Dissolved Oxygen TMDL for the Souris River in Renville and Burke Counties, North Dakota

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1.0 INTRODUCTION AND DESCRIPTION OF THE WATERSHED

The Souris, or Mouse, River originates in the Yellow Grass Marshes north of Weyburn, Saskatchewan, Canada, and flows southeast, crossing the northern boundary of North Dakota west of Sherwood, North Dakota. It then forms a loop and flows back north, entering Manitoba, Canada near Westhope, North Dakota. The river eventually flows into the Assiniboine River near Brandon, Manitoba (Figure1). A map of the entire Souris River watershed can be found in Appendix C. Flow in the upper Souris River is regulated by three reservoirs in Canada (Boundary Reservoir, 48,990 acre-ft; Rafferty Reservoir, 356,400 acre-ft; and Alameda Reservoir, 85,560 acre-ft). Total reservoir capacity is about 490,000 acre-ft. Some diversions for irrigation and municipal supply exist on the river.

The Total Maximum Daily Load (TMDL) listed segment (ND-09010001-001-S_00) of this river is located in Renville County and the northeast portion of Burke County. It consists of 43.4 miles of the Souris River from the border with Saskatchewan, Canada to Lake Darling in North Dakota (Figure 2). Its watershed has an area of approximately 109,103 acres inside the United States (Figure 3). Limited data for the Canadian portion of this watershed is available. Table 1 summarizes some of the geographical, hydrological and physical characteristics of this TMDL listed segment of the Souris River.

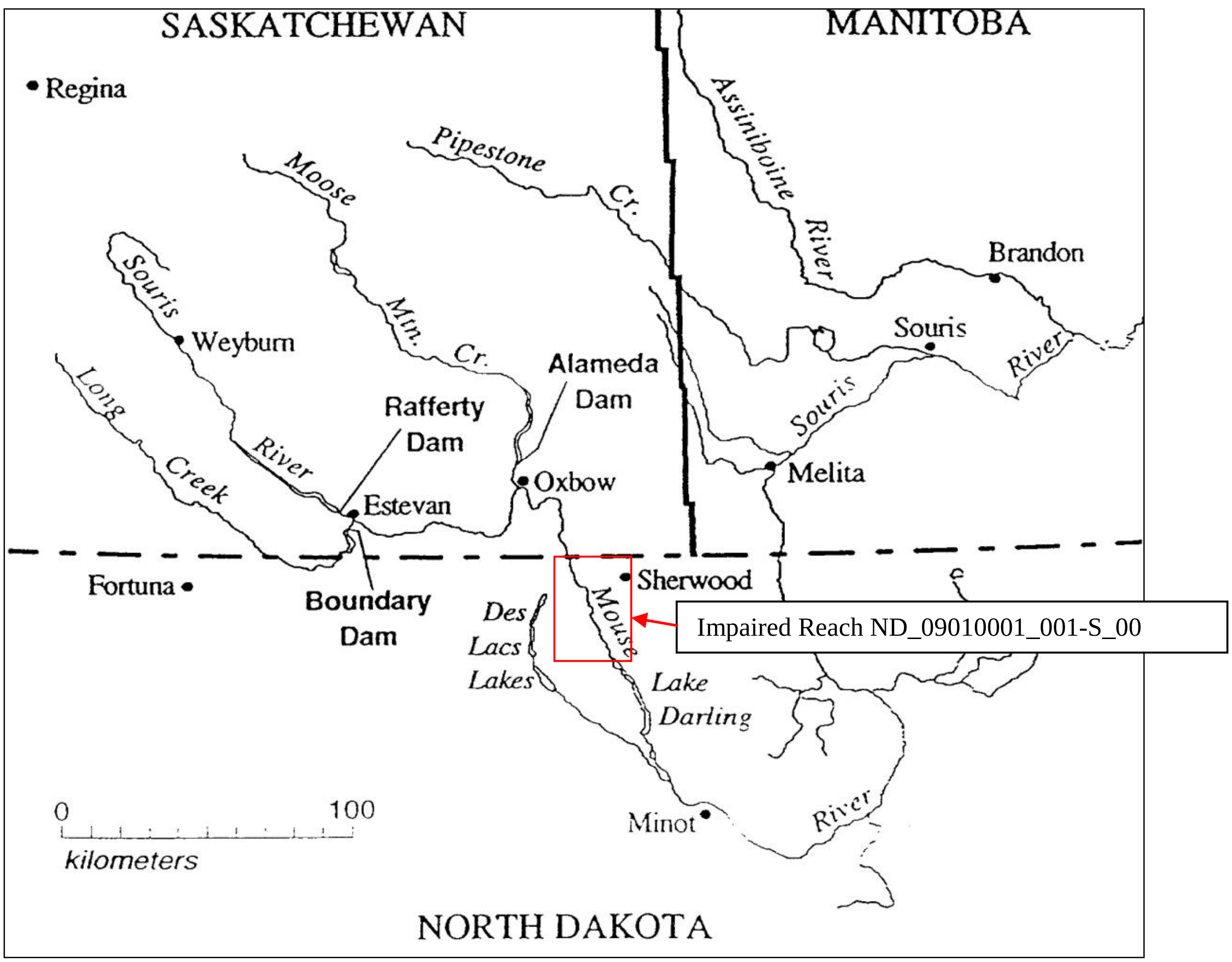

Figure 1. Souris River and TMDL Impaired Reach.

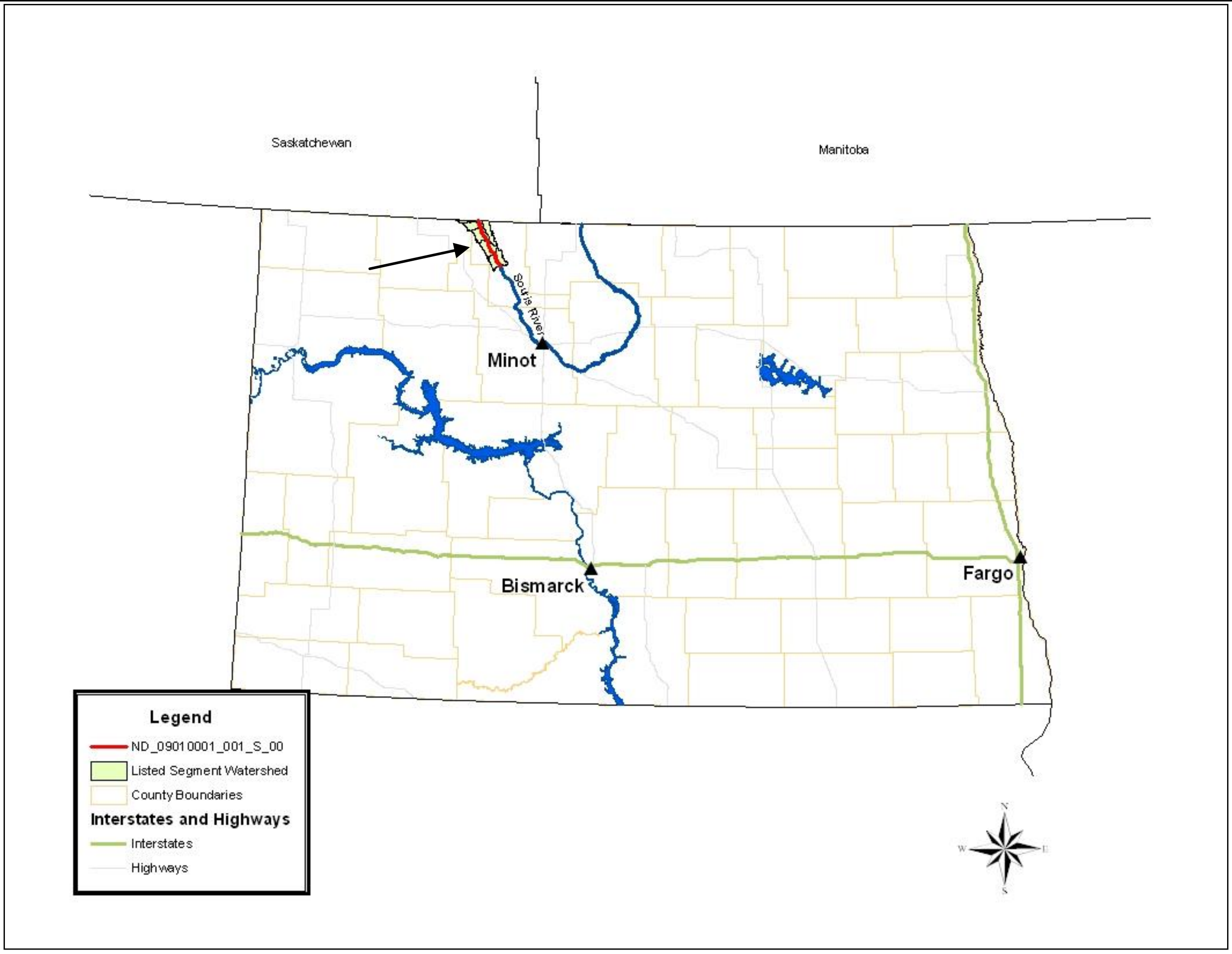

Figure 2. Location of Souris River in North Dakota.

Table 1. General Characteristics of the Souris River and Its Watershed.

Legal Name	Souris (Mouse) River[1]
Stream Classification	Class IA
Major Drainage Basin	Souris (Mouse) River[1]
8 Digit HUC	09010001
County	Renville and Burke Counties, ND
Eco-region	Level III: Northern Glaciated Plains - 46 Level IV: Northern Black Prairie – 46g
Watershed Area	109,103.72 acres
River Miles	43.4 miles

[1] Recent local legislation passed that determined the river shall be called Mouse River on all identifiable signs. It is also known as the Souris River in Canada and too many state and federal agencies within North Dakota

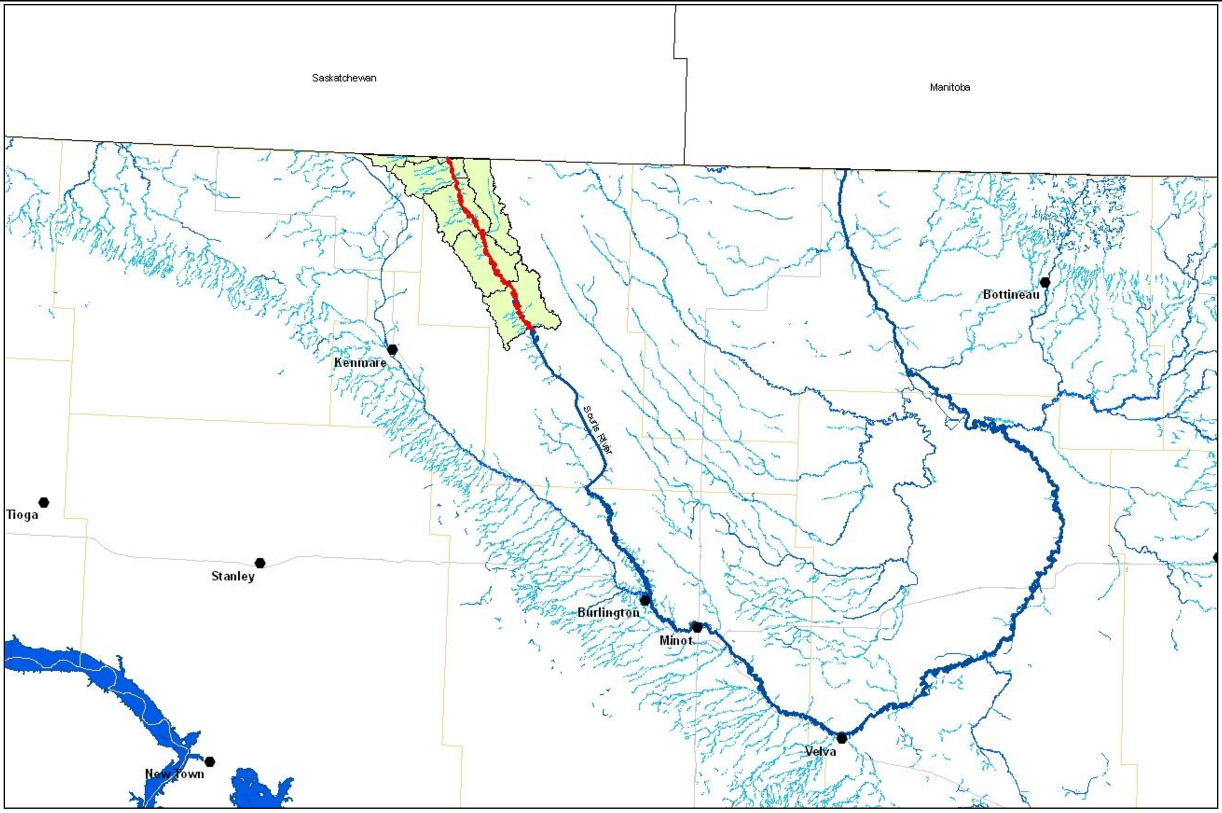

Figure 3. Location of the TMDL Listed Segment of the Souris River and Its Watershed.

1.1 Clean Water Act Section 303(d) Listing Information

Based on the 2010 Section 303(d) list of impaired waters needing TMDLs, the North Dakota Department of Health (NDDoH) has identified segment ND-09010001-001-S_00 of the Souris River as fully supporting, but threatened for fish and other aquatic life beneficial use due low dissolved oxygen concentrations. It is also listed as fully supporting, but threatened for fish and other aquatic life beneficial use due to sedimentation and fully supporting, but threatened for recreation beneficial use due to fecal coliform bacteria.

Table 2. 2010 Section 303(d) TMDL Listing Information for Souris River, Assessment Unit ID ND-09010001-001-S_00 (NDDoH, 2010).

Assessment Unit ID	ND-09010001-001-S_00
Waterbody Description	Souris River from the Saskatechewan, Canada border downstream to Lake Darling. Located in Renville County and a portion of NE Burke County.
Size	43.4 miles
Impaired Designated Use	Fish and Aquatic Life
Use Support	Fully Supporting, but Threatened
Impairment	Low Dissolved Oxygen
TMDL Priority	High

The recreation impairment due to fecal coliform bacteria has been addressed in a separate TMDL, while the aquatic life impairment due to sedimentation/siltation will need to be address in a future TMDL report. The results of this dissolved oxygen TMDL report have also identified nutrients as contributing to the organic enrichment impairment resulting in low dissolved oxygen. As the NDDoH develops and implements nutrient criteria for rivers and streams, it is likely a nutrient TMDL will also be required for the Souris River.

1.2 Ecoregions/Land Cover

This segment of the Souris River watershed lies within the Northern Black Prairie level IV ecoregion (46g) (Figure 4) which belongs to the Northern Glaciated Plains level III ecoregion.

Within the Northern Glaciated Plains level III ecoregion, the subhumid conditions foster a grassland transition between the tall and short grass prairie. High concentrations of temporary and seasonal wetlands are found throughout the region. Additionally, the Northern Black Prairie level IV ecoregion represents a broad phenological transition zone marking the introduction of boreal influence in climate from the north. Aspen and birch appear in wooded areas, willows grow on wetland perimeters, and rough fescue becomes evident in grassland associations. This ecoregion has the shortest growing season and lowest January temperatures of any level IV ecoregion in the Dakotas.

This watershed is characterized as glaciated and generally flat, with occasional “washboard” undulations. High concentrations of temporary and seasonal wetlands are present and the drainage pattern is simple. Surficial material consists of glacial till over Cretaceous Pierre Shale. The soils present belong to the Order Mollisols and are typically Barnes, Svea, Hamerly, Cresbard, Buse, and Parnell. Though the till soil is very fertile, agricultural success is subject to annual climatic fluctuations (USEPA, et al. 1998). Elevation in the watershed ranges from 1,500 to 1,970 msl (USGS, 2006).

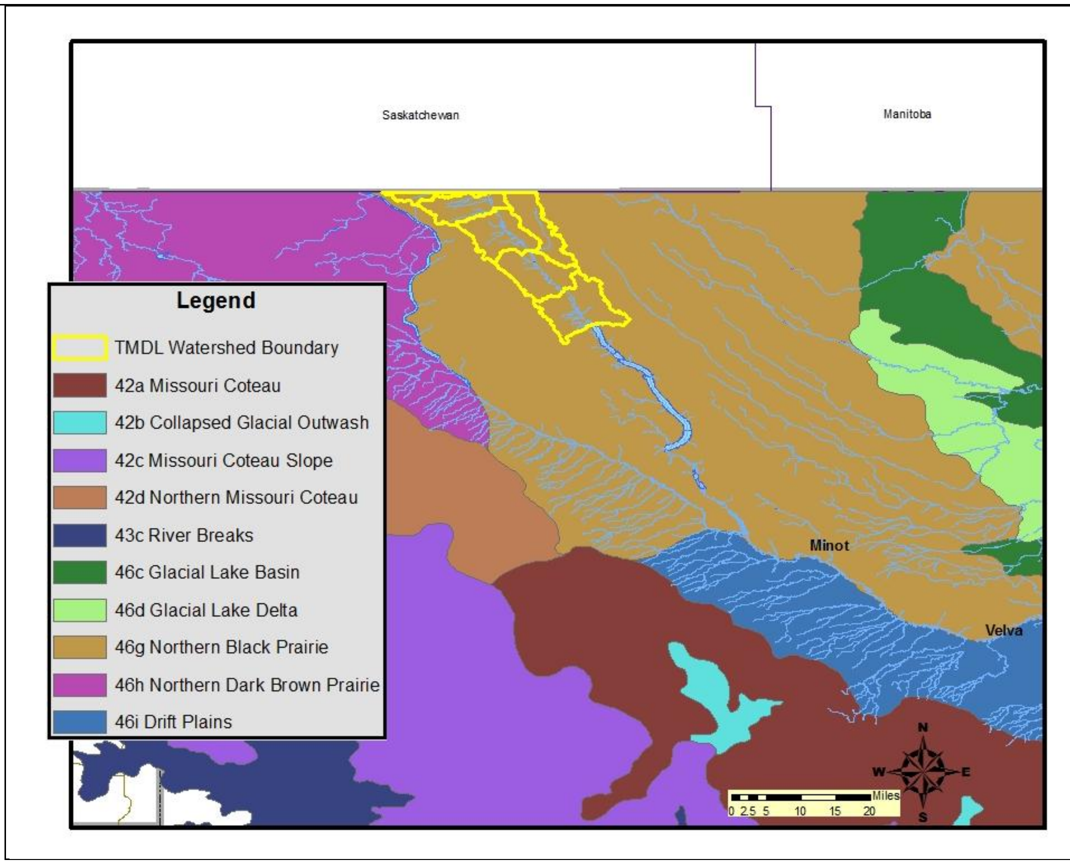

Figure 4. Level IV Ecoregions for the Souris River TMDL Watershed.

1.3 Land Use

Land use data from the North Dakota Agricultural Statistics Service (NDASS, 2006) indicates that the North Dakota portion of the watershed is primarily agricultural (70.47 percent), consisting of crop production and livestock grazing. Forty-nine percent of the agricultural land is actively cultivated, tilled mainly for durum, spring wheat, and other small grains, but including a variety of crops. Twenty-one percent is in pasture/range/haylands. Water and woods make up over eighteen percent of the watershed (Tables 3 and 4, Figure 5). There are two permitted animal feeding operations (AFOs) (one medium and one small) which allow zero discharge and no confined animal feeding operations (CAFOs) within the contributing US drainage. The number of non-permitted animal feeding operations within the watershed is unknown, but is believed to be significant (see also Section 1.5.7 Other Data).

Table 3. Major Land Use Categories in the Section 303(d) Listed Souris River Watershed (based on 2006 NASS data).

Major Category	Acres	Percent of Watershed
Agriculture/Cultivated	53,923.6	49.43
Pasture/Range/Hay	22,955.2	21.04
Barren/Fallow	1,257.9	1.15
Urban/Roads	10,778.6	9.88
Water	18,298.8	16.77
Woods	1,889.6	1.73

Table 4. Land Use Types in the Section 303 (d) Listed Souris River Watershed (based on 2006 NASS data).

Land Use Type	Acres	Percent of Watershed
Winter Wheat	635.07	0.58
Durum/SpringWheat	35,576.44	32.61
Rye/Oats/Other Small Grains	6,744.44	6.18
Beans/Peas/Lentils	2,456.67	2.26
Sunflowers	1,400.70	1.28
Corn	860.14	0.79
Oil Seeds	6,250.12	5.73
Barren/Fallow	1,257.91	1.15
Alfalfa	409.33	0.37
Pasture/Grass/CRP	22,545.85	20.67
Water	18,298.86	16.77
Woods	1,889.59	1.73
Urban/Roads	10,778.60	9.88
TOTAL	109,103.72	100

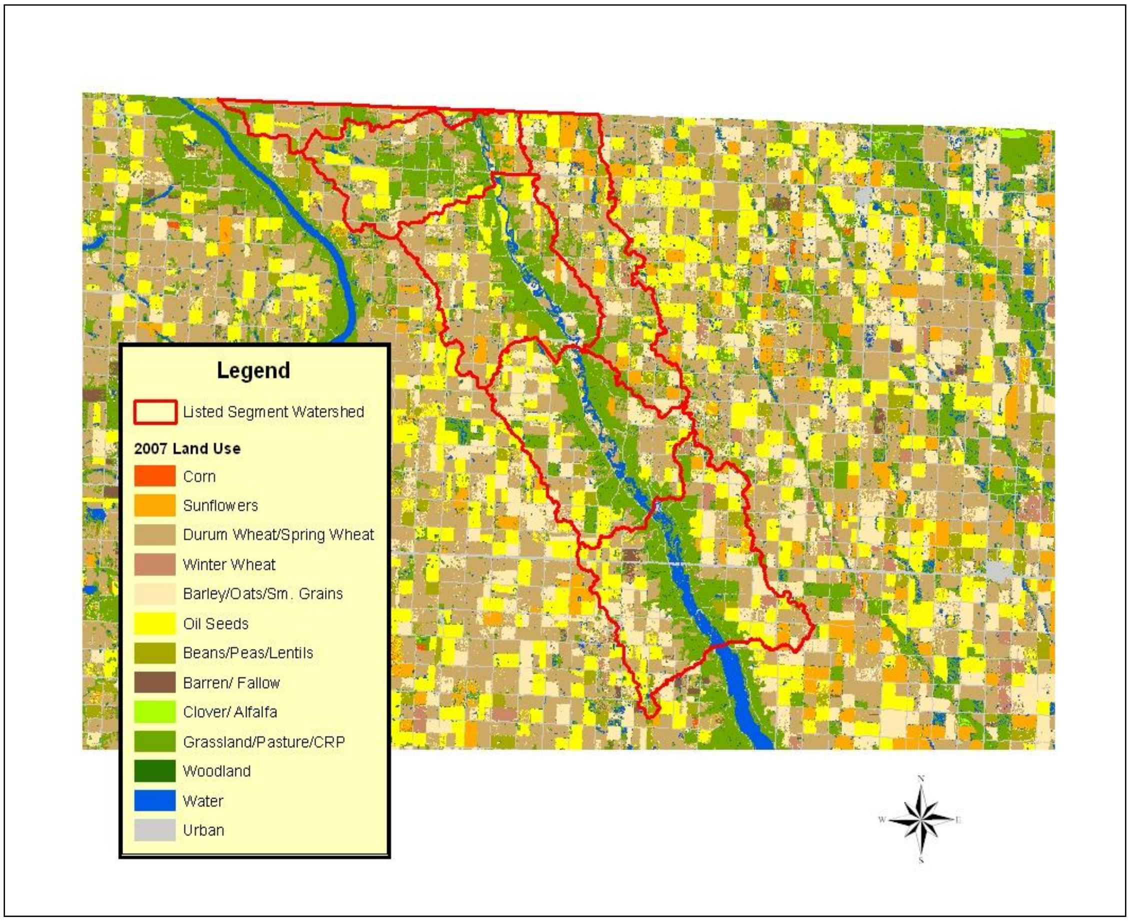

Figure 5. Land Use Map for the Souris River Watershed (NDASS, 2006).

1.4 Climate and Precipitation

North Dakota's climate is characterized by large temperature variation across all time scales, light to moderate irregular precipitation, plentiful sunshine, low humidity, and nearly continuous wind. Its location at the geographic center of North America results in a strong continental climate, which is exacerbated by the mountains to the west. There are no barriers to the north or south so a combination of cold, dry air masses originating in the far north and warm humid air masses originating in the tropical regions regularly flow over the state. Movement of these air masses and their associated fronts cause near continuous wind and often result in large day to day temperature fluctuations in all seasons. The average last freeze in spring occurs in late May. In the fall, the first 32 degree or lower temperature occurs between September 10^{th} and 25^{th}. However, freezing temperatures have occurred as late as mid-June and as early as mid-August. About 75 percent of the annual precipitation falls during the period of April to September, with 50 to 60 percent occurring between April and July. Most of the summer rainfall is produced during thunderstorms, which occur on an average of 25 to 35 days per year. On the average, rains occur once every three or four days during the summer. Winter snowpack, although persistent from December through March, only averages around 15 inches (Enz, 2003). Historical average precipitation data for the climate station at Mohall, ND, which is within the watershed, were obtained from the High Plains Regional Climate Center (HPRCC) and can be seen in Figure 6.

Average yearly air temperatures at the Mohall North Dakota Agricultural Weather Network (NDAWN) station, located within the Souris River watershed, were 42^{o} F(2006) and 40^{o} F(2007), with an average wind speed of 9 mph. Average annual precipitation ranges from 7.89 inches (2006) to 11.07 inches (2007) (NDAWN, 2009). Figure 7 shows the monthly precipitation totals for 2006 and 2007.

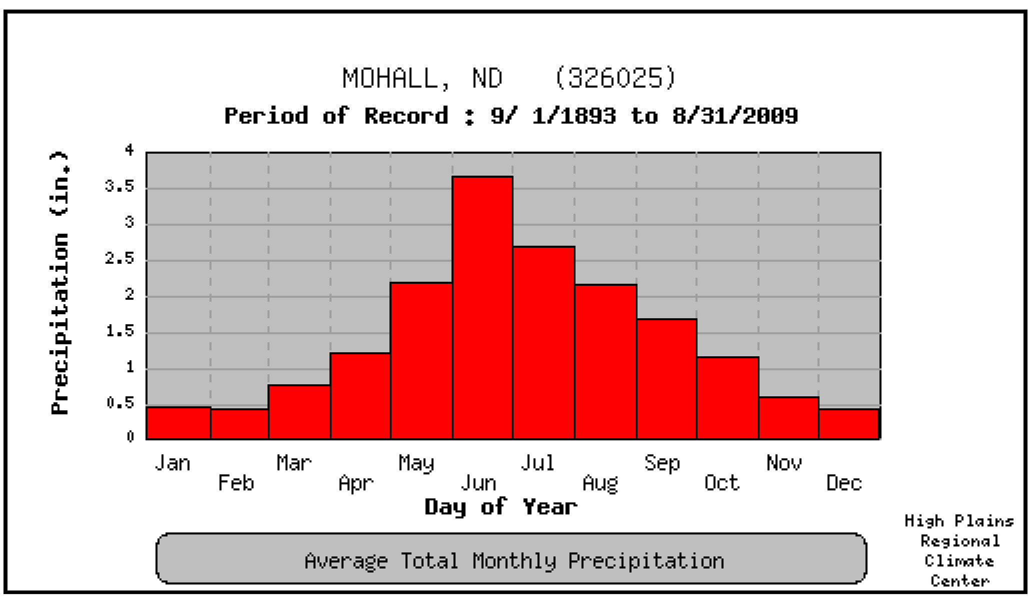

Figure 6. Average Total Monthly Precipitation Data for HPRCC Mohall Station 326025, 1893 – 2009.

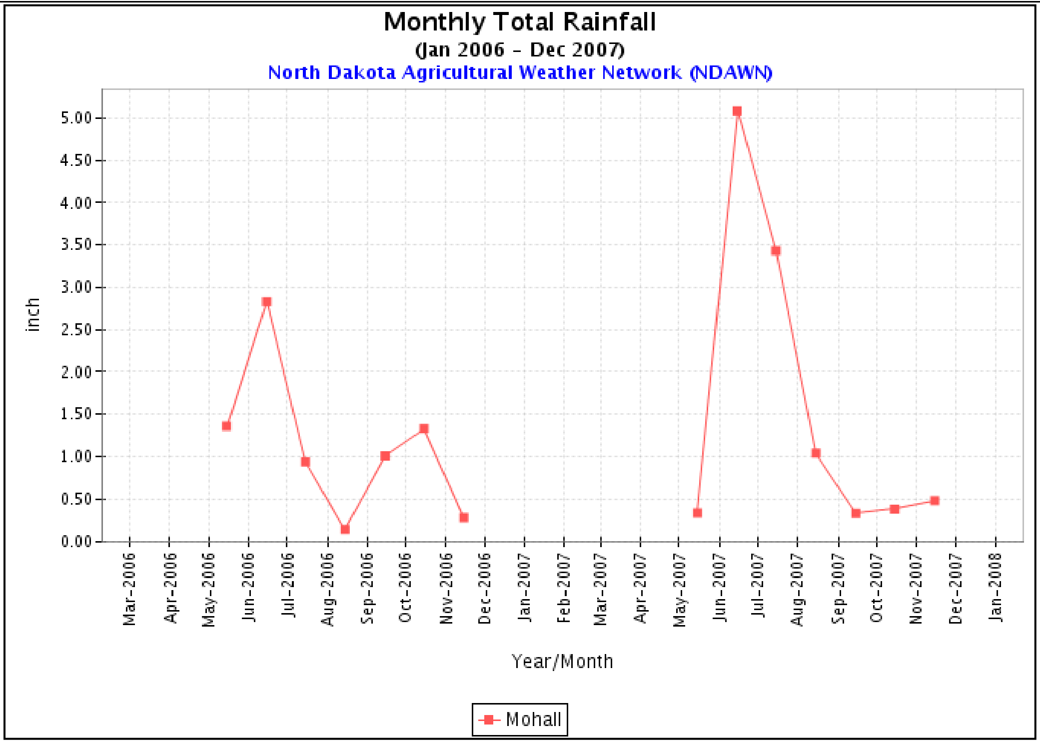

Figure 7. Rainfall Amounts at the North Dakota Agricultural Weather Network (NDAWN) Mohall Station, 2006-2007.

1.5 Available Data

Five sites (four in North Dakota and one upstream in Saskatchewan, Canada) were sampled along the Souris River from October, 2006 through September, 2007(Figure 8, Table 5). There is a U.S.Geological Survey (USGS) stream gauging station (05114000) located approximately 14 miles west of Sherwood, North Dakota, near the United States/Canada border.

Table 5. Sampling Site Summary.

Site Name	Site STORET Number	Site USGS Gauging Station Number	Country of Location
Highway 9	**30 miles upstream from Glen Ewen**		Canada
Glen Ewen	385404		Canada
USGS Sherwood		05114000	United States
County Road 2 Bridge	380091		United States
Stafford Bridge	385403		United States
Johnson Bridge	385402		United States
County Road 3 Bridge	385220		United States

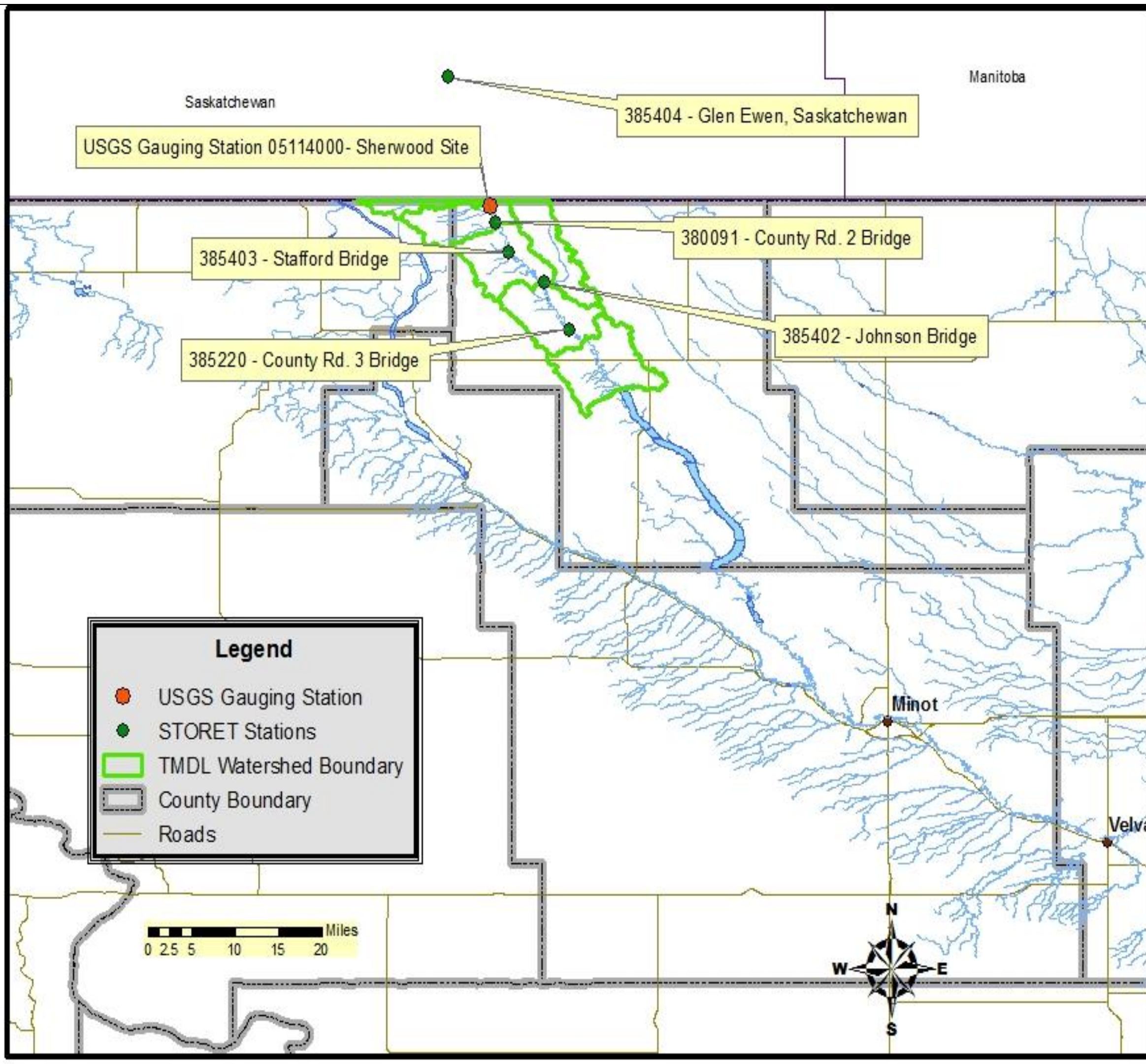

Figure 8. Location of Water Quality Sampling Sites and USGS Gauging Station for the TMDL Listed Segment ND-09010001-001-S_00.

1.5.1 Dissolved Oxygen Data

Historical Data (1994 – 2004):
Data collected from USGS Gauging Station 5114000 between August 1994 and September 2004 were analyzed for variation of dissolved oxygen (DO) levels in the Souris River (Figure 9). Generally, the DO measurements were taken at this gauging station on a monthly basis; however, fewer samples were taken during the winter months. From 1994 to 1999, a total of 115 DO samples were taken, of which 13 data points (11.3 percent) show DO level less than the minimum standard level of 5 mg/L. The lowest readings of DO were recorded on March 6, 2003 (1 mg/L) and February 15, 2001 (1.6 mg/L). These results confirmed impairment as classified by the Health Department of North Dakota.

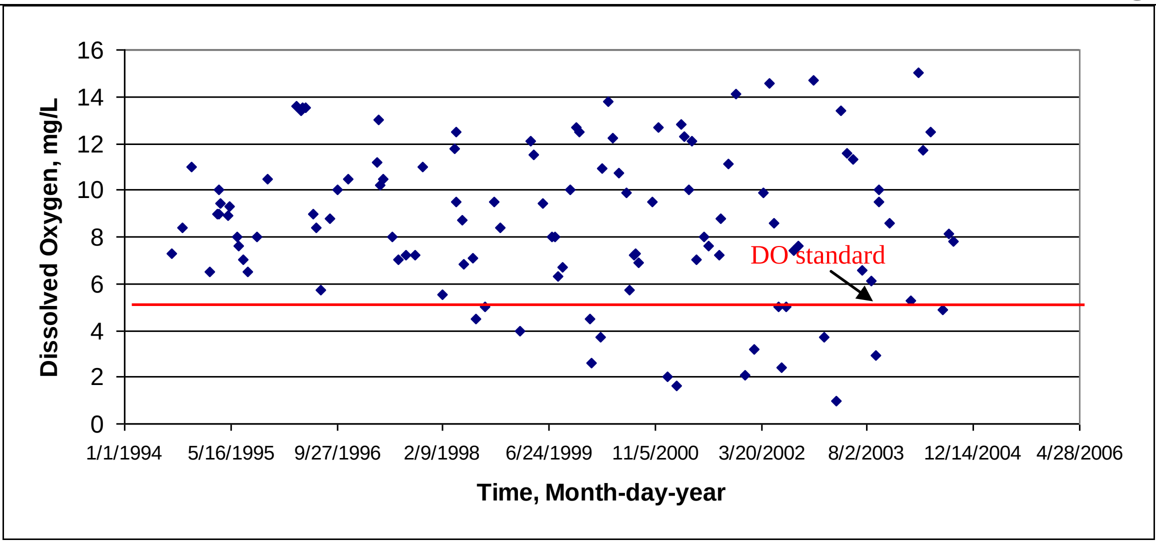

Figure 9. Dissolved Oxygen Levels in the Souris River 1994-2006 USGS Gauging Station (05114000) near Sherwood, ND (Lin et al., 2007).

In Figure 10, DO concentration is plotted versus flow rate with winter data highlighted in red squares. This shows that most low DO readings were recorded during winter months when the river is covered by ice and flow was low.

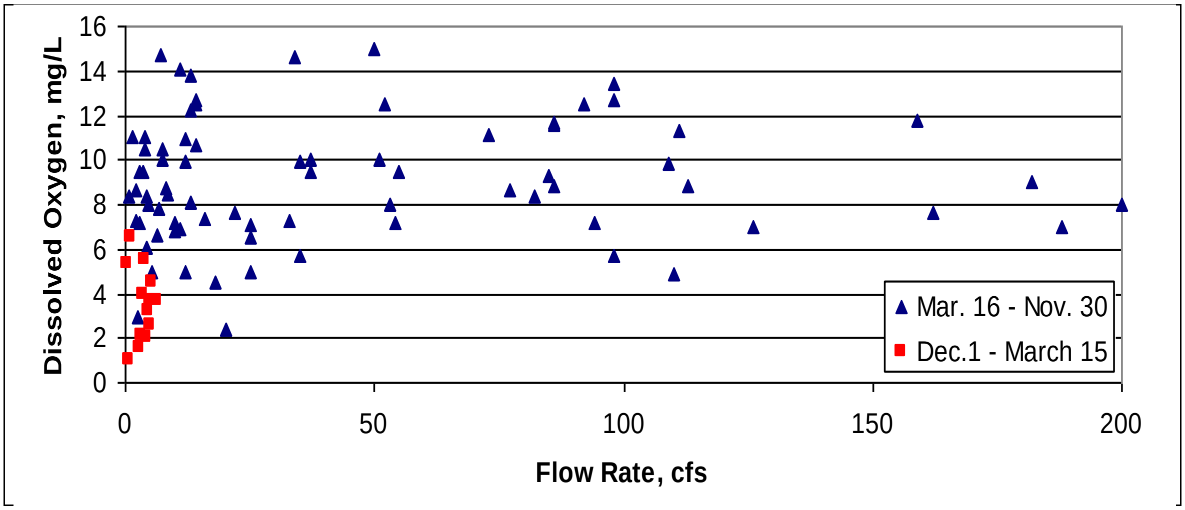

Figure 10. Flow Compared with DO near Sherwood (380091), ND 1994-2006. (Lin et al., 2007).

Fish kills are usually an indicator of low dissolved oxygen in the water column. When oxygen levels drop below 5 mg/L, warm water species, like those found on the Souris River, become highly stressed. A fish kill event occurred in February 1999 in the Souris River in North Dakota. Low dissolved oxygen and high levels of ammonia were noticed at Mouse River Park near the head of Lake Darling. Fish kills also occurred in 2002, 2003, and 2004 (Kellow and Fewless, 2002). It can be difficult to assign a specific cause and effect relationship to fish kills; quick action is needed to determine why a particular event took place. In the winter the timeframe of a fish kill is difficult to ascertain. Fish kills primarily serve as an event indicating a problem and prompting further study.

Current Data (2006-2007):

Dissolved oxygen results were above the standard DO level of 5 mg/L except for two time intervals within the sampling period of record. The first low DO period was between December and March 2007. The second low DO interval was between June and July 2007. Dissolved oxygen results were very consistent in the five sampling points throughout the reach. Figure 11 displays the field dissolved oxygen measurements for the entire study time and reach interval.

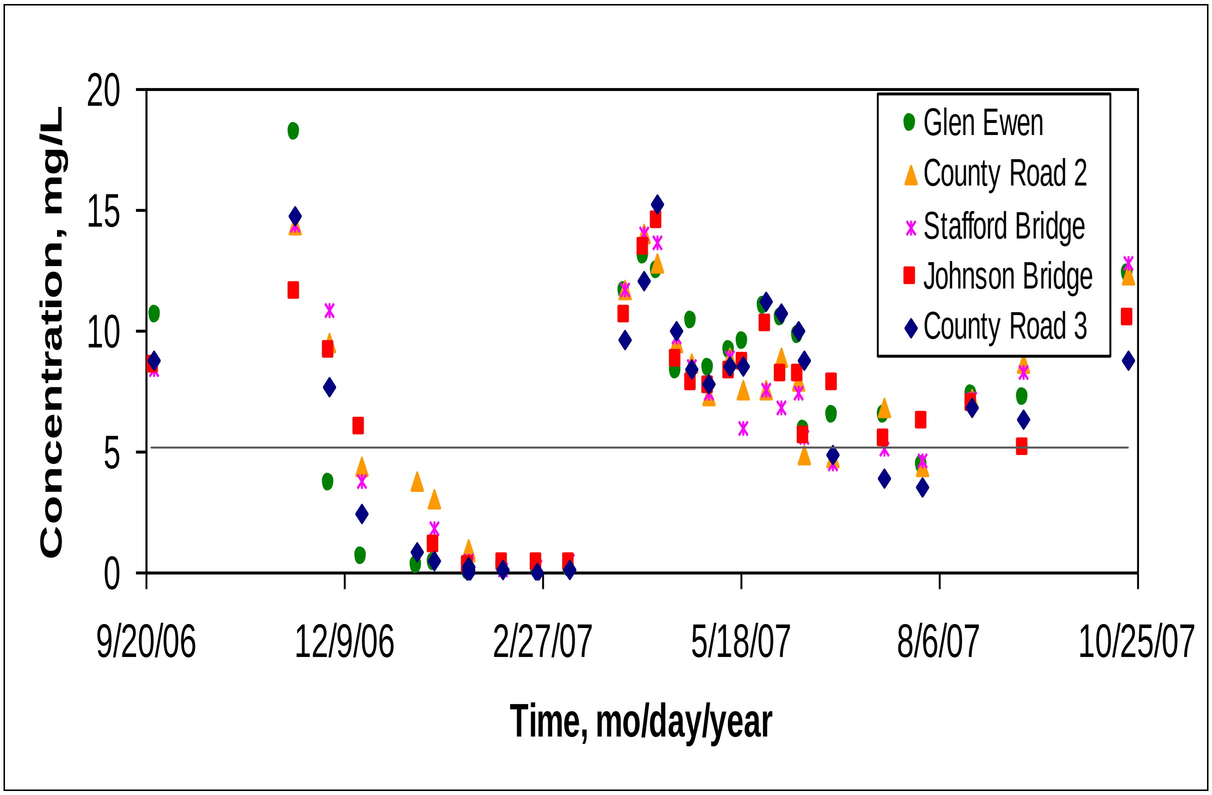

Figure 11. Dissolved Oxygen Concentrations for Five Sampling Sites (Lin et al., 2010).

Two declining periods shown in Figure 11 precede the DO deficits on the Souris River in 2006-2007. The first and most severe deficit occurred in December, and coincided with the formation of ice on the river. The period of dangerously low DO lasted nearly three months from December to March of 2007. Dissolved oxygen levels returned to acceptable levels with the increase in flow and “ice out”. On March 10, 2007 there was still approximately one foot of ice cover and on April 1, 2007 little to no ice cover existed. Re-aeration occurred very quickly following ice out, when DO levels rebounded to approximately 10 mg/L. Data from the USGS site (05114000) is provided in Figure 12.

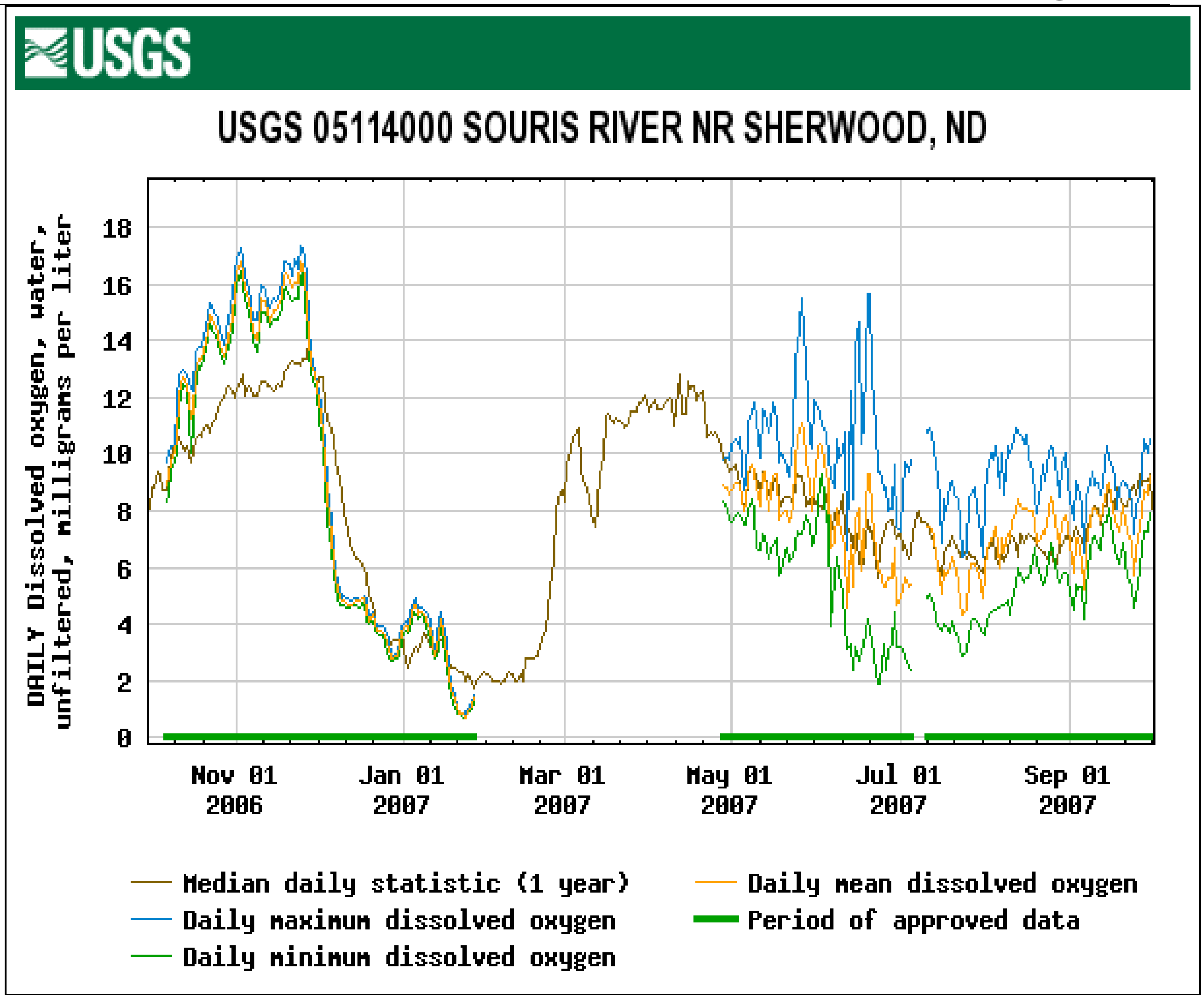

Figure 12. Maximum and Minimum DO, Sherwood Automatic Sampler (USGS, 2009).

The USGS gauging station located near the Canadian border automatically monitors the river 24 hours a day. Figure 13 shows a prominent 24-hour variation of dissolved oxygen in June 2007. The values in Figure 13 are for one 7-day period for the Souris River and vary from week to week. Note the high amplitude in the diurnal variation.

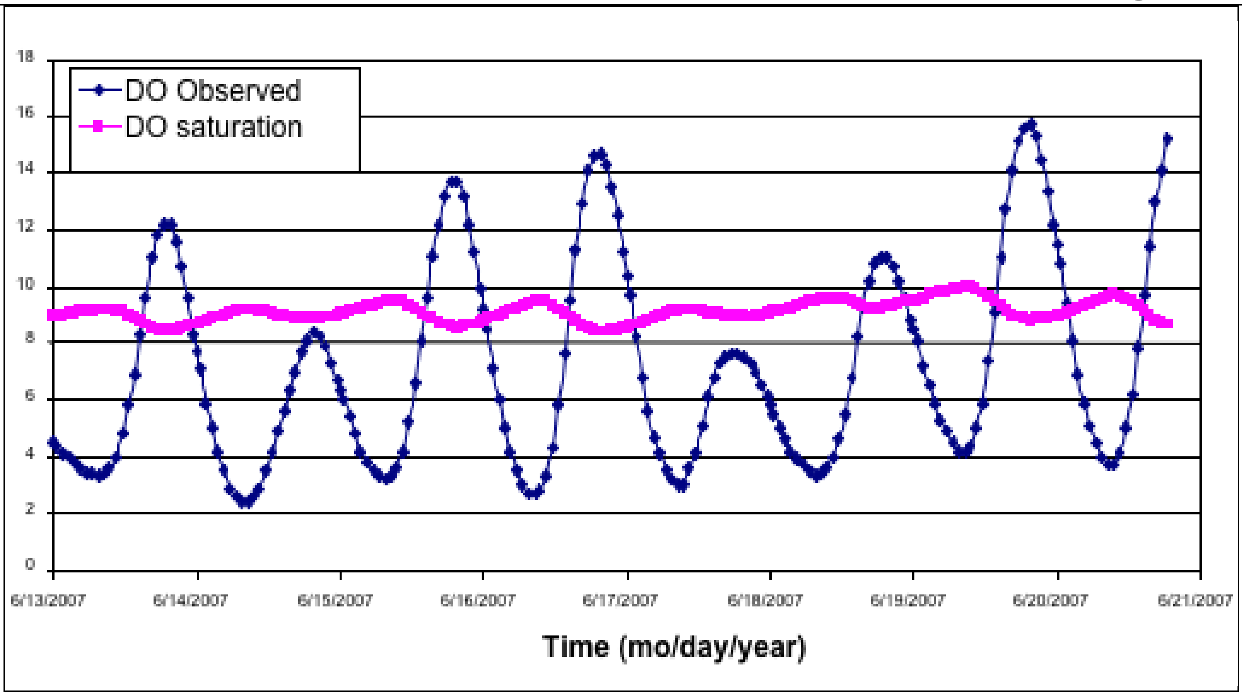

Figure 13. Diurnal Dissolved Oxygen Variation at USGS Gauging Station 05114000 (USGS, 2009).

1.5.2 Nutrients

Historical Data (1971-1992)
Canadian water input greatly influences the upstream water flow rate and its quality on the impaired reach. Water quality data for a station approximately 30 river miles upstream from Glen Ewen (385404) for the period of record 1971 to 1992, was obtained from the Saskatchewan Watershed Authority (Figure 14). High total phosphorus concentrations occur, with more than 90 percent of the samples exceeding the interim North Dakota state standards limit of 0.1 mg/L (ND Century Code, 2001). Phosphorus concentrations as high as 2 mg/L have been reported in Saskatchewan, Canada (Saskatchewan Watershed Authority, 2005). Water quality at County Road 2 site (380091), the NDDoH site nearest US/CAN border, met ammonia and nitrate-nitrogen standards most of the time. Phosphorus concentrations consistently exceed the interim guideline value.

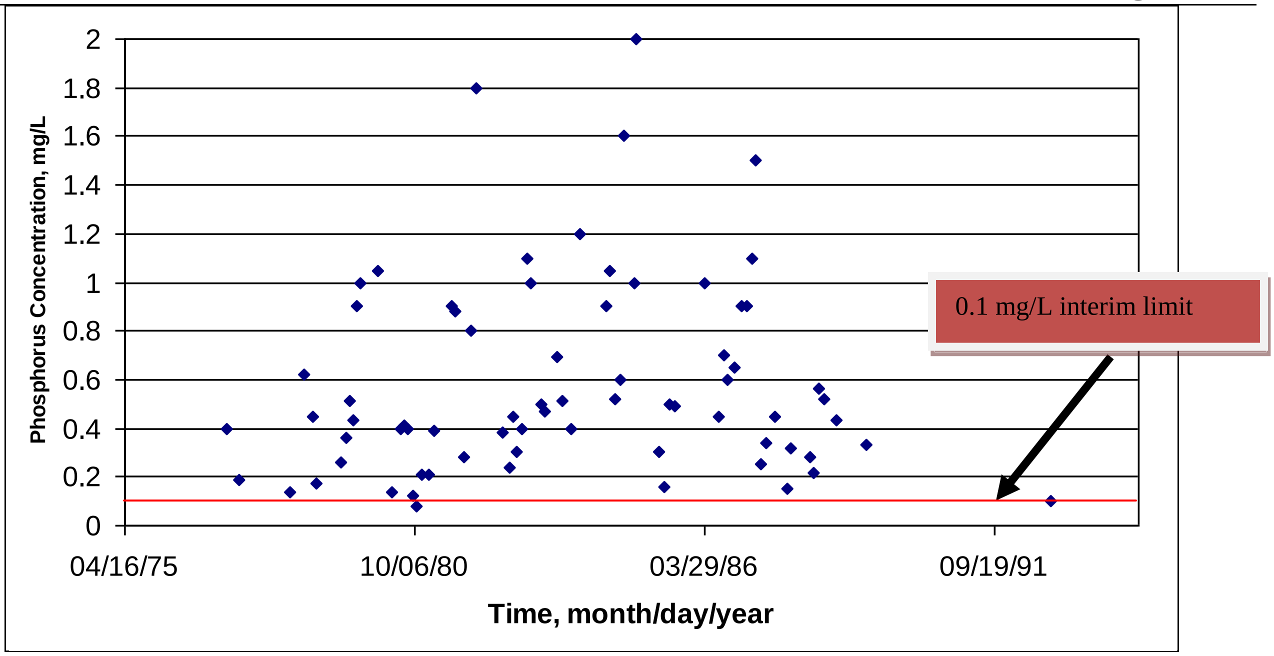

Figure 14. Souris River Phosphorus Concentrations at Highway 9, 30 Miles Upstream of Glen Ewen (385404), 1974-1986 (Saskatchewan Water Authority, 2005).

Current Data (2006-2007):
Data collected in this study show that elevated levels of phosphorus (Figure 15) in the impaired reach (ND-09010001-001-S_00) are consistent with historic data. Phosphorous levels from the site nearest the USGS station, County Road 2 (Figure 16) compare directly with the increase in diurnal variation of maximum/minimum DO levels indicated by Figure 13.

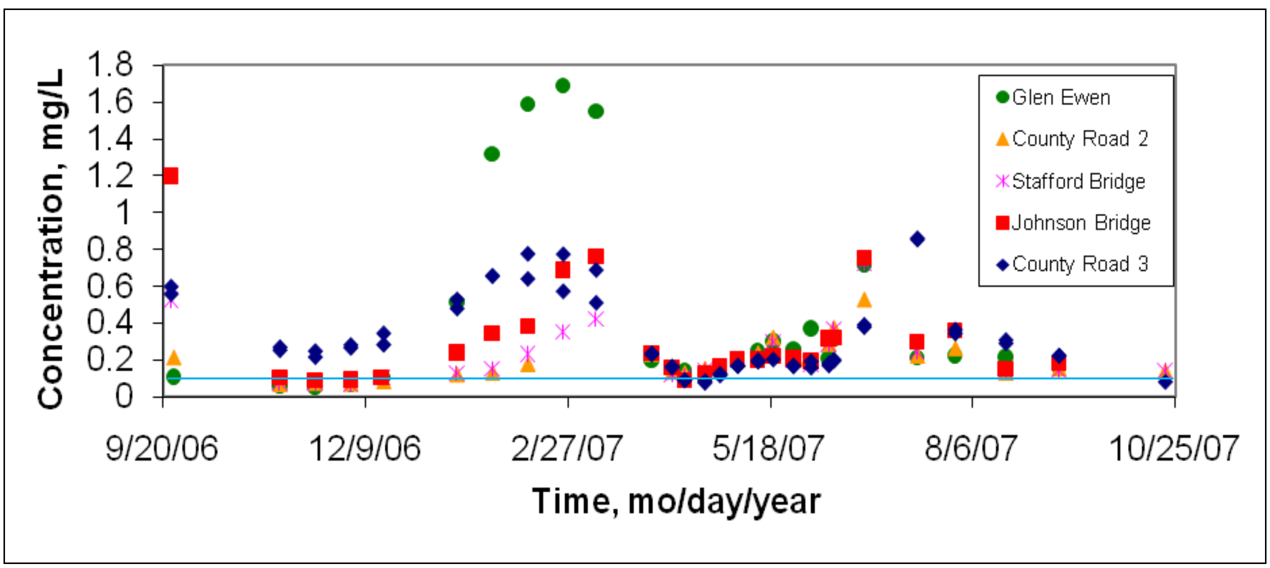

Figure 15. Phosphorus Levels on Impaired Reach ND-09010001-001-S_00 (Lin et al., 2010).

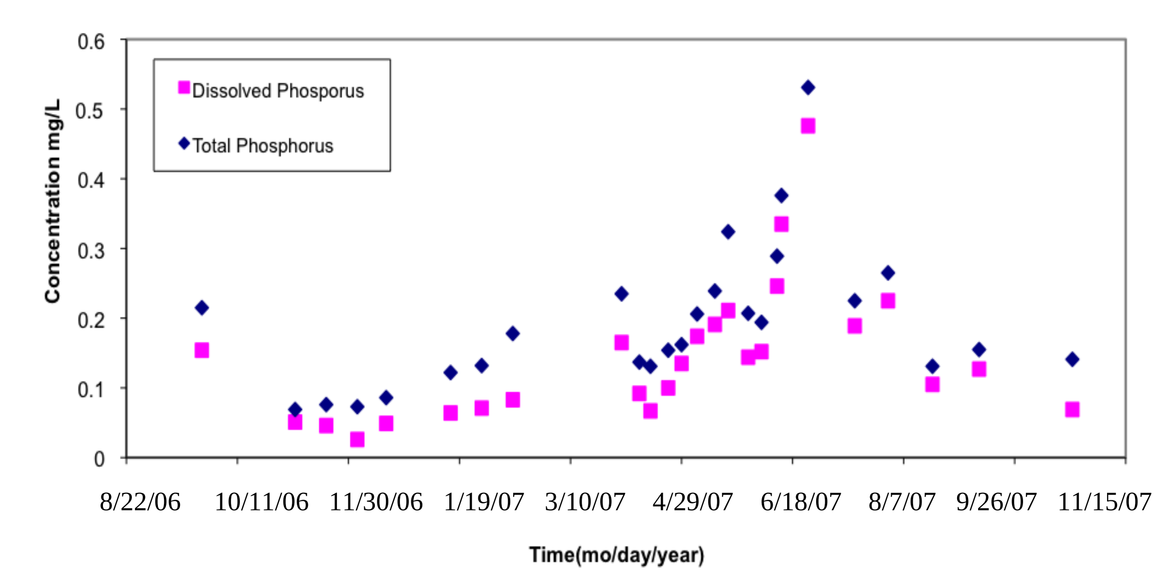

Figure 16. Phosphorous Levels at County Road 2 (380091) (Lin et al., 2010).

1.5.3 Sediment Oxygen Demand

Sediment oxygen demand (SOD) is a possible oxygen depleting source. An observation of the sediment during field visits indicated sediments were black in color and smelled of H_2S, which can be a sign of the sediment having a high percentage of organic material. Following this observation, sediment samples were gathered at each site for analysis in the lab by graduate student Matt Baker. Five of these sites are displayed in Figure 17.

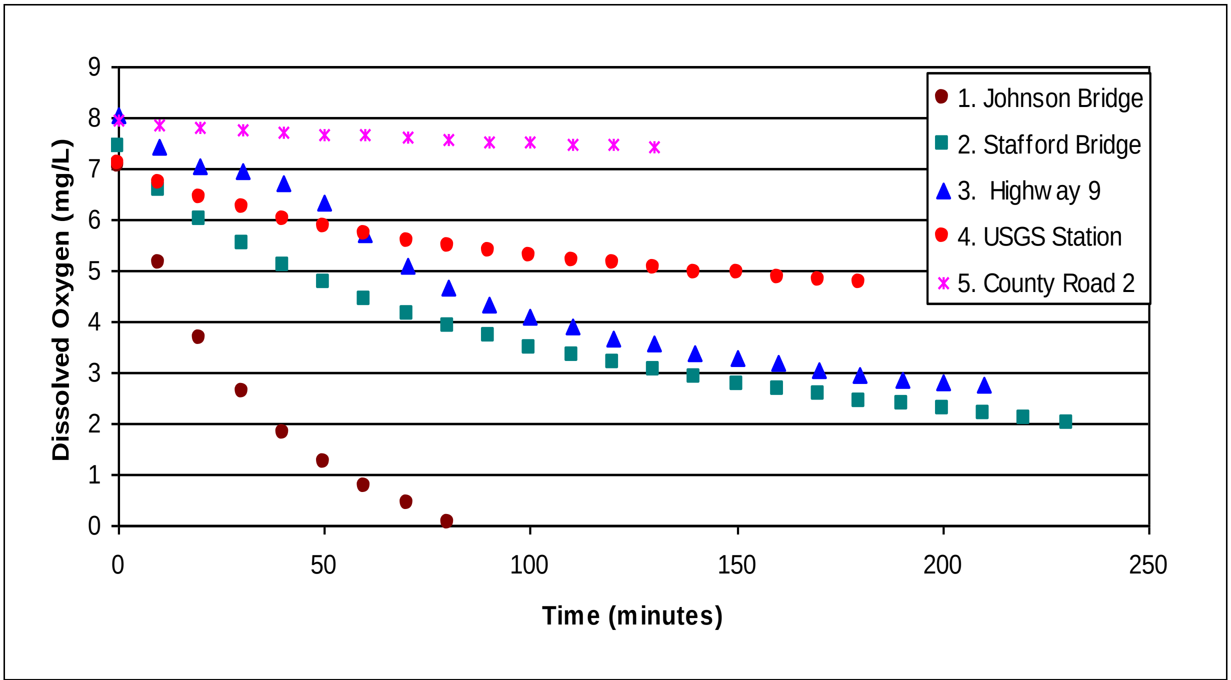

Figure 17: Oxygen Depletion from Sediment in Completely Mixed Reactors (Lin et al., 2010).

Characteristics of the sediment tested are displayed in Table 6. The higher the organic content in the soil, the faster oxygen is depleted. The sites with lower percent organics consisted more of rocky and sandy sediment while the higher percent organic sediments were black in color and made up of finer material. The higher percent organic soil was found where the water was deeper and wider. Lower velocity water allows sediments to settle out in larger pools. Oxygen depletion tests on sediment were conducted by using a completely mixed method.

Table 6. Characteristics of Sediment Samples .

Site	Site Location	% Organic	Coarse Composition Observed
Hwy 9	Upstream	9.45	Very Little Coarse (twigs)
USGS		6.1	No Coarse Retained
County 2		2.61	Mostly Coarse Aggregate
Stafford		13.23	Little to no Coarse
Johnson	Downstream	14.91	Algae and Plant remains

1.5.4 Macroinvertebrates

In addition to the water quality sites, four sites were sampled for macroinvertebrates. Three of the four sites correspond to the water quality sites (Table 7). In order to interpret these biological data and to develop a biological assessment methodology, the NDDoH has adopted the "multi-metric" index approach to assess biological integrity or aquatic-life use support for rivers and streams. The multi-metric index approach assumes that various measures of the biological community (e.g., species richness, species composition, trophic structure, and individual health) respond to human-induced stressors (e.g., pollutant loadings or habitat alterations). Each measure of the biological community, termed a "metric," is evaluated and scored on either a 1-, 3-, 5-point scale (fish) or on a scale of 0-100 (macroinvertebrates). The higher the score, the better will be the biological condition and, presumably, the lower the pollutant or habitat impact.

Currently the multi-metric IBI for the Souris River Basin of the Northern Glaciated Plains (46) level III ecoregion is under development. However, enough data has been compiled and analyzed to allow a general interpretation of the IBI scores for the Souris River (Table 8).

Table 7: IBI Scores for the Souris River, 2007.

Macro Station ID	Corresponding WQ Site ID	Final IBI Score	Biological Integrity Class	Aquatic Life Designated Use
552059	385404	58	Poor	Not Supporting
552057	None	8	Poor	Not Supporting
552036	380091	24	Poor	Not Supporting
552053	385403	24	Poor	Not Supporting

Table 8: IBI Threshold Condition Values for the Northern Glaciated Plains Ecoregion(46).

Good - Fully Supporting	Fair - Supporting	Poor - Not Supporting
25th Percentile or $\geq$ 70 IBI	$\leq$ 69 IBI and $\geq$ 59 IBI	10th Percentile or $\leq$ 58 IBI

1.5.5 Stream Cross Sections

Cross sections were surveyed at four of the five sampling sites (385404, 385403, 385402, 385220) in order to record accurate flow and show river bottom changes (Figure 18). County Road 2 site (380091) was not surveyed since past USGS testing data exists.

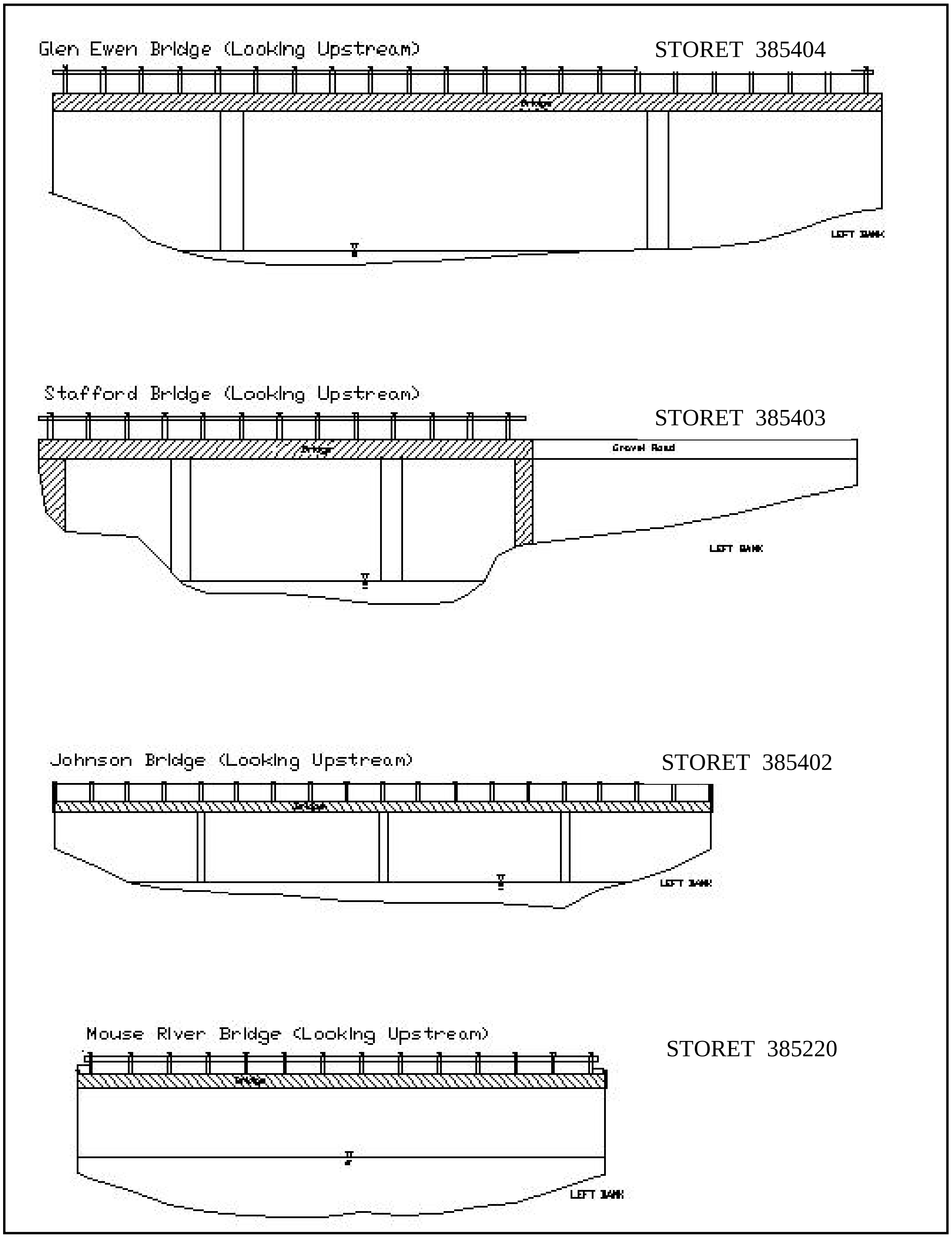

Figure 18. Surveyed Profiles of Selected Sampling Sites (385404, 385403, 385402, 385220).

1.5.6 Hydraulic Discharge

Flow in the upper reach of the Souris River is regulated by three reservoirs in Canada: the Boundary, Rafferty, and Alameda Reservoirs (Figure 19). Constructed by the Rafferty-Alameda Project (1988-1995), these reservoirs provide water to users in the area, as well as flood protection for residents downstream, including those in North Dakota. Water releases are governed in accordance with the Boundary Waters Treaty and determined by the International Souris River Board of Control (ISRB), under the International Joint Commission.

Specifically, "the Province of Saskatchewan shall have the right to divert, store, and use waters which originate in the Saskatchewan portion of the Souris River basin, provided that such diversion, storage, and use shall not diminish the annual flow of the river at the Sherwood Crossing more than fifty percent of that which would have occurred in the state of nature, as calculated by the Board. For the benefit of riparian users of water between the Sherwood Crossing and the upstream end of Lake Darling, the Province of Saskatchewan shall so far as practicable regulate its diversions, storage, and sues in such as manner that the flow in the Souris River channel at the Sherwood Crossing shall not be less than 0.113 cubic meters per second (four cubic feet per second) when that much flow would have occurred under conditions of water use development prevailing in the Saskatchewan portion of the Souris River basin prior to construction of the Boundary Dam, Rafferty Dam, and Alameda Dam" (ISRB, 1992). The ISRB has established numeric fecal coliform bacteria objectives for water crossing the boundary (see Section 2.3).

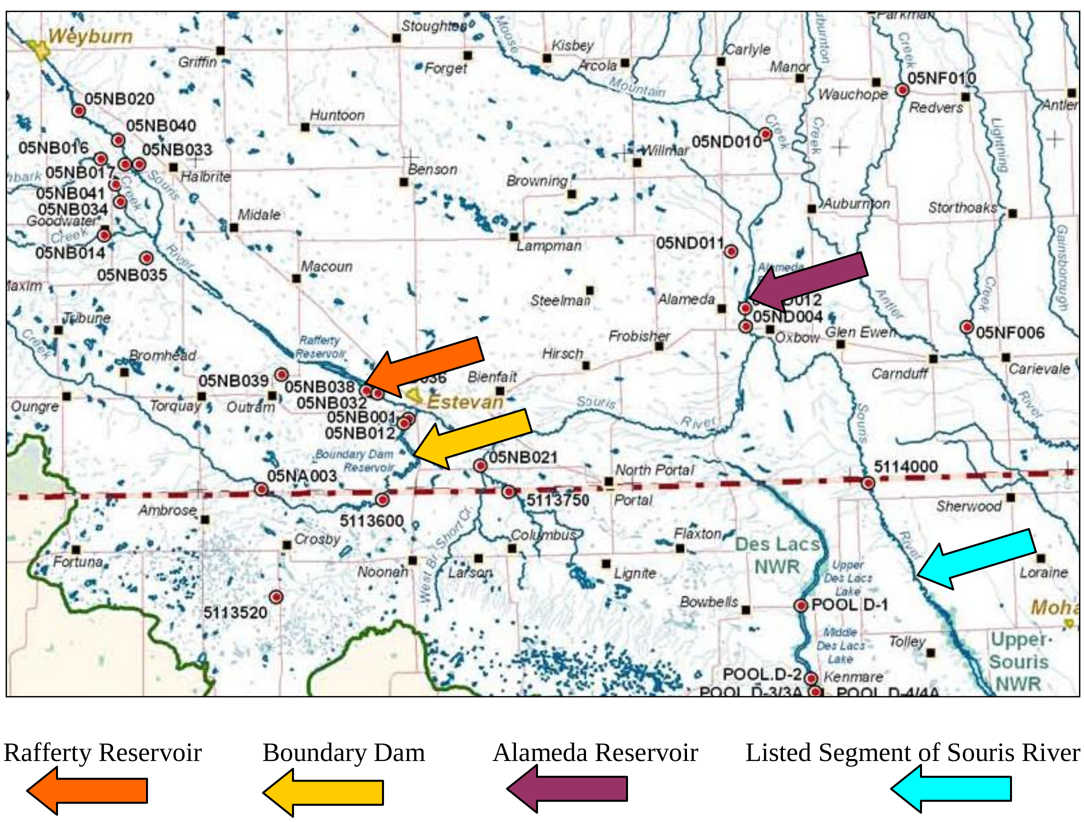

Figure 19. Location of Canadian Reservoirs Controlling Souris River Flow.

The discharge record from USGS site 05114000 was chosen to represent the entire listed reach (ND-09010001-001-S_00). For this immediate watershed in North Dakota, there are no major tributaries or streams flowing into the Souris River. As such, it has been determined that flow is similar (i.e. not gaining or losing) all along the 43.4-mile TMDL listed reach. Because of the effect the upstream reservoirs have on flow, only the flow record from 1991, the date the first reservoir, Rafferty, was completed, to present were used in the construction of the flow and load duration curves. For comparison, flows prior to reservoir construction (1931 to 1991) and after reservoir construction (1991 to 2010) are illustrated in Figure 20. Discharge for the sampling period is show in Figure 21.

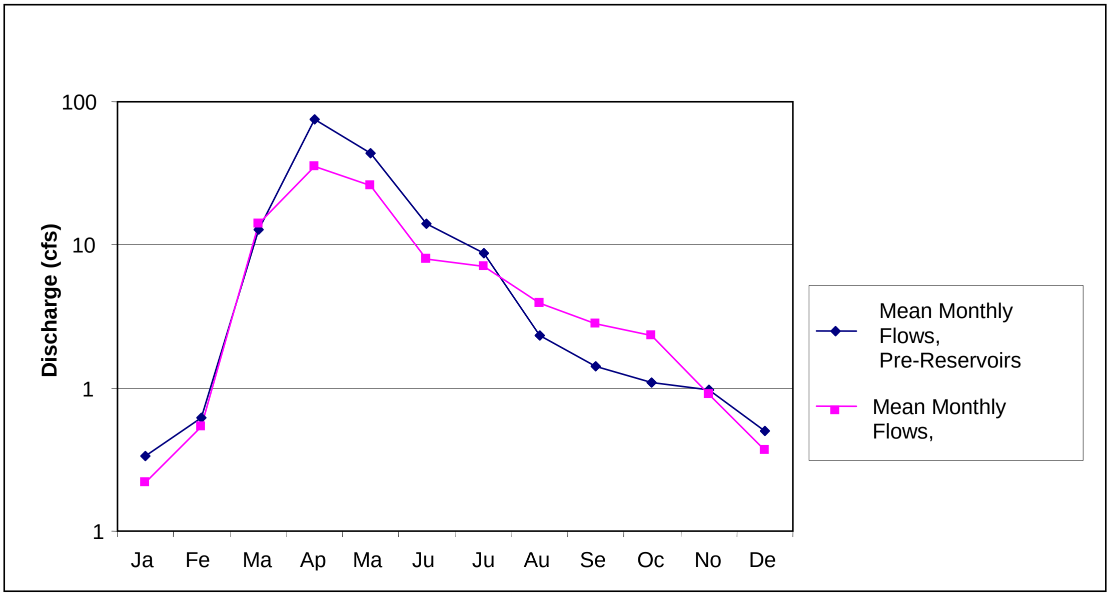

Figure 20. Mean Monthly Flows at USGS Gauging Station 05114000, Pre- and Post- Canadian Reservoir Construction.

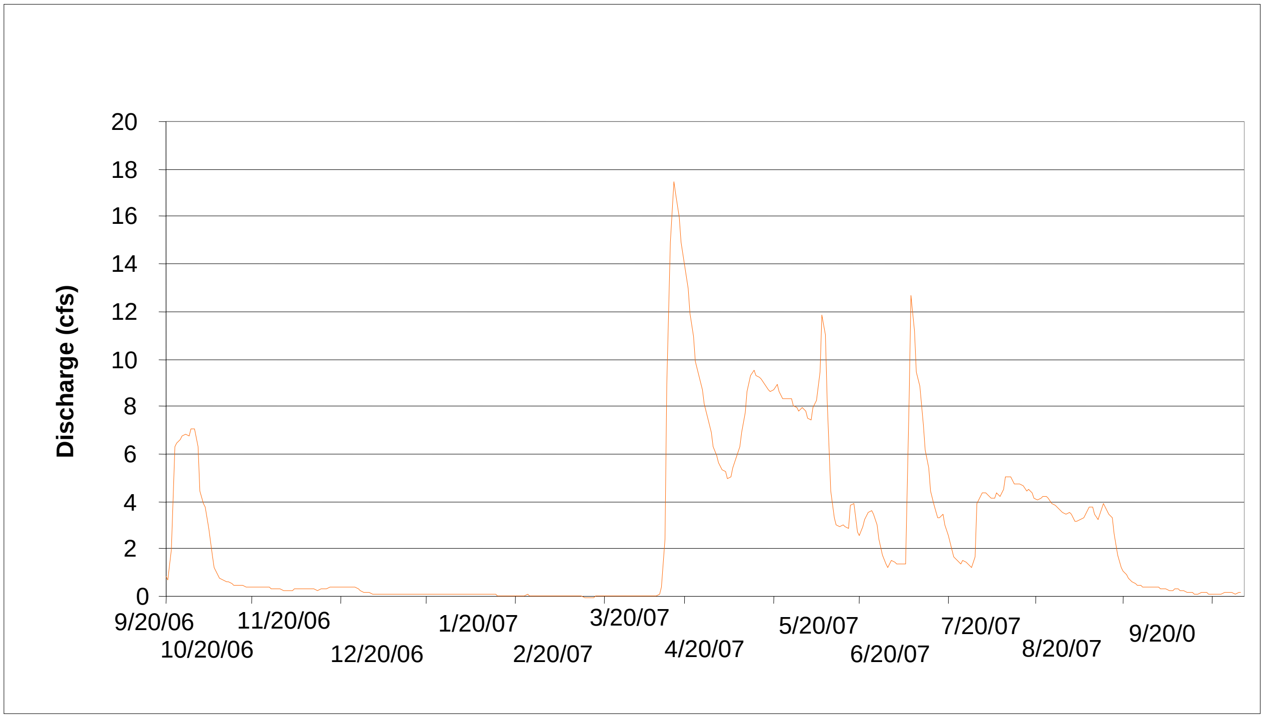

Figure 21. Discharge for USGS Gauging Station 05114000, 2006-2007.

1.5.7 Other Data

On May 27 and 28, 2007 a North Dakota State University(NDSU) field team canoed along the Souris River from Glen Ewen, Saskatchewan, Canada to County Road 3 in North Dakota, excluding a few miles near the border on the Canadian side, covering a total distance of 52 river miles. The purposes of the trip included identifying point sources and potential nonpoint sources; assessing river characteristics, water depth and bank slopes; taking sediment samples; and surveying river cross sections at predetermined locations. The NDSU field team surveyed 13 cross sections, recorded ten log-jammed sections which were restricting flow, and identified 64 locations where the river was used as part of livestock operations (Figure 22). The majority of livestock crossings and water sites were found in Saskatchewan, Canada where water is shallow. At several locations, livestock were found on river banks or in the river. As water depth increased in the lower portion of the reach, fewer cattle operations along the river were found. No point sources were identified. Based on this field trip, livestock usage of the river was identified as a primary source for fecal contamination of the river reach.

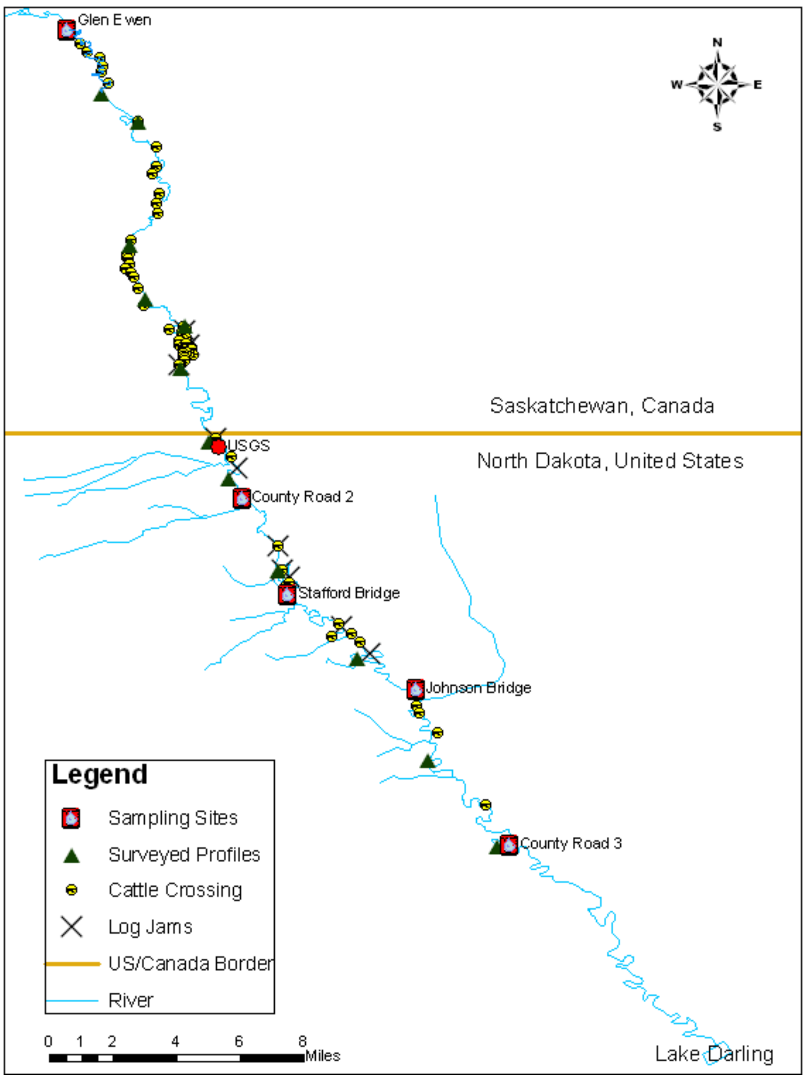

Figure 22. Visual Assessment of Livestock Along the Souris River, Conducted by NDSU Personnel, May 27 - 28, 2007 (Lin, et. al, 2006).

2.0 WATER QUALITY STANDARDS

The Clean Water Act requires that Total Maximum Daily Loads (TMDLs) be developed for waters on a state's Section 303(d) list. A TMDL is defined as “the sum of the individual wasteload allocations for point sources and load allocations for nonpoint sources and natural background” such that the capacity of the waterbody to assimilate pollutant loadings is not exceeded. The purpose of a TMDL is to identify the pollutant load reductions or other actions that should be taken so that impaired waters will be able to attain water quality standards. TMDLs are required to be developed with seasonal variations and must include a margin of safety that addresses the uncertainty in the analysis. Separate TMDLs are required to address each pollutant or cause of impairment (i.e., low dissolved oxygen).

2.1 Narrative Water Quality Standards

The North Dakota Department of Health has set narrative water quality standards that apply to all surface waters in the State. The narrative general water quality standards are listed below (NDDoH, 2006).

- All waters of the State shall be free from substances attributable to municipal, industrial, or other discharges or agricultural practices in concentrations or combinations that are toxic or harmful to humans, animals, plants, or resident aquatic biota.

- No discharge of pollutants, which alone or in combination with other substances, shall:

    1. Cause a public health hazard or injury to environmental resources;

    2. Impair existing or reasonable beneficial uses of the receiving waters; or

    3. Directly or indirectly cause concentrations of pollutants to exceed applicable standards of the receiving waters.

In addition to the narrative standards, the NDDoH has set a biological goal for all surface waters in the State. The goal states that “the biological condition of surface waters shall be similar to that of sites or waterbodies determined by the department to be regional reference sites” (NDDoH, 2006).

2.2 Numeric Water Quality Standards

The Souris River is a Class IA stream. The NDDoH definition of a Class IA Stream is shown below (NDDoH, 2006)

> **Class IA** - The quality of waters in this class shall be suitable for the propagation or protection, or both, of resident fish species and other aquatic biota and for swimming, boating, and other water recreation. The quality of the waters shall be suitable for irrigation, stock watering, and wildlife without injurious effects. After treatment consisting of coagulation, settling filtration, and chlorination, or equivalent treatment processes, the water quality shall meet the bacteriological, physical, and chemical requirements of the Department for municipal or domestic use. Treatment for municipal use may also require softening to meet the drinking water requirements. Numeric criteria have been developed for Class IA streams for dissolved oxygen (Table 9).

Table 9. North Dakota Dissolved Oxygen Standards for Class IA Streams.

	Water Quality Standard (minimum value)
Dissolved Oxygen	5.0 mg/L[1]

[1] **Up to 10% of representative samples collected during any 3yr period may be less than this value provided lethal conditions are avoided.**

2.3 Water Quality Objectives Set by the International Souris River Board

The International Souris River Board has set water quality objectives for the Souris River as it crosses the boundary from Canada to the United States, which is the upper portion of this TMDL reach. As documented in their most recent Annual Report to the International Joint Commission, the dissolved oxygen objective is 5 mg/L (ISRB, 2007).

3.0 TMDL TARGETS

A TMDL target is the value that is measured to judge the success of the TMDL effort. TMDL targets must be based on state water quality standards, but can also include site specific values when no numeric criteria are specified in the standard. The following TMDL target for the Souris (Mouse) River is based on the North Dakota water quality standard for dissolved oxygen. If the target is met, the aquatic life beneficial use will be fully supported.

3.1 Dissolved Oxygen Target

The North Dakota State Water Quality Standard for dissolved oxygen is "5.0 mg/L as a daily minimum (up to 10 percent of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided)" and will be the dissolved oxygen target for the Souris (Mouse) River.

4.0 SIGNIFICANT SOURCES

4.1 Point Sources

Within this listed segment of the Souris (Mouse) River watershed there are no point sources permitted through the North Dakota Pollutant Discharge Elimination System (NDPDES) Program. Towns located within the watershed utilize septic waste systems.

There are two permitted AFOs in the watershed, one medium (300 to 999 cattle) and one small (299 cattle or less) however they are zero discharge facilities and are not deemed a significant source for this report. There are several unpermitted animal feeding operations in the watershed as indicated by the presence of livestock during the river survey (Figure 13). The exact number of these operations is unknown.

4.2 Nonpoint Source

The data collected during the water quality assessment indicate that the primary nonpoint sources contributing to the low dissolved oxygen levels in the Souris (Mouse) River watershed are as follows:

- Nutrient runoff from cropland contributing to the organic load;
- Runoff of manure, which contributes to the organic load, from animal feeding areas; and
- Direct deposit of manure into Souris River by livestock;

5.0 TECHNICAL ANALYSIS

In TMDL development, the goal is to define the linkage between the water quality target and the identified source or sources of the pollutant/impairment (i.e. low dissolved oxygen) to determine the load reduction needed to meet the target. To determine the cause-and-effect relationship between the water quality target and the identified source, the QUAL2K model was used. The loading capacity or TMDL is the amount of pollutant a waterbody can receive and still meet and maintain water quality standards and beneficial uses. The following technical analysis addresses the low dissolved oxygen through a sediment oxygen demand (SOD) load allocation and the load allocation reductions necessary to achieve the water quality standards target of 5.0 mg/L dissolved oxygen minimum, plus a margin of safety.

5.1 Definition of Water Quality Terms

One of the most important parameters in aquatic ecosystems is dissolved oxygen (DO). Fish and macroinvertebrates require minimum levels of oxygen in order to grow, reproduce, and survive. Groundwater, the primary source of river flow during dry weather, or in this case low discharge from the upstream reservoirs, is naturally low in DO. Aquatic plant life serves as both a source (photosynthetic oxygen production) and a sink (respiration and decomposition). However, the measurement of oxygen concentrations does not directly measure the pollutants contributing to the impairment. Some analysis into interactions with other chemical processes as well as determining the relationship between them is required (Figure 23).

Biochemical oxygen demand (BOD) represents the amount of dissolved oxygen required by aerobic biological organisms in a body of water to break down (oxidize) organic matter present in a given water sample at a certain temperature over a specific period of time. The greater the BOD, the greater the oxygen depletion in a stream or lake.

Carbonaceous biochemical oxygen demand (CBOD) is the amount of oxygen required by bacteria to oxidize organic carbon material to carbon dioxide (its lowest energy state). In rural areas, sources of oxygen-demanding substances may include diffuse runoff of agricultural fertilizer and animal wastes (from manure application or grazing animals), soil erosion, and runoff from concentrated animal operations (Vellidis, 2006). Nutrient levels from runoff can sometimes cause enough eutrophication to generate CBOD loads from decaying algae. These may not occur locally, but instead downstream where velocities are slow and the algae populations collect (MPCA, 2008). This is part of the process in this impaired reach of the Souris river as the shallow reaches upstream in Canada contain a great deal of deadfall and logjams in the river, then as the river flows through North Dakota it is incised which slows the flow. Where the water velocities drop, excess algae growth is noted.

Nitrogenous biochemical oxygen demand (NBOD) is the amount of oxygen required by bacteria to oxidize ammonia to nitrite, then nitrite to nitrate (Tchobanoglous, 1985).

Sediment oxygen demand (SOD) is defined as the combination of several processes, primarily the aerobic decay of organic material that has settled to the bottom of the streambed. Examples of organic materials that can act as sources of SOD include leaf litter, particulate BOD in wastewater discharge, and algae or plant biomass.

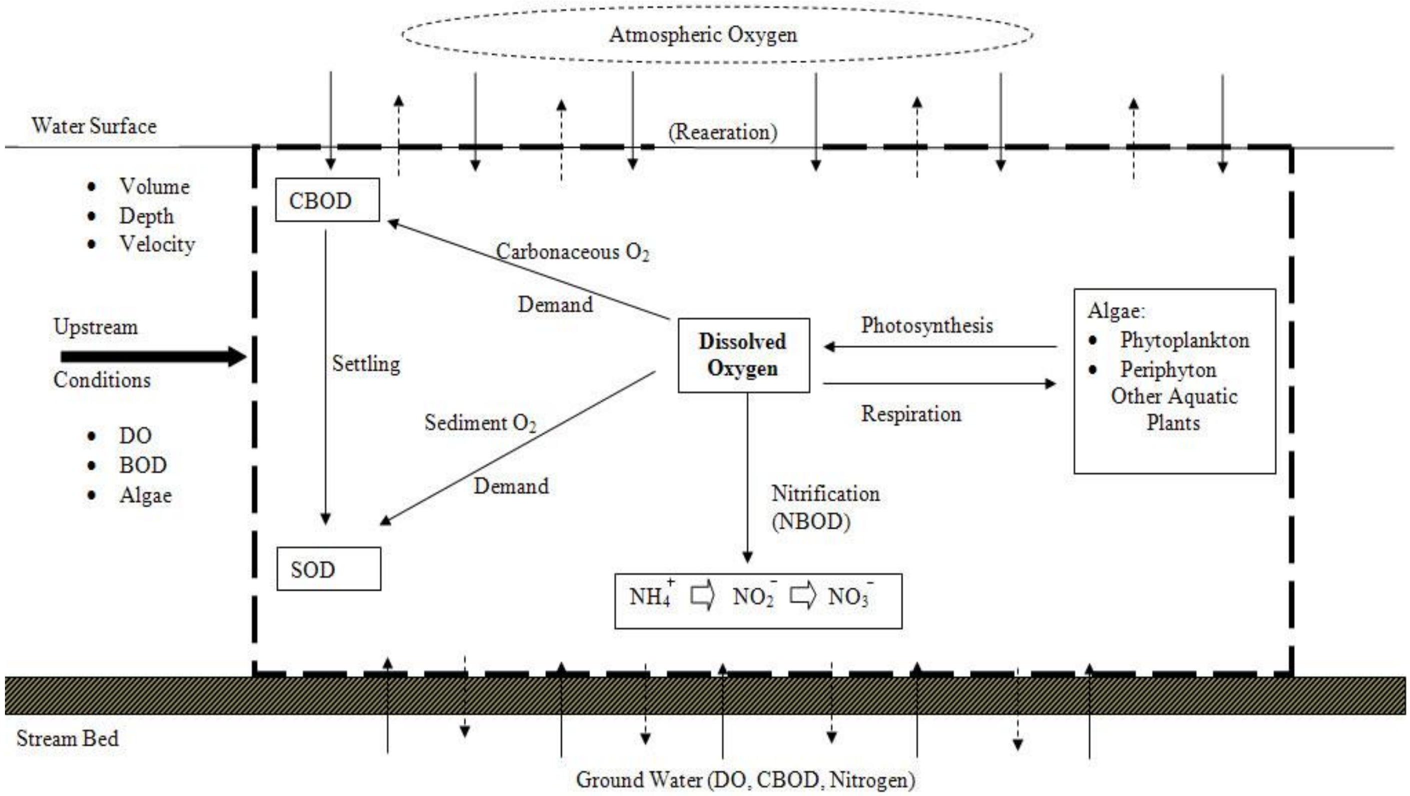

Figure 23. Schematic of the Major Processes Influencing DO in Rivers (MPCA, 2008).

5.2 Dissolved Oxygen Interactions

The amount of DO in a river at any point in time reflects the combination of physical, chemical, and biological sources and sinks of oxygen within the reach. Sources of oxygen include re-aeration, transport from upstream (flow), ground water, and photosynthetic production by algae and aquatic plants. Sinks for oxygen loss include the biochemical oxidation of suspended and dissolved organic material, oxygen demands from settled organic and inorganic materials, respiration of aquatic plants, and the conversion of nitrogen through nitrification (MPCA, 2008).

Water's main source of oxygen is from the atmosphere (Figure 23). Water movement, either by flow or wind, can increase the renewing surface area of water that can interact with the atmosphere. Agitation of the surface and the formation of waves can increase the contact surface area of water and air. These processes (re-aeration) can significantly increase the dissolved oxygen transfer rate. Water movement brings surface water (high in dissolved oxygen) into contact with deeper (dissolved oxygen poor) water. The depth of the water severely limits the transport of oxygen from the surface. Ice and snow cover prevent re-aeration almost completely. Diffusion without mixing can be a very slow process. (Tchobanoglous, 1985).
Direct discharge of pollutants from point and nonpoint sources into a river segment adds to its

CBOD and NBOD, creating an oxygen demand that may depress DO below acceptable concentrations. High nutrient (nitrogen and phosphorus) levels can cause the eutrophication process to generate CBOD loads from decaying algae. (Vellidis, 2006).

Oxygen demand caused by benthic sediments can represent a significant oxygen sink in some rivers. The deposition of organic material originating from external sources, such as leaf litter or aquatic plant decay, can create a SOD that is localized and more detrimental at areas in the river such as deep pools. The flow and volume of water can modify the pollutant concentrations. Organic loads are subject to chemical, biological, and biochemical processes that degrade it into stable end products. However, a pollutant load of oxygen-demanding organics that is large enough to overwhelm the oxygen resources of a water body creates an imbalance that leads to aquatic life impairments that, with added physical impairments such as low winter flows, is sustained throughout the year.

In times of low flow, pools where sediments have settled out create an oxygen demand that can contribute to SOD. SOD during the winter months, when a river is covered by ice, can cause low DO conditions. Ice and snow prevents re-aeration and photosynthesis. Oxygen depletion can become widespread throughout the stream without points where water is open to the air (Parr, 2004).

During the summer months a high density of aquatic plants can cause oxygen levels to vary widely (Mulholland et al., 2005). Slow movement of water, high water temperature, high levels of nutrients, and strong solar radiation, such that occur in the summer, increase photosynthesis and plant growth. During the night, plants undergo respiration, an oxygen dependant reaction, which creates an oxygen demand. When algae densities are high, large diurnal swings in DO can occur. An idealized diurnal stream response for DO is show in Figure 24. Highly eutrophic conditions can occur, especially during low flow conditions when increased residence times are favorable for producing lots of algae, causing periods of active plant growth and respiration. When the growth factors change and become less favorable, plants will die, decompose, and use up oxygen resources. (Vellidis, 2006). The potential BOD load created from increased organic content in the sediment can be transported miles downstream creating oxygen deficits (MPCA, 2008). This magnifies the amplitude in the diurnal response (Figure 25).

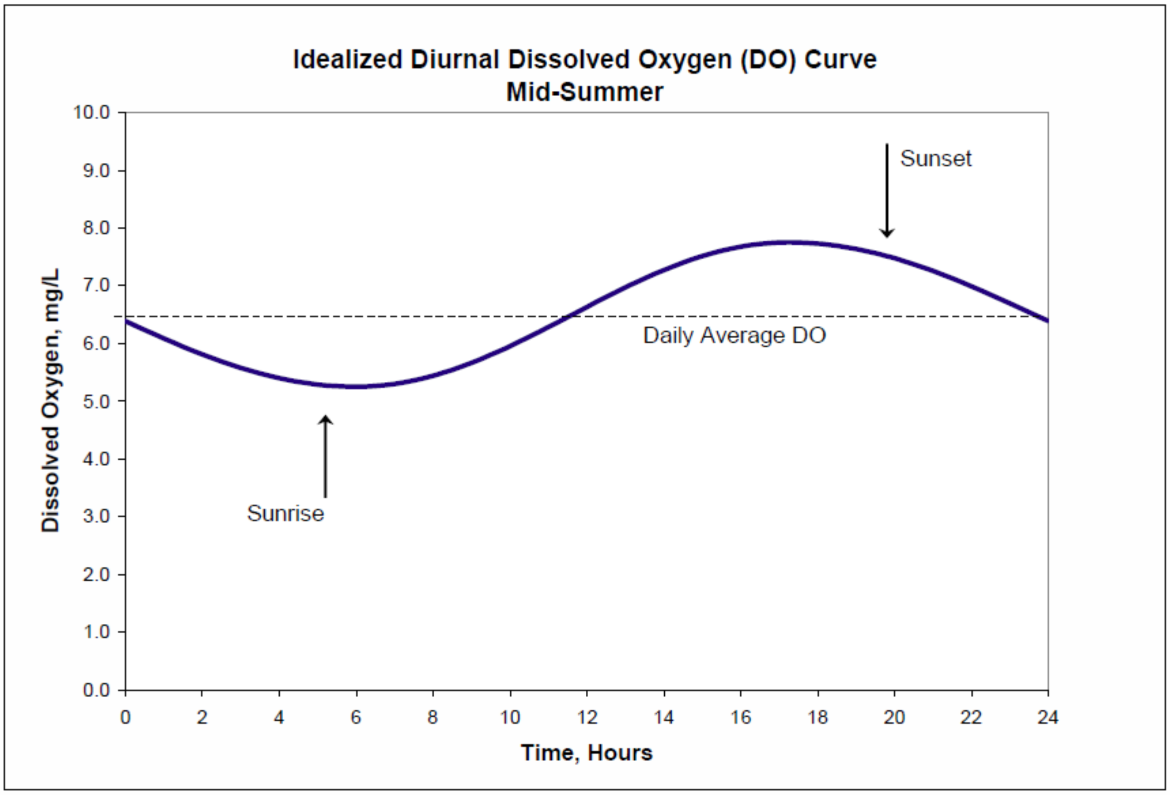

Figure 24. Idealized Diurnal Dissolved Oxygen Response to Photosynthetic Cycles. (MPCA, 2008).

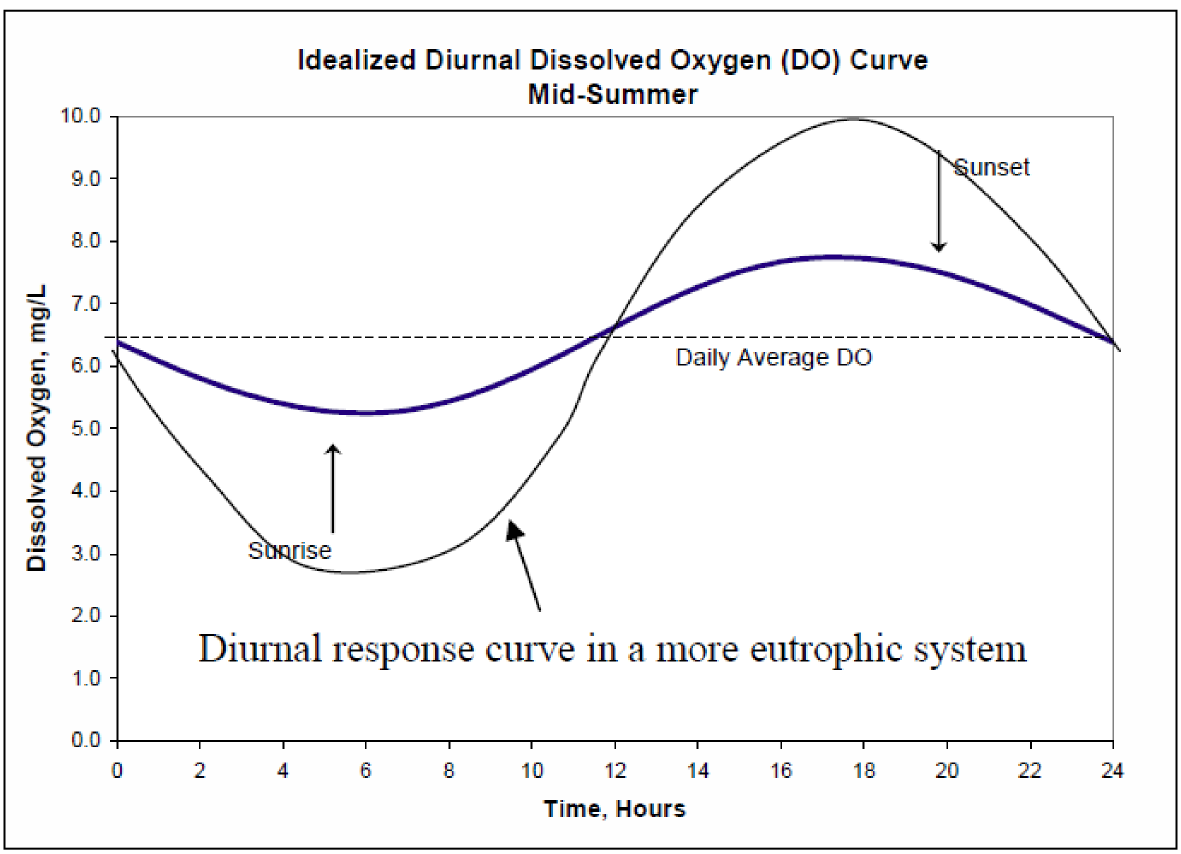

Figure 25. Diurnal Dissolved Oxygen Response in Ideal vs. Eutrophic Systems (MPCA, 2008).

5.3 Determination of Causes for Dissolved Oxygen Impairment Within Listed Reach.

To look specifically at this impaired reach of the Souris River (ND-09010001-001-S_00), several of the above conditions can be noted. First of all there is high nutrient loading occurring from nonpoint sources throughout the reach, as well as above the reach in Canada. This nutrient loading is leading to excessive algal growth during the summer months as indicated by both conversations with local residents, and the very large diurnal swings that were noted (Figure 13). The algae then goes through boom and bust cycles that create both an oxygen deficit in the summer (Figure 10), as well as contribute organic matter to the benthic sediment during die-off. Organic matter is also a result of manure runoff from the numerous livestock noted along the reach (Figure 22).

Second, the large amounts of organic matter are aided in their deposition, and subsequent incorporation into the benthic sediment by the reduced spring floods since the construction of three large reservoirs upstream in Saskatchewan, Canada, which have also reduced the scour of organic matter that usually occurs with spring floods. Also, the North Dakota portion of the river channel is incised, which slows the velocity of the river since the channel can hold more water. This slow moving water, which reaches almost no flow except for that contributed by groundwater during the winter months due to apportionment rules, decreases the re-aeration of the water. Add to that ice cover that during winter that halts re-aeration entirely. During this period, sediment oxygen demand causes almost three months of dissolved oxygen concentrations to be near zero (Figure 10).

Because the DO levels in the winter are the most critical and longest lasting, SOD was chosen as the TMDL load representing low dissolved oxygen for this reach. Since it is the organic content of the sediment, which is built over the course of the entire year, that drives the SOD, a correlation was set up between SOD and percent organic content of the sediment, so that SOD could be modeled using QUAL2K.

5.4 QUAL2K Model Analysis

River and Stream Water Quality model (QUAL2K) is a comprehensive steam water quality model that can simulate up to 15 water quality constituents in any desired combination. The QUAL2K model simulates dissolved oxygen in the river using one dimensional advection-dispersion mass transport equation, with consideration of various oxygen sources and sinks. The river is modeled as series of completely mixed reactors, defined as computational elements, which are grouped into reaches with 20 or less computational elements in each sub reach. Within each reach, geometric properties, such as river bed slope, channel cross section, and Manning's roughness; and hydrological properties, such as dispersion, and biological properties such as decay rate are remained same. The computational elements are used to input the sources such as wastewater treatment plant discharges, runoff outfall discharge points and sinks such as water treatment plant withdrawals. Multiple loadings (sources) and withdrawals (sinks) can be input to any computational element.

5.4.1. Flow Calibration

The Qual2K was first calibrated for the river flow using discharge data obtained from USGS Gauging Station 05114000 (Figure 8), river cross sections surveyed along the river (Figure 18), and water depth measured at sampling sites.

Field surveying was conducted at 13 different locations, including the Glen Ewen, Saskatchewan, Canada site (385404), USGS Gauging Station 05114000, and the site at the downstream end of the reach (385220), to determine river cross section profiles. A least square regression based method was developed to transform field measured river cross sections into trapezoidal sections. It was assumed that river cross section remained the same between two adjacent surveyed cross sections. For Qual2K simulations, the river reach was divided into 17 segments, with Glen Ewen as the headwater and Lake Darling as the end point. These river segments and 13 surveyed cross sections are shown in Figure 26.

Elevation data along with latitude and longitude information for each segment was obtained from GIS data. The river bed slopes were calculated from the elevation data and distances of each segment. When river bed slope is milder than 0.0001, a slope of 0.0001 (minimum slope for Qual2K) was use. Manning's roughness coefficient was adjusted for each segment until simulated water depth matched with measured data. The literature range for natural stream channels of 0.025 to 0.2 (Chapra S, Pelletier G and Tao H, 2008) was used as a guideline for selection of Manning's coefficient.

Because winter months were identified as critical conditions for low DO's, the Qual2K was calibrated for a low flow condition of 30 cfs and river water depths were available at all sampling points. Calibrated Manning's coefficient for all the segments are listed in Table 10 and calibrated river profile is shown in Figure 27.

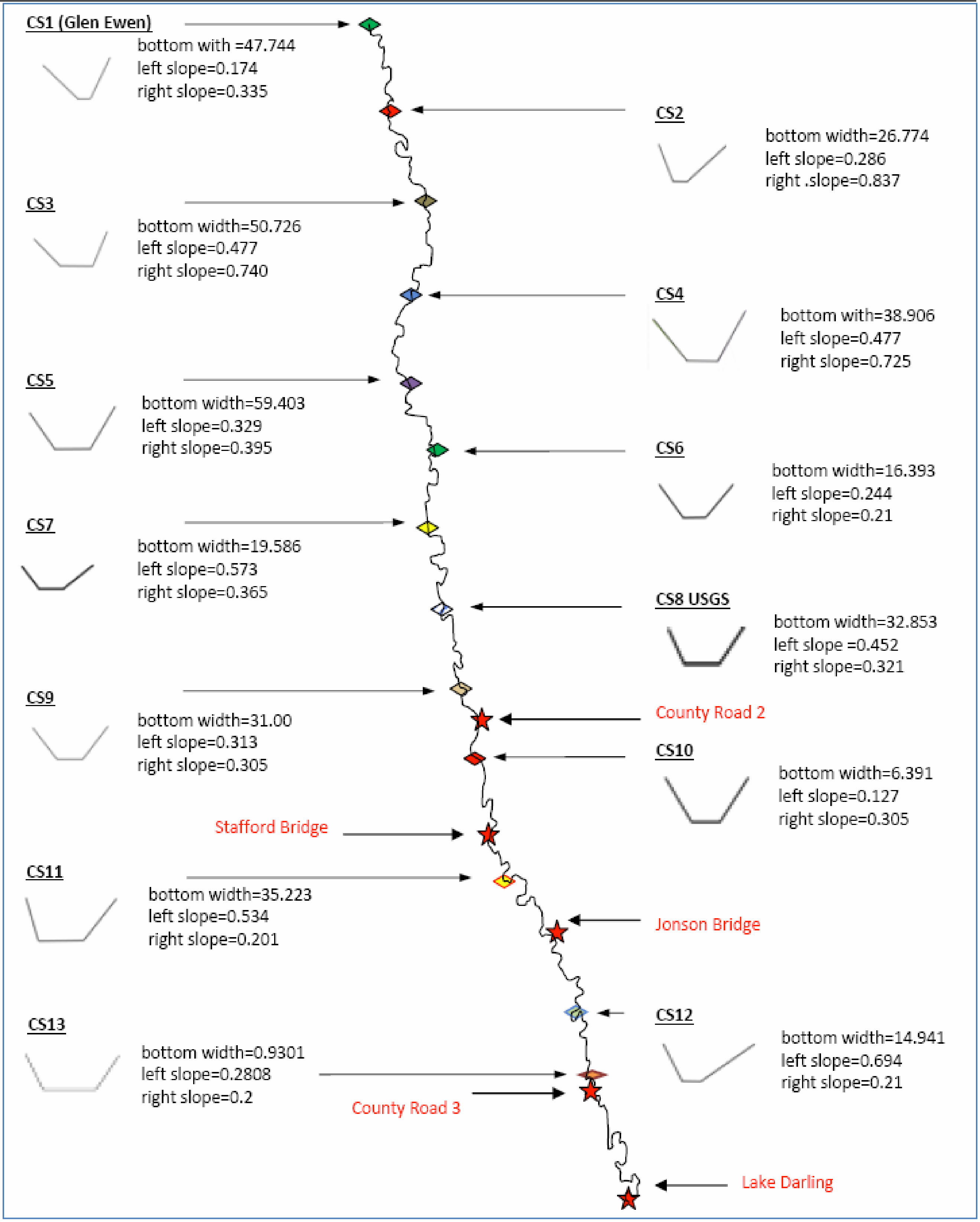

Figure 26. Souris River QUAL2K Simulation River Sub-Reaches and Cross Section Profiles (Lin, et. al, 2010).

Table 10. Calibrated Manning's Roughness Constant

Segment	STORET Number	Manning's Roughness Constant
CS1 – Glen Ewen, Saskatchewan	385404	0.065
CS2		0.065
CS3		0.050
CS4		0.080
CS5		0.090
CS6		0.020
CS7		0.065
CS8 – USGS Site		0.010
CS9		0.010
County Road 2 Bridge	380091	0.010
CS10		0.010
Stafford Bridge	385403	0.009
CS11		0.050
Johnson Bridge	385402	0.050
CS12		0.050
CS13		0.010
County Road 3 Bridge	385220	0.020

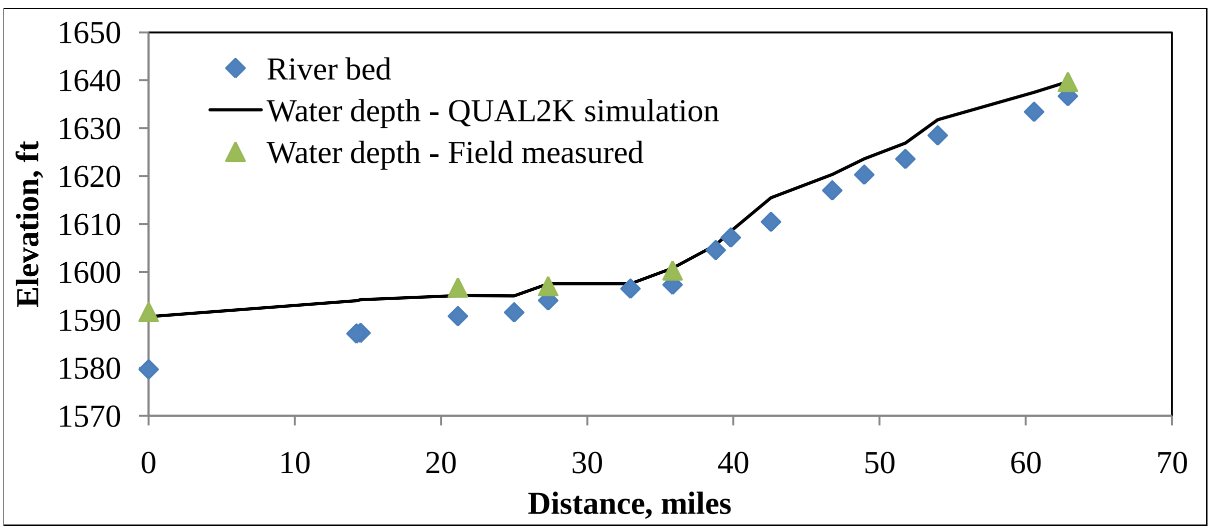

Figure 27. Calibrated Souris River Profile (Lin, et. al., 2010).

5.4.2 Dissolved Oxygen Calibration

Sediment oxygen demand (SOD) was identified as the major oxygen sink along this impaired reach of the Souris River, and the critical condition was identified as winter months when the re-aerations is zero due to ice cover and almost no flow. Qual2K was calibrated assuming this critical condition and SOD was the only dissolved oxygen sink.

Sediment samples were taken from several locations along the river reach. Sediment organic contents and SOD rates were determined in the laboratory. A linear correlation between SOD rates and organic contents were established and this relationship was used to determine SOD rates at other locations. Results from this study are shown in Table 11 and Figure 28.

Table 11. Organic Content of Sediment and SOD Rates.

Sample Locations	Percent Organic Content	SOD ($gO_2/m^2/day$)
Glen Ewen (385404)	3.58	0.14[a]
Cross Section 3 (CS3)	3.00	0.15[a]
Cross Section 5 (CS5)	5.80	0.65[b]
USGS Site (5114000)	6.11	0.74[a]
Country Road 2 (380091)	2.61	0.14[a]
Stafford Bridge (385403)	13.32	2.03[b]
Johnson Bridge (385402)	14.91	2.32[b]
Cross Section 12 (CS12)	1.33	0.01[b]
County Road 3 (385220)	4[c]	0.33[a]

[a] SOD rate measured in laboratory
[b] SOD rate estimated from linear correlation
[c] Organic content estimated from SOD rate based on linear correlation

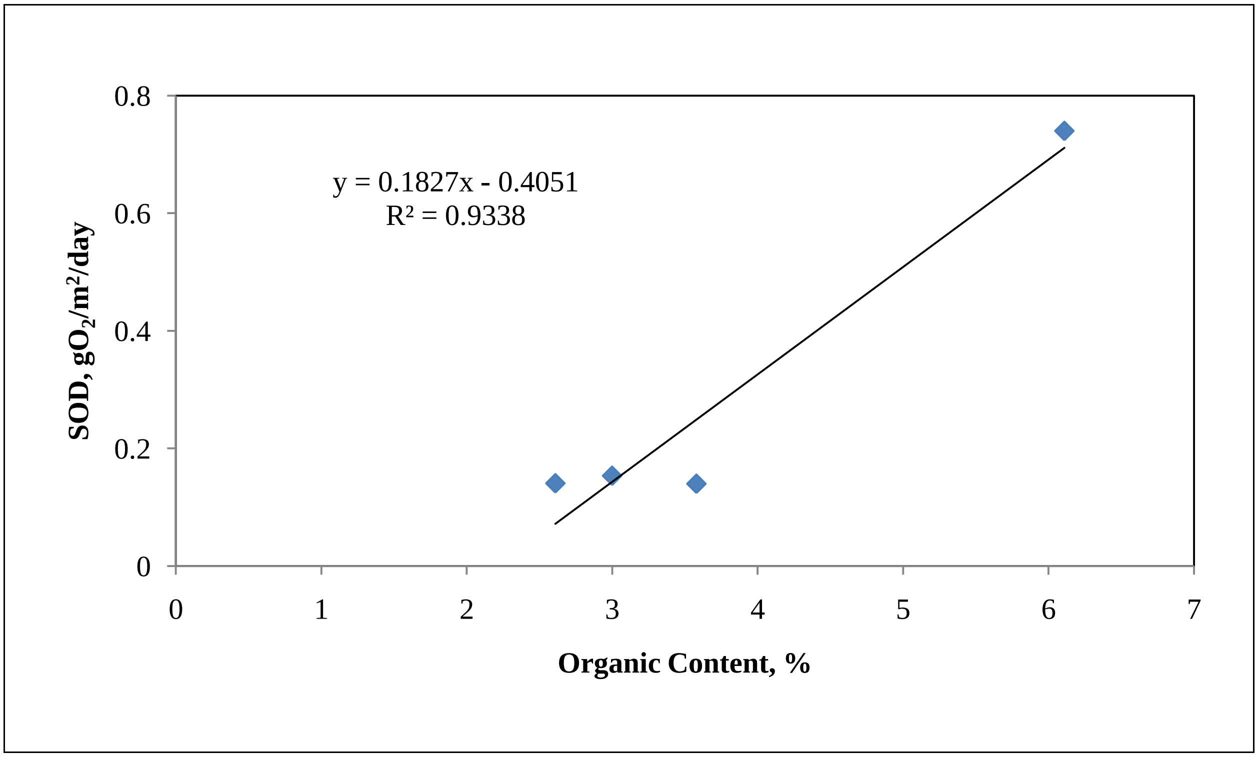

Figure 28. Relationship Between SOD Rates and Sediment Organic Contents (Lin, et. al, 2010).

Using the SOD rates and organic contents obtained above, the Qual2K was run to match the field data from January 28, 2008. An increase of DO concentration at USGS Gauging Station 05114000 was observed and this could be caused by opening in the ice cover upstream. It was assumed that the river is getting aerated at this location with an aeration rate of 0.5 day^{-1}. Resulted DO profile from this calibration is presented in Figure 29.

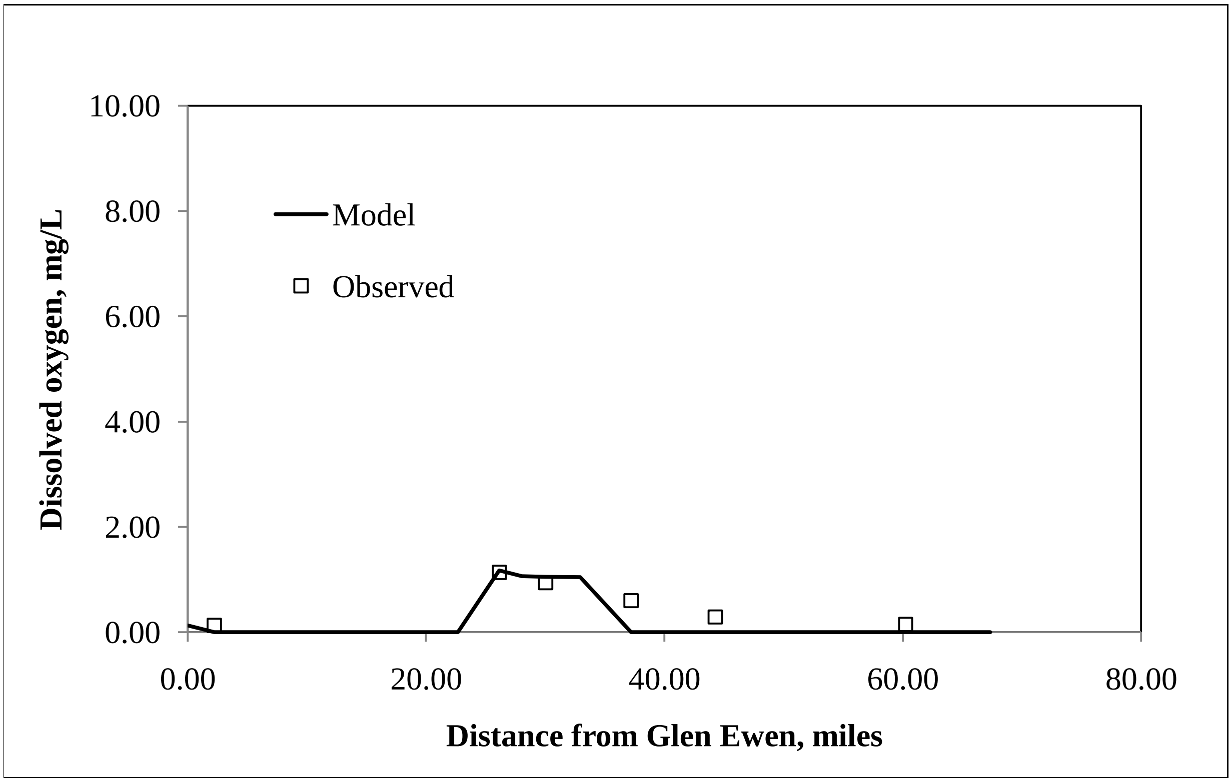

Figure 29. QUAL2K DO Calibration (Lin, et. al., 2010).

5.4.3 Dissolved Oxygen QUAL2K Simulations

To improve dissolved oxygen levels during winter months, organic contents in the sediments have to be reduced to decrease SOD. It should be noted that reduction of SOD also has to be carried out upstream from the Glen Ewen, Saskatchewan site as well. High sediment organic contents were observed and dissolved oxygen was almost completely depleted at the Glen Ewen site as well as at the Sherwood site just south of the North Dakota border. The calibrated Qual2K model was used to develop two simulated dissolved oxygen levels along the impaired reach (ND09010001-001-S_00). The first simulation assumed a reduction in the organic contents of sediment upstream of Glen Ewen, Saskatchewan only. The second simulation assumed a reduction in the organic content of sediment both upstream of Glen Ewen and along the impaired reach of the Souris River in North Dakota.

QUAL2K Simulation 1: Reduction of sediment organic content in Canada only

For this simulation it was assumed that organic content and nutrient loading upstream of Glen Ewen was reduced so that the dissolved oxygen level at the Glen Ewen site reached 8 mg/L in the winter months. Qual2K was run to determine whether this change will result in meeting dissolved oxygen standard of 5 mg/L through the entire impaired reach. From the results of this simulation (Figure 30) it is clear that reduction of organic content upstream of the US/Canada border alone is not sufficient for meeting the dissolved oxygen standard downstream. Even with the dissolved oxygen concentration at Glen Ewen as high as 8 mg/L, dissolved oxygen levels dropped below 1 mg/L downstream from the Johnson Bridge (385402). Conclusion is that reduction of sediment organic content within the study reach is needed as well.

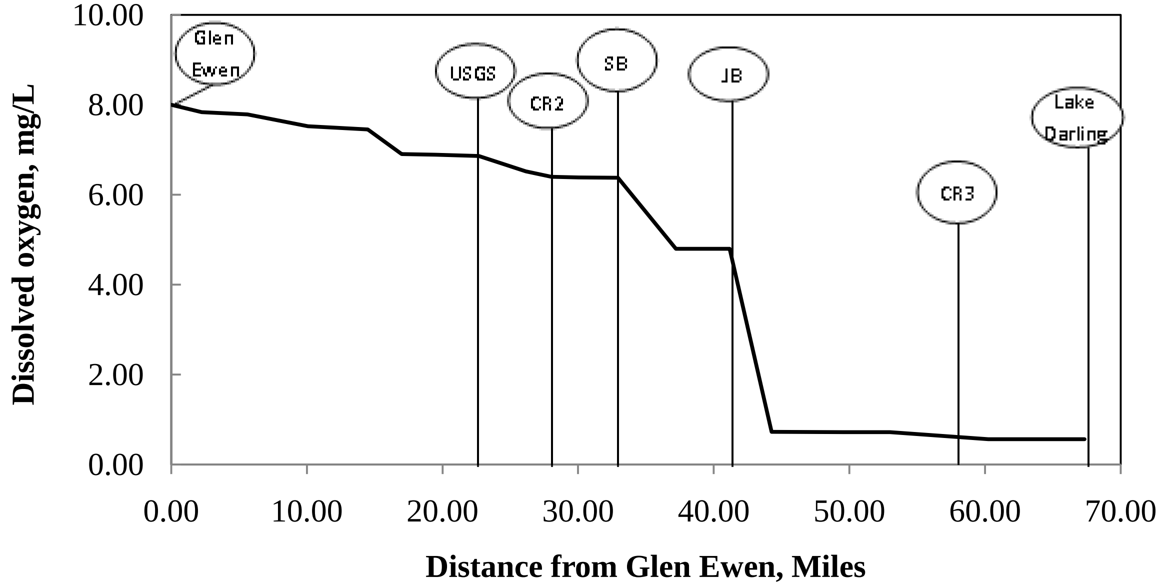

Figure 30. QUAL2K Simulation Results, Assuming 8 mg/L DO at Glen Ewen, Saskatchewan (Lin, et. al, 2010).

<u>QUAL2K Simulation 2: Reduction of sediment organic content both upstream and downstream of the US/Canada border</u>

To increase dissolved oxygen levels to 5 mg/L throughout the impaired reach, Qual2K simulations were performed to determine percent sediment organic reductions that would be needed for different dissolved oxygen values at Glen Ewen. Simulations were run with the initial upstream values of 6, 7, and 8 mg/L, at Glen Ewen. Results of these simulations are shown in Table 12 and Figure 31. As initial values of the border condition are set lower, greater reduction in sediment organic content is needed.

Table 12. Sediment Organic Content Reductions for Varied Initial DO Concentrations.

Initial (Border) Dissolved Oxygen Concentration	Reduction in Sediment Organic Content
8 mg/L	31%
7 mg/L	39%
6 mg/L	53%

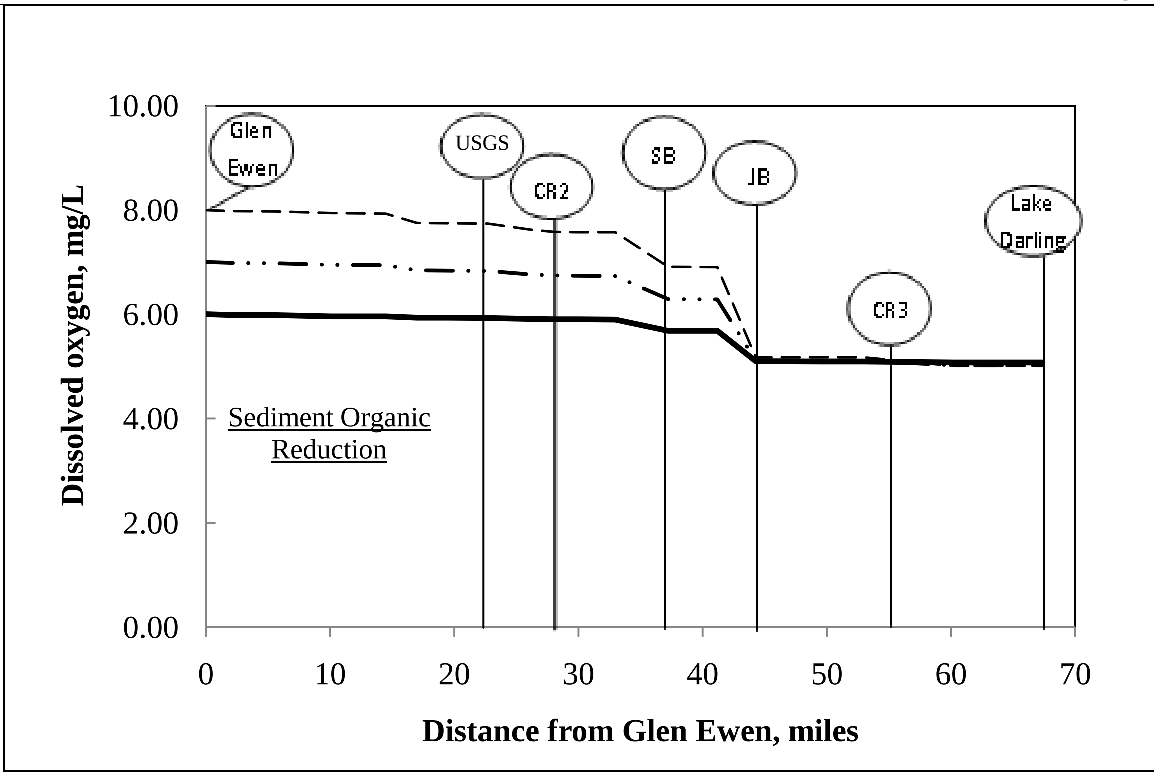

Figure 31. QUAL2K Simulation Results to Maintain 5 mg/L Dissolved Oxygen at End of Impaired Reach (ND-09010001-001-S_00) (Lin, et. al, 2010).

5.5 Calculation of Existing Load and TMDL Load

The existing SOD load was calculated as a volume weighted mean of each section of the impaired reach (Table 13). Using the linear relationship noted in Figure 28, a 53 percent reduction in percent organic content of the sediment is equivalent to the 53 percent reduction in SOD needed to achieve the 5.0 mg/l throughout the reach. This is the value used as the TMDL.

Table 13. Volume Weighted Mean of SOD as Current Load.

Section Name	SOD (gO2/m2/day)	Length of River Section (mi.)	Weighted
USGS	0.74	3.78	2.80
CoRd2	0.14	5.83	0.82
Stafford Bridge	2.03	5.64	11.44
CS11	0.01	2.32	0.02
Johnson Bridge	2.32	3.85	8.92
CS12	0.01	6.94	0.07
CoRd3	0.33	14.22	4.69
Total		**42.58**[1]	**28.76**
Weighted Mean SOD (US)	**0.68**	(=weighted/total river length)	

[1] This value is slightly less than the total reach distance due to the fact the sampling station is slightly downstream from the actual border with Canada.

6.0 MARGIN OF SAFETY AND SEASONALITY

6.1 Margin of Safety

Section 303(d) of the Clean Water Act and the U.S. Environmental Protection Agency's (EPA) regulations require that "TMDLs shall be established at levels necessary to attain and maintain the applicable narrative and numerical water quality standards with seasonal variations and a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality." The margin of safety (MOS) can be either incorporated into conservative assumptions used to develop the TMDL (implicit) or added as a separate component of the TMDL (explicit).

To account for the uncertainty associated with known sources and the TBOD/SOD load reductions necessary to reach the TMDL dissolved oxygen target of 5.0 mg/L, a ten percent explicit margin of safety was used for this TMDL. The MOS was calculated as ten percent of the TMDL. In other words ten percent of the TMDL is set aside from the load allocation as a MOS.

6.2 Seasonality

Section 303(d)(1)(C) of the Clean Water Act and associated regulations require that a TMDL be established with seasonal variations. The Souris (Mouse) River TMDL addresses seasonality because the reduction of SOD is related to the period of the season when the greatest deficit of dissolved oxygen occurs.

7.0 TMDL

Table 14 provides an outline of the critical elements of the Souris (Mouse) River dissolved oxygen TMDL. The TMDL is presented in Table 15. This Table provides an estimate of the existing daily load and an estimate of the average daily loads necessary to meet the water quality target (i.e. TMDL load). This TMDL load includes a load allocation from known nonpoint sources and a ten percent margin of safety. It should be noted that the TMDL loads, load allocations, and the MOS are estimated based on available data and reasonable assumptions and are to be used as a guide for implementation. The actual reduction needed to meet the applicable water quality standards may be higher or lower depending on the results of future monitoring.

Table 14. TMDL Summary for Impaired Reach ND-09010001-001-S_00, Souris River.

Category	Description	Explanation
Beneficial Use Impaired	Aquatic Life	Fish and other aquatic life impairments
Pollutant/Impairment	Low Dissolved Oxygen Due to high sediment oxygen demand (SOD)	See Section 2.1
TMDL Target	5.0 mg/L dissolved oxygen	Based on North Dakota water quality standards
WLA		No contributing point sources in the watershed.
LA	Nonpoint Source Contributions	Loads are a result of nonpoint sources (i.e., rangeland, pasture land, etc.)
Margin of Safety (MOS)	Explicit	10 percent

Table 15. Dissolved Oxygen TMDL for ND-09010001-001-S_00, Expressed as SOD in $g/m^2/day$.

Existing Load	0.68 $g/m^2/day$ (as a volume weighted mean of the segment)
TMDL[1]	0.320 $g/m^2/day$ (53% reduction)
WLA	None
LA	0.288 $g/m^2/day$
MOS	0.032 $g/m^2/day$

[1] Assumes a 6mg/L DO Border Condition at the Saskatchewan/ND border.

The TMDL can be described by the following equation**:**

TMDL = LC = WLA + LA + MOS where:

LC = loading capacity, or the greatest loading a waterbody can receive without violating water quality standards;

WLA = wasteload allocation, or the portion of the TMDL allocated to existing or future point sources;

LA = load allocation, or the portion of the TMDL allocated to existing or future nonpoint sources;

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

8.0 ALLOCATION

There are no known point sources that could potentially impact the watershed. Therefore, the entire dissolved oxygen load for this TMDL is allocated to nonpoint sources in the watershed. The entire nonpoint source load is allocated as a single load because there is not enough detailed source data to allocate the load to individual uses (e.g., animal feeding, septic systems, riparian grazing, upland grazing).

A specific allocation of SOD to Saskatchewan, Canada cannot be given due to lack of data. However the conclusion of the model indicates that improvement to the stream on both sides of the international border in the form of reduced nutrients and organic content to the sediment, along with additional flows in the winter to provide re-aeration will be needed in order to meet water quality standards.

In 2005, the Saskatchewan Watershed Authority completed a State of the Watershed report for the Lower Souris River (that portion of the Canadian watershed just above the border). Of the three conditions used to rank watersheds throughout Saskatchewan, Canada, (healthy, stressed, and impacted) based on ecosystem services, ecosystem function, and the watershed's resistance and resilience to change, the Lower Souris River watershed is categorized as stressed (Davies, 2010). There are 22 stressor indicators that contribute to that watershed condition. An advisory board was established to determine ways to implement best management practices to improve water quality. The International Souris River Board also has set water quality objectives for the Souris River crossing the border, so the issue is important to both countries.

To achieve the TMDL targets identified in the report, it will require the wide spread international support and voluntary participation of landowners and residents in the immediate watershed as well as those living upstream. The TMDLs described in this report are a plan to improve water quality by implementing best management practices through non-regulatory approaches. "Best management practices" (BMPs) are methods, measures, or practices that are determined to be a reasonable and cost effective means for a land owner to meet nonpoint source pollution control needs," (USEPA, 2002). This TMDL plan is put forth as a recommendation for what needs to be accomplished for Souris River, its tributaries and associated watershed to restore and maintain its recreational uses. Water quality monitoring should continue to assess the effects of the recommendations made in this TMDL. Monitoring may indicate that BMP implementation and/or the loading capacity recommendations should be adjusted.

Controlling nonpoint sources is a difficult undertaking requiring extensive financial and technical support. Provided that technical and financial assistance is available to stakeholders, these BMPs have the potential to significantly reduce fecal coliform bacteria loading to the Souris River. The following describe in detail those BMPs that will improve dissolved oxygen levels in the Souris River by reducing organic matter and nutrients.

8.1 Livestock Management Recommendations

Livestock management BMPs are designed to promote healthy water quality and riparian areas through management of livestock and associated grazing land. Organic matter and nutrients from livestock manure and erosion from poorly managed grazing land and riparian areas can be a significant source of organic loading to surface water. Precipitation, plant cover, number of animals, and soils are factors that affect the amount a pollutant delivered to a waterbody as a result of livestock. The following specific BMPs are known to reduce NPS pollution from livestock.

<u>Livestock exclusion from riparian areas</u> - This practice is established to remove livestock from grazing riparian areas and watering in the stream. Livestock exclusion is accomplished through fencing. A reduction in stream bank erosion can be expected by minimizing or eliminating hoof trampling. A stable stream bank will support vegetation that will hold banks in place and serve a secondary function as a filter from nonpoint source runoff. Added vegetation will create aquatic habitat and shading for macroinvertebrates and fish. The cooler temperatures will improve dissolved oxygen levels in the river. Direct deposit of manure into the stream and stream banks will be eliminated as a result of livestock exclusion by fencing.

<u>Water well and tank development</u> - Fencing animals from stream access requires an alternative water source, installing water wells and tanks satisfies this need. Installing water tanks provides a quality water source and keeps animals from wading and defecating in streams.

<u>Prescribed grazing</u> – This practice provides increased ground cover and ground stability by rotating livestock throughout multiple fields. Grazing with a specified rotation minimizes

overgrazing and resulting erosion. The Natural Resources Conservation Service (NRCS) recommends grazing systems to improve and maintain water quality and quantity. Duration, intensity, frequency, and season of grazing can be managed to enhance vegetation cover and litter, resulting in reduced runoff, improved infiltration, increased quantity of soil water for plant growth, and better manure distribution and increased rate of decomposition, (NRCS, 2001).

Waste management system - Waste management systems can be effective in controlling up to 90 percent of the loading originating from confined animal feeding areas. A waste management system is made up of various components designed to control NPS pollution from concentrated animal feeding operations (CAFOs) and animal feeding operations (AFOs). Diverting clean water around the feeding area and containing dirty water from the feeding area in a pond are typical practices of a waste management system. Manure handling and application procedures are also integral to the waste management system. The application of manure is designed to be adaptive to environmental, soil, and plant conditions to minimize the probability of organic matter from manure reaching the surface water.

8.2 Other Recommendations

Vegetated Filter Strip – Vegetated filter strips are used to reduce the amount of sediment, particulate organics, dissolved contaminants, nutrients, and organic matter to streams. The effectiveness of filter strips and other BMPs as control measures to reduce nonpoint source pollution is quite successful (Table 16). The ability of the filter strip to remove contaminants is dependent on field slope, filter strip slope, erosion rate, amount and particulate size distribution of sediment delivered to the filter strip, density and height of vegetation, and runoff volume associated with erosion producing events (NRCS, 2001).

Septic System – Septic systems provide an economically feasible way of disposing of household wastes where other means of waste treatment are unavailable (e.g., public or private treatment facilities). The basis for most septic systems involves the treatment and distribution of household wastes through a series of steps involving the following:

1. A sewer line connecting the house to a septic tank
2. A septic tank that allows solids to settle out of the effluent
3. A distribution system that dispenses the effluent to a leach field
4. A leaching system that allows the effluent to enter the soil

Septic system failure occurs when one or more components of the septic system do not work properly and untreated waste or wastewater leaves the system. Wastes may pond in the leach field and ultimately run off directly into nearby streams or percolate into groundwater. Untreated septic system waste is a potential source of nutrients (nitrogen and phosphorus), organic matter, and suspended solids. Land application of septic system sludge, although unlikely, may also be a source of contamination.

Failure of septic systems can occur for several reasons, although the most common reason is improper maintenance (e.g. age and inadequate pumping). Other reasons for failure include improper installation, location, and choice of system. Harmful household chemicals can also cause failure by killing the bacteria that digest the waste. While the number of systems that are not functioning properly is unknown, it is estimated that 28 percent of the systems in North Dakota are failing (USEPA, 2002).

Table 16. Relative Gross Effectiveness of Confined Livestock Control Measures (Pennsylvania State University, 1992a)

Practice[b] Category	Runoff[c] Volume	Total[d] Phosphorus Percent	Total[d] Nitrogen Percent	Sediment Percent	Fecal Coliform Bacteria Percent
Animal Waste System[e]	-	90	80	60	85
Diversion System[f]	-	70	45	NA	NA
Filter Strips[g]	-	85	NA	60	55
Terrace System	-	85	55	80	NA
Containment Structures[h]	-	60	65	70	90

NA = Not Available
a Actual effectiveness depends on site-specific conditions. Values are not cumulative between practice categories.
b Each category includes several specific types of practices.
c - = reduction; + = increase; 0 = no change in surface runoff.
d Total phosphorus includes total and dissolved phosphorus; total nitrogen includes organic-N, ammonia-N, and nitrate-N
e Includes methods for collecting, storing, and disposing of runoff and process-generated wastewater.
f Specific practices include diversion of uncontaminated water from confinement facilities.
g Includes all practices that reduce contaminant losses using vegetative control measures.
h Includes such practices as waste storage ponds, waste storage structures, and waste treatment lagoons.

9.0 PUBLIC PARTICIPATION

To satisfy the public participation requirement of this TMDL, a hard copy of the TMDL for Souris River and request for comment was mailed to participating agencies, partners, and to those requesting a copy. Those included in the hard copy mailing were:

- Burke and Renville County Soil Conservation Districts
- International Souris River Board of Control
- Saskatchewan Watershed Authority
- US Fish and Wildlife Service, Upper Souris National Wildlife Refuge
- US EPA - Region VIII
- USDA-NRCS State Offices

In addition to mailing copies of this TMDL for Souris River to interested parties, the TMDL was posted on the North Dakota Department of Health, Division of Water Quality web site at http://www.ndhealth.gov/WQ/SW/Z2_TMDL/TMDLs_Under_PublicComment/B_Under_Public_Comment.htm . A 30 day public notice soliciting comment and participation was also published in the following newspapers:

- The Bismarck Tribune
- Minot Daily News
- Renville County Farmer
- Burke County Tribune

Comments were only received from US EPA Region 8, which were provided as part of their normal public notice review (Appendix E). The NDDoH's response to these comments are provided in Appendix F.

10.0 MONITORING

As stated previously, it should be noted that the TMDL loads, load allocations, and the MOS are estimated based on available data and reasonable assumptions and are to be used as a guide for implementation. The actual reduction needed to meet the applicable water quality standards may be higher or lower depending on the results of future monitoring.

To insure that the implementation of BMPs will reduce the sediment oxygen demand to the necessary levels to meet the dissolved oxygen standard, water quality monitoring will be conducted in accordance with an approved Quality Assurance Project Plan (QAPP).

Specifically, monitoring will be conducted for all variables that are currently causing impairments to the beneficial uses of the waterbody. These include, but are not limited to dissolved oxygen. Once a watershed restoration plan (e.g. Section 319 Non point Source Project Implementation Plan (PIP) is implemented, monitoring will be conducted in the watershed beginning two years after implementation and extending five years after the implementation project is complete.

11.0 TMDL IMPLEMENTATION STRATEGY

Implementation of TMDLs is dependent upon the availability of Section 319 NPS funds or other watershed restoration programs (e.g. USDA EQIP), as well as securing a local project sponsor and required matching funds. Provided these three requirements are in place, a project implementation plan (PIP) is developed in accordance with the TMDL and submitted to the ND Nonpoint Source Pollution Task Force and US EPA for approval. The implementation of the best management practices contained in the NPS PIP is voluntary. Therefore, success of any TMDL implementation project is ultimately dependant on the ability of the local project sponsor to find cooperating producers.

Monitoring is an important and required component of any PIP. As a part of the PIP, data are collected to monitor and track the effects of BMP implementation as well as to judge overall project success. Quality Assurance Project Plans (QAPPs) detail the strategy of how, when, and where monitoring will be conducted to gather the data needed to document the TMDL implementation goal(s). As data are gathered and analyzed, watershed restoration tasks are adapted to place BMPs where they will have the greatest benefit to water quality.

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Appendix A
Water Quality Data Provided by NDSU

Sampling Data

Source: NDSU
Location: Glen Ewen, Canada to County Road 3, US
Period: September 2006, May 200

On Site Sampling Data 9/06 to 10/07, County Road 3

	Flow Measurement				Field Mornitoring Data								
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Avg. Water Temp.	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius	Celcius		mg/L	mg/L	µS/cm	
9/23/06	10:15						13.00	13.00	8.65	8.75	8.75	1835	
11/5/06	9:30	14.6		10	0.5		3.70	3.70	8.61				
11/19/06	8:45	14.7		10	0.5		3.90	3.90	8.60	14.70	14.70	1336	
12/3/06	9:00	14.5		5.6	0.6		4.33	4.33	8.21	7.63	7.63	1662	
12/16/06	8:15	14.1	0.188*	12.7	0.9		4.78	4.78	8.21	2.41	2.41	1553	
1/7/07	8:15	14.8		12.3	1	10.00	4.37	5.45	8.20	0.82	0.23	1843	
1/7/07						4.00		4.30	8.00		0.80	1448	
1/7/07						3.00		3.71	7.96		1.25	1340	
1/7/07				13.1	1	9.00		5.27	8.20		0.11	1830	
1/7/07						3.00		3.12	7.96		1.73	1301	
1/14/07	7:53			12.2	1.75	7.20	4.47	4.38	8.14	0.45	0.33	1666	
1/14/07						6.40		4.54	8.13		0.25	1621	
1/14/07						4.40		3.31	7.90		1.11	1339	
1/14/07						9.00		4.91	8.13		0.65	1860	
1/14/07				12.6	1.1	8.00		4.94	8.07		0.14	1683	
1/14/07						10.00		5.32	8.08		0.08	1813	
1/14/07						6.00		4.79	8.60		0.20	1660	
1/14/07						4.00		3.59	7.82		0.83	1324	
1/28/07	8:45			11.9	1.4	7.7	4.63	5.7	8.09	0.14529	0.23	1781	
1/28/07				11.9	1.4	11.7		5.7	8.09		0.09	1870	
1/28/07				11.9	1.4	9.7		5.69	8.1		0.07	1869	
1/28/07				11.9	1.4	7.7		5.08	8.13		0.08	1736	
1/28/07				11.9	1.4	5.7		4.24	7.97		0.11	1550	
1/28/07				11.9	1.4	3.7		2.52	7.75		0.35	1385	
1/28/07				13.4	1.3	8.5		5.52	8.12		0.08	1851	
1/28/07				13.4	1.3	2		1.56	7.77		0.35	1403	
1/28/07				13.4	1.3	4		2.88	7.74		0.17	1359	
1/28/07				13.4	1.3	6		4.29	8.11		0.07	1673	
1/28/07				13.4	1.3	8		4.97	8.13		0.05	1755	
1/28/07				13.4	1.3	10		5.46	8.11		0.06	1853	
1/28/07				13.4	1.3	12		5.58	8.11		0.08	1859	
1/28/07				13.4	1.3	13		5.63	8.09		0.08	1863	
1/28/07				11.9		10				0	0		Titration
1/28/07				11.9		7				0.3	0.3		Titration
1/28/07				11		4				0.3	0.3		Titration
2/11/07				11.6	1.3	7.5	5.111666667	5.54	8.1	0.10833	0.14	1830	
2/11/07				11.6	1.3	9.5		5.72	8.1		0.1	1853	
2/11/07				11.6	1.3	5.5		4.32	8.05		0.23	1649	
2/11/07				12.7	1.3	7.75		5.05	8.15		0.06	1737	
2/11/07				12.7	1.3	9.75		5.52	8.11		0.08	1828	
2/11/07				12.7	1.3	5.75		4.52	8.06		0.04	1642	
2/25/07	7:50	13		11.3	1.7	7.5	5.228333333	5.33	8.2	0.05167	0.08	1839	
2/25/07				11.3	1.7	9.5		5.74	8.2		0.08	1905	
2/25/07				11.3	1.7	5.5		4.13	8		0.04	1651	
2/25/07				12.6	1.6	8		5.65	8.21		0.04	1886	
2/25/07				12.6	1.6	10		5.76	8.2		0.03	1903	
2/25/07				12.6	1.6	6		4.76	8.19		0.04	1749	
3/10/07	9:00	13		11.2	1.2	7.2	5.151666667	5.05	7.96	0.135	0.04	1828	
3/10/07				11.2	1.2	9.2		5.69	7.98		0.05	1880	
3/10/07				11.2	1.2	5.2		3.65	7.69		0.08	1572	
3/10/07				12.6	1.6	8		5.89	8.01		0.16	1870	
3/10/07				12.6	1.6	10		5.95	7.99		0.25	1896	
3/10/07				12.6	1.6	6		4.68	7.86		0.23	1662	
4/1/07	8:00	13.5		12.2		7.32	0.82	0.9	7.85	9.625	9.61	688	
4/1/07	8:30			12.1		7.2		0.74	7.85		9.64	679	
4/9/07	8:30	15.35		10.65		6.4	2.145	2.18	8.11	12.085	12.16	885	
4/9/07		15.8		11		6.6		2.11	8.1		12.01	884	
4/14/07	7:10	14.95		11		6.6	4.17	4.19	8.64	15.255	15.14	998	
4/14/07	7:30	15.1		10.6		6.36		4.15	8.64		15.37	1000	
4/22/07	7:23	14.5		12.3		6.38	11.305	11.37	8.63	10.05	10.87	1049	
4/22/07	7:40	14.9		12		7.2		11.24	8.63		9.23	1028	
4/28/07	6:42	14.1		11.8		7.08	14.095	14.01	8.63	8.455	8.35	1181	
4/28/07	7:40	14.2		11.65		6.99		14.18	8.55		8.56	1181	
5/5/07	7:30	14		12		7.2	17.27	17.3	8.33	7.745	7.7	1093	
5/5/07	7:40	14		12.8		7.68		17.24	8.36		7.79	1092	
5/13/07	6:00	14.3		11.7		6	16.645	16.65	8.36	8.485	8.53	1080	
5/13/07	6:30	14		11.8		6		16.64	8.37		8.44	1080	
5/19/07	8:00	14		12		7.2	16.61	16.19	8.44	8.59	8.35	1168	
5/19/07	8:30	14				7.2		17.03	8.48		8.83	1175	
5/28/07	17:00	14		12		7.2	15.48	15.91	8.56	11.21	11.33	1029	
5/28/07	17:30	14.2		12.1		7.26		15.05	8.58		11.09	1029	
6/3/07	21:15	14.1		11.8		7.26	16.45	16.6	8.58	10.705	11.06	1019	
6/3/07	21:30	14.2				7.08		16.3	8.55		10.35	1017	
6/10/07	21:00	14.8	0.2226	11.8		7.08	19.22	19.6	8.38	10.05	10.23	1138	
6/10/07	21:30	14.8	0.238	11.2		6.72		18.84	8.39		9.87	1139	
6/12/07	14:30	14	0.0913	12		7.2	20.49	20.77	8.21	8.755	8.96	1242	
6/12/07	14:50	14	0.0913	11.8		7.08		20.21	8.16		8.55	1243	
6/24/07	7:15	14.1		11.9		7.14	20.815	21.2	8.34	4.935	5.89	1315	
6/24/07	7:20	14.1		12.4		7.44		20.43	8.2		3.98	1300	
7/15/07	8:30	14.3		11.7		6	23.085	23.37	8.6	3.91	4.8	1780	
7/15/07	8:30	14.3		11.6		6		22.8	8.48		3.02	1776	
7/30/07	6:30	14.5		12.5		7.5	25.335	25.17	8.24	3.575	3.47	1130	
7/30/07	7:00	14.5		11.15		6.9		25.5	8.25		3.68	1126	
8/19/07	8:00	14.2		13.3		7.98	20.285	20.27	8.55	6.8	6.76	1090	
8/19/07	8:30	14.1		11.8		7.08		20.3	8.56		6.84	1091	
9/9/07	9:00	13.6		12.6		7.56	16.67	16.67	8.63	6.39	6.43	1098	
9/9/07	9:30	13.2		12.4		7.5		16.67	8.64		6.35	1100	
10/21/07	7:30	16.6		9.4		5.6	8.55	8.62	8.6	8.74	8.77	1089	
10/21/07	8:15	16.4		10.3		6.18		8.48	8.6		8.71	1082	

On Site Sampling Data 9/06 to 10/07, Johnson Bridge

	Flow Measurement				Field Mornitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius			mg/L	µS/cm	
9/23/06	18:00						12.60	8.58	8.58	8.58	2274	
11/5/06	10:30	15.9		4.5	0.5		3.48	8.59				
11/19/06	10:30	17		4.3	0.25		3.45	8.29	11.60	11.60	1126	
12/3/06	11:30	16.5		2.85	0.8		2.55	8.08	9.11	9.11	1229	
12/15/06	9:30	17.2	0.00*	4.3	0.7		1.92	7.82	5.99	5.99	1291	
1/14/07	10:15			4.2	1.25	2.4	1.37	7.45	1.05	0.77	1524	
1/14/07						2	0.99	7.44		0.72	1530	
1/14/07				2.4	1.15	1.15	1.12	7.45		0.77	1526	
1/14/07						1,2	0.66	7.45		1.92	1832	
1/28/07	10:00			3.9	1.45	3.00	1.10	7.44	0.29	0.35	1871	
1/28/07				3.9	1.45	2.50	0.80	7.45		0.17	1880	
1/28/07				4.3	1.4	3.50	0.96	7.45		0.53	1871	
1/28/07				4.3	1.4	2.50	0.93	7.45		0.17	1877	
1/28/07				3.9	1.45	1.90			0.20	0.20		Titrition method
1/28/07				3.9	1.45	2.90			0.30	0.30		Titrition method
1/28/07				3.9	1.45	3.70			0.30	0.30		Titrition method
2/11/07	9:00	16.6		4.1	1.6	3.10	0.36	7.49	0.35	0.32	2032	
2/11/07				4.1	1.6	2.10	0.15	7.49		0.23	2036	
2/11/07				3.9	1.6	3.00	0.56	7.50		0.42	2006	
2/11/07				3.9	1.6	2.00	0.22	7.90		0.42	2029	
2/25/07	9:11	16.6		3.8	1.7	3.00	1.34	7.55	0.32	0.35	2121	
2/25/07				4.1	1.7	3.00	1.22	7.55		0.28	2117	
3/10/07	11:45	16.6		3.8	1.6	3.00	1.33	7.39	0.39	0.40	2295	
3/10/07				3.8	1.6	2.00	0.73	7.41		0.42	2239	
3/10/07				3.2	1.7	2.60	1.04	7.41		0.50	2271	
3/10/07				3.2	1.7	3.00	1.16	7.41		0.24	2268	
4/1/07	9:00	16.5		5.6		3.36	0.38	8.02	10.58	10.58	866	
4/9/2007	9:50	14.9		5.6		3.36	1.18	8.25	13.36	13.36	1046	
4/14/2007	8:10	14.6		6.1		3.66	5.15	8.71	14.54	14.54	1057	
4/22/2007	9:00	16.4		8		4.8	11.13	8.64	8.79	8.79	1079	
4/28/2007	8:35	15		5.6		3.36	14.25	8.4	7.84	7.84	1188	
5/5/2007	9:15	16	0.263	6		3.6	16.72	8.34	7.65	7.65	1071	
5/13/2007	7:10	16.7	0.105	5.3		3.18	15.85	8.36	8.29	8.29	1044	
5/19/2007	9:00	16.5		5.6		3	16.38	8.36	8.69	8.69	1197	
5/28/2007	15:20	16.7		5		3	15.1	8.26	10.19	10.19	1176	
6/3/2007	19:45	16.9		5.1		3.06	18.06	8.2	8.22	8.22	1096	
6/10/2007	19:30	16.3	0.146	5.7		3.42	20.52	8.35	8.12	8.12	1309	
6/12/2007	16:15	16.5	0.23	5.5		3.3	20.38	8.06	5.64	5.64	1433	
6/24/2007	8:20	17.4		5.5		3.12	24.36	8.62	7.80	7.8	1670	
7/15/2007	9:44	15.3	0.153	5.4		3.24	24.03	8.38	5.48	5.48	1109	
7/30/2007	8:16	15.3	0.106	5.7		3.42	25.77	8.31	6.24	6.24	1121	
8/19/2007	9:00	15.3	0.116	5.1		3.06	19.36	8.63	6.99	6.99	979	
9/9/2007	10:00	15.9		4.2		2.52	15.48	8.42	5.14	5.14	1006	
10/21/2007	9:00	16		4.5		2.7	7.66	8.59	10.53	10.53	1056	

<u>On Site Sampling Data 9/06 to 10/07, Stafford Bridge</u>

	Flow Measurement				Field Mornitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	mg/L	μS/cm	
9/23/06	15:15						11.85	8.29	8.42	8.42	1767	
11/5/06	11:30	23.4		2			3.48	8.52				
11/19/06	11:30	23.25		2			2.03	8.29	14.45	14.45	1193	
12/3/06	12:30	23.3		2.8	0.9		0.31	8.11	10.87	10.87	1354	
12/16/06	10:15	23	0.163	2.8	0.7		0.40	7.65	3.73	3.73	1459	
1/14/07	11:46			2.7	0.8	0.60	0.23	7.49	1.85	1.89	1810	
1/14/07						1.20	0.12	7.43		1.94	1680	
1/14/07						0.60	0.13	7.42		1.81	1821	
1/14/07						1.80	0.14	7.42		1.74	1809	
1/28/07	10:50			2.7	1	2.00	0.22	7.40	0.54	0.56	2146	
1/28/07				2.7	1	1.50	0.16	7.40		0.53	2148	
1/28/07				2.65	1	2.00	0.12	7.45		0.69	2158	
1/28/07				2.65	1	1.50	-0.10	7.45		0.60	2159	
1/28/07				2.7	1	2.00		7.45	0.50	0.50		Titration
1/28/07				2.7	1	2		7.45	0.35	0.35		Titration
2/11/07	10:00	23		2.8	1.5	2	0.3	7.49	0.18	0.21	2458	
2/11/07				2.8	1.5	2.5	0.25	7.49		0.2	2460	
2/11/07				2.7	1.5	2	0.23	7.5		0.14	2476	
2/11/07				2.7	1.5	2.5	0.22	7.49		0.15	2472	
2/25/07	9;50	23		2.7	1.2	2	0.14	7.52	0.23	0.13	2709	
2/25/07				2.7	1.2	2.3	0.13	7.52		0.24	2710	
2/25/07				2.65	1	2	0.13	7.52		0.32	2710	
3/10/07	13:00	23		2.8	1	1.72	0.27	7.41	0.45	0.35	2466	
3/10/07				2.8	1	1.2	0.76	7.41		0.34	2594	
3/10/07				2.5	0.5	1.7	0.83	7.39		0.57	2583	
3/10/07				2.5	0.5	2.2	0.51	7.4		0.52	2600	
4/1/07	9:30	22.1		3.4		2	1.53	8.1	11.66	11.66	905	
4/9/07	10:30	22	1.27	1.8		1.8	1.27	8.45	14.06	14.06	889	
4/14/07	9:10	22.4	0.603	3.2		1.92	4.96	8.73	13.66	13.66	1066	
4/22/07	9:41	22.5	0.707	3		1.8	10.02	8.5	9.71	9.71	1070	
4/28/07	9:40	22.5	0.707	3		1.8	11.8	8.44	8.50	8.5	13.95	
5/5/07	10:10	22.5	0.66	3		2	16.45	8.36	7.38	7.38	1057	
5/13/07	7:51	23	0.568	2.5		1.5	15.28	8.31	8.95	8.95	1084	
5/19/07	10:00	23.7	0.2	1.3		0.78	15.81	8.11	6.02	6.02	1341	
5/28/07	8:22	23	0.338	2.6		1.56	15.5	8.19	7.51	7.51	1158	
6/3/07	19:18	23.3	0.3345	2.6		1.56	22	7.98	6.89	6.89	1097	
6/10/07	18:30	22.6	0.8	3.1		1.86	21.65	8.37	7.49	7.49	1345	
6/12/07	17:00	23	0.741	2.5		1.5	22.56	8.23	5.61	5.61	1413	
6/24/07	8:50	23	0.187	2.2		1.32	25.48	8.63	4.48	4.48	1850	
7/15/07	11:00	22.7	0.561	2.9		1.74	24.15	8.39	5.13	5.13	1129	
7/30/07	9:00	22.9	0.383	2.9		1.74	25.32	8.26	4.60	4.6	1099	
8/19/07	9:55	23	0.145	3.1		1.86	19.23	8.56	7.20	7.2	969	
9/9/07	10:30	23.4	0.175	2.1		1.26	14.85	8.41	8.33	8.33	1058	
10/21/07	9:30	23.2	0.101	2.2		1.32	7.43	8.48	12.82	12.82	1120	

On Site Sampling Data 9/06 to 10/07, County Road 2

	Flow Measurement				Field Mornitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	mg/L	µS/cm	
9/24/06												
11/5/06	12:30	30.7		1	1		2.17	8.57				
11/19/06	13:00	30.8		2			2.03	8.29	14.45	14.45	1193	
12/3/06	13:30	30.8		1.4	0.6		0.00	8.01	9.57	9.57	893	
12/16/06	10:50	32	0.125		0.9		0.01	7.62	4.37	4.37	1482	
1/7/07	11:30	31.8		0.8	open		-0.40	7.54	3.79	3.82	1814	
1/7/07	11:30	31.8		0.8	open		-0.04	7.54		3.76	1813	
1/14/07	13:00			1.3	0.6	0.40	0.15	7.32	3.01	2.99	1936	
1/14/07	13:00					0.60	0.01	7.35		2.94	1941	
1/14/07	13:00			1.7	1.2	0.30	-0.80	7.35		3.06	1951	
1/14/07	13:00					0.20	-0.02	7.36		3.04	1944	
1/28/07	11:30			1.3	1	1.20	-0.03	7.41	0.94	1.02	2294	
1/28/07				1	0.8	1.00	-0.04	7.41		1.02	2296	
1/28/07				1.3	1				0.80	0.80		Titration
1/28/07				1.3	1				0.90	0.90		Titration
2/11/07												Too shallow to sample
2/25/07												Too shallow to sample
3/10/07	No water present											
4/1/07	10:00	29		2.9		1.74	1.01	8.10	11.66	11.66	928	
4/9/07	11:50	27.4	2.17,1.75,2.07	3.4		2.00	1.13	8.40	13.99	13.99	985	
4/14/07	11:00	28	0.946	3		1.8	4.44	8.67	12.86	12.86	1065	
4/22/07	10:42	28.5	0.94	4		2.4	9.64	8.55	9.51	9.51	1072	
4/28/07	10:20	28.5	0.94	3		1.8	13.17	8.44	8.66	8.66	1051	
5/5/07	11:00	32	0.741	3		1.8	15.69	8.36	7.29	7.29	1055	
5/13/07	8:39	26.3	0.237	2.3		1.38	15.04	8.33	8.93	8.93	1083	
5/19/07	11:00	29.5	0.645	2		1.2	14.34	8.29	7.60	7.6	1354	
5/28/07	6:23	29.5		1.8		1	15.72	8.28	7.60	7.6	1164	
6/3/07	18:29	31.3	0.255	1.5		0.9	23.51	8.29	8.92	8.92	1163	
6/10/07	18:00	31	0.8	3		1.8	21.86	8.36	7.95	7.95	1371	
6/12/07	18:00	28	0.765	3.3		1.98	23.02	8.3	4.82	4.82	1436	
6/24/07	9:36	28	0.475	1.8		1.08	25	8.64	4.79	4.79	1950	
7/15/07	12:00	28.9	0.666	2.4		1.44	24.56	8.42	6.79	6.79	1116	
7/30/07	10:00	29.3	0.546	2.1		1.26	25.87	8.37	4.40	4.4	1088	
8/19/07	10:30	29.4	0.5	2		1.2	19.17	8.71	7.19	7.19	961	
9/9/07	11:30	29.7	0.183	1.5		0.9	14.48	8.36	8.62	8.62	1045	
10/21/07	10:30	29.8	0.183	1.4		0.84	7.52	8.62	12.28	12.28	1673	

On Site Sampling Data 9/06 to 10/07, Glen Ewen

	Flow Measurement				Field Mornitoring Data							
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	Avg. DO	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	mg/L	μS/cm	
9/24/06	13:30						12.94	8.57	10.67	10.67	1053	
11/5/06	13:30	26.8		-	0.17		2.00	8.56				
11/19/06	13:00	26.8	*	surface	0.25		1.11	8.35	18.12	18.12	1833	
12/3/06	15:47	26.5		2.6	0.8		0.02	7.75	3.71	3.71	1667	
12/16/06	13:30	28*	0.383**	surface	0.8		0.00	7.59	0.59	0.59	1990	
1/7/07	13:30	29.7		4.8	1.3		-0.04	7.58	0.19	0.23	2586	
1/7/07	7:12	29.7		3.6	1.8		-0.05	7.58		0.14	2582	
1/14/07	15:15			2.5	1.8	2.02	-0.12	7.45	0.41	0.93	2958	
1/14/07						2.35	-0.09	7.51		0.30	2976	
1/14/07						0.80	-0.08	7.55		0.20	2980	
1/14/07						0.10	-0.08	7.50		0.22	2980	
1/28/07	15:09			8.8	1.7	5.90	0.41	7.50	0.19	0.37	3111	at a culvert about
1/28/07				8.8	1.7	8.00	0.15	7.50		0.16	3076	1 km down stream
1/28/07				8.8	1.7	5.00	0.10	7.50		0.11	3085	of the bridge because
1/28/07				8.8	1.7	3	0.07	7.5		0.13	3085	site is frozen through
1/28/07				8.8		4			0.00	0		Titration
1/28/07				8.8		8			0.00	0		Titration
2/11/07	12:45			8.8	2.3	6.1	0.18	7.57	0.19	0.34	3191	Smelly black water
2/11/07				8.8	2.3	8	0.32	7.57		0.12	3209	
2/11/07				8.8	2.3	4	0.24	7.57		0.1	3188	
2/25/07	12:30			8.5	2	6	0.97	7.69	0.13	0.16	2952	
2/25/07				8.5	2	8	0.98	7.7		0.17	2945	
2/25/07				8.5	2	4	0.74	7.7		0.07	2925	
3/10/07	14:30			8.5	2.2	6	1.42	7.51	0.18	0.24	2663	
3/10/07				8.5	2.2	8	1.42	7.51		0.16	2670	
3/10/07				8.5	2.2	4	1.14	7.52		0.14	2803	
4/1/07	11:30	26		3.6		1.56	0.47	7.99	11.62	11.62	1013	Back to original location
4/9/07	13:50	25.4	2.47	4		2.4	2.61	8.32	13.09	13.09	1041	
4/14/07	12:30	25.5	1.17	4		2.4	5.39	8.48	12.42	12.42	1087	
4/22/07	12:23	25.5	0.68	3.5		2.1	9.92	8.54	8.31	8.31	1068	
4/28/07	12:30	26	0.68	4		2.4	13.11	8.42	10.33	10.33	1118	
5/5/07	13:05	27	0.635	3		1.8	15.08	8.42	8.44	8.44	1003	
5/13/07	11:00	26.3	0.271	3.4		2	14.63	8.64	9.14	9.14	1202	
5/19/07	12:30	26	0.334	3.5		2.1	11.89	8.59	9.53	9.53	1276	
5/27/07	7:15	29.6	0.28	2.9		1.8	13.52	8.78	10.99	10.99	1127	
6/3/07	16:44	23.65	0.238	6		3.6	23.59	8.71	10.48	10.48	1268	
6/10/07	15:30	25.5	0.8	4.5		2.7	20.79	8.67	9.75	9.75	1425	
6/12/07	20:00	25.9	0.345	3.7		2.22	23.13	8.55	5.91	5.91	1929	
6/24/07	11:00	26.9	0.168	2.9		1.74	25.25	8.84	6.41	6.41	1888	
7/15/07	14:00	26	0.539	3.6		2.16	26.15	8.61	6.43	6.43	1134	
7/30/07	12:35	26.1	0.442	3.6		1.56	26.15	8.49	4.38	4.38	1056	
8/19/07	12:30	26.6	0.111	3		1.8	18.75	8.71	7.28	7.28	1012	
9/9/07	14:30	26.9	0.15	1.8		1.8	15.06	8.2	7.21	7.21	1418	
10/21/07	12:00	27.2	0.15	2.2		1.32	7.61	8.62	12.28	12.28	1673	

On Site Sampling Data 9/06 to 10/07, USGS Site

		Flow Measurement				Field Mornitoring Data					
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	μS/cm	
9/24/06	8:30						11.48	8.56	8.78	1584	
11/5/06	14:30	1.54	2.9				0.50		15.60	1260	
11/19/06	12:30	1.61	3.8				0.10		16.10	1380	
12/3/06	13:30	1.45					0.00		10.80	1540	
12/15/06	12:30	1.54					0.00		4.80	1660	
1/28/07	12:15			3.3	1.8	3	0.02	7.42	1.52	2266	Field sample
1/28/07				3.3	1.8	2.00	0.01	7.42	1.39	2369	Field sample
1/28/07	12:30						-0.20		0.70	478	Field sample
1/28/07						2.00			1.10		Titration
1/28/07						2.00			1.00		Titration
2/11/07	11:00			2.5	1.5	2.10	-0.10	7.44	0.44	2664	
9/9/07	12:39						14.31	8.36	8.13	1055	
9/9/07	12:44						14.04	8.39	8.07	1055	
9/9/07	12:49						14.04	8.39	8.17	1053	
9/9/07	12:54						14.04	8.41	8.20	1052	
9/9/07	13:00						14.07	8.41	8.19	1052	

On Site Sampling Data 9/06 to 10/07, Highway 9 Bridge

		Flow Measurement				Field Mornitoring Data					
Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	DO	Conductivity	Notes
		ft.	fps	ft.	ft.	ft	Celcius		mg/L	μS/cm	
1/7/07	16:00			3.7	0.8	2.20	0.14	8.29	0.71	3741	
1/7/07	16:00			3.8	0.7	2.00	0.16	8.29	0.42	3740	
1/28/07	16:20			2.9	1	2.20	0.26	8.10	0.26	3756	
1/28/07				2.9	1	2.50	0.23	8.10	0.19	3730	
1/28/07				2.9	1	1.50	0.14	8.10	0.30	3729	
1/28/07				2.9	1				0.2		Titration
1/28/2007				2.9	1				0.1		Titration
2/11/2007	14:00			3.2	1.6	2.9	0.02	8.02	0.2	3853	Black smelly water
2/11/2007				3.2	1.6	1.9	0.01	8.02	0.16	3854	
2/11/2007				3.2	1.6	2.8	0.02	8.02	0.14	3853	
2/25/2007	14:00			2.7	1.1	2	0.14	8.3	0.32	3939	
2/25/2007				3	1.3	2.3	0.13	8.14	0.27	3939	
3/10/2007	17:00			3.3	1	2.4	0.6	7.86	0.1	3842	
3/10/2007				3.3	1	1.4	0.35	7.86	0.1	3869	
3/10/2007				3.3	1	3.1	0.36	7.85	0.14	3860	

On Site Sampling Data 9/06 to 10/07, Other Sampling Locations

Description					Flow Measurement				Field Mornitoring Data				
Site Name	Latitude	Longitude	Sampling Date	Sampling Time	Stage	Flow Velocity	Water Depth	Ice	Sampling Depth	Temperature	pH	DO	Conductivity
					ft.	fps	ft.	ft.	ft	Celcius		mg/L	μS/cm
Alameda Res	49.262	-102.237	1/7/07	15:15			29.7	1.6	18	1.45	1027	10.25	8.36
N of 05114000	48.274	-101.433	1/7/2007	10:15			1.3	1		-0.04	1876	4.04	7.54
N of 05114000	48.274	-101.433	1/7/2007	10:30			1.3	1		-0.04	1654	4.06	7.54

Souris River Water Quality Data

Source: USGS

Location: Gaging Station 5114000, near Sherwood, ND

Period: 1994 – 2004

Souris River Fecal Coliform, Ammonia, Copper, and Organic Carbon Data and Calculated Standards for Ammonia and Copper

Date	Flow Rate cfs	Water Temp C	pH	Ammonia nitrogen mg/L	fecal coliform CFU/100ml	Hardness mg/L as $CaCO_3$	Org. carbon unfltrd mg/L	Copper g/L	Ammonia Standard Acute mg/L	Ammonia Standard Chronic mg/L	Cu standards CMC g/L	Cu standards CCC g/L
10/6/98	3	8.5	8.1			--	--	--				
11/3/98	4.2	--	8.4	0.023		350	11	1	3.88	1.20	44.03419	26.1221
2/9/99	3.6	0	7.4	1.84	K4	430	18	2	22.97	4.70	53.47138	31.1459
3/30/99	1600	0.5	8.1	0.185	K77	62	17	4	6.95	2.02	8.60466	5.952518
4/13/99	2050	7.5	8			190	--	4	8.41	2.36	24.74679	15.49876
5/26/99	1100	16.3	8.1	0.039	K15	190	52	4	6.95	1.81	24.74679	15.49876
7/6/99	344	19.9	8.1			--	--	--	6.95	1.44		
7/20/99	407	23.1	8.2			220	14	4	5.73	1.00	28.41698	17.56719
8/5/99	303	24.1	8.1			--	--	--	6.95	1.11		
8/24/99	353	20.9	8.3	<.020	120	--	--	--	4.71	0.97		
9/30/99	51	7.5	7.9	0.042	100	310	15	7	10.13	2.73	39.27101	23.5489
10/27/99	14	0.1	8.1	<.020	100	400	14	--	6.95	2.02	49.94521	29.27941
11/16/99	14	0	8.2	<.020	K8	410	19	--	5.73	1.71	51.12221	29.90376
1/6/00	5.3	0.1	7.4	--	--	--	--	1	22.97	4.70		
1/12/00	5	0.1	7.4	--	--	--	--	--	22.97	4.70		
2/23/00	5.1	5.3	7.5	0.951	42	460	11	1	19.89	4.32	56.98363	32.99352
3/1/00	12	10.1	7.7	--	--	--	--	2	14.44	3.52		
3/28/00	13	16	8.3	<.020	<2	320	13	2	4.71	1.31	40.46491	24.19651
4/19/00	13	19.1	8.4	--	K9	320	--	--	3.88	0.91	40.46491	24.19651
5/17/00	14	23.5	8.4	<.020	64	370	14	3	3.88	0.69	46.40399	27.39242
6/26/00	35	24.6	8.3	--	--	--	--	--	4.71	0.77		
7/7/00	98	22.8	8.2	0.167	420	290	19	--	5.73	1.02	36.87658	22.24442
7/25/00	54	21.5	8.3	--	--	--	--	--	4.71	0.93		
8/8/00	33	19.7	8.4	<.020	K380	--	20	--	3.88	0.87		
8/15/00	12	--	--	--	--	--	--	4				
8/22/00	11	5.2	8.3	--	--	--	--	2	4.71	1.44		
9/6/00	6.6	2.9	8.3	0.118	680	370	19	1	4.71	1.44	46.40399	27.39242

Souris River Fecal Coliform, Ammonia, Copper, and Organic Carbon Data and Calculated Standard for Ammonia and Copper (Cont.)

Date	Flow Rate cfs	Water Temp C	pH	Ammonia nitrogen mg/L	fecal coliform CFU/100ml	Hardness mg/L as $CaCO_3$	Org. carbon unfltrd mg/L	Copper µg/L	Ammonia Standard		Cu standards	
									Acute mg/L	Chronic mg/L	CMC µg/L	CCC µg/L
10/19/00	3.6	9.2	8.3	--	--	--	--	--	4.71	1.44		
11/20/00	98	0	8.3	0.114	E21	330	17	1.8	4.71	1.44	41.6567	24.84118
1/4/01	4.3	0	7.6	--	--	--	--	--	17.03	3.93		
2/15/01	3	0	7.5	--	--	--	--	--	19.89	4.32		
3/9/01	340	0	8.2	0.046	E4	360	18	1.1	5.73	1.71	45.22002	26.75855
3/22/01	1740	0	8	0.139	E3	170	15	2.9	8.41	2.36	22.28194	14.09356
3/29/01	1320	0.1	--	--	--	--	--	--				
4/5/01	806	4.8	--	--	--	--	--	--				
4/12/01	1530	7.3	8.1	--	--	--	--	--	6.95	2.02		
4/24/01	1500	8.6		--	E20	180	--	4.1			23.51631	14.799
5/9/01	2180	11	--	--	--	--	--	--				
5/16/01	629	16.1	7.9	--	--	--	--	--	10.13	2.47		
6/20/01	207	18.4	8.1	E.034	96	280	14	2.8	6.95	1.58	35.67589	21.58731
7/18/01	162	26.2	8.3	<.040	290	220	14	3.2	4.71	0.70	28.41698	17.56719
8/31/01	94	17.8	8.3	E.022	120	--	14	--	4.71	1.17		
9/12/01	113	14.4	8.3	<.040	160	210	13	4.8	4.71	1.45	27.19694	16.88256
10/18/01	73	5.8	8.5			--			3.20	1.00		
11/19/01	11	0.6	8.3	e.03	13k	390	11	1.8	4.71	1.44	48.76653	28.65278
1/3/02	3.2	0	7.4			--			22.97	4.70		
2/13/02	4.6	0	7.5	0.81	<2	430	10.2	1.6	19.89	4.32	53.47138	31.1459
3/29/02	12	0.1	7.6			--			17.03	3.93		
4/17/02	61	2.2				--						
4/25/02	34	5.5	8.6	<.04	<2	230	12.9	1.5	2.65	0.82	29.63388	18.24729
5/16/02	77	10.9	8.3			--			4.71	1.44		
6/6/02	12	19.9	8		540	340		2.4	8.41	1.68	42.84643	25.48301
6/18/02	12	22.1				--						
6/27/02	20	25.7	7.9	0.39	>1200	340	15.5	2.9	10.13	1.35	42.84643	25.48301
7/18/02	25	25.2	8.3	e.04	75	290	21.9	3.6	4.71	0.75	36.87658	22.24442
8/22/02	16	17.1	8.6	<.04	135	290	15.5	1.8	2.65	0.71	36.87658	22.24442
9/11/02	22	19.2	8.3	0.05	104	--	14.9		4.71	1.08		

Souris River Fecal Coliform, Ammonia, Copper, and Organic Carbon Data and Calculated Standards for Ammonia and Copper (Cont.)

Date	Flow Rate cfs	Water Temp C	pH	Ammonia nitrogen mg/L	fecal coliform CFU/100ml	Hardness mg/L as $CaCO_3$	Org. carbon unfltrd mg/L	Copper µg/L	Ammonia Standard		Cu standards	
									Acute mg/L	Chronic mg/L	CMC µg/L	CCC µg/L
10/8/02		6	--	--	--	--	--	--				
11/20/02	7.1	8	8.2	<0.04	42	500	15.3	1	5.73	1.71	61.64658	35.43006
1/8/03	6.2	0	7.6	--	--	--	--	--	17.03	3.93		
3/6/03	0.7	0	7.6	1.34	<2k	590	18.1	0.8	17.03	3.93	72.06349	40.81268
3/26/03		0	--	--	--	--	--	--				
4/2/03	98	6	8.1	0.18	6k	210	19.4	2.6	6.95	2.02	27.19694	16.88256
4/18/03		10	--	--	--	--	--	--				
4/30/03	86	16	8.4	--	17k	330	--	2.3	3.88	1.10	41.6567	24.84118
5/28/03	111	27	8.4	<0.04	21k	320	16.8	6	3.88	0.56	40.46491	24.19651
7/11/03	6.4	21	8.3	E.03	62	360	21.1	3.1	4.71	0.96	45.22002	26.75855
8/21/03	4.3	27	8.4	0.04	232	--	22.6	--	3.88	0.56		
9/10/03	2.6	16	8.3	0.08	220	380	22.7	4.3	4.71	1.31	47.58614	28.02381
9/26/03	37	15	8.7	--	--	--	--	--	2.20	0.66		
9/26/03	37	16	8.8	--	--	--	--	--	1.84	0.52		
11/13/03	2.3	0.5	8	<0.04	280k	450	21.5	4	8.41	2.36	55.81436	32.37965
1/14/04	0.61	1	7.6	--	--	--	--	--	17.03	3.93		
2/25/04	0.43	1.1	7.7	0.73	4	580	19.5	2.1	14.44	3.52	70.91078	40.22085
3/24/04	5	0	--	--	--	--	--	--				
4/1/04	50	0.5	8.5	E.03n	20k	320	30.2	3.2	3.20	1.00	40.46491	24.19651
4/22/04	86	7.9	8.7	--	54	390	--	2.8	2.20	0.68	48.76653	28.65278
5/26/04	52	13	8.7	<0.04	92	390	19.6	3.5	2.20	0.68	48.76653	28.65278
6/16/04	333	19	--	--	--	--	--	--				
7/21/04	110	24.5	7.6	0.12	220	310	24.3	5.5	17.03	2.08	39.27101	23.5489
8/17/04	13	20.5	7.5	<0.04	70k	--	19.2	--	19.89	2.95		
9/8/04	6.9	14.3	7.8	<0.04	--	400	23.4	4.1	12.14	3.17	49.94521	29.27941
9/13/04	6.8	16	--	--	--	--	--	--				

Souris River Dissolved Oxygen and Nutrients Data (1994 – 2004)

Sample Date	Sample Time	DO mg/L	NO_2,NO_3 Nitrogen mg/L	Phosphorus mg/L	Sample Date	Sample Time	DO mg/L	NO_2,NO_3 Nitrogen mg/L	Phosphorus mg/L
2/22/94	12:30	4.5	0.25	0.23	8/27/96	12:00	8.8	< .05	0.3
3/16/94	13:00	12	1.4	0.6	10/1/96	9:00	10		
3/21/94	14:30	12	0.47	0.33	11/21/96	10:00	10.5	0.07	0.1
3/24/94	10:30	13	0.35	0.27	4/1/97	11:00	11.2	0.61	0.37
4/1/94	11:00	11.9	0.37	0.25	4/10/97	11:00	13	0.27	0.2
5/2/94	13:00	10.9	< .050	0.28	4/16/97	11:00	10.2	0.35	0.19
6/20/94	13:30	9.8	< .050	0.36	5/6/97	13:30	10.5	0.14	0.16
7/18/94	13:00	8.5			6/16/97	13:30	8		
8/8/94	12:00	7.3			7/15/97	10:00	7	< .05	0.15
10/3/94	12:30	8.4			8/19/97	10:00	7.2	< .05	0.17
11/14/94	12:30	11	< .05	0.17	9/30/97	10:30	7.2		
2/6/95	13:00	6.5	0.19	0.3	11/4/97	11:00	11	0.07	0.1
3/16/95	11:00	9	0.59	0.74	2/10/98	10:00	5.5	0.28	0.09
3/20/95	11:00	9	0.59	0.31	4/7/98	10:00	11.8	0.51	0.22
3/23/95	11:30	10	< .05	0.29	4/9/98	10:00	12.5	0.54	0.08
3/27/95	15:00	9.4	0.69	0.34	4/14/98	10:00	9.5	0.36	0.15
5/2/95	13:00	8.9	0.3	0.19	5/11/98	10:00	8.7		
5/10/95	12:00	9.3			5/20/98	11:30	6.8	< .05	0.24
6/12/95	12:00	8	< .05	0.21	6/30/98	12:00	7.1		
6/25/95	14:00	7.6	0.35	0.42	7/14/98	10:00	4.5	< .05	0.03
7/17/95	12:00	7			8/25/98	10:00	5	0.05	0.24
8/7/95	12:00	6.5			10/6/98	14:00	9.5		
9/18/95	12:00	8			11/3/98	10:10	8.4	< .05	0.08
11/6/95	12:30	10.5	1.1	0.15	2/9/99	10:00	4	0.08	0.1
2/12/96	12:30		0.25	0.22	3/30/99	11:00	12.1	0.31	0.3
3/19/96	10:00	13.6	0.35	0.28	4/13/99	10:30	11.5		
4/12/96	10:30	13.4	0.34	0.33	5/26/99	17:00	9.4	0.07	0.16
4/16/96	12:00	13.5	0.17	0.31	7/6/99	13:15	8		
4/30/96	10:30	13.5	0.1	0.2	7/20/99	17:00	8		
6/4/96	11:00	9	< .05	0.21	8/5/99	16:00	6.3		
6/25/96	14:00	8.4			8/24/99	11:15	6.7	< .05	0.2
7/16/96	9:30	5.7	0.06	0.21	9/30/99	11:20	10	0.12	0.19

Appendix B
Surveyed Profiles of Souris River Provided by NDSU

Souris River Sampling/Field Investigation Sites

Source: NDSU

Location: Glen Ewen, Canada to County Road 3, US

Period: September 2006, May 2007

Surveyed Profiles of Sampling Sites, County Road 3

Site Number: 382020

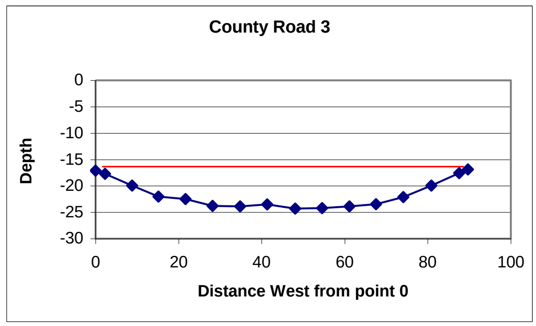
Site Location: DLAT: N 48º48' 510"

DLONG: W 101º49' 514"

Point	Distance from East Bank	Profile of River Bottom
0	0	-17.120
1	2.283	-17.711
2	8.812	-19.937
3	15.169	-22.017
4	21.641	-22.503
5	28.206	-23.800
6	34.808	-23.886
7	41.334	-23.486
8	48.076	-24.297
9	54.547	-24.183
10	61.111	-23.890
11	67.537	-23.483
12	74.128	-22.119
13	80.847	-19.946
14	87.579	-17.570
15	89.685	-16.869

Conditions of river on 9/23/06

	Station 4	Station10
Width of Bridge	32.22'	32.15
T/ ºC	12.99	13.00
Cond/µS/cm	1836	1834
DO%:	84.1	83.4
DO / mg/L:	8.78	8.73
Depth/m:	1.991	2.006
pH:	8.64	8.66



Date: Sept, 23 2006

Measured by: Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super

Recorded by: Dr. B.Sini-Eidukat

measured from top of metal rail

	V-A	H-A	hor. angle	tape hor.	Water Surface	river bed	ave corrected +0.25
0	1.944	24.328	296° 63' 48"	0	14.25	17.12	17.1
1	3.753	26.611		2.3'	15.880	19.520	
2	3.787	33.140		8.85'	15.950	21.780	21.82'
3	3.837	39.497		15.45'	16.100	23.910	23.92'
4	3.881	45.969		22.08'	16.110	24.440	24.43'
5	3.894	52.534		28.65'	16.120	25.750	25.78'
6	3.938	59.136		35.24'	16.150	25.880	25.90'
7	3.958	65.662		41.82'	16.125	25.500	25.50'
8	3.977	72.404	303°4'5"	48.35'	16.145	26.330	26.32'
9	3.951	78.875	303°25'52"	54.90'	16.255	26.190	26.17'
10	3.924	85.439	303°34'58"	61.50'	16.130	25.870	25.85'
11	3.901	91.865	303°58'18"	68.10'	16.115	25.440	25.48'
12	3.855	98.456	304°24'47"	74.70'	16.060	24.030	24.04'
13	3.803	105.175	304°35'28"	81.25'	15.990	21.805	21.785'
14	3.754	111.907	304°42'08"	87.85'	15.920	19.380	19.39'
15	2.135	114.013	304°48'05"	90.15'	14.350	17.060	

Surveyed Profiles of Sampling Sites, Johnson Bridge

Site Number: 385402
Site Location: DLAT: N 48º52' 752"
DLONG: W 101º52' 071"

Point	Distance from East Bank	Profile of River Bottom
1	0	0
2	29.600	-11.020
3	35.944	-14.130
4	42.105	-16.413
5	48.520	-17.977
6	54.392	-21.080
8	66.782	-20.331
10	79.383	-20.237
12	91.579	-19.907
14	104.083	-18.891
15	110.377	-18.812
16	116.360	-18.131
17	122.632	-17.789
18	128.911	-16.667
WE 19	135.064	-13.709
20	141.362	-10.958

Souris River measurements

T/ ºC	12.6
Cond/µS/cm	2274
DO%:	86.5
DO / mg/L:	9.11
Depth/m:	1.265
pH:	8.58
Time:	6:00pm

Date: Sept, 23 2006
Measured by: Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super
Recorded by: Dr. B.Sini-Eidukat
measurement using 5' staff

	S-A	H-A	V-A	V-Angle	HAR H-Angle	measurement bed
1	not measured					
2	29.619	29.600	1.058	2°2'50"	0°2'28"	11.2
3	35.959	35.944	1.058	1°38'16"	359°56'35"	14.31
4	42.117	42.105	0.995	1°21'15"	0°0'0"	16.53
5	48.529	48.520	0.966	1°08'25"	359°57'07"	18.07
6	54.399	54.392	0.878	0°55'29"	359°59'43"	21.08
7	66.788	66.782	0.917	0°47'11"	359°58'01"	20.37
8	79.388	79.383	0.921	0°39'54"	359°58'02"	20.28
12	91.584	91.579	0.971	0°36'27"	359°58'47"	20.00
14	104.088	104.083	1.027	0°33'54"	359°57'30"	19.04
15	110.382	110.377	1.026	0°31'58"	359°57'38"	18.96
16	116.365	116.360	1.047	0°30'54"	359°59'59"	18.30
17	122.637	122.632	1.049	0°29'23"	359°58'04"	17.96
18	128.916	128.911	1.051	0°28'01"	359°56'47"	16.84
WE 19	135.068	135.064	1.029	0°26'11"	359°56'46"	13.86
20	141.366	141.362	1.030	0°25'02"	359°55'51"	11.11

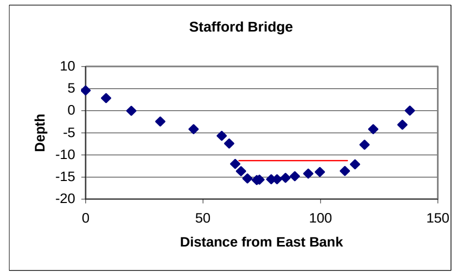
Surveyed Profiles of Sampling Sites, Stafford Bridge

Site Number:	485403	
Site Location:	DLAT:	N 48º55' 362"
	DLONG:	W 101º55' 582"

	Point	Distance from East Bank	Profile or River Bottom
	0	138.119	0
	1	134.905	-3.175
	2	122.517	-4.206
	3	118.844	-7.721
WE	4	114.716	-12.158
	5	110.431	-13.664
	6	99.731	-13.894
	7	94.861	-14.242
	8	89.113	-14.822
	9	85.112	-15.195
	10	81.484	-15.503
	11	79.037	-15.534
	12	74.07	-15.600
	13	72.912	-15.711
	14	68.878	-15.325
	15	66.217	-13.708
WE	16	63.716	-12.054
	17	61.17	-7.435
	18	58.022	-5.715
	19	46.034	-4.199
	20	31.779	-2.476
	21	19.494	-0.037
	22	8.756	2.840
	23	0.000	4.545
	Bridge bolt	99.351	10.777

Souris River water Data

T/ ºC	11.85
Cond/μS/cm	1767
DO%:	78.4
DO / mg/L:	8.42
pH:	8.2
time:	3:58pm
bolt to water surface	22.12 feet
bolt to water bed	25.55 feet



Date:	Sept, 23 2006
Measured by:	Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super
Recorded by:	Dr. B.Sini-Eidukat

	Point	S-A	H-A	V-A	V-Angle	HAR H-Angle	
	0	85.455	85.257	5.812	3°54'0"	11'42"	
	1	82.086	82.043	2.637	1°50'26"	4'46"	
	2	69.674	69.655	1.606	1°19'13"	15'52"	
	3	66.010	65.982	-1.909	358°20'34"	0'39"	
WL	4	62.179	61.854	-6.346	354°8'30"	3'35"	
	5	58.102	57.569	-7.852	352°14'0"	359°59'13"	
	6	47.561	46.869	-8.082	350°13'01"	359°52'24"	
	7	42.837	41.999	-8.430	348°39'02"	359°52'24"	
	8	37.354	36.251	-9.010	346°2'34"	0°0'49"	
	9	33.587	32.250	-9.383	343°46'43"	359°35'19"	
	10	30.218	28.622	-9.691	341°17'44"	359°42'31"	
	11	27.923	26.175	-9.722	339°37'30"	359°54'27"	
	12	23.358	21.208	-9.788	335°13'32"	359°38'33"	
	13	22.361	20.050	-9.899	333°43'27"	359°14'21"	
	14	18.629	16.016	-9.513	329°17'29"	359°39'22"	
	15	15.515	13.355	-7.896	329°24'22"	0°15'40"	
WE	16	12.521	10.854	-6.242	330°05'48"	0°0'02"	
	17	8.465	8.308	-1.623	348°56'47"	359°45'25"	
	18	5.161	5.160	0.097	1°4'49"	359°29'21"	
	19	7.016	6.828	1.613	13°17'31"	180°20'40"	
	20	21.345	21.083	3.336	8°59'31"	180°04'45"	
	21	33.864	33.368	5.775	9°49'06"	180°44'38"	
	22	44.946	44.106	8.652	11°05'54"	180°19'44"	
	23	53.867	52.862	10.357	11°05'07"	180°45'42"	
	Additional point, surveyed later						
	stn 8.5	35.816	34.643	-9.093	345°17'34"	359°05'26"	staff resting on bed
	stn 8.5	35.028	34.534	-5.862	350°21'56"	359°09'25"	staff on water surface
	CL bridge bolt	49.360	46.489	16.589	19°38'22"	329°30'07"	staff on center bolt

Surveyed Profiles of Sampling Sites, Glen Ewen

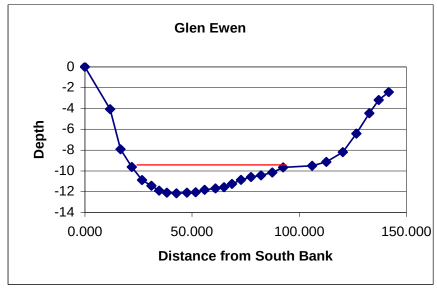
Site Number: 385405
Site Location: DLAT: N 49º10' 811"
DLONG: W 102º01' 650"
(All measurements at 6 foot staff transect location is 150' E of Bridge)

River Bottom Profile as of 9/24/06

	Point	Distance from South bank	Profile of river bottom
	1	0.000	0
	2	11.771	-4.074
	3	16.649	-7.932
WE	4	21.964	-9.634
	5	26.673	-10.882
	6	31.114	-11.437
	7	34.655	-11.908
	8	38.242	-12.101
	9	42.785	-12.150
	10	47.647	-12.092
	11	51.759	-12.066
	12	55.905	-11.819
	13	60.935	-11.688
	14	64.984	-11.576
	15	68.705	-11.249
	16	72.820	-10.868
	17	77.521	-10.600
WE	18	82.234	-10.433
	19	87.463	-10.162
	20	92.580	-9.668
	21	106.100	-9.518
	22	112.739	-9.151
	23	120.363	-8.213
	24	126.755	-6.426
	25	132.799	-4.456
	26	137.148	-3.194
	27	141.831	-2.423

Conditions of river

T/ ºC	12.94
Cond/μS/cm	1053
DO%:	101.30%
DO / mg/L:	10.67
Depth:	1.00
pH:	8.57



Date: 9/24/2006
Measured by: Dr. Wei Lin, Dr. B.Sini-Eidukat, Joe Super
Recorded by: Dr. B.Sini-Eidukat

	S-A	H-A	V-A	V-Angle	HAR hor-Angle
1	151.172	151.162	1.784	0°40'35"	0°0'0"
2	139.401	139.383	-2.290	359°03'33"	0°0'16"
3	134.523	134.382	-6.148	357°22'49"	359°48'20"
4	129.208	128.969	-7.850	356°30'59"	359°44'52"
5	124.499	124.166	-9.098	355°48'33"	359°54'26"
6	120.058	119.669	-9.653	355°23'18"	359°53'34"
7	116.517	116.076	-10.124	355°00'55"	0°6'34"
8	112.930	112.458	-10.317	354°45'29"	0°18'13"
9	108.387	107.890	-10.366	354°30'43"	0°9'15"
10	103.525	103.011	-10.308	354°17'09"	0°05'56"
11	99.413	98.880	-10.282	354°03'49"	0°18'04"
12	95.267	94.737	-10.035	353°57'12"	0°10'50"
13	90.237	89.692	-9.904	353°41'57"	0°15'39"
14	86.188	85.630	-9.792	353°28'35"	0°26'09"
15	82.467	81.922	-9.465	353°24'33"	0°23'01"
16	78.352	77.823	-9.084	353°20'32"	0°15'00"
17	73.651	73.122	-8.816	353°07'30"	0°17'17"
18	68.938	68.394	-8.649	352°47'34"	0°0'19"
19	63.709	63.156	-8.378	352°26'36"	0°02'15"
20	58.592	58.059	-7.884	352°16'00"	359°48'30"
21	45.072	44.403	-7.734	350°07'09"	359°59'36"
22	38.433	37.720	-7.367	348°56'58"	0°31'30"
23	30.809	30.131	-6.429	347°57'21"	0°19'04"
24	24.417	23.972	-4.642	349°02'28"	1°03'12"
25	18.373	18.177	-2.672	351°38'22"	0°50'58"
26	14.024	13.953	-1.410	354°13'40"	0°20'45"
27	9.341	9.319	-0.639	356°04'26"	0°01'49"

Appendix C
QUAL2K Model Summary Provided by NDSU

Qual2K Simulations

Qual2K was used to simulate the impact of sediment oxygen demand (SOD) on Souris River DO levels during winter conditions with the river covered with ice.

Flow Calibration

The Qual2K was first calibrated for the river flow using discharge data obtained from USGS Gaging Station 5114000, river cross sections surveyed along the river, and water depth measured at 5 sampling sites.

Field surveying was conducted at 13 different locations, including the Glen Ewen site (upper end of the reach), USGS Gaging Station 5114000 and the County Road 3 site, to determine river cross section profiles. A least square regression based method was developed to transform field measured river cross sections into trapezoidal sections. It was assumed that river cross section remained the same between two adjacent surveyed cross sections. For Qual2K simulations, the river reach was divided into 17 segments, with Glen Ewen as the headwater and Lake Darling as the end point. These river segments and 13 surveyed cross sections are shown in Figure ???.

Elevation data along with latitude and longitude information for each segment was obtained from GIS data. The river bed slopes were calculated from the elevation data and distances of each segment. When river bed slope is milder than 0.0001, a slope of 0.0001 (minimum slope for Qual2K) was use. Manning's roughness coefficient was adjusted for each segment until simulated water depth matched with measured data. The literature range for natural stream channels of 0.025 to 0.2 (Chapra S, Pelletier G and Tao H, 2008) was used as a guideline for selection of Manning's coefficient.

Because winter months were identified as critical conditions for low DO's, the Qual2K was calibrated for a low flow condition of 30 cfs and river water depths were available at all sampling points. Calibrated Manning's coefficient for all the segment are listed in Table ??? and calibrated river profile is shown in Figure ???

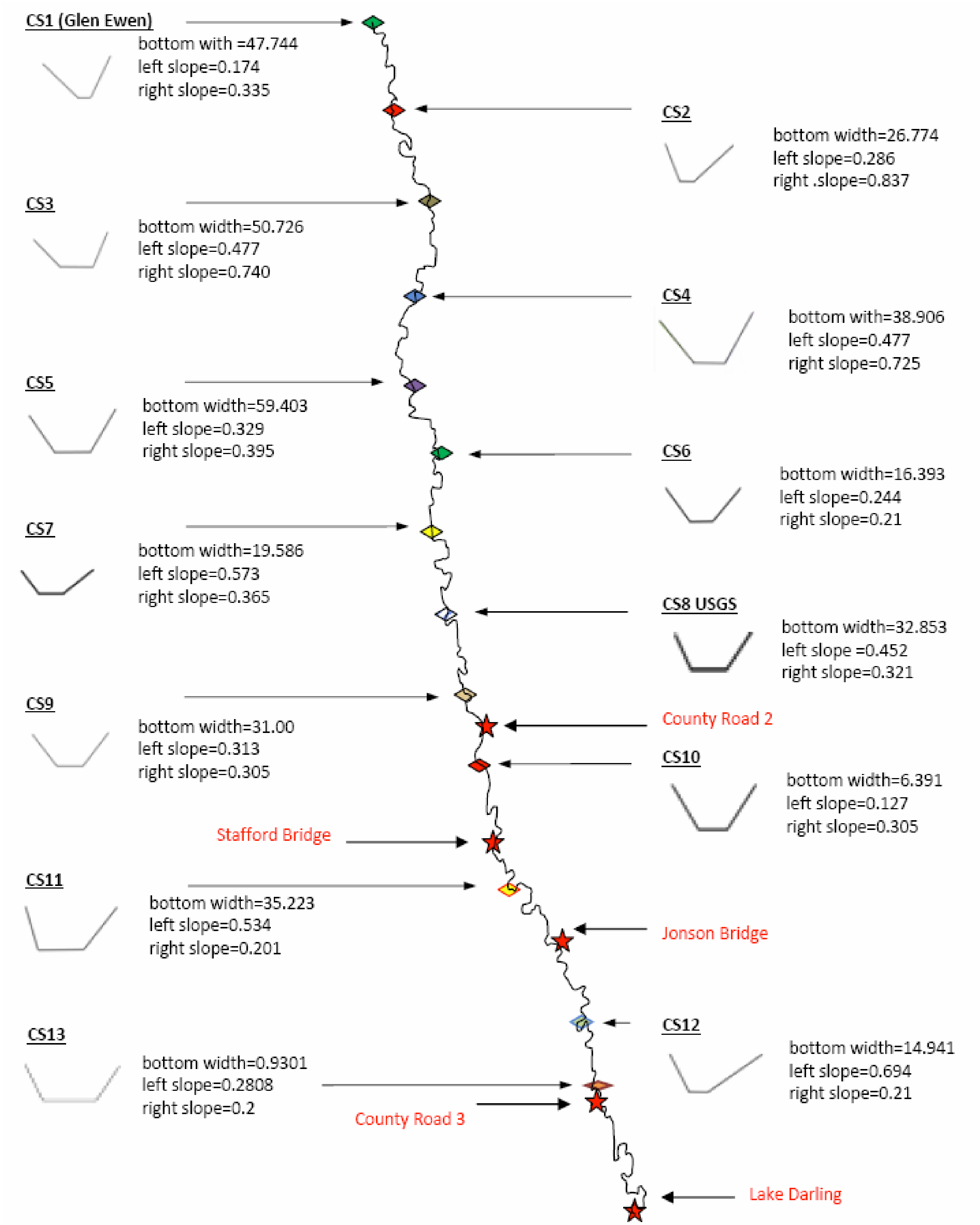


Figure 1. Upper Souris River Qual2K Simulation River Sub-reaches and Cross Section Profiles

Table ???. Calibrated Manning's roughness constant

Segment Name	Manning's Roughness Constant
Glen Ewen	0.065
2	0.065
3	0.050
4	0.080
5	0.090
6	0.020
7	0.065
USGS	0.010
9	0.010
County Road 2	0.010
10	0.010
Stafford Bridge	0.009
11	0.050
Johnson Bridge	0.050
12	0.050
13	0.010
County Road 3	0.020

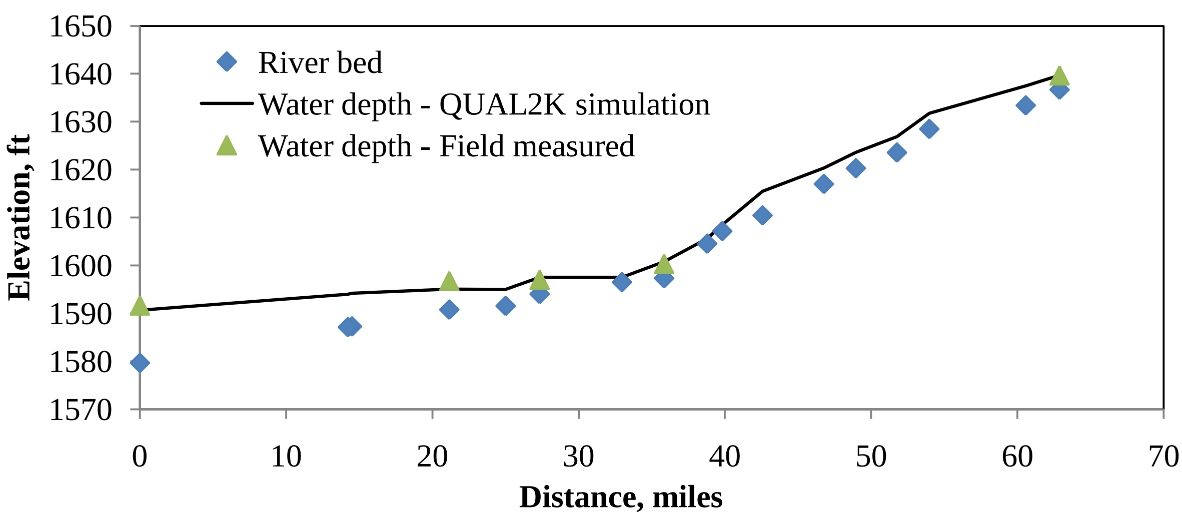


Figure ??? Calibrate river profile

DO Calibration

Sediment oxygen demand (SOD) was identified as the major oxygen sink along the study reach, and critical condition was identified in winter months when the river is covered with ice and flow is very low. Qual2K was calibrated assuming no aeration with ice cover and SOD was the only DO sink.

Sediment samples were taken from several locations along the river reach. Sediment oganic contents and SOD rates were determined in the laboratory. A linear correlation between SOD rates and organic contents were established and this relationship was used to determine SOD rates at other locations. Results from this study are shown in Table ??? and Figure ???

Using the SOD rates and organic contents obtained above, the Qual2K was run to match the field data from January 28, 2008. An increase of DO concentration at USGS Gaging Station 511400 was observed and this could be caused by opening in the ice cover upstream. It was assumed that the river is getting aerated at this location with an aeration rate of 0.5 day^{-1}. Resulted DO profile from this calibration is presented in Figure ???

Table ??? Organic Contents and SOD Rates

Sample locations	**Organic content %**	**SOD $gO_2/m^2/day$**
Glen Ewen	3.58	0.14*
Road Crossing (RC)	3.00	0.15*
Bridge Crossing (BC)	5.80	0.65**
USGS	6.11	0.74*
Country Road 2 (CR2)	2.61	0.14*
Stafford Bridge (SB)	13.32	2.03**
Johnson Bridge (JB)	14.91	2.32**
Cross section 12 (CS 12)	1.33	0.01**
County Road 3 (CR3)	4***	0.33*

* SOD rate measured in laboratory

**SOD rate estimated from the linear correlation

*** Organic content estimated from SOD rate based in the linear correlation

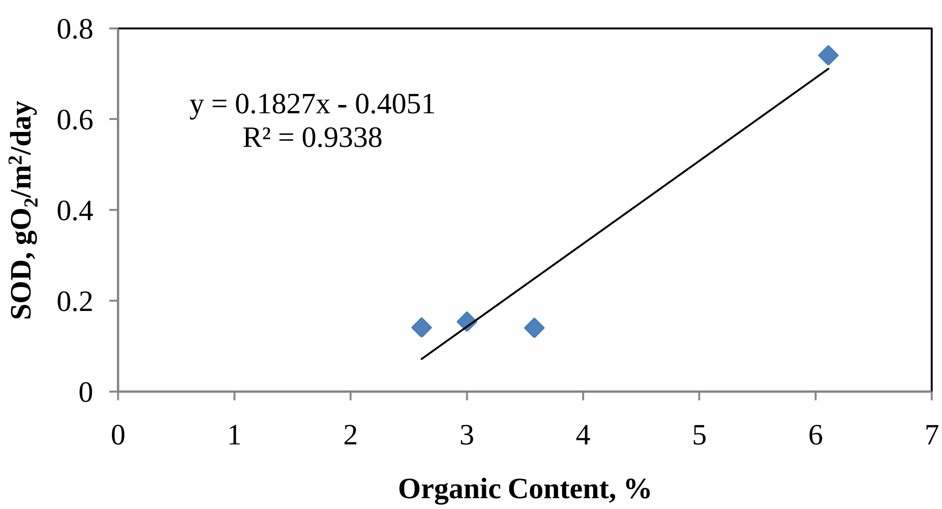


Figure ??? Relationship between SOD rates and sediment organic contents

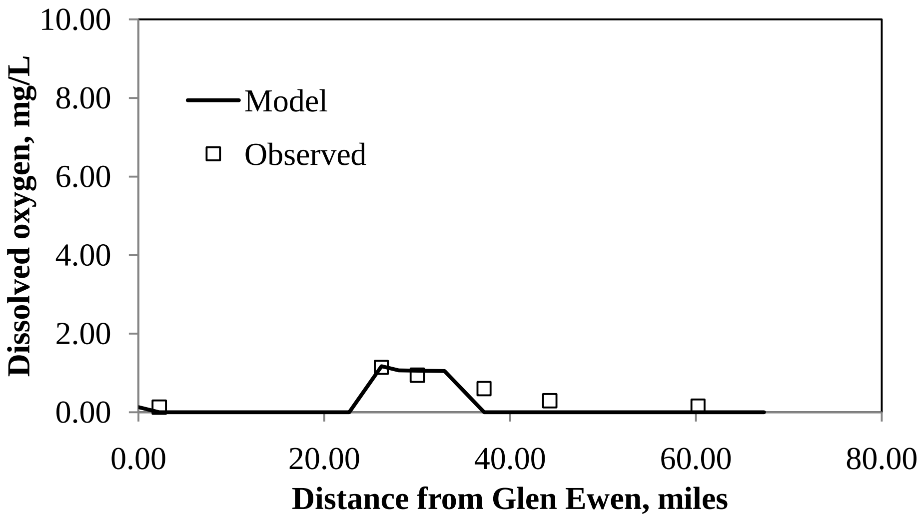


Figure ??? DO Calibration

<u>**DO Simulations**</u>

To improve DO levels during winter months, organic contents in the sediments have to be reduced to decrease SOD. It should be noted that reduction of SOD also has to be carried out upstream from Glen Ewen as well, because high sediment organic contents were observed and DO was almost completely depleted at Glen Ewen. Calibrated Qual2K was used to simulate DO along the study reach with assumptions of (1) reduction of sediment organic contents upstream of Glen Ewen only and (2) reduction of sediment organic contents both upstream of Glen Ewen and in the study reach.

(1) Reduction of sediment organic content upstream only

It was assumed that upstream was cleaned up and at Glen Ewen DO level reached 8 mg/L in winter months. Qual2K was run to determine whether this change will result in meeting DO standard of 5 mg/L through the entire study reach. Results of this simulation is shown in Figure ???. It is clear from the simulation results that upstream cleanup alone is not sufficient for meeting the DO standard downstream. Even the DO concentration at Glen Ewen was as high as 8 mg/L, DO dropped to below 1 mg/L downstream from the Johnson Bridge. Reduction of sediment organic content in the study reach is needed.

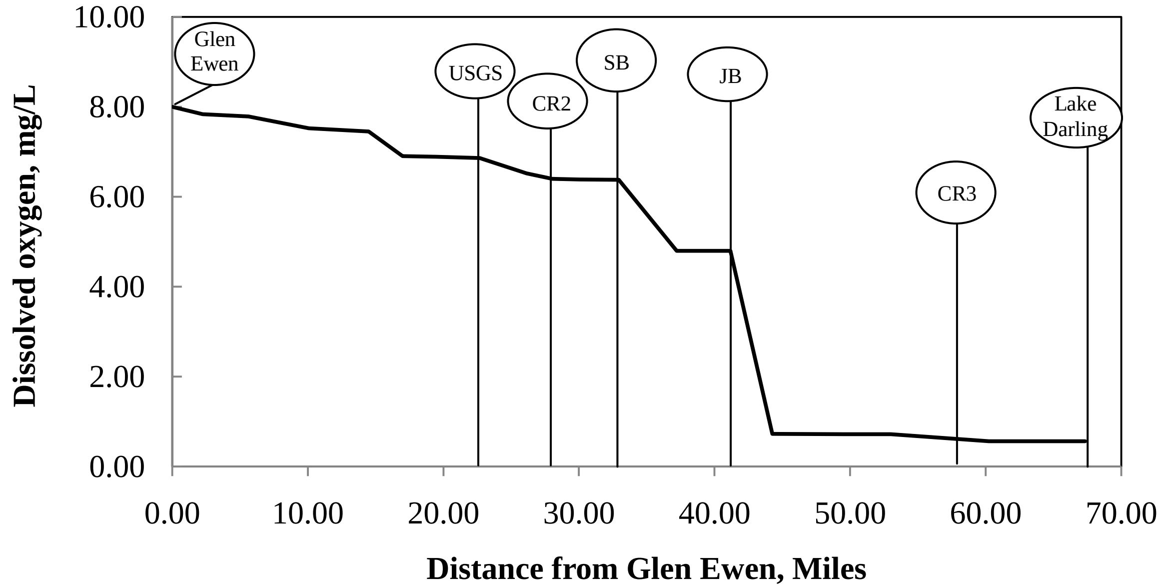


Figure ??? Qual2K simulation results assuming DO at Glen Ewen 8 mg/L

(2) Reduction of sediment organic content both upstream and downstream from Glen Ewen

To improve DO level to 5 mg/L at the entrance to Lake Darling, Qual2K simulations were performed to determine percent sediment organic reductions would be needed for different DO values, 6, 7, or 8 mg/L, at Glen Ewen. Results of these simulations (Figure ???) show that to maintain a minimum DO of 5 mg/L at Lake Darling, 31% sediment organic reduction along the reach would be needed if DO level at Glen Ewen could be raised to 8 mg/L. If DO level at Glen Ewen is lower than 8 mg/L, more sediment organic reductions would be needed. A 39% and a 55% sediment organic reductions would be required if DO at Glen Ewen is 7 mg/L and 6 mg/L, respectively.

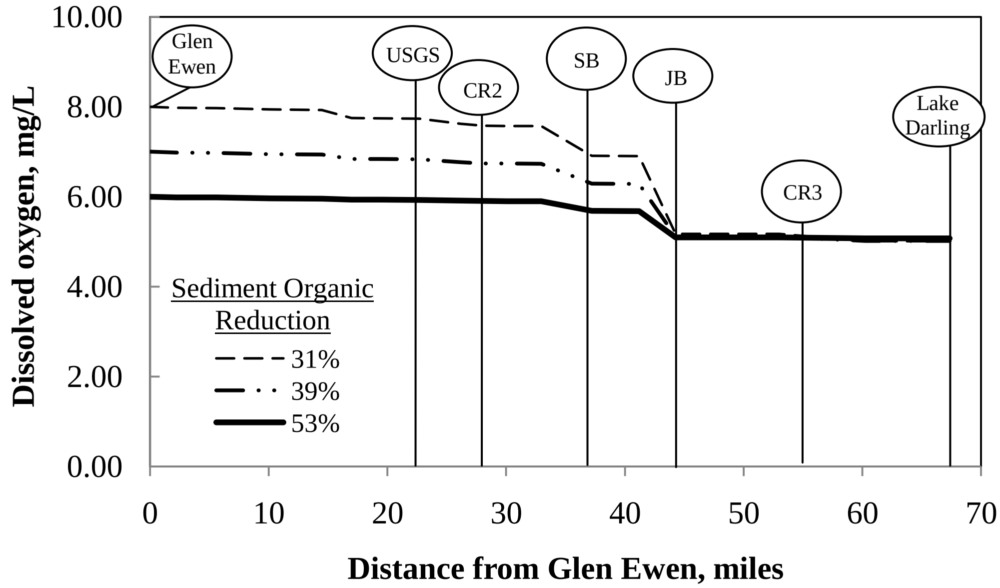


Figure ??? Required sediment organic reductions to maintain 5 mg/L DO at Lake Darling

References

Chapra, S.C., Pelletier, G.J. and Tao, H. 2008. QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 2.11: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA.

Appendix D
Macroinvertebrate Data

Data from 2007

2StationID	Waterbody Name	Location	Lat_Dec	Long_Dec	CollDate	ActivityID	BenSampID	Max Count	EPT Tax
552036	Souris River	From SHERWOOD, 14.5 Mi W.	48.96634	-101.94749	13-Sep-07	B-404081	14473	300	6
552053	Souris River	2.5 Mi South, 13.5 Mi West of Sherwood	48.92272	-101.92698	13-Sep-07	B-404085	14477	300	6
552057	Souris River	1 mi N of Canadian Border	49.02111	-101.973	13-Sep-07	B-404083	14475	300	3
552059	Souris River	13 mi N of Canada border	49.18018	-102.0275	13-Sep-07	B-404087	14480	300	8

StationID	WaterbodyName	Location	CollDate	EPTTax	IntolTax	PredPct	Beck BI	% Trich	% Intol Taxa
552036	Souris River	From SHERWOOD, 14.5 Mi W.	13-Sep-07	6	0	26.40264026	3	0.66	0
552053	Souris River	2.5 Mi South, 13.5 Mi West of Sherwood	13-Sep-07	6	1	53.93700787	2	2.76	1.57
552057	Souris River	1 mi N of Canadian Border	13-Sep-07	3	0	79.59183673	1	0	0
552059	Souris River	13 mi N of Canada border	13-Sep-07	8	1	4.332129964	4	19.49	2.89

Standardized Scores	EPTTax	IntolTax	PredPct	Beck BI	% Trich	% Intol Taxa	***IBI Score***	**Final IBI Score**
552036	60	0	31.470845	50	2.173913043	0	23.94079301	24
552053	60	33.33	0	33.33	9.090909091	6.26746507	23.67084014	24
552057	30	0	0	16.67	0	0	7.777777778	8
552059	80	33.33	91.10475557	66.67	64.19631094	11.53692615	57.80633211	58

Appendix E
Photos of Two Sampling Sites: One in US, One in Canada

Stafford Bridge, North Dakota, United States, Sampling Site

Glen Ewen, Saskatchewan, Canada, Sampling Site.

Appendix F
US EPA Region VIII
Public Notice Review

(No other comments from other agencies or individuals were received)

EPA REGION VIII TMDL REVIEW

TMDL Document Info:

Document Name:	**Dissolved Oxygen TMDL for the Souris River in Renville and Burke Counties, North Dakota**
Submitted by:	**Mike Ell, North Dakota Department of Health**
Date Received:	**August 13, 2010**
Review Date:	**August 25, 2010**
Reviewer:	**Vern Berry, EPA**
Rough Draft / Public Notice / Final?	**Public Notice**
Notes:	

Reviewers Final Recommendation(s) to EPA Administrator (used for final review only):

- ☐ Approve
- ☐ Partial Approval
- ☐ Disapprove
- ☐ Insufficient Information

Approval Notes to Administrator:

This document provides a standard format for EPA Region 8 to provide comments to state TMDL programs on TMDL documents submitted to EPA for either formal or informal review. All TMDL documents are evaluated against the minimum submission requirements and TMDL elements identified in the following 8 sections:

1. Problem Description
   1.1. TMDL Document Submittal Letter
   1.2. Identification of the Waterbody, Impairments, and Study Boundaries
   1.3. Water Quality Standards
2. Water Quality Target
3. Pollutant Source Analysis
4. TMDL Technical Analysis
   4.1. Data Set Description
   4.2. Waste Load Allocations (WLA)
   4.3. Load Allocations (LA)
   4.4. Margin of Safety (MOS)
   4.5. Seasonality and variations in assimilative capacity
5. Public Participation
6. Monitoring Strategy
7. Restoration Strategy
8. Daily Loading Expression

Under Section 303(d) of the Clean Water Act, waterbodies that are not attaining one or more water quality standard (WQS) are considered “impaired.” When the cause of the impairment is determined to be a pollutant, a TMDL analysis is required to assess the appropriate maximum allowable pollutant loading rate. A TMDL document consists of a technical analysis conducted to: (1) assess the maximum pollutant loading rate that a waterbody is able to assimilate while maintaining water quality standards; and (2) allocate that assimilative capacity among the known sources of that pollutant**.** A well written TMDL document will describe a path forward that may be used by those who implement the TMDL recommendations to attain and maintain WQS.

Each of the following eight sections describes the factors that EPA Region 8 staff considers when reviewing TMDL documents. Also included in each section is a list of EPA's minimum submission requirements relative to that section, a brief summary of the EPA reviewer's findings, and the reviewer's comments and/or suggestions. Use of the verb "must" in the minimum submission requirements denotes information that is required to be submitted because it relates to elements of the TMDL required by the CWA and by regulation. Use of the term "should" below denotes information that is generally necessary for EPA to determine if a submitted TMDL is approvable.

This review template is intended to ensure compliance with the Clean Water Act and that the reviewed documents are technically sound and the conclusions are technically defensible.

1. Problem Description

A TMDL document needs to provide a clear explanation of the problem it is intended to address. Included in that description should be a definitive portrayal of the physical boundaries to which the TMDL applies, as well as a clear description of the impairments that the TMDL intends to address and the associated pollutant(s) causing those impairments. While the existence of one or more impairment and stressor may be known, it is important that a comprehensive evaluation of the water quality be conducted prior to development of the TMDL to ensure that all water quality problems and associated stressors are identified. Typically, this step is conducted prior to the 303(d) listing of a waterbody through the monitoring and assessment program. The designated uses and water quality criteria for the waterbody should be examined against available data to provide an evaluation of the water quality relative to all applicable water quality standards. If, as part of this exercise, additional WQS problems are discovered and additional stressor pollutants are identified, consideration should be given to concurrently evaluating TMDLs for those additional pollutants. If it is determined that insufficient data is available to make such an evaluation, this should be noted in the TMDL document.

1.1 TMDL Document Submittal Letter

When a TMDL document is submitted to EPA requesting formal comments or a final review and approval, the submittal package should include a letter identifying the document being submitted and the purpose of the submission.

Minimum Submission Requirements.

☒ A TMDL submittal letter should be included with each TMDL document submitted to EPA requesting a formal review.

☒ The submittal letter should specify whether the TMDL document is being submitted for initial review and comments, public review and comments, or final review and approval.

☐ Each TMDL document submitted to EPA for final review and approval should be accompanied by a submittal letter that explicitly states that the submittal is a final TMDL submitted under Section 303(d) of the Clean Water Act for EPA review and approval. This clearly establishes the State's/Tribe's intent to submit, and EPA's duty to review, the TMDL under the statute**.** The submittal letter should contain such identifying information as the name and location of the waterbody and the pollutant(s) of concern, which matches similar identifying information in the TMDL document for which a review is being requested.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The public notice draft Souris River dissolved oxygen TMDL was submitted to EPA for review via an email from Mike Ell, NDDoH on August 13, 2010. The email included the draft TMDL document and a request to review and comment on the TMDL document.

COMMENTS: None.

1.2 Identification of the Waterbody, Impairments, and Study Boundaries

The TMDL document should provide an unambiguous description of the waterbody to which the TMDL is intended to apply and the impairments the TMDL is intended to address. The document should also clearly delineate the physical boundaries of the waterbody and the geographical extent of the watershed area studied. Any additional information needed to tie the TMDL document back to a current 303(d) listing should also be included.

Minimum Submission Requirements:

☒ The TMDL document should clearly identify the pollutant and waterbody segment(s) for which the TMDL is being established. If the TMDL document is submitted to fulfill a TMDL development requirement for a waterbody on the state's current EPA approved 303(d) list, the TMDL document submittal should clearly identify the waterbody and associated impairment(s) as they appear on the State's/Tribe's current EPA approved 303(d) list, including a full waterbody description, assessment unit/waterbody ID, and the priority ranking of the waterbody. This information is necessary to ensure that the administrative record and the national TMDL tracking database properly link the TMDL document to the 303(d) listed waterbody and impairment(s).

☒ One or more maps should be included in the TMDL document showing the general location of the waterbody and, to the maximum extent practical, any other features necessary and/or relevant to the understanding of the TMDL analysis, including but not limited to: watershed boundaries, locations of major pollutant sources, major tributaries included in the analysis, location of sampling points, location of discharge gauges, land use patterns, and the location of nearby waterbodies used to provide surrogate information or reference conditions. Clear and concise descriptions of all key features and their relationship to the waterbody and water quality data should be provided for all key and/or relevant features not represented on the map

☐ If information is available, the waterbody segment to which the TMDL applies should be identified/geo-referenced using the National Hydrography Dataset (NHD). If the boundaries of the TMDL do not correspond to the Waterbody ID(s) (WBID), Entity_ID information or reach code (RCH_Code) information should be provided. If NHD data is not available for the waterbody, an alternative geographical referencing system that unambiguously identifies the physical boundaries to which the TMDL applies may be substituted.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Souris River watershed is a 109,103 acre watershed located in Renville and Burke Counties, in north western North Dakota. The listed segment of the Souris River mainstem is from the North Dakota / Saskatchewan, Canada border downstream to Lake Darling (43.4 miles; ND-09010001-001-S_00). It is part of the larger Souris River basin in the Upper Souris sub-basin (HUC 09010001). This segment is listed as impaired for sediment/siltation, fecal coliform and dissolved oxygen. The TMDL document included in this review only addresses the dissolved oxygen impairment. The other impairments will be addressed in separate documents.

The designated uses for this segment of the Souris River are based on the Class IA stream classification in the ND water quality standards (NDCC 33-15-02.1-09).

COMMENTS: None.

1.3 Water Quality Standards

TMDL documents should provide a complete description of the water quality standards for the waterbodies addressed, including a listing of the designated uses and an indication of whether the uses are being met, not being met, or not assessed. If a designated use was not assessed as part of the TMDL analysis (or not otherwise recently assessed), the documents should provide a reason for the lack of assessment (e.g., sufficient data was not available at this time to assess whether or not this designated use was being met).

Water quality criteria (WQC) are established as a component of water quality standard at levels considered necessary to protect the designated uses assigned to that waterbody. WQC identify quantifiable targets and/or qualitative water quality goals which, if attained and maintained, are intended to ensure that the designated uses for the waterbody are protected. TMDLs result in maintaining and attaining water quality standards by determining the appropriate maximum pollutant loading rate to meet water quality criteria, either directly, or through a surrogate measurable target. The TMDL document should include a description of all applicable water quality criteria for the impaired designated uses and address whether or not the criteria are being attained, not attained, or not evaluated as part of the analysis. If the criteria were not evaluated as part of the analysis, a reason should be cited (e.g. insufficient data were available to determine if this water quality criterion is being attained).

Minimum Submission Requirements:

☒ The TMDL must include a description of the applicable State/Tribal water quality standard, including the designated use(s) of the waterbody, the applicable numeric or narrative water quality criterion, and the anti-degradation policy. (40 C.F.R. §130.7(c)(1)).

☒ The purpose of a TMDL analysis is to determine the assimilative capacity of the waterbody that corresponds to the existing water quality standards for that waterbody, and to allocate that assimilative capacity between the significant sources. Therefore, all TMDL documents must be written to meet the existing water quality standards for that waterbody (CWA §303(d)(1)(C)).

Note: In some circumstances, the load reductions determined to be necessary by the TMDL analysis may prove to be infeasible and may possibly indicate that the existing water quality standards and/or assessment methodologies may be erroneous. However, the TMDL must still be determined based on existing water quality standards. Adjustments to water quality standards and/or assessment methodologies may be evaluated separately, from the TMDL.

☒ The TMDL document should describe the relationship between the pollutant of concern and the water quality standard the pollutant load is intended to meet. This information is necessary for EPA to evaluate whether or not attainment of the prescribed pollutant loadings will result in attainment of the water quality standard in question.

☒ If a standard includes multiple criteria for the pollutant of concern, the document should demonstrate that the TMDL value will result in attainment of all related criteria for the pollutant. For example, both acute and chronic values (if present in the WQS) should be addressed in the document, including consideration of magnitude, frequency and duration requirements.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Souris River segment addressed by this TMDL document is impaired based on dissolved oxygen concentrations for fish and aquatic life uses. The Souris River is Class IA stream that shall be suitable for the propagation and/or protection of resident fish species and other aquatic biota and for swimming, boating, and other water recreation. Class IA streams shall also be suitable for irrigation, stock watering and wildlife without injurious effects. Numeric criteria for dissolved oxygen in Class IA streams have been established and are presented in the excerpted Table 9 shown below. Discussion of additional applicable water quality standards for Souris River can be found on pages 20 and 21 of the TMDL.

Table 9. North Dakota Dissolved Oxygen Standards for Class IA Streams.

	Water Quality Standard (minimum value)
Dissolved Oxygen	5.0 mg/L[1]

[1] **Up to 10% of representative samples collected during any 3 year period may be less than this value provided lethal conditions are avoided.**

The International Souris River Board has set water quality objectives for the Souris River as it crosses the boundary from Canada to the United States, which is the upper portion of this TMDL reach. As documented in their most recent Annual Report to the International Joint Commission, the dissolved oxygen bacteria objective is 5 mg/L (ISRB, 2007).

COMMENTS: None.

2. Water Quality Targets

TMDL analyses establish numeric targets that are used to determine whether water quality standards are being achieved. Quantified water quality targets or endpoints should be provided to evaluate each listed pollutant/water body combination addressed by the TMDL, and should represent achievement of applicable water quality standards and support of associated beneficial uses. For pollutants with numeric water quality standards, the numeric criteria are generally used as the water quality target. For pollutants with narrative standards, the narrative standard should be translated into a measurable value. At a minimum, one target is required for each pollutant/water body combination. It is generally desirable, however, to include several targets that represent achievement of the standard and support of beneficial uses (e.g., for a sediment impairment issue it may be appropriate to include a variety of targets representing water column sediment such as TSS, embeddeness, stream morphology, up-slope conditions and a measure of biota).

Minimum Submission Requirements:

☒ The TMDL should identify a numeric water quality target(s) for each waterbody pollutant combination. The TMDL target is a quantitative value used to measure whether or not the applicable water quality standard is attained.

Generally, the pollutant of concern and the numeric water quality target are, respectively, the chemical causing the impairment and the numeric criteria for that chemical (e.g., chromium) contained in the water quality standard. Occasionally, the pollutant of concern is different from the parameter that is the subject of the numeric water quality target (e.g., when the pollutant of concern is phosphorus and the numeric water quality target is expressed as a numerical dissolved oxygen criterion). In such cases, the TMDL should explain the linkage between the pollutant(s) of concern, and express the quantitative relationship between the TMDL target and pollutant of concern. In all cases, TMDL targets must represent the attainment of current water quality standards.

☐ When a numeric TMDL target is established to ensure the attainment of a narrative water quality criterion, the numeric target, the methodology used to determine the numeric target, and the link between the pollutant of concern and the narrative water quality criterion should all be described in the TMDL document. Any additional information supporting the numeric target and linkage should also be included in the document.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The water quality target for this TMDL is based on the numeric water quality standards for dissolved oxygen based on the fish and aquatic life beneficial use for Souris River. The target for the Souris River segment included in the TMDL document is the dissolved oxygen standard expressed as daily minimum of 5.0 mg/L (up to 10 percent of representative samples collected during any three year period may be less than this value provided that lethal conditions are avoided).

The International Souris River Board has set water quality objectives for the Souris River as it crosses the boundary from Canada to the United States. As documented in their most recent Annual Report to the International Joint Commission, the dissolved oxygen objective is 5 mg/L (ISRB, 2007). This objective, effective at the border, creates a boundary condition of 5 mg/L and is equivalent to the North Dakota target.

COMMENTS: None.

3. Pollutant Source Analysis

A TMDL analysis is conducted when a pollutant load is known or suspected to be exceeding the loading capacity of the waterbody. Logically then, a TMDL analysis should consider all sources of the pollutant of concern in some manner. The detail provided in the source assessment step drives the rigor of the pollutant load allocation. In other words, it is only possible to specifically allocate quantifiable loads or load reductions to each significant source (or source category) when the relative load contribution from each source has been estimated. Therefore, the pollutant load from each significant source (or source category) should be identified and quantified to the maximum practical extent. This may be accomplished using site-specific monitoring data, modeling, or application of other assessment techniques. If insufficient time or resources are available to accomplish this step, a phased/adaptive management approach may be appropriate. The approach should be clearly defined in the document.

Minimum Submission Requirements:

☒ The TMDL should include an identification of all potentially significant point and nonpoint sources of the pollutant of concern, including the geographical location of the source(s) and the quantity of the loading, e.g., lbs/per day. This information is necessary for EPA to evaluate the WLA, LA and MOS components of the TMDL.

☒ The level of detail provided in the source assessment should be commensurate with the nature of the watershed and the nature of the pollutant being studied. Where it is possible to separate natural background from nonpoint sources, the TMDL should include a description of both the natural background loads and the nonpoint source loads.

☒ Natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g. measured in stream) unless it can be demonstrated that all significant anthropogenic sources of the pollutant of concern have been identified, characterized, and properly quantified.

☒ The sampling data relied upon to discover, characterize, and quantify the pollutant sources should be included in the document (e.g. a data appendix) along with a description of how the data were analyzed to characterize and quantify the pollutant sources. A discussion of the known deficiencies and/or gaps in the data set and their potential implications should also be included.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The TMDL document includes the landuse breakdown for the watershed based on the 2006 National Agricultural Statistics Service data. In 2006, approximately 49 percent of the landuse in the watershed was cropland under active cultivation, 21 percent was pasture/range/haylands, and the remaining 30 percent was idle/fallow, water or roads.

Within the U.S. portion of Souris River watershed there are no point sources permitted through the North Dakota Pollutant Discharge Elimination System (NDPDES) Program. Towns located within the watershed utilize septic waste systems. The upstream city of Estevan, Saskatchewan, Canada discharges from an advanced wastewater treatment system.

There are two permitted animal feeding operations in the watershed, however, they are zero discharge facilities and are not deemed a significant source for this report.

The data collected during the water quality assessment indicate that the primary nonpoint sources contributing to the low dissolved oxygen levels in the Souris River watershed are as follows:

- Nutrient runoff from cropland contributing to excessive macrophyte and algal growth resulting in organic enrichment;
- Runoff of manure from animal feeding areas, which contributes directly to the organic load;
- Direct deposit of manure into Souris River by livestock; and
- Background levels associated with wildlife.

Sediment oxygen demand (SOD) is a possible oxygen depleting source. An observation of the sediment during field visits indicated sediments were black in color and smelled of hydrogen sulfide (H_2S), which can be a sign of the sediment having a high percentage of organic material. The higher the organic content in the soil, the faster oxygen is depleted. The sites with lower percent organics consisted more of rocky and sandy sediment while the higher percent organic sediments were black in color and made up of finer material. The higher percent organic soil was found where the water was deeper and wider. Lower velocity water allows sediments to settle out in larger pools.

COMMENTS: None.

4. TMDL Technical Analysis

TMDL determinations should be supported by a robust data set and an appropriate level of technical analysis**.** This applies to **all** of the components of a TMDL document. It is vitally important that the technical basis for **all** conclusions be articulated in a manner that is easily understandable and readily apparent to the reader.

A TMDL analysis determines the maximum pollutant loading rate that may be allowed to a waterbody without violating water quality standards. The TMDL analysis should demonstrate an understanding of the relationship between the rate of pollutant loading into the waterbody and the resultant water quality impacts. This stressor → response relationship between the pollutant and impairment and between the selected targets, sources, TMDLs, and load allocations needs to be clearly articulated and supported by an appropriate level of technical analysis. Every effort should be made to be as detailed as possible, and to base all conclusions on the best available scientific principles.

The pollutant loading allocation is at the heart of the TMDL analysis. TMDLs apportion responsibility for taking actions by allocating the available assimilative capacity among the various point, nonpoint, and natural pollutant sources. Allocations may be expressed in a variety of ways, such as by individual discharger, by tributary watershed, by source or land use category, by land parcel, or other appropriate scale or division of responsibility.

The pollutant loading allocation that will result in achievement of the water quality target is expressed in the form of the standard TMDL equation:

$$TMDL = \sum LAs + \sum WLAs + MOS$$

Where:

TMDL = Total Pollutant Loading Capacity of the waterbody

LAs = Pollutant Load Allocations

WLAs = Pollutant Wasteload Allocations

MOS = The portion of the Load Capacity allocated to the Margin of safety.

Minimum Submission Requirements:

☒ A TMDL must identify the loading capacity of a waterbody for the applicable pollutant, taking into consideration temporal variations in that capacity. EPA regulations define loading capacity as the greatest amount of a pollutant that a water can receive without violating water quality standards (40 C.F.R. §130.2(f)).

☒ The total loading capacity of the waterbody should be clearly demonstrated to equate back to the pollutant load allocations through a balanced TMDL equation. In instances where numerous LA, WLA and seasonal TMDL capacities make expression in the form of an equation cumbersome, a table may be substituted as long as it is clear that the total TMDL capacity equates to the sum of the allocations.

☒ The TMDL document should describe the methodology and technical analysis used to establish and quantify the cause-and-effect relationship between the numeric target and the identified pollutant sources. In many instances, this method will be a water quality model.

☒ It is necessary for EPA staff to be aware of any assumptions used in the technical analysis to understand and evaluate the methodology used to derive the TMDL value and associated loading allocations. Therefore, the TMDL document should contain a description of any important assumptions (including the basis for those assumptions) made in developing the TMDL, including but not limited to:

(1) the spatial extent of the watershed in which the impaired waterbody is located and the spatial extent of the TMDL technical analysis;
(2) the distribution of land use in the watershed (e.g., urban, forested, agriculture);
(3) a presentation of relevant information affecting the characterization of the pollutant of concern and its allocation to sources such as population characteristics, wildlife resources, industrial activities etc…;
(4) present and future growth trends, if taken into consideration in determining the TMDL and preparing the TMDL document (e.g., the TMDL could include the design capacity of an existing or planned wastewater treatment facility);
(5) an explanation and analytical basis for expressing the TMDL through surrogate measures, if applicable. Surrogate measures are parameters such as percent fines and turbidity for sediment impairments; chlorophyll *a* and phosphorus loadings for excess algae; length of riparian buffer; or number of acres of best management practices.

☒ The TMDL document should contain documentation supporting the TMDL analysis, including an inventory of the data set used, a description of the methodology used to analyze the data, a discussion of strengths and weaknesses in the analytical process, and the results from any water quality modeling used. This information is necessary for EPA to review the loading capacity determination, and the associated load, wasteload, and margin of safety allocations.

☒ TMDLs must take critical conditions (e.g., steam flow, loading, and water quality parameters, seasonality, etc…) into account as part of the analysis of loading capacity (40 C.F.R. §130.7(c)(1)). TMDLs should define applicable critical conditions and describe the approach used to determine both point and nonpoint source loadings under such critical conditions. In particular, the document should discuss the approach used to compute and allocate nonpoint source loadings, e.g., meteorological conditions and land use distribution.

☐ Where both nonpoint sources and NPDES permitted point sources are included in the TMDL loading allocation, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document must include a demonstration that nonpoint source loading reductions needed to implement the load allocations are actually practicable [40 CFR 130.2(i) and 122.44(d)].

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The technical analysis should describe the cause and effect relationship between the identified pollutant sources, the numeric targets, and achievement of water quality standards. It should also include a description of the analytical processes used, results from water quality modeling, assumptions and other pertinent information. The following technical analysis addresses the low dissolved oxygen impairment through a sediment oxygen demand (SOD) load allocation and the organic load allocation reductions necessary to achieve the dissolved oxygen water quality standards target of $\geq$ 5.0 mg/L, plus a margin of safety.

Fish and macroinvertebrates require minimum levels of dissolved oxygen (DO) in order to grow, reproduce, and survive. Groundwater, which often flows into streams during dry weather, is naturally low in DO. Aquatic plant life serves as both a source (photosynthetic oxygen production) and a sink (respiration and decomposition) for DO in aquatic ecosystems. However, the measurement of dissolved oxygen concentrations does not directly measure the pollutants contributing to the impairment. Some analysis into interactions with other chemical processes as well as the need to determine the relationship between them is required.

Biochemical oxygen demand (BOD) represents the amount of dissolved oxygen required by aerobic biological organisms in a body of water to break down (oxidize) organic matter present in a given water sample at a certain temperature over a specific period of time. The greater the amount of BOD; the greater the oxygen depletion in a stream or lake. Carbonaceous biochemical oxygen demand (CBOD) is the amount of oxygen required by bacteria to oxidize organic carbon material to carbon dioxide (its lowest energy state). In rural areas, sources of oxygen-demanding substances may include diffuse runoff of agricultural fertilizer and animal wastes (from manure application or grazing animals), soil erosion, and runoff from concentrated animal operations. Excessive nutrient levels from runoff can sometimes cause enough eutrophication to generate CBOD loads from decaying algae. The accumulation and decomposition of organic matter may not occur at the pollutant load source, but may show up downstream where velocities are slow and the algae populations collect. This is part of the process in this impaired reach of the Souris river as the shallow reaches upstream in Canada contain high nutrient concentrations, and a great deal of deadfall and logjams in the river, then as the river flows through North Dakota it is incised which slows the flow. Where the water velocities drop, excess algae growth is may occur. In addition to CBOD, nitrogenous biochemical oxygen demand (NBOD) can also be a significant source of oxygen depletion in surface waters.

Sediment oxygen demand (SOD) is a combination of several processes, primarily the aerobic decay of organic material that has settled to the bottom of a streambed or lake bottom. Examples of organic materials that can act as sources of SOD include leaf litter, particulate organic matter from point or nonpoint sources, and algae or plant biomass.

Direct discharge of pollutants from point and nonpoint sources into a river segment adds to its CBOD and NBOD, creating an oxygen demand that may depress DO below levels need to support designated aquatic life uses. High nutrient (nitrogen and phosphorus) levels can cause the eutrophication process to generate CBOD loads from decaying algae.

Oxygen demand caused by benthic sediments can represent a significant oxygen sink in some rivers. The deposition of organic material originating from external sources, such as leaf litter or aquatic plant decay, can create a SOD that is localized and more detrimental at areas in the river such as deep pools. In times of low flow, pools where sediments have settled out create an oxygen demand that can contribute to SOD. SOD during the winter months, when a river is covered by ice, can cause low DO conditions. Ice and snow prevents re-aeration and photosynthesis. Oxygen depletion can become widespread throughout the stream without points where water is open to the air.

The impaired reach of the Souris River (ND-09010001-001-S_00) has several of the conditions described above. First, there is high nutrient loading occurring from nonpoint sources throughout the reach, as well as above the reach in Canada. This nutrient loading is leading to excessive algal growth during the summer months as indicated by both conversations with local residents, and the very large diurnal DO swings that are noted in the TMDL document. The algae then goes through boom and bust cycles that create both an oxygen deficit in the summer, as well as contribute organic matter to the benthic sediment during die-off. Second, the construction of three large reservoirs upstream in Canada, have reduced the scour of organic matter that usually occurs with spring floods. This has aided in the deposition of large amounts of organic matter, and subsequent incorporation into the benthic sediment, in the impaired reach of North Dakota. The North Dakota portion of the river channel is also incised, which slows the velocity of the river since the channel can hold more water. This slow moving water, which reaches almost no flow during the winter months, decreases the re-aeration of the water. During the winter when the river is covered with ice, and has very little flow, the re-aeration of the river is halted entirely. During this period, sediment oxygen demand causes almost three months of dissolved oxygen concentrations to be near zero.

Because the DO levels in the winter are the most critical and longest lasting, SOD was chosen to represent the dissolved oxygen load for the impaired reach of the Souris River. Because it is the organic content of the sediment, which accumulates over the course of the entire year, that drives the SOD rate, a linear regression model was developed between SOD rate and the percent organic content of the sediment. This regression model was then used to estimate SOD rate based on measured percent organic matter for stream reaches without measured SOD rates and to estimate SOD rates for stream reaches based on reductions in percent organic content of the sediment.

The QUAL2K model, a comprehensive stream water quality model, was used to simulate water quality conditions in the impaired reach. The QUAL2K model simulates dissolved oxygen in the river using one dimensional advection-dispersion mass transport equation, with consideration of various oxygen sources and sinks. Because winter months were identified as critical conditions for low DO, the QUAL2K model was calibrated for a low flow condition of 30 cfs and river water depths were available at all sampling points.

In order to evaluate the effects of varying headwater DO concentrations and reductions in SOD rate, multiple QUAL2K DO model simulations were run. The purpose of these model simulations were to determine which combination of headwater DO concentration and SOD rate reduction would be necessary and reasonable to meet the TMDL DO target of 5 mg/L throughout the impaired reach. It is assumed, based on the linear regression model, that to reduce SOD to rates necessary to meet the DO target during winter months, the percent organic content in the sediments has to be reduced.

To increase dissolved oxygen levels to 5 mg/L throughout the impaired reach, three QUAL2K simulations were performed. These simulations assessed the combined effect of altering the headwater DO concentration and the accompanying reduction in SOD rate needed to meet the 5 mg/L DO standard throughout the impaired reach. Three simulations were run with the initial upstream DO concentration set at 6, 7, and 8 mg/L at Glen Ewen, Canada. Accompanying each headwater DO concentration was a different set of SOD rates needed to meet the 5 mg/L standard. SOD rates used in the three model simulations were estimated from reductions in the percent organic content of the sediments. For the 8 mg/L DO headwater scenario, a 31 percent reduction in percent organic content was necessary to reduce SOD rate needed to meet the DO target. For the 7 mg/L headwater scenario a 39 percent reduction in percent organic matter is needed, and for the 6 mg/L scenario a 53 percent reduction is needed.

Table 17, excerpted from the TMDL, provides an estimate of the existing daily load (expressed as the weighted average SOD rate) and an estimate of the average daily load (expressed as the weighted average SOD rate based on a 53% reduction in percent organic content of sediment) necessary to meet the dissolved oxygen water quality target. This TMDL load includes a load allocation from known nonpoint sources and a ten percent margin of safety.

Table 17. Dissolved Oxygen TMDL for ND-09010001-001-S_00 (expressed as SOD in $gO^2/m^2/day$

Existing Load	0.68	Based on weighted average existing SOD rate for the impaired reach.
TMDL[1]	0.29	Based on a 53% reduction in percent organic content of sediments in each of the segments in the impaired reach
WLA	None	
LA	0.26	TMDL-MOS
MOS	0.03	Based on a 10% Explicit MOS

[1] Assumes a 6 mg/L headwater DO concentration near Glen Ewen, Sask.

COMMENTS: None.

4.1 Data Set Description

TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis. An inventory of the data used for the TMDL analysis should be provided to document, for the record, the data used in decision making. This also provides the reader with the opportunity to independently review the data. The TMDL analysis should make use of all readily available data for the waterbody under analysis unless the TMDL writer determines that the data are not relevant or appropriate. For relevant data that were known but rejected, an explanation of why the data were not utilized should be provided (e.g., samples exceeded holding times, data collected prior to a specific date were not considered timely, etc…).

Minimum Submission Requirements:

☒ TMDL documents should include a thorough description and summary of all available water quality data that are relevant to the water quality assessment and TMDL analysis such that the water quality impairments are clearly defined and linked to the impaired beneficial uses and appropriate water quality criteria.

☒ The TMDL document submitted should be accompanied by the data set utilized during the TMDL analysis. If possible, it is preferred that the data set be provided in an electronic format and referenced in the document. If electronic submission of the data is not possible, the data set may be included as an appendix to the document.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Souris River TMDL data description and summary are included in the Available Data section of the TMDL, in tables throughout the document and in the data tables in Appendices B - E. They consist of historic (1994 – 2004) dissolved oxygen data from USGS gauging station 5114000, more recent water quality monitoring (2006-2007) at five sites (four along the impaired reach and one in Canada), historic and current nutrient data, macroinvertebrate data, flow data, sediment oxygen demand data, and observational data. The various types of data described were used, along with cross section profile data of the river, to run the QUAL2K model.

COMMENTS: None.

4.2 Waste Load Allocations (WLA):

Waste Load Allocations represent point source pollutant loads to the waterbody. Point source loads are typically better understood and more easily monitored and quantified than nonpoint source loads. Whenever practical, each point source should be given a separate waste load allocation. All NPDES permitted dischargers that discharge the pollutant under analysis directly to the waterbody should be identified and given separate waste load allocations. The finalized WLAs are required to be incorporated into future NPDES permit renewals.

Minimum Submission Requirements:

☒ EPA regulations require that a TMDL include WLAs for all significant and/or NPDES permitted point sources of the pollutant. TMDLs must identify the portion of the loading capacity allocated to individual existing and/or future point source(s) (40 C.F.R. §130.2(h), 40 C.F.R. §130.2(i)). In some cases, WLAs may cover more than one discharger, e.g., if the source is contained within a general permit. If no allocations are to be made to point sources, then the TMDL should include a value of zero for the WLA.

☒ All NPDES permitted dischargers given WLA as part of the TMDL should be identified in the TMDL, including the specific NPDES permit numbers, their geographical locations, and their associated waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: Within the U.S. portion of Souris River watershed there are no point sources permitted through the North Dakota Pollutant Discharge Elimination System (NDPDES) Program. Towns located within the watershed utilize septic waste systems. The upstream city of Estevan, Saskatchewan, Canada discharges from an advanced wastewater treatment system.

There are two permitted animal feeding operations in the watershed, however, they are zero discharge facilities and are not deemed a significant source for this report. Therefore, the WLA for the dissolved oxygen TMDL is zero.

COMMENTS: None.

4.3 Load Allocations (LA):

Load allocations include the nonpoint source, natural, and background loads. These types of loads are typically more difficult to quantify than point source loads, and may include a significant degree of uncertainty. Often it is necessary to group these loads into larger categories and estimate the loading rates based on limited monitoring data and/or modeling results. The background load represents a composite of all upstream pollutant loads into the waterbody. In addition to the upstream nonpoint and upstream natural load, the background load often includes upstream point source loads that are not given specific waste load allocations in this particular TMDL analysis. In instances where nonpoint source loading rates are particularly difficult to quantify, a performance-based allocation approach, in which a detailed monitoring plan and adaptive management strategy are employed for the application of BMPs, may be appropriate.

Minimum Submission Requirements:

- ☒ EPA regulations require that TMDL expressions include LAs which identify the portion of the loading capacity attributed to nonpoint sources and to natural background. Load allocations may range from reasonably accurate estimates to gross allotments (40 C.F.R. §130.2(g)). Load allocations may be included for both existing and future nonpoint source loads. Where possible, load allocations should be described separately for natural background and nonpoint sources.
- ☒ Load allocations assigned to natural background loads should not be assumed to be the difference between the sum of known and quantified anthropogenic sources and the existing *in situ* loads (e.g., measured in stream) unless it can be demonstrated that all significant anthropogenic sources of the pollutant of concern have been identified and given proper load or waste load allocations.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The TMDL document includes the landuse breakdown for the watershed based on the 2006 National Agricultural Statistics Service data. In 2006, approximately 49 percent of the landuse in the watershed was cropland under active cultivation, 21 percent was pasture/range/haylands, and the remaining 30 percent was idle/fallow, water or roads. There are no known point sources that could potentially impact the watershed. Therefore, the entire 53 percent reduction in the organic content of the sediment and the resulting SOD load for this TMDL is allocated to nonpoint sources in the watershed.

The entire nonpoint source load is allocated as a single load because there is not enough detailed source data to allocate the load to individual uses (e.g., animal feeding, septic systems, riparian grazing, upland grazing).
A specific allocation of SOD to Saskatchewan, Canada cannot be given due to lack of data. However the conclusion of the model indicates that improvement to the stream on both sides of the international border in the form of reduced nutrients and organic content to the sediment, along with additional flows in the winter to provide reaeration will be needed in order to meet water quality standards.

COMMENTS: None.

4.4 Margin of Safety (MOS):

Natural systems are inherently complex. Any mathematical relationship used to quantify the stressor → response relationship between pollutant loading rates and the resultant water quality impacts, no matter how rigorous, will include some level of uncertainty and error. To compensate for this uncertainty and ensure water quality standards will be attained, a margin of safety is required as a component of each TMDL. The MOS may take the form of a explicit load allocation (e.g., 10 lbs/day), or may be implicitly built into the TMDL analysis through the use of conservative assumptions and values for the various factors that determine the TMDL pollutant load → water quality effect relationship. Whether explicit or implicit, the MOS should be supported by an appropriate level of discussion that addresses the level of uncertainty in the various components of the TMDL technical analysis, the assumptions used in that analysis, and the relative effect of those assumptions on the final TMDL. The discussion should demonstrate that the MOS used is sufficient to ensure that the water quality standards would be attained if the TMDL pollutant loading rates are met. In cases where there is substantial uncertainty regarding the linkage between the proposed allocations and achievement of water quality standards, it may be necessary to employ a phased or adaptive management approach (e.g., establish a monitoring plan to determine if the proposed allocations are, in fact, leading to the desired water quality improvements).

Minimum Submission Requirements:

☒ TMDLs must include a margin of safety (MOS) to account for any lack of knowledge concerning the relationship between load and wasteload allocations and water quality (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)). EPA's 1991 TMDL Guidance explains that the MOS may be implicit (i.e., incorporated into the TMDL through conservative assumptions in the analysis) or explicit (i.e., expressed in the TMDL as loadings set aside for the MOS).

- ☐ If the MOS is implicit, the conservative assumptions in the analysis that account for the MOS should be identified and described. The document should discuss why the assumptions are considered conservative and the effect of the assumption on the final TMDL value determined.
- ☒ If the MOS is explicit, the loading set aside for the MOS should be identified. The document should discuss how the explicit MOS chosen is related to the uncertainty and/or potential error in the linkage analysis between the WQS, the TMDL target, and the TMDL loading rate.
- ☐ If, rather than an explicit or implicit MOS, the TMDL relies upon a phased approach to deal with large and/or unquantifiable uncertainties in the linkage analysis, the document should include a description of the planned phases for the TMDL as well as a monitoring plan and adaptive management strategy.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Souris River TMDL includes an explicit MOS for the listed segment derived by calculating 10 percent of the loading capacity. To account for the uncertainty associated with known sources and the SOD load reductions necessary to reach the TMDL dissolved oxygen target of 5.0 mg/L, a ten percent explicit margin of safety was used for this TMDL. The explicit MOS for the Souris River segment is included in Table 17 of the TMDL document.

COMMENTS: None.

4.5 Seasonality and variations in assimilative capacity:

The TMDL relationship is a factor of both the loading rate of the pollutant to the waterbody and the amount of pollutant the waterbody can assimilate and still attain water quality standards. Water quality standards often vary based on seasonal considerations. Therefore, it is appropriate that the TMDL analysis consider seasonal variations, such as critical flow periods (high flow, low flow), when establishing TMDLs, targets, and allocations.

Minimum Submission Requirements:

☒ The statute and regulations require that a TMDL be established with consideration of seasonal variations. The TMDL must describe the method chosen for including seasonal variability as a factor. (CWA §303(d)(1)(C), 40 C.F.R. §130.7(c)(1)).

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The TMDL addresses seasonal variability in dissolved oxygen loads by looking at the conditions that cause the lowest concentrations. The Souris River TMDL addresses seasonality because the reduction of SOD is related to the period of the season when the greatest deficit of dissolved oxygen occurs.

COMMENTS: None.

5. Public Participation

EPA regulations require that the establishment of TMDLs be conducted in a process open to the public, and that the public be afforded an opportunity to participate. To meaningfully participate in the TMDL process it is necessary that stakeholders, including members of the general public, be able to understand the problem and the proposed solution. TMDL documents should include language that explains the issues to the general public in understandable terms, as well as provides additional detailed technical information for the scientific community. Notifications or solicitations for comments regarding the TMDL should be made available to the general public, widely circulated, and clearly identify the product as a TMDL and the fact that it will be submitted to EPA for review. When the final TMDL is submitted to EPA for approval, a copy of the comments received by the state and the state responses to those comments should be included with the document.

Minimum Submission Requirements:

☒ The TMDL must include a description of the public participation process used during the development of the TMDL (40 C.F.R. §130.7(c)(1)(ii)).

☐ TMDLs submitted to EPA for review and approval should include a summary of significant comments and the State's/Tribe's responses to those comments.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The TMDL document includes a summary of the public participation process that has occurred. It describes the opportunities the public had to be involved in the TMDL development process. Copies of the draft TMDL document were mailed to stakeholders in the watershed during public comment. Also, the draft TMDL document was posted on NDoDH's Water Quality Division website, and a public notice for comment was published in local newspapers.

COMMENTS: None.

6. Monitoring Strategy

TMDLs may have significant uncertainty associated with the selection of appropriate numeric targets and estimates of source loadings and assimilative capacity. In these cases, a phased TMDL approach may be necessary. For Phased TMDLs, it is EPA's expectation that a monitoring plan will be included as a component of the TMDL document to articulate the means by which the TMDL will be evaluated in the field, and to provide for future supplemental data that will address any uncertainties that may exist when the document is prepared.

Minimum Submission Requirements:

☒ When a TMDL involves both NPDES permitted point source(s) and nonpoint source(s) allocations, and attainment of the TMDL target depends on reductions in the nonpoint source loads, the TMDL document should include a monitoring plan that describes the additional data to be collected to determine if the load reductions provided for in the TMDL are occurring.

☒ Under certain circumstances, a phased TMDL approach may be utilized when limited existing data are relied upon to develop a TMDL, and the State believes that the use of additional data or data based on better analytical techniques would likely increase the accuracy of the TMDL load calculation and merit development of a second phase TMDL. EPA recommends that a phased TMDL document or its implementation plan include a monitoring plan and a scheduled timeframe for revision of the TMDL. These elements would not be an intrinsic part of the TMDL and would not be approved by EPA, but may be necessary to support a rationale for approving the TMDL. http://www.epa.gov/owow/tmdl/tmdl_clarification_letter.pdf

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Souris River segments will be monitored according to an approved quality assurance project plan. Once a watershed restoration plan is developed and implemented (e.g., a Section 319 Project Implementation Plan), monitoring will be conducted on Souris River according to a future Quality Assurance Project Plan.

COMMENTS: None.

7. Restoration Strategy

The overall purpose of the TMDL analysis is to determine what actions are necessary to ensure that the pollutant load in a waterbody does not result in water quality impairment. Adding additional detail regarding the proposed approach for the restoration of water quality is not currently a regulatory requirement, but is considered a value added component of a TMDL document. During the TMDL analytical process, information is often gained that may serve to point restoration efforts in the right direction and help ensure that resources are spent in the most efficient manner possible. For example, watershed models used to analyze the linkage between the pollutant loading rates and resultant water quality impacts might also be used to conduct "what if" scenarios to help direct BMP installations to locations that provide the greatest pollutant reductions. Once a TMDL has been written and approved, it is often the responsibility of other water quality programs to see that it is implemented. The level of quality and detail provided in the restoration strategy will greatly influence the future success in achieving the needed pollutant load reductions.

Minimum Submission Requirements:

☒ EPA is not required to and does not approve TMDL implementation plans. However, in cases where a WLA is dependent upon the achievement of a LA, "reasonable assurance" is required to demonstrate the necessary LA called for in the document is practicable). A discussion of the BMPs (or other load reduction measures) that are to be relied upon to achieve the LA(s), and programs and funding sources that will be relied upon to implement the load reductions called for in the document, may be included in the implementation/restoration section of the TMDL document to support a demonstration of "reasonable assurance".

Recommendation:
☐ Approve ☒ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Allocation section (Section 8.0) of the TMDL document includes a list of BMPs that are recommended to meet the TMDL loads. NDDoH typically works with local conservation districts or other cooperators to develop and implement Watershed Restoration Projects after the TMDL has been developed and approved. Detailed project implementation plans are developed as part of this process if Section 319 money is used.

There are no significant permitted point sources in the watershed so it's not necessary to fully document reasonable assurance demonstrating that the nonpoint source loadings are practicable.

COMMENTS: The Livestock Management Recommendations in Section 8.1 and the Other Recommendations in Section 8.2 should be checked to make sure they are applicable to this DO TMDL. The description of the waste management system mentions a 90% reduction in loading, but it's not clear if this is applicable to organic loading or fecal loading. Also the description of vegetated filter strips specifically mentions fecal coliform bacteria as the focus of the TMDL document.

Also, we want to stress the importance of working with stakeholders in the watershed to initiate a 319 project in the watershed. It appears, based on the documentation in the TMDL, that nutrients are a contributing source of the dissolved oxygen impairment. It's is likely that a nutrient TMDL will be needed in the future unless efforts to reduce nutrient loading are implemented to restore the river and make a nutrient TMDL unnecessary.

8. Daily Loading Expression

The goal of a TMDL analysis is to determine what actions are necessary to attain and maintain WQS. The appropriate averaging period that corresponds to this goal will vary depending on the pollutant and the nature of the waterbody under analysis. When selecting an appropriate averaging period for a TMDL analysis, primary concern should be given to the nature of the pollutant in question and the achievement of the underlying WQS. However, recent federal appeals court decisions have pointed out that the title TMDL implies a "daily" loading rate. While the most appropriate averaging period to be used for developing a TMDL analysis may vary according to the pollutant, a daily loading rate can provide a more practical indication of whether or not the overall needed load reductions are being achieved. When limited monitoring resources are available, a daily loading target that takes into account the natural variability of the system can serve as a useful indicator for whether or not the overall load reductions are likely to be met. Therefore, a daily expression of the required pollutant loading rate is a required element in all TMDLs, in addition to any other load averaging periods that may have been used to conduct the TMDL analysis. The level of effort spent to develop the daily load indicator should be based on the overall utility it can provide as an indicator for the total load reductions needed.

Minimum Submission Requirements:

☒ The document should include an expression of the TMDL in terms of a daily load. However, the TMDL may also be expressed in temporal terms other than daily (e.g., an annual or monthly load). If the document expresses the TMDL in additional "non-daily" terms the document should explain why it is appropriate or advantageous to express the TMDL in the additional unit of measurement chosen.

Recommendation:
☒ Approve ☐ Partial Approval ☐ Disapprove ☐ Insufficient Information

SUMMARY: The Souris River dissolved oxygen TMDL document includes daily loads expressed as SOD in gO^2 / m^2 / day for the listed segment of the river. The daily TMDL loads are included in TMDL section (Section 7.0) of the document.

COMMENTS: None.

Appendix G
NDDoH Response to US EPA Region VIII Comments

US EPA Region VIII Comments: The Livestock Management Recommendations in Section 8.1 and the Other Recommendations in Section 8.2 should be checked to make sure they are applicable to this DO TMDL. The description of the waste management system mentions a 90% reduction in loading, but it's not clear if this is applicable to organic loading or fecal loading. Also the description of vegetated filter strips specifically mentions fecal coliform bacteria as the focus of the TMDL document.

Also, we want to stress the importance of working with stakeholders in the watershed to initiate a 319 project in the watershed. It appears, based on the documentation in the TMDL that nutrients are a contributing source of the dissolved oxygen impairment. It's is likely that a nutrient TMDL will be needed in the future unless efforts to reduce nutrient loading are implemented to restore the river and make a nutrient TMDL unnecessary.

NDDoH Response to Comments: Livestock Management Recommendations in Section 8.1 and Other Recommendations in Section 8.2 have been rewritten to focus on organic enrichment which is the primary source of sediment oxygen demand in this dissolved oxygen TMDL. The mention of fecal coliform bacteria as the focus of the TMDL was an error and has been deleted.

Stakeholder involvement has been instrumental in the development of this TMDL and will continue through any 319 Implementation Project that is undertaken. It was the local Soil Conservation District that first voiced concerns about the water quality in this portion of the Souris River, and it was their continued input that led to the assessment. They also participated in the collection of some of the samples. The local Soil Conservation District will be strongly encouraged to proceed with submitting a grant application for a 319 Implementation Project, and any technical assistance they request during this process will be provided by the North Dakota Department of Health.

Additionally, the Saskatchewan Watershed Authority (Canada), with the help of local stake holders, has developed a watershed threat assessment and watershed management plan for the Lower Souris River Watershed (Canada), which is the watershed just upstream of the US/CAN border. They are in the process of developing a similar assessment and plan for the Upper Souris River Watershed (Canada) immediately upstream of the Lower Souris River Watershed, which also has portions in North Dakota. Local North Dakota stakeholders serve on the Advisory Committee, and a North Dakota Department of Health representative is on the Technical Committee for this project. All parties involved are interested in continuing a watershed wide approach to improve water quality in the Souris River.

The NDDoH recognizes the need to address nutrient enrichment within this reach of the Souris River and its role in organic enrichment. Additional language has been added to Section 1.1 describing the likely need for a nutrient TMDL when nutrient criteria have been developed.