yield Map

Figure 7. Jewitts Creek Historical Dissolved Oxygen Concentrations







Additional monitoring and sampling was conducted in 2006 in anticipation of the TMDL development to continue to collect data from locations within the watershed. These data were collected at a limited number of locations, including three main stem locations: the Rockford USGS gauging site, the City of Rockford, and CSAH9 – Waverly. In addition, the CD31, Mill Creek, and St. Michael tributaries were monitored. These sites have generally included grab samples every two weeks with some periods of data missing. The 2006 data have been evaluated using statistical tools. These evaluations are discussed later in this report. All data collected in 2006 have been provided in graphical format in Appendix B. In 2006, fewer locations were monitored, resulting in a lack of comprehensive data necessary to evaluate all the existing impairments, including bracketing of stream segments to identify the sources.

Turbidity data from 2006 shown in Appendix B include data at CSAH 9 – Waverly showing data exceeding the water quality standard of 25 NTUs. It is interesting to note that this segment has not been previously identified as an impaired segment. In addition, dissolved oxygen collected at this location showed one reading below the water quality standard of 5 mg/l in August 2006. The downstream Rockford site also shows turbidity impairments during the same periods; however, this segment has been identified as impaired and is discussed in the next section of this report including a description of each of the existing impairments.

No direct discharger (NPDES) data were available for the 2006 period at the time of this data evaluation. As a result, the relative contributions of point and non-point source loadings were not evaluated as was done for the Diagnostic Study; however, these data will be evaluated in future phases.

3.2 Stream Impairments

Table 1 identifies the current impairments which include dissolved oxygen, turbidity and fecal coliform. The locations of the impairments are also shown on Figure 4.

Each of these water quality parameters has unique characteristics which must be fully understood to accurately complete the TMDL and to identify actions which will achieve the desired water quality improvements. It is essential to have sufficient water flow rate and quality data throughout the watershed to calculate pollutant loads and to evaluate spatial and temporal water quality variability and trends. The completion of these efforts leads to the thorough understanding of cause and effect relationships and the identification of impairment sources.

The MPCA has established TMDL Development Protocols for waters impaired for dissolved oxygen, turbidity and bacteria. These protocols outline specific procedures to determine the causes of the impairment, the affects of the impairment, the sources and magnitudes of responsible loads, the allowable loading capacity and the loading allocation for all point and non-point sources. Dissolved oxygen and turbidity are similar in that they cannot be expressed as a load and are a water quality result of constantly changing physical, chemical and biological processes. It is not uncommon to have major changes in dissolved oxygen and turbidity values over a single day. As a result of this, grab sampling alone is not a sufficient method to assess impairment. Since neither dissolved oxygen nor turbidity can be expressed as a load, it is necessary to identify and quantify the constituent load(s) which causes the change in value. Monitoring should be performed to evaluate seasonal and diurnal variations in loads and resulting surface water quality.

Since fecal coliform and E. coli may indicate human health risks, it is important to monitor these indicators similar to dissolved oxygen and turbidity to identify patterns related to time and/or space, to assess variability and to determine the severity of the impairment. It is also important to determine if the bacteria source is natural or anthropogenic. If the indicator organism concentrations are consistently well above the standard, it may be worthwhile to perform field assessments and source tracking to identify the major sources. Any significant anthropogenic sources can be targeted for reduction in the TMDL.

Additional discussion and examples of the impairments are provided in the following sections.

3.2.1 Dissolved Oxygen

Dissolved oxygen is an important water quality indicator parameter for the protection and management of aquatic ecosystems. The amount of oxygen a given volume of water can hold is a function of atmospheric pressure, water temperature and the amount of other substances dissolved in the water. The dissolved oxygen water quality standard for Class 2B waters is 5 mg/l.

Examples of the dissolved oxygen (DO) impairments that have been measured in the North Fork – Lower Crow River are depicted in the Figures 8 through 13 These figures show data collected that depict the DO impairments for each of the reaches including Grove, Jewitts, CD31, Mill Creek, St. Michael, and main stem. The graphs show the data collected in the 2001 and 2002 monitoring period including flow. Each of the DO impairments is occurring in the summer period during relatively low flow conditions. The historical data available through the recent monitoring suggests that the DO is being influenced by several factors; however, the limited data collected to date doesn't allow us to fully understand the specific source(s) or cause(s) of the DO impairment. The impairments are likely a result of a combination of point source and/or non-point sources. Potential causes of lower DO values include higher temperatures and increased nutrient and BOD concentrations.

To determine the constituent loadings causing the DO impairment and the resulting water quality conditions, additional seasonal and diurnal monitoring will be necessary as outlined later in this report. The parameters will generally include flow, NO_3, NH_3, TKN, OP, TP, chlorophyll a, TSS, TVS, color, alkalinity and hardness and field measurements of pH, temperature, DO, conductivity and turbidity. Due to the sheer scale of this watershed, any one sub-watershed could entail a significant study in and of itself. As a result, it is recommended that continuation of the historical monitoring locations be maintained. Data available for known point sources will also be collected and coupled with monitoring data to determine all sources and magnitudes of loadings and the affect of these loadings on dissolved oxygen values for each of the impaired reaches. Based the initial data results, additional monitoring may be recommended to further refine the development of the TMDL.

3.2.2 Turbidity

Water turbidity is caused by suspended and dissolved matter such as soil, organic matter, algae and color. Turbidity limits light penetration and is recognized as an indicator of water quality – the greater the turbidity the greater the pollution. The water quality standard for turbidity in Class 2B waters is 25 NTUs. Turbidity data from the Rockford monitoring location in 2001 and 2002 is shown in Figure 14. The data from the Dayton location is shown in Figure 15. Exceedances of the turbidity standard occur mainly in the summer months under low flow conditions. It is interesting to note that lower turbidity values are observed at higher flow conditions.

Figure 16 depicts turbidity data at the Rockford USGS monitoring site. This location is downstream of the confluence of the South Fork of the Crow River. Again, exceedances of the turbidity standard occur mainly in the summer months under low flow conditions. Lower turbidity values were observed at higher flow conditions. Since turbidity values cannot be converted to a load, it will be necessary to select a surrogate water quality parameter for turbidity so that a TMDL can be developed. Additional data collection will be recommended later in this report to understand the relationship between turbidity and other parameters such as flow, nutrients, bacteria or TSS as well as to understand the spatial relationships within the watershed. The same general monitoring parameters identified for DO will be used to evaluate turbidity.

Figure 8
North Fork - Lower Crow River TMDL
Dissolved Oxygen Measurements at Grove Creek

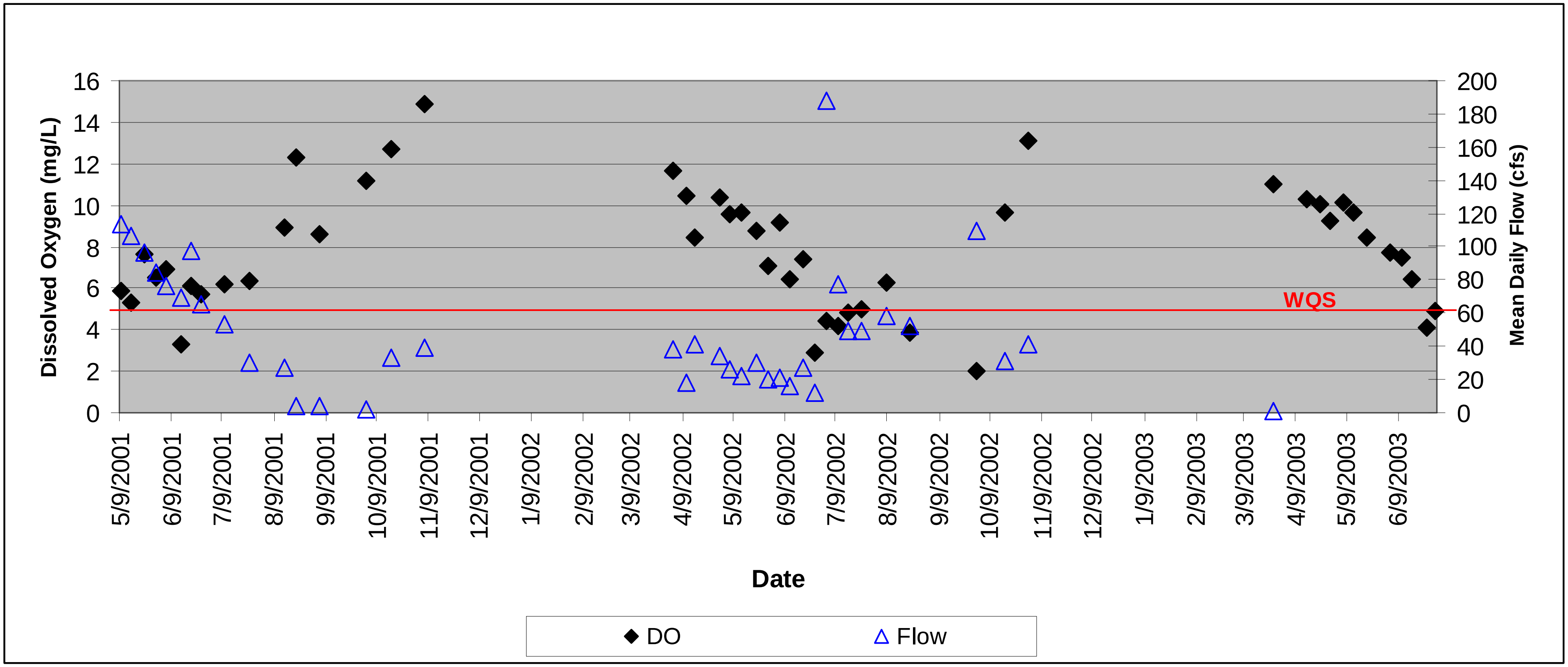


Figure 9
North Fork - Lower Crow River TMDL
Dissolved Oxygen Measurements at Jewitts Creek

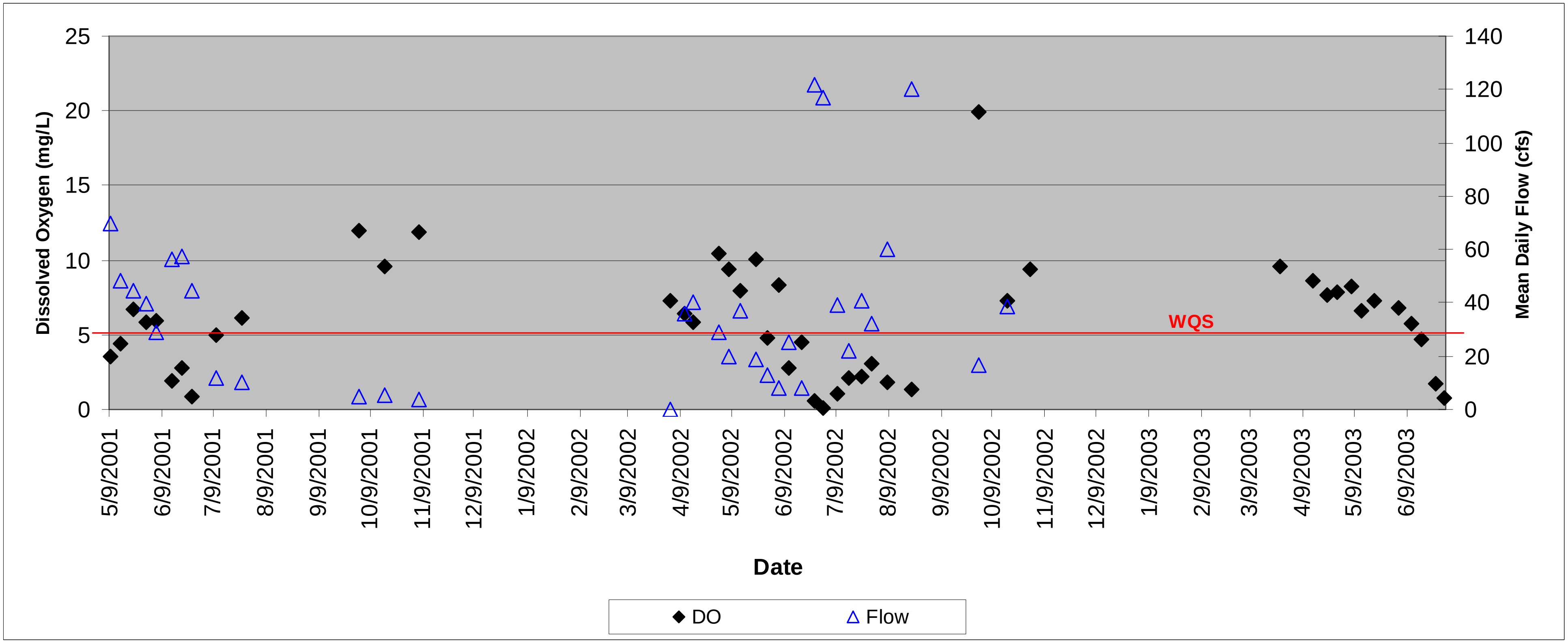


Figure 10
North Fork - Lower Crow River TMDL
Dissolved Oxygen Measurements at CD 31

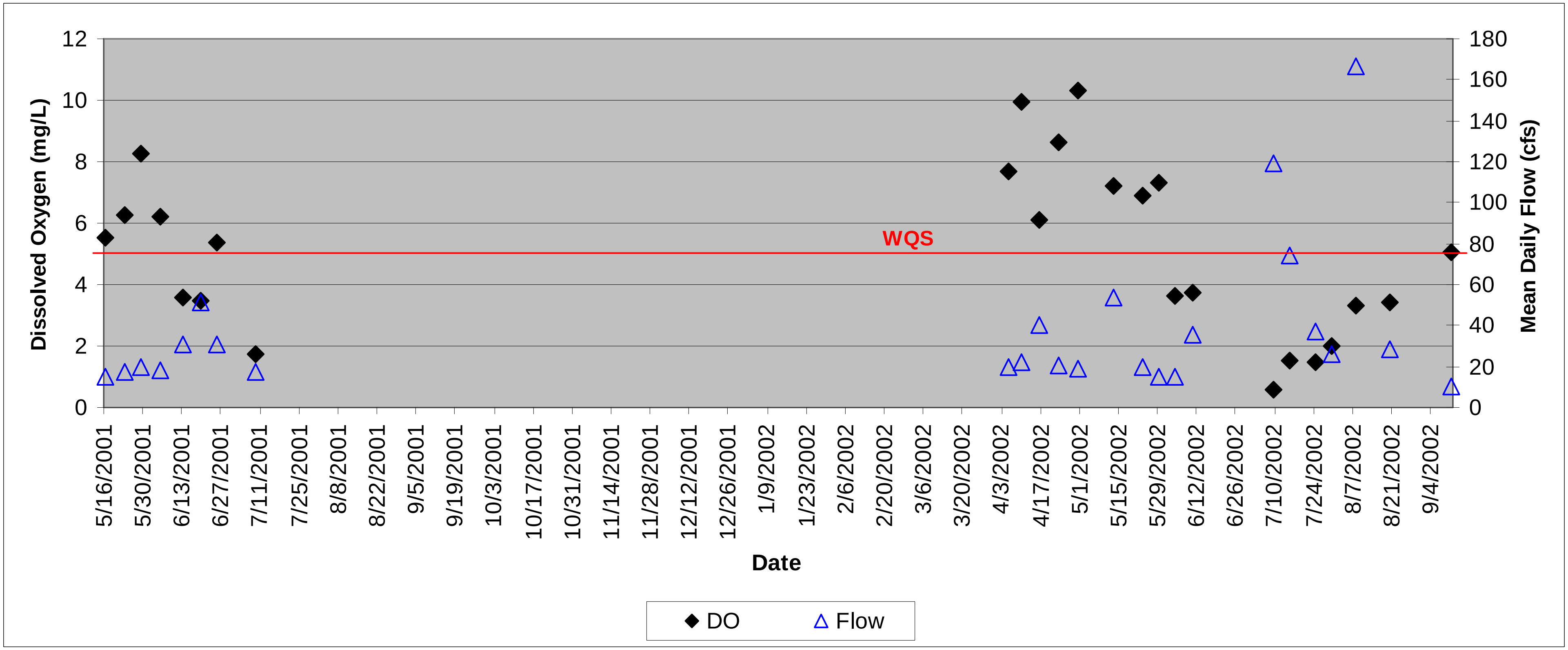


Figure 11
North Fork - Lower Crow River TMDL
Dissolved Oxygen Measurements at Mill Creek

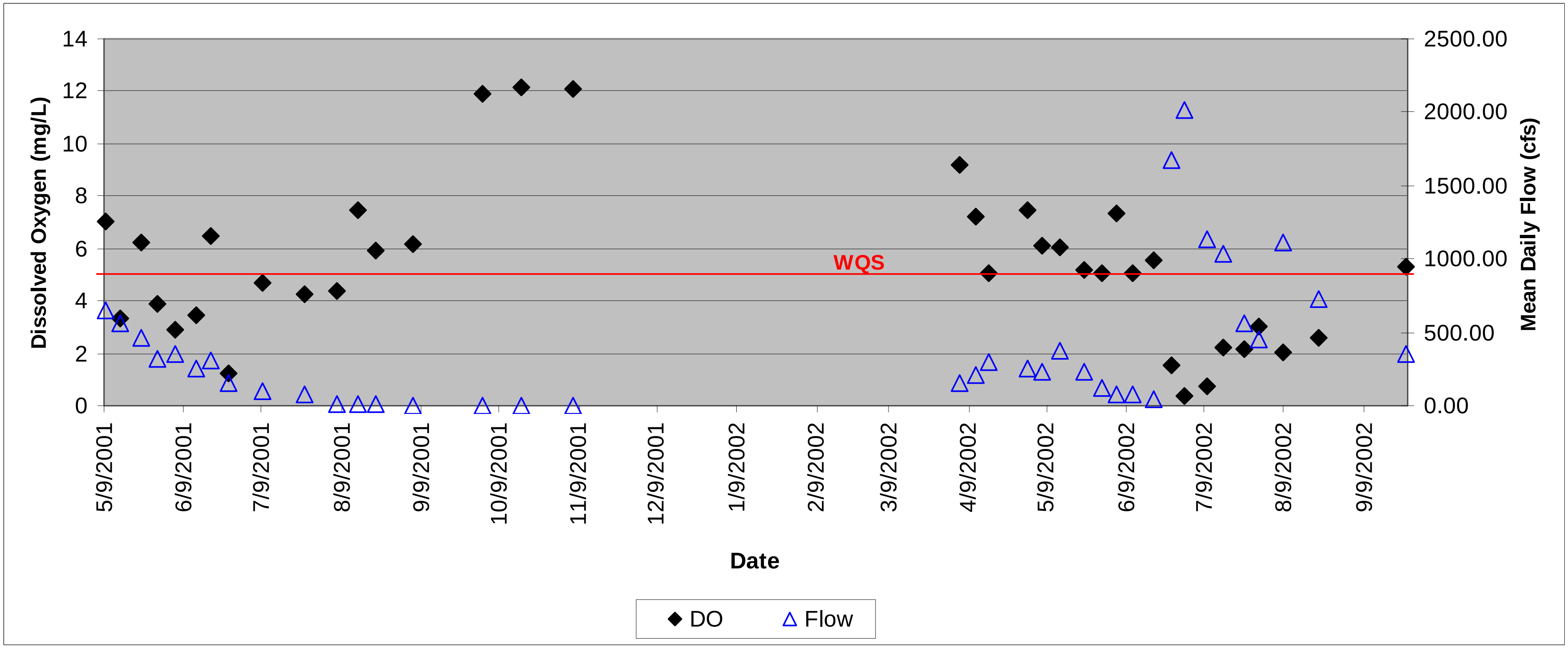


Figure 12
North Fork - Lower Crow River TMDL
Dissolved Oxygen Measurements at St. Michael

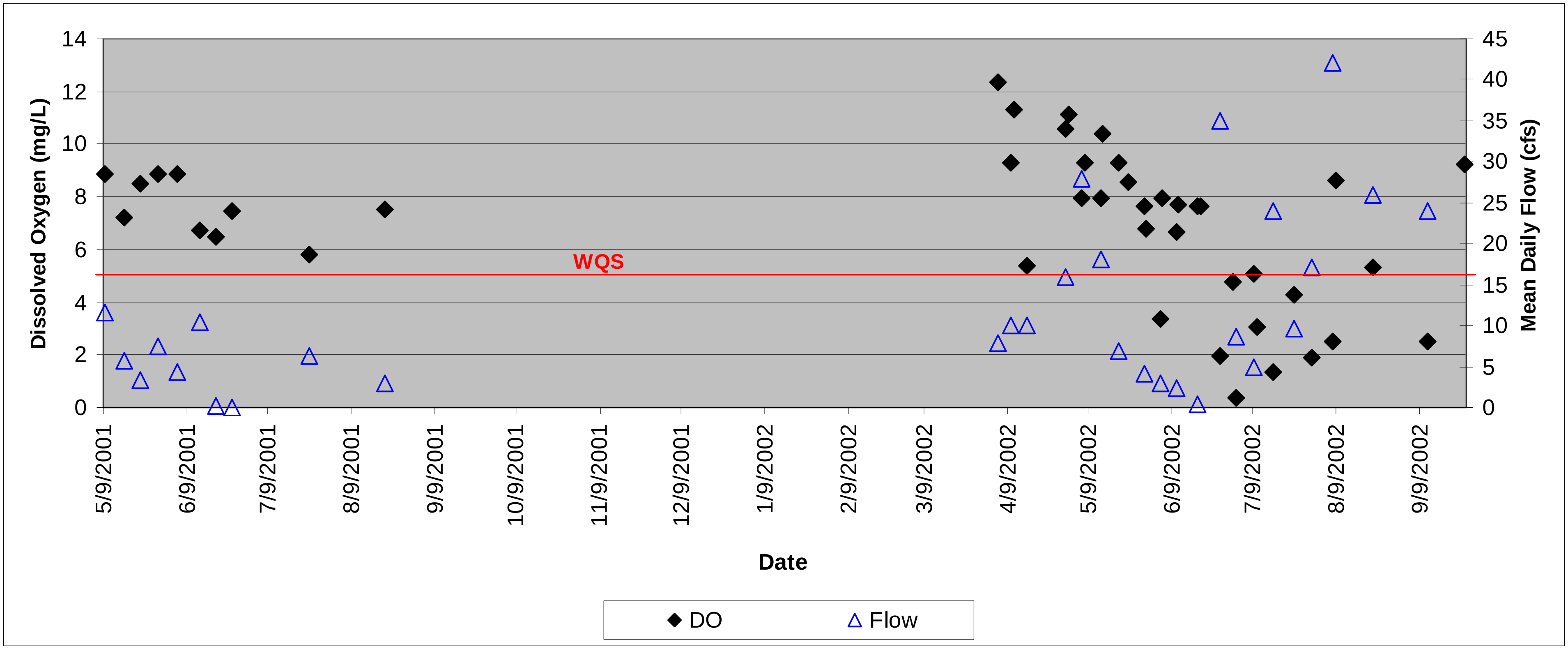


Figure 13
North Fork - Lower Crow River TMDL
Dissolved Oxygen Measurements at Rockford

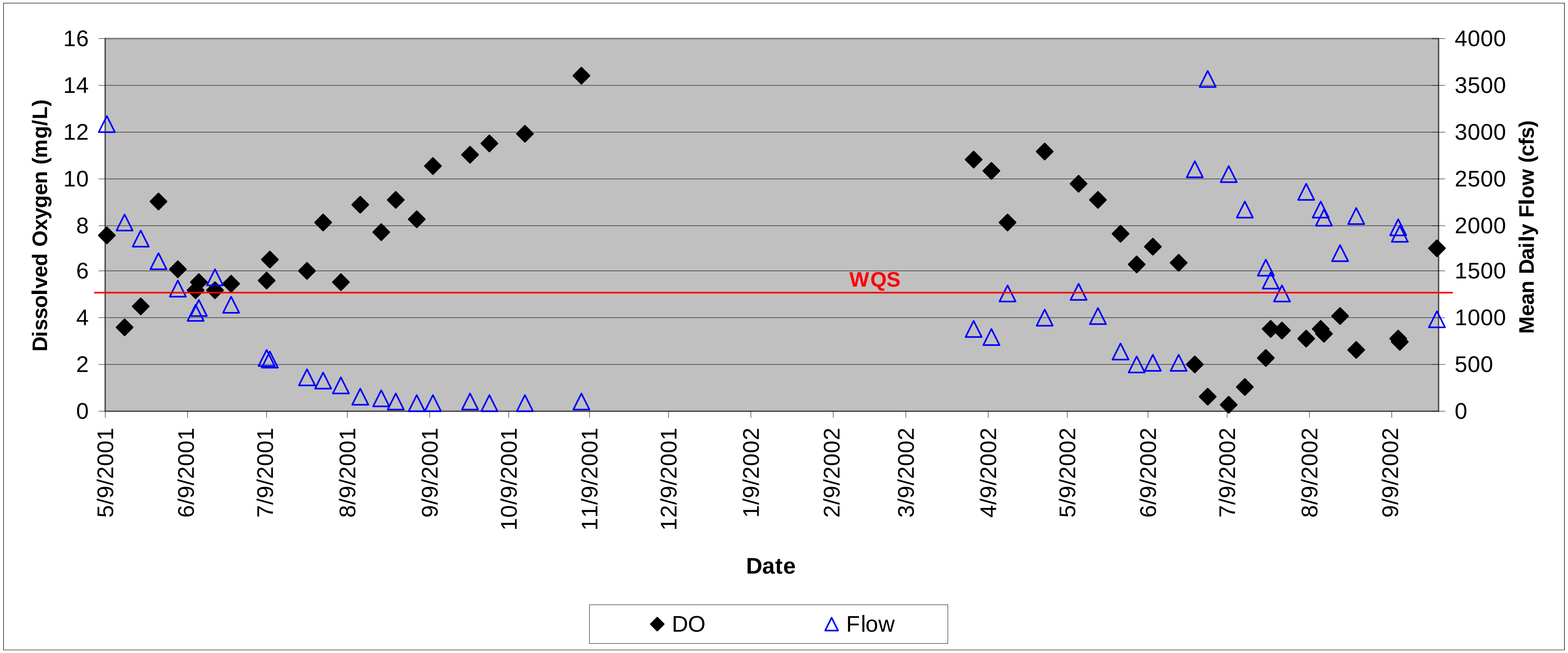


Figure 14
North Fork - Lower Crow River TMDL
Turbidity Measurements at Rockford

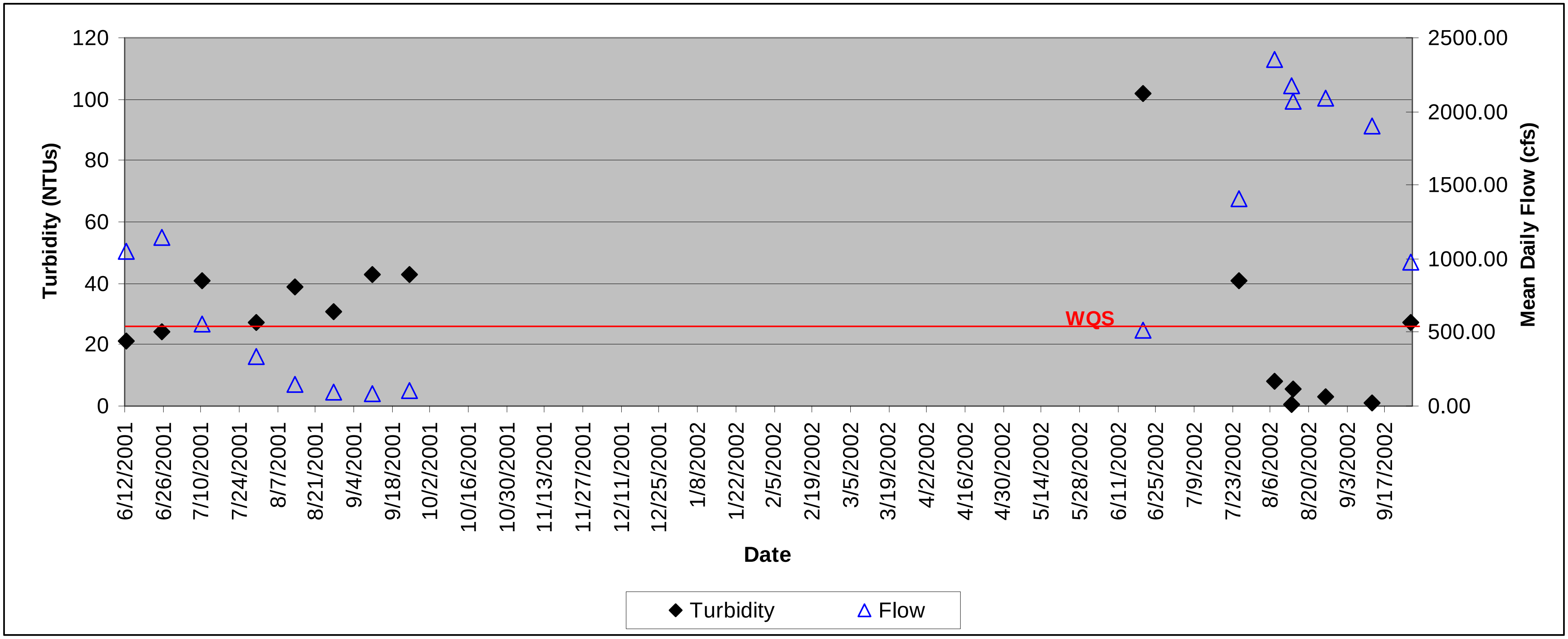


Figure 15
North Fork - Lower Crow River TMDL
Turbidity Measurements at Dayton

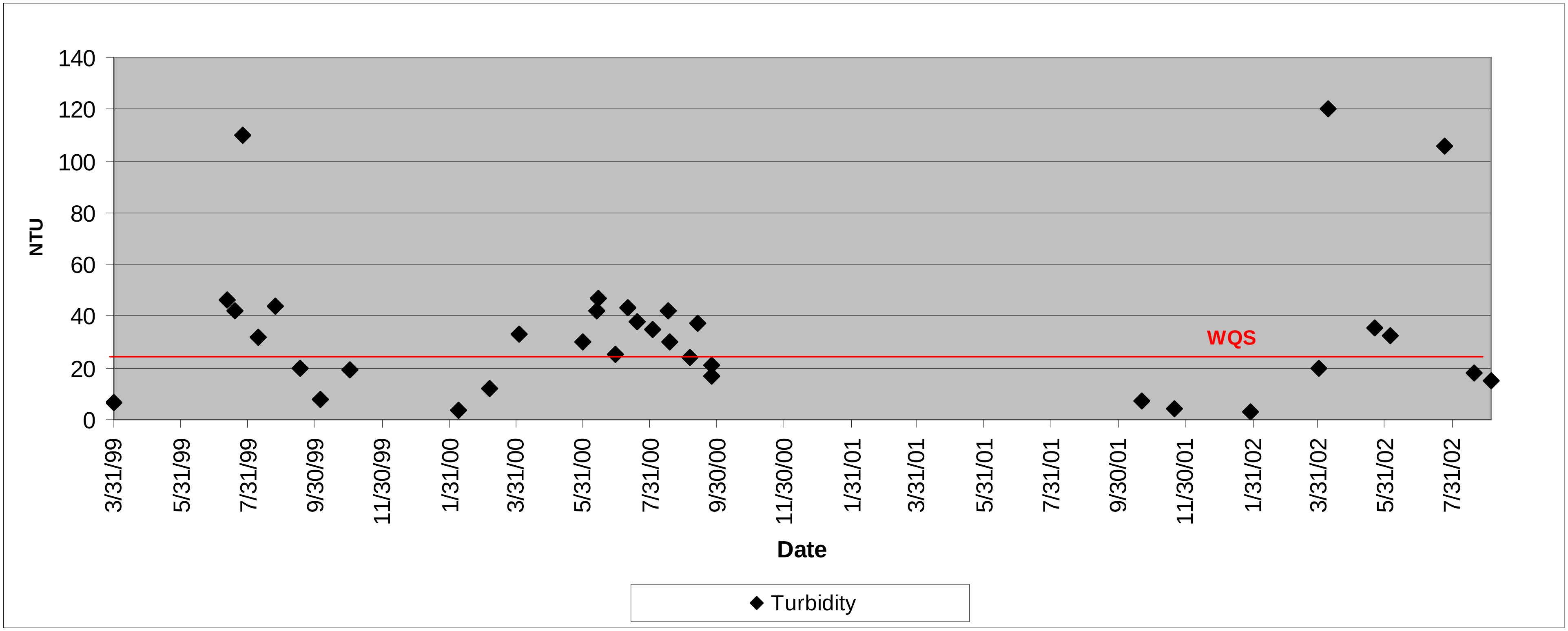
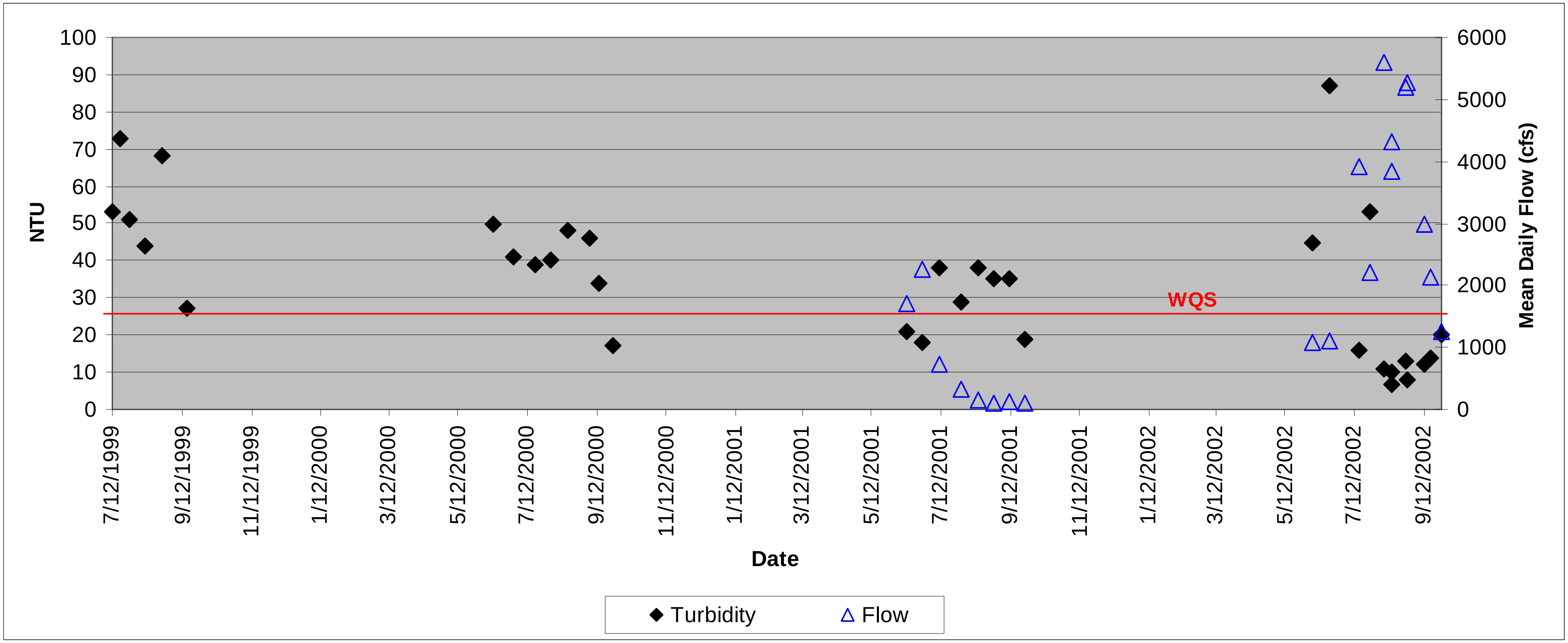


Figure 16
North Fork - Lower Crow River TMDL
Turbidity Measurements at Rockford (USGS)



3.2.3 Fecal coliform

Two closely related bacteria groups, Fecal coliform and E. coli have been used for decades as "indicator organisms" in water pollution control and water quality monitoring. They provide an indication of the possible presence of pathogens, which in turn pose a potential human health risk. Minnesota is currently attempting to shift from the fecal coliform to E. coli in its water quality standards, based on USEPA guidance. The fecal coliform standard for Class 2B waters is a monthly geometric mean of 200 cfu/100 ml. The recent and future monitoring will include E. coli with the understanding that a relationship has been developed between these bacteria groups.

The complex behavior of fecal coliform and E. coli in the environment is not completely understood. Factors affecting bacteria densities include seasonality, stream flow, water temperature, hydrologic proximity of pollution sources, livestock management practices, wildlife activity, sewage overflows and rainfall, to name a few.

Very little data is currently available on the bacteria in the watershed. Table 3 shows only a few locations with a limited number of samples that are available for bacteria. Figure 17 depicts fecal coliform data for the impaired reach at the Rockford USGS monitoring site. These limited historical data are not adequate to identify patterns related to time and/or space, to assess variability or to determine the severity of the impairment. The monitoring of E. coli will be recommended later in this report to assess these issues and to develop an understanding of the relationship between water E. coli concentrations and activities in the watershed. It is envisioned that simple analytical approaches will provide an adequate basis for bacteria assessment and TMDL development.

3.3 Statistical Analysis of 2006 Data

As noted previously, limited data exists for defining the impairments of bacteria and turbidity. Due to the lack of data on bacteria, there has been no specific analysis conducted to date. In an effort to evaluate the turbidity and DO impairments, use of a statistical analysis was employed to identify any relationships that might exist relating to the cause and effect of the impairments from the 2006 data set. More specifically, in order to identify any preliminary relationships between existing data, a statistical step-wise linear regression model was developed. The model looks at the strength of relationships (based on highest R^2) between the dependent variable (DO and turbidity) and the other measured parameters (independent variables), one at a time, to find the best combination of variables to predict the dependent variable.

The challenge with the data collected to date is the limited number of data available and the large geographic extent of the monitoring locations. However, these initial relationships do provide some insight that can be advanced with additional data that will be collected in future monitoring. For example, Figure 18 shows the results of the statistical relationship of DO to other water quality parameters for only the main stem sampling sites. The resulting relationship shows the most important independent variables as OP and TP. This is evident by their relatively higher coefficients shown in the equation at the top of the graph. In other words, these two parameters have the most influence on predicting DO, based on the dataset used in this analysis. The R^2 value for this data set is 0.73. A total of 32 observations were used in the analysis. This suggests how important OP and TP may be in effecting DO in the Crow River. These data were based on only parameters measured in the main stem portion of the river and not in the upstream tributaries. A separate analysis was performed on only those data collected in the upstream subwatersheds. The data are shown on Figure 19 and illustrate a different relationship that exists in the tributaries with an R^2 of 0.82. Here the most significant variable is time of day with a coefficient of 17. This would suggest that it will be important to collect data in the subwatersheds on a continuous basis for DO to determine to what extent diurnal changes are part of the impairments.

Figure 20 shows the relationship for turbidity for the main stem sites only since the impairments are only on the main stem. Similar to the DO relationships on the main stem, the analysis shows the most significant influence on turbidity is from OP and TP. This initial analysis suggests nutrients are an important factor. It is also possible that turbidity may be influenced by higher flows during wet-weather conditions causing scour and increased solids in the water column. However, there is not adequate information available to evaluate this kind of relationship in the existing data. Additional flow and water quality data collected during dry and wet-weather will be necessary. Plots of TP and OP for each of the impaired reaches for the 2001/2002 are included in Appendix C, where data is available.

These analyses looked at more than 200,000 unique combinations of input variables to find the best fit of measured water quality parameters to DO and turbidity. Results, shown in the above referenced figures, indicate that DO and turbidity do show a trend with other data and should be explored further as more data are collected. Further strengthening of these relationships with additional data can set the basis for establishing the allowable loadings for the impaired reaches. Due to the limited data, continued collection of the parameters is recommended.

Figure 17
North Fork - Lower Crow River TMDL
Fecal Coliform Measurements at Rockford (USGS)

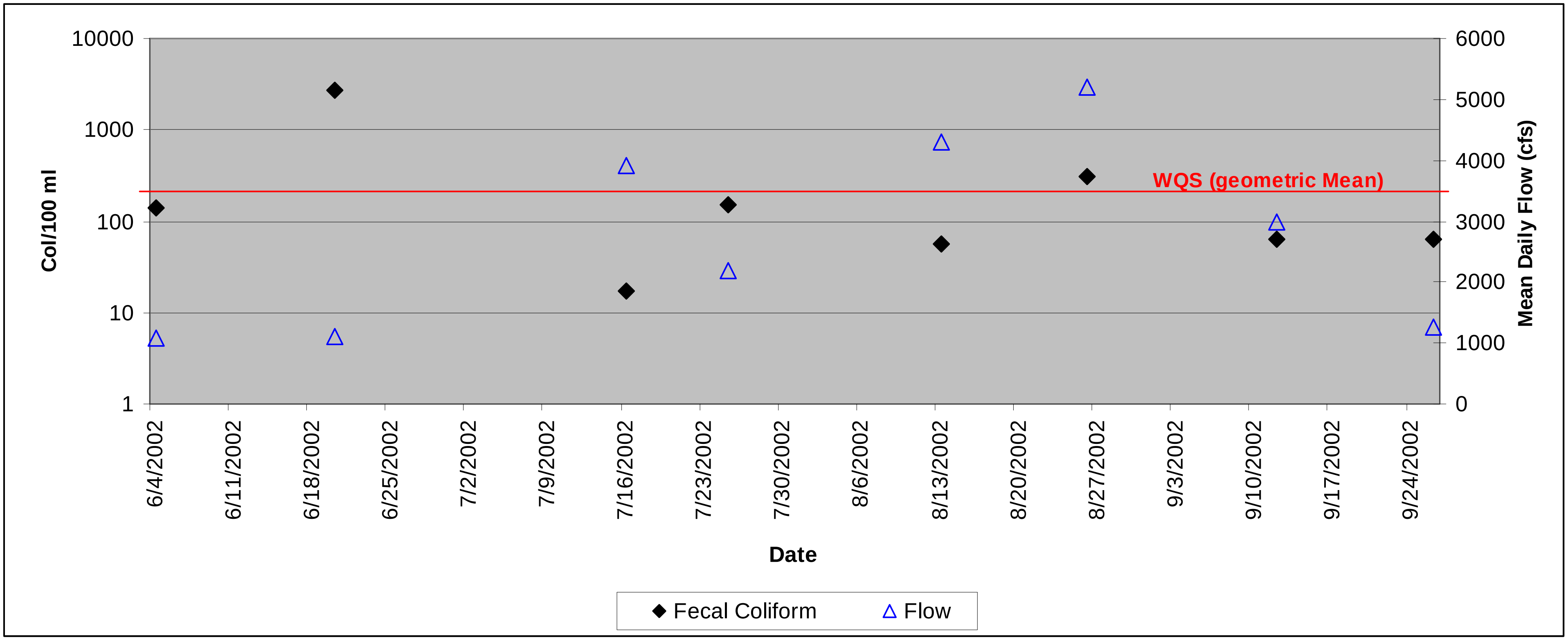


Figure 18
DO Regression Analysis for Main Stem
2006 Data

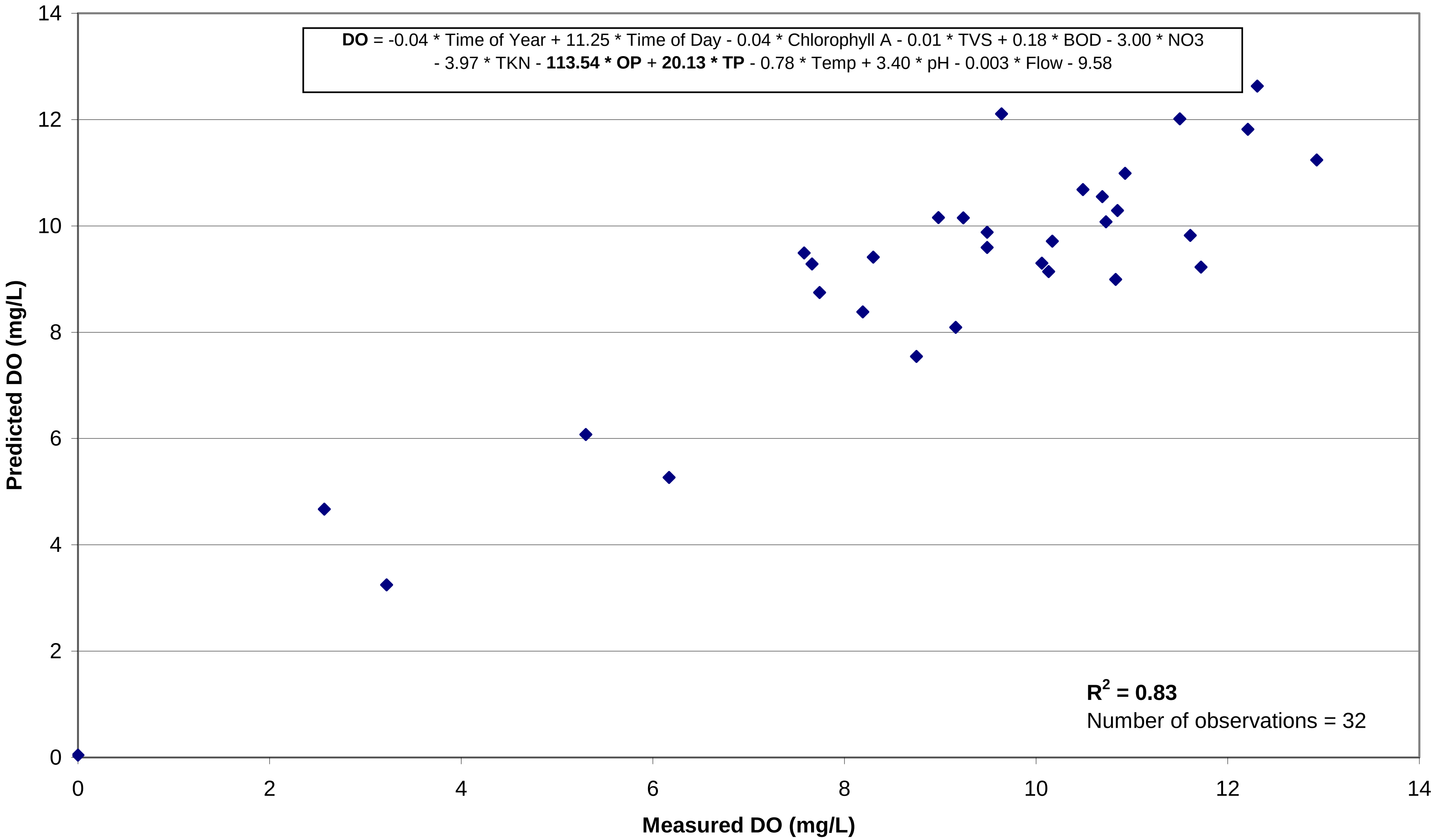


Figure 19
DO Regression Analysis for Subbasins
2006 Data

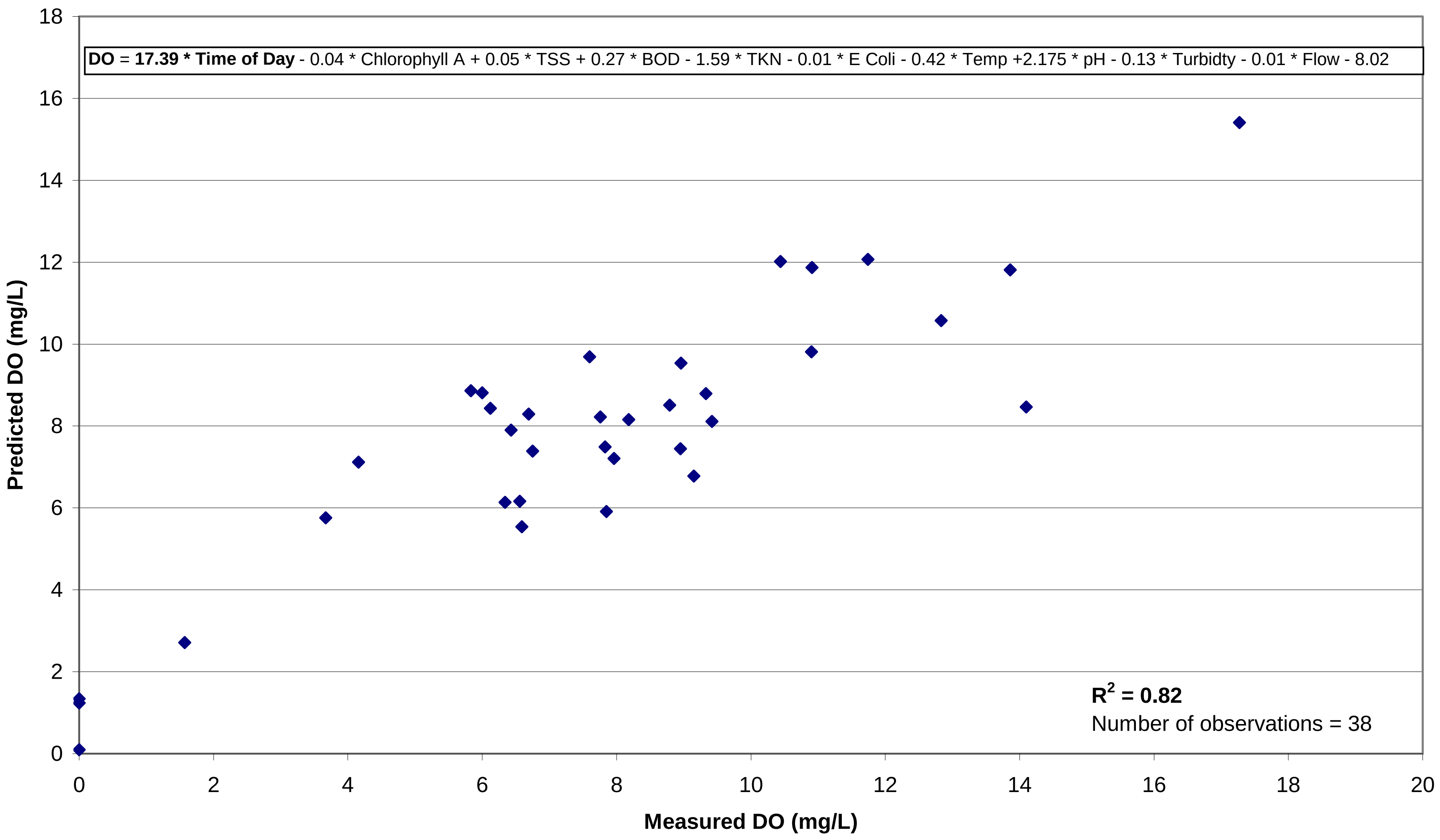
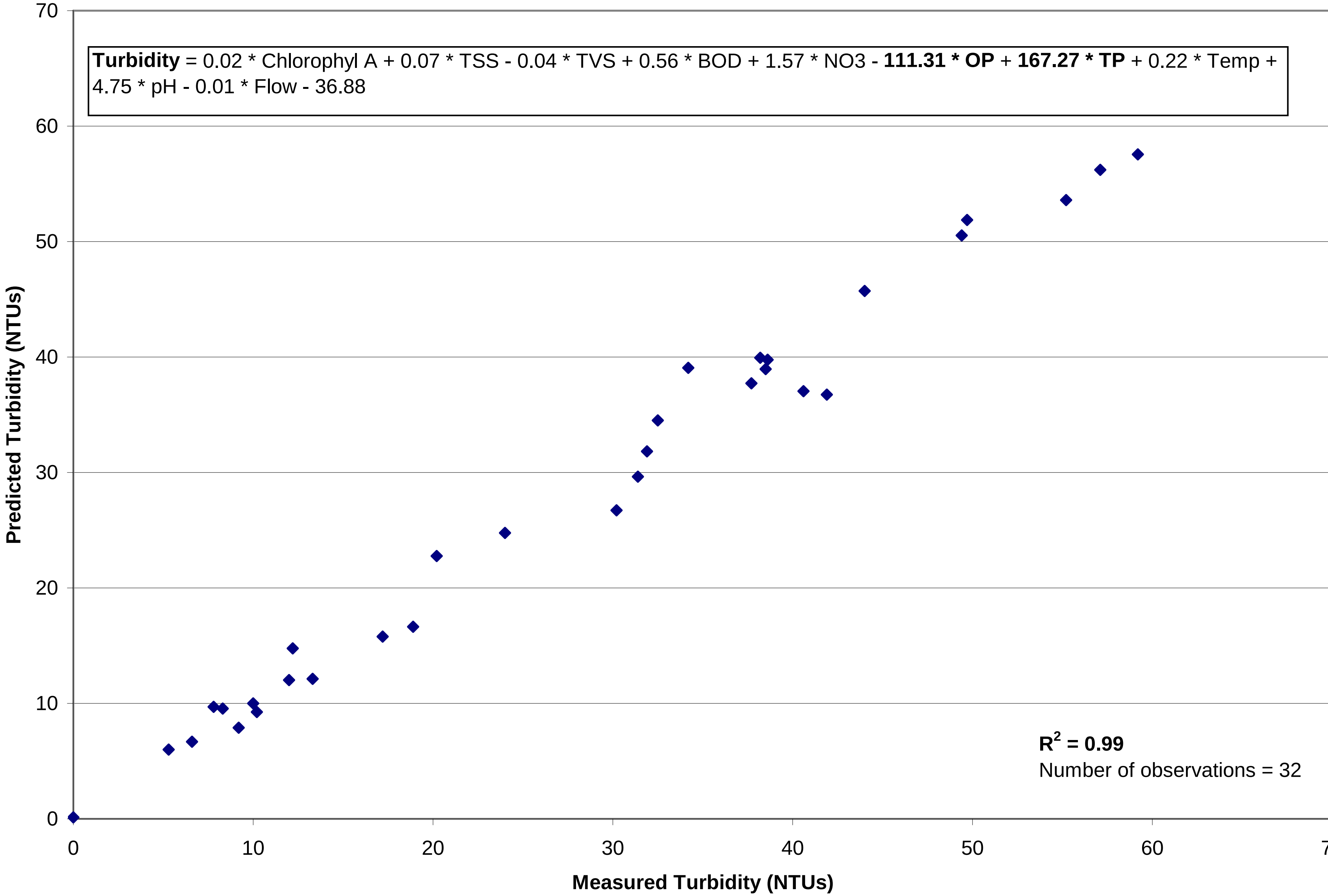


Figure 20
Turbidity Regression Analysis for Main Stem
2006 Data



4. MODELING APPROACH

To support the development of the TMDLs, a number of modeling tools will be developed and used. Due to size, complexity and lack of data available in this watershed, these tools will be developed to evaluate data on a relatively coarse scale. These tools will include hydrologic modeling to define the relationship of flow (hydrology) at critical watershed locations (impaired locations) and water quality models/tools to identify the water quality relationships at key locations in the watershed.

Based on the watershed characteristics and the initial data evaluation noted above the tools will address the following:

- Capable of estimating flows and loads at key locations in watershed
- Quantify sources of non-point and point source pollution
- Consist of public-domain tools
- Able to address a large complex watershed

Based on its intended use in the South Fork Crow Watershed, and the requirements above, HSPF was chosen for the hydrologic model of the watershed. A stochastic or spreadsheet model will be used.

The modeling will include critical conditions such as 7Q10, wet-weather flows, and other characteristic flows that represent impairment conditions that will be defined following the monitoring phase of the project. Note that the modeling strategy will focus on the impaired reaches and lake modeling is not anticipated at this time.

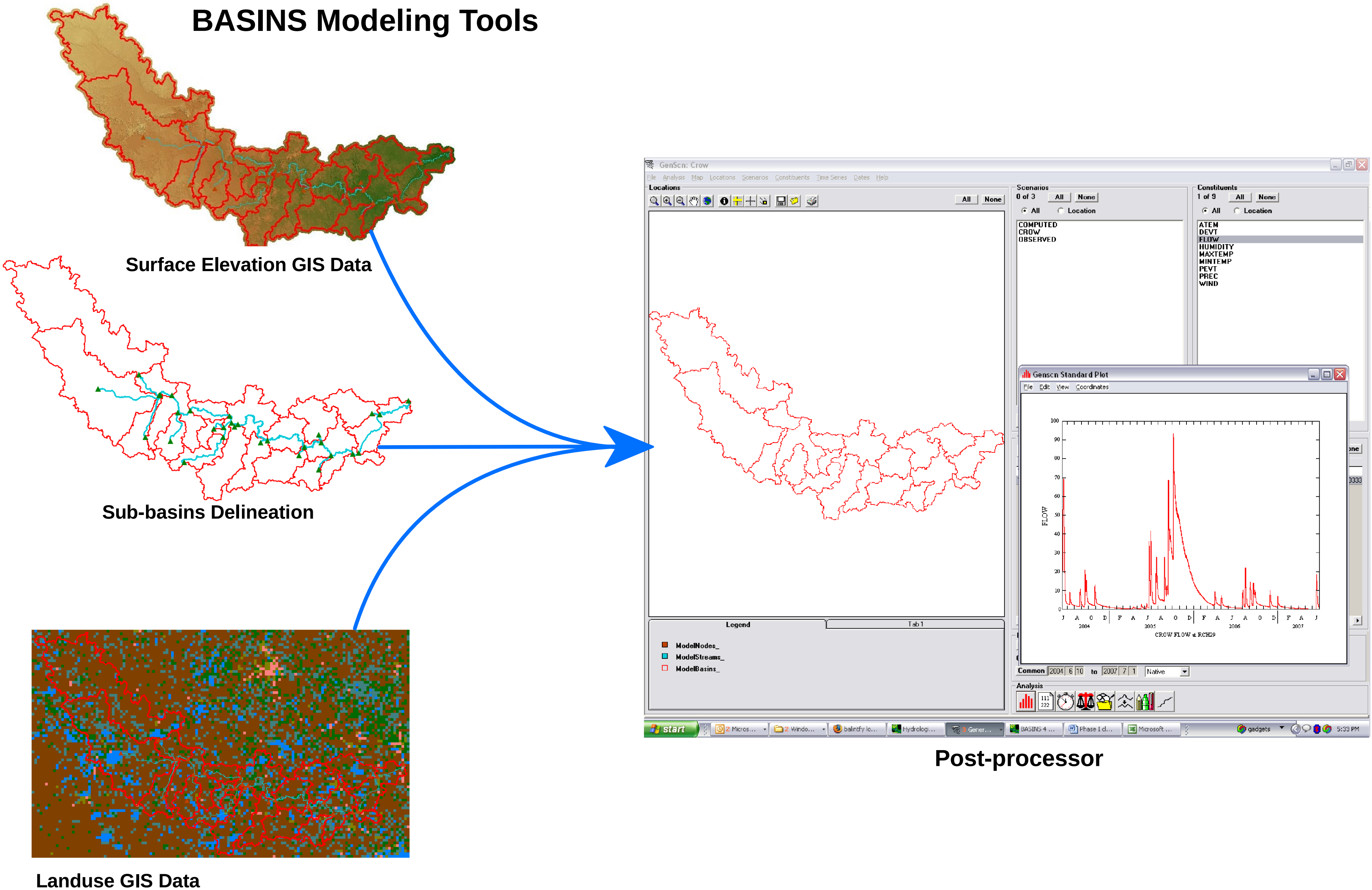
4.1 Hydrology

An initial hydrologic model has been developed using the Hydrologic Simulation Programs in FORTRAN (HSPF) developed by the US EPA as part of the BASINS modeling framework. BASINS is a multi-purpose environmental analysis and modeling framework that integrates modeling and GIS tools. Figure 21 shows some of the tools in BASINS including data layers and example output from the model. Appendix D provides a general description of the HSPF model.

The HSPF model will only be used to model surface runoff which utilizes the PWATER and IWATER modules. These modules require input time series for precipitation, wind speed, and potential evapotranspiration. Precipitation and wind speed will come from meter stations available only at Buffalo, Litchfield, and Maple Lake. The PEVT comes from the Hamon Daily PET calculation using minimum and maximum air temperature, which is then disaggregated to hourly intervals.

Geographic data such as streams, land use, and watersheds has already been compiled into a BASINS GIS database. The model has been developed initially; however, has not been adequately developed for calibration. While the original intent was to provide a working model of the watershed, data has not been sufficient to take the model beyond initial preparation for use in phase III of the project.

Figure 21
North Fork - Lower Crow River TMDL
BASINS Modeling Tools



The level of detail used in the initial model development is limited to what is available from publicly available data but sufficient to capture hydrologic processes and tributary flow in sufficient detail to understand the inputs from each sub basin to the main stem. Therefore, the initial model used the following inputs:

- Stream Network: due to limitations in channel data, a constant prismatic channel cross section shape will be assumed (in future more detailed modeling, this will be refined based on any available information including site visits conducted in 2008). Survey data is not available for channel cross sections and is not planned to be collected as part of this project.

- Land Use: As percent imperviousness is the driving characteristic of land use, land use has been reclassified to 4 categories for simplification: Urban, residential / agricultural, forested, and open water / wetlands. This simplification allows more manageable computations and processing overhead, given the size of the overall watershed.

- Sub Basins: The tributaries to the main stem have been identified based on the USGS 14-digit HUC delineations (Bill to verify). The sub basins upstream of and including Lake Koronis will not be modeled; instead the outflow from Lake Koronis will be input directly into the main stem reach in the model. This simplification is done under the assumption that water quality concerns upstream of Lake Koronis are negligible, based on the recent Rice Lake \ Lake Koronis Restoration Project and the fact that all impaired stream areas are downstream of Lake Koronis.

Point source discharges will be added in the form of average daily flow from each of the dischargers.

Model calibrations have not been conducted to date due to the lack of continuous flow records for the North Fork. While continuous flow data is collected at the USGS Gauge station at Rockford, this site is downstream of the confluence of the South and North Forks. The data from the Rockford site will require subtraction of flows from the South Fork to the extent that data is available. Model calibration conducted in Phase III will be based on data at monitoring locations from the 2001, 2002, 2006 and later periods that will be available from the Phase III monitoring.

4.2 Water Quality Tools

Another layer of modeling will evaluate water quality using up to two separate tools. The initial analysis will use a stochastic model as discussed in Section 3.3. Alternatively, a physically-based spreadsheet model may be used, depending on relationships and understandings developed during the initial analysis for each TMDL parameter.

4.2.1 Stochastic Water Quality Model

A stochastic model developed from analysis using multi-variate linear regression modeling was used in conjunction with measured data in 2006 to develop an understanding of the relationships between the water quality parameters for data collected in 2006. This approach has been successful in providing some initial understanding of the relationships of DO and turbidity impairments to other water quality parameters. This model framework will be further developed based on additional data collected in Phase II.

To understand the difference between the priority watershed sampling sites and the main stem sampling sites, models will be developed for each site separately.

4.2.2 QUAL2K Water Quality Model

If necessary, a physically-based spreadsheet model in the form of the EPA-developed QUAL2K may be used. A brief description of the QUAL2K model is provided in Appendix B .

To provide the inputs for the QUAL2K model, non-point source loadings along stream segments will be developed using the HSPF model and point source inputs.

It is important to note that the QUAL2K model would be developed based on limited available watershed data. Due to the size of the sub-watersheds, and the cost to gather detailed data, it is proposed to use simplified data that can be derived from known information in the watersheds and from limited field visits. This in combination with sensitivity analyses can determine the level of confidence in this approach.

5. PHASE II MONITORING

In order to better understand the cause and effect relationships and to complete the calculations and modeling efforts and TMDL development, additional data collection is required. This section outlines a monitoring program which builds on historical data collection efforts by increasing the number of parameters and locations for monitoring and sampling that will be conducted as part of Phase II of this project in 2008.

Figure 22 illustrates the recommended monitoring and sampling program in terms of geographic locations, parameters, and frequency. As noted previously, the size of the watershed poses a significant challenge. Each of the impaired reaches includes at least one monitoring location with some upstream bracketing to better understand the upstream conditions relating to the impairment. The following provides an outline of the recommended monitoring program.

5.1 Subwatershed Monitoring Locations

For the sub-watersheds identified with dissolved oxygen impairments continued monitoring is proposed at the historic pour-point locations. Monitoring at each location would include the following list of parameters:

Alkalinity	Color
Chlorophyll a	NO_3
Chloride	NH_3
TSS	TKN
TVS Hardness	OP
BOD	TP
Turbidity	E. coli

At each location, a continuous monitoring probe (with data logger) would collect temperature, pH, turbidity, conductivity and dissolved oxygen data throughout the monitoring period. Three sampling events per month would include two during dry-weather periods and one during wet-weather periods. The wet-weather periods should include three to four discrete samples during the event. This will help in identifying what impact wet-weather has on the impaired segments. It may be advantageous to set up continuous samplers for at least some of the sampling locations to capture samples during wet-weather events. Due to the size of the watershed, some areas will receive wet-weather conditions while others will not. Specialized setups may be needed to trigger the samplers at the appropriate times. For example, a site might include a depth sensor tied to the sampler to initiate sampling once the wet-weather conditions are measured. During dry-weather, grab samples will be taken at each identified location.

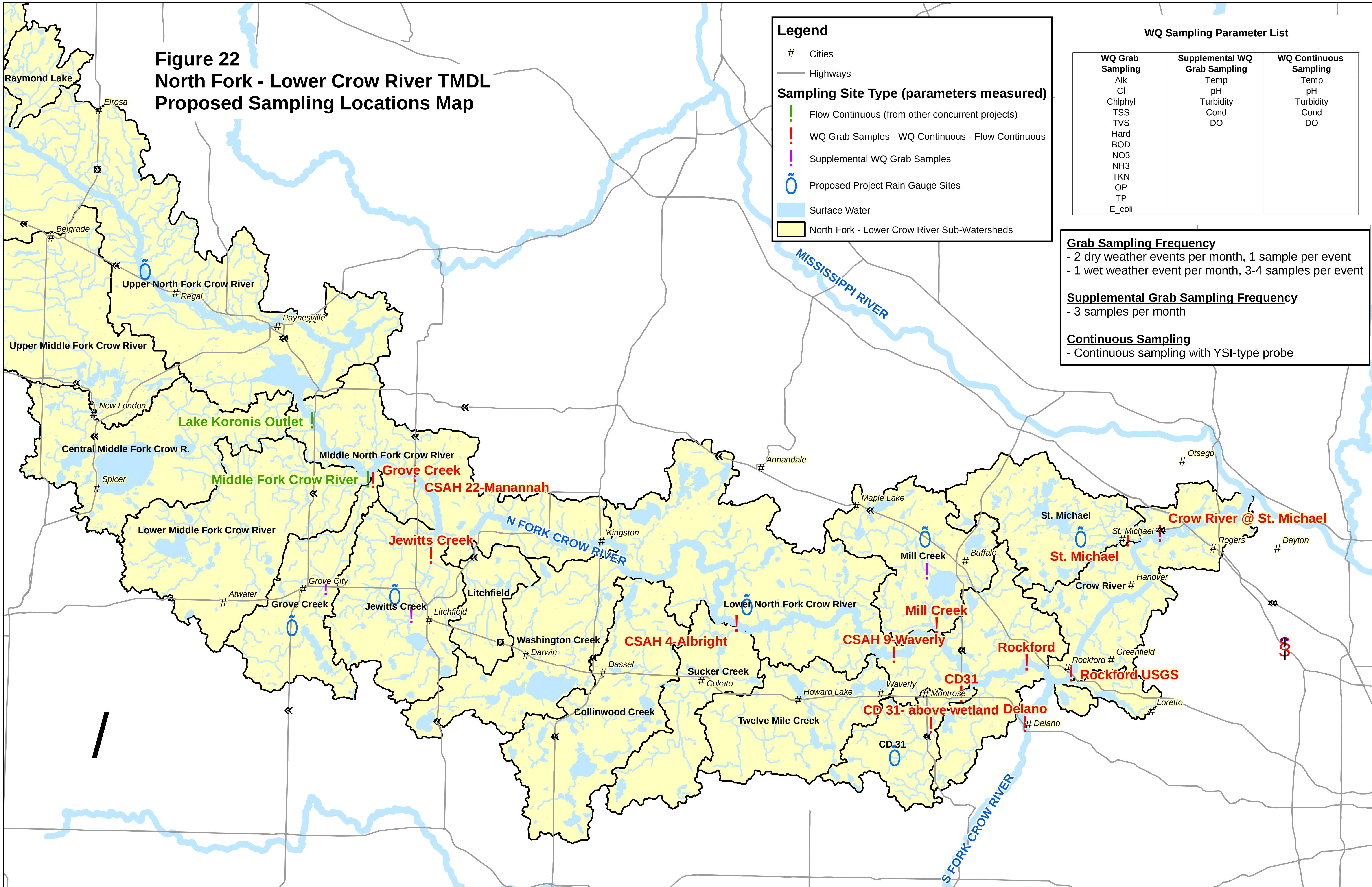


Figure 22
North Fork - Lower Crow River TMDL
Proposed Sampling Locations Map
Legend
Cities
Highways
Sampling Site Type (parameters measured)
Flow Continuous (from other concurrent projects)
WQ Grab Samples - WQ Continuous - Flow Continuous
Supplemental WQ Grab Samples
Proposed Project Rain Gauge Sites
Surface Water
North Fork - Lower Crow River Sub-Watersheds
WQ Sampling Parameter List
WQ Grab Sampling
Alk
Cl
Chlphyl
TSS
TVS
Hard
BOD
NO3
NH3
TKN
OP
TP
E_coli
Supplemental WQ Grab Sampling
Temp
pH
Turbidity
Cond
DO
WQ Continuous Sampling
Temp
pH
Turbidity
Cond
DO
Grab Sampling Frequency
- 2 dry weather events per month, 1 sample per event
- 1 wet weather event per month, 3-4 samples per event
Supplemental Grab Sampling Frequency
- 3 samples per month
Continuous Sampling
- Continuous sampling with YSI-type probe
MISSISSIPPI RIVER
N FORK CROW RIVER
S FORK CROW RIVER
Raymond Lake
Elrosa
Belgrade
Upper North Fork Crow River
Regal
Paynesville
Upper Middle Fork Crow River
New London
Lake Koronis Outlet
Central Middle Fork Crow R.
Spicer
Middle Fork Crow River
Middle North Fork Crow River
Grove Creek
CSAH 22-Manannah
Lower Middle Fork Crow River
Jewitts Creek
Grove City
Atwater
Grove Creek
Jewitts Creek
Litchfield
Litchfield
Washington Creek
Darwin
Dassel
Kingston
CSAH 4-Albright
Sucker Creek
Cokato
Collinwood Creek
Lower North Fork Crow River
Twelve Mile Creek
Howard Lake
Annandale
Maple Lake
Mill Creek
Mill Creek
Buffalo
CSAH 9-Waverly
Waverly
Montrose
CD31
CD 31- above wetland
CD 31
Delano
Delano
Rockford
Rockford
Rockford USGS
Greenfield
Loretto
St. Michael
St. Michael
St. Michael
Crow River @ St. Michael
Crow River
Hanover
Rogers
Dayton
Otsego

Grove Creek, Jewitts and Mill Creek include an additional site upstream of the primary monitoring location that will be used to collect grab samples using portable monitoring equipment such as a YSI so that will temperature, pH, turbidity, conductivity and dissolved oxygen can be collected. These data will provide more insight into the spatial extent of conditions contributing to the impairment. Based on review of these data during the initial data collection, additional water quality samples may be necessary at these locations.

Per discussions with the MPCA, CD31 includes a wetland area upstream of the historical sampling location. It is recommended to sample (at least initially) for the same constituents upstream of the wetland in addition to the downstream site to determine if the wetland is contributing to the impaired reach. Similarly, it is recommended to monitor upstream of Buffalo Lake to begin to understand the extent of upstream dissolved oxygen conditions that may contribute to the downstream conditions.

5.2 Mainstem Monitoring Locations

Several mainstem sites have been identified for continued sampling using the same frequency as noted above for the sub-watersheds to allow consistent sample times and to relate individual samples in each event. The locations are listed below and include those reaches with impairments as well as bracketing to understand upstream contributions to the impairments:

- Lower Crow River downstream of St. Michael
- Rockford USGS site
- City of Rockford
- CSAH 9 – Waverly
- CSAH 4 – Albright
- CSAH 22-Manannah

These locations will provide additional information related to pollutant distribution for the watershed. The furthest downstream location (below St. Michael) is new and will provide an end point for the impaired segment associated with Lower Crow River that has not previously been monitored.

It is understood that other ongoing studies will provide additional data (flow and water quality) on the middle Fork and Lake Koronis outlet; however, they will not be directly related in terms of timing and comprehensive in terms of the list of parameters. As a result, the CSAH 22-Manannah monitoring site will provide an upper boundary (with the exception of Grove Creek) for the monitoring program during Phase I.

5.3 Rain Gauging

Seven supplemental rain gauge locations have been identified for continuously recording rainfall data. The locations have been selected based on the priority watershed locations as well as additional locations necessary to understand the rainfall distribution during the monitoring period..

6. SUMMARY

This report summarizes Phase I elements of the North Fork – Lower Crow River TMDL. Phase I included a review of historical data provided by the MPCA and the development of a database that will be the basis for future compilations of flow and water quality data collected as part of Phase II of this study.

Initial tools have been developed, including a hydrologic model framework using the HSPF model to be used for estimating flow within the watershed in later phases of the project. In addition, a multi-variate linear regression model framework has been developed to assist in identifying relationships between water quality parameters collected to date. Some trends between nutrients and the identified impairments have been identified but additional data is needed to further develop these tools and others for the development of the TMDL.

In addition, recommendations have been made for additional monitoring and sampling in the watershed for building on the existing information. Phase II will include additional monitoring and sampling to be collected in 2007-2008. Phase III will include the development of additional tools for the development of the TMDL.

Each TMDL will be expressed as a total maximum daily load as presented in the following equation:

$$\text{TMDL} = \text{sumWLAs} + \text{sumLAs} + \text{MOS} + \text{RC}$$

The TMDL will include waste load allocations (WLAs), load allocations (LA), a margin of safety (MOS) and a reserve capacity (RC) for future growth. The WLAs will include loads from all existing NPDES wastewater, industrial and other point sources and existing NPDES MS4 stormwater "point" sources. The LA will include loads from any other existing non-point sources and natural sources not covered by an NPDES MS4 permit. The MOS will be included implicitly in the TMDL loading analyses. The RC will include anticipated future point and non-point loads as a result of future growth. The RC can be established as a separate component of the TMDL or can be included in the WLA and LA components.

For the turbidity and dissolved oxygen TMDLs, it will be first necessary to identify the pollutant(s) of concern and then to calculate the current loadings using the results of the monitoring program and modeling efforts. For the bacteria TMDL, it is direct evaluation of bacteria concentrations and corresponding bacteria loads. Loadings from future growth in the form of NPDES wastewater and other point source discharges, NPDES MS4 discharges and non-NPDES non-point sources may be significant and must be included in the TMDL. Future NPDES wastewater discharge loadings will be estimated using population projections, per capita flow generation and anticipated effluent pollutant concentrations. Future stormwater loadings from NPDES MS4 and non-NPDES sources will be estimated based on future land use maps, and areal pollutant loading factors for each land use. This will provide the total estimated pollutant loads from all existing and future discharges.

The next step is to determine the loading capacity for each impaired water segment. This will be completed using the monitoring results and the watershed/receiving water models/tools. This information will be used to determine the maximum load of the pollutant of concern that the receiving water can accept and meet state water quality standards. Depending on the findings of the monitoring program and the modeling effort, the allowable load may be expressed in many different ways including load duration curves, seasonal, or monthly loads. It will also be necessary to distinguish natural background conditions from anthropogenic impacts and seasonal affects.

Once the loading capacity is established, it will be equitably allocated to all existing and future dischargers in the form of WLAs, LAs and RC. Load reductions may be expressed in the form of a percent reduction or a load reduction. This will require extensive coordination with all stakeholders. Potential TMDL implementation actions include, but are not limited to:

- reduction in water volume or pollutant concentration from existing NPDES wastewater, industrial and other point sources;
- reduction in water volume or pollutant concentration from existing NPDES MS4 or non-point sources including improved maintenance procedures for existing facilities and the implementation of structural and non-structural BMPs;
- implementation of stricter stormwater treatment regulations for new development to reduce loads from new development
- for the bacteria TMDL, actions may include the above and may also include additional actions targeted at known specific sources such as septic tanks, animal operations or illicit wastewater connections to the drainage system.

APPENDIX A: PUBLIC MEETING INFORMATION

Meeting Notes

North Fork Lower Crow River TMDL Public Meeting
August 2, 2007
Wright County Courthouse, Buffalo, MN.

A public information meeting was held at 4 p.m. on August 2, 2007 for the North Fork Lower Crow River dissolved oxygen, turbidity and bacteria TMDL. A presentation by the Crow River Organization of Water (C.R.O.W.), Minnesota Pollution Control Agency (MPCA), and Brown and Caldwell (BC) included information leading to the development of a Total Maximum Daily Load (TMDL) Report. The news release for the meeting, held at Wright County Courthouse in Buffalo, MN, is shown in Attachment A.

The following summarizes the presentation and questions raised during the meeting.

Presentations

- Diane Sander of the C.R.O.W. provided an overview of the organization, and described its creation, structure, mission, and programs and activities, including the 2001-2003 Diagnostic Study. Diane's slides are shown in attachment B.

- Maggie Leach of the MPCA provided an overview of the TMDL process, the legislation that authorizes and initiates TMDLs, and requirements and goals associated with TMDLs. Maggie's presentation is shown in Attachment C.

- Bill Ruhberg and Dan Davis of BC provided an overview of the North Fork Lower Crow Study Area and summarized the stream impairments that resulted from the 2001-2003 C.R.O.W Diagnostic Study. In addition, examples of the results from the Diagnostic Study water quality sampling were presented, as well as the strategy for developing the North Fork Lower Crow River specific TMDL. The slides used for this portion of the presentation are included in Attachment D.

Question and answer period.
Qustions were addressed by the presenters as well as Jim Hodgson with the MPCA.

Question 1: How will you deal with the South Fork and its influence on water quality in the lower portion of the study area?

Answer: There is some data available from Diagnostic Study data for the South Fork and that sampling and modeling of the South Fork is currently on-going. The South Fork contribution will provide a challenge with regards to the North Fork and Lower Crow TMDL; however, with historical data and additional data being collected on the South Fork, it is anticipated that the South Fork can be partitioned from the Lower Crow River segment.

Question 2: How do we overcome limited data that is not very historical?

Answer: The available data is limited but will be expanded upon in the 2007-2008 time period. Budget limitations will be a factor in the extent of monitoring that will be accomplished. Additional monitoring will be further refined over the next few weeks as Phase I of the study is completed.

Question 3: Have the beneficial uses of the waters been determined?

Answer: The beneficial uses have been determined, and were described. The MPCA standard for what is considered a recovered stream, is to support a warmwater fishery and be of sufficient water quality to allow swimming activities. These are the basis for the water quality standards of 25 NTUs for Turbidity, a geometric mean of 200 col/100 ml for fecal coliform and 5 mg/l of dissolved oxygen in the impaired reaches.

Question 4: Why has the study been portioned the way it has?

Answer: Despite the challenge associated with developing a TMDL on a watershed the size of the North Fork - Lower Crow, it was necessary to begin the analysis based on the existing known impairments as outlined in the presentation. The study will likely be an iterative process that is revisited following development of the initial TMDL. As more data is collected, it will provide an opportunity of refinement of the TMDL.

Question 5: Will there be sampling upstream of the Diagnostic Study water quality sampling sites to more specifically define where pollution loadings are coming from?

Answer: This is an important consideration and challenge for this project given the size of the watershed and limited funding available. Additional sampling efforts will be finalized over the next few weeks and will be based on funding and what is necessary to develop the TMDL.

Question 6: How do we overcome the current drought conditions in our need to collect additional data?

Answer: This type of dry period we are currently experiencing is a good opportunity to collect data for extreme conditions and will help in better understanding the critical conditions that can cause the impairments (such as low dissolved oxygen). It is important to note that we encountered wet conditions during the Diagnostic Study and now we are experiencing drier conditions. These conditions offer variability which will be important in developing the TMDL.

The attendance list is shown in attachment E.

ATTACHMENT A

Minnesota Pollution Control Agency

NEWS RELEASE

www.pca.state.mn.us ● Toll-free and TDD 800-657-3864
St. Paul ● Brainerd ● Detroit Lakes ● Duluth ● Mankato ● Marshall ● Rochester ● Willmar

For immediate release: July 24, 2007

Contacts: Forrest Peterson, 320-214-3789
Maggie Leach, 218-855-5018

Public Information Meeting Aug. 2 on Dissolved Oxygen, Turbidity and Bacteria Pollution in North Fork Lower Crow River

Buffalo, Minn. — A public information meeting will be held at 4 p.m. Thursday, Aug. 2 at the Wright County Courthouse, Room 120A, in Buffalo about a report on pollution in the North Fork Lower Crow River. Water quality testing shows low dissolved oxygen, turbidity and fecal coliform bacteria pollution. The Crow River Organization of Water (CROW), Brown and Caldwell, and the Minnesota Pollution Control Agency (MPCA) will present information leading to the development of a Total Maximum Daily Load (TMDL) report.

The TMDL report is part of a nationwide effort under the federal Clean Water Act to identify and clean up pollution in streams, rivers and lakes. Every two years states are required to submit a list of impaired waters to the U.S. Environmental Protection Agency (EPA). A TMDL report is a scientific study that calculates the maximum amount of a pollutant a water body can receive (known as the "loading capacity") without violating water quality standards.

The TMDL report focuses on the dissolved oxygen, turbidity and fecal coliform bacteria loading capacity of the North Fork Lower Crow River, and general allocations or limits imposed on all sources necessary to meet water quality standards. Sources of bacteria, turbidity and low dissolved oxygen include failing septic systems, unsewered communities, wildlife, and stormwater runoff from urban landscapes, livestock feedlots and manure applied to cropland. An official public comment period will be announced later; however, questions and concerns heard now will be considered in the report.

Prior to the meeting the Crow River Organization of Water (CROW) joint powers board will be conducting its monthly meeting beginning at 3 p.m. The public is welcome to arrive early for the board meeting and stay for the TMDL information meeting at 4 p.m.

Following approval of the study by the U.S. EPA, a plan will be developed to bring the North Fork Lower Crow River back to water quality standards. For more information about the TMDL study contact Maggie Leach, 218-855-5018; or Diane Sander, 763-682-1933 ext 112. More information on the state's impaired waters list and TMDL studies is available on the Web at: www.pca.state.mn.us/water/tmdl/index.html.

Broadcast version:

There will be a public information meeting at 4 p.m. Thursday, August 2 on pollution in the North Fork Lower Crow River. State and local environment officials will report on a study that will be looking at pollution from bacteria, turbidity, and low dissolved oxygen. The meeting will be held in Room 120A of the Wright County Courthouse in Buffalo. The public is also welcome to arrive early for the monthly meeting of the Crow River Organization of Water joint powers board at 3 p.m.

ATTACHMENT B

- Formed in 1999
  - Goals
    - Preserving
    - Protecting
    - Restoring
  - Supporting & facilitating
    - Local governments
    - Federal and State agencies
    - Agricultural communities
    - Businesses
    - Schools
    - Non Profits
    - Citizens
  - Non regulatory & Non permitting

C.R.O.W. Joint Powers
CROW RIVER ORGANIZATION OF WATER

CROW JPB Mission

To improve water quality in the Crow River Basin through educational outreach and collaboration with our partners and citizens.

CROW Partners

- SWCD
- Environmental Services
- Water Planners
- NRCS
- Buffalo Creek Watershed District
- Middle Fork Crow River Watershed District
- North Fork Crow River Watershed District
- Metropolitan Council
- University of MN Extension
- BWSR
- DNR
- USFWS
- MPCA
- Cities & Townships
- Upper Mississippi River Source Water Protection Project
- USGS
- MN Waters
- Pheasants Forever
- Local Businesses
- Local Water Management Task Force

CROW Volunteer Partners

- Lake Associations
- Buffalo Lake Rod & Gun Club
- Lake Lillian Sportsmen Club
- South Fork Crow River Association
- Crow River Pride
- St. Michael Area River Team
- Green Lake Property Owners Association
- National Honor Society
- Jobs for MN Graduates
- Citizen Stream Monitors
- Boy Scouts
- Local Schools
- River Clean Up Volunteers
- Girl Scouts
- Cub Scouts
- Hanover Area River Team (HART)
- Delano Dream Team
- Crow River Trail Guards

CROW Board & Staff

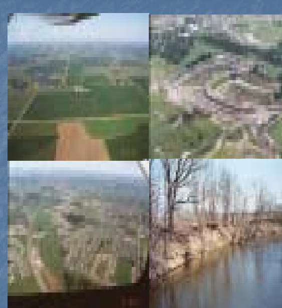
Crow River Watershed

CROW Projects

- Grant writing
- Conduct water quality monitoring
- Provide watershed management
- Promote Best Management Programs
- Assist citizen groups & Lake Associations
- Develop & expand volunteer programs
- Water Quality Education
- Public Awareness

Best Management Practice Programs

- Buffer Strip Incentive Program
- Wetland Restorations
- Feedlot Upgrades
- Stream Bank Stabilization
- Low Interest Loans for Septic System Upgrades
- Open Tile Intake Alternatives
- Waterways, Filter strips
- Rain Gardens



Implementation Grant

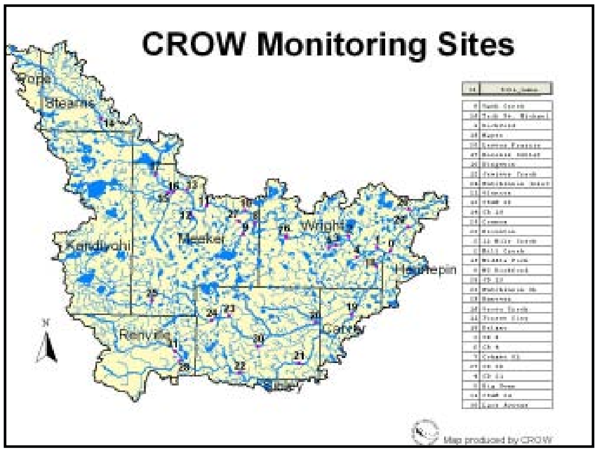
- Completed 39 BMP project's
  - Enrolled 943 acres into CRP
  - Saved 24,008 lbs P & 6,377 tons of sediment

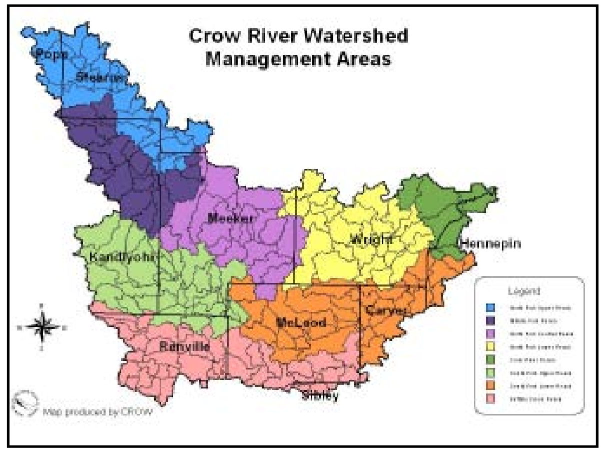
Volunteer Programs and Water Quality Awareness

- Citizen Stream Monitoring Program
- Citizen Lake Monitoring Program
- River Clean Up
- Storm Drain Stenciling
- E-Currents
- Earth Day
- SWCD Field Days
- Youth Education

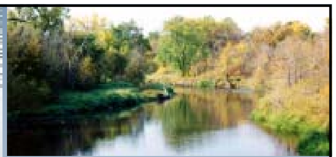
Diagnostic Study

- **Conducted basin-wide study**
- **Monitored 2001-2003**
- **Collected baseline information: P, TSS, N, Fecal**
- **Developed Management Areas**


CROW Monitoring Sites
Pope
Stearns
Kandiyohi
Meeker
Wright
Hennepin
Renville
Carver
Sibley
Map produced by CROW


Crow River Watershed
Management Areas
Pope
Stearns
Meeker
Wright
Hennepin
Kandiyohi
McLeod
Carver
Renville
Sibley
Legend
Map produced by CROW

ATTACHMENT C



Setting the Course for Improved Water Quality

North Fork – Lower Crow River TMDL
Dissolved Oxygen, Turbidity and Fecal Coliform

August 2, 2007

Minnesota Pollution Control Agency

Presentation Outline

Minnesota Pollution Control Agency

- Clean Water Act
- Water quality
- Impaired waters
- TMDLs 101

Legal Authority

Minnesota Pollution Control Agency

Federal Clean Water Act (CWA) of 1972 – framework for protecting, restoring water quality

Focus:
CWA Section 303 – establishes national water quality standards and Impaired Waters (TMDL) programs

What does Section 303 of the CWA require?

Minnesota Pollution Control Agency

Develop water quality standards for all MN waters:

1. Designate beneficial uses for Minnesota rivers, drainage ditches, streams, wetlands, lakes
2. Develop water quality criteria to protect beneficial uses

How do we determine whether standards are being met?

Minnesota Pollution Control Agency

First, MPCA and other partners monitor water quality statewide

Then, MPCA analyzes monitoring data and compares to water quality criteria to determine whether standards are being met

- Standards not met?
- *Section 303 (d)* requires placing the water body on the *Impaired Waters List*

Why is the Impaired Waters List Important?

Minnesota Pollution Control Agency

303(d) Lists:

- Inform/educate the public
- Ensure that *further study* of impaired waters occurs (**the TMDL Study**)
- **Encourage action to restore water quality**

What is a Total Maximum Daily Load (TMDL)?

- It is a process

- It is a formula

Minnesota Pollution Control Agency

TMDLs – The Process

Assess waters → Determine if impaired → Place water on 303 (d) list → Monitor, study water body further → Complete pollutant load allocation formula → Develop restoration strategy → Implement strategy → Monitor changes in water quality → Next steps – Delist?

Minnesota Pollution Control Agency

TMDL – A Mathematical Formula

A TMDL Study must complete this pollution load allocation formula:

LA(s) + WLA(s) + Margin of Safety + Reserve Capacity = Total Maximum Daily Load

Where:
LA = Load allocations from nonpoint sources
WLA = Waste load allocations from point sources
Margin of Safety = to account for potential scientific error
Reserve capacity = set aside for future development

Minnesota Pollution Control Agency

Which will tell you…

the maximum amount of a specific pollutant that can be discharged to a waterbody and still meet water quality standards

Minnesota Pollution Control Agency

Why are Total Maximum Daily Load Studies Important?

Provides the mechanism for studying a water body so that:

1. You can determine how much pollution must be reduced from all sources
2. You can plan an effective strategy for reducing existing pollutant loads to meet water quality standards

Minnesota Pollution Control Agency

What must a TMDL Study include?

1. A ***public participation plan*** to ensure engagement, collaboration, success
2. An ***assessment*** *of what's causing impairment* *(may include biological, chemical, habitat, flow, etc.)*
3. A ***technical analysis*** of existing pollutant loads from point and nonpoint sources

Minnesota Pollution Control Agency

What must a TMDL Study include?

Minnesota Pollution Control Agency

4. An ***allocation*** of acceptable pollutant loads from point and nonpoint sources

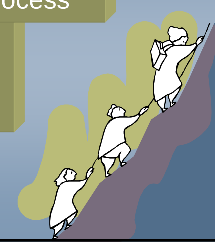
5. An ***implementation strategy***

6. A ***monitoring strategy*** to determine effectiveness of restoration activities

If you help develop a TMDL, what can you expect?

Minnesota Pollution Control Agency

- Better Partnerships
- Integrated planning process
- More and better knowledge
- Challenging process



Resources Available to Start a TMDL Study

Minnesota Pollution Control Agency

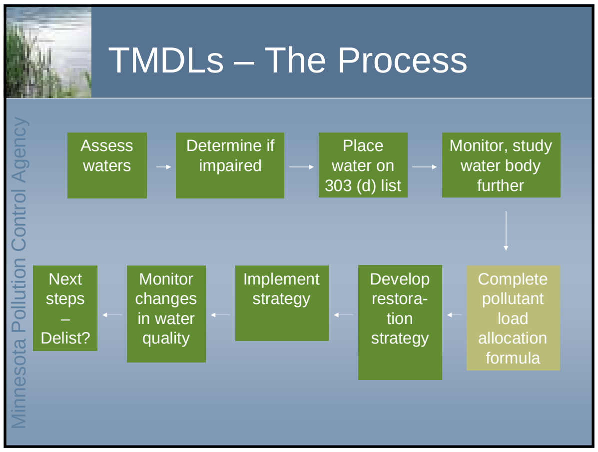
- Funding for TMDL Studies
- MPCA staff assistance
- Consultant pool

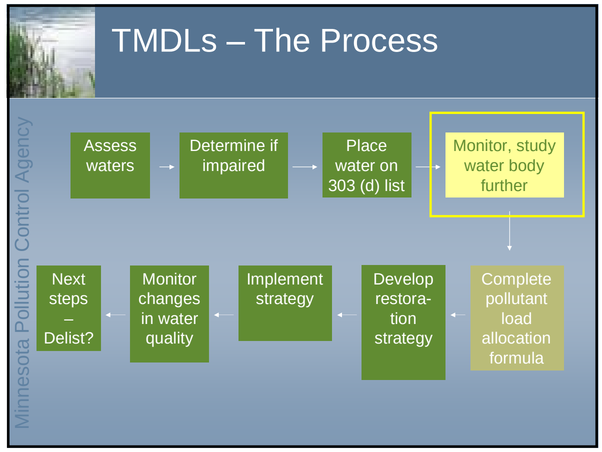
Contacts

Minnesota Pollution Control Agency

- Diane Sander, CROW – (763) 682-1933 ext. 112
  diane.sander@mn.nacdnet.net
- Jenny Gieseke, CROW – (507) 766-0173
  crowriverorg@yahoo.com
- Maggie Leach, MPCA – (218) 855-5018
  margaret.leach@pca.state.mn.us

ATTACHMENT D


TMDLs – The Process
Minnesota Pollution Control Agency
Assess waters
Determine if impaired
Place water on 303 (d) list
Monitor, study water body further
Complete pollutant load allocation formula
Develop restora-tion strategy
Implement strategy
Monitor changes in water quality
Next steps – Delist?


TMDLs – The Process
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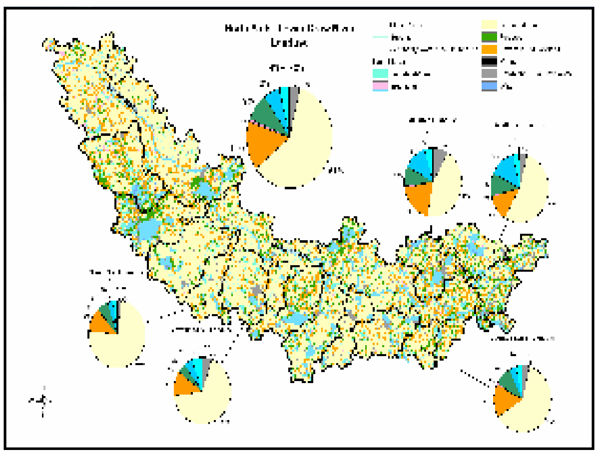
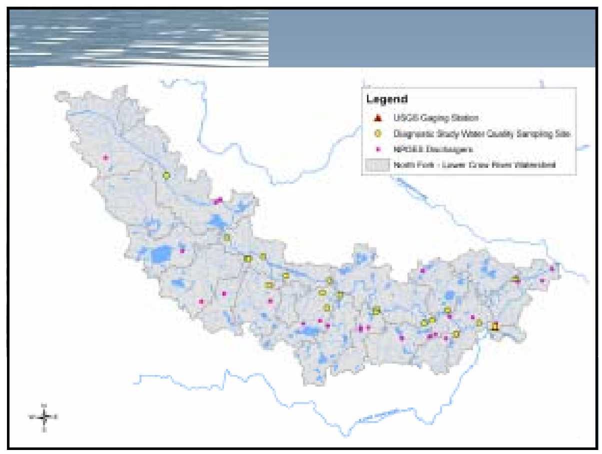
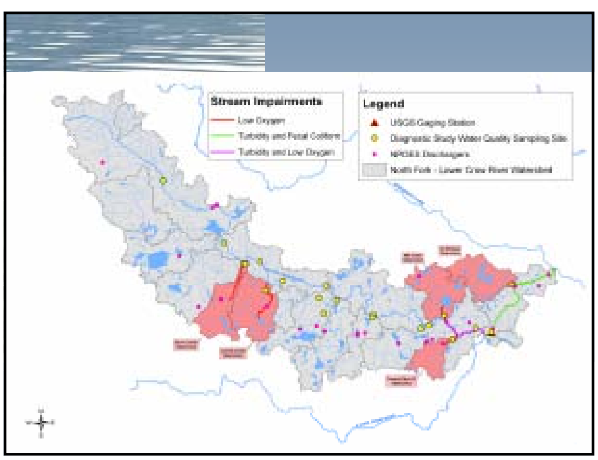
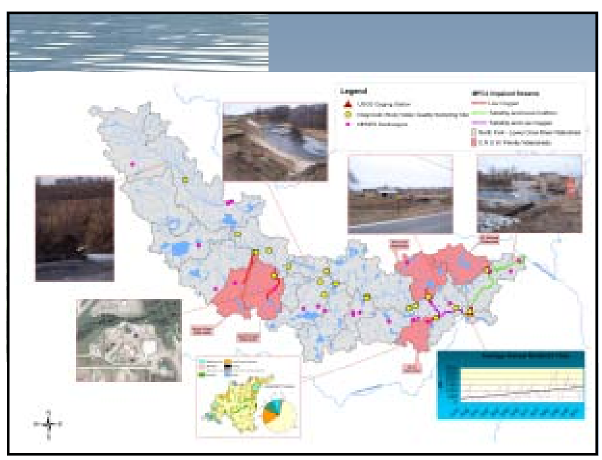


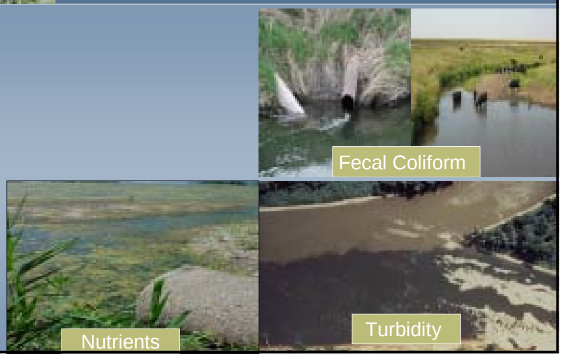

Legend
USGS Gaging Station
Diagnostic Study Water Quality Sampling Site
NPDES Dischargers
North Fork - Lower Crow River Watershed


Stream Impairments
Low Oxygen
Turbidity and Fecal Coliform
Turbidity and Low Oxygen
Legend
USGS Gaging Station
Diagnostic Study Water Quality Sampling Site
NPDES Dischargers
North Fork - Lower Crow River Watershed



Examples of Impairment

Minnesota Pollution Control Agency



Impairment Parameters

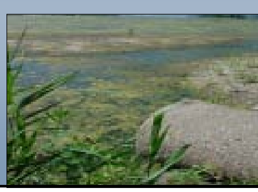
Minnesota Pollution Control Agency

- Dissolved Oxygen
- Turbidity
- Fecal coliform

Impairment Parameters

Minnesota Pollution Control Agency

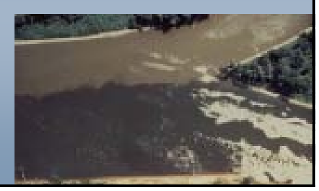
Dissolved Oxygen – Amount of oxygen a given volume of water can hold



Impairment Parameters

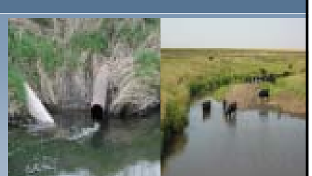
Minnesota Pollution Control Agency

Turbidity – cloudiness or opacity of a liquid caused by particles (is an indication of the clarity of water and water quality)

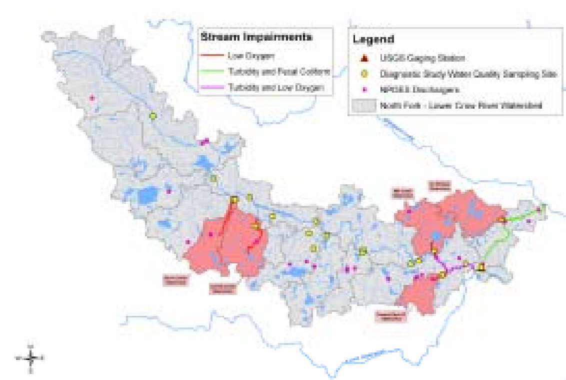


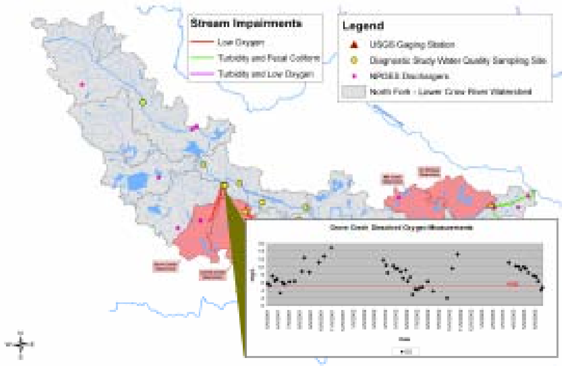
Impairment Parameters

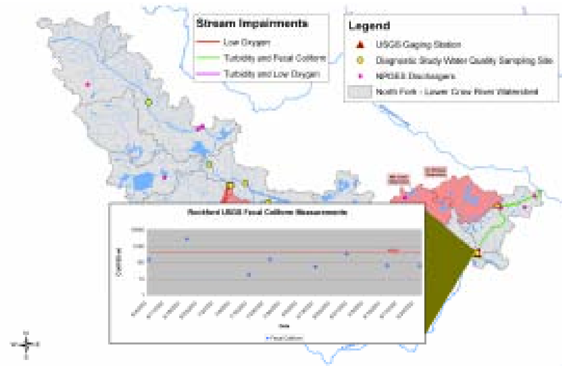
Minnesota Pollution Control Agency

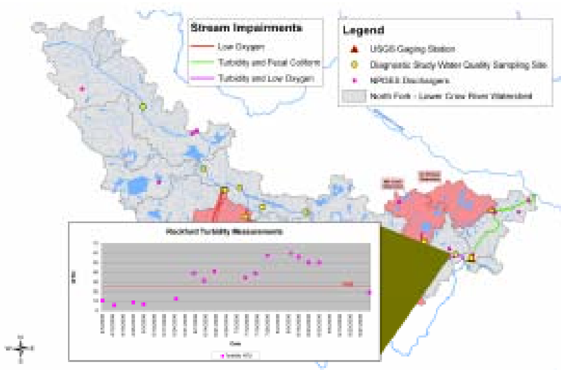


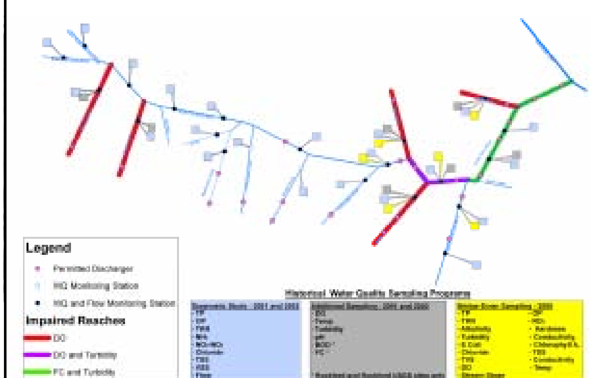
Fecal coliform – A group of bacteria that indicate the presence of human or animal fecal matter.











Diagnostic Study Results
Point Source TP Significance

Minnesota Pollution Control Agency

Stream or Discharger Reach	Average % TP [illegible]	Point source Significance
KORONIS		Low
CLIM	3%	
Middle Fork	2.4%	Moderate
GROVE Cr.	4%	Low
JEWITTS Ck	100%+	VERY HIGH
CSAH22	4%	Low
FOREST	53%	HIGH
KINGSTON	35%	Moderate
Washington Creek	1%	Low
Bigelow Cr.	0.1%	Very Low
Cokato Lake Outlet	82%	VERY HIGH
NFCR4	55%	Moderate
Twelve Mile	13%	Low
NFCR9	40%	HIGH
MILL CK	100% +	VERY HIGH
CD31	5%	Low
Rockford	27%	Moderate

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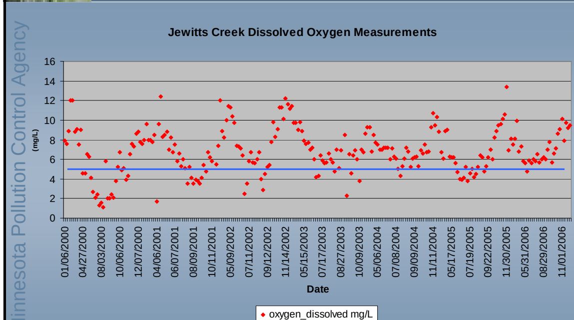
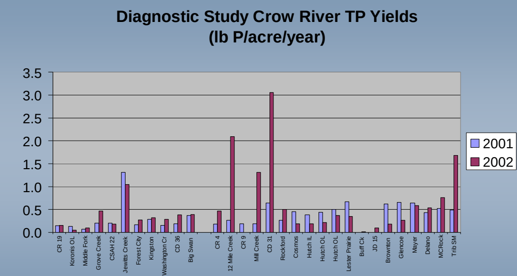
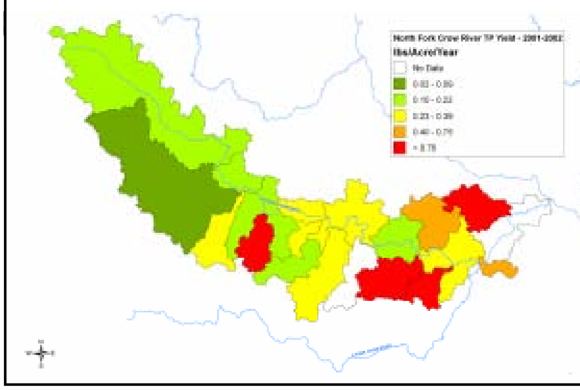


Diagnostic Study Results

Minnesota Pollution Control Agency





North Fork – Lower Crow TMDL

Minnesota Pollution Control Agency

- **Phase I – Data review and approach**
- Phase II – Monitoring and sampling
- Phase III –Quantify loads

North Fork – Lower Crow TMDL

Minnesota Pollution Control Agency

- **Phase I – Data review and approach**
  - Recommending additional data be collected
  - Strategy for Phase III
    - Develop hydrologic model for flow estimates
    - Develop spreadsheet type models for water quality relationships

North Fork – Lower Crow TMDL

Minnesota Pollution Control Agency

- Phase II – Monitoring and Sampling (2007 – 2008)
- Phase III – Develop models and quantify loadings (2008 – 2009)
  - Flow x Concentration = Loading
    - Flow is derived using a hydrologic model
    - Concentration is derived from the water quality sampling data collected

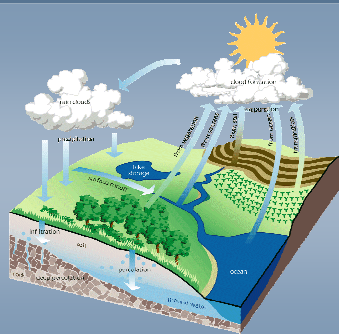
North Fork – Lower Crow TMDL

Minnesota Pollution Control Agency

- Watershed Modeling Strategy (Phase III)
  - Hydrologic model development (HSPF)
    - Based on physical processes
    - Public domain, widely used for TMDLs
  - Water quality model
    - Based on stochastic or spreadsheet model
  - Utilize models to estimate loads

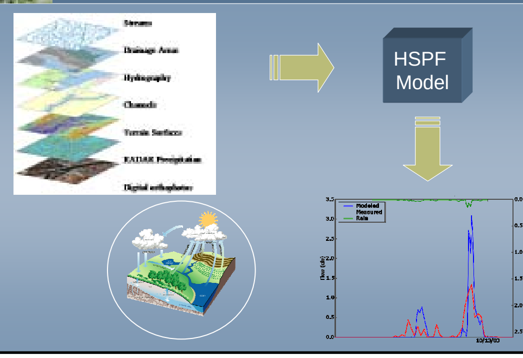
Modeled Hydrologic Processes

Minnesota Pollution Control Agency



Hydrologic Model

Minnesota Pollution Control Agency

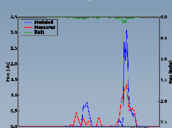


Phase III

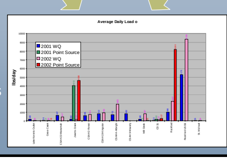
Minnesota Pollution Control Agency

- Water Quality Model + Hydrologic Output => Loading Estimate

date	Flow	BOD5	Conductivity	Chloride	DO
7/12/1999		2.2	608		7.2
7/19/1999		4.5	637		7.9
7/26/1999		5.7	633		7.7
8/9/1999		6.6	577		8.1
8/25/1999		4.4	540		7.2
9/16/1999		3.3	600		7.3
6/12/2000		8.5	867		7.5
6/29/2000		7.1	737		10.2
7/19/2000		3.9	702		8.8
8/2/2000		7.5	610		7.9
8/17/2000		5	649		6.9
9/5/2000		6.8	722		10.6
9/13/2000		6.1	724		12.8
9/25/2000		8	880		17.2



Loading Estimates



North Fork – Lower Crow TMDL Schedule

Minnesota Pollution Control Agency

- **Phase I – Data review and approach (2007)**
- Phase II – Monitoring and sampling (2007/2008)
- Phase III –Quantify loads (2008/2009)

Setting the Course for Improved Water Quality

Minnesota Pollution Control Agency

- Questions?

ATTACHMENT E

NORTH FORK -- LOWER CROW DO, TURBIDITY AND FECAL COLIFORM TMDL PROJECT MEETING

August 2, 2007

	NAME	ADDRESS	PHONE	EMAIL	REPRESENTING
1	Peter Ebnet		320-796-0888	Peter@mfcrow.org	Middle Fork Crow Watershed
2	Randy Nelson		320-231-0008 x5	randy.nelson@mn.usda.gov	Prairie Country RC&D
3	Thomas Klett	212 Central Ave, Buffalo	763-684-5431		City of Buffalo
4	Tracy Janikula	102 2nd St NW Buffalo	763-682-7334	tracy.janikula@co.wright.mn.us	P+Z of Wright County
5	Brad DeWolf	2040 Hwy 12 E. Willmar MN 56201	612-756-1032	bradde@bolton-menk.com	Buffalo
6	Steve Bot	3150 Lander Ave NE St. Michael, MN 55376	763-497-2041 x122	Sbot@ci.st-michael.mn.us	St. Michael
7	Bob Derus	" " " " " " "	" "	bderus@ci.st-michael.mn.us	City of St. Michael
8	Merton Auger	212 Central Ave, Buffalo, Mn	763.682.1181		COB
9	Tim Lynch	17050 32nd St Mayer M	952-353-2598		Carver Co
10	Dale Drealan	Lws 600 E 4th St Chaska MN 55317	952-361-1823	[illegible]	Crow Co
11	George Schlagel	54231 870th Ave Buffalo Lake 55314	320-587-8562	None	BCWD
12	Roger Strudel	940 Industrial Drive S103, Sauk Rapids 56379	320-255-2976	roger.strudel@dnr.state.mn.us	DNR
13	Sean Ness	Box 210 Buffalo MN 55313	763-286-4694	sness@centrasota.com	Centra Sota Coop
14	Tyson Kaldenberg	PO Box 238 Cokato MN	320-286-6142	tkaldenberg@centrasota.com	Centra Sota Coop
15	Charles Schwartz	916 E St. Paul St Litchfield, MN	(320)693-7287	Charles.Schwartz@mn.usda.gov	Meeker Co. NRCS
16	Adam Barka	916 E St. Paul St. Litchfield 55355	(320)693-7287 x112	adam.barka@mn.nacdnet.net	Meeker SWCD
17	Jack Russek	309 Bridge AV E Delano	763-972-2396	jack.russek@co.wright.mn.us	Wright Co. Comm.
18	David Bronstrom	2151 Berkeley Ave St Paul MN 55105	651-690-0190	bront004@umn.edu	Upper Miss R. Source Water Protection Project
19	James Larson	707 Armitage Ave SW, Buffalo	763 682 4455	tjohill@earthlink.net	Deer Lake Assn
20	George Bakeberg	8870 Grover ave SW Waverly 55390	320 543 3849		MMPA
21	Ellen Sones	Henn Co ES 417 N 5th St, Mpls.	612 596-1173	ellen.sones@co.hennepin.mn.us	Henn. Co.
22	Joel Wurscher	Sibley Co Service Center, Gaylord MN	(507) 237-4050	joelw@co.sibley.mn.us	High Island Watershed
23	Ronald Otto	111 6th St Gaylord MN	507 237-5435	Ron.Otto@mn.nacdnet.net	Sibley Soil & Water
24	Gordy Behm	13851 Diamond Shores Rd Atwater, MN	320 974-8242	gbehm@wecnet.com	MFCRWD
25	Ron Kutzke				CROW
26	Josh Reed	Box 40, 120 Prairie Ave N Brooten MN 56316	320-346-2869	[illegible]	NFCRWD
27	Joe Jacobs	311 Brighton Ave Buffalo MN 55313	763 682 1970	joe.jacobs@mn.nacdnet.net	Wright SWCD
28	Kerry Saxton	311 Brighton Ave Buffalo MN 55313	763-682-1970	kerry.saxton@mn.nacdnet.net	- Wright SWCD
29	Craig Peterson	6120 Earle Brown Dr Rm 650 Brooklyn Center MN 55430	763-566-2941	craig.peterson@mn.usda.gov	NRCS
30	Jim Onstad	311 Brighton Ave Ste. C, Buffalo, MN 55313	763-682-1933	jim.onstad@mn.usda.gov	Wright NRCS
31	Christopher Strand	PO Box 212 St Michael MN 55376	763-497-9447	chris.strand@jbsurv.com	J&B Survey, Inc
32	John Paulson	111 Hassan St SE Hutchinson, MN 55350	320-234-5682	jpaulson@ci.hutchinson.mn.us	City of Hutchinson
33	Chuck Johnson	Baxter, MN	218-828-6075	chuck.g.johnson@state.mn.us	MPCA
34	Dennis Peterson	3605 113 AV NE Spicer 56288	320 796-5661	dk peters @ net	Kandiyohi Co Crow
35	Ray Bayerl	20778 Cable Ave Lester Prairie	320-485-2181		McLeod County
36	Maggie Leach				MPCA

	NAME	ADDRESS	PHONE	E-MAIL	REPRESENTING
37	LAUREL MEZNER	MPCA 7678 COLLEGE RD BAXTER, MN 56425	(218) 828-6068	laurel.mezner@pca.state.mn.us	MPCA - BRAINERD
38	JIM HODGSON	MPCA 7678 COLLEGE RD, BAXTER, MN	218-828-6065	james.hodgon@pca.state.mn.us	MPCA-BRAINERD
39	John F. Blackstone	SPRWS 1900 Rice St. Paul Mn	651 266 6324	john.f.blackstone@ci.stpaul.mn.us	SPRWS/UMRSWPP
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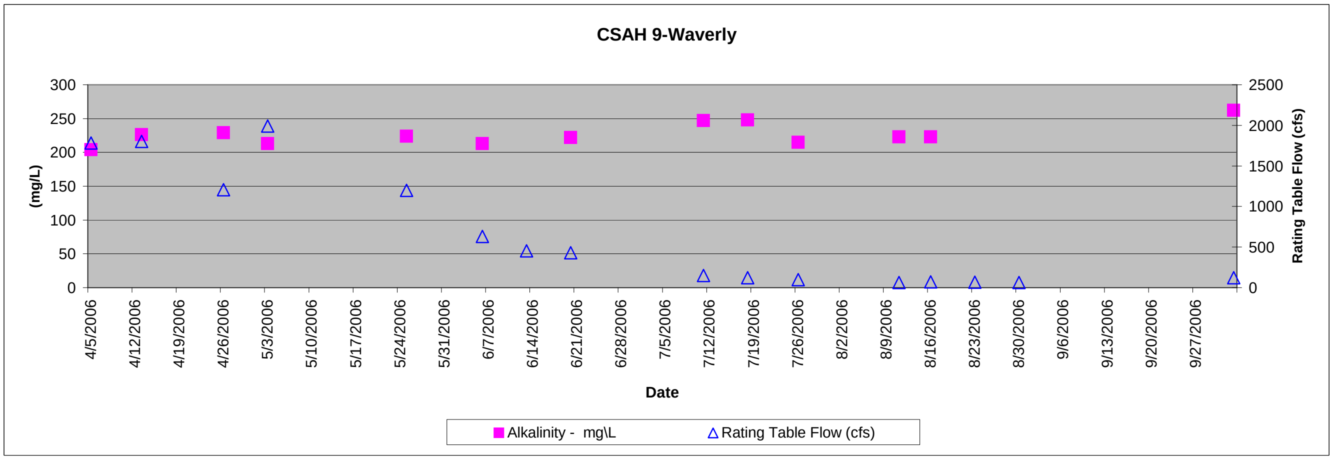
APPENDIX B: 2006 MONITORING DATA


CSAH 9-Waverly
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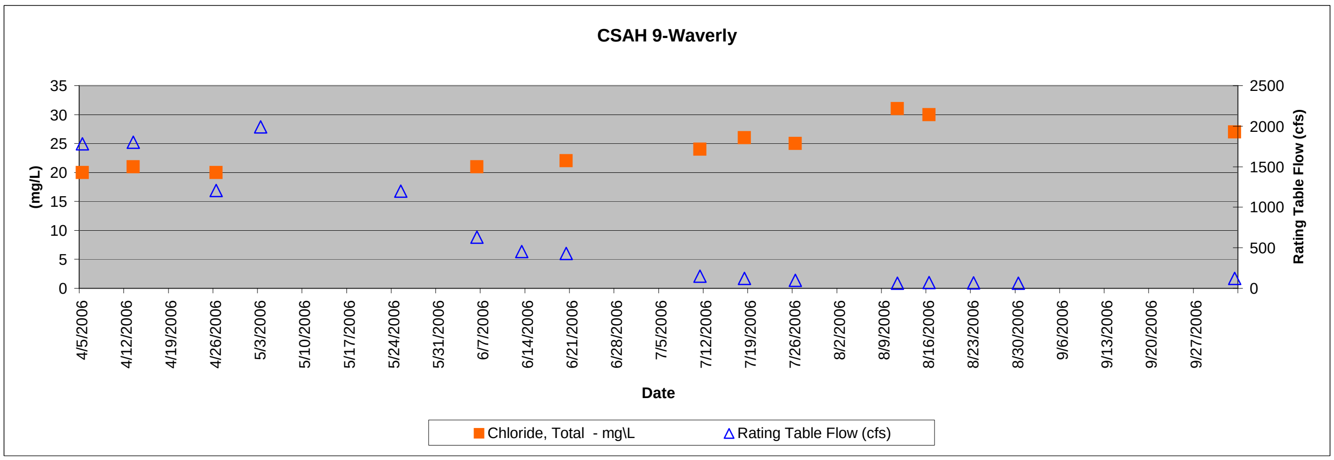
Rating Table Flow (cfs)
Date
Alkalinity - mg\L
Rating Table Flow (cfs)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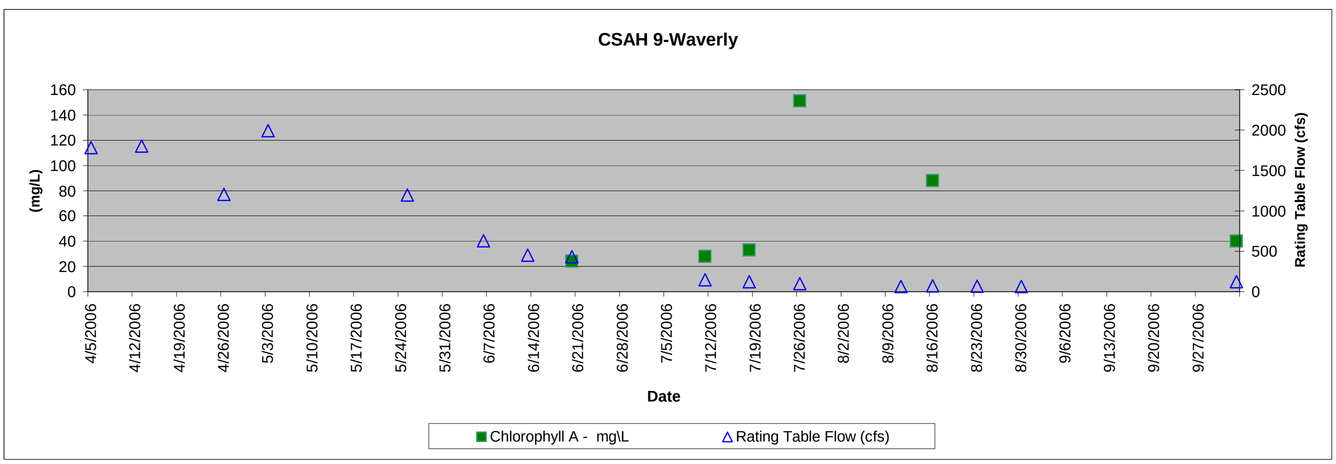
Chloride, Total - mg\L
Rating Table Flow (cfs)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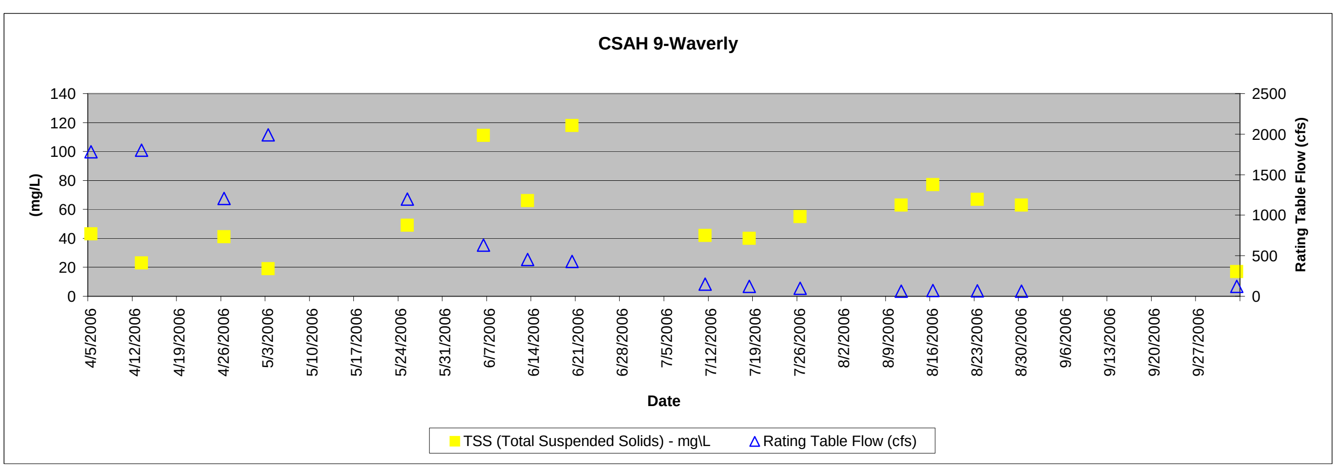
Date
Chlorophyll A - mg\L
Rating Table Flow (cfs)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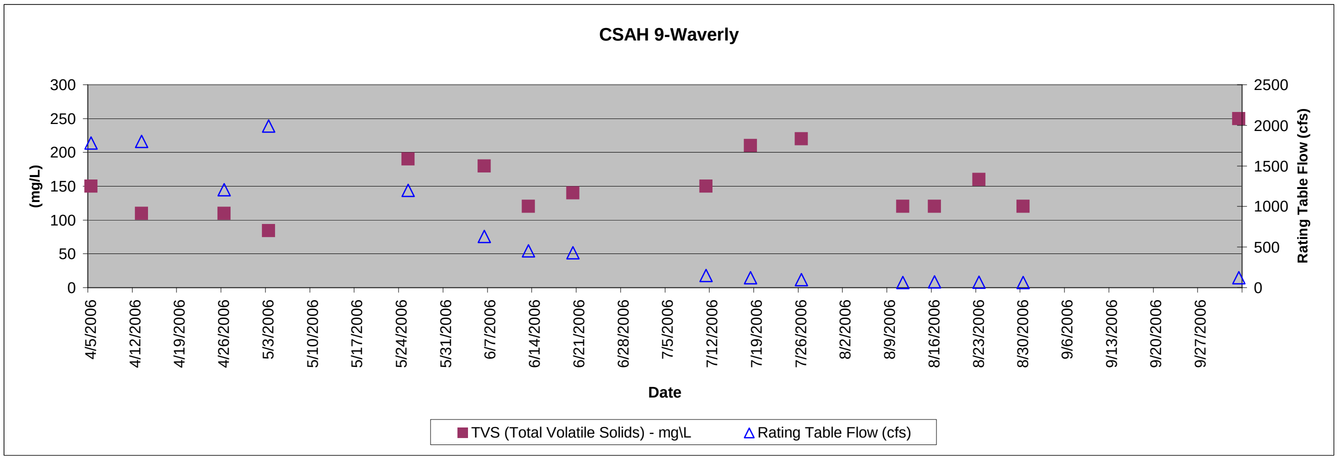
TSS (Total Suspended Solids) - mg\L
Rating Table Flow (cfs)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TVS (Total Volatile Solids) - mg\L
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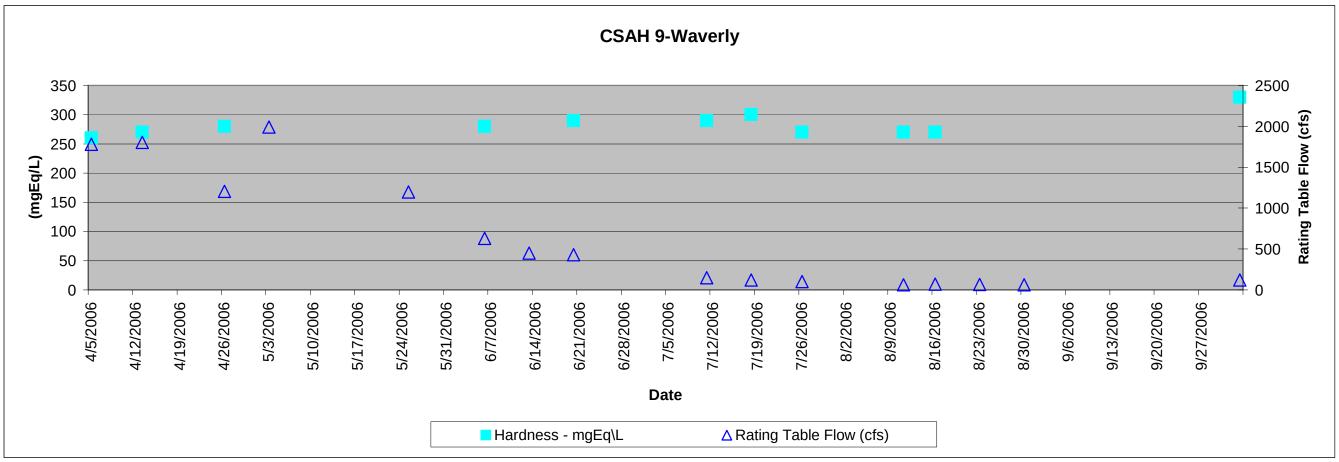
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Hardness - mgEq\L
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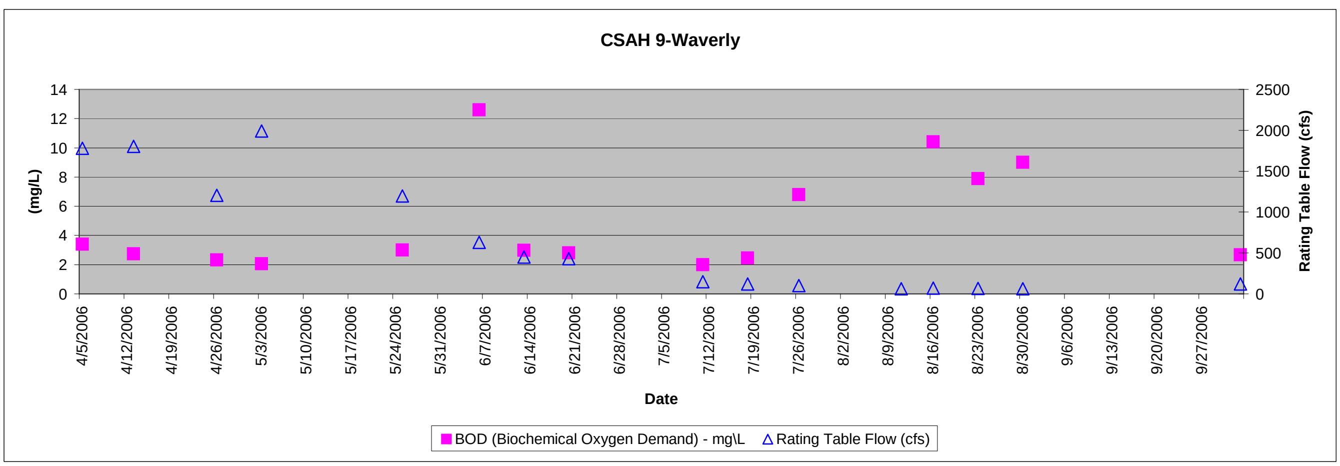
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Date
BOD (Biochemical Oxygen Demand) - mg\L
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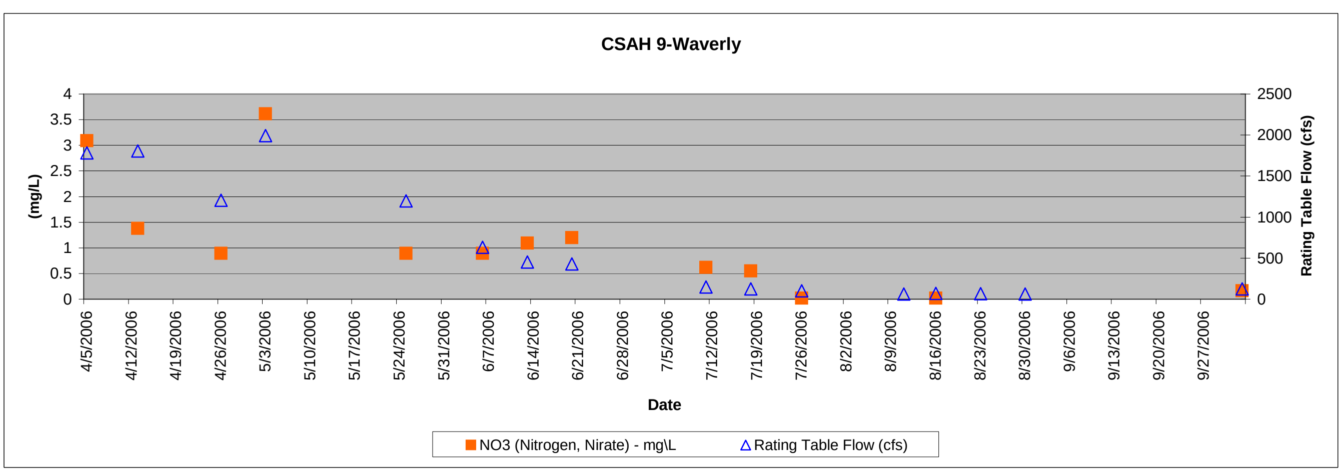
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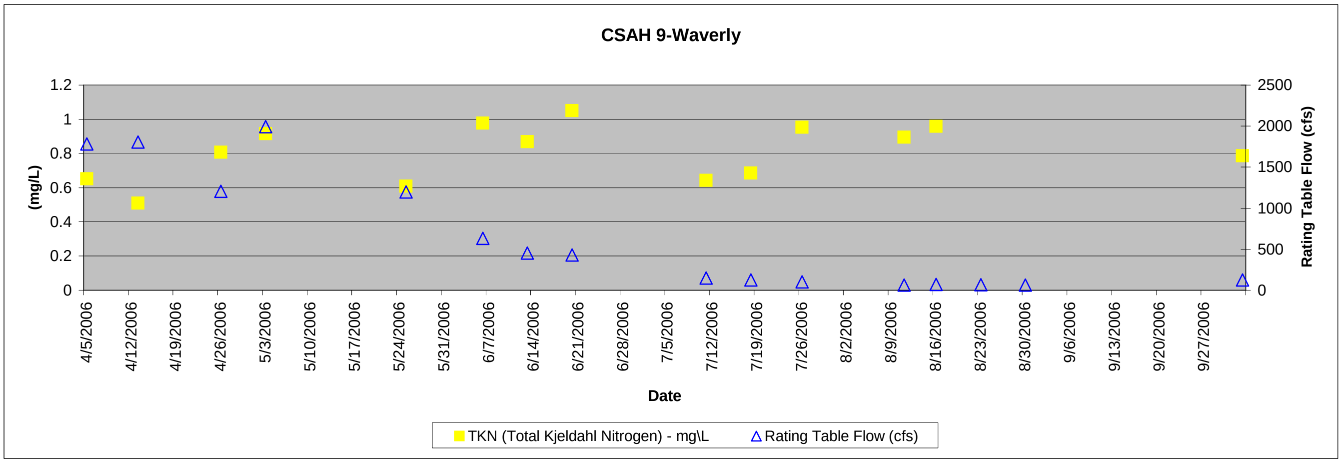
NO3 (Nitrogen, Nirate) - mg\L
Rating Table Flow (cfs)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0.4
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1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
TKN (Total Kjeldahl Nitrogen) - mg\L
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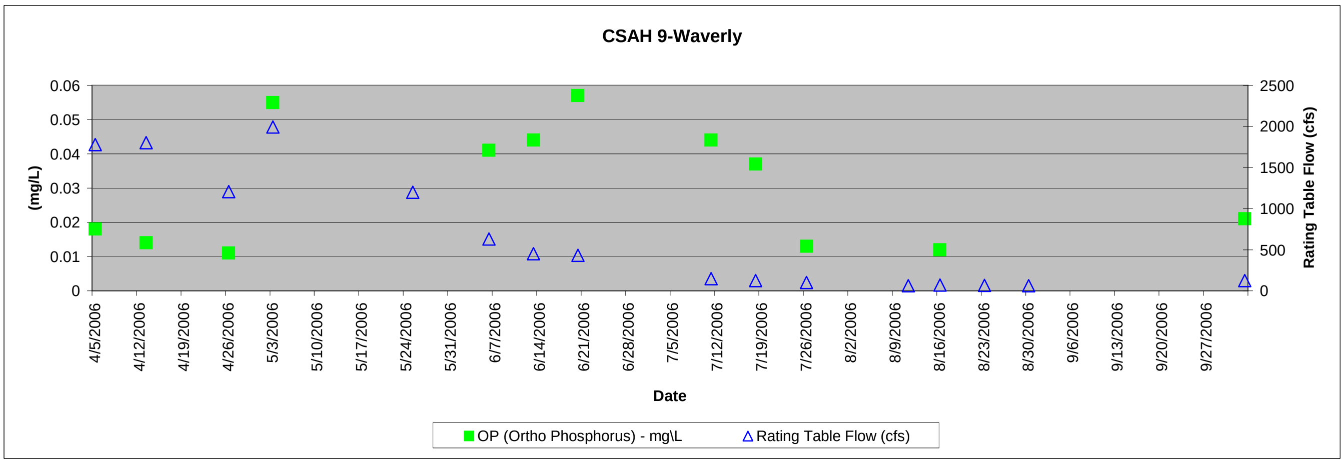
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(mg/L)
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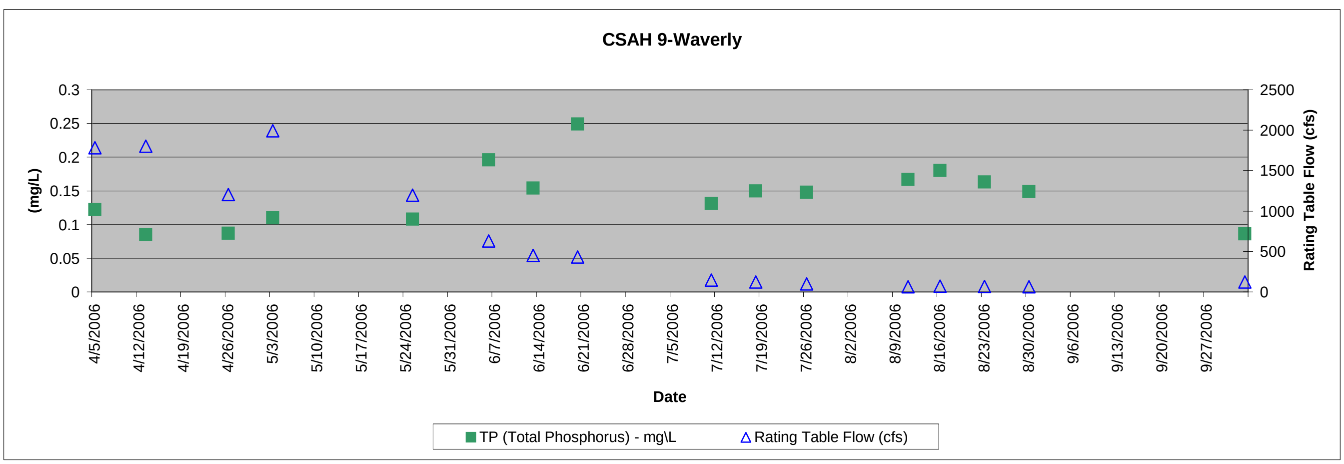
0.05
0.04
0.03
0.02
0.01
0
Rating Table Flow (cfs)
2500
2000
1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
OP (Ortho Phosphorus) - mg\L
Rating Table Flow (cfs)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(mg/L)
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0.2
0.15
0.1
0.05
0
Rating Table Flow (cfs)
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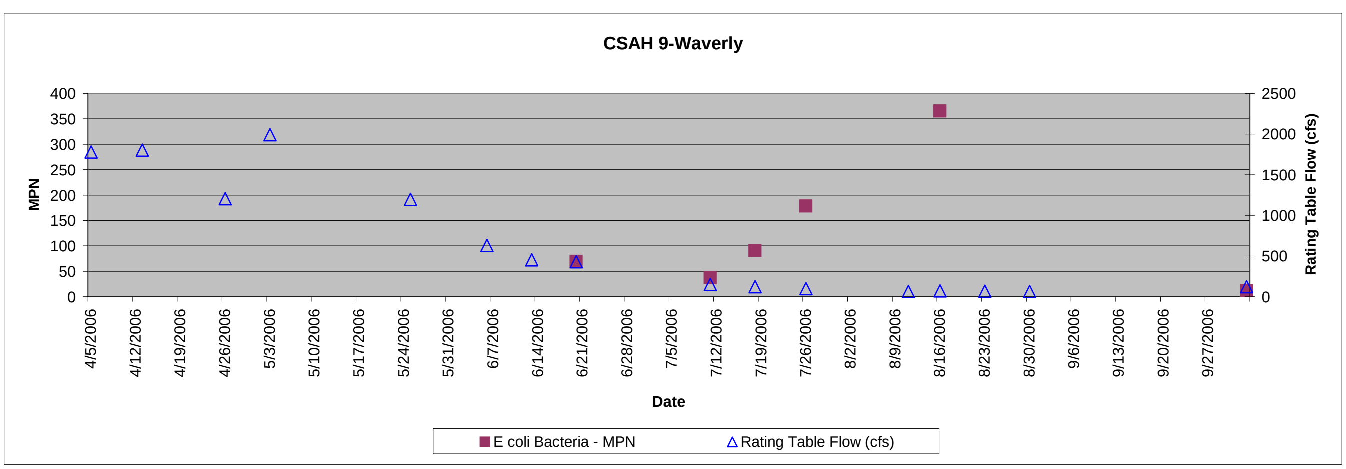
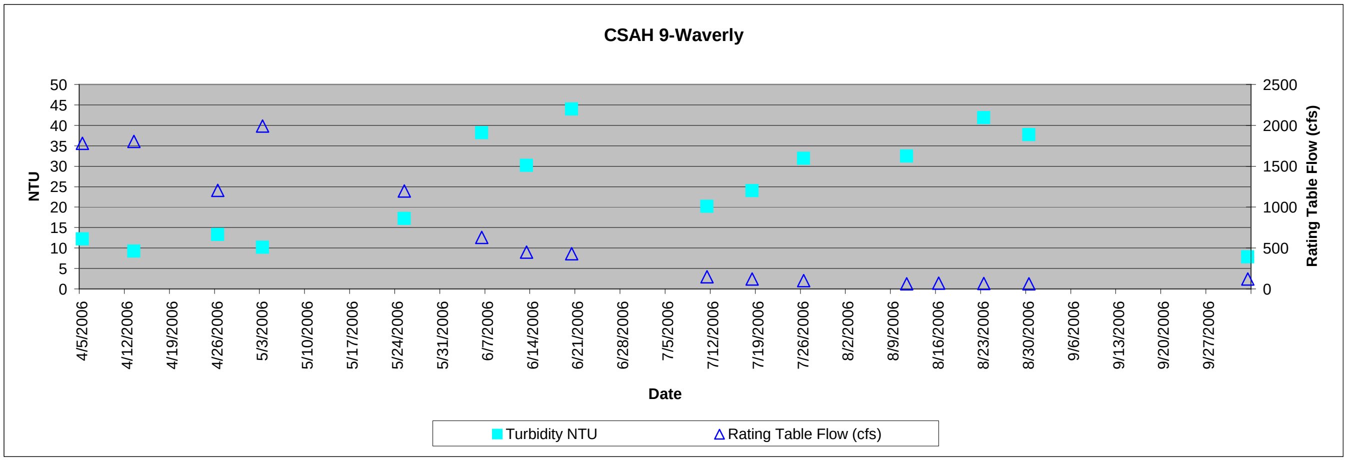
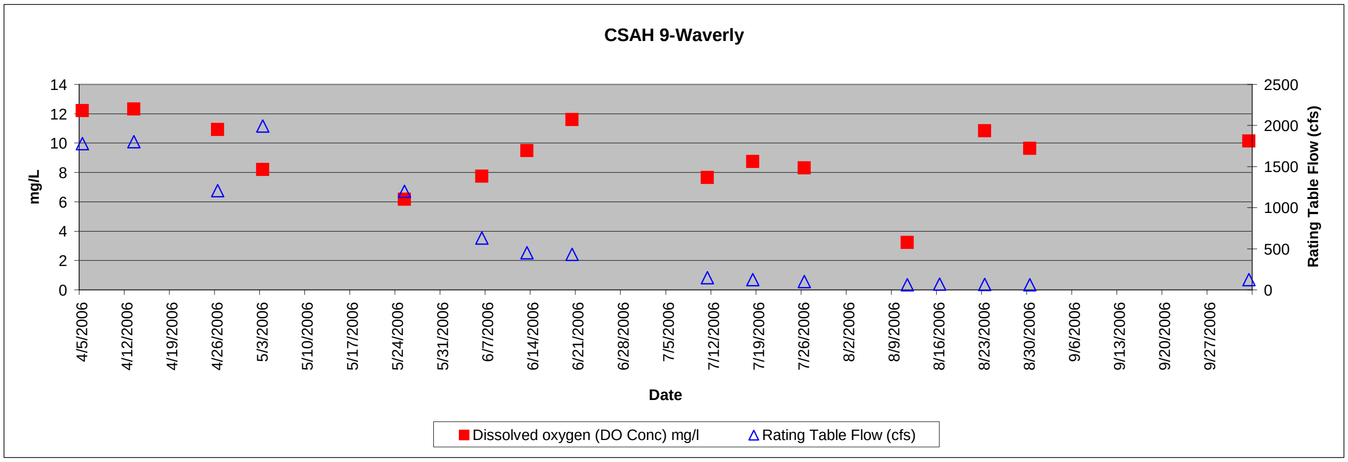
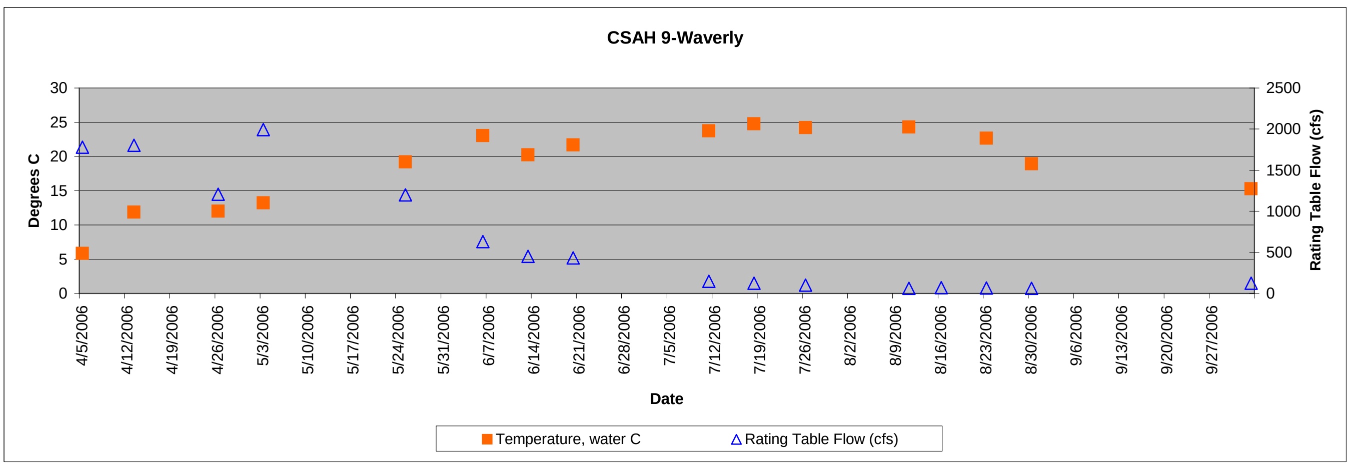
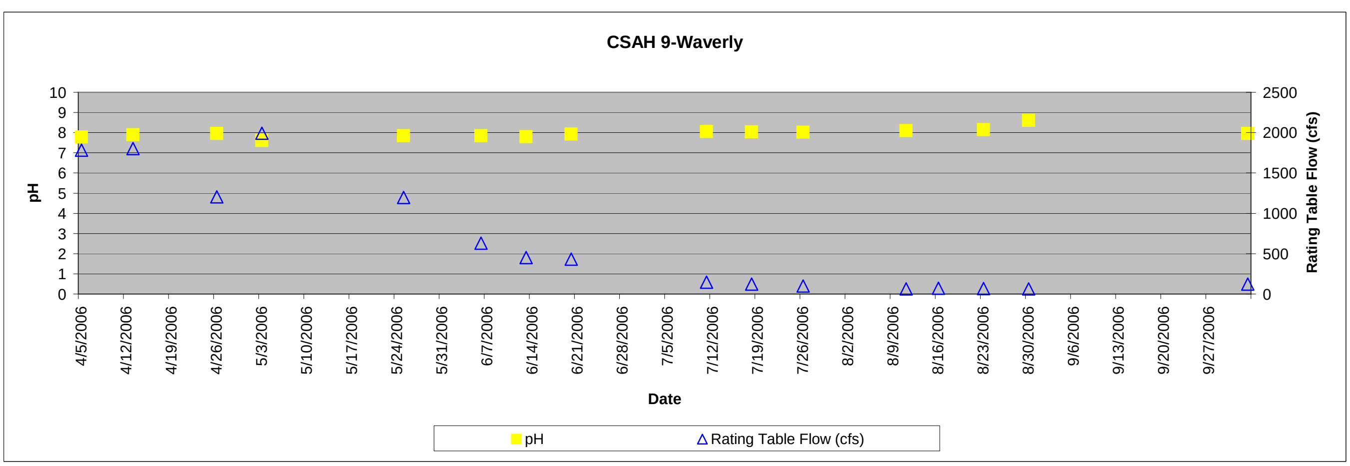
2000
1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
TP (Total Phosphorus) - mg\L
Rating Table Flow (cfs)

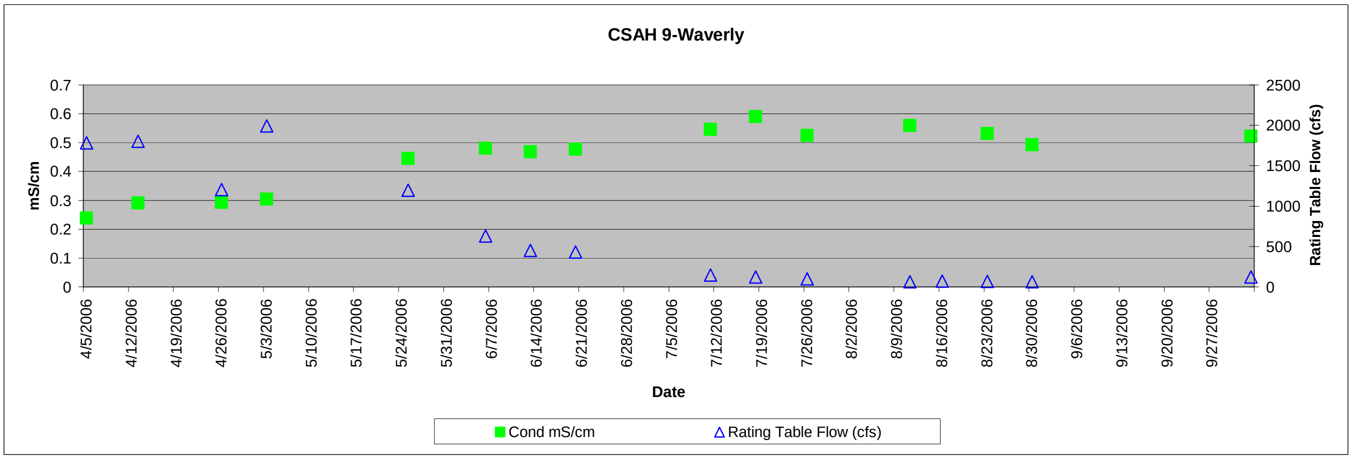

CSAH 9-Waverly
MPN
400
350
300
250
200
150
100
50
0
Rating Table Flow (cfs)
2500
2000
1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
E coli Bacteria - MPN
Rating Table Flow (cfs)

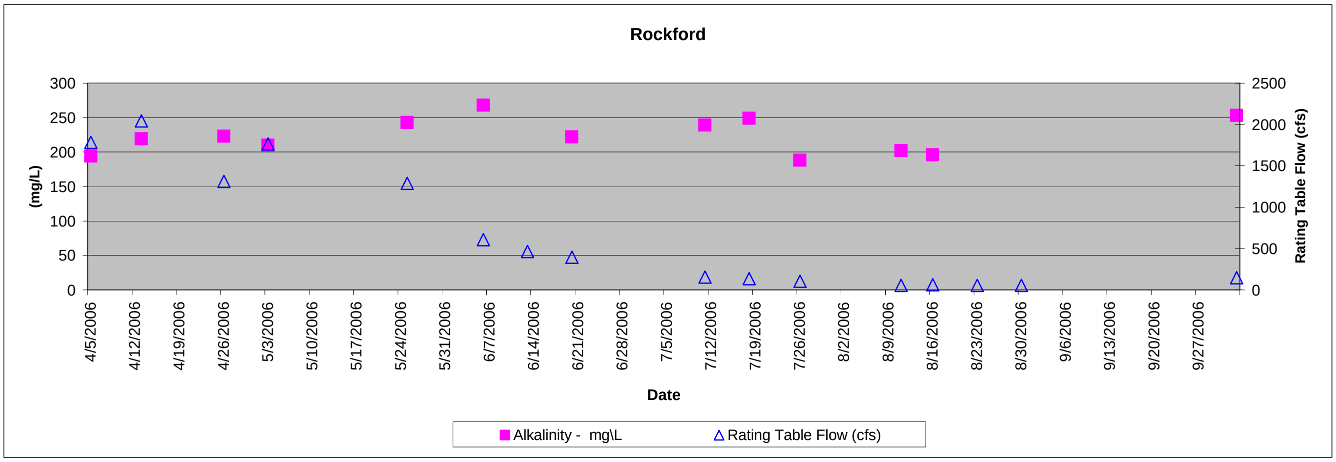

CSAH 9-Waverly
NTU
Rating Table Flow (cfs)
Date
Turbidity NTU
Rating Table Flow (cfs)

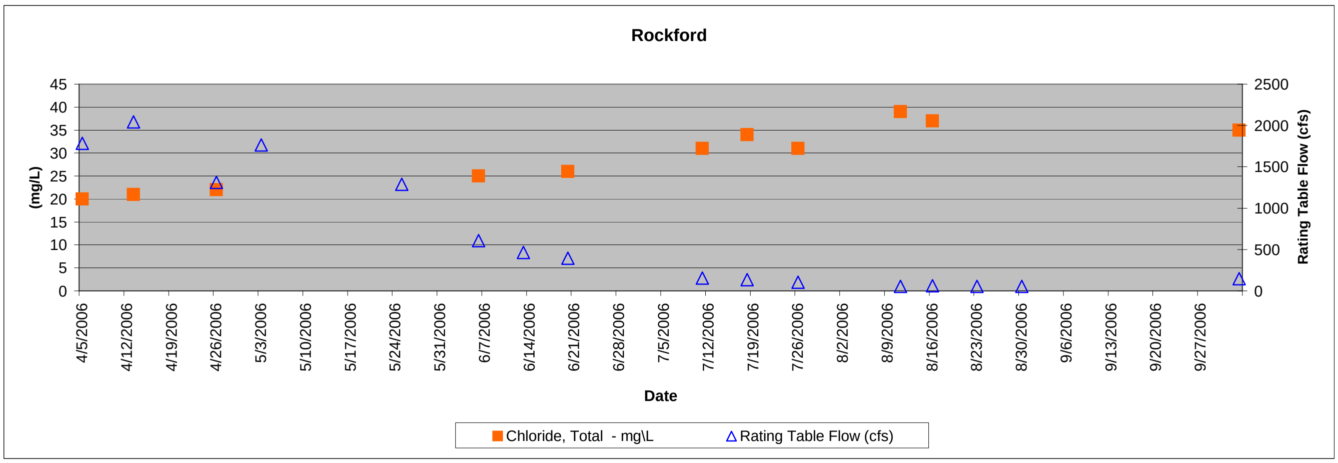

CSAH 9-Waverly
mg/L
Rating Table Flow (cfs)
Date
Dissolved oxygen (DO Conc) mg/l
Rating Table Flow (cfs)

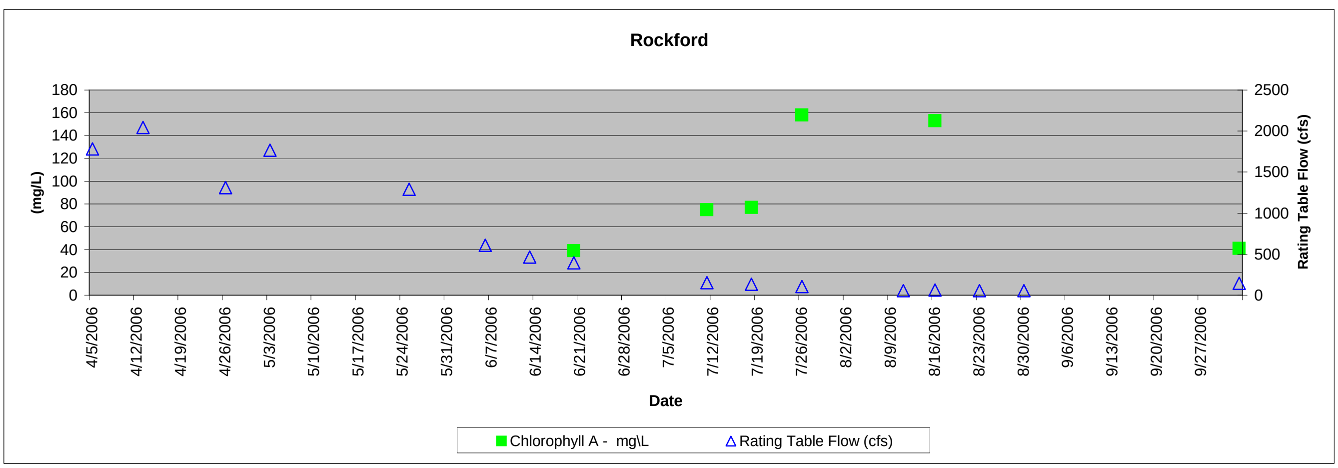

CSAH 9-Waverly
Degrees C
Rating Table Flow (cfs)
Date
Temperature, water C
Rating Table Flow (cfs)

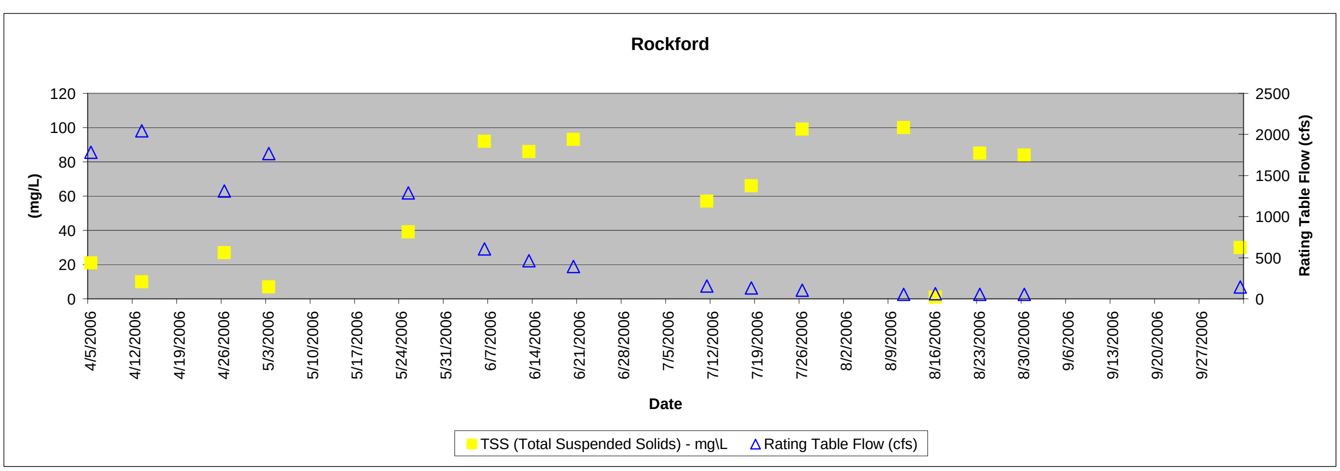

CSAH 9-Waverly
pH
Rating Table Flow (cfs)
Date
pH
Rating Table Flow (cfs)

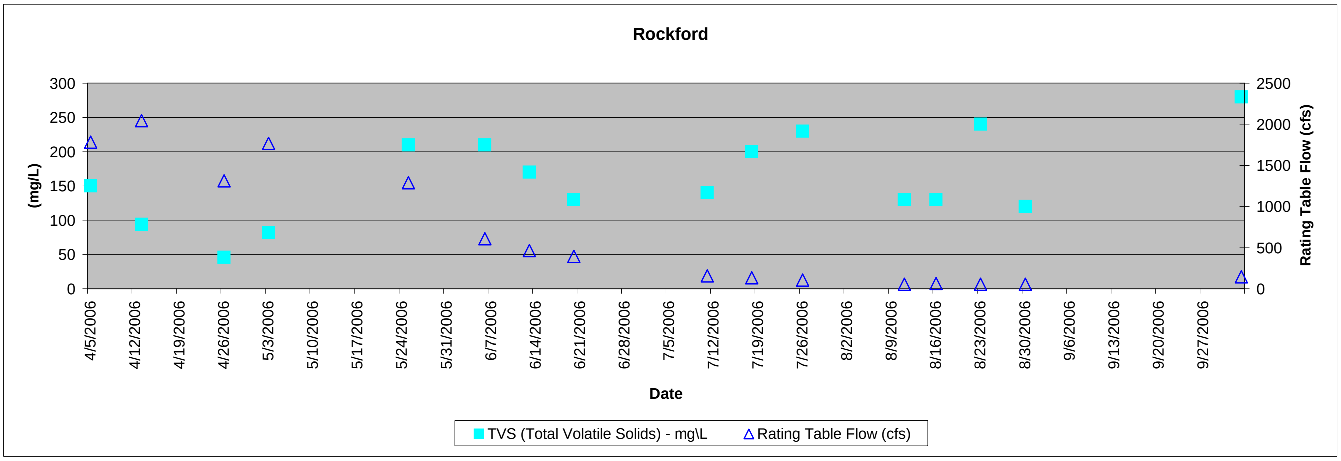

CSAH 9-Waverly
mS/cm
Rating Table Flow (cfs)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
2500
2000
1500
1000
500
0
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Cond mS/cm
Rating Table Flow (cfs)

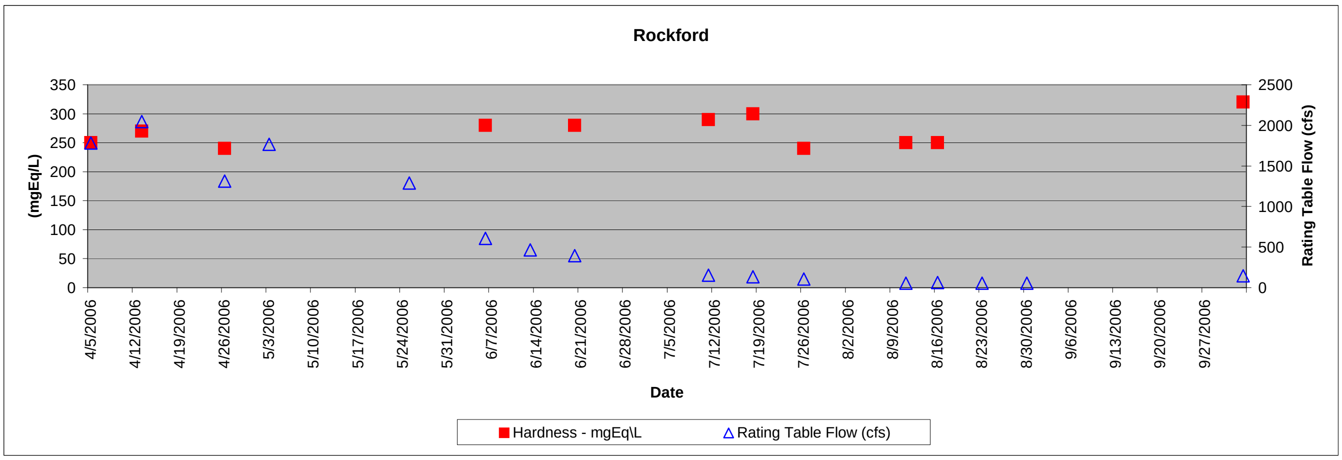

Rockford
(mg/L)
300
250
200
150
100
50
0
2500
2000
1500
1000
500
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Alkalinity - mg\L
Rating Table Flow (cfs)

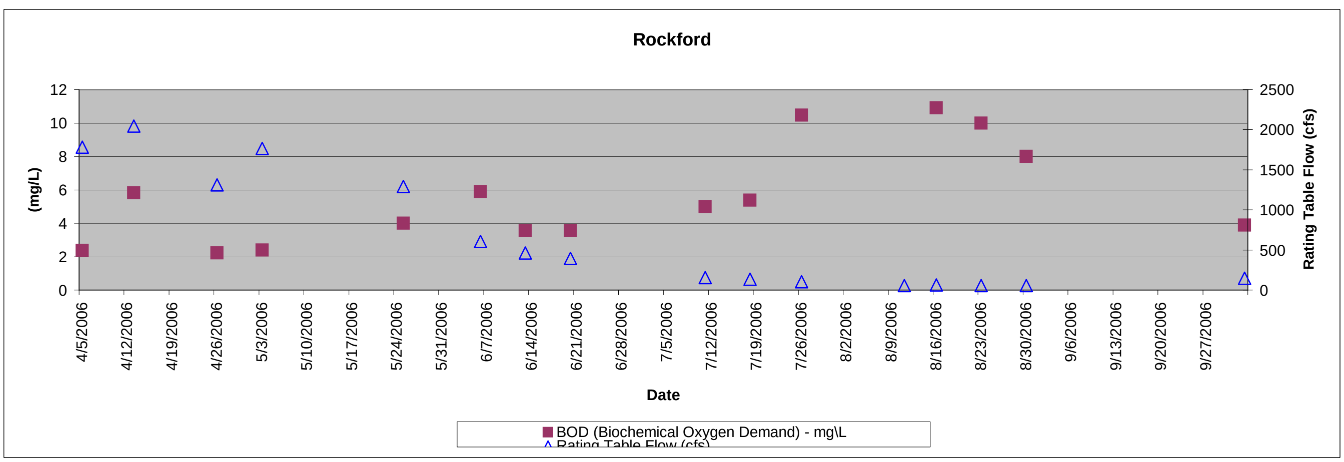

Rockford
(mg/L)
45
40
35
30
25
20
15
10
5
0
2500
2000
1500
1000
500
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Chloride, Total - mg\L
Rating Table Flow (cfs)

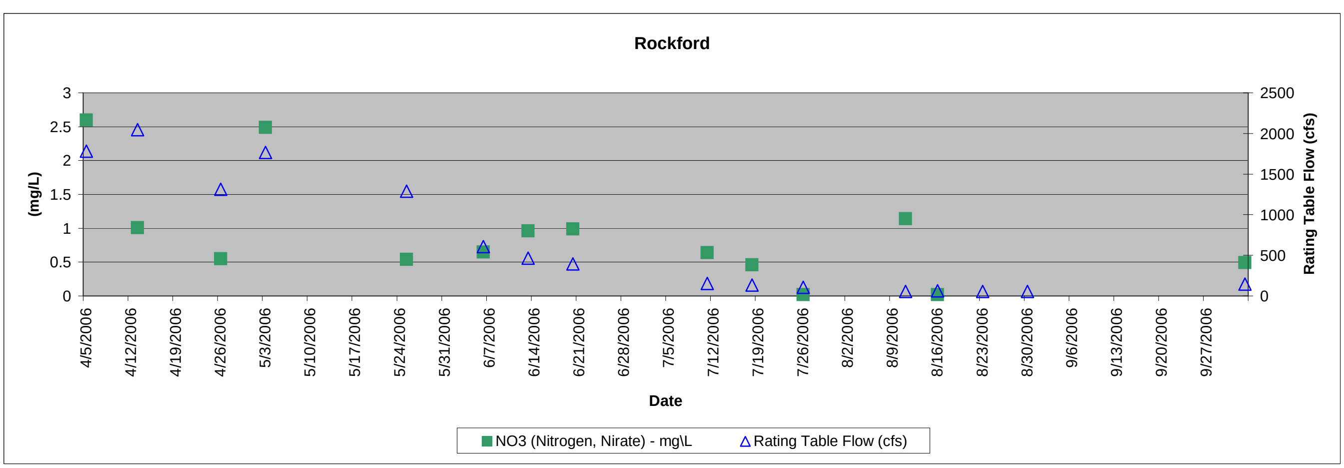

Rockford
(mg/L)
180
160
140
120
100
80
60
40
20
0
2500
2000
1500
1000
500
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Chlorophyll A - mg\L
Rating Table Flow (cfs)

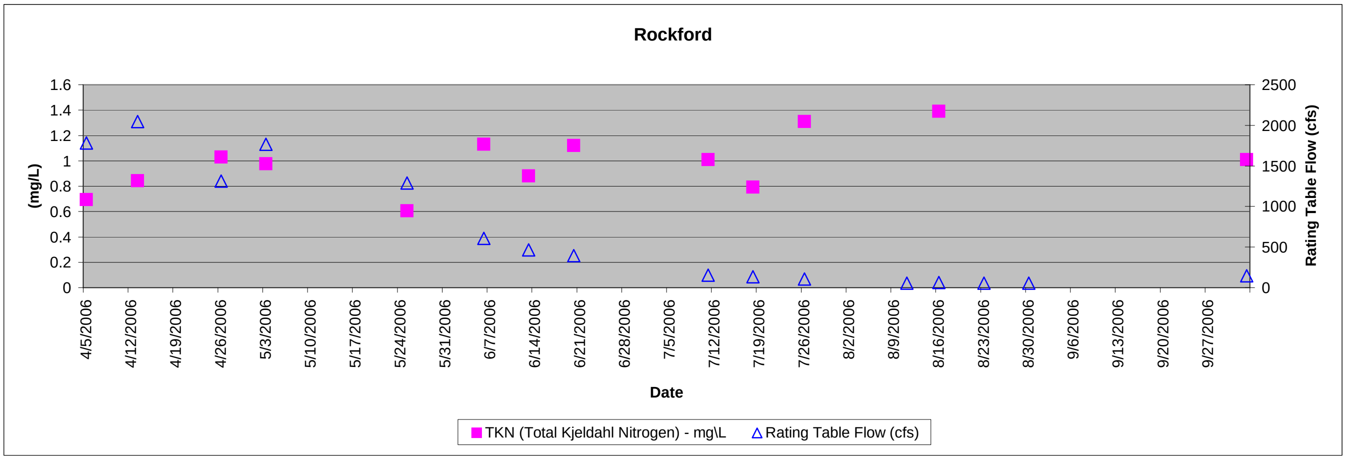

Rockford
(mg/L)
120
100
80
60
40
20
0
2500
2000
1500
1000
500
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
TSS (Total Suspended Solids) - mg\L
Rating Table Flow (cfs)


Rockford
(mg/L)
300
250
200
150
100
50
0
Rating Table Flow (cfs)
2500
2000
1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
TVS (Total Volatile Solids) - mg\L
Rating Table Flow (cfs)

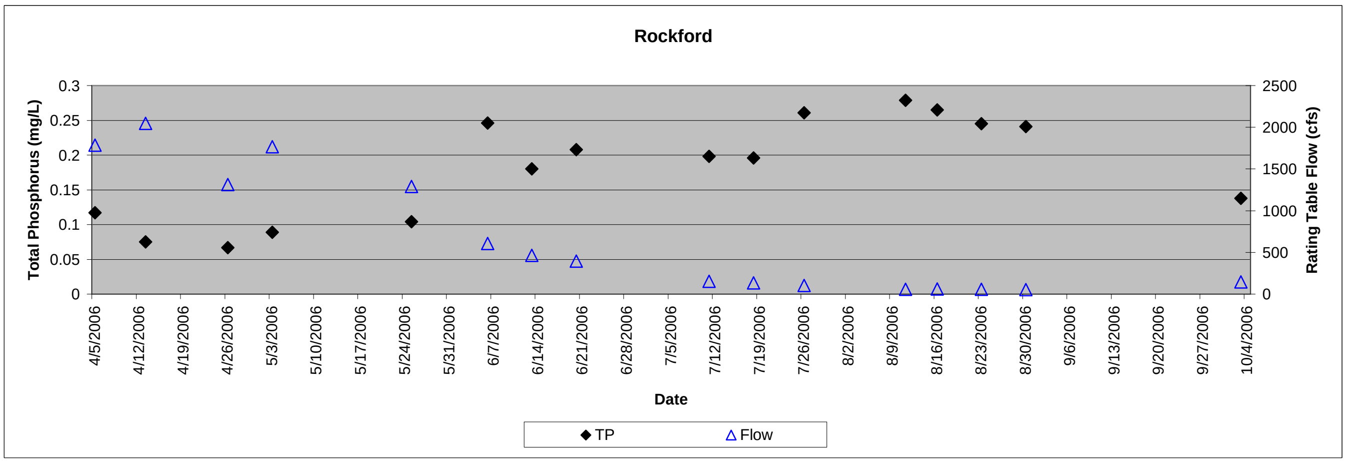

Rockford
(mgEq/L)
350
300
250
200
150
100
50
0
Rating Table Flow (cfs)
2500
2000
1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
Hardness - mgEq\L
Rating Table Flow (cfs)


Rockford
(mg/L)
12
10
8
6
4
2
0
Rating Table Flow (cfs)
2500
2000
1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
BOD (Biochemical Oxygen Demand) - mg\L

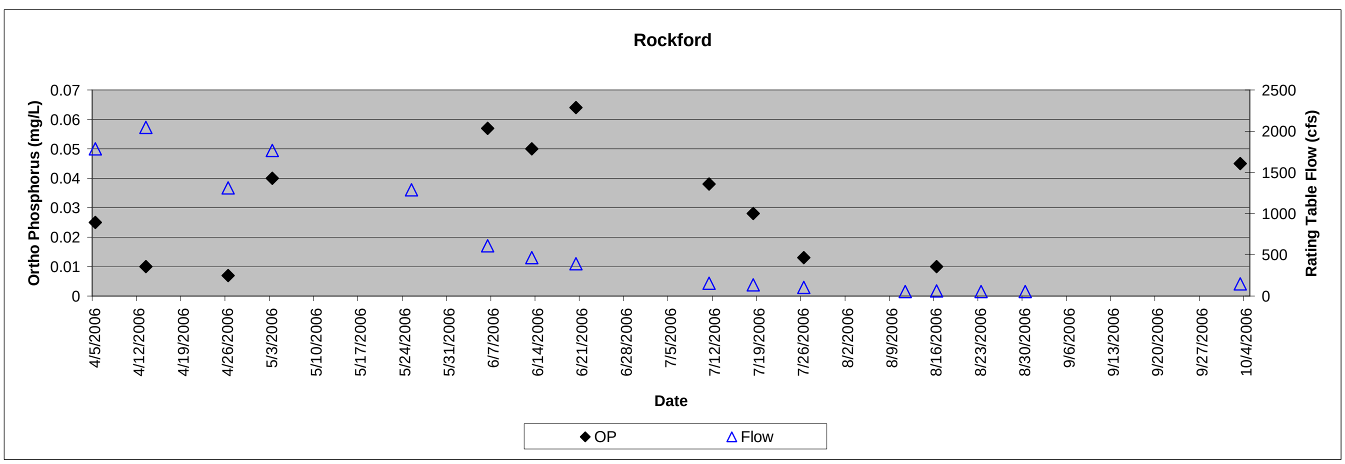

Rockford
(mg/L)
3
2.5
2
1.5
1
0.5
0
Rating Table Flow (cfs)
2500
2000
1500
1000
500
0
4/5/2006 4/12/2006 4/19/2006 4/26/2006 5/3/2006 5/10/2006 5/17/2006 5/24/2006 5/31/2006 6/7/2006 6/14/2006 6/21/2006 6/28/2006 7/5/2006 7/12/2006 7/19/2006 7/26/2006 8/2/2006 8/9/2006 8/16/2006 8/23/2006 8/30/2006 9/6/2006 9/13/2006 9/20/2006 9/27/2006
Date
NO3 (Nitrogen, Nirate) - mg\L
Rating Table Flow (cfs)



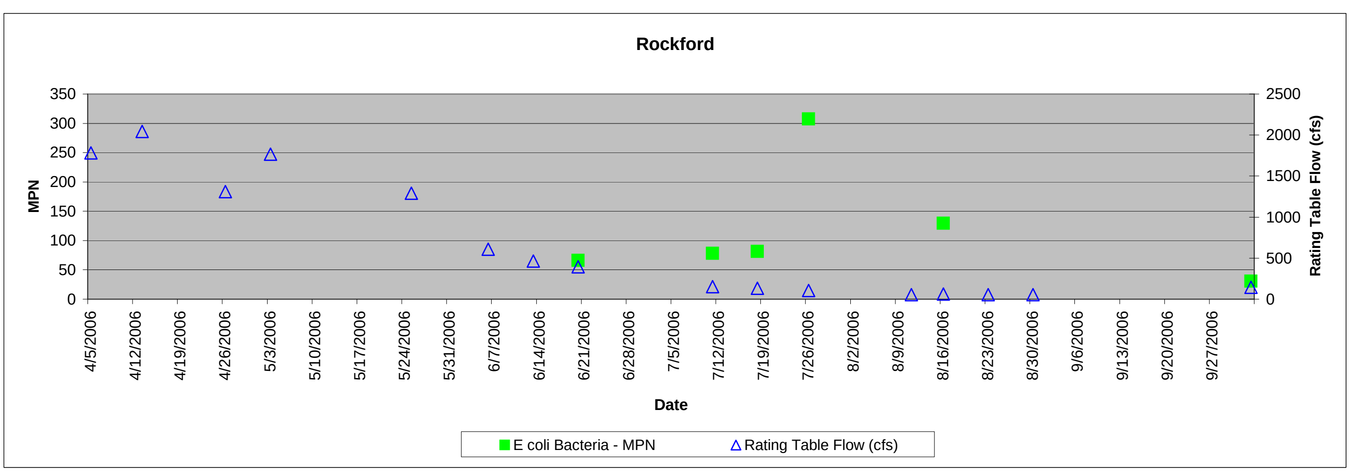
Rockford
(mg/L)
Rating Table Flow (cfs)
Date
TKN (Total Kjeldahl Nitrogen) - mg\L
Rating Table Flow (cfs)



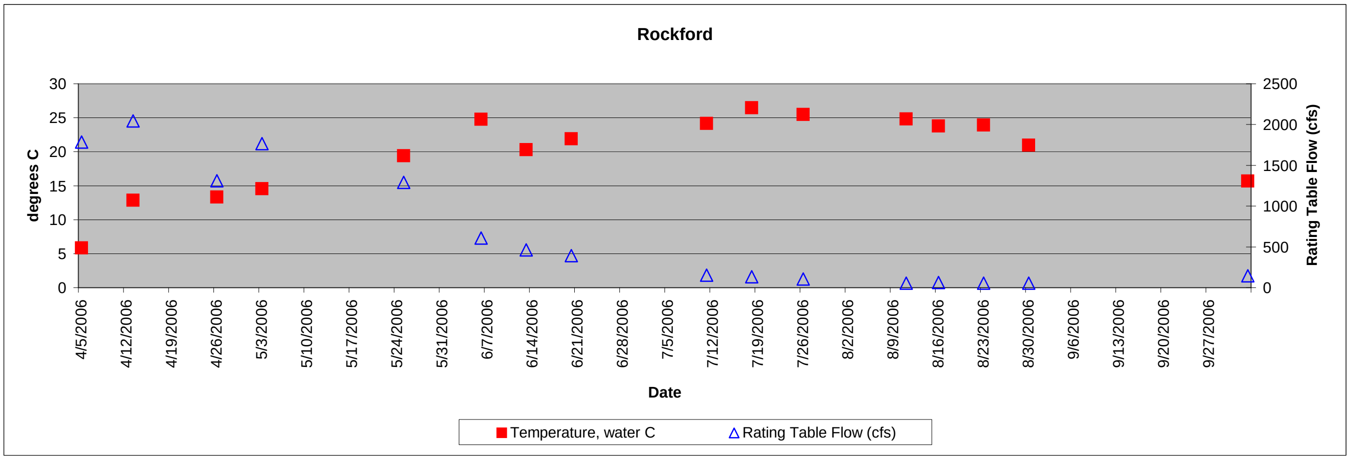
Rockford
Total Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
TP
Flow

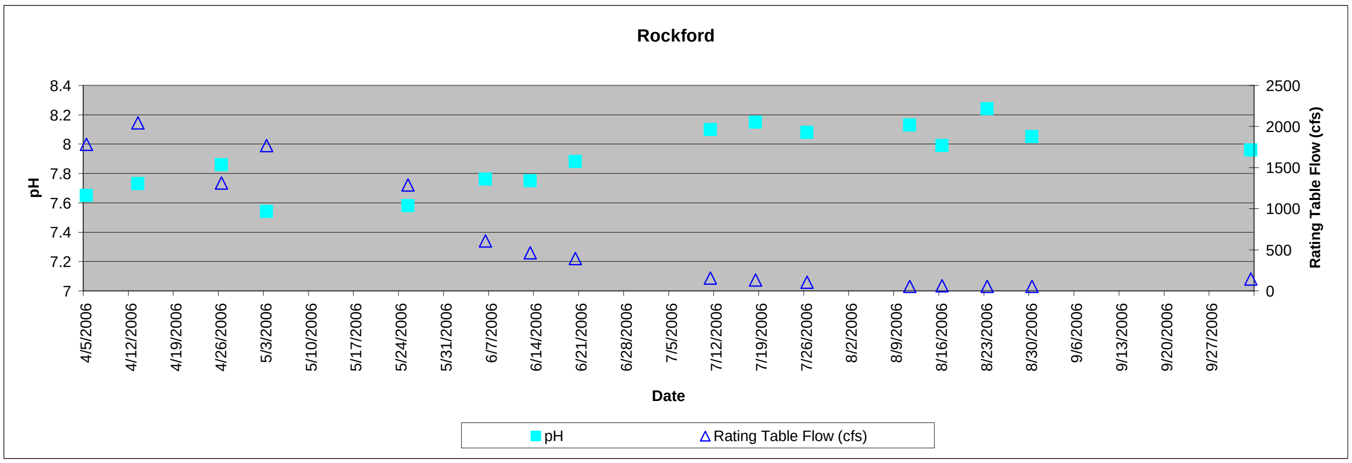


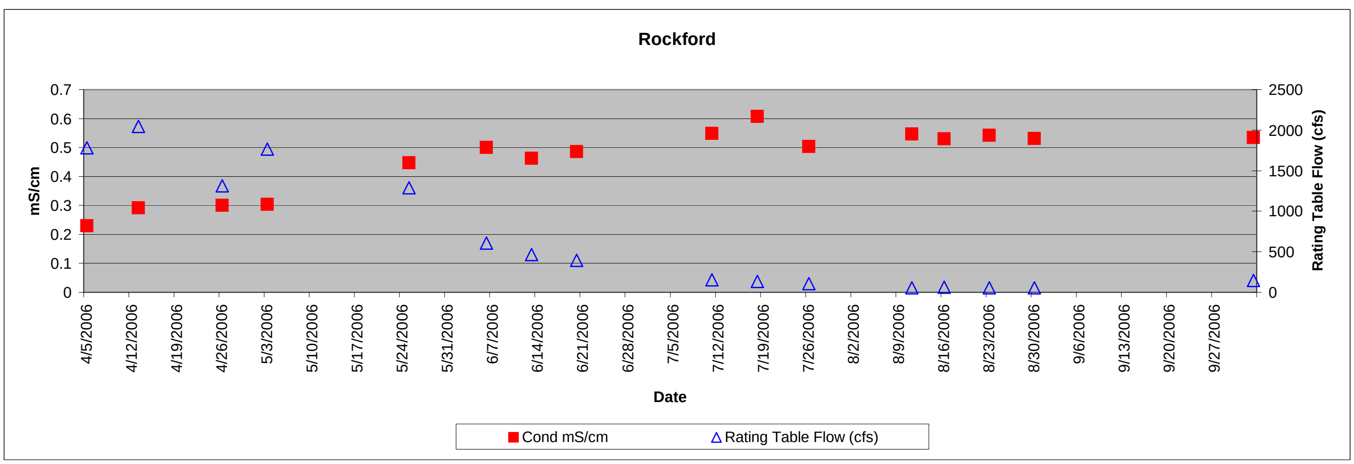
Rockford
Ortho Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
OP
Flow

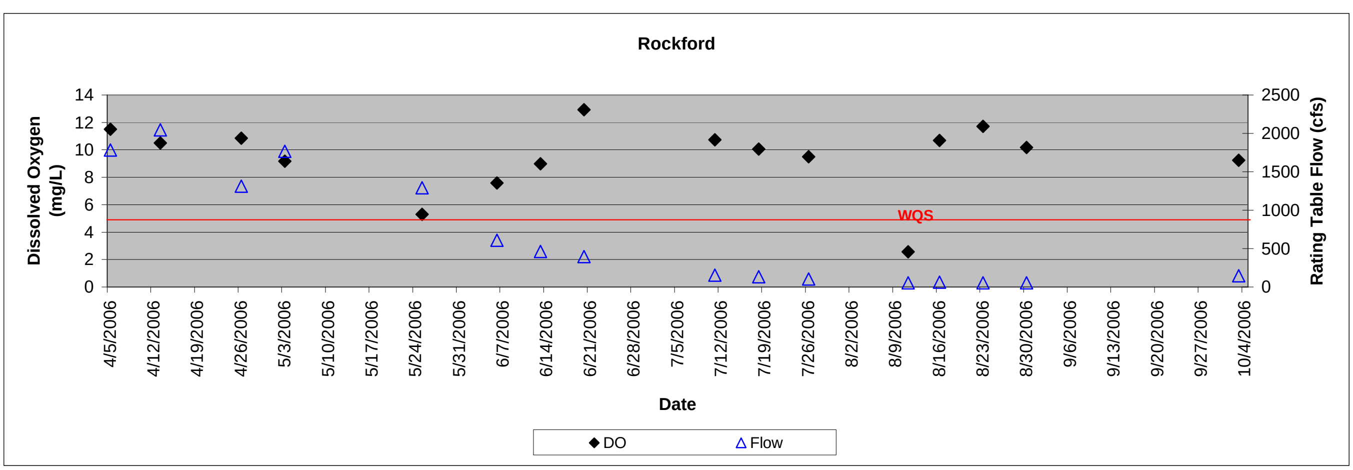


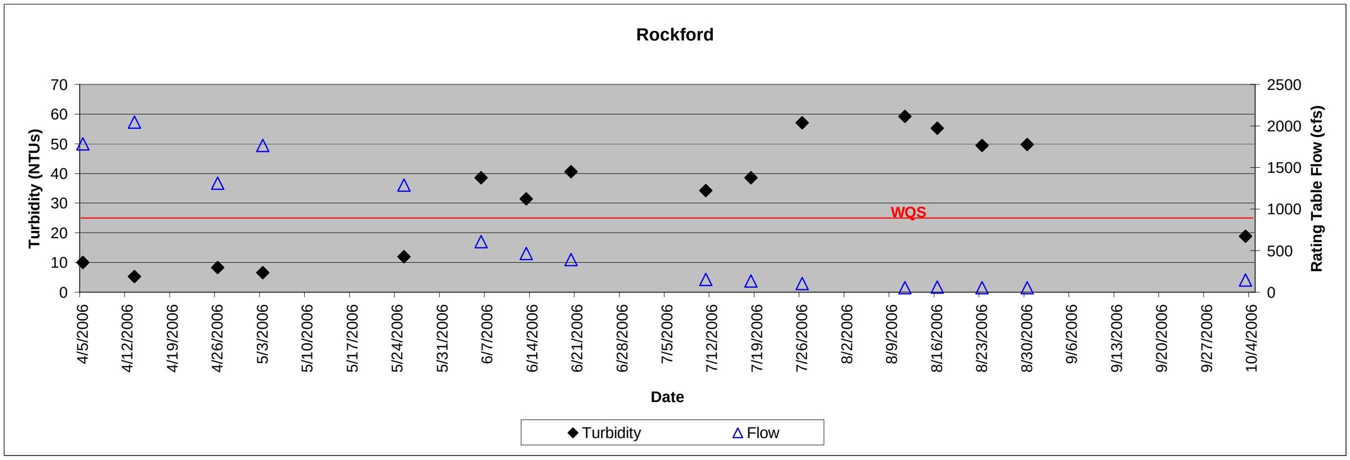
Rockford
MPN
Rating Table Flow (cfs)
Date
E coli Bacteria - MPN
Rating Table Flow (cfs)

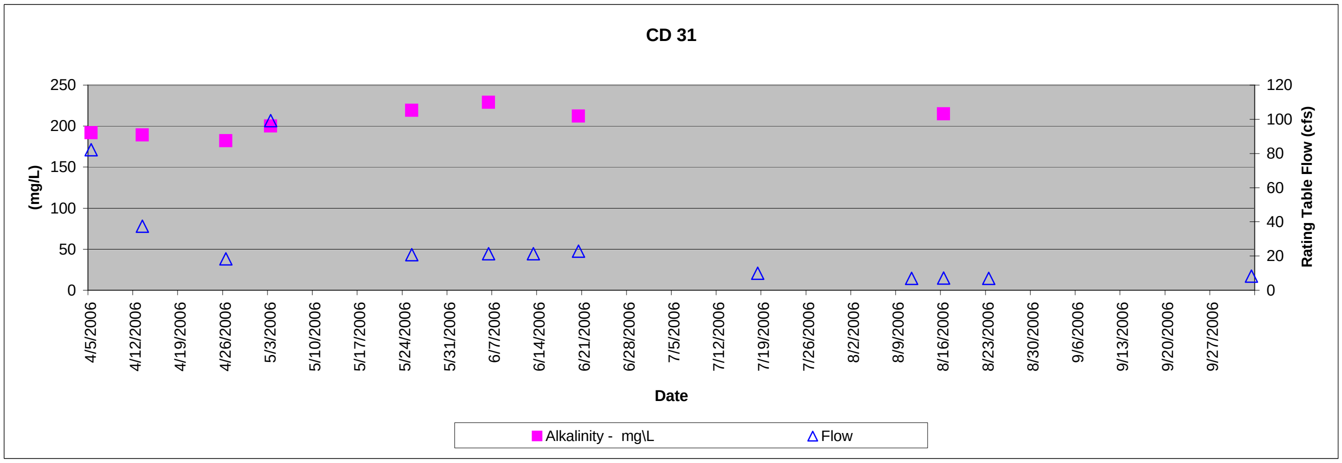

Rockford
degrees C
Rating Table Flow (cfs)
Date
Temperature, water C
Rating Table Flow (cfs)

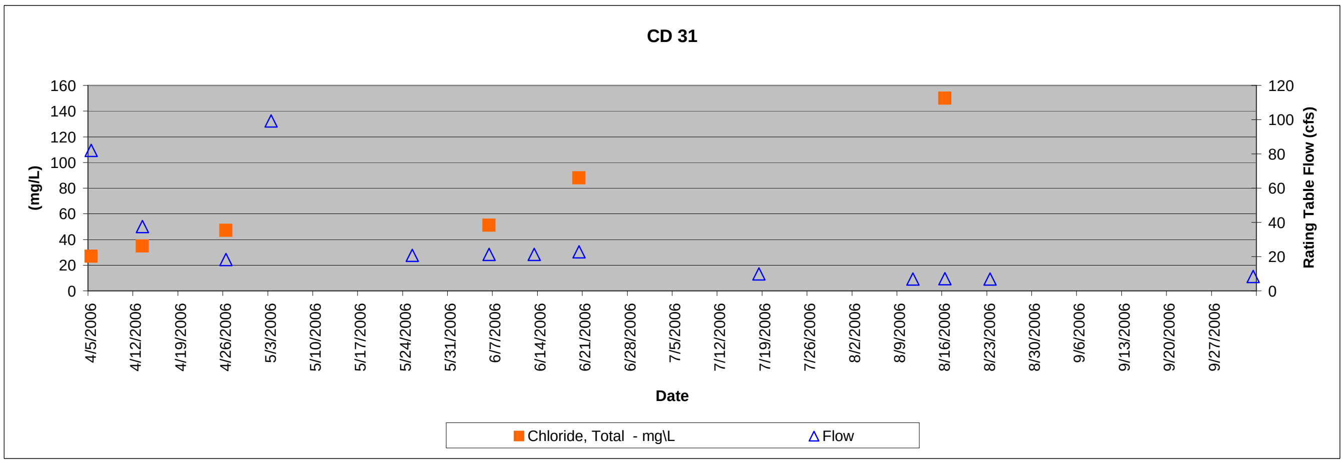

Rockford
pH
Rating Table Flow (cfs)
Date
pH
Rating Table Flow (cfs)

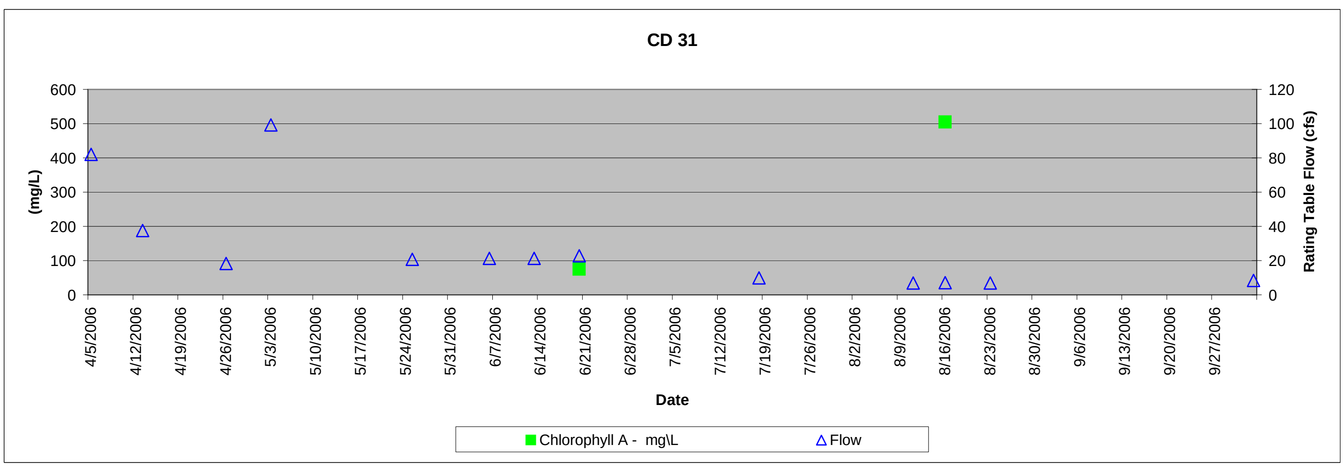

Rockford
mS/cm
Rating Table Flow (cfs)
Date
Cond mS/cm
Rating Table Flow (cfs)

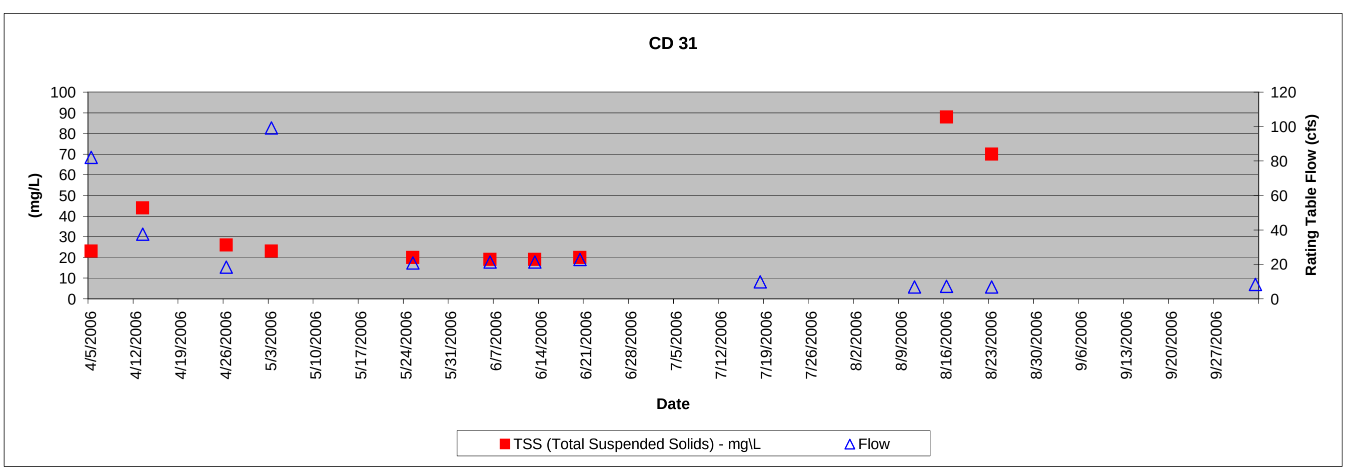

Rockford
Dissolved Oxygen (mg/L)
Rating Table Flow (cfs)
WQS
Date
DO
Flow

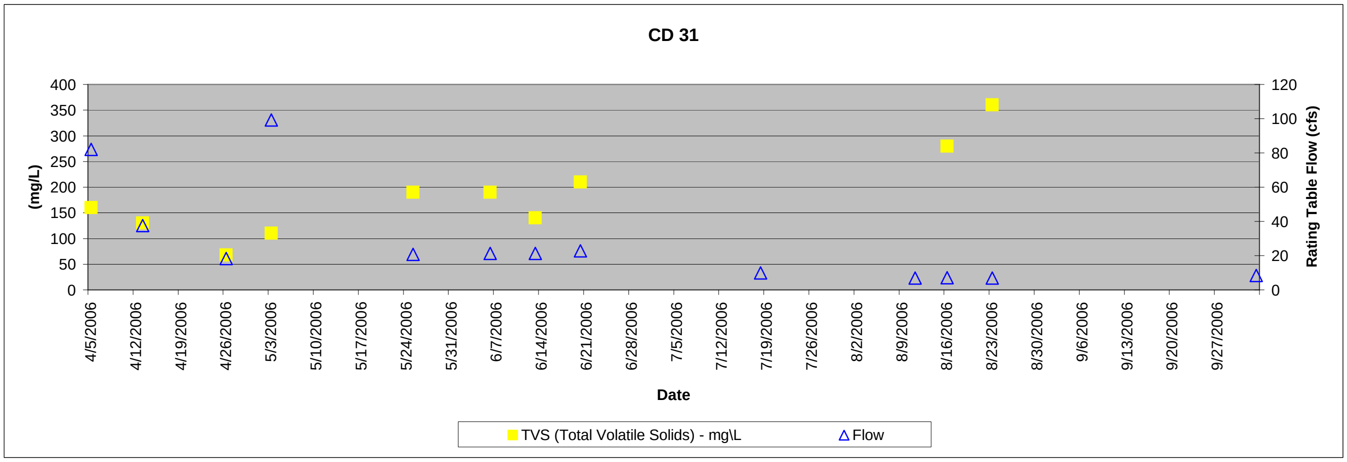

Rockford
Turbidity (NTUs)
Rating Table Flow (cfs)
70
60
50
40
30
20
10
0
2500
2000
1500
1000
500
0
WQS
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
10/4/2006
Date
Turbidity
Flow

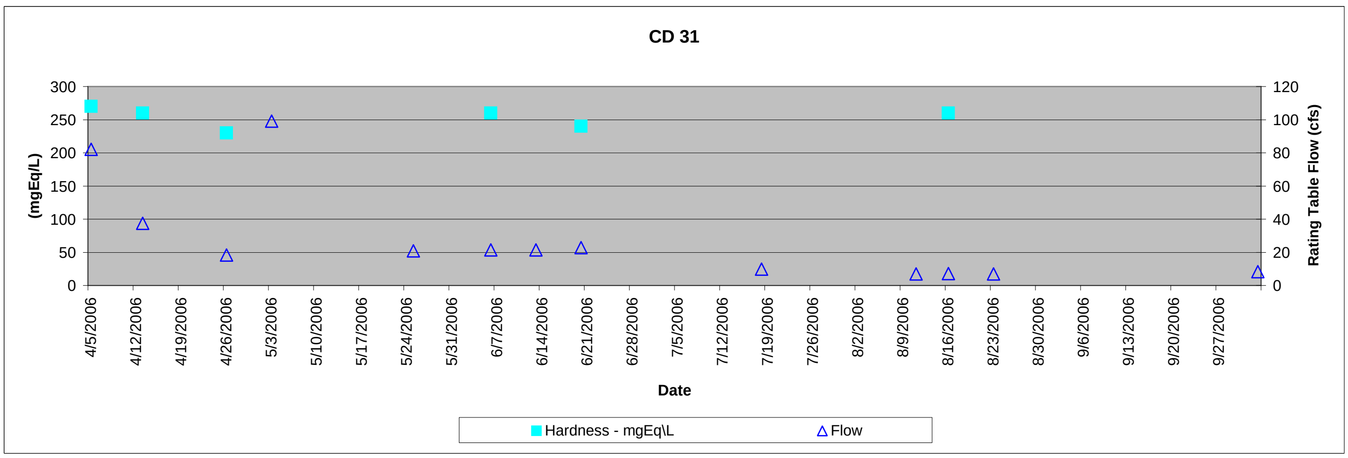

CD 31
(mg/L)
Rating Table Flow (cfs)
Date
Alkalinity - mg\L
Flow

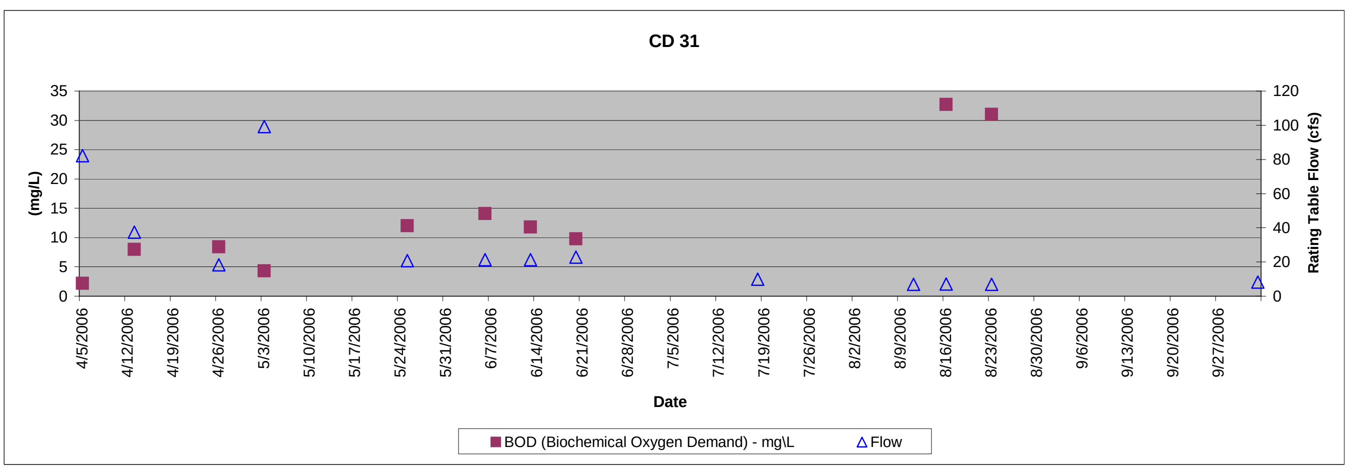

CD 31
(mg/L)
Rating Table Flow (cfs)
Date
Chloride, Total - mg\L
Flow

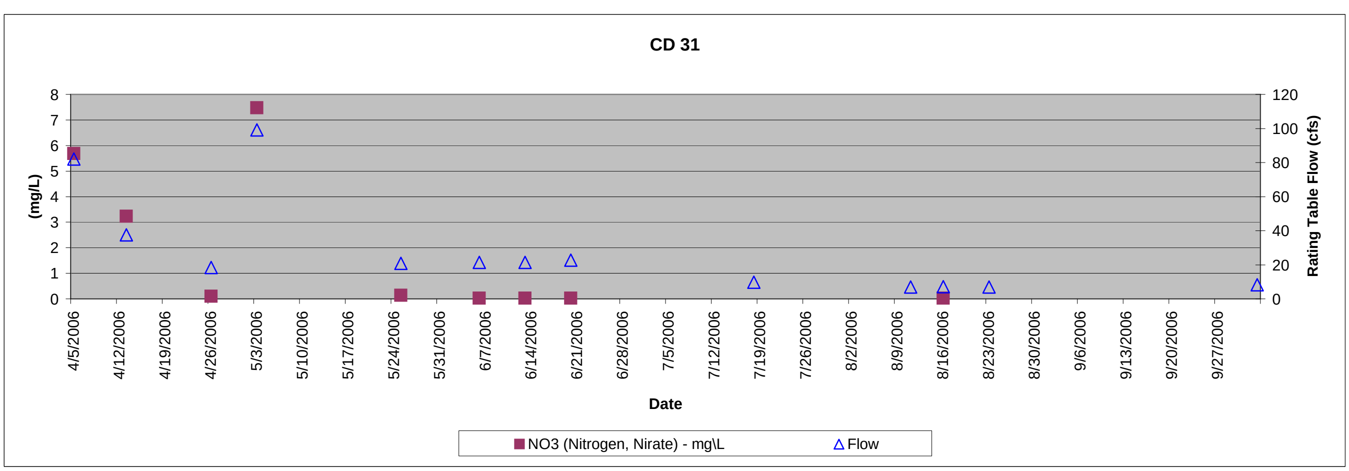

CD 31
(mg/L)
Rating Table Flow (cfs)
Date
Chlorophyll A - mg\L
Flow

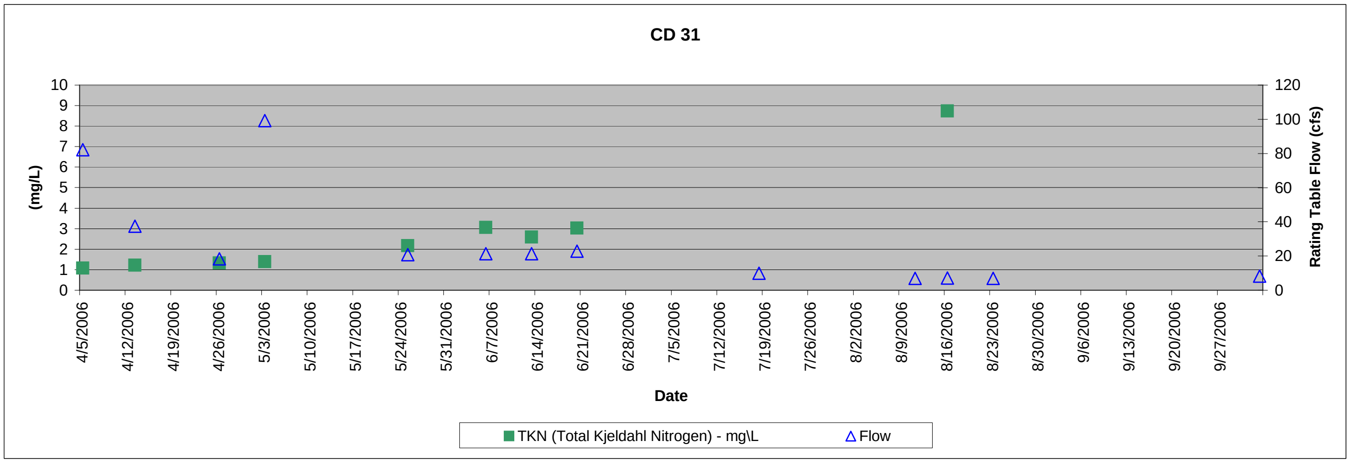

CD 31
(mg/L)
Rating Table Flow (cfs)
Date
TSS (Total Suspended Solids) - mg\L
Flow

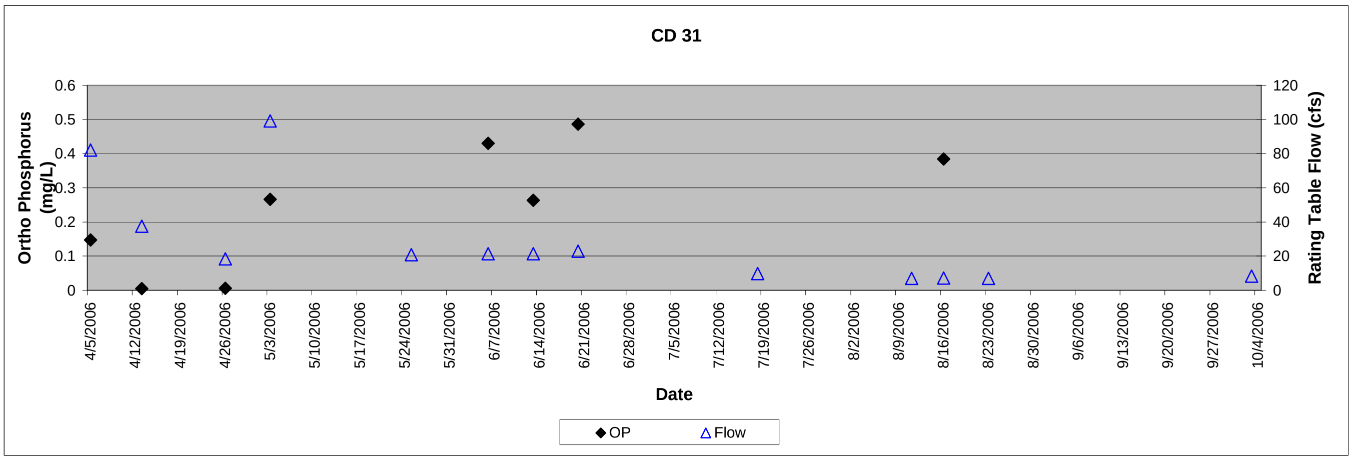

CD 31
400
350
300
250
200
150
100
50
0
(mg/L)
120
100
80
60
40
20
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
TVS (Total Volatile Solids) - mg\L
Flow

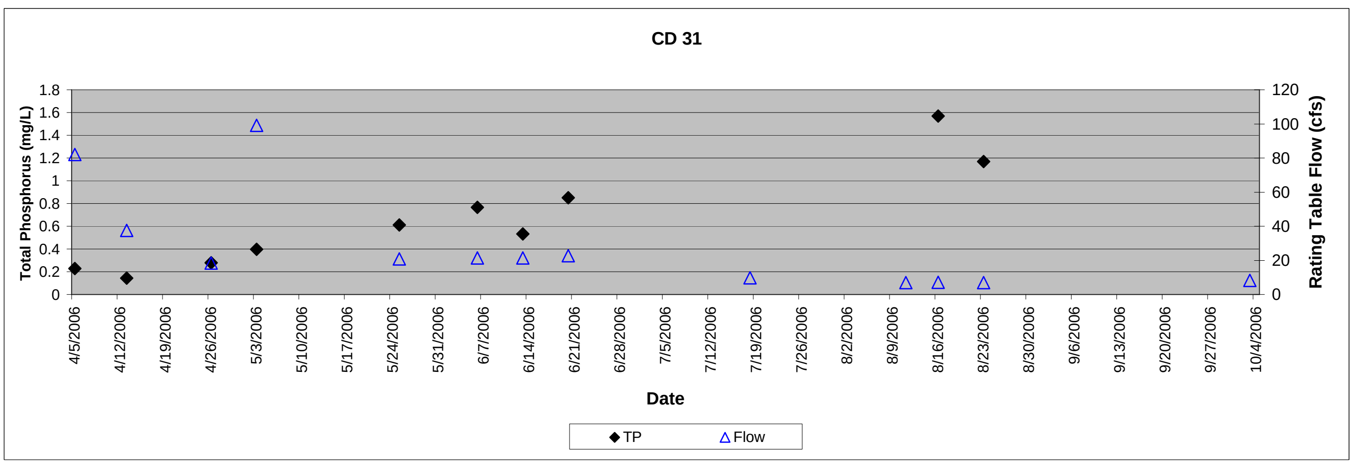

CD 31
300
250
200
150
100
50
0
(mgEq/L)
120
100
80
60
40
20
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Hardness - mgEq\L
Flow

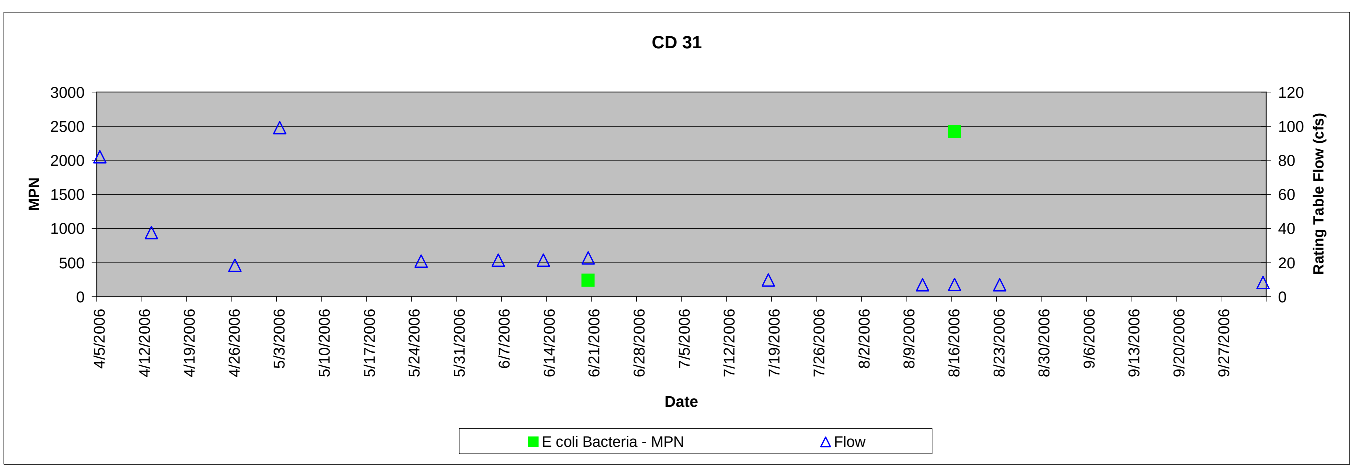

CD 31
35
30
25
20
15
10
5
0
(mg/L)
120
100
80
60
40
20
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
BOD (Biochemical Oxygen Demand) - mg\L
Flow

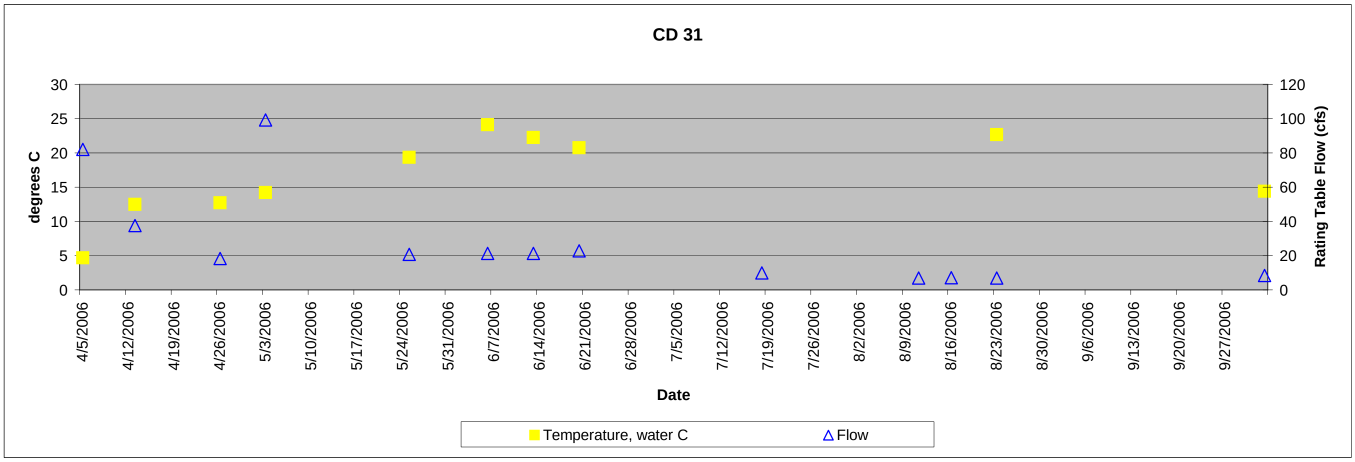

CD 31
8
7
6
5
4
3
2
1
0
(mg/L)
120
100
80
60
40
20
0
Rating Table Flow (cfs)
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
NO3 (Nitrogen, Nirate) - mg\L
Flow


CD 31
(mg/L)
Rating Table Flow (cfs)
Date
TKN (Total Kjeldahl Nitrogen) - mg\L
Flow

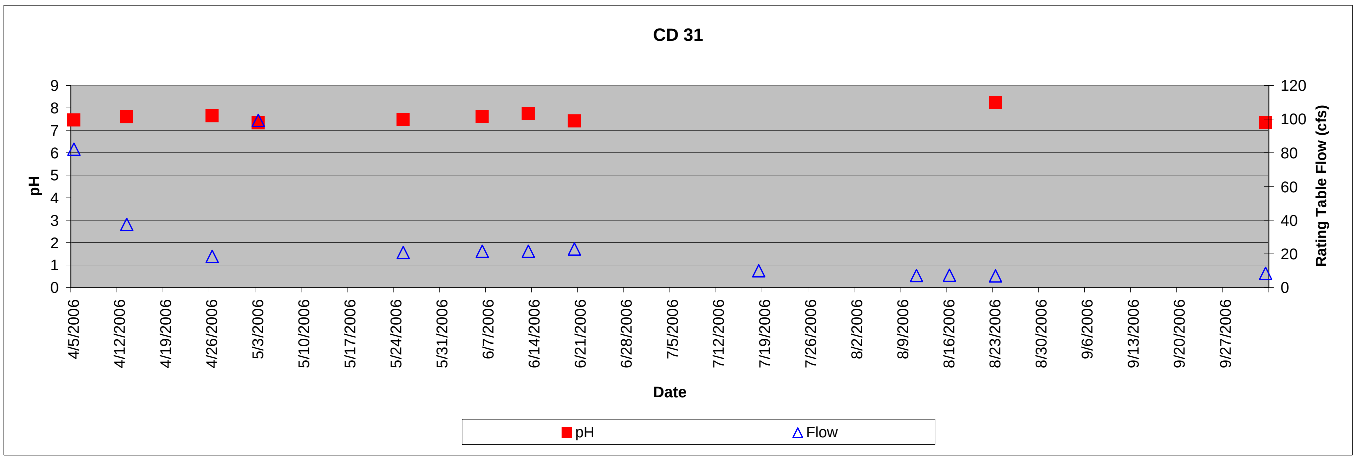

CD 31
Ortho Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
OP
Flow


CD 31
Total Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
TP
Flow

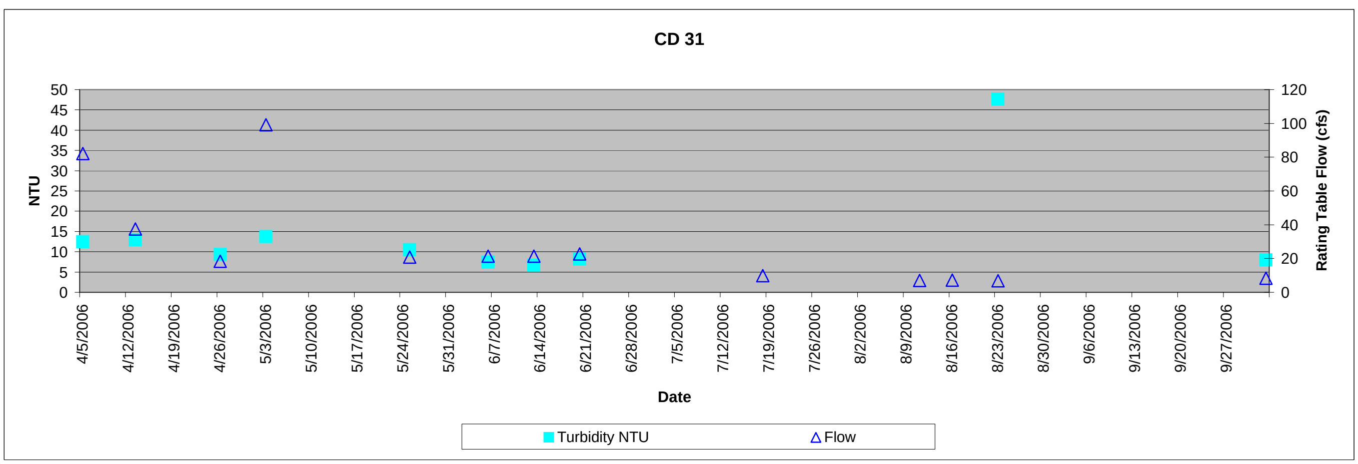

CD 31
MPN
Rating Table Flow (cfs)
Date
E coli Bacteria - MPN
Flow



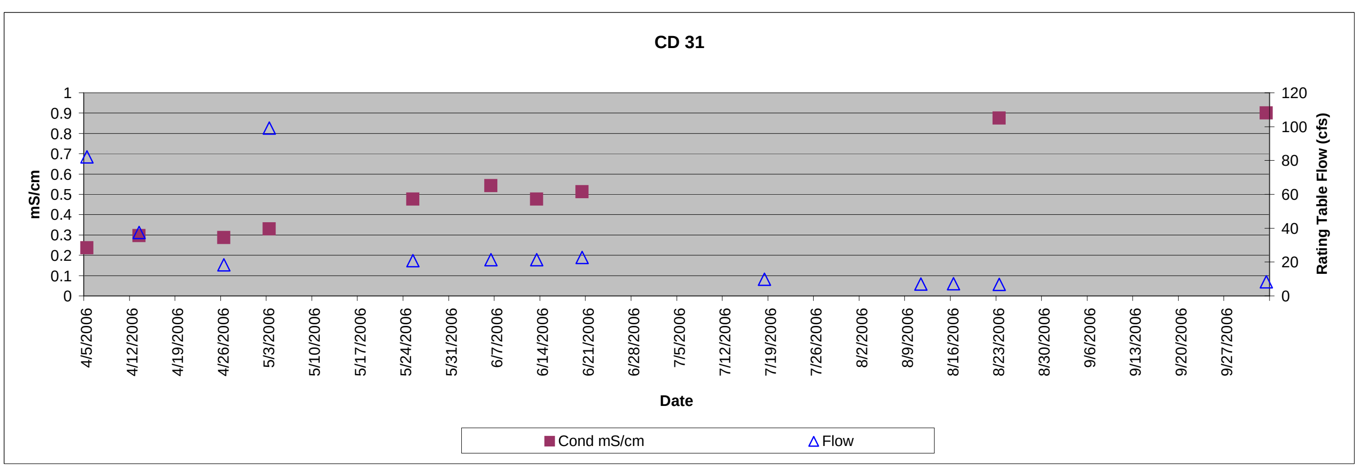
CD 31
degrees C
Rating Table Flow (cfs)
Date
Temperature, water C
Flow



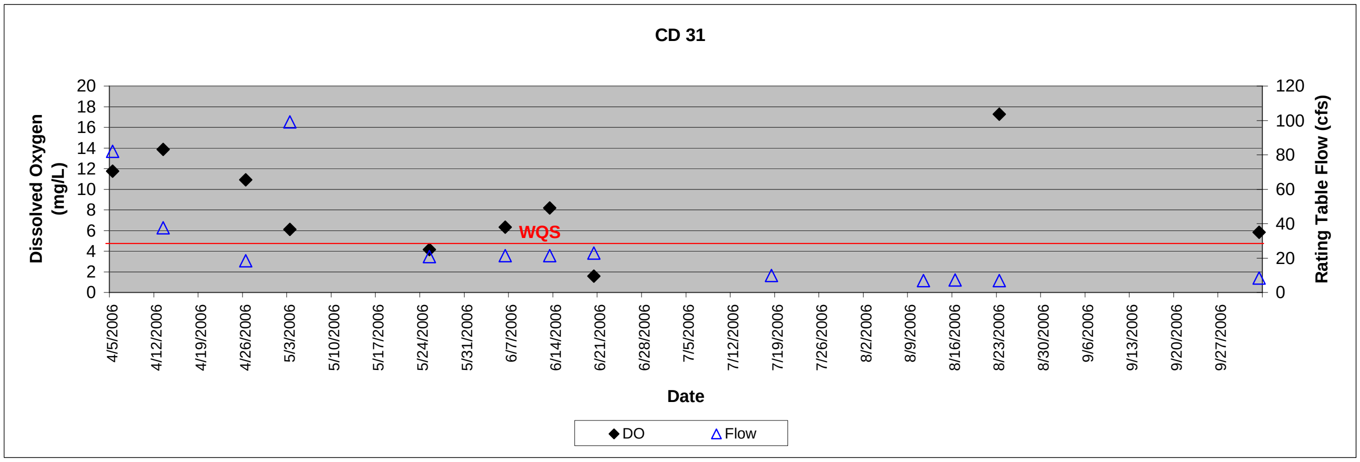
CD 31
pH
Rating Table Flow (cfs)
Date
pH
Flow



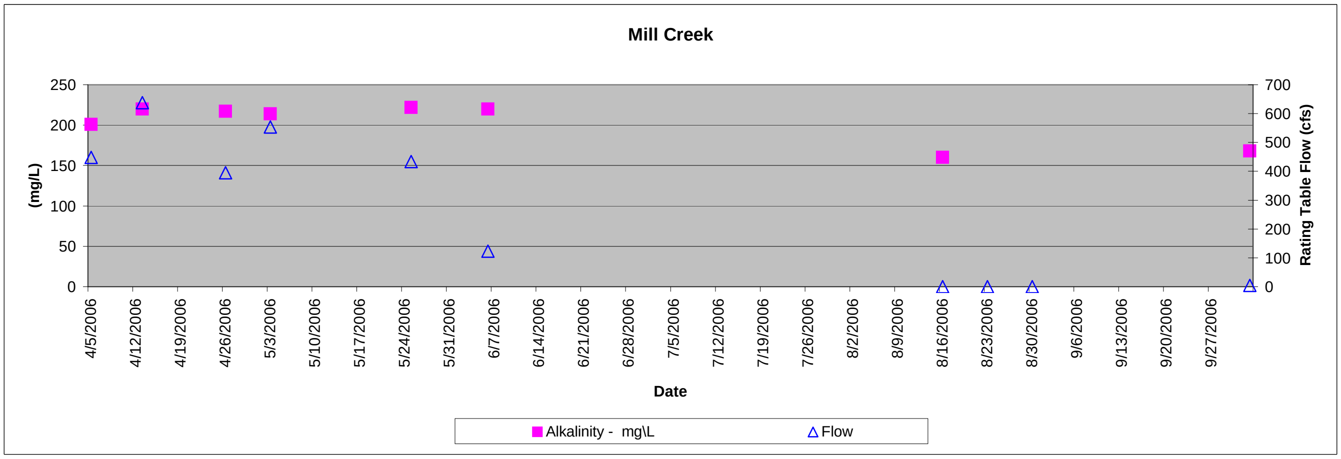
CD 31
NTU
Rating Table Flow (cfs)
Date
Turbidity NTU
Flow



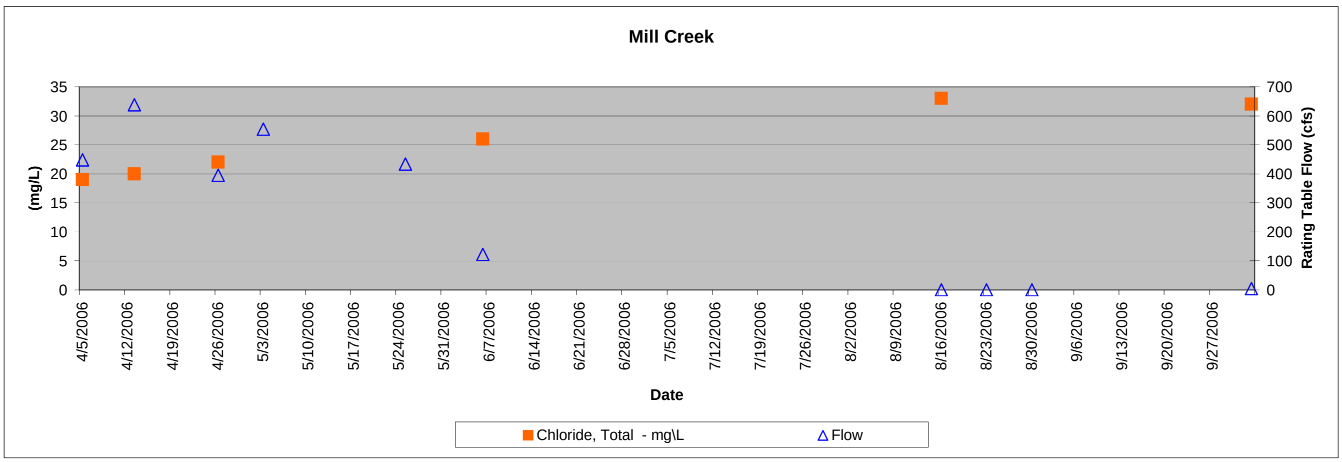
CD 31
mS/cm
Rating Table Flow (cfs)
Date
Cond mS/cm
Flow



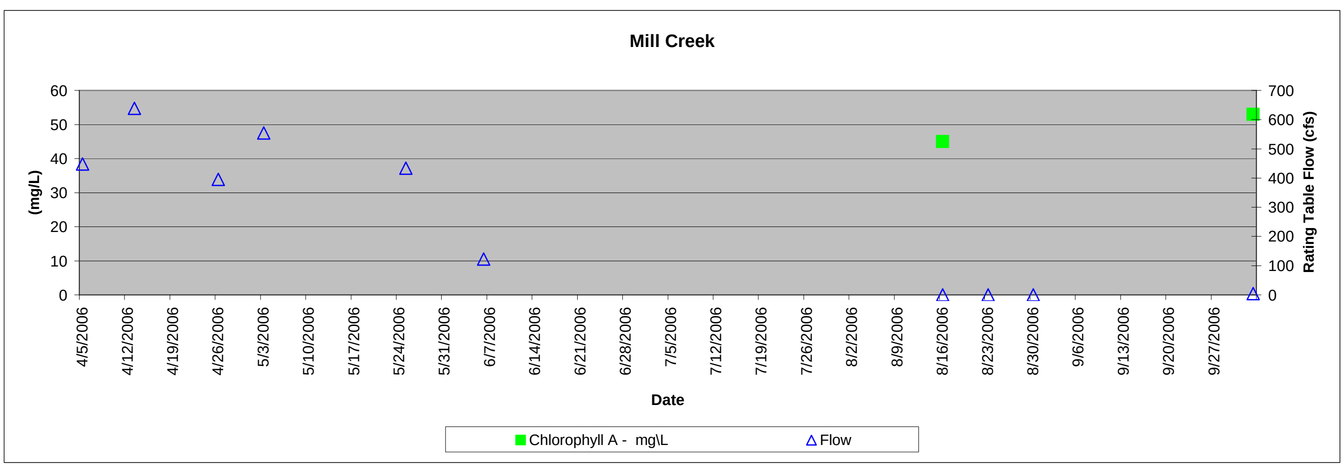
CD 31
Dissolved Oxygen (mg/L)
Rating Table Flow (cfs)
WQS
Date
DO
Flow



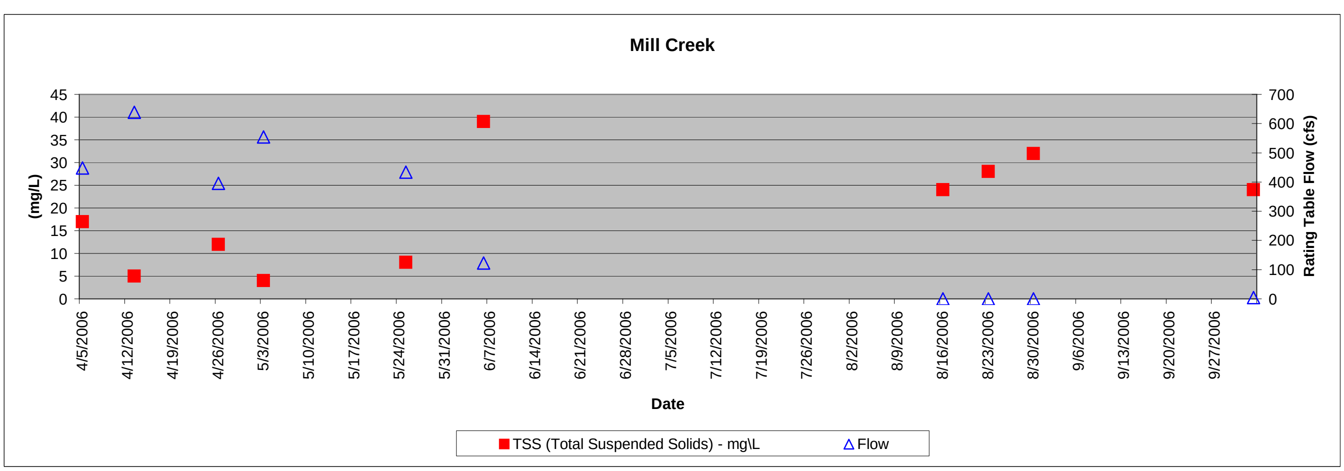
Mill Creek
(mg/L)
Rating Table Flow (cfs)
Date
Alkalinity - mg\L
Flow



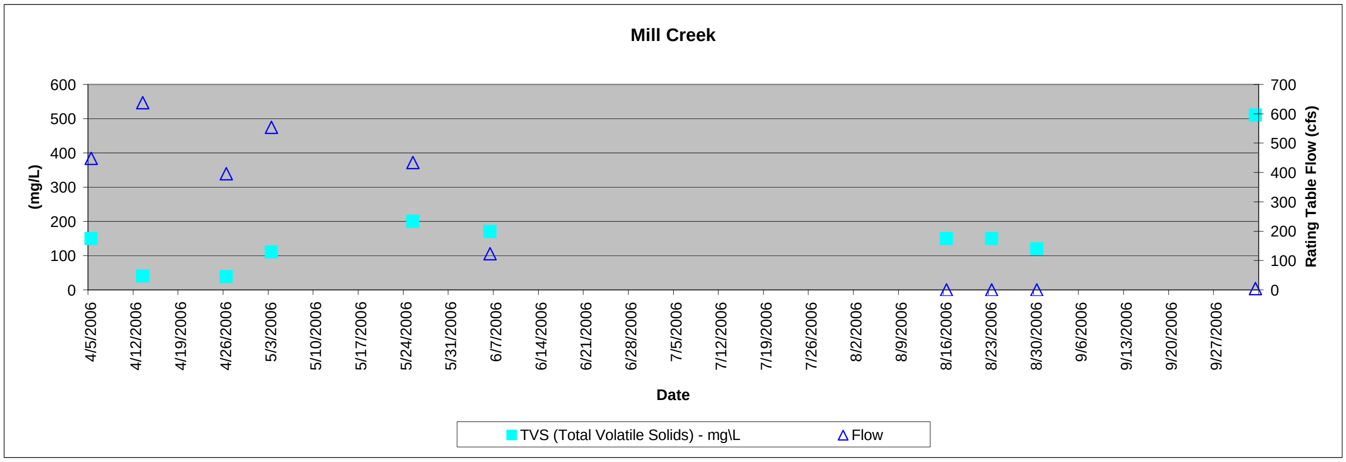
Mill Creek
(mg/L)
Rating Table Flow (cfs)
Date
Chloride, Total - mg\L
Flow



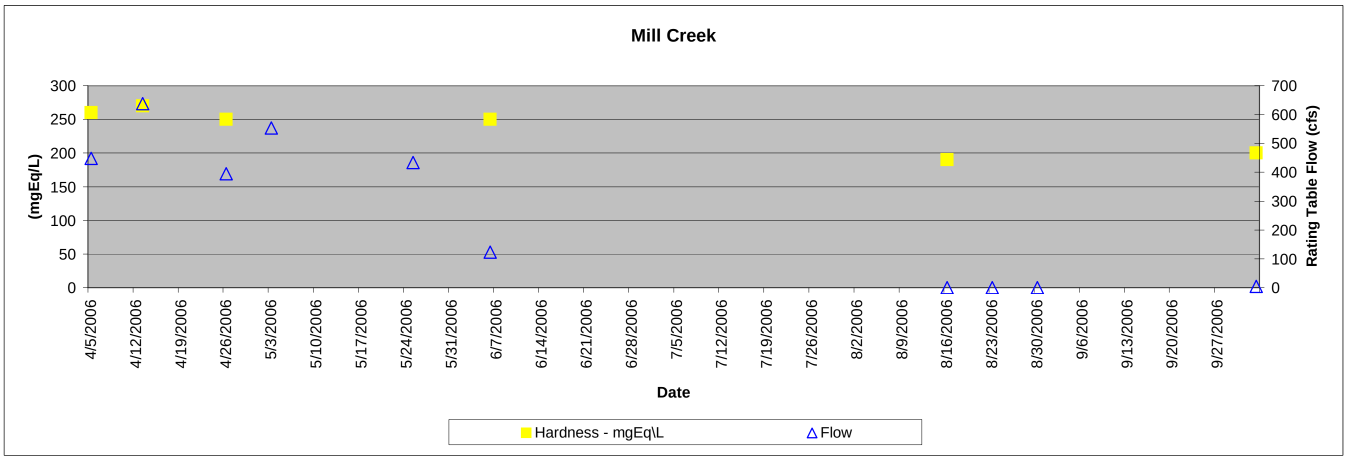
Mill Creek
(mg/L)
Rating Table Flow (cfs)
Date
Chlorophyll A - mg\L
Flow



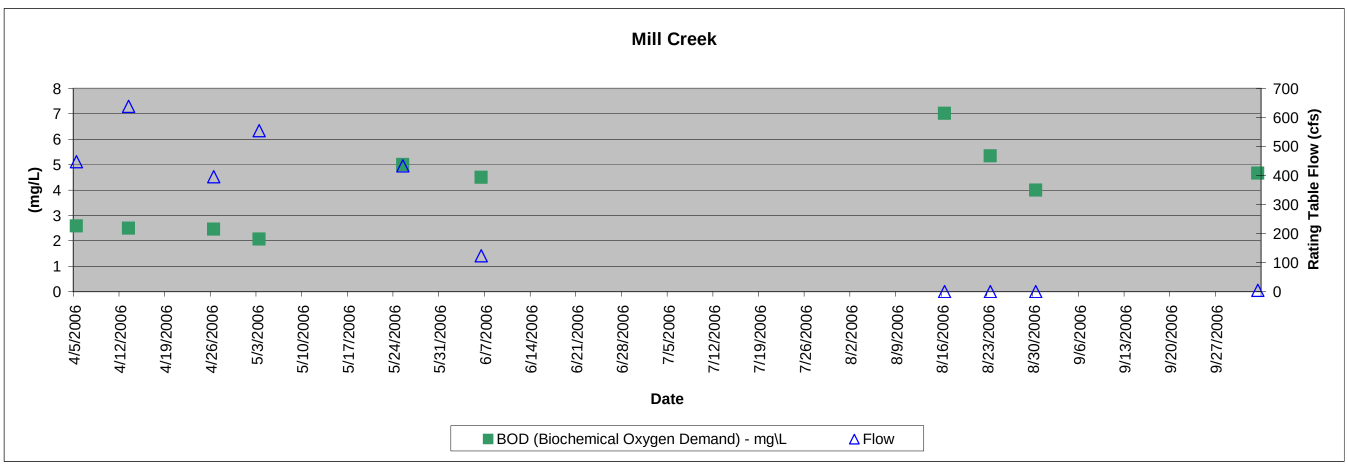
Mill Creek
(mg/L)
Rating Table Flow (cfs)
Date
TSS (Total Suspended Solids) - mg\L
Flow



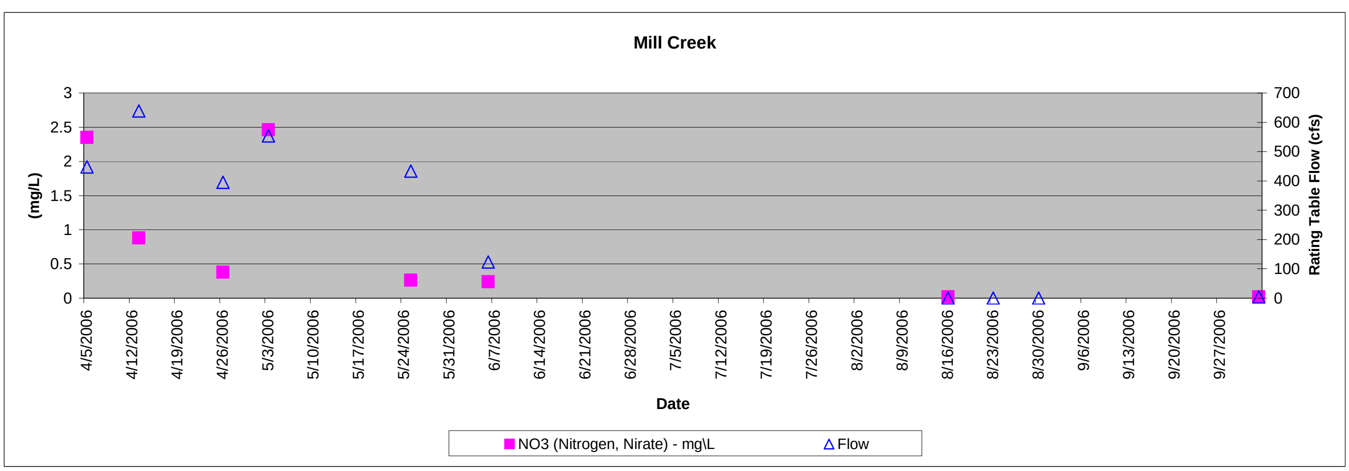
Mill Creek
(mg/L)
Rating Table Flow (cfs)
0
100
200
300
400
500
600
700
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
TVS (Total Volatile Solids) - mg\L
Flow



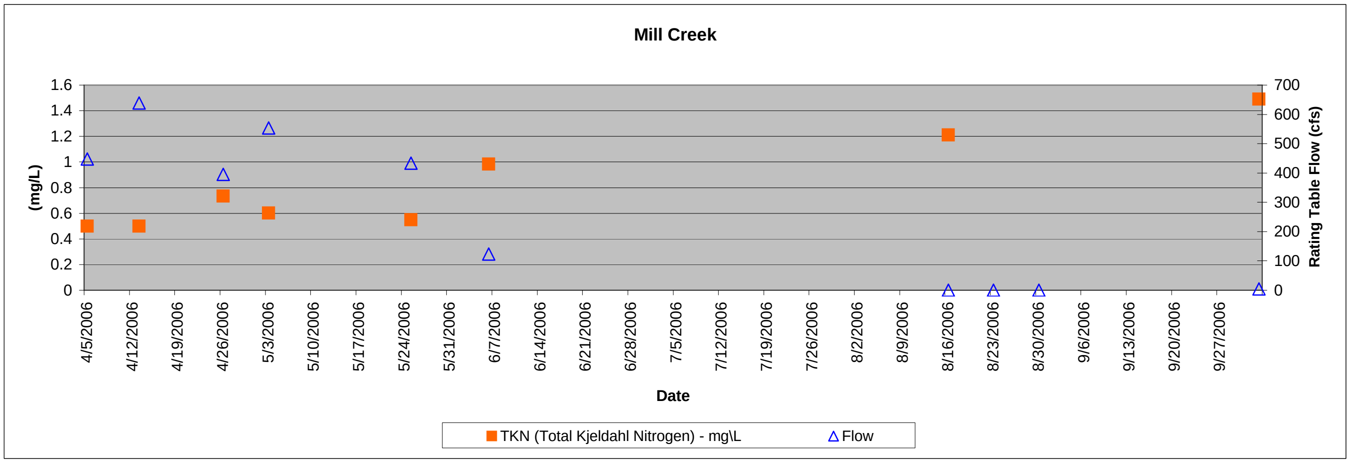
Mill Creek
(mgEq/L)
Rating Table Flow (cfs)
0
50
100
150
200
250
300
Date
Hardness - mgEq\L
Flow

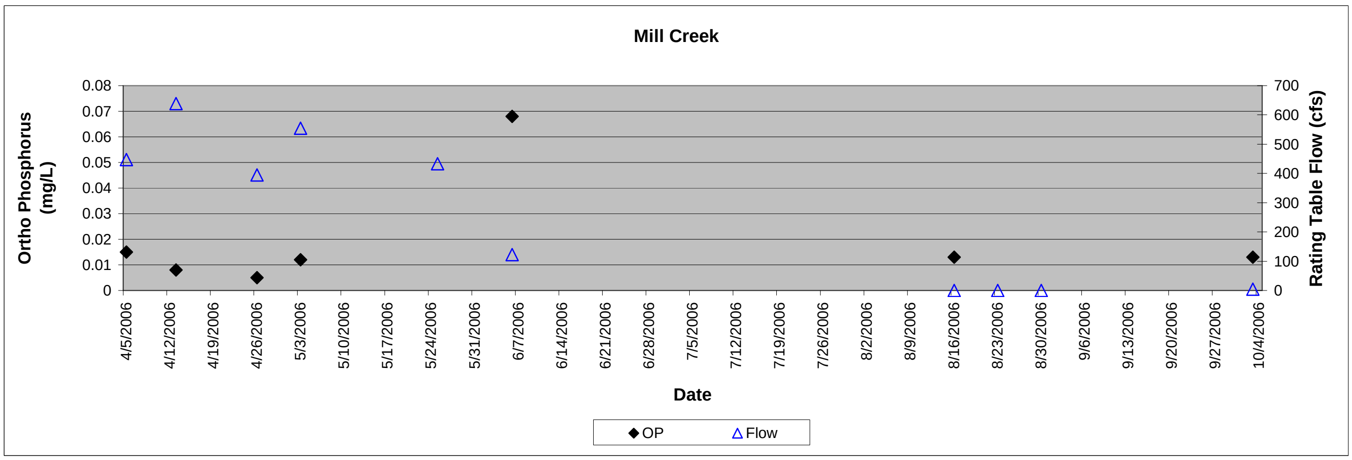


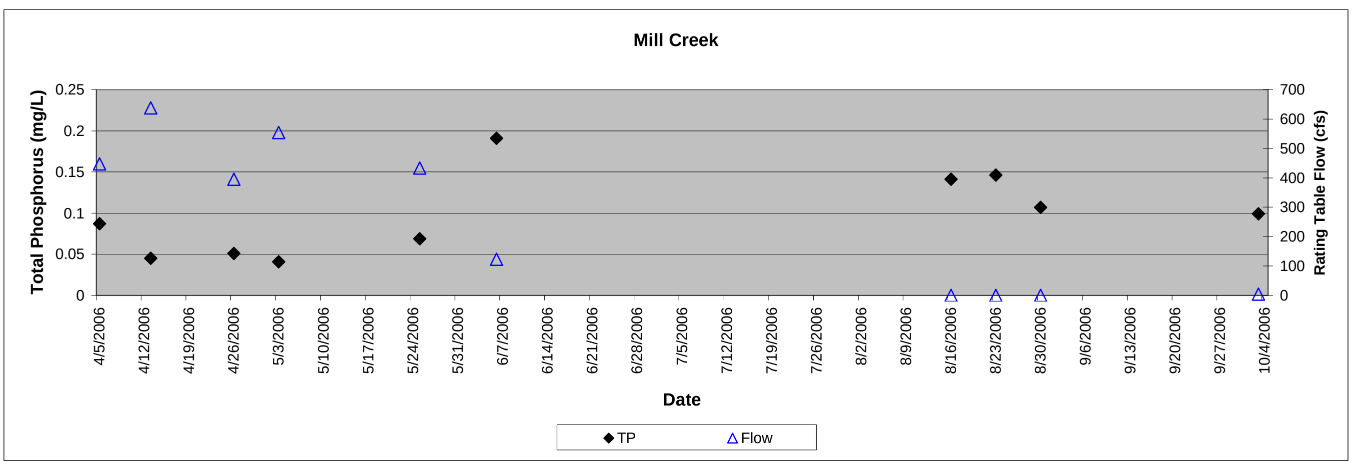
Mill Creek
(mg/L)
Rating Table Flow (cfs)
0
1
2
3
4
5
6
7
8
Date
BOD (Biochemical Oxygen Demand) - mg\L
Flow

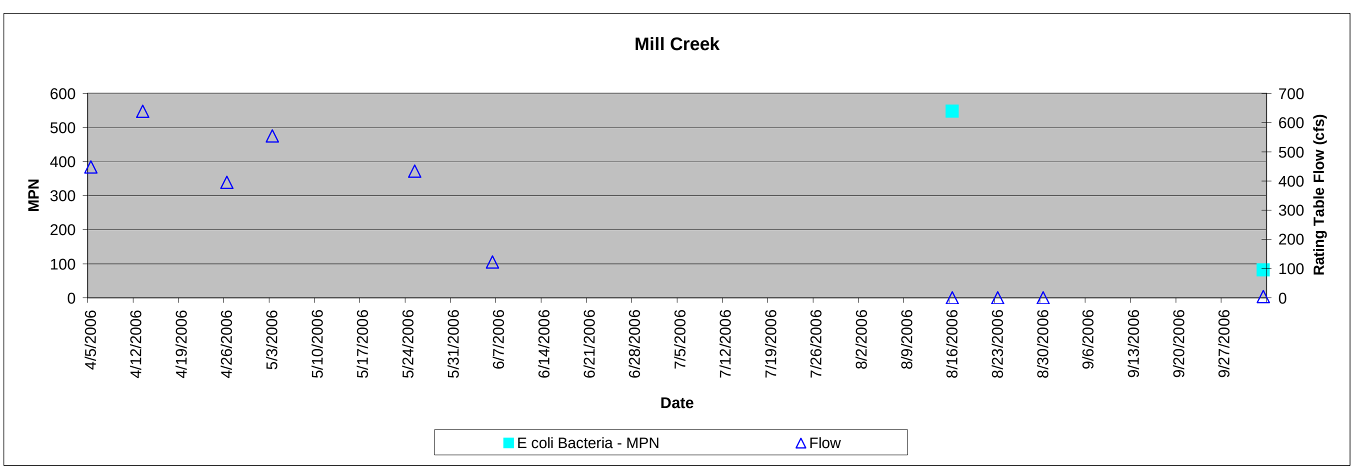


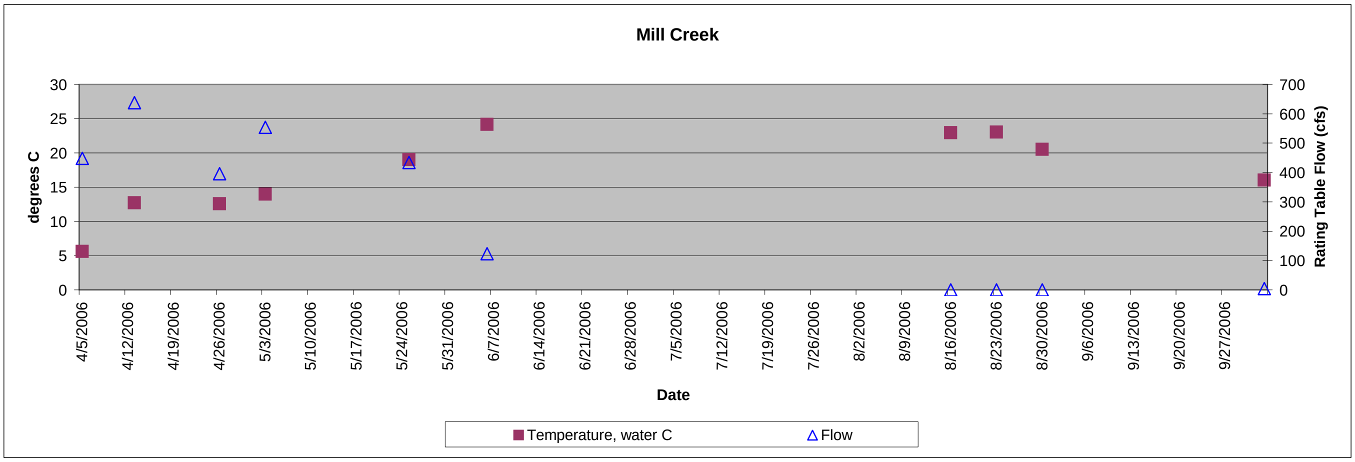
Mill Creek
(mg/L)
Rating Table Flow (cfs)
0
0.5
1
1.5
2
2.5
3
Date
NO3 (Nitrogen, Nirate) - mg\L
Flow

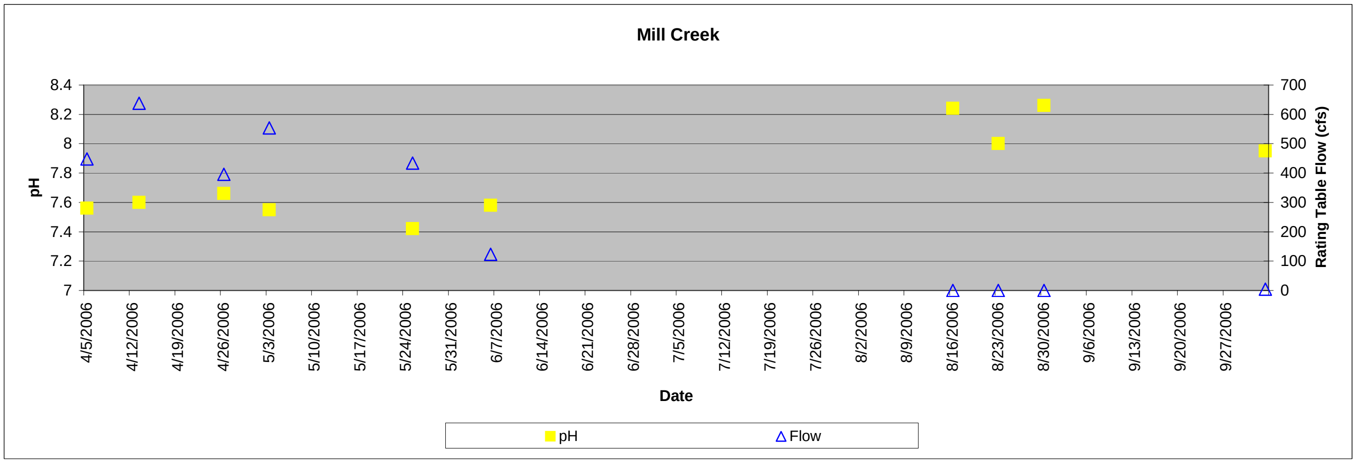

Mill Creek
(mg/L)
Rating Table Flow (cfs)
Date
TKN (Total Kjeldahl Nitrogen) - mg\L
Flow

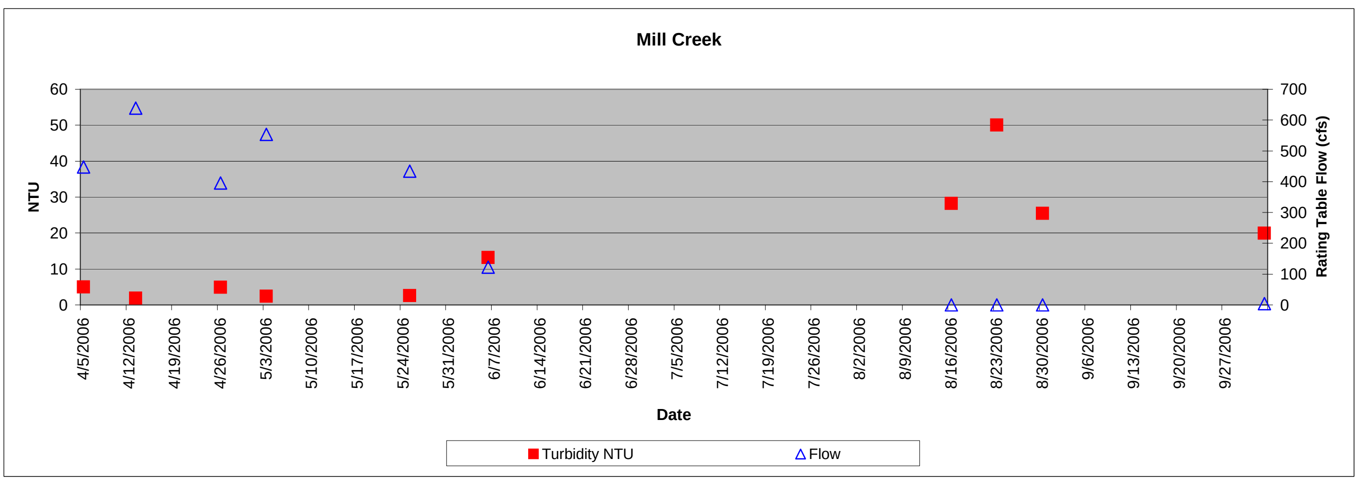

Mill Creek
Ortho Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
OP
Flow

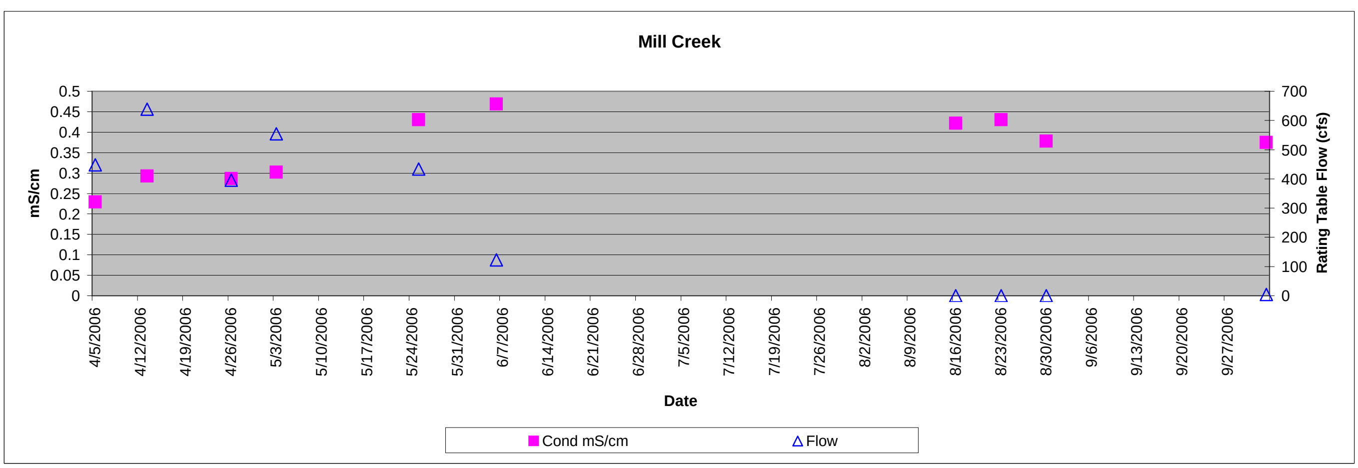

Mill Creek
Total Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
TP
Flow

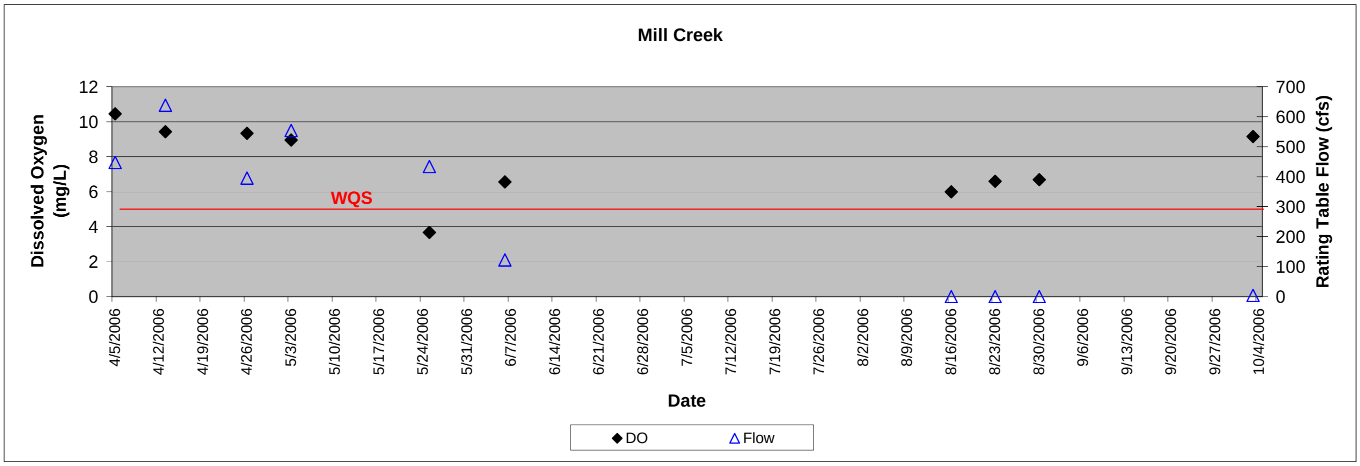

Mill Creek
MPN
Rating Table Flow (cfs)
Date
E coli Bacteria - MPN
Flow


Mill Creek
degrees C
Rating Table Flow (cfs)
Date
Temperature, water C
Flow

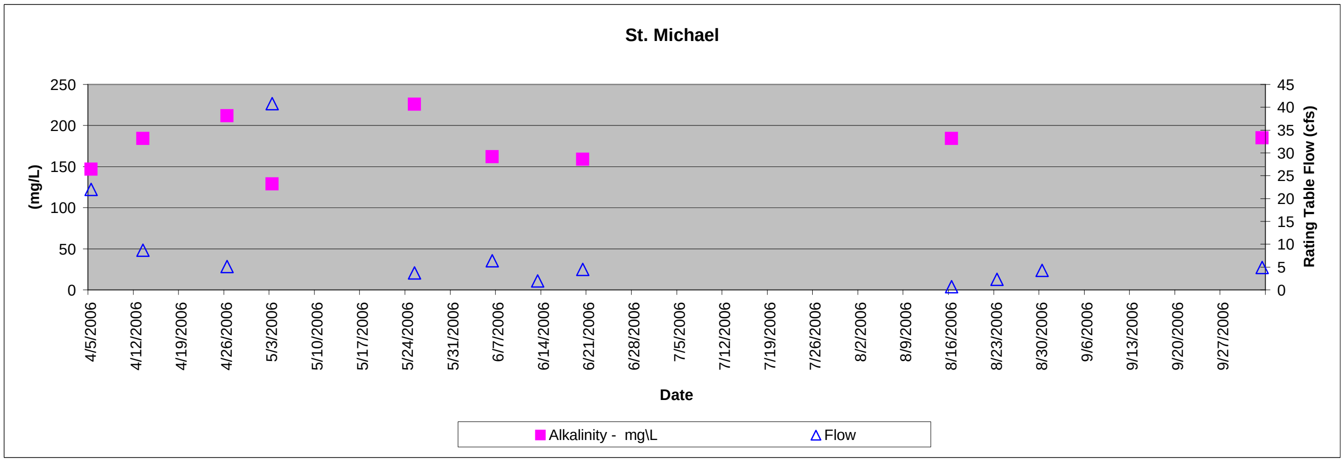

Mill Creek
pH
Rating Table Flow (cfs)
Date
pH
Flow

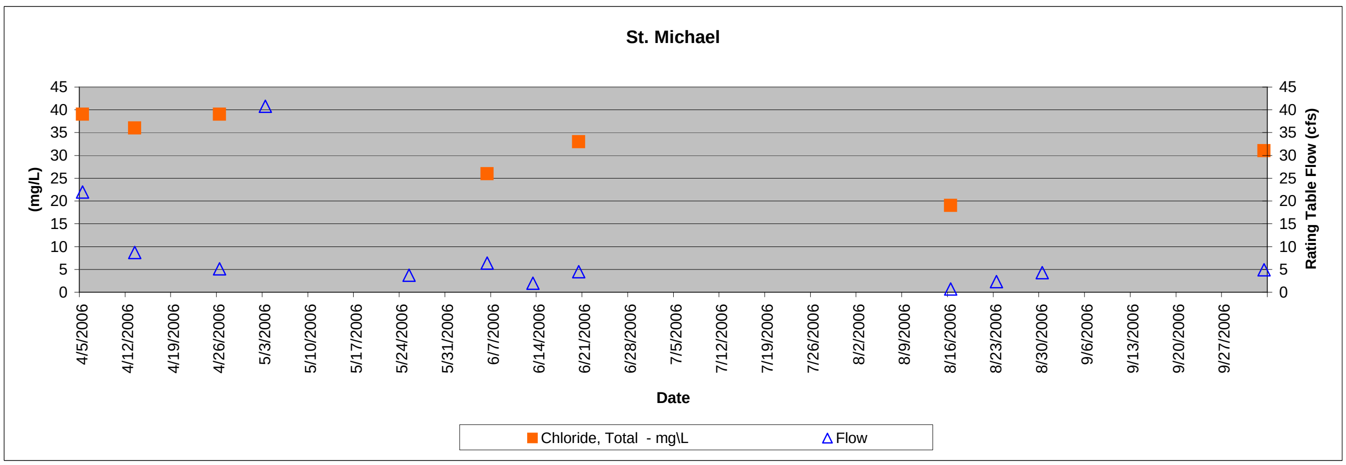

Mill Creek
NTU
Rating Table Flow (cfs)
Date
Turbidity NTU
Flow

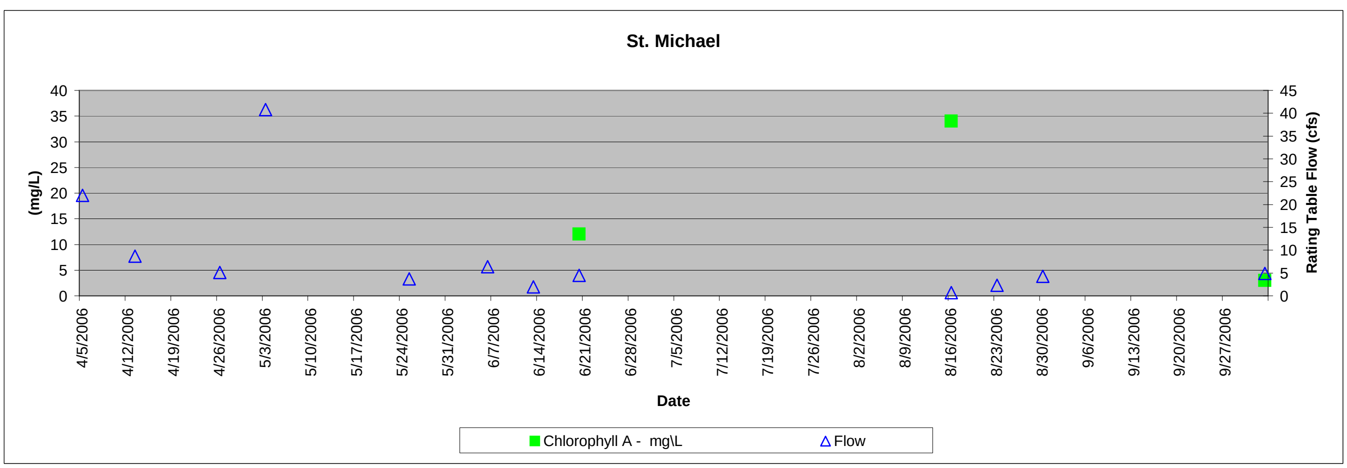

Mill Creek
mS/cm
Rating Table Flow (cfs)
Date
Cond mS/cm
Flow

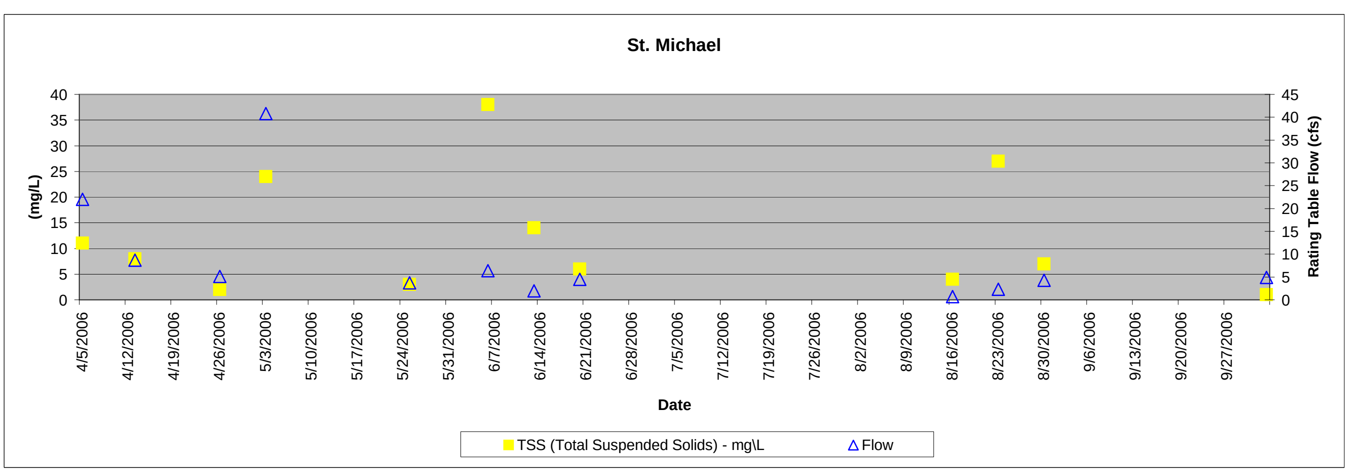


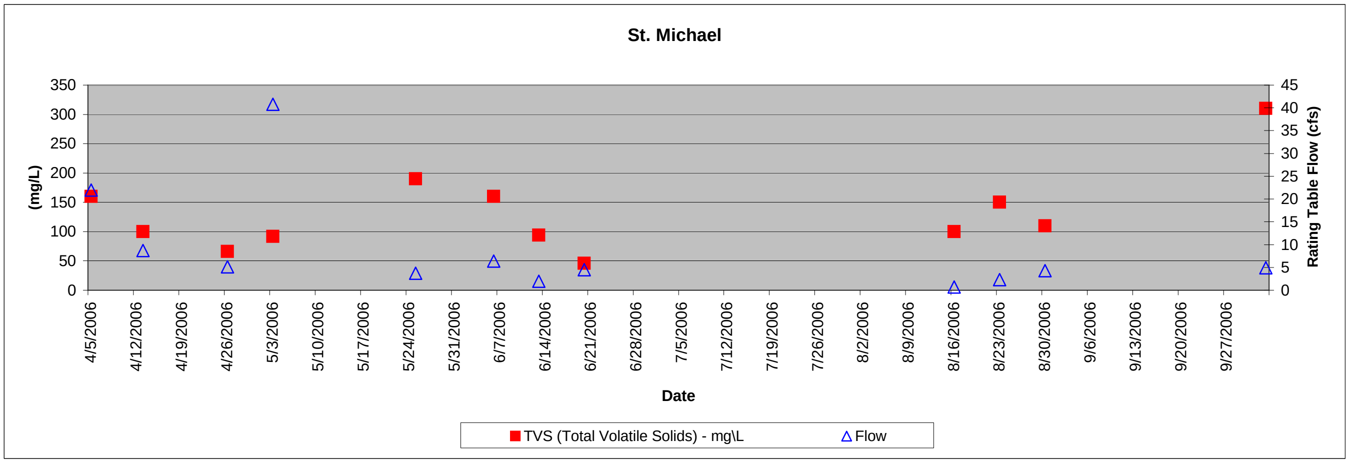
Mill Creek
Dissolved Oxygen (mg/L)
Rating Table Flow (cfs)
WQS
Date
DO
Flow

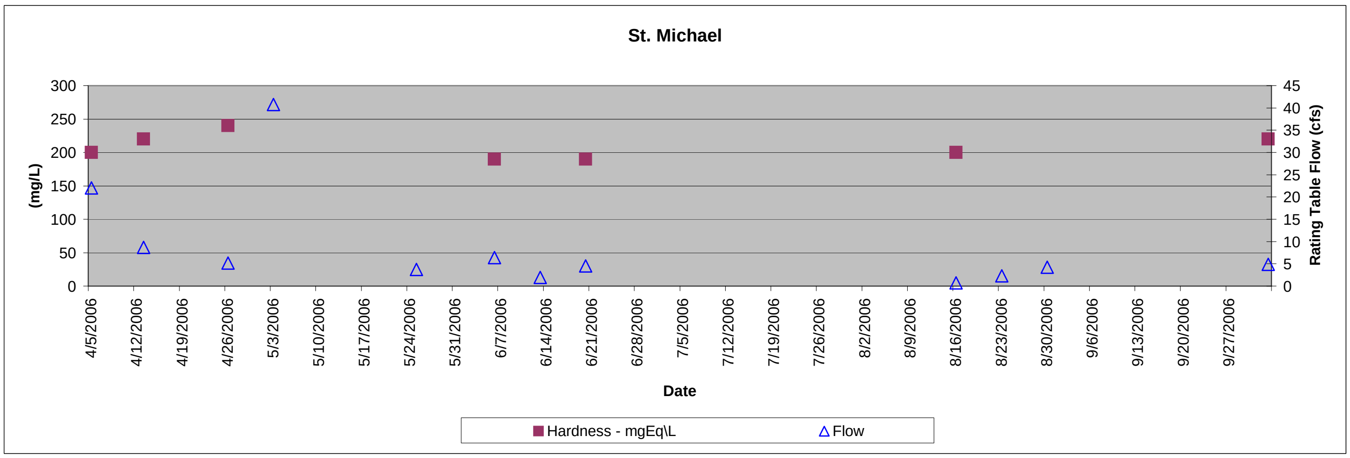

St. Michael
(mg/L)
250
200
150
100
50
0
Rating Table Flow (cfs)
45
40
35
30
25
20
15
10
5
0
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Alkalinity - mg\L
Flow

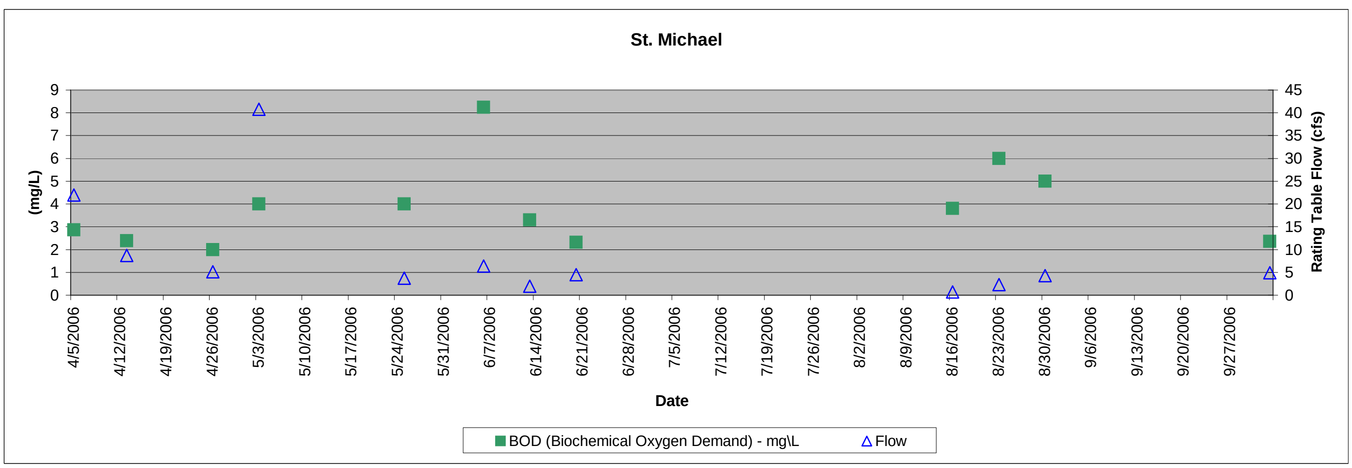

St. Michael
(mg/L)
45
40
35
30
25
20
15
10
5
0
Rating Table Flow (cfs)
45
40
35
30
25
20
15
10
5
0
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Chloride, Total - mg\L
Flow

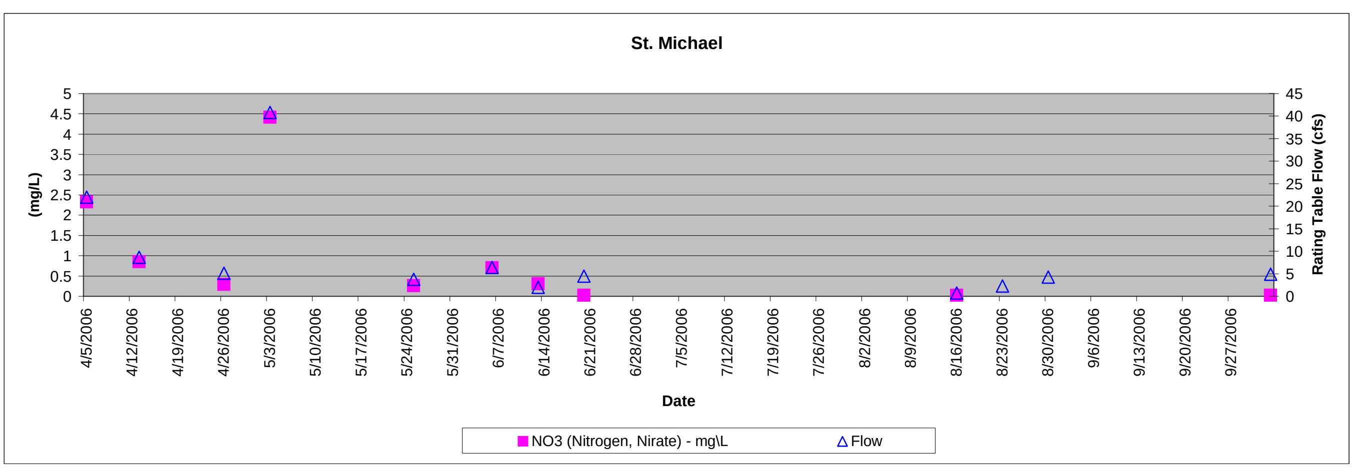

St. Michael
(mg/L)
40
35
30
25
20
15
10
5
0
Rating Table Flow (cfs)
45
40
35
30
25
20
15
10
5
0
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
Chlorophyll A - mg\L
Flow

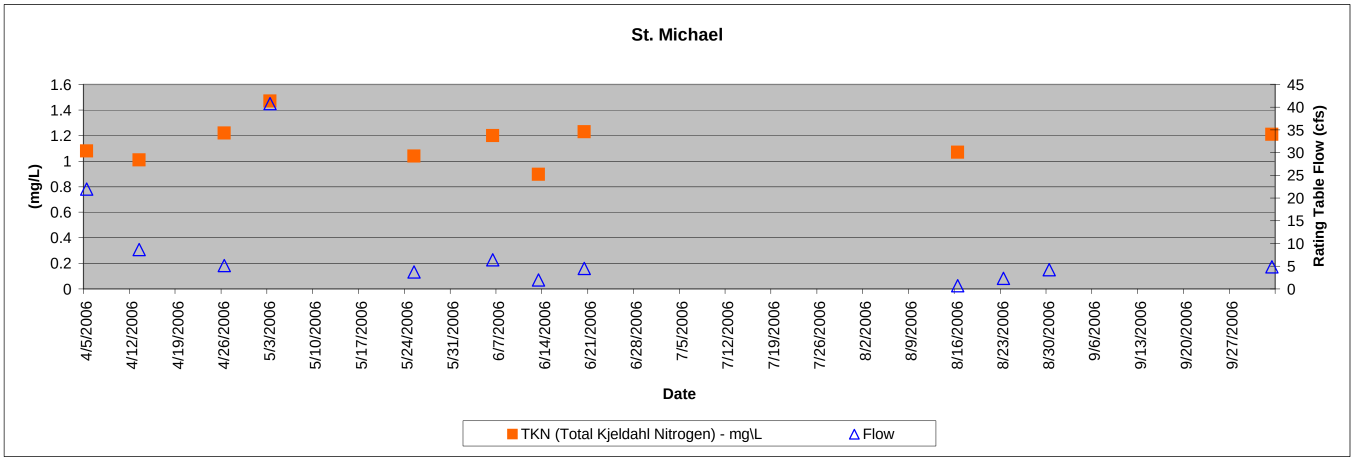

St. Michael
(mg/L)
40
35
30
25
20
15
10
5
0
Rating Table Flow (cfs)
45
40
35
30
25
20
15
10
5
0
4/5/2006
4/12/2006
4/19/2006
4/26/2006
5/3/2006
5/10/2006
5/17/2006
5/24/2006
5/31/2006
6/7/2006
6/14/2006
6/21/2006
6/28/2006
7/5/2006
7/12/2006
7/19/2006
7/26/2006
8/2/2006
8/9/2006
8/16/2006
8/23/2006
8/30/2006
9/6/2006
9/13/2006
9/20/2006
9/27/2006
Date
TSS (Total Suspended Solids) - mg\L
Flow

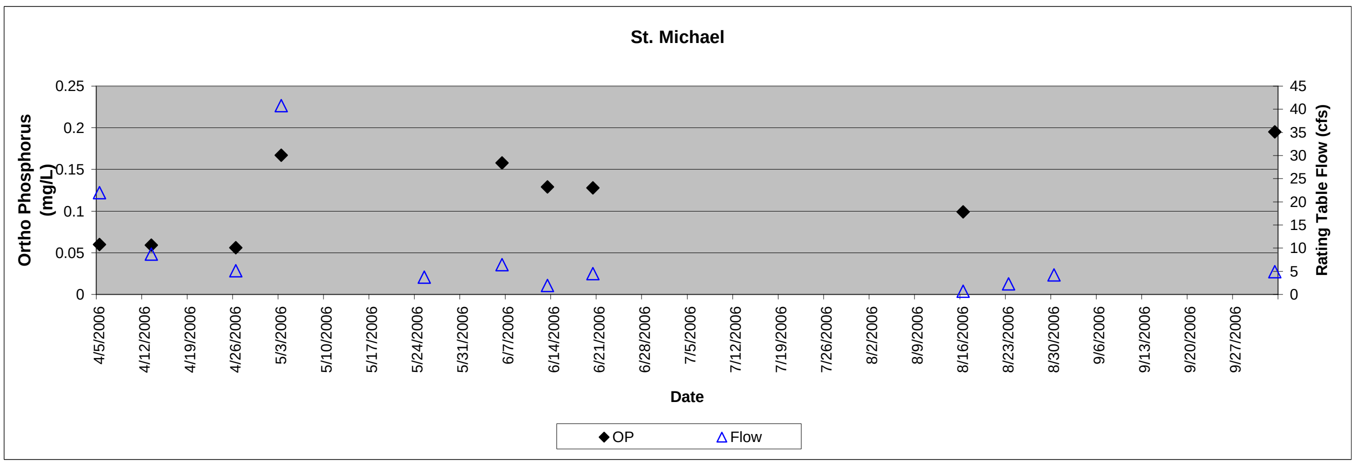

St. Michael
(mg/L)
Rating Table Flow (cfs)
Date
TVS (Total Volatile Solids) - mg\L
Flow

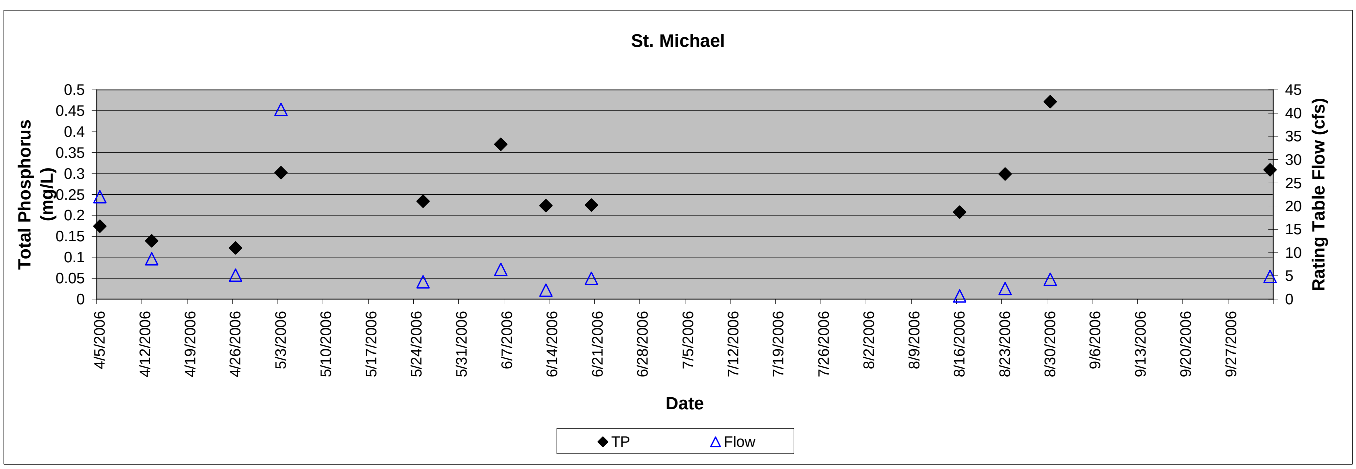

St. Michael
(mg/L)
Rating Table Flow (cfs)
Date
Hardness - mgEq\L
Flow

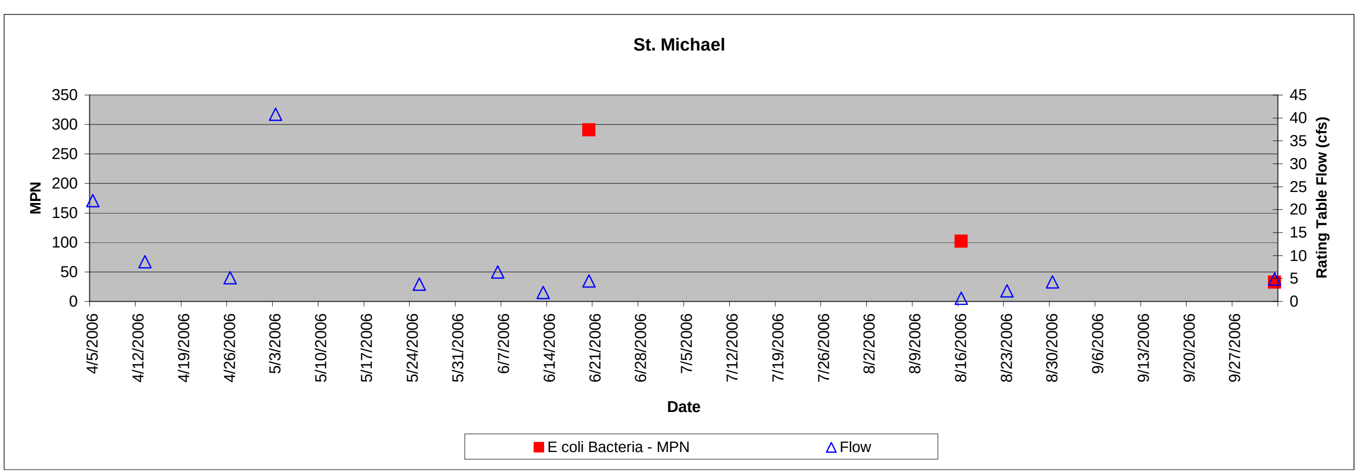

St. Michael
(mg/L)
Rating Table Flow (cfs)
Date
BOD (Biochemical Oxygen Demand) - mg\L
Flow

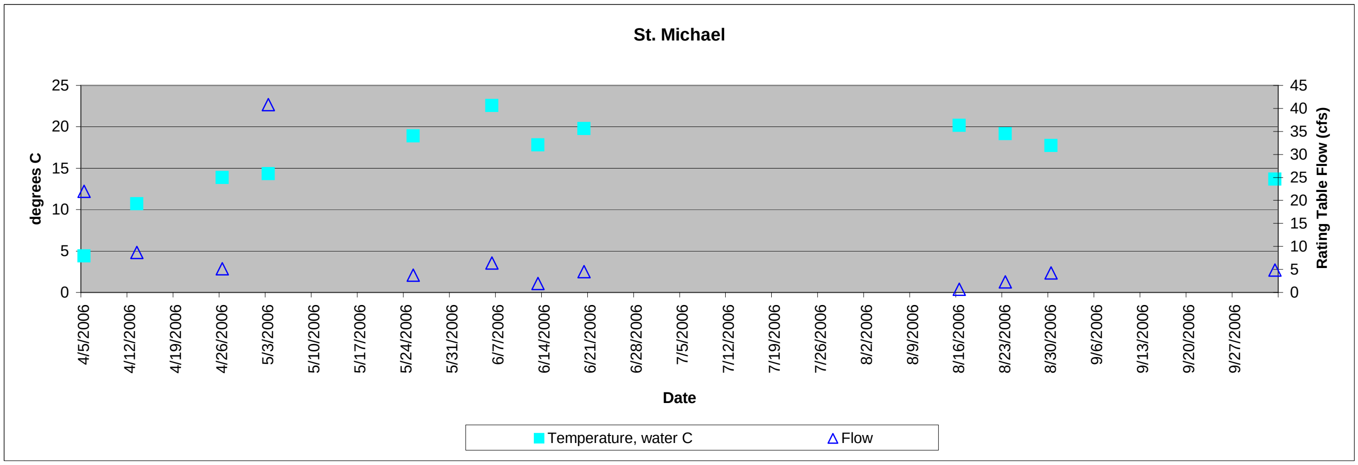

St. Michael
(mg/L)
Rating Table Flow (cfs)
Date
NO3 (Nitrogen, Nirate) - mg\L
Flow

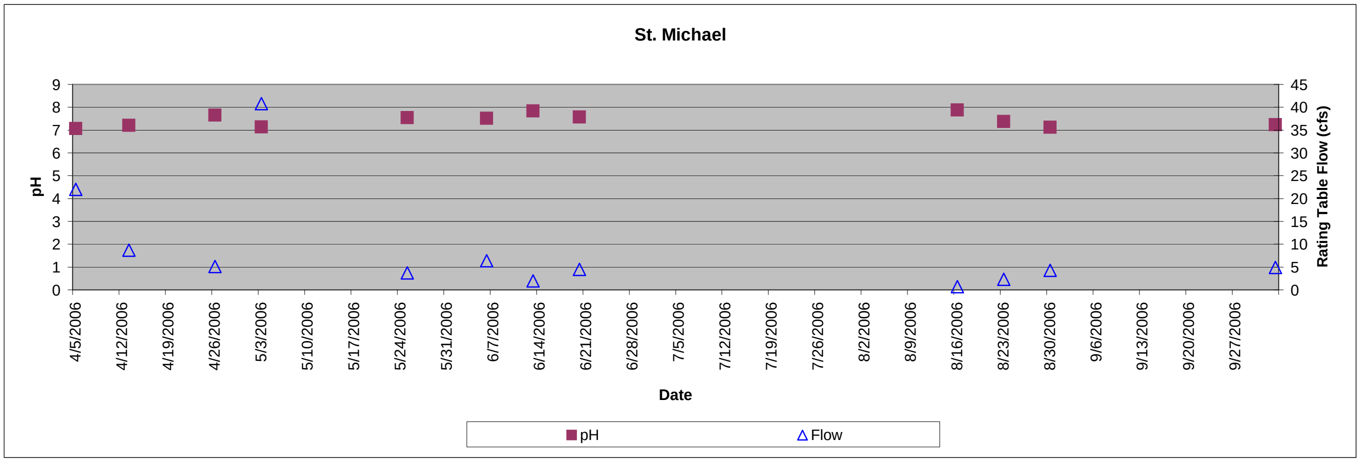

St. Michael
(mg/L)
Rating Table Flow (cfs)
Date
TKN (Total Kjeldahl Nitrogen) - mg\L
Flow

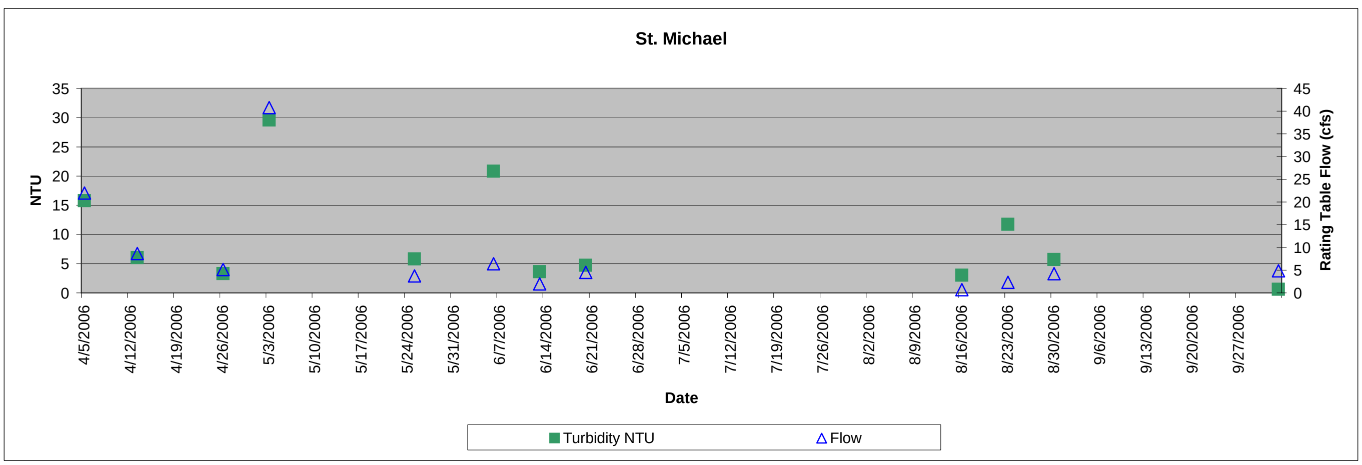

St. Michael
Ortho Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
OP
Flow

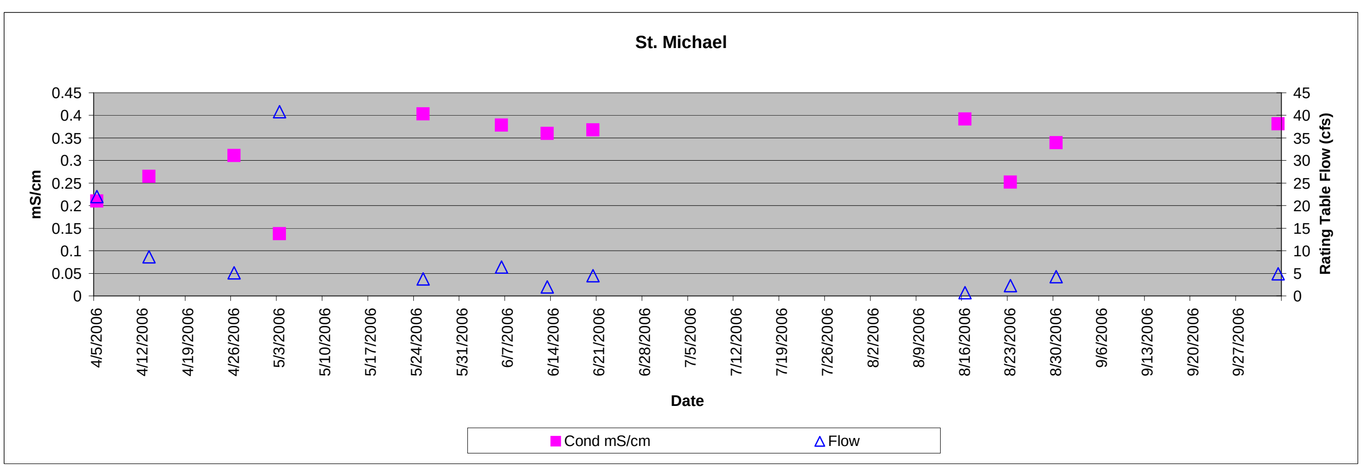

St. Michael
Total Phosphorus (mg/L)
Rating Table Flow (cfs)
Date
TP
Flow

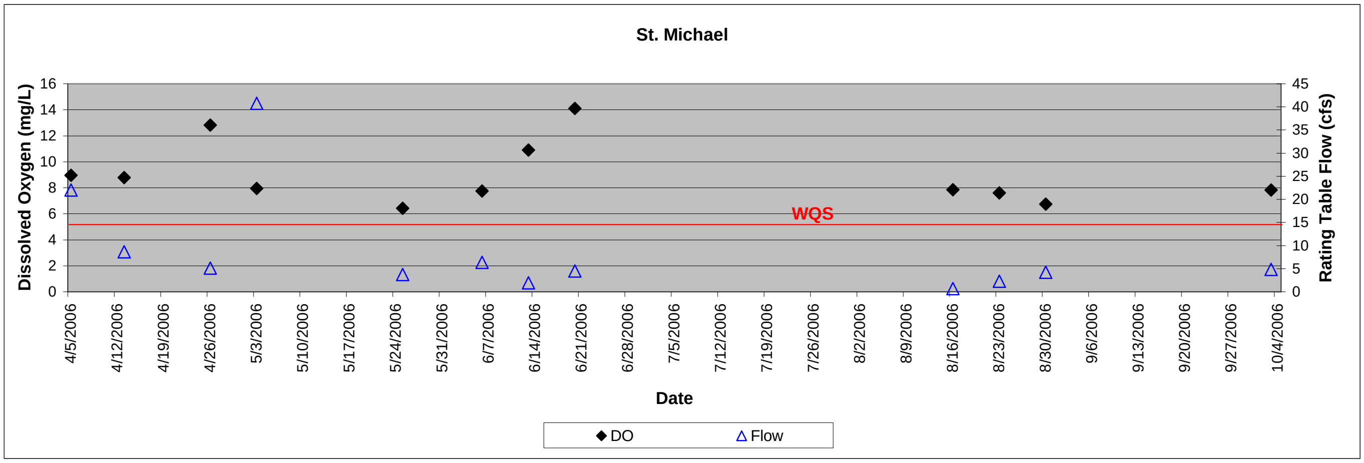

St. Michael
MPN
Rating Table Flow (cfs)
Date
E coli Bacteria - MPN
Flow


St. Michael
degrees C
Rating Table Flow (cfs)
Date
Temperature, water C
Flow

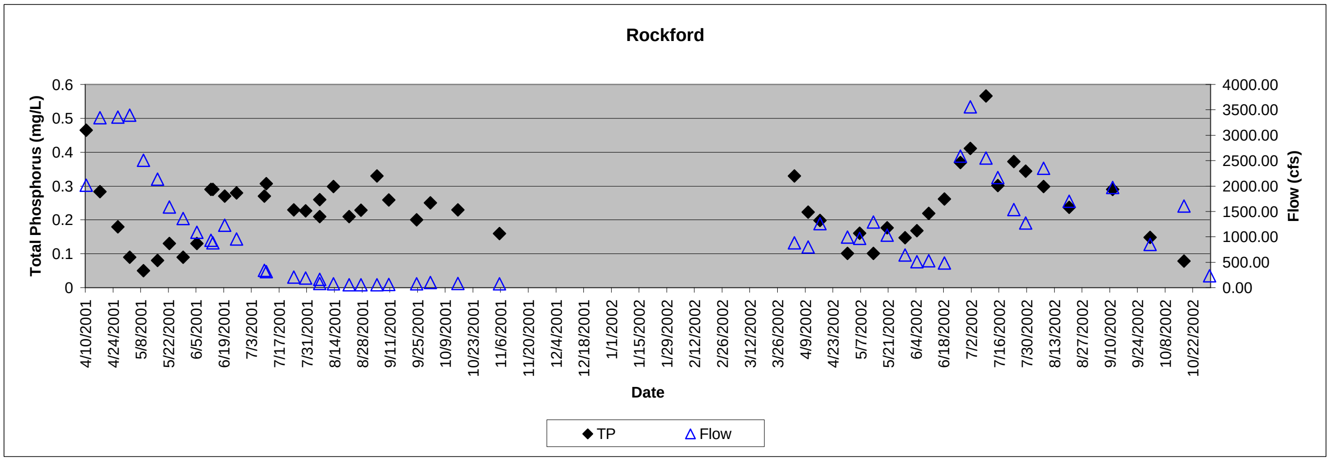

St. Michael
pH
Rating Table Flow (cfs)
Date
pH
Flow

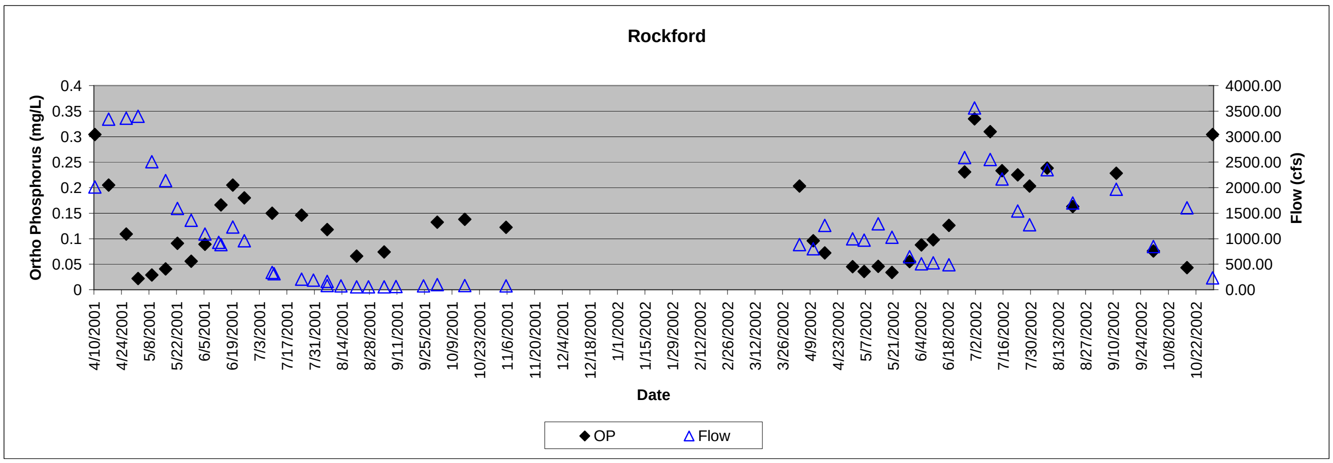

St. Michael
NTU
Rating Table Flow (cfs)
Date
Turbidity NTU
Flow

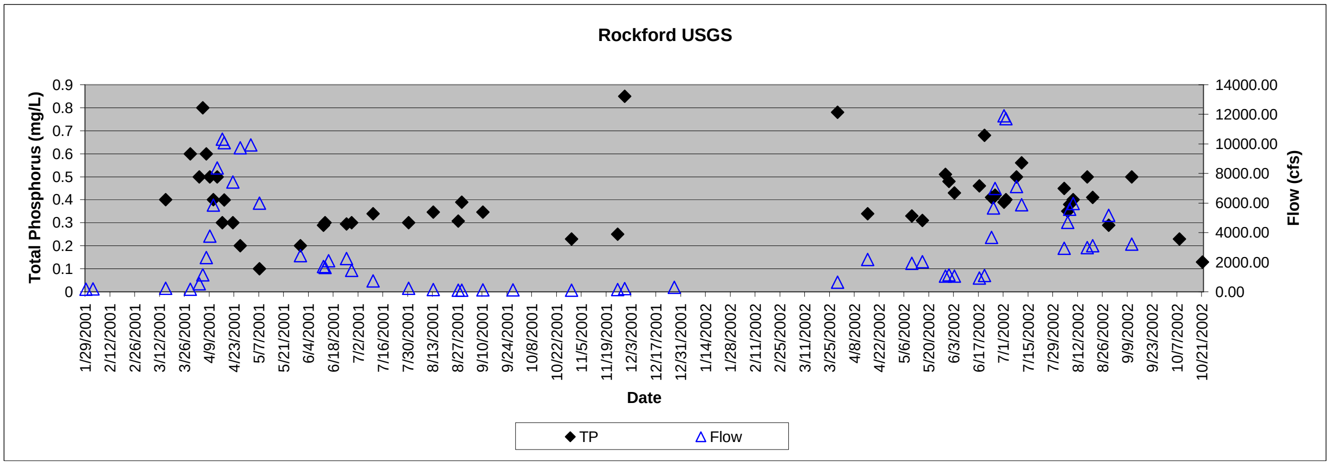

St. Michael
mS/cm
Rating Table Flow (cfs)
Date
Cond mS/cm
Flow

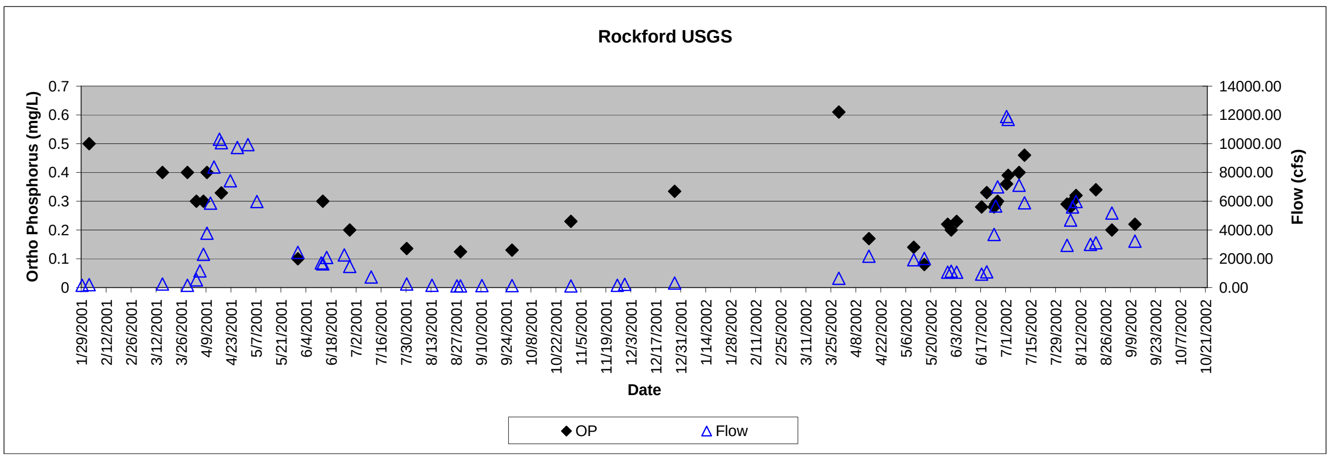

St. Michael
Dissolved Oxygen (mg/L)
Rating Table Flow (cfs)
WQS
Date
DO
Flow

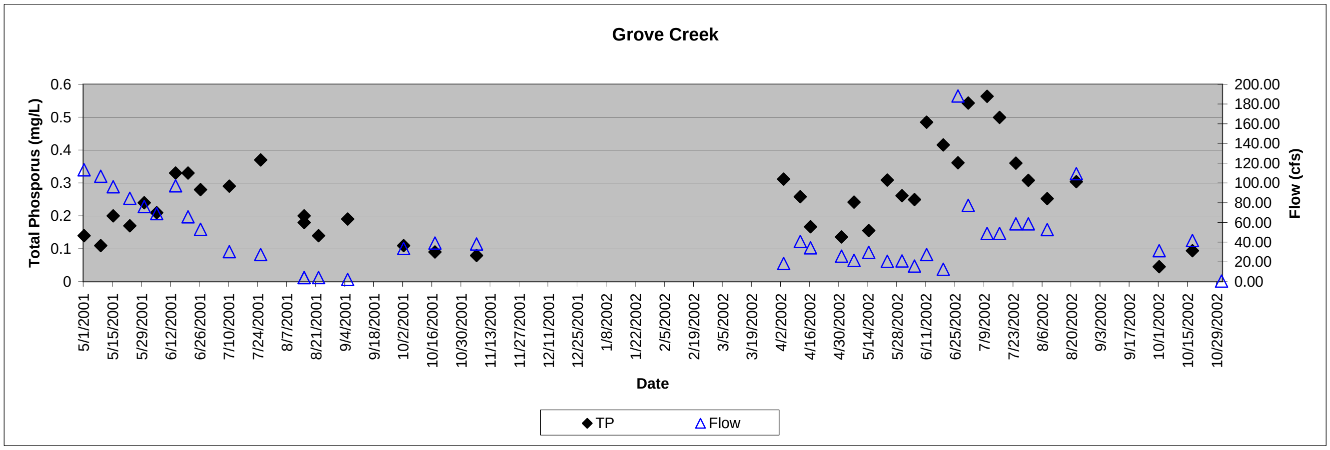
APPENDIX C: DIAGNOSTIC DATA – OP AND TP

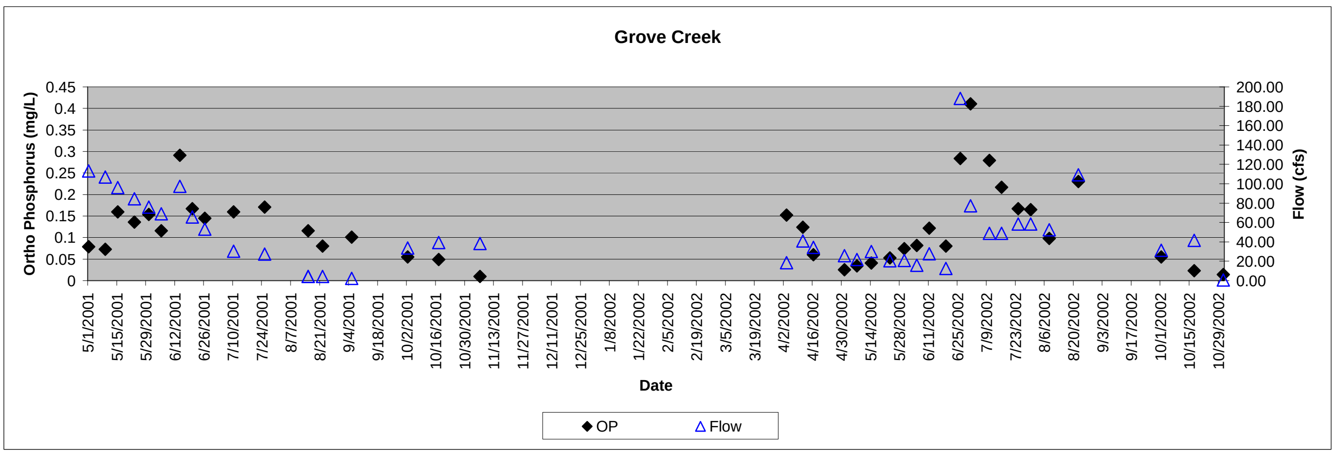

Rockford
Total Phosphorus (mg/L)
Flow (cfs)
Date
TP
Flow


Rockford
Ortho Phosphorus (mg/L)
Flow (cfs)
Date
OP
Flow


Rockford USGS
Total Phosphorus (mg/L)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flow (cfs)
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
Date
1/29/2001 2/12/2001 2/26/2001 3/12/2001 3/26/2001 4/9/2001 4/23/2001 5/7/2001 5/21/2001 6/4/2001 6/18/2001 7/2/2001 7/16/2001 7/30/2001 8/13/2001 8/27/2001 9/10/2001 9/24/2001 10/8/2001 10/22/2001 11/5/2001 11/19/2001 12/3/2001 12/17/2001 12/31/2001 1/14/2002 1/28/2002 2/11/2002 2/25/2002 3/11/2002 3/25/2002 4/8/2002 4/22/2002 5/6/2002 5/20/2002 6/3/2002 6/17/2002 7/1/2002 7/15/2002 7/29/2002 8/12/2002 8/26/2002 9/9/2002 9/23/2002 10/7/2002 10/21/2002
TP
Flow


Rockford USGS
Ortho Phosphorus (mg/L)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Flow (cfs)
14000.00
12000.00
10000.00
8000.00
6000.00
4000.00
2000.00
0.00
Date
1/29/2001 2/12/2001 2/26/2001 3/12/2001 3/26/2001 4/9/2001 4/23/2001 5/7/2001 5/21/2001 6/4/2001 6/18/2001 7/2/2001 7/16/2001 7/30/2001 8/13/2001 8/27/2001 9/10/2001 9/24/2001 10/8/2001 10/22/2001 11/5/2001 11/19/2001 12/3/2001 12/17/2001 12/31/2001 1/14/2002 1/28/2002 2/11/2002 2/25/2002 3/11/2002 3/25/2002 4/8/2002 4/22/2002 5/6/2002 5/20/2002 6/3/2002 6/17/2002 7/1/2002 7/15/2002 7/29/2002 8/12/2002 8/26/2002 9/9/2002 9/23/2002 10/7/2002 10/21/2002
OP
Flow


Grove Creek
Total Phosporus (mg/L)
Flow (cfs)
Date
TP
Flow
0.6
0.5
0.4
0.3
0.2
0.1
0
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
5/1/2001
5/15/2001
5/29/2001
6/12/2001
6/26/2001
7/10/2001
7/24/2001
8/7/2001
8/21/2001
9/4/2001
9/18/2001
10/2/2001
10/16/2001
10/30/2001
11/13/2001
11/27/2001
12/11/2001
12/25/2001
1/8/2002
1/22/2002
2/5/2002
2/19/2002
3/5/2002
3/19/2002
4/2/2002
4/16/2002
4/30/2002
5/14/2002
5/28/2002
6/11/2002
6/25/2002
7/9/2002
7/23/2002
8/6/2002
8/20/2002
9/3/2002
9/17/2002
10/1/2002
10/15/2002
10/29/2002


Grove Creek
Ortho Phosphorus (mg/L)
Flow (cfs)
Date
OP
Flow
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
200.00
180.00
160.00
140.00
120.00
100.00
80.00
60.00
40.00
20.00
0.00
5/1/2001
5/15/2001
5/29/2001
6/12/2001
6/26/2001
7/10/2001
7/24/2001
8/7/2001
8/21/2001
9/4/2001
9/18/2001
10/2/2001
10/16/2001
10/30/2001
11/13/2001
11/27/2001
12/11/2001
12/25/2001
1/8/2002
1/22/2002
2/5/2002
2/19/2002
3/5/2002
3/19/2002
4/2/2002
4/16/2002
4/30/2002
5/14/2002
5/28/2002
6/11/2002
6/25/2002
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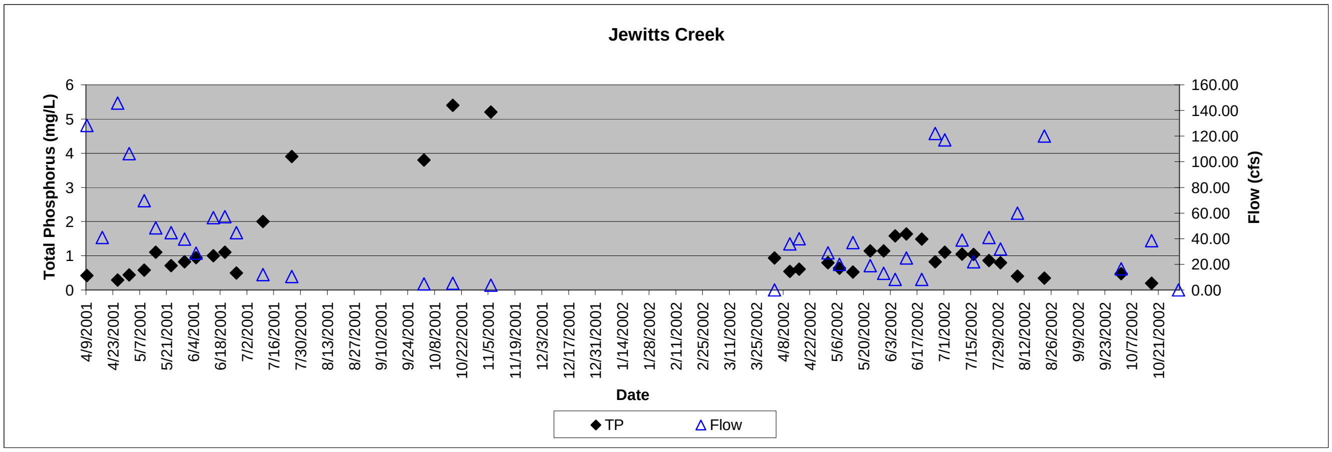
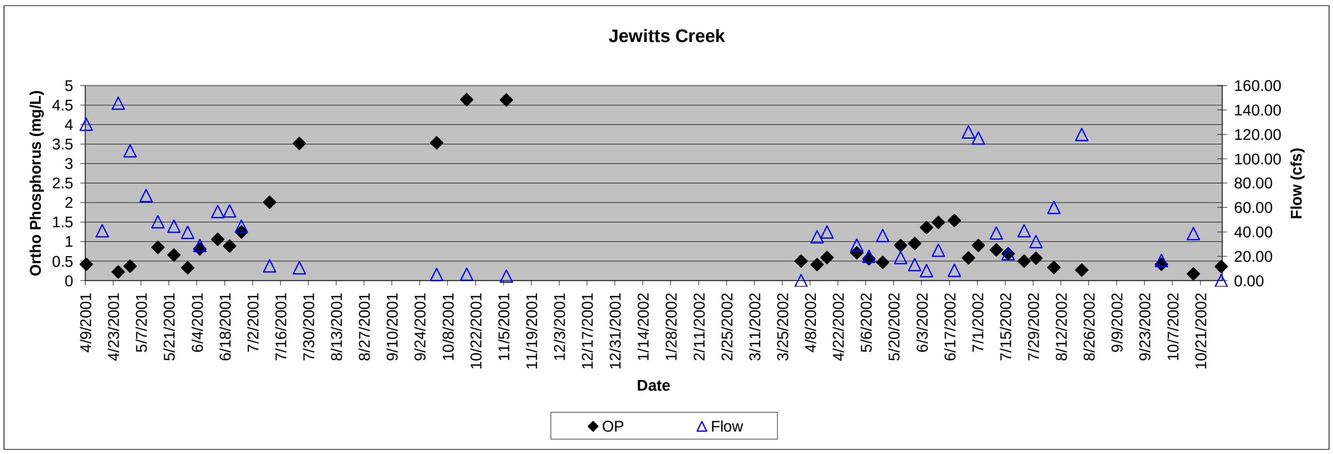
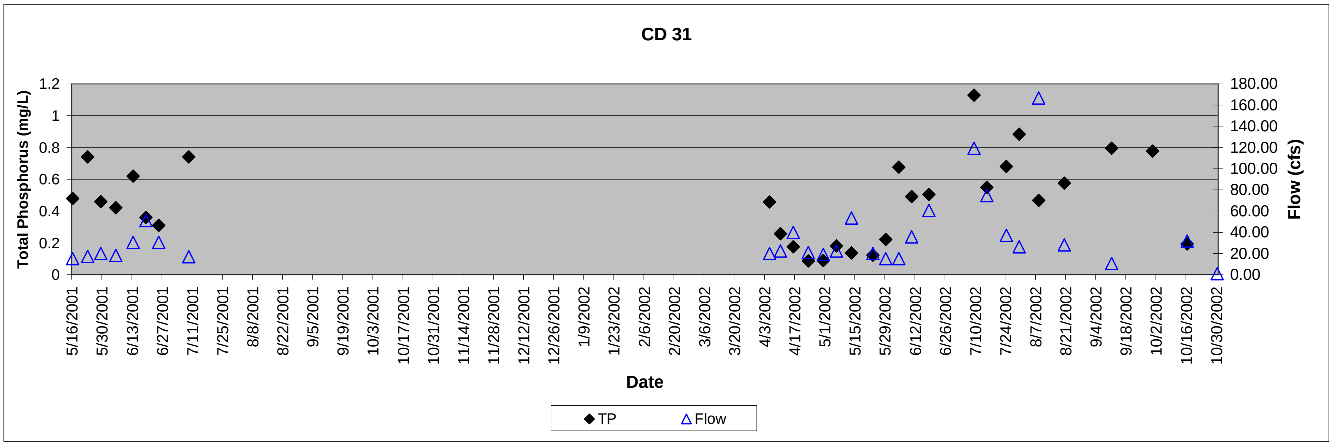
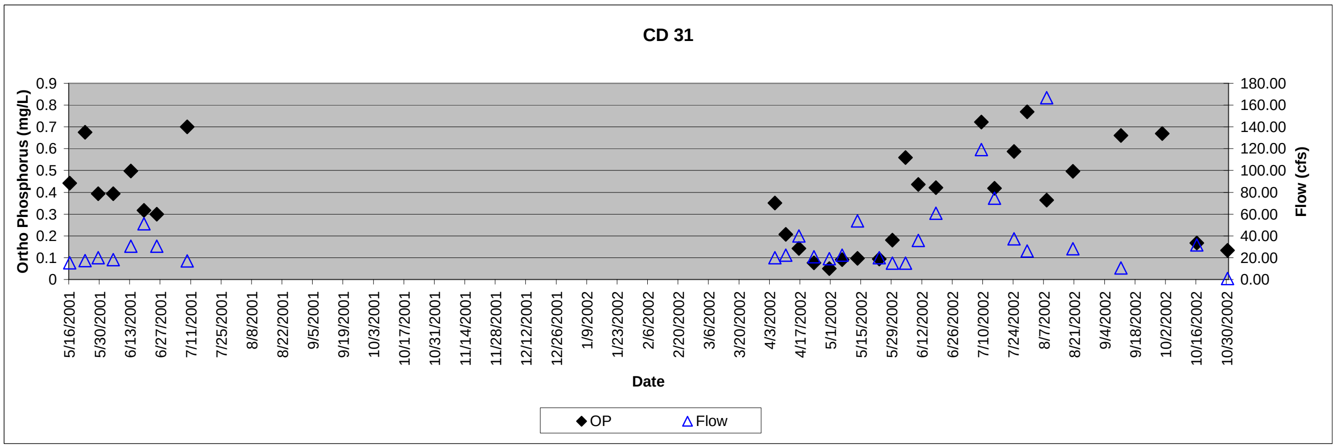
9/17/2002
10/1/2002
10/15/2002
10/29/2002


Jewitts Creek
Total Phosphorus (mg/L)
Flow (cfs)
Date
TP
Flow

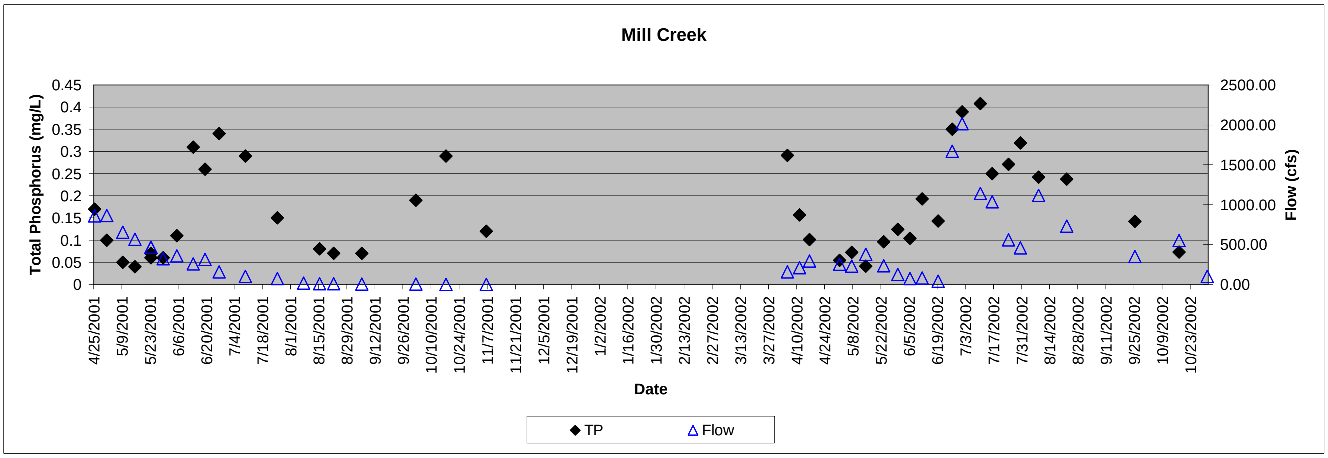

Jewitts Creek
Ortho Phosphorus (mg/L)
Flow (cfs)
Date
OP
Flow

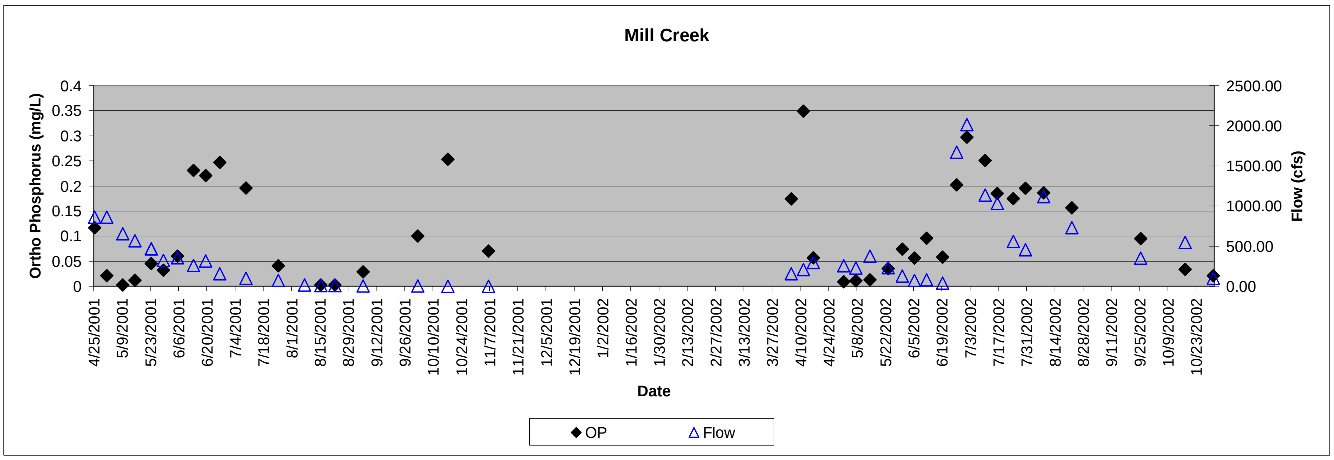


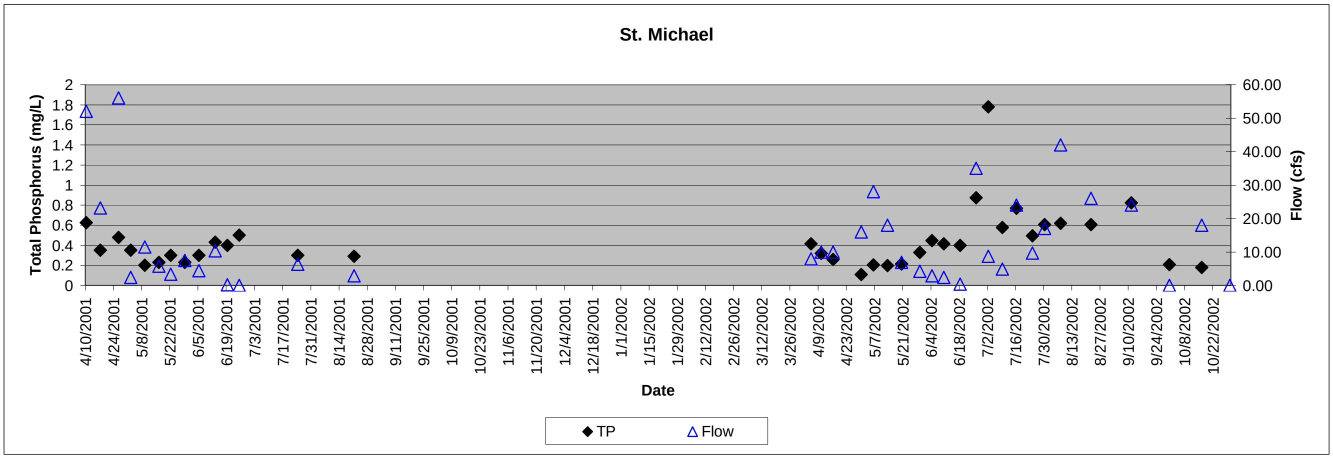
CD 31
Total Phosphorus (mg/L)
Flow (cfs)
Date
TP
Flow

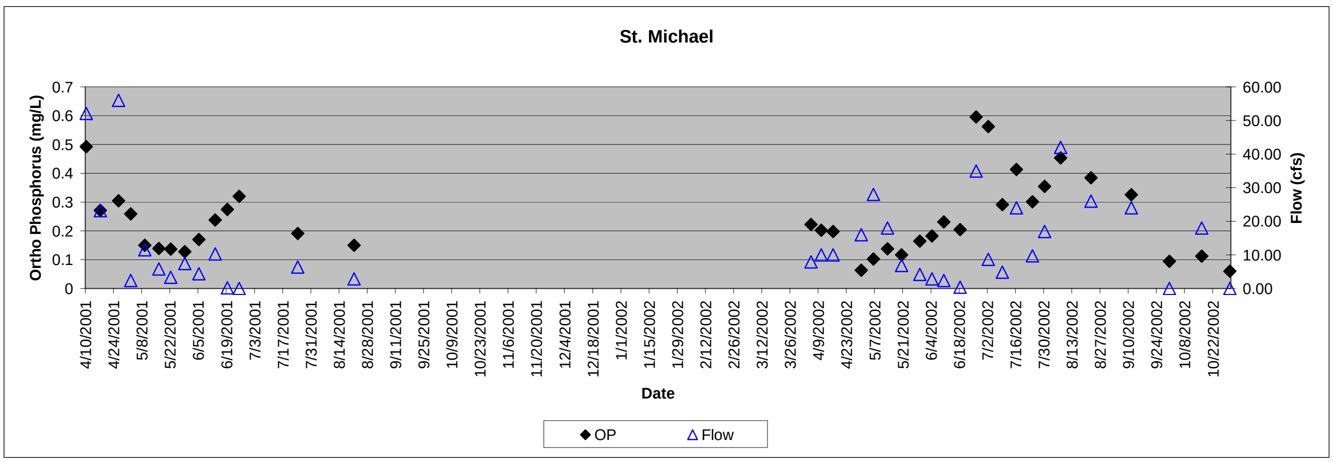


CD 31
Ortho Phosphorus (mg/L)
Flow (cfs)
Date
OP
Flow


Mill Creek
Total Phosphorus (mg/L)
Flow (cfs)
Date
TP
Flow


Mill Creek
Ortho Phosphorus (mg/L)
Flow (cfs)
Date
OP
Flow


St. Michael
Total Phosphorus (mg/L)
Flow (cfs)
Date
TP
Flow


St. Michael
Ortho Phosphorus (mg/L)
Flow (cfs)
Date
OP
Flow

APPENDIX D: HSPF MODEL INFORMATION

HSPF MODEL DESCRIPTION

Hydrologic Simulation Program – FORTRAN (HSPF) is the successor to the Stanford Watershed model, developed by Crawford and Linsley at Stanford in the 1960's. It incorporates many hydrological processes and hundreds of variables (Rahman and Salbe, 1995). HSPF assigns a set of variables to each unique land segment, and routes the water to a stream. Area, slope, and surface characteristics are used to define land segments.

HSPF uses three sets of algorithms, depending on the type of land use. Segments are categorized as either pervious, impervious, or water body (reach). The algorithms in these categories differ in the manner in which water is routed, sediment deposited or scoured, and contaminants mixed. Point sources can be input at specified reach locations, to be routed and mixed with the NPS runoff.

The pervious overland surface runoff module is called PERLAND. The impervious overland surface runoff module is called IMPLAND. These two modules both simulate the runoff of spatially-distributed rainfall into receiving water bodies, or reaches. These will be the key modules in this project, and used to quantify the amount of runoff from each tributary to the main stem of the North Fork Crow River.

Every variable in each of the processes can be output at time steps as small as seconds, and thus any variable can be compared with measured data. This provides the opportunity to study individual processes at a variety of temporal resolutions. This also makes calibration of the model very complex. All variables in HSPF have a range at which they are physically reasonable, allowing calibration of almost all parameters. This leads to a difficult task of assigning values to a large number of variables (USEPA 2000), further complicating the calibration process. Because of this, the USEPA supplies a default data set, which has an approximate value for each variable based on studies around the world. The EPA has also released a reference tutorial recommending calibration techniques for the pervious runoff based on sensitivity studies (USEPA 2002d). This document offers scenarios that indicate the most important variables, so that modelers can focus on measuring and calibrating typically less than a dozen variables.

WinHSPF is an adaptation of HSPF, which provides a graphical user interface and uses an updated version of HSPF (version 12). It is included in a water resources modeling package distributed for free by the USEPA called BASINS.

BASINS stands for *B*etter *A*ssessment *S*cience *I*ntegrating point and *N*on-point *S*ource pollution. It contains the SWAT, Qual2e, PLOAD, and WinHSPF models, centering around a geographical information system (GIS) in an ArcView environment (USEPA 2002e).

Rahman, M., and Salbe, I. (1995). Modeling Impacts of Diffuse and Point Source Nutrients on the Water Quality of South Creek Catchment. *Environmental International*, vol. 21, No.5, pgs 597-603

USDA. (2002). *Soil and water assessment tool* [www document] (USDA, accessed 2002); http://www.brc.tamus.edu/swat/swatdoc.html

USEPA. (2002d). *Calibration Scenarios* [www document] (USEPA, accessed 2002); http://www.epa.gov/waterscience/ftp/basins/training/tutorial/scenario.htm

USEPA. (2002e). *BASINS 3* [www document] (USEPA, accessed 2002); http://www.epa.gov/ost/basins/