IDENTIFYING CAUSES OF DISSOLVED OXYGEN DEPLETION AND DETERMINATION OF SEDIMENT OXYGEN DEMAND IN THE SOURIS RIVER

A Thesis
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

Mathew Ernest Baker

In Partial Fulfillment
For the Degree of
MASTER OF SCIENCE

Major Program:
Environmental Engineering

October 2013

Fargo, North Dakota

North Dakota State University
Graduate School

Title

IDENTIFYING CAUSES OF DISSOLVED OXYGEN DEPLETION AND DETERMINATION OF SEDIMENT OXYGEN DEMAND IN THE SOURIS RIVER

By

Mathew Ernest Baker

The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

MASTER OF SCIENCE

SUPERVISORY COMMITTEE:

Dr. Wei Lin
Chair

Dr. G Padmanabhan

Dr. Bernhardt Saini-Eidukat

Dr. Xinhua Jia

Approved:

10/31/13
Date

Dr. Dinesh Katti
Department Chair

ABSTRACT

The Upper Souris River was placed on the Environmental Protection Agencies (EPA) impaired waters list for low dissolved oxygen (DO). A Total Maximum Daily Load (TMDL) study was conducted to determine possible causes of DO depletion. From sampling and site visits it was determined nonpoint sources contributed the majority of organic loadings to the Upper Souris River. Through preliminary testing, it was determined that sediment oxygen demand (SOD) played a key role in depleting DO levels during winter months and required further investigation. River profile surveying, water quality sampling, and laboratory testing of SOD were carried out to determine parameters required for water quality modeling. SOD tests were conducted to determine impacts of sediment organic contents and temperature on SOD rate. Sediment oxygen demand rates ranged from 0.37 to 1.22 g $O_2/m^2/d$. The QUAL2K model was calibrated to simulate DO variations along the study reach under ice covered conditions.

ACKNOWLEDGMENTS

I would like to thank my advisor, Dr. Wei Lin, for his guidance, support and patience throughout the completion of my research. In addition, I wish to express my utmost gratitude to the members of my research Supervisory Committee; Dr. G. Padmanabhan, Dr. Bernhardt Saini-Eidukat, and Dr. Xinhua Jia.

I would like to thank Mr. Joseph Super for his efforts and time put into sampling for the Souris River TMDL. Thank you to Mr. Murthy Kasi for his expertise and assistance with modeling. I would like to thank my wife, Jennifer, for her patience and support during the completion of my research.

My research would not have been possible without funding provided by the North Dakota Department of Health and North Dakota State University.

DEDICATION

To my mother, father, and grandma

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDIX TABLES

1. INTRODUCTION

This objective of this research was to identify the causes for dissolved oxygen (DO) depletion along the Upper Souris River during winter months. Water quality sampling was performed as part of a Total Maximum Daily Load (TMDL) study to identify and quantify river impairments. Water quality sampling and field investigations identified sediment as the leading source of oxygen depletion. Nonpoint sources were also determined to be a major contributor to high organic matter concentrations found in the river sediment. A correlation between sediment organic matter and sediment oxygen demand was determined through a newly developed sampling and testing technique. The identified correlation was used to help calibrate a QUAL2K model that assisted in identifying possible best management practices that would reduce the impacts of the high oxygen demand from the existing sediment.

1.1. Problem Statement

Low dissolved oxygen levels were present along the Upper Souris River located between Canada and Lake Darling in 2002 and 2004. This river reach was identified as "Fully Supporting but Threatened" for aquatic life and recreational purposes. A number of fish kills have been recorded along the Upper Sours River leading to a TMDL started in the fall of 2006. The intent of the study was to identify the cause for impairment and determine possible solutions to improve water quality. During initial TMDL water quality sampling, it was found that dissolved oxygen levels dropped to levels which no longer supported aquatic life during winter months. Further investigation was needed to identify the cause of the oxygen depletion and to quantify its impact on the Upper Souris River.

1.2. Objectives

The objectives of this research are to provide additional information to the development of the Upper Souris River TMDL including a greater understanding of the impacts of sediment oxygen demand on dissolved oxygen depletion. Specific objectives of this thesis include:

1. to identify the causes and the extent for low DO concentrations along the Upper Souris River reach.
2. to analyze sediment for organic content and relation to sediment oxygen demand rates under varying water temperatures.
3. to gather river geometric information and water quality data for calibration of a QUAL2K model which can then be used to support the development of the Upper Souris River dissolved oxygen TMDL.

1.3. Scope of Work

Extensive site visits, field sampling, lab tests, data analysis, and model work was conducted as part of this thesis work. The following tasks outline how to reach the objectives of this thesis:

1. Thorough literature review was conducted to gain knowledge on dissolved oxygen, sediment characteristics, sediment oxygen demand, and QUAL2K river modeling.
2. Field work including site visits and sampling to determine observed sources for contamination, collect water quality samples and sediment samples, and gather geographical river information for the model.

3. Experiments were conducted to determine the sediment organic content, sediment oxygen demand (SOD) rates, and effects of water velocity and temperature on SOD for Souris river sediment.
4. Data gathered was input into the QUAL2K model and calibrated prior to running simulations for TMDL DO scenarios. Based on model findings, presented potential reduction in dissolved oxygen demands to support aquatic life of the Upper Souris River.

2. LITERATURE REVIEW

This chapter is divided into four sections. Section 2.1 provides an introduction to the Upper Souris River TMDL Study and historical water characteristic information relevant to this thesis. River quality modeling software, information required, and new methods for river cross sectional area model inputs are discussed in Section 2.2. Components in a river which may impact dissolved oxygen concentrations are discussed in Section 2.3. Research and methods relating to the understanding and testing of sediment and more specifically, sediment oxygen demand, are discussed in Section 2.4.

2.1. Upper Souris River TMDL Background

Identifying Causes of Dissolved Oxygen Depletion and Determination of Sediment Oxygen Demand in Souris River study is a detailed analysis of sediment and river quality modeling from the Upper Souris River TMDL study. North Dakota Department of Health has called upon North Dakota State University to assist in identifying pollutants and pollution sources for the Upper Souris River reach which stems from the Canada/North Dakota border to Lake Darling near Minot, ND. As part of the TMDL, the sampling and river assessment was extended from the Canada/North Dakota border to Glen Ewen located in Saskatchewan, Canada.

2.1.1. Background

The Souris River is designated as a Class IA river for having suitable water quality for the propagation and/or protection of resident fish species and other aquatic biota; for swimming, boating, and other recreation; for irrigation, stock water, and wildlife without injurious effects; and for water municipal and domestic water supply after conventional treatment and water softening (North Dakota Century Code, 2001). General information for the Souris River can be found in Table 1. The original TMDL area was located in the United States, however, after preliminary investigation it was determined that extending the study into Canada was imperative.

Table 1. Souris River Study Description

Legal Name	Upper Souris River
Drainage Basin	Souris Basin
Physiographic Region	Northern Glaciated Plains
River Length from Rafferty Reservoir, Canada to Lake Darling, North Dakota	355 kilometers (km)
River Length for Extended TMDL Reach From Glen Ewen, Saskatchewan, Canada to Lake Darling, North Dakota	138.3 km
River Length for Original TMDL Reach From United States Border with Canada To Lake Darling, North Dakota	90.6 km
Type of Water Body	River
Reservoirs Upstream for Modeling	Rafferty
Fishery Type	Bullhead, Carp, Northern, Sucker, Walleye

The Souris River, otherwise known as 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, ND. It then forms a loop and flows back north, entering Manitoba near Westhope. The river eventually flows into the

Assiniboine River near Brandon, Manitoba. A map of the Souris River system is shown in (Duchscherer, 2010).

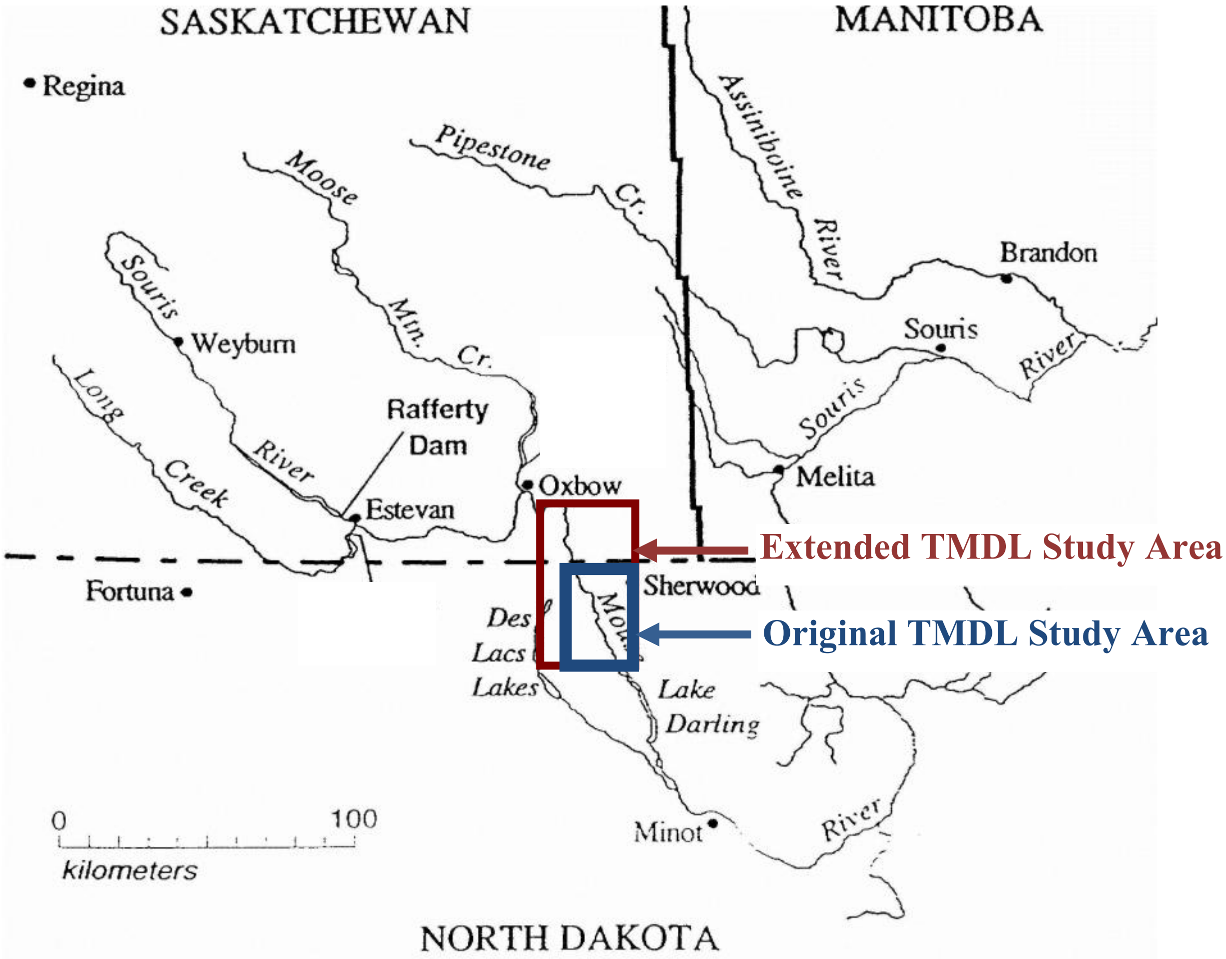

Figure 1. General Location of Souris River System and Impaired Reach Location

2.1.2. Clean Water Act Section 303(d) Listing Information

The upper portion of the Souris River, EPA ID No. ND-09010001-001-S_0, from the border of Saskatchewan, Canada to Lake Darling, a total of 90.6 km, has been on the North Dakota Section 303(d) list for water quality impairments since 1998. This river reach has been identified as "Fully Supporting but Threatened" for aquatic life and recreation purposes. This classification means that water quality and/or river conditions have not met the standards for designated uses infrequently, but often enough to raise concerns. Specific water quality and biological parameters that are of concern are summarized in Table 2 from the North Dakota, United States/Saskatchewan, Canada border downstream to Lake Darling, North Dakota. Dissolved oxygen is the primary interest of this thesis.

Table 2. Impairments of Souris River Reach (EPA, 2007)

Function	**Parameter**	**303(d) listing**
Aquatic life	Sediment/siltation	1998, 2004
	Habitat, flow	1998
	Metals	1998, 2004
	Nutrients/Eutrophication	2002, 2004
	Oxygen, dissolved	**2002, 2004**
	Biological indicators	2004
Recreation	Bacteria	1998
	Total fecal coliform	2002, 2004

2.1.3. 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 (Duchscherer, 2010). The first zero degree Celsius or lower temperature on average occurs in September and lasts until late May. 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. Winter snowpack, although persistent during winter months, averages 38 centimeters (cm) (Enz, 2003). River flows peak during the spring thaw typically in May. River flows taper off throughout the summer until late fall where river flow is very little to the point of not being measurable. Winter months have observed Upper Souris River near zero flow.

2.1.4. Land Use and Land Cover

Land uses in the surrounding areas are mainly cultivated agricultural lands with some small pastures and open water areas (Duchscherer, 2010). Along the impaired reach, the river banks are mostly covered by grasses as seen in Figure 2. A detailed analysis of the land use, using GIS data, shows that the most popular crops in the area are small grains with smaller areas of fallow and pasturelands.

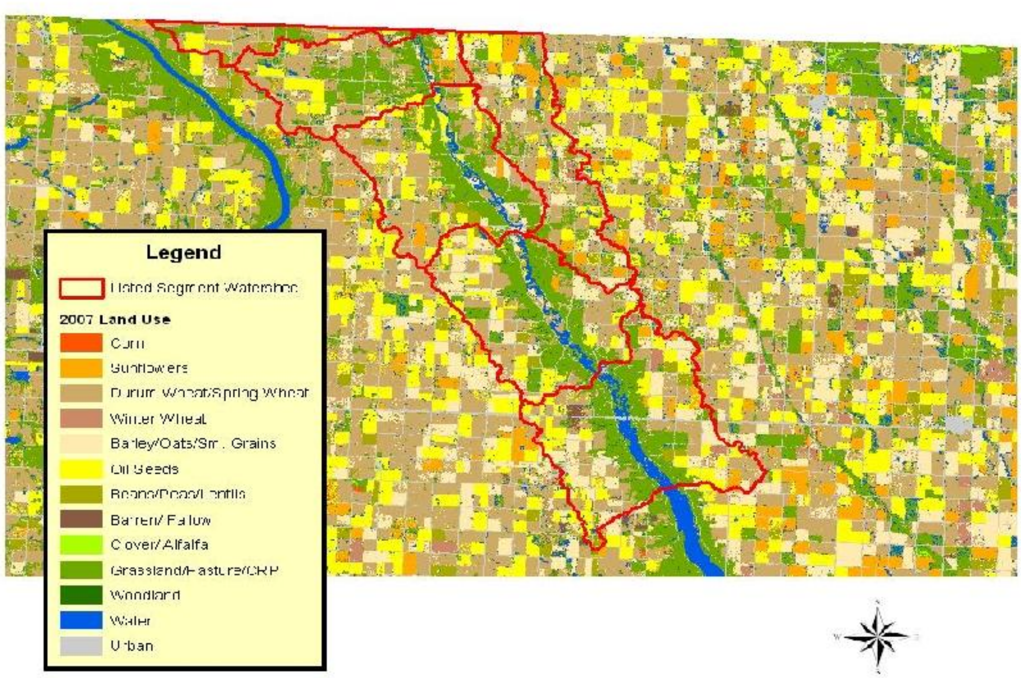

Figure 2. United States River Reach Land Use Information (NDASS, 2006)

2.2. River Quality Modeling

River quality models contain numerous parameters for modeling of multiple constituents. This thesis focuses on dissolved oxygen modeling. Sediment oxygen demand is later described as an important parameter for adequately modeling DO for the Upper Souris River. Models that do not adequately equate SOD can misrepresent the dissolved oxygen system within the river section being studied (Crompton, 2005). The longest duration of anoxia, little to no DO, is most typical found in eutrophic lakes or low flow rivers which have high SOD (Fang, 1997). The QUAL2K model, chosen for this thesis, accommodates lack of oxygen by reducing oxidation reactions to zero at low oxygen levels (Chapra, 2007). In addition, denitrification is modeled as a first-order reaction that becomes pronounced at low oxygen concentrations.

The difficulty with estimating SOD is the multiple variables which effect SOD rates. Some of these variables include light, water temperature, water velocity, soil type, percent organics, and time of year a sediment sample is gathered. Light contributes to photosynthetic oxygen production and therefore during freeze over and snow cover, oxygen production approaches zero (Fang, 1997). Water temperature greatly affects biological activity and dissolved oxygen saturation values which are later described in detail. SOD is affected by water velocity because of increased sediment suspension in high velocity water and coarser sediment remaining. SOD effects from soil types and percent organics are further described later in this thesis.

The QUAL2K model, used for this thesis, is a steady state model (Chapra, et.al., 2007). SOD is input and used as a constant rate as DO depletion of the river water occurs (Chapra, et.al., 2007). This is a limitation in using the model to estimate DO depletion based on SOD. Sediment oxygen demand decrease normally as DO levels decrease to near zero because DO is not readily available for biological activity nutrient transformation which leads to further decrease in DO levels. In order to provide the QUAL2K model with the best-fit sediment parameters, an average SOD rate for each river section modeled must be input for the conditions under which the model is being run to provide the most accurate results.

QUAL2K is a newer and expanded version of QUAL2E. The model demonstrates a string of completely mixed reactors simulating plug flow (Chapra, 2007). For each river stream segment, the model treats this segment similar to a separate completely mixed reactor with a detention time varied with flow and volume of river in that particular segment. Input river water characteristics entering each of these reactors are equal to the effluent from the upstream reactor (Chaudhury, et.al., 1998). This process continues from upstream to the furthest downstream segment to find the output parameters. The model also allows the user to input certain parameters sampled along each river segment if data is available. The QUAL2K program in itself is a complex spreadsheet that uses generally accepted means of calculating hydrological, chemical, and biological changes over time (Chapra, 2007). Primary input parameters effecting dissolved oxygen modeling for the QUAL2K model are further discussed in following chapters of this thesis in more detail.

2.3. Dissolved Oxygen

Dissolved oxygen is a measure of oxygen concentration in water. DO is an important parameter for a water body to support life. The availability of suitable dissolved oxygen concentration in lakes can control freshwater fish populations (Coutant, 1990). Massive fish kills in water bodies have been caused from depleted dissolved oxygen levels all over the world. Absence of DO in water prevents fish and other life from receiving oxygen and eventually suffocates the fish. Fish kills events occurred along the Upper Souris near the head of Lake Darling in 1999, 2002, 2003, and 2004 (Kellow and Fewless, 2004). Low dissolved oxygen levels can occur more frequently during winter months in colder climates where lakes or rivers freeze over because there is no reaeration from the atmosphere (Fang, 1997). This freezing over leads to no re-aeration from the atmosphere and organics suspended or settled in the water body can deplete DO levels throughout this freeze over period to near zero DO concentration (Chapra, 2007).

Dissolved oxygen has a major effect on salmonids. The acute lethal limits for salmonids are at or below 3 milligrams per liter (mg/L) DO (Quality Criteria for Water, 1986). Coldwater minimum DO criteria is established at 4 mg/L because many insect species common to salmonid habitats are less tolerant of acute exposures to low DO levels. Some bodies of water have more stringent DO concentration criteria if water bodies contain more sensitive species, for example: smallmouth bass. Exposure to DO levels below 3 mg/L can lead to mortality in salmonid waters in embryos, larval, and other life stages. Minimum DO concentration effects on aquatic life vary between species from 3 mg/L to 11 mg/Land DO concentration effects are site specific based on the aquatic life present. (USEPA, 1988)

2.3.1. Temperature Effects

Oxygen in water has saturation values that vary with temperature (Whipple, et.al., 1911). The equation stated provides the dissolved oxygen saturation value in water at any given temperature (USEPA, 1995). Figure 3 shows this change. Water vapor pressure and atmospheric pressure were determined based on Minot, ND data and Souris River water elevation at County Road 3. DO saturation is included in the QUAL2K model. If aeration were to occur during colder temperatures, DO levels could reach as high as 14 mg/L. In summary, the cooler temperatures achieve higher DO concentrated waters compared to warmer temperatures. Temperature impact on dissolved oxygen levels in the Souris River play a key role during winter months and assists in explaining DO levels recorded during sampling.

$$DO_{sat} = \frac{.678\,(P_{atm} - P_{water\ vapor})}{(Temp + 35)} \quad (1)$$

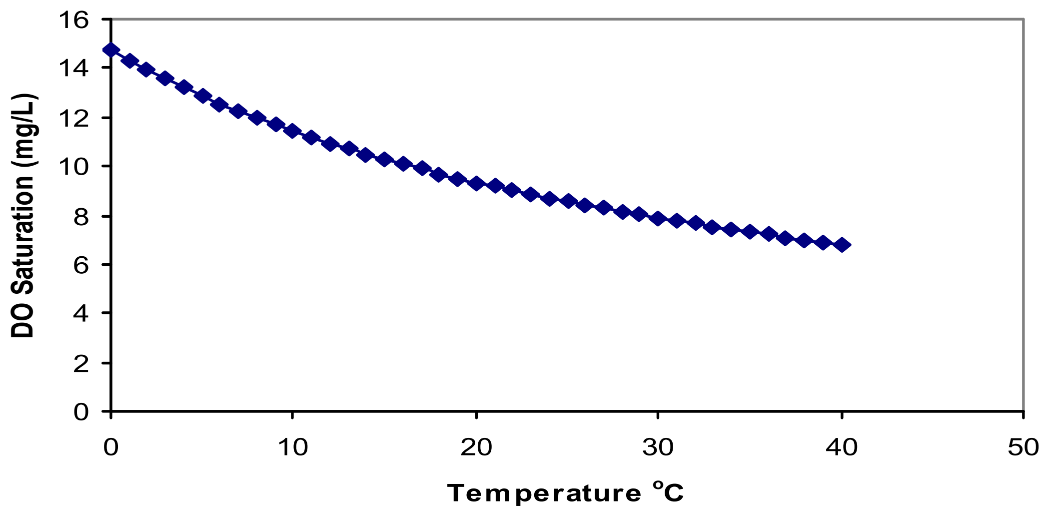

Figure 3. Oxygen Saturation Values in Water at Varying Temperatures

2.3.2. Biological Effects

DO is greatly influenced by organics and biological degradation of organic material or release of oxygen from organic material (Chapra, 2007). One example of increasing or decreasing DO within a water body can be seen with algae. During warmer weather algae growth can be prevalent if there are sufficient nutrients available. When light comes in contact with algae, the algae will begin to grow and multiply and in turn release oxygen in the form of O_2 and consume carbon dioxide in a process called photosynthesis (Kim and Lee, 2001). However, when the UV light is removed from the algae, which occurs at night, algae will stop growing and be consumed by microorganisms which consume oxygen.

Primary water characteristics which greatly affect biological growth and play a key role in DO levels within a water body are carbon, nitrogen, and phosphorus. Algae require the presence of all three nutrients; however, multiple organisms also require these three for growth. These three nutrients play a role because organisms that live off of organics in the water require these nutrients to thrive while consuming oxygen in the process. Figure 4 displays the primary components that affect dissolved oxygen in rivers and lakes.

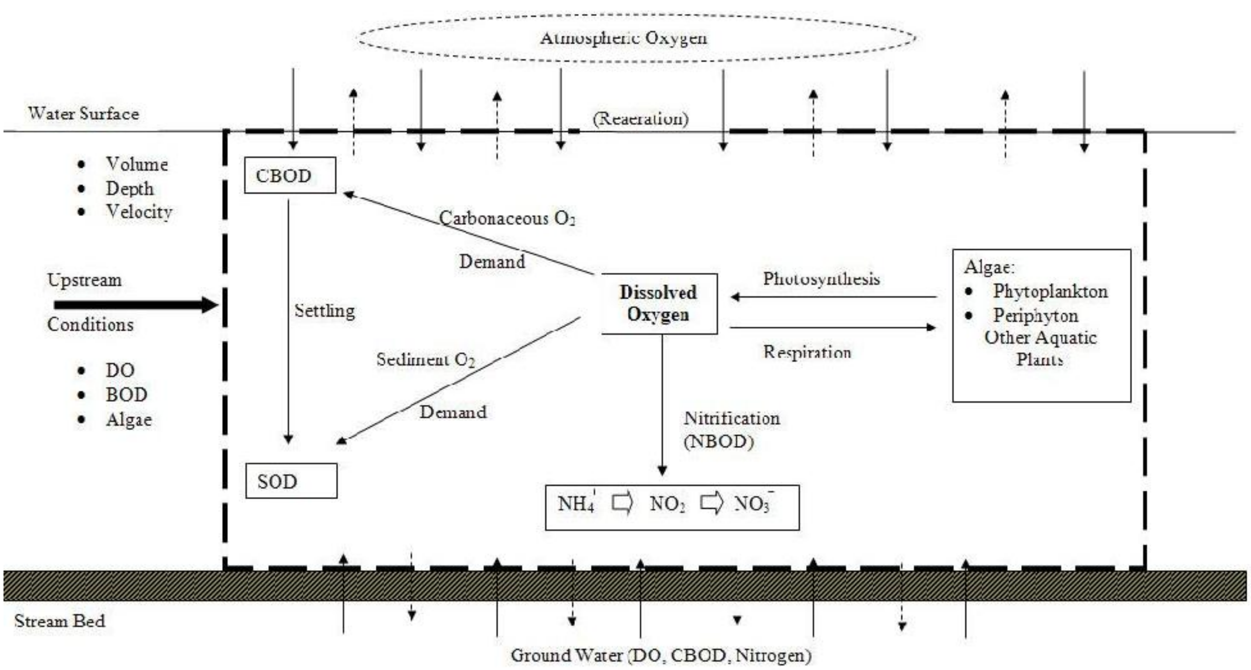

Figure 4. Major River Processes Influencing Dissolved Oxygen (MPCA, 2008)

Figure 4 shows the primary components effecting dissolved oxygen concentration in water which primarily includes; reaeration of the water from atmospheric oxygen, groundwater infiltrating or exfiltration the water, transformation of ammonia to nitrate and nitrite, photosynthesis and respiration from varying forms of algae, and decay of organic matter from carbonaceous biochemical oxygen demand and sediment oxygen demand. The figure also illustrates how the upstream water and river characteristics also play a key role in effecting DO concentration.

Nitrogen is primarily present in water in the following forms: organic nitrogen, nitrate, nitrite, ammonia-nitrogen, and total kjeldahl nitrogen. Phosphorus is primarily in the form of inorganic phosphorus and organic phosphorus. Carbon is present in the form of organic carbon and some inorganic carbon. Nitrogen and Carbon can be removed from the water through multiple processes, however, it is difficult to remove phosphorus. Removal of phosphorus may come in the form of vegetation uptake and removal of vegetation, transfer of phosphorus downstream with current, or transfer of phosphorus to greater sediment depths that minimize the possibility for entering back into the overlying water. Nitrogen removal occurs after the nitrogen forms present as organic nitrogen and ammonia are converted to nitrites and nitrates by nitrification, ammonia oxidation, in aerobic conditions followed by denitrification, or lack of oxygen, and conversion of the nitrites to nitrogen which is eventually released into the air (Lenntech Water Treatment Solutions, 2012). For this process to occur there must be an adequate food or organic carbon source.

2.4. Sediment

Sediment oxygen demand and organic content are important parameters when evaluating a body of water. Sediment is defined as a material that settles to the bottom of a liquid (Merriam-Webster, 2012). Sediment has become a leading cause of surface water quality degradation (USEPA, 1995). Sediment sampling can provide information about how healthy a body of water is and possible past contamination. A number of methods exist and have been researched for gathering sediment samples, testing sediment samples for organic material and gradient of percent fines, and testing sediment relationships with dissolved oxygen for depletion rates, also known as sediment oxygen demand.

2.4.1. Sediment Sampling

Sediment samples can be gathered for analysis by means of a number of methods. Sediment samples are primarily gathered by a sampling auger, dredge, or coring device. Methods and procedures for sediment gathering, equipment preparation, and handling techniques are described in EPA's "Sediment Sampling" (USEPA, 1994). A sampling auger uses an auger to dig down into the sediment. The sampling auger method mixes the sediment sample together and sediment layers are not as well defined when using this approach. Ekman Dredge method extracts a sediment sample by scraping the bottom of a lake or river (State of Ohio EPA, 2001). In shallow waters it is easy to skim the surface using a shovel or scoop; however in deeper waters a dredge device is used. A heavy device with two scoops on each edge is dropped to the bottom and then pulled together with the sample contained inside. One disadvantage with this method is that some of the sample is lost in transport to the surface and only the top portion of sediment is gathered.

Another sampling method is core sampling. This allows a person to analyze the sediment sample to greater depths than just the top few centimeters. One disadvantage with this method is the difficulty in gathering samples from deep water due to limitations of access. This can still be done however larger mechanically driven equipment is needed.

Multiple variations of these sampling devices and techniques have been established with pros and cons of each device through sampling (USEPA, 2004). For this research, a hand core sampler is primarily used for sample collection and an Ekman Dredge sampler is used if the water depths were too deep to use a hand core sampler.

2.4.2. Storage of Sediment Samples

Preservation of sediment is very important once the sample is extracted from the body of water. Sites for gathering sediment samples can be fairly inaccessible and long distances from a lab where analysis takes place. Multiple sediment samples may be gathered at once and may not be sampled in the lab for considerable lengths of time. Chemical preservation of solids is generally not recommended. Sediment samples collected shall be stored in containers at 4 degrees Celsius prior to use (Price, et.al., 1994). Samples should be kept out of light and refrigerated (USEPA, 1994). Equal portions of sediment sample should be gathered when feasible.

Sample collection time can affect SOD results as well as certain times of the year may contribute a larger organic loading than others. Sample holding times greater than 1 month may also affect results even if kept in cold storage (Price, et.al., 1994). Sediment samples for this thesis were placed in storage anywhere from one week to 5 months for sediment oxygen demand testing and one week to one month for organics testing. An Oregon study found that SOD rates do not differ significantly throughout the year (Wood, 2001). This is important as this allows sediment samples to be gathered at convenience of the sampler as opposed to a specific timeframe to yield results. The sediment samples for this thesis were a gathered in the spring.

2.4.3. Sediment Characteristics

Sediment characteristics impact how the sediment interacts with the overlying water body. Primary sediment characteristics discussed as part of this thesis include coarse and fine material, silts, clays, sand, phosphorus, carbon, nitrogen, and organic matter. Organic matter and coarse and fine material are tested for in lab tests during to compare relations to sediment oxygen demand tests.

Sediment characteristics vary with sediment depth, deeper sediments typically contain less reactive organic matter and shallow sediments near the surface-water interface contain higher reactive organic matter (Price, et.al., 1994). Deposition of sediment and organic content along the surface is the greatest factor contributing to this. Typically, nonpoint and point sources deposit organics into the water body; some of this organic matter will settle out into sediment. Other sediment characteristics such as whether the sediment is primarily made up of fine material or coarse material is important as well. For a river, coarse rock bottom sediment may be a sign of higher flows in that area of the river and finer sediment siltation is more pronounced in the deeper pool and in the bar tail area of the river (Diplas, 1994). A brief inspection of river sediment along the river reach may point to sources of contamination due to abrupt changes in sediment characteristics. An example of this would be if upstream sediment appeared to be natural sand or gravel until further downstream where the sediment abruptly changes to silty material, black in color, and contain high odors. Upstream of this sediment change could be a good location for possible source of contamination.

Multiple organisms live in the sediment. By analyzing the types and quantity of organisms living in the sediment, some conclusion can be made about the sediment and overlying water body. Sediment which contains no microorganisms may be contaminated with chemicals that contain heavy metals or high BOD. Sediment with an active population of organisms may also coincide with a healthy water body. Sediment toxicity testing has been widely conducted with the use of worms and insect species because of their burrowing activity, rapid life cycle, sensitivity, and ease of culturing. Some species used to evaluate sediment toxicity include but are not limited to the following: vascular plants, worms, amphipods, mayflies, midges, cladocerans, fish, and other miscellaneous species. (Whittemore, et.al., 2002)

2.4.4. Sediment Flux

Sediment flux is a term used to describe to what degree of water quality constituents being sampled are transferred from the sediment to the water and vice versa at the sediment-water interface. Sediment-water flux were measured to better understand the sediment water interface and provided equation 2 for measuring the flux rate (Price, et al., 1994).

$$F_{sw} = \frac{V(C_f - C_i)}{A \times \Delta t} \qquad (2)$$

F_{sw} = sediment-water flux (mass per square distance per time)

V = volume of overlying water (cubic distance)

A = area of sediment-water interface (square distance)

C_f = concentration in water at end of incubation (mass per cubic distance)

C_i = concentration in water at beginning of incubation (mass per cubic distance)

Δt = length of incubation (time)

From equation 2, the sediment flux rate is greatly affected by the volume of water, concentration of sampled water characteristic, and time. Sediment flux water characteristics primarily effecting DO concentration are carbon, nitrogen, and phosphorus. These three sediment characteristics are of particular importance because of their role in plant and algae growth as well as their relation to DO consumption through growth of algae or decay of organics. Nitrogen and carbon also have oxidation potential and are present in water in different forms. See previous section for discussion of relating to phosphorus, nitrogen, and carbon and the role they may play in oxygen consumption.

2.4.5. Aerobic and Anaerobic Interface

The sediment-water interface is made up of an aerobic and anaerobic layer which drives the release or absorption of varying constituents (Hantush, 2006). For this research, we are primarily concerned with how sediment characteristics affect oxygen depletion. These nutrients were previously defined as carbon, nitrogen, and phosphorus because of their importance in the biological growth and decay cycles as well as direct consumption of oxygen in the aerobic or anaerobic layer.

Through the aerobic layer mass transfer of dissolved constituents occurs by diffusion. The sediment layer receives a flux of particulate organic matter of which decomposes to produce ammonia and methane. Ammonia generated in the anaerobic layer diffuses upward into the aerobic layer, partly undergoes nitrification to produce nitrate and remainder escapes to water column by diffusion through the boundary layer. See Figure 5 for diagram illustrating the nitrogen and carbon flux. (Hantush, 2006)

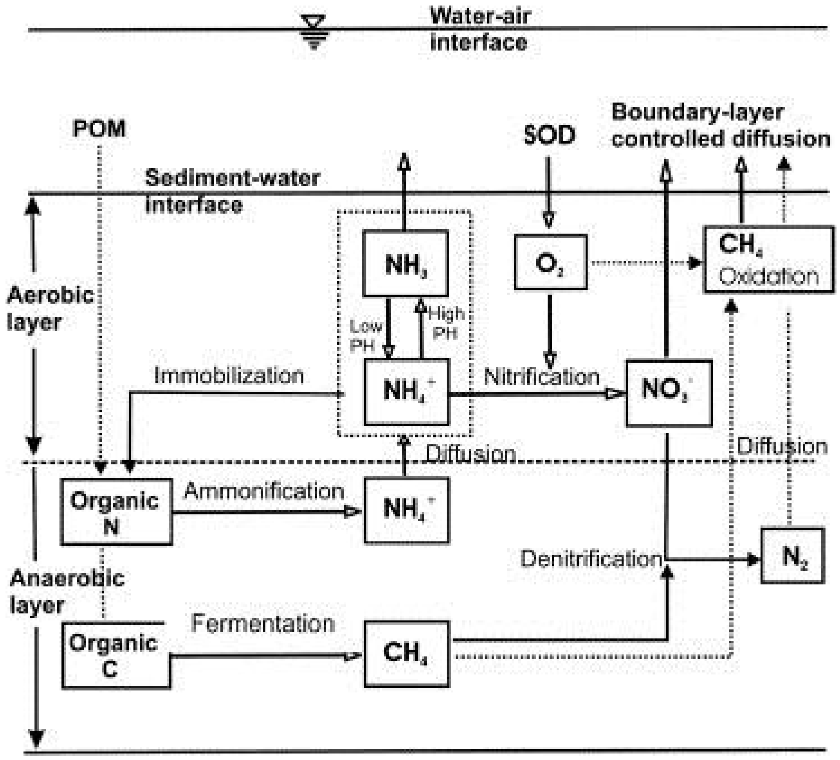

Figure 5. Sediment-Water Interface Diagram (Hantush, 2006)

Phosphorus reacts differently than carbon and nitrogen at the sediment water interface. Carbon and nitrogen have the potential to be removed over time through the production of nitrogen and methane gas where carbon and nitrogen are released not only from the sediment water interface but from the water into the atmosphere. Phosphorus does not get removed through release to the atmosphere. Phosphorus is typically introduced into the water body and eventually is removed through suspension in water moving phosphorus downstream, uptake through vegetation and eventual removal of that vegetation, or transfer of phosphorus deep into sediment layers. Considerable time and sometimes more drastic measures, such as dredging, are required for phosphorus removal compared to carbon and nitrogen removal.

2.4.6. Sediment Oxygen Demand

Sediment oxygen demand is a measure of the amount of oxygen consumed in a water body by the sediment. To measure SOD, DO concentration is measured in the overlying water over time within a set volume of water inside the testing apparatus. In-situ and ex-situ testing are the two methods for measuring SOD.

In-situ SOD testing is conducted on site in the body of water to measure oxygen depletion (Yun and Cheng, 2011). A chamber is lowered in the body of water and pressed into the sediment. The sampler must be careful as to minimize disruption of the sediment inside the chamber. The chamber has a DO probe reading the DO of the water in the chamber. A number of other pumps, inlets and outlets, and means to move water within the chamber may also exist depending on the complexity of the system. Once suspended sediment has a chance to settle, SOD analysis can proceed.

Ex-situ SOD testing takes place in a controlled lab environment. The sediment sample is carefully extracted from the field and brought back to the lab for analysis. The sample is placed inside a container within a controlled environment and water is placed on top of the sediment within the container. DO is measured over a period of time to determine the SOD rate similar to in-situ measuring. In a lab, a stirrer can be used to simulate water velocities over the sediment. One key component to ex-situ testing is to provide a sealed system to prevent oxygen transfer from the atmosphere. Two methods have been used as a sufficient means to seal the system water from atmospheric contact using a mineral oil layer or plexiglass lids (Price, et.al., 1994). This thesis used a lid for containing the system water as mineral oil potentially contaminates the sample.

A study found that in-situ chambers are more accurate than lab studies in estimating SOD rates as some lab methods have predicted SOD rates to be significantly lower than what was measured in the stream (Crompton, 2005). Crompton also reported that coefficients of variance between trials are found to be smaller for in-situ studies than corresponding lab studies (Crompton, 2005). For this thesis numerous in-situ and ex-situ studies were researched to determine which method is better for our circumstance. Investigation found that multiple research papers had limitations in methods for sampling and testing SOD both for in-situ and ex-situ testing. Because of the large variance in methods, the ex-situ method was chosen for this thesis work because of the lab controlled environment and difficulty in SOD analysis at the remote river location.

The following is a brief list of common limitations found when reviewing a large variety of research papers for sampling and testing sediment:

1. In-situ Measurement
    a. Sampling chambers began sampling dissolved oxygen immediately following insertion. The disturbed sediment greatly decreased the dissolved oxygen rates as the surface area for biological growth increased exponentially.
    b. Sampling did not take into account varying water temperature, sunlight, weather, or uncharacteristic objects in the sediment at sampling location.
    c. A number of chamber tests did not include compensation for water velocity across the sediment. A small pump could be included to provide internal recycle of the water inside the chamber.
2. Ex-situ Measurement

a. Tests did not include mixing to simulate water flowing across the sediment.
b. Sampling chambers were not constructed properly which provided multiple areas for sample contamination as well as reaeration.
c. Some tests used oil to prevent oxygen transfer from the atmosphere and oil can affect the DO readings by coating the DO probe as well as mixing with the water.
d. Tests provided completely mixed chambers which is uncharacteristic of natural conditions.
e. Formation of the aerobic layer was not provided prior to sampling.
f. DO concentrations exceeded saturation rates for room temperature in some instances which greatly increased the SOD rate from their study.

The following are two studies including some of the stated limitations in measurement of SOD. A study using ex situ SOD measurement in Hong Kong, China gathered core samples and analyzed sediment immediately (Chau, 2002). The study did not form an aerobic layer on the sediment and resulted in very high SOD rates around 1 g of $O_2/m^2/d$. The test was also performed in BOD bottles with no mixing and used water from the field which could increase DO depletion rates based on suspended matter in the water. The study also used a linear relation to volume of container for a short measuring time period. A second study provided by Joseph Lee in 1999 uses in-situ measurement for SOD rates (Lee et.al., 2000). The process described included a pump with a separate chamber to move water through the unit. One issue that arose during the experiment dealt with an abundant amount of hose required from the SOD chamber to the pump. This allowed for multiple locations with air pockets within the pumping lines.

Historical SOD research relates SOD to chemical oxygen demand (COD) and volatile solids (VS) in the water body. Preliminary testing in 1984 showed a near linear rate for relation of COD to SOD stated in equation 3 (DiToro, 2001). Di Toro research for SOD rates stated a relation between SOD rate reduction and time if the source of SOD is removed. Research has shown that SOD rates are nearly 2.5 times greater at day zero than they are at day one hundred and nearly double at day one hundred than day two hundred. This illustrates that if sources causing high SOD rates were removed or reduced, SOD rates would also decrease in a fairly short timeframe. (DiToro, 2001)

$$SOD = b_1(COD)^{.5} \tag{3}$$

SOD = Sediment oxygen demand

COD = Chemical oxygen demand

b_1 = constant

Equation 4 was established through extensive sampling of sediment and monitoring dissolved oxygen concentration over time in a controlled environment using an ex-situ technique for sediment monitoring (Price, et.al., 1994).

$$SOD = H/\Delta t \ (C_f - BOD_f - \Delta C_S) \tag{4}$$

SOD = Sediment oxygen demand

H = Water column height

Δt = Change in time

C_f = Dissolved oxygen concentration

ΔC_s = Dissolved oxygen introduced by experiment sample replacement

BOD_f = DO concentration in BOD bottle at end of incubation

Dissolved oxygen concentrations are monitored and recorded throughout SOD experiments. Technological advances have allowed dissolved oxygen sampling to be conducted with electronic probes much more efficiently than previous chemical titration methods. Recording dissolved oxygen concentrations every 20 minutes is sufficient, however if manual observation of the DO level is being used more time such as 30 to 45 minutes may also work. Ohio Environmental Protection Agency stated readings should be taken every five minutes during SOD testing and readings may be complete after DO concentrations decrease by 2 mg/l, or after two hours (State of Ohio EPA, 2001). This statement was found to be incorrect during this thesis testing. A decrease of 2 mg/l does not provide enough data to accurately provide SOD rates. Also, sampling every five minutes is excessive as dissolved oxygen concentrations require significant amount of time to deplete oxygen levels. Typically, once the DO has reached below 1.5 mg/L the test may be stopped.

2.4.7. Sediment Oxygen Demand Modeling

Models that include sediment oxygen demand as a parameter typically treat SOD as a linear rate. Because oxygen concentration affects SOD rate, linear rates must be extrapolated from data. In order to calculate SOD the slope of oxygen depletion curves must be calculated using linear regression. Oxygen depletion can be calculated using the following equation (Crompton, 2005).

$$SOD = 1.44\ V/A\ (b1-b2) \qquad (5)$$

SOD = Sediment oxygen demand in g O_2/m^2d

b_1 = Slope from the oxygen depletion curve in mg/L*minute

b_2 = Slope from the oxygen depletion curve of the control chamber

V = Volume of the chamber in L

A = Area of bottom sediment covered by the chamber in m^2

1.44 = Unit conversion constant (Caldwell and Doyle, 1995.)

Once SOD is calculated from the data it is temperature corrected to 20°C using the modified Van't Hoff form of the Arrhenius equation and an appropriate literature value for the constant theta shown in equation 6. Values for theta are given by Bowie et. al. (1985) based on DO model; therefore, a value of 1.047 is suggested for use in this TMDL study and variance from this constant is discussed later. (Thomann and Mueller, 1987)

$$SOD_t = SOD_{20} * Theta^{(T-20)} \qquad (6)$$

SOD = Sediment Oxygen Demand

T = Temperature in Degrees Celsius

Theta = 1.047

Typical SOD values are provided as follows from the QUAL2K model based on experience and research (Chapra, 2007):

- Mineral Soils – .05-1 $g/m^2/d$
- Sandy Soils – 0.2-1 $g/m^2/d$
- Estuarine Mud – 1-2 $g/m^2/d$
- Municipal Sewage Sludge Downstream of Outfall – 1-2 $g/m^2/d$
- Municipal Sewage Sludge at Outfall – 2-10 $g/m^2/d$
- Zebra Mussels ($6000/m^2$) – 5 $g/m^2/d$
- Sphaerolitus (10g dry weight per m^2) – 7 $g/m^2/d$

For QUAL2K SOD modeling, Ficks Law plays a role for incorporation of SOD into the model. Primary SOD is determined with equation 7. Sediment oxygen demand is broken up into the two primary consumers of dissolved oxygen in water bodies' nitrogen and carbon; as described in previous research material and stated in equation 7 (Chapra, 2007). CSOD is the amount of oxygen demand generated by methane oxidation and NSOD is the amount of oxygen generated by nitrification.

$$SOD = CSOD + NSOD \tag{7}$$

$$CSOD = \frac{\kappa_{CH4,1}^2}{s} \theta_{CH4}^{T-20} CH_{4,1}$$

$$NSOD = r_{on} \frac{\kappa_{NH4,1}^2}{s} \theta_{NH4}^{T-20} \frac{K_{NH4}}{K_{NH4} + NH_{4,1}} \frac{o}{2K_{NH4,O2} + o} f_{da1} NH_{4,1}$$

T = Temperature [degrees Celsius]

r_{on} = 4.57 [gO_2/gN]

$\kappa_{CH4,1}$ = the reaction velocity for methane oxidation in the aerobic sediments [m/d]

$K_{NH4,O2}$ = oxygen half-saturation constant [mgO_2/L]

$\kappa_{NH4,1}$ = the reaction velocity for nitrification in the aerobic sediments [m/d]

$NH_{4,1}$ and $NH_{4,2}$ = the concentration of total ammonium in the aerobic layer and the anaerobic layers, respectively [gN/m^3]

f_{da1} = fraction of ammonia in dissolved form

ө = SOD temperature correction factor [dimensionless]

s = SOD [gO_2/m^3] / DO of overlying water [gO_2/m^3]

Figure 5 previously illustrated the carbon and nitrogen transition along the sediment water interface. The QUAL2K model uses the same process for the transformation of nitrogen and carbon in the aerobic and anaerobic layers as illustrated in Figure 6. Figure 6 illustrates the transformation of particulate organic matter (POM) from water to the sediment. Organic matter is primarily composed of carbon, nitrogen, and phosphorus.

Along the left hand side of Figure 6 in the anaerobic zone, organic carbon (POC) is shown converting to methane gas and released into the water as carbon dioxide or methane gas. Note that if dissolved oxygen is present, methane will be converted to carbon dioxide, while no oxygen presence carbon stays in the form of methane gas for release into the overlying water and eventually air. Organic nitrogen in the aerobic and anaerobic layer is converted to nitrites in the aerobic layer and nitrogen in the anaerobic layer where this moves from the aerobic, anaerobic, and water layer. Organic phosphorus is converted to phosphate and transfers between the anaerobic, aerobic and water surface. Primary dissolved oxygen consumers from the water are conversion of carbon to carbon dioxide and nitrogen to nitrates. Figure 6 also shows phosphorus transfer not being removed from water bodies in addition to carbon and nitrogen being removed. (Chapra, 2007)

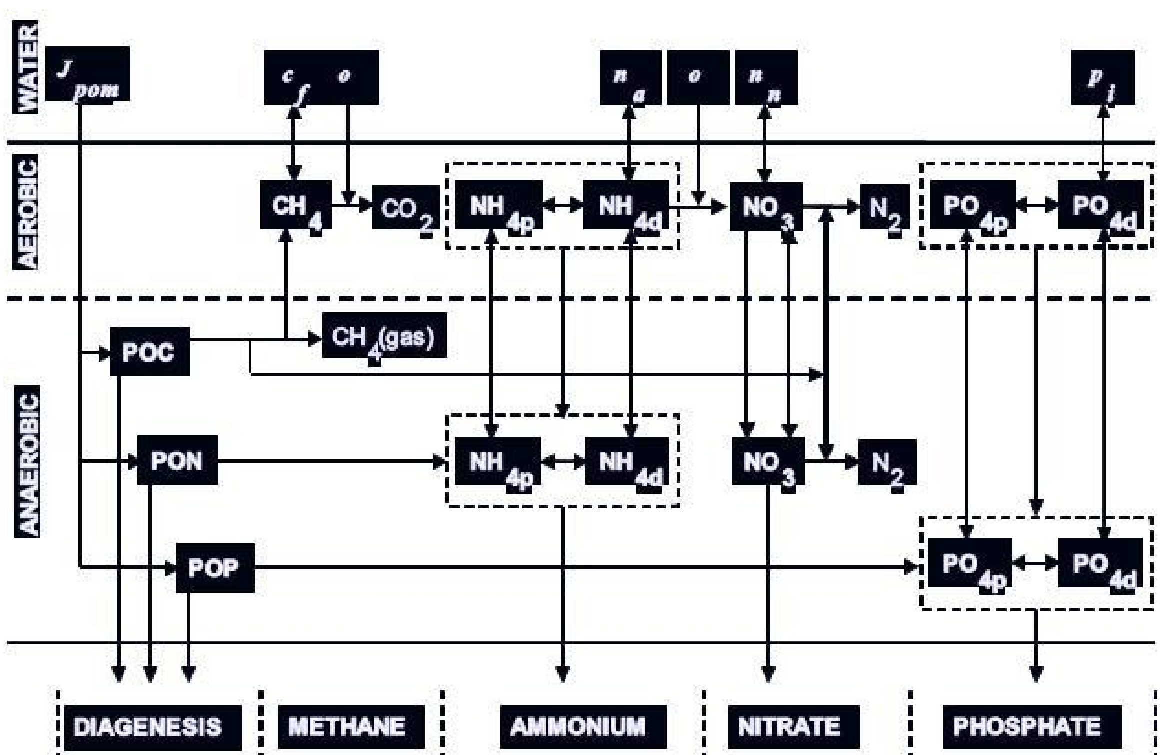

Figure 6. QUAL2K Sediment Oxygen Demand Model, Sediment-Water Interface (Chapra et. al., 2007)

3. MATERIALS AND METHODS

During the Souris River TMDL study a series of testing and site visits took place which led to further investigative research into sediment and river modeling. This section describes site visits, sampling and testing methods for sediment and information gathered for the model. Procedural methods are described for each test performed. In Section 3.1, water quality sampling sites, parameters sampled and sample collection procedures are reviewed. Preliminary SOD testing method is presented in Section 3.2 for a completely mixed reactor. Sediment collection and analysis procedures are described in Section 3.3. Sediment oxygen demand testing utilizing the ex situ technique is detailed in Section 3.4. QUAL2K model input parameters and methods used for river analysis are discussed in Section 3.5.

3.1. River Water Quality Sampling and Site Visit Information

The Souris River water quality analysis was a crucial component of the TMDL study. The following information summarizes portions of sampling which took place and directly affect further works for this thesis.

3.1.1. Site Locations

The Upper Souris River TMDL has five primary sampling locations. From upstream to downstream these sampling site names are Glen Ewen, County Road 2, Stafford Bridge, Johnson Bridge, and County Road 3. Glen Ewen lies in Saskatchewan, Canada. The other four locations are located in North Dakota, USA near the Canadian border. These sampling locations were chosen because of ease of access in order to gather samples in a timely manner. Two additional sites upstream of Glen Ewen, Oxbow and Highway 9, were used during winter months for sediment sampling and dissolved oxygen testing. A USGS gauging station (05114000) that monitors the river stage, flow rate and some water quality parameters 24 hours a day is located next to the North Dakota and Saskatchewan border. Cross sections were surveyed at the five primary sampling sites but not at Oxbow and Highway 9 because these sites were not included as part of the TMDL study. Table 3 gives a description of sampling sites along with their location.

Table 3. Sampling Sites

Site	Latitude (degrees, minutes, seconds)	Longitude (degrees, minutes, seconds)	Distance from Glen Ewen (km)	Description
Highway 9	49°4'27.82"N	102° 17' 50.57"W	-75.2	Canada site surrounded by sloped embankment and grazing area
Oxbow	49°12'53.48"N	102° 12' 16.70"W	-41.9	South of City of Oxbow near bridge on gravel road
Glen Ewen	49°10'48.72"N	102° 1'39.00"W	0	Canada site surrounded by pasture, faster moving water, steeper banks in Canada
USGS 05114000	48°59'24.00"N	101°57'28.80"W	53.7	24 hr. Gauging station located in dammed pool Heavily wooded area here and South to Lake Darling
County Road 2	48°57'58.68"N	101°56'51.00"W	55.7	Just South of Cattle Farm, shallow water, rocky bottom
Stafford Bridge	48°55'21.72"N	101°55'35.04"W	66.8	Typical Site in US with woody banks
Johnson Bridge	48°52'45.12"N	101°52'4.44"W	83.4	Lake Darling begins to effect with depth increasing
County Road 3	48°45'49.20"N	101°46'33.30"W	104.7	Lake Darling drastic effect with 3 meter depth and large cross sectional area

3.1.2. Souris River Water Parameters Measured

Specific parameters measured for the TMDL study included the following: channel depth, temperature, DO, pH, conductivity, ice thickness, chemical oxygen demand, biochemical oxygen demand, dissolved phosphorus, total phosphorus, total Kjeldahl nitrogen (TKN), ammonia nitrogen (NH_3-N), nitrate-nitrite nitrogen (NO_2/NO_3-N), suspended solids, Fecal Coliform, Fecal Instrep, E Coli, Sulfate, Chloride, Alkalinity, Hardness, Aluminum, Antimony, Arsenic, Barium, Beryllium, Boron, Cadmium, Chromium, Copper, Iron, Lead, Manganese, Nickel, Silver, Selenium, Thallium, and Zinc. Dissolved metals were tested year round but total metals were only tested from spring through fall. Sediment samples were also gathered and tested once preliminary results lead to sediment being a major contributing component to the impairment of the river. Total and dissolved metals analyses are not included as part of this thesis.

3.1.3. Sample Handling and Custody

Sampling occurred one of two ways. The first method includes on-sight sampling for DO, pH, conductivity, and temperature. A probe was lowered into the water and data was logged. The second method included grabbing a sample on sight and fixed with acid to be shipped to the lab for further analysis. During the summer months, samples were obtained by lowering equipment into the water from a bridge. In winter months, a hole was drilled in the ice with an auger and samples were gathered through this opening. Samples were kept in certified containers in a cooler during transport. The lab received the samples the following day for analysis.

3.1.4. Quality Control Measures

Duplicate on-sight and grab samples were performed when samples were gathered. These duplicates were always taken at the same sampling site, County Road 3. Equipment used for field measurement was calibrated immediately before and after each sampling trip in accordance with the manufacturer's specifications. Care was taken to ensure clean equipment. Samples were gathered in the same fashion when possible. All water samples were analyzed according to methods and procedures described in the NDDoH Laboratory Services Division Quality Assurance Plan (NDDoH, 2000).

3.1.5. Sampling Schedule

A testing schedule was followed under the TMDL quality assurance project plan guidelines that consisted of 29 sampling dates. An additional 12 fecal coliform sampling dates were also established during summer months. Appendix C4 lists all sampling dates and site visits. Measurements taken on sampling days at five sampling sites when Joe Super was testing are as follows:

- Depth of water
- Distance from bridge to water level
- Ice thickness
- Measurements for DO, pH, Conductivity, and Temperature with portable meter.
- Gather samples for lab analysis

All sites were located near a bridge for ease of access and sampling. At each of these locations, velocity was measured if flows were high enough to register on a pygmimeter or AA meter. The pygmimeter was used when the water was accessible for wading and the AA meter was used when the water was too deep to wade across. These measurements were taken at the standard 60% depth to give an average velocity for the entire river. The depth of water at the same location was also logged. Surveyed information and water depth allow for the calculation of cross sectional area. Velocity was multiplied by cross sectional area to provide flow at the sampling location. Flow is a vital tool for modeling purposes. Because of the ice cover and immeasurable velocity, the flows during winter months were near zero for the Souris River.

Dora Abernathy with the NDDoH gathered samples for fecal matter analysis. Matt Baker gathered sediment samples for analysis. Dr. Lin and Dr. Eidukat surveyed river cross sections and performed site observations.

3.1.6. Field Visits and Inspections

In addition to scheduled sampling, field inspections were conducted. The first inspection occurred on September 23, 2006 to survey cross sections of sampling sites, observe land use, and gather a procedure for collecting data. A site visit on January 28, 2007 was made to verify the DO probe readings. Extra sites were also established for sediment sampling and DO analysis upstream of the furthermost site, Glen Ewen. On May 26, 2007 a canoe trip took place following the river from Glen Ewen to County Road 3 to observe landuse, point and nonpoint sources, and survey the river for modeling. On July 30, 2007 a trip was conducted to collect sediment core samples, later described. These additional site visits provided valuable information for this thesis.

3.2. Preliminary Sediment Oxygen Depletion Testing

Preliminary sediment oxygen depletion tests were conducted to determine if sediment samples gathered from the Souris River bottom contributed to DO depletion.

3.2.1. Equipment and Materials

A dissolved oxygen depletion test was performed with the following equipment:

- Computer
- DO meter

- De-ionized water
- 300 mL BOD bottle
- Pipette
- Magnetic mixer
- Fine sediment sample

3.2.2. Method

A sediment sample gathered from the field was put through a No. 30 sieve. The fine material passing through the No. 30 sieve was used for this experiment. Sediment was screened by washing the sediment on the sieve with distilled water. Making sure the fine sample has been mixed thoroughly, 5 mL of the sediment and distilled water was removed and placed in a 300 mL BOD bottle. Use the same pipette and withdraw additional distilled water releasing into the BOD bottle until the inner walls of the pipette are free of sediment. Distilled water was added to the BOD bottle until full. The sediment/water mixture was stirred during the experiment to ensure complete mixing of sediment and water. The DO probe was then placed into the BOD bottle with the sensor approximately one-third the distance from the bottom of the bottle. The BOD bottle was plugged to prevent re-aeration. The new sample in the BOD bottle was given a moment to mix completely then DO recording began. Every five minutes the temperature and DO level was recorded.

Data points were logged over an extended period of time. The data was plotted on a graph with time along the horizontal axis and dissolved oxygen concentration on the vertical axis. The DO depletion rate was obtained by the curve slope. The higher the level of organics the less time the process took. This test demonstrates the significance that sediment from the bottom of the Souris River was contributing to the depletion of DO levels. The same procedure was followed for all sites sampled. This method was used as a tool for quick evaluation of sediment and was not intended to give accurate sediment oxygen demand (SOD) rates for modeling or analysis. Test DO depletion rates may not reflect the actual SOD in the river because sediment material was completely mixed in the reactors whereas river sediment is mostly settled and does not suspend during winter months and low flow conditions. This thesis experiment was similar to a Colorado River study where sediments were kept in complete suspension through rapid stirring of the sample for preliminary results. This would indicate if there was a high SOD rate for that portion of the river (Matlock et al., 2003). This thesis provides a very similar if not same method for determining if there was a problem with SOD.

3.2.3. Computer Logging

A laptop computer used for dissolved oxygen experiments was directly linked to a DO meter and set up to record DO readings every five minutes automatically. The experiment continued to run until the DO was depleted to a point where it decreases very little between measurements. Preloaded computer software, HyperTerminal, allowed for a direct connection to another device. This connection receives data from the DO meter in five minute intervals. Data includes temperature, time, dissolved oxygen concentration, or an error message if the probe was damaged or other interference occurs. This setup allowed for multiple sampling runs over extended periods of time. The computer would log data until it could be copied into Notepad and then transferred into Microsoft Excel for further interpretation. Computer logging proved to be valuable throughout this thesis lab analysis as multiple points could be logged over an extended experiment run time.

Logging and repetitive analysis also led to multiple key factors for ex-situ sediment oxygen demand testing, described later.

3.3. Sediment Sampling

Sediment Oxygen Demand has been identified as a major source causing low dissolved oxygen levels in the Upper Souris River from the preliminary dissolved oxygen depletion testing. Further investigation of sediment in the Upper Souris River was required. The primary goal of sediment sampling is to determine how sediment changes along the river reach and the effects sediment has on DO depletion of the overlying water. Sediment core samples were gathered to determine how sediment changes with depth. The coarse, fine, organic, and inorganic content of each core was analyzed. A number of sites were chosen for gathering sediment samples along the river reach with a number of cores gathered along each cross section. In summary, sediment sampling tests lead to the following results:

- Percent organics for each layer of sediment.
- Percent inorganic for each layer of sediment.
- Percent fine for each layer of sediment.
- Percent coarse for each layer of sediment.
- How sediment varies with depth.
- How sediment varies along a particular cross section.
- How sediment varies along the Souris River.

3.3.1. Gathering Sediment Samples

Sediment samples were gathered in the field for further lab analysis. The following were equipment and methods used for gathering samples. Gathering of sediment samples comply with state and federal guidelines listed in Sediment Sampling Standard Operating Procedure No. 2016 (EPA, 1994).

3.3.1.1. Equipment and Materials

Equipment for gathering samples includes the following:

- Sediment Dredger (Figure 7, Item b.)
- 5.1 centimeter diameter, 20.3 centimeter long clear coring tubes in Sediment Coring Equipment (Figure 7, Item a.)
- 5.1 centimeter diameter plastic caps for 5.1 centimeter diameter coring tubes
- 1 liter bottles with cap
- Cooler
- Ice

a. Sediment Coring Equipment

b. Sediment Dredger

Figure 7. Examples of Sediment Sampling Equipment

3.3.1.2. Method

Samples were gathered at a number of locations along the river reach. Sediment samples were gathered with a core sampler except at County Road 3 where a sediment dredger was required. The core sampler was not capable of gathering core samples at water depths greater than 1.5 meters. For deeper sampling locations, such as County Road 3, the dredging sampling technique was used. Five cores were gathered at each site location along the cross section of the river. An example of a typical sediment core sample can be seen in Figure 8.

Figure 8. Sediment Core Gathering Photo

One core sample was gathered approximately 1.5 meters from each shoreline. A single core sample was gathered at the deepest river cross section location. The other two cores samples were gathered between the edge and center sediment sample cores. Samples were taken along the cross section to see how the sediment changes from fast moving current to slow moving current and from the river bank to the center of the river. All sites were established away from man-made objects such as bridges or culverts. Sediment sample material adjacent and downstream of these structures varies from native sediment and do not provide a representative sediment sample for the river reach. After the samples were extracted they were placed in a cooler and kept at $4^{o}C$ during shipment (Whittemore, et.al., 2002).

3.3.2. Sediment Sample Analysis

The experimental procedure for sediment sample analysis is described in the following subsections.

3.3.2.1. Equipment and Materials

The following equipment and materials were used to run tests on sediment samples:

- Quart gallon size sealable bags
- Crucibles
- Furnace heating to 103 ^{o}C
- Furnace heating to 550 ^{o}C
- Scale
- No. 30 Sieve

3.3.2.2. Method

Once sediment samples were gathered in the field and brought back to the lab, each sediment core was divided up into sections and analyzed for organic content of coarse and fine material. Visual observations of sediment layers may not be visible due to sediment smears along the inside walls of the clear gathering tubes. Therefore, it is important to log each section carefully and make visual observations after the sediment core sample has been removed from the sampling tube. Sediment samples were optimally 20.3 centimeters long if the 5.1 centimeter diameter clear coring tubes were filled completely with sediment. This was not possible for all locations due to limitations from sediment characteristics. Some sediment materials, such as coarse aggregate, prevent a full core sample from being gathered with equipment available. The core was divided up into 5.1 centimeter sections as the sediment sample is pushed out of the sampling tube. The 5.1 centimeter sections start from the surface of the sediment sample and placed into a storage bag. The bags were sealed to prevent contact with the air. The top section was labeled "A" and the next lower section "B" and so on. The left bank core was labeled "1" and increase along the cross section to "5" for the right bank. Each core also has the site name on it. An example for a top section left bank core sample in Glen Ewen is GE1A.

After the sediment cores were divided, the core sample was completely mixed. A small sample from each section was then taken for analysis. The sample for each 5.1 centimeter core section was put through a No. 30 sieve, 0.5 mm opening, to separate the fine from the coarse material. To divide sediment between coarse and fine material a 0.5 mm to 2 mm screen mesh is recommended by the EPA (Whittemore, et.al., 2002). The fine and coarse samples were placed into their own porcelain dish and weighed before putting in the furnace at 103^{o}C. After one hour, the sample was allowed to cool in a moisture reduced environment and weighed. The sample was then placed in the furnace at 550 ^{o}C. The sample is removed from the oven, allowed to cool in a desiccator, and weighed one last time. This procedure provides the percent organics and percent inorganics for both the fine and coarse material of each section of core sample.

A portion of the remaining material for each core sample section was also tested as described except without screening the material. This allowed the sample to be analyzed without separation of coarse and fine material. The remaining material for each top layer of sediment in the same cross section was completely mixed together. This sample was not put through a No. 30 sieve. A portion of this sample was placed in a dish, weighed, and heated according the previous procedure for percent organics and percent inorganics. The remainder of the combined top layer sample was used for the sediment oxygen demand test.

3.4. Sediment Oxygen Demand Testing

The SOD measuring method for this thesis was an ex-situ method where sediment was placed in the bottom of a reactor while slightly mixing the overlying water. This method was chosen because of the ability to simulate the river conditions in a controlled environment. The remote river location also prevented in-depth analysis because of harsh field conditions. A diagram of SOD experimental setup is shown in Figure 9.

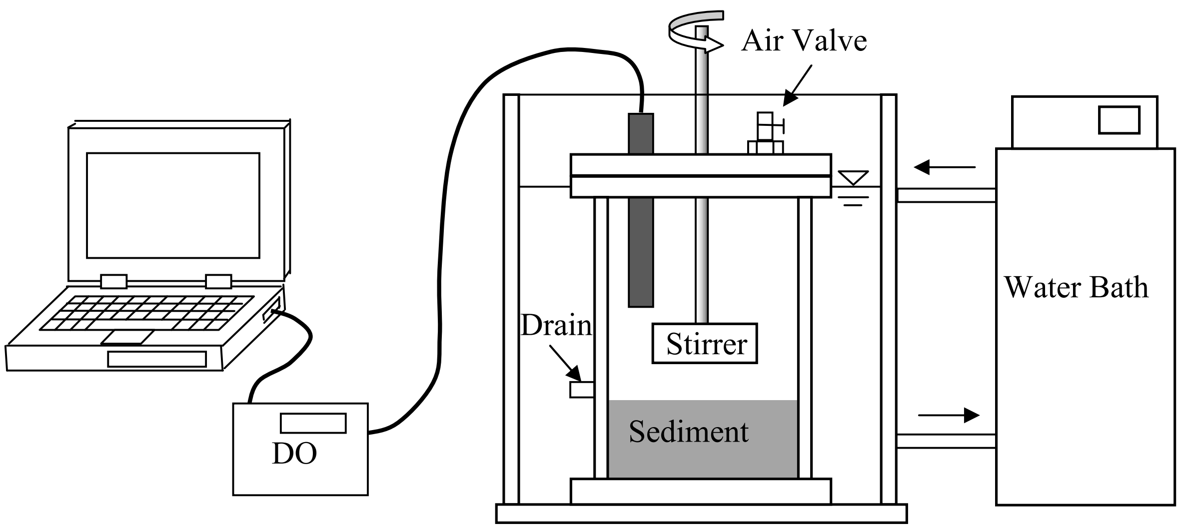

Figure 9. Sediment Oxygen Demand Experimental Setup

3.4.1. Equipment and Materials

The following is a summary of equipment and materials required to run the ex situ sediment oxygen demand experiment:

- Water Bath
- DO Meter
- Computer

- Stirrer
- Sediment Oxygen Demand Reactor (as illustrated in Figure 10)
- Clear Containers
- Fish Tank Aerator
- Peristaltic Pump with Tubing
- Tape Measure
- 10 Pound Weight
- Rubber Hose and Clamps
- Aluminum Foil and Foam Insulation

Figure 10. Sediment Oxygen Demand Reactor Design

3.4.2. Method

To begin SOD testing, follow the sediment analysis procedure described in the previous section of this thesis. Gather four-fifths of the sediment out of each top layer sample for a single cross section and place into a large bag. Mix sediment in bag thoroughly. Remove any large debris from sediment such as large rocks or sticks that are not a good representation of the sediment sample.

The sediment sample is now prepared for sediment oxygen demand testing. Place 5.4 centimeters of the mixed sediment sample into the bottom of the cleaned SOD reactor. An end result of 5.1 centimeters of sediment depth is desired, the extra 0.3 centimeters of sediment is to compensate for settling. Clean edges of reactor with deionized (DI) water to prevent sediment attaching to the walls of the container. Fill reactor with water to obtain 1.3 centimeters of water depth and allow sediment to settle.

Adding 1.3 centimeters of water initially prevents sediment disturbance when the reactor is filled with water. After one day of settling, remove any algae which may have collected in the sediment sample. If sediment top layer is not flat, flatten the surface being careful not to stir up or compact the sediment. This is important because SOD rates are presented in $gO_2/m^2/d$ which is based on surface area of sediment (Chapra, 2007). After approximately three days of settling, an aerobic sediment layer should form at an approximate depth of one and one-half to two millimeters (mm). Aerobic layer thickness varies between sediments. Higher organic sediment tends to have a thicker aerobic layer. Measure the aerobic layer which can be seen by the lighter color sediment at the water/surface interface.

Seal lid on reactor after sediment aerobic layer formation occurs and place in constant temperature bath set at 20°C. This temperature is used because it is near room temperature and common for the majority of SOD rate model values. Allow one hour for SOD reactor to rest then fill slowly with DI water and remove any trapped air. Calibrate the DO probe and place into reactor. Close off the air release valve and turn on the stirring paddle. Speed of the stirring paddle should reflect the most commonly observed water velocity of the stream or lake. The bottom of the stirring paddle should be placed half way between the lid and the surface of the sediment. Cover the container with a wrap to block excessive light penetration which can lead to algae growth. A small amount of light was allowed to enter the top of the reactor to reflect river conditions.

The reactor is now ready to begin logging DO measurements which occurred every twenty minutes. The first logged DO point was removed from data because the water column is not fully mixed at this point and does not accurately represent DO of the water column as a whole. The SOD test was run for approximately one and a half days to two and a half days depending on depletion rate of the dissolved oxygen. Tests were stopped once dissolved oxygen depletion rates became fairly steady and leveled off to minimal DO depletion. The tests were also stopped if DO reached below 1.5 mg/L. It was noticed that further oxygen depletion took considerable time and oxygen depletion rates had reached a very low depreciation rate.

After the SOD test is complete, drain the water but leave approximately 1.3 centimeters in the bottom of the reactor to prevent disturbing sediment when filled for a second run. Aerate the extracted water for two hours. Air was run through a jar with water in the bottom so the air used to aerate the water was not dry air. This reduces evaporative loss of water through aeration. Place 50 mL of new DI water in with the original aerated water to account for losses during aeration. Allow the water to sit in a water bath set at the same temperature as the reactor for thirty minutes. Pump water back into reactor and repeat the experiment.

A sediment sample of aerobic layer and a sample of anaerobic layer after sediment oxygen demand testing were taken for analysis. Tests for percent organic material were run on the samples to find changes in percent organic makeup and differences between aerobic and anaerobic layers. The percent organics of each layer varied greatly and is discussed in more detail in the results section of this thesis. In the water body, an aerobic layer is formed on the sediment – water surface interface. During the first sediment sampling tests it was shown that the formation of this aerobic layer does play a large role in sediment oxygen demand rates. Because the formation of the aerobic layer was important, an initial sediment oxygen demand run was conducted prior to the actual SOD runs for each site and the data was not used for analysis as previously stated.

For this experiment SOD testing was performed at temperatures of 20^{o}C, 15^{o}C, 10^{o}C, and 5^{o}C temperature tests. Tests were also conducted at varying impeller speeds to show the effects of water velocity on SOD rate. SOD tests were performed for a variety of sites to illustrate an accurate SOD rate for different portions of the river.

3.5. QUAL2K River Quality Modeling

QUAL2K is a steady state water quality modeling software that allows the modeler to evaluate a river at a single moment where input river parameters such as flow and water characteristics remain constant and do not allow accumulation of value over model run time. For the Souris River TMDL, a QUAL2K model was used to evaluate the river reach. The QUAL2K program was also used to evaluate lab SOD rates compared to actual field SOD rates during winter months and discussed further in the results section of this thesis. The majority of model work for SOD analysis incorporates river water characteristics sampled during the TMDL, surveys of river cross sections taken during site visits, river lengths and elevations measured through site visits and geographical information systems (GIS) maps, and DO testing data. Once information is entered into the model, lab tested SOD rates are entered and the model was run for analysis. Model results for dissolved oxygen depletion rates are then compared with winter DO depletion rates for model and SOD sampling accuracy comparison along with model calibration.

3.5.1. River Cross Section Profile Survey

Prior to sampling on the Souris River, profiles of the river bottom were surveyed at four of the five sampling sites. These four surveys were conducted using a Total Station and multiple points were taken across the river section. County Road 2 was not surveyed since data already existed from a previous work.

Additional cross sections were required for the Qual2k model. Thirteen additional cross sections were measured during the canoe trip and site visit for model calibration. A survey point was recorded at each of the top banks, at the river's edge, midway from the river's edge to the lowest point, and at the lowest point for each side of the river at each cross section. The latitude, longitude, and elevations were taken using a GPS unit for the top of the bank surveyed point. The rest of the points were surveyed using a total station. This method was not always followed as some areas did not allow access to all points of measurement required with the use of a total station. For cross sections with water depth greater than 1.5 meters, a handheld depth finder and tape measure were used to give approximate river depths along a cross section. These surveys were used for cross sections of the QUAL2K model.

3.5.2. Calculated River Cross Section for Model

A new method developed by Brent Hanson (Hanson and Lin, 2008), a former NDSU graduate student, was used for inputting river cross sections into the QUAL2K model. This method includes surveying profiles in the field, USGS AreaComp software, and setting up a spreadsheet to provide accurate cross sections of the river through mathematical means. The QUAL2K model, as well as many other models, allows inputs of cross sectional areas to be made up of two side slopes and one bottom channel width. The profile of the river bottom is required to be a trapezoidal shape and cannot be entered as a non-linear cross section.

Research by Brett Hanson provided a detailed approach to calculating a trapezoidal river cross section from surveyed data. AreaComp, developed by USGS, was used to find the area of each surveyed cross section with varying river depths. River depths should be kept relatively close to river flows modeled to provide the most accurate information. For this thesis, the river depths were plus or minus one half foot of the river depth measured during the survey. Once the areas are computed for each of the depths, divide the area by depth then graph the area/depth on the y axis and the river depth on the x axis. Excel was then used to create a linear equation through the set of points graphed. This linear equation provided a base width of the cross section and the right bank slope. The horizontal distance from the left bank water edge to the start of the river bottom flat portion requires to be manually input. Once this is selected, the remainder of the river slopes, depth, and distances can be populated using geometry. A sum of differences between the surveyed points and the calculated points can also be calculated. Minimizing the sum of differences provides the most accurate river profile.

3.5.3. QUAL2K Inputs

The QUAL2K model was a tool used to compare lab SOD results to DO concentration depletion in the river during winter months. To analyze DO depletion, the model was calibrated during the winter months as the river experienced freeze over. A number of input parameter assumptions were made due to information gathered from field investigations and water quality sampling. Complete shade, no reaeration, and no affect from wind or weather was assumed due to ice and snow cover of the river. No point sources along impaired reach were identified due to site visit information. A temperature of one degree Celsius was input based on sampling results. Little DO depletion from suspended solids due to low temperature and limited means for biological growth. Biochemical oxygen demand water samples were also gathered during winter months and showed non-detect results. Water quality from sampling site Glen Ewen just before river freeze over occurred were used as upstream input parameters for the model. River cross sections and river lengths were entered based on field survey results and GIS mapping. Sediment oxygen demand rates were entered based on lab testing results and calculated rates based on a developed procedure later discussed in this thesis.

4. RESULTS AND DISCUSSION

Results for this thesis are divided into five sections. Physical characteristics of the impaired Souris River reach are presented in Section 4.1. In Section 4.2, river quality sampling results specifically related to DO depletion are presented. Sediment characteristic results are described in Section 4.3. SOD testing results are reviewed in Section 4.4 and includes testing data that shows where errors occurred and possible areas for improvement with other experiments. QUAL2K model information is provided in Section 4.5.

4.1. Souris River Observations

On May 27 and 28, 2007 a canoe trip took place following the river from Glen Ewen to County Road 3. During this trip, surrounding terrain and river bank conditions were observed. In addition to visual assessment of the river, cross sections at thirteen sites were surveyed . Bank slope and river depth were gathered from these surveys. Surveyed sites were chosen based on accessibility and to provide an approximate similar distance between one another. In addition to thirteen sites surveyed during the canoe trip, the five primary water quality sampling sites of County Road 3, Johnson Bridge, Stafford Bridge, County Road 2, and Glen Ewen were sampled on September 23, 2006. All 18 cross sections were used in the river water quality modeling. See Figure 11 for a typical surveyed profile at one of the five sampling locations and Figure 12 for a typical surveyed profile of a site not used for sampling.

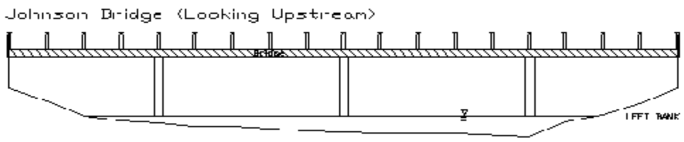

Figure 11. River Cross Section Sample Location Drawings

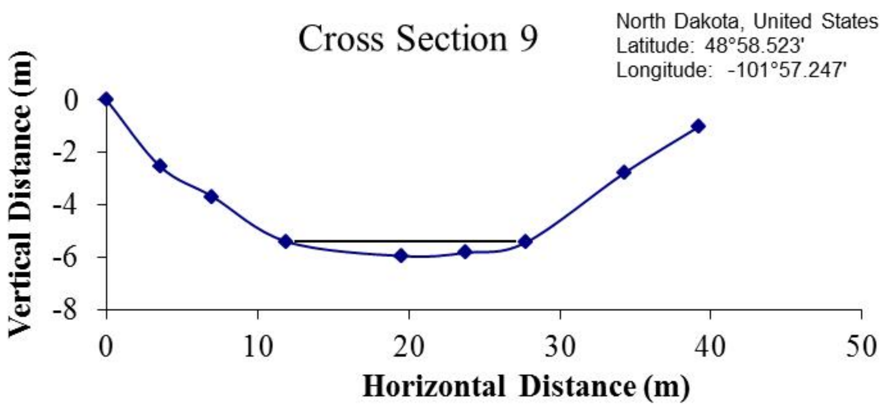

Figure 12. River Cross Section With No Sampling

Surveyed profile locations were selected to be approximately equal distances from one another with an average distance between surveyed sites of 5 kilometers. Figure 13 shows a diagram of the river and where these profiles were measured. GPS measurements were taken at each surveyed profile to accurately determine each site location. Distance in river kilometers between sites can be found in Appendix A.

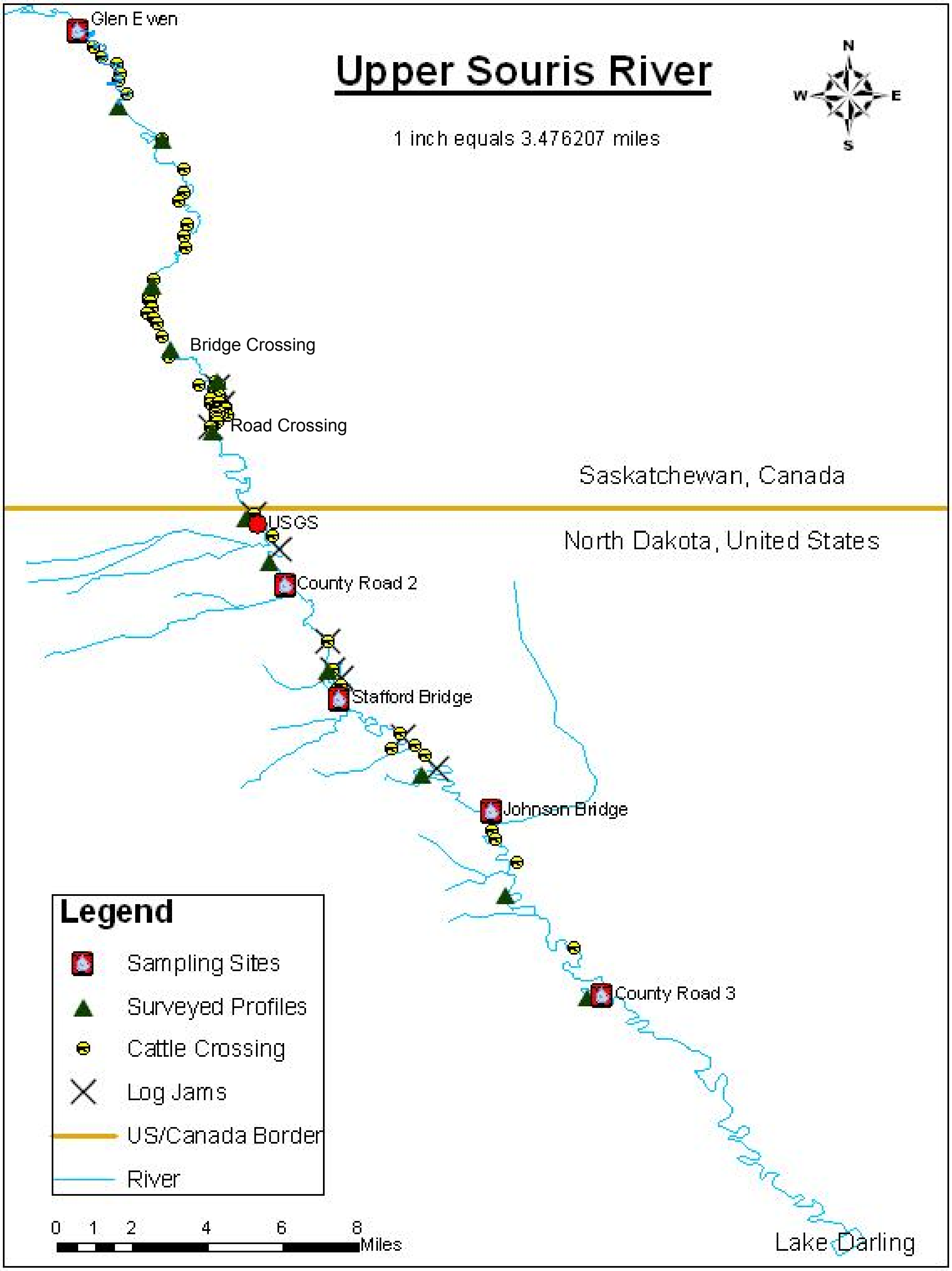

Figure 13. River Investigation Map

4.1.1. River Mapping

GIS ArcMap was used to map the Souris River. River kilometers between each site were found using the GIS program and satellite image overlays and displayed in Table 4.

Table 4. River Distances for Key Sites

Site From	Site To	Distance (km)	Total Distance (km)
Rafferty Dam	Hwy 47	12.1	12.1
Hwy 47	Questionable	24.1	36.2
Questionable	Hwy 35	22.2	58.5
Hwy 35	Dirt Road	44.5	103.0
Dirt Road	Hwy 9	39.0	142.0
Hwy 9	Intersection	33.2	175.3
Intersection	GE	41.9	217.3
GE	2	9.0	226.3
2	3	4.5	230.9
3	4	12.5	243.4
4	Bridge Crossing (5)	4.1	247.5
Bridge Crossing (5)	6	5.7	253.3
6	Road Crossing (7)	4.2	257.5
Road Crossing (7)	8	8.2	265.8
8	9	5.1	271.0
9	CR2	2.0	273.0
CR2	10	5.5	278.5
10	SB	5.5	284.1
SB	11	11.5	295.6
11	JB	5.0	300.7
JB	12	7.7	308.4
12	13	12.9	321.3
13	MR	0.6	322.0
MR	Lake Darling	33.5	355.6
Alamade Dam	Intersection	7.8	
Pool	Hwy 47	5.4	

Detailed satellite imagery was attainable for the United States through the North Dakota GIS site; however, Canada satellite imagery was not readily available and showed little detail for mapping the river. Screen shots were taken using Google Earth and then imported as images into the GIS program. Canada resolution was at 15 meter DEM's compared to United States resolution of 1 meter DEM's. Because of the less detailed Canada data, the measurements stated can be off by 0.16 kilometers or greater. Much care was taken to reduce the error in order to receive the best results for future modeling work. The river segment can be found in Figure 13 and Table 4.

4.1.2. Field Observations

A number of field observations were made during site visits and canoe trip. Log jams on the Souris River were encountered and mapped during the canoe trip. Log jams act as dams during flood release and hinder the proper management of the river. Five significant log jams were found with two log jams being extremely large. The largest being over 150 meters long. Refer to Figure 14 for a photo of one of the major log jams along the river.

Figure 14. Souris River Log Jam Photo

No point sources from municipal or industrial wastes were found south of Glen Ewen. After observing the land use along the Souris River valley, it was found that the majority of the land use is populated by grazing cattle. Cattle were found in or next to the river both in the United States and Canada during this trip. Figure 13 shows significant cattle crossings or grazing locations that were recorded.

During the two day canoe trip, field investigations took place that resulted in observations of cattle grazing. Water sampling dates and sediment sample gathering also observed extensive cattle grazing occurring along the Souris River. Large cattle operations are located along the river and the cattle appeared to spend the majority of time in or near the river water. Refer to Figure 15 for a photo of a typical cattle grazing area along the river in Canada.

Figure 15. Souris River Cattle Grazing Area

Cattle in or adjacent to the river can adversely affect water quality. Cattle excrete large amounts of feces on a daily basis. Grazing cattle have been found to desecrate feces on average 7.8 times per day averaging 1.3 kg per defecation (Bond, et.al., 2014). Feces directly deposited in the river or conveyed by runoff to the river decompose and deplete

DO levels. The secondary effect feces has on the river body is the organic loading of nutrients which further effect DO levels long term as well as SOD rates.

During site visits, it was noticed that the sediment turned black in color and had an odor if disturbed. The water also had a septic smell during winter months. Figure 16 shows a photo of the sediment after being disturbed.

Figure 16. Souris River Sediment Disturbance Photo

4.1.3. Summary of Findings

No point sources or industries were found along the Souris River which further leads to the conclusion that nonpoint sources, specifically cattle operations, are the primary cause of impairment along the Souris River and contribute the majority of the loading to the sediments. Runoff from agricultural planting operations has been established as minimal for areas within the TMDL because of the topography and landuse with buffer zones separating agriculture and the river. Other possible sources of the dark color sediment with odor could be naturally occurring decay of vegetation that exists along the river banks after this vegetation falls into the river during fall months. Field visits proved vital in identifying possible sources of contamination. River water samples collected further support causes for impairment of the Upper Souris River and are later described in this thesis.

4.2. River Quality Sampling

4.2.1. General Observations

Through sampling provided during the Upper Souris River TMDL, it was found that metals were not above acute or chronic limits for the Upper Souris River based on the North Dakota Department of Health Water Quality Standards. Primary river water characteristics found to be problematic were Nitrogen, Phosphorus, Carbon, and Dissolved Oxygen. Each of these water characteristics sampled are further described later in this thesis. Spring, summer, and fall months, April through November, showed little river water characteristic changes during that timeframe except for DO level. During winter months, December through March, sampling showed a slow but steady increase in many river water characteristic concentrations throughout the winter. Flow became immeasurable and temperatures dropped to near zero degrees Celsius. Conductivity also showed a steady increase during winter months. Also, nearly all samples indicated the northern most site, Glen Ewen, to have the highest concentration of parameters sampled. This also lead one to believe the problem was occurring around Glen Ewen or upstream.

4.2.2. Dissolved Oxygen Analysis

Dissolved Oxygen sampled results for all five sites are shown in Figure 17. Dissolved Oxygen levels during the early fall months stayed at above 5 mg/L, stated previously in this thesis as the DO level desired for reproduction and thriving environment for the majority of aquatic species. High DO levels continue until ice cover which was first observed on November 19, 2006. Immediately following ice cover, dissolved oxygen levels began to drop and in two months DO was depleted to levels below 2 mg/L and shortly after below 0.5 mg/L. Ice coverage during these cold months prevents air from oxygenating the river and hence the dramatic drop in dissolved oxygen once ice starts to form. The DO remains low throughout the winter until ice melt in spring months when DO levels rebound and stay within reasonable EPA DO limit requirements.

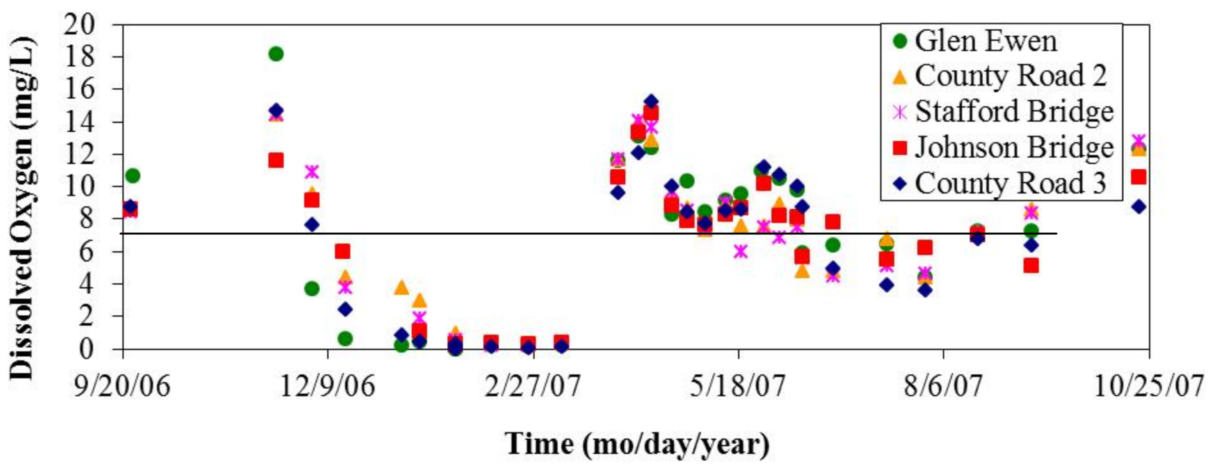

Figure 17. Dissolved Oxygen Concentration for Sampling Sites

4.2.3. Winter Dissolved Oxygen Analysis

DO levels of 5 mg/L to support life were not achieved during winter months. Low DO was the main reason for the impairment along the Souris River. Figure 18 illustrates

DO levels for five consecutive visits in early winter months. On January 7, 2007, Johnson Bridge and Stafford Bridge DO concentrations were not sampled due to weather and time constraints. After January 14, 2007, samples for DO were near zero at all sites until spring thaw and can be seen in Figure 17. DO concentrations at kilometer 0 (Glen Ewen) drop off first with increased DO concentrations to kilometer 55.7 (County Road 2) and decline in concentration to County Road 3. This was due to areas where water is reaerated due to the large number of low head dams, field and road crossings, and higher velocity river water which prolongs the period for freeze over between Glen Ewen and County Road 2 site. Areas where water is more turbulent take a longer time period to freeze over. These areas will observe rapidly increased DO levels due to the low temperature and high DO saturation values until freeze over eventually occurs because of the extreme cold temperatures seen around the Upper Souris River territory. Also, based on previous information of cross sections surveyed, Lake Darling began to affect water depth just downstream of County Road 2 and with the increased cross sectional area, the velocity was lower freeze over occurred sooner than turbulent areas.

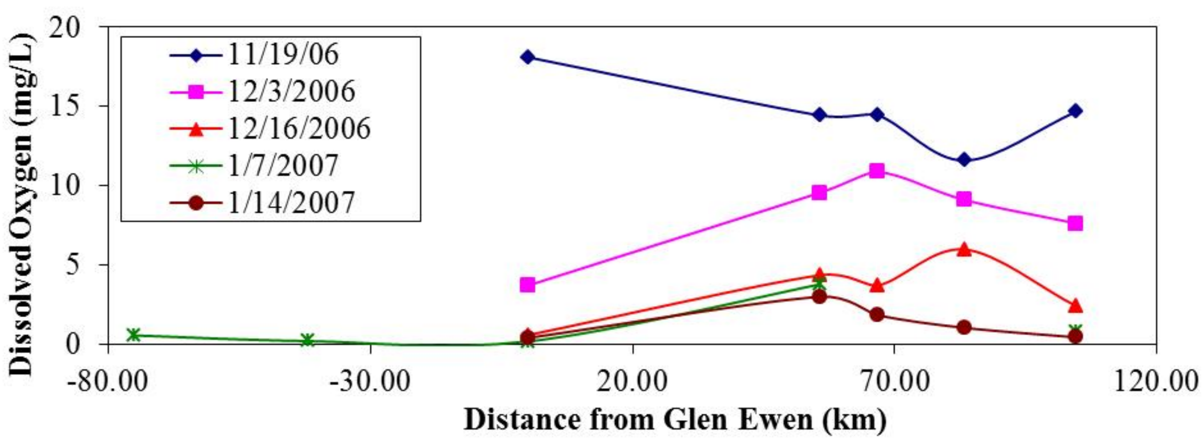

Figure 18. Dissolved Oxygen vs. Distance Downstream from Glen Ewen

4.2.4. Summer Months Dissolved Oxygen Analysis

Summer DO levels had large diurnal variations due to algae plumes along the river reach. For the Souris River TMDL Study, the USGS gauging station located near the Canada border was put back into working order. This station monitored the river 24 hours a day. Figure 19 shows a 24 hour swing of Dissolved Oxygen due to photosynthesis by aquatic plants, also shown is the oxygen saturation value for the given temperature. A large variation between observed and saturated dissolved oxygen values occurred. The Souris River was either super saturated or depleted of DO between day and night concentration levels. Cloud cover effected DO changes and prevented extreme increases in concentration compared to sunny days where the water was supersaturated with oxygen. Refer to Figure 20 for weather patterns on each DO sampling day (weather.com, 2007).

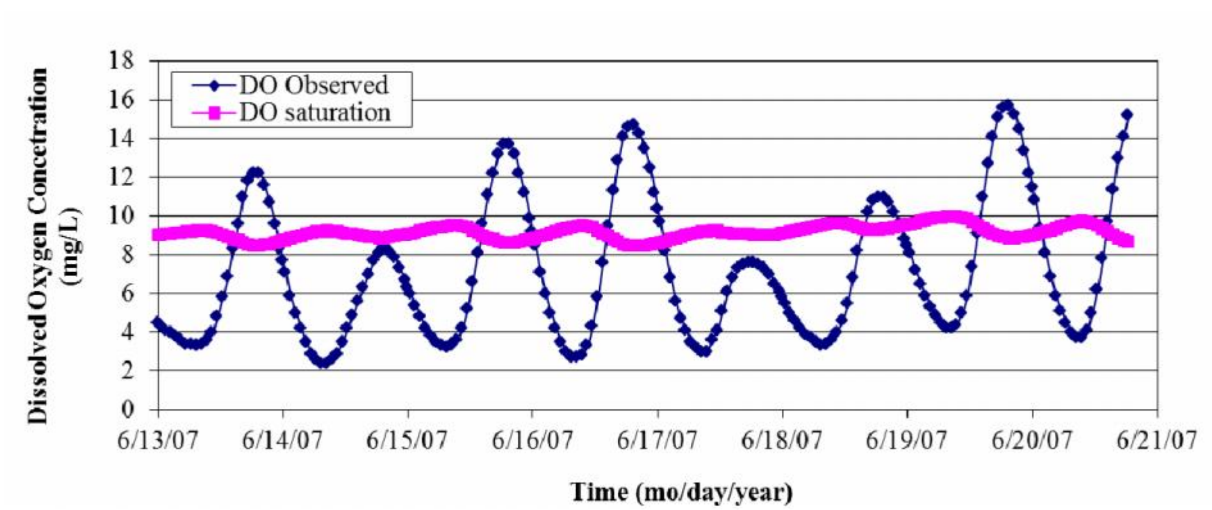

Figure 19. Dissolved Oxygen for Summer Eight Day Period at USGS Gauging Station

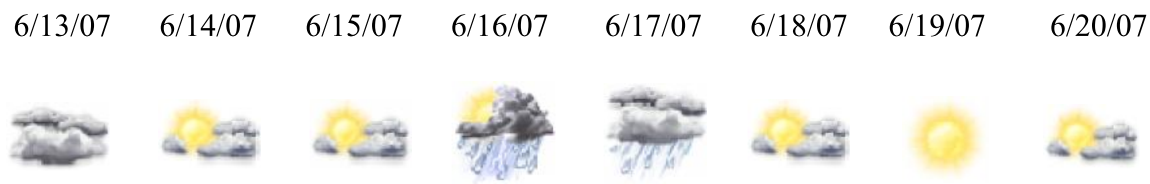

Figure 20. Weather for Summer Eight Day Sampling Period at USGS Gauging Station

Re-aeration and DO saturation levels at during warm summer temperatures did not impact the overall Upper Souris River DO concentration as much as photosynthesis as shown in the large DO swing of Figure 19. Excess nutrients in the Souris River provide nutrients and feed the abundant algal growth contributing to the DO variation. During the day, sunlight feeds the algae growth and the water body becomes oxygen rich. During nighttime, algae begin to decay, consuming DO in the water. Algae growth and decay are leading causes for the large diurnal DO variation.

4.2.5. Biochemical Oxygen Demand and Chemical Oxygen Demand

Low BOD levels were observed as the majority of samples were below the minimum detectable range for the Upper Souris River. COD results were within testing limits and results are shown in Figure 21. COD levels are typically between 30 mg/L and 50 mg/L throughout the year. Increases in COD was found at Glen Ewen during winter months for a short period and then declined throughout winter. Increase in COD occurred after DO levels reached near 0 mg/L. A minor increase in COD levels at further south sites occurred in January. COD level increases closely aligned with Nitrogen and Phosphorus increases shown in following sections. The source of COD increase was not found, however, this increase could be a sign of upstream contamination, or a result of release of nutrients and carbon into the water after sediment has reached anaerobic conditions. See literature review section of this thesis for sediment transfer of nutrients. Glen Ewen was also observed to have large cattle operations upstream of the sampling site which could have greatly contributed to the increase in COD through cattle feces entering the river as cattle were found on the river throughout winter months.

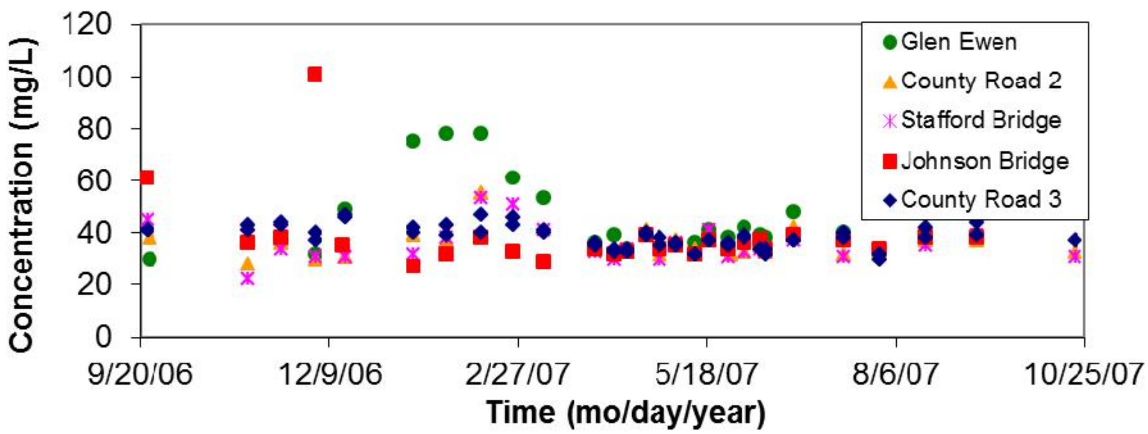

Figure 21. Chemical Oxygen Demand Results for Sampling Sites

4.2.6. Nitrogen

Ammonia, Nitrate + Nitrite, Total Kjeldahl Nitrogen, and Total Nitrogen were tested for on the Upper Souris River. During the winter months, all four of these nutrients grew in concentration and in the spring dropped back to levels reflecting the results in the fall months.

Refer to Figure 22 for total nitrogen levels at each site. Upstream sites began an increase in nitrogen concentration earlier than downstream sites. This further showed how more sources of nitrogen are upstream of Glen Ewen. Downstream sites also have larger volumes of water per square meter of sediment surface area. This would decrease the amount of nitrogen being released from sediment per volume of water. Also, some smaller towns are along the river upstream of our study which may discharge wastewater into the river upstream of Glen Ewen sampling site.

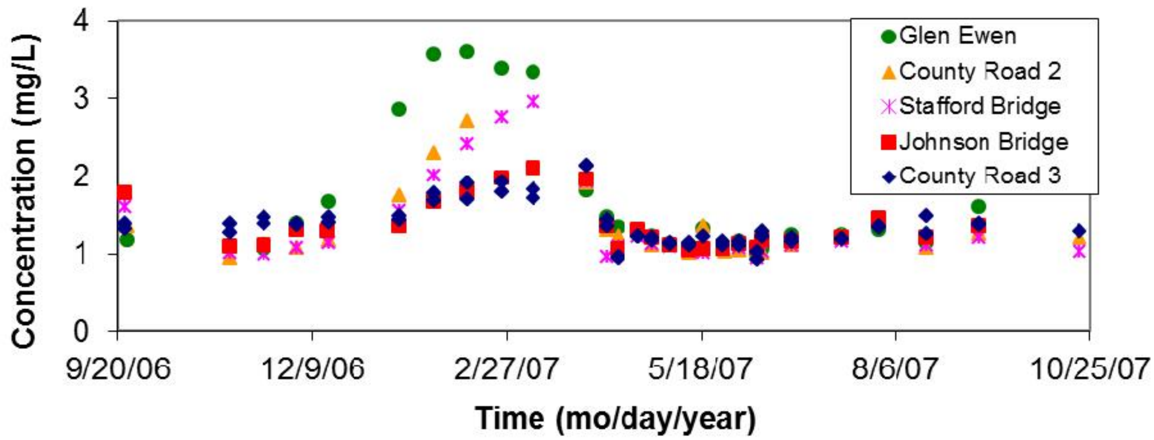

Figure 22. Total Nitrogen Concentration for Sampling Sites

4.2.7. Phosphorus

Total phosphorus levels for all sampling sites are presented in Figure 23. Phosphorus levels sampled along the Upper Souris River were higher than the interim guideline set at 0.1 mg/L. All sites exceeded this limit throughout the year. Glen Ewen had higher phosphorus levels than other sampling sites during winter months. The combination of more nonpoint sources and possible point sources upstream of Glen Ewen and lower DO levels contribute to the higher phosphorus concentrations during winter months. One source for increased water phosphorus levels during winter months is the release of phosphorus from sediment. Sediment adsorbs phosphorus in summer months during aerobic conditions. During low DO levels, anaerobic conditions take place in the water body and sediment which releases phosphorus into the overlying water body.

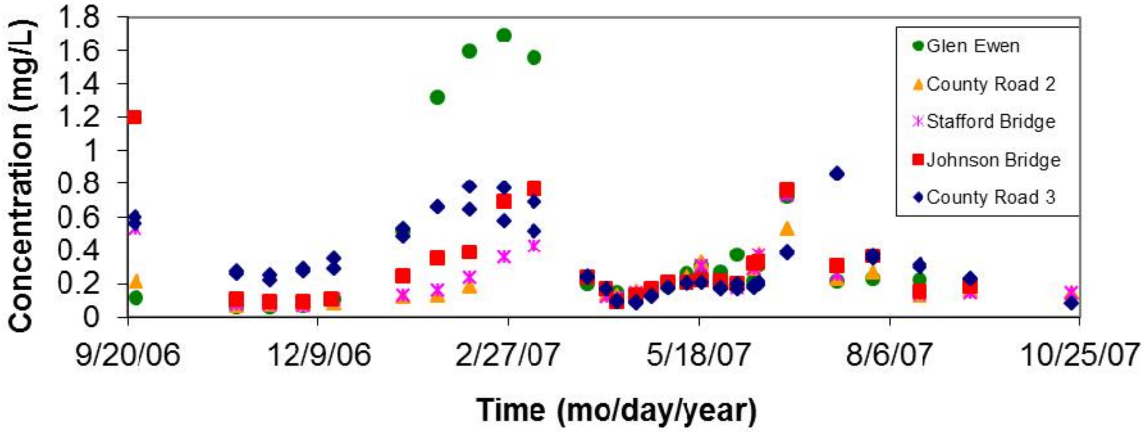

Figure 23. Total Phosphorus Concentration for Sampling Sites

4.2.8. Discussion

A rapid decrease in DO levels during the winter was observed through sampling. Low DO levels were found to be the most likely cause for fish kills along the Upper Souris River which occurred during late winter months in previous years. DO levels also showed large diurnal variations during summer months caused from large algae blooms. The algae blooms are signs of nutrient loading to the river. Primary nutrients of phosphorus, nitrogen, and COD levels were not excessive during summer months, however, during winter months these nutrients increased after DO levels were depleted. The release of these nutrients after low DO levels illustrates the release of phosphorus, nitrogen, and carbon from sediment as stated previously in this thesis during anaerobic and anoxic conditions. The depletion and large effect on DO levels from nutrients further supports contamination of the river water from cattle operations stated in this thesis from field observations as not point sources were found. Because of low flows observed along the river from sampling during the TMDL study, nutrients from nonpoint sources is absorbed by the sediment and released during winter months as shown from the sampled data and leads to the conclusion that sediment plays a role in DO depletion during winter months. Sediment oxygen demand and sediment characteristics are discussed further in following sections.

4.3. Sediment Characteristics

4.3.1. Sites Sampled

Sediment characteristics vary greatly by location along a river reach. Sites used for sediment sampling include Highway 9, Glen Ewen, Road Crossing, Bridge Crossing, USGS, County Road 2, Stafford Bridge, Johnson Bridge, and County Road 3. Sediment sampling sites included a variety of river cross section types to include a variety of sediment characteristics for the entire Upper Souris River reach.

4.3.2. Preliminary Sediment Analysis

The leading DO depleting source during winter months was found to be SOD after suspended matter and BOD were found to have only trace or non-detect levels and COD concentrations measured could not cause the significant decreased DO levels measured during winter sampling. An observation of the sediment showed a black color and smells of hydrogen sulfide, H_2S, which can be a sign of the sediment having a high percentage of organic material. After field observations, sediment samples were gathered for lab analysis. Five sediment sampling sites are displayed in Figure 24. Characteristics of the sediment tested are displayed in Table 5.

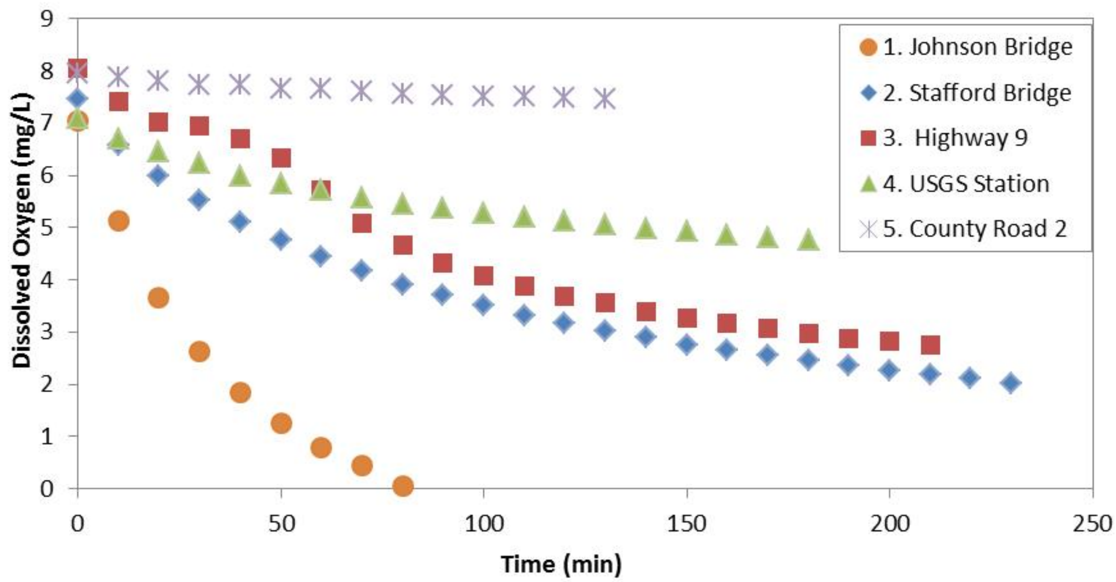

Figure 24. Dissolved Oxygen Depletion in Completely Mixed Reactor from Sediment
(1 being highest percent organics in soil and 5 being lowest percent organics)

Table 5. Preliminary Sediment Sample Percent Organic Concentration

Site	Site Location	% Organic	Coarse Composition Observed
Hwy 9	Upstream	9.45	Very Little Coarse with some twigs
USGS	US/Canada	6.1	No Coarse Aggregate Retained
CR 2	Bridge	2.61	Mostly Coarse Aggregate
Stafford	Bridge	13.23	Little to no Coarse Material
Johnson	Downstream	14.91	Algae and Plant Remains

Testing results illustrated higher organic content increased oxygen depletion rates. County Road 2 in Table 7 has the lowest percent organic concentration of 2.61% and the lowest DO depletion as shown in Figure 24. Johnson Bridge site had the highest percent organic concentration of 14.91% and the highest DO depletion rate as shown in Figure 24 by depleting DO levels from 7 mg/L to 0 mg/L in the shortest interval of time. The lower percent organic sediment of County Road 2 consisted of rocky and sandy sediment while the higher percent organic sediments of Johnson Bridge were black in color and made up of finer and organic material. The higher percent organic soils were found where river cross sections were deeper and wider. This is an indication that this material was carried there and settled out at these locations because of lower velocities. This test was only for preliminary analysis of the sediment. Preliminary results from this test show SOD is a leading cause for depletion of oxygen during winter months. Sediment samples have high organic percentage. Further sediment sampling and analysis was required to provide a better understanding of sediment effects on dissolved oxygen and SOD rates for model simulations.

4.3.3. Sediment Material

Further analysis of the sediment was required to get an accurate rate of SOD in order to properly model the river. Sediment Core samples were gathered at five locations. Sampling sites included Glen Ewen, Road Crossing, Bridge Crossing, County Road 2, and County Road 3. The core samples were analyzed for percent fine and percent organic composition to illustrate how the sediment changes with depth, along a cross section, and along the length of the river. Additional sites that had a single sample gathered with the coring sampler or the dredger for analysis included Highway 9 and Stafford Bridge. Procedures for sediment analysis were described earlier.

4.3.3.1. Sediment Organics Compared to River Depth

Table 6 compares percent organic of sediment to maximum river depth of the cross section at six of the sediment sampling sites. Average percent organic sediment measurements are shown for the top layer and river depths reflect the deepest portion of the sites cross section. The table confirms previous hypothesis that deeper sections of the river have lower velocities and therefore settle out more solids and organics which in turn increase percent organics of the sediment.

Table 6. Sediment Percent Organics Comparison to River Depth

Site	Percent Organics (%)	River Depth at Deepest Location (m)
Highway 9	7.11	2.7
County Road 3	6.32	2.1
Stafford Bridge	4.74	1.1
Bridge Crossing	3.09	0.9
County Road 2	2.5	1.0
Road Crossing	1.64	1.1
Glen Ewen	1.11	0.7

4.3.3.2. Sediment Percent Organics at River Cross Section and Sediment Depth

Four sediment sampling sites were analyzed with core samples taken along the river cross section and are Glen Ewen, Bridge Crossing, Road Crossing, and County Road 2. Three additional sites, Highway 9 and County Road 3, sediment samples were gathered in one sample at each location due to river depth and equipment available for gathering samples. Figure 25 provides a summary of information for one of the four sediment sampling sites with cross section analysis, Bridge Crossing. Sediment sample analysis for all six sites can be found in Appendix F2. Other sampling sites have similar sediment percent organic trends to Bridge Crossing shown in Figure 25.

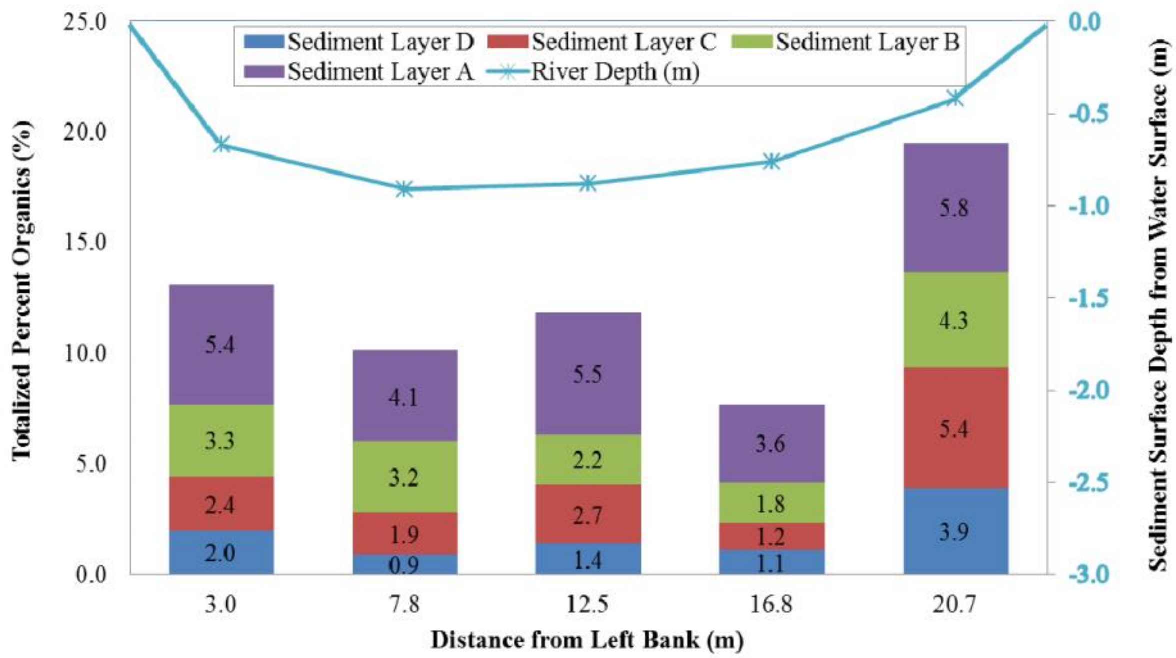

Figure 25. Sediment Percent Organics Concentration of River Cross Section at Bridge Crossing Site

Data shown in Figure 25 provides insight into how sediment changes over time. The top 5.1 centimeters of sediment typically have higher organic concentration than deeper sediment samples as shown. Organic material decreases with depth. Results show sediment organic material is still prevalent at greater sediment depths. It is unknown from this study if the organic material is from rapid deposition of new sediments or slow rate of decay of the organic material in the sediment.Rapid deposition of sediments is caused from erosion of bank material and deposition in low river velocity areas. A possible reason for slow rate of organic material decay may be the extreme low temperatures this area has for a large portion of the year. Low temperatures can slow the rate of decay (Chapra 2007).

Results also show edges of the river having higher organic concentration than the center of the river. Higher velocities are typically seen nearest the center of the river along straight river runs and carry sediment and organics away. Also, the higher velocities in the center bring more oxygenated water across the sediment which can increase the rate of decay of organic matter found there. Higher organic content at rivers edge was not seen for low water depth cross sections such as County Road 2 where the water flows rapidly across the entire river cross section. Another possible source to higher concentrations of organic material along the edge of the river is non point sources, mainly cattle, which reside along the rivers edge. Precipitation runoff collects near rivers edge as well. All options contribute to sediment organic concentrations being higher near the edge of the river and decrease with sediment depth.

4.3.3.3. Sediment Percent Fine Compared to Percent Coarse Material

Sediment composition for percent fine and percent coarse material was also conducted for each sample. Percent coarse material is shown in Figure 26 for site Bridge Crossing. All site information for percent coarse material is shown in Appendix F3. All sites vary, typical trends stay the same for percent increase and decrease of fine material across a cross section and with depth of sediment. However, Bridge Crossing has one exception where a specific core sample has significant higher concentrations of coarse material compared to the rest of the sediment. Sites with lower percent organics tend to have higher percent coarse concentration. Typical coarse material along the Souris River includes rocks, shells, as well as sticks or pieces of plantlife.

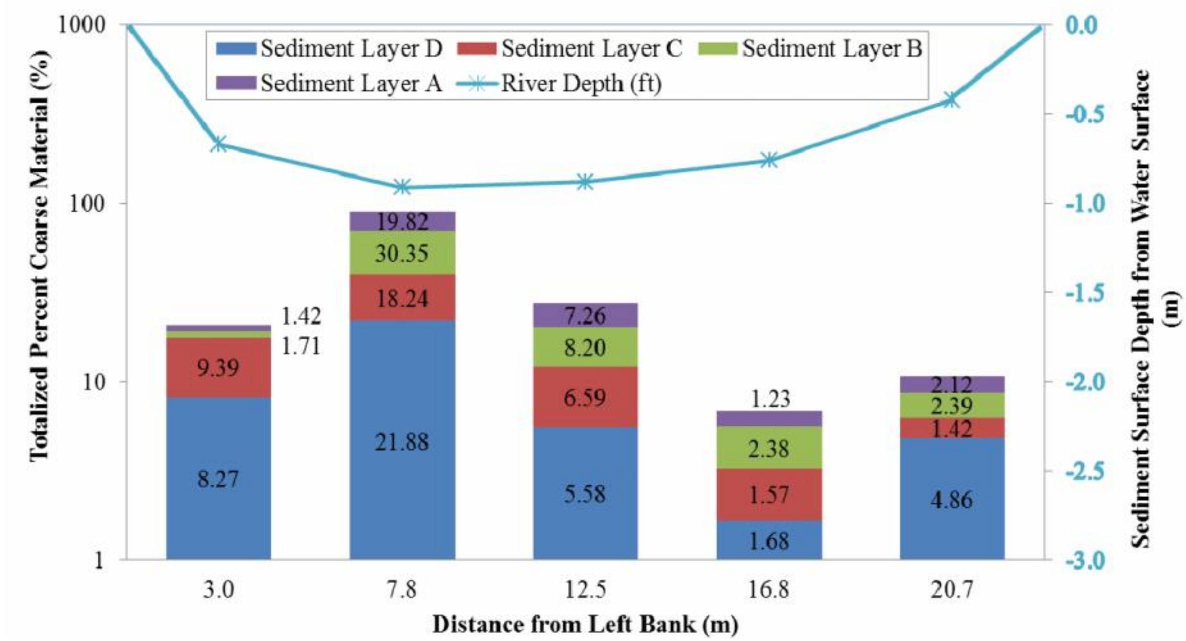

Figure 26. Sediment Percent Coarse Material of River Cross Section at Bridge Crossing Site

4.3.4. Sediment Sampling Accuracy

Sediment sampling resulted in a minimum of two tests for each sediment sample. Fine and coarse percent organics sediment samples were compared against non separated percent organics sediment samples to find the difference and error in measurements. All data for fine and coarse percent organics sediment samples compared to non separated percent organics sediment samples is shown in Appendix F3. Table 7 provides results for the difference in percent organics between the two methods. Results provided a standard deviation of approximately 0.65% for percent organics measured. Although samples were uniformly mixed and precautions taken to assure accurate measurement, variance of sampling is fairly high. For a confidence interval of 95%, sediment samples can be +/- 1.3% organic concentration. The difference between the two types of sampling results can be seen in Figure 27.

Table 7. Sediment Percent Organic Accuracy Comparing Original Sample to Separated Samples for Percent Coarse and Fine Material

Original vs. Separated Fine and Coarse Percent Organic Sample	
Description	Value (% organic)
Average	-0.03
Median	-0.02
Minimum	-1.69
Maximum	1.84
Sum	-2.09
Number of Samples	75.00
Standard Deviation	0.65

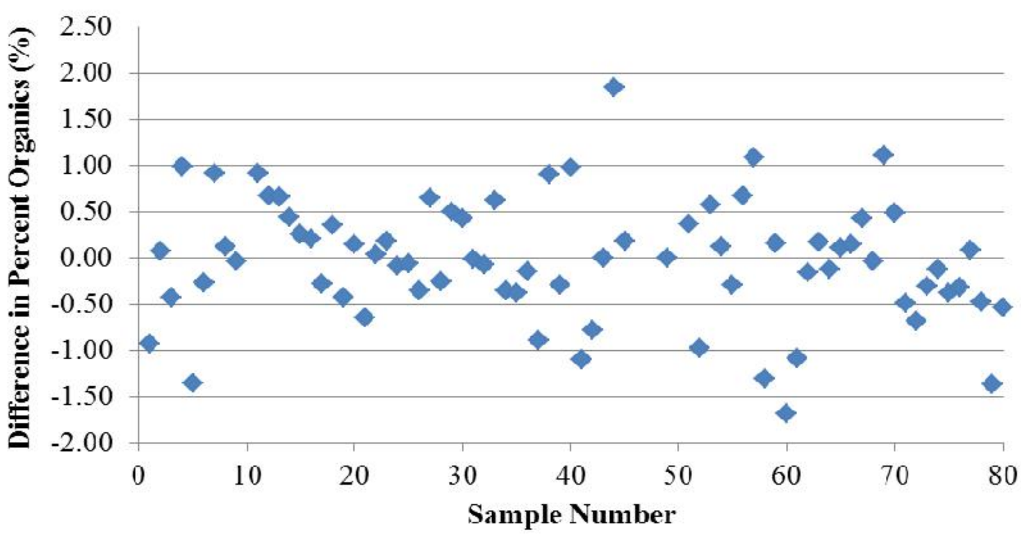

Figure 27. Difference in Percent Organics Comparing Original Sample to Separated Samples

A second analysis was conducted on a single sediment sample from County Road 3 and tested a total of ten times. Results from this test showed standard devation of percent organics measured to be 0.27% with a 95% confidence interval of 0.54%. Appendix F summarizes data obtained.

A third method of sediment analysis was conducted seperating sediment samples by percent organics. Samples were seperated into four categories which include 0% to 1% organics, 1% to 2% organics, 2% to 3% organics, and greater than 3% organics. Each category has a different standard devation, however, standard deviations did not vary greatly from original values as previously thought. One trend was found when comparing low percent organic sediment to high percent organic sediment. The orginal non-separated sample tended to measure higher in percent organics than the separated samples for higher organic sediments and visa versa for lower percent organic sediments.

Fine and coarse percent material of each sediment sample varies greatly between tests for the same sediment sample. A sediment sample from Stafford Bridge was used for analysis of percent coarse and percent fine standard deviation. A single 5.1 centimeter core sample was tested a total of ten times to find the percent error for each test compared to the sample as a whole. A summary of values from the coarse and fine testing can be seen in Table 8.

Table 8. Sample Accuracy for Percent Coarse of Sediment Sample

Description	Value
Average	9.90
Median	9.59
Minimum	6.23
Maximum	15.68
Sum	99.00
Number of Samples	10.00
Standard Deviation	6.41

Results provided a standard deviation of approximately 6.41% for percent coarse measured. Although samples were uniformly mixed and precautions taken to assure accurate measurement, variance of sampling is fairly high. For a confidence interval of 95%, sediment samples can be +/- 12.82% coarse concentration.

4.4. Sediment Oxygen Demand Experiments

Sediment has been identified as the leading DO depleting source during winter months and high organic contents in the sediment from non-point sources is the main reason of high SOD. Further analysis of the sediment needed to be done to get an accurate rate of SOD in order to properly model the river. The core samples were analyzed for percent fine and percent organic composition to find how the sediment changes with depth, along a cross section, and along the length of the river. Procedures used for this analysis along with results can be seen in previous sections. After sediment analysis, the combined top sediment layers from a sediment sampling site were placed into a reactor to find the SOD rate. The SOD rate was entered into QUAL2K, a steady state river quality modeling software, and models DO over distance of the study reach. Sediment samples from 5 sites previously listed and Highway 9 were tested for SOD.

4.4.1. De-Ionized Water Effects

After sediment samples were gathered and SOD tests commenced, a number of unforeseen problems with the original sediment oxygen demand testing procedure arose. One problem was the effect of De-Ionized water on the sediment sample. Originally, new water was going to be oxygenated and placed in the reactor each time the experiment was run. During initial testing for percent error between multiple consecutive experiments, the SOD depletion rate reduced significantly with each preceding experiment. The cause was found to be the use of new de-ionized water for each experiment. Figure 28 represents new deionized water for each experiment. Sediment from Highway 9 was used for this experiment and initial experiment setup because it is located outside of the TMDL river reach and there was an abundant amount of sediment for use.

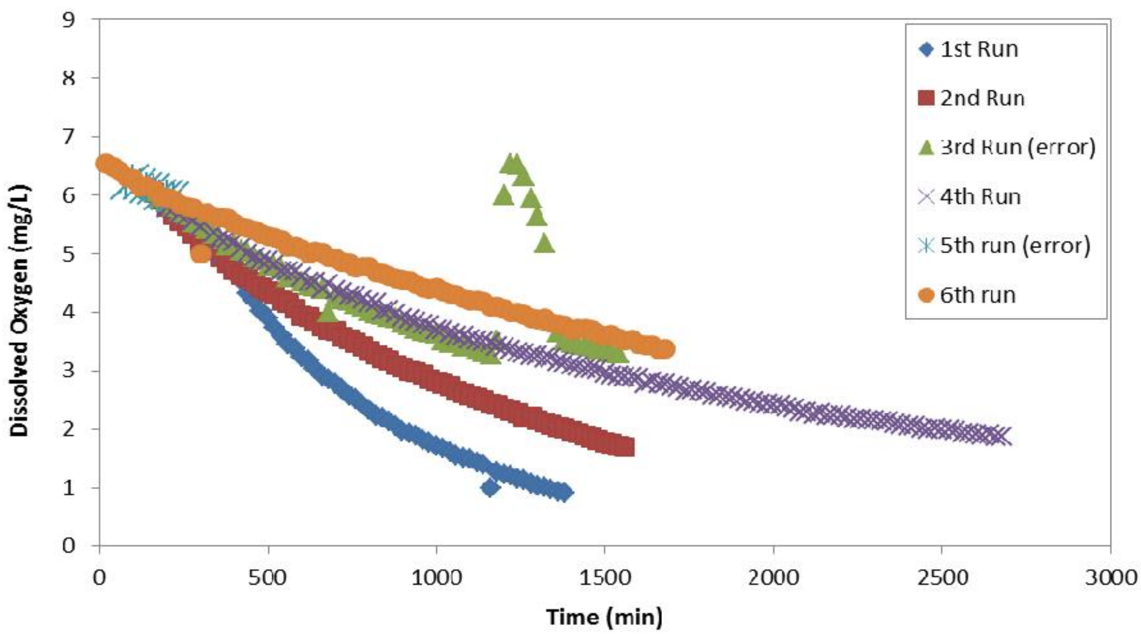

Figure 28. Sediment Oxygen Demand Test for Highway 9, De-ionized Water Replaced

De-ionized water is nearly pure water. De-ionized water is stripped of minerals, suspended matter, and even dissolved solids and charge. The use of this water reduces effects from outside source contamination. In this case, the water acted as a solution to accept minerals, salts, metals, anions and cations. The water depleted the sediment of carbon and nitrogen as well as these other characteristics at the sediment water interface. The water was then removed and discarded, completely removing and the water characteristics just removed from the sediment therefore affecting SOD testing. Using de-ionized water did not realistically reflect a river as this does not show an accurate representation of sediment/water interface. Once de-ionized water was reused, SOD rates did not decrease dramatically between each test run.

4.4.2. Improper Reactor Setup Errors

During initial reactor setup and SOD tests with Highway 9 sediment, reactor design or possible points of failure were seen while running experiments. Some errors occurred with improper sealing of the reactor from the atmosphere as shown in Figure 29. The air release port in the first run was not plugged properly and the seal broke around the edge of the lid of the reactor in the second experiment. After the lid was secured, the DO levels began to drop again as predicted. One additional error occurred during all the remaining experiments from reactor failure and that particular SOD test was removed from the data set. The failure occurred from the bearing seal of the impeller shaft at the reactor lid and a new bearing was installed.

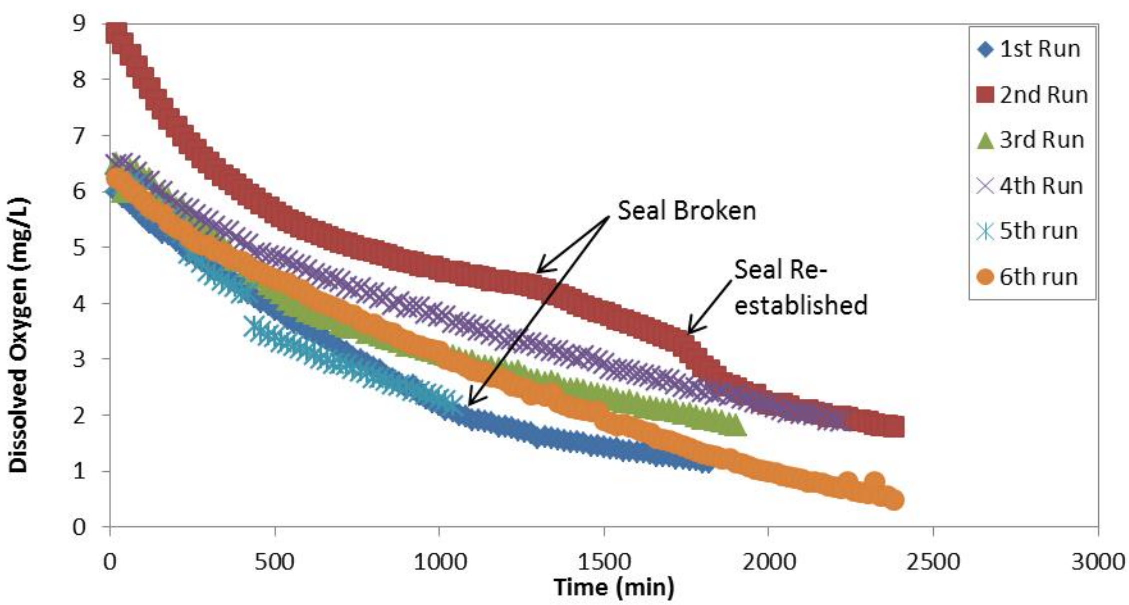

Figure 29. Sediment Oxygen Demand for Highway 9 Reactor Errors

4.4.3. Aerobic Layer Formation

A large contributing factor to consistent and accurate SOD rates over multiple tests is the formation of the aerobic layer. Initial testing showed formation of this layer crucial to accurate SOD rates. See Figure 30 for aerobic layer formation SOD testing of County Road 3 sediment.

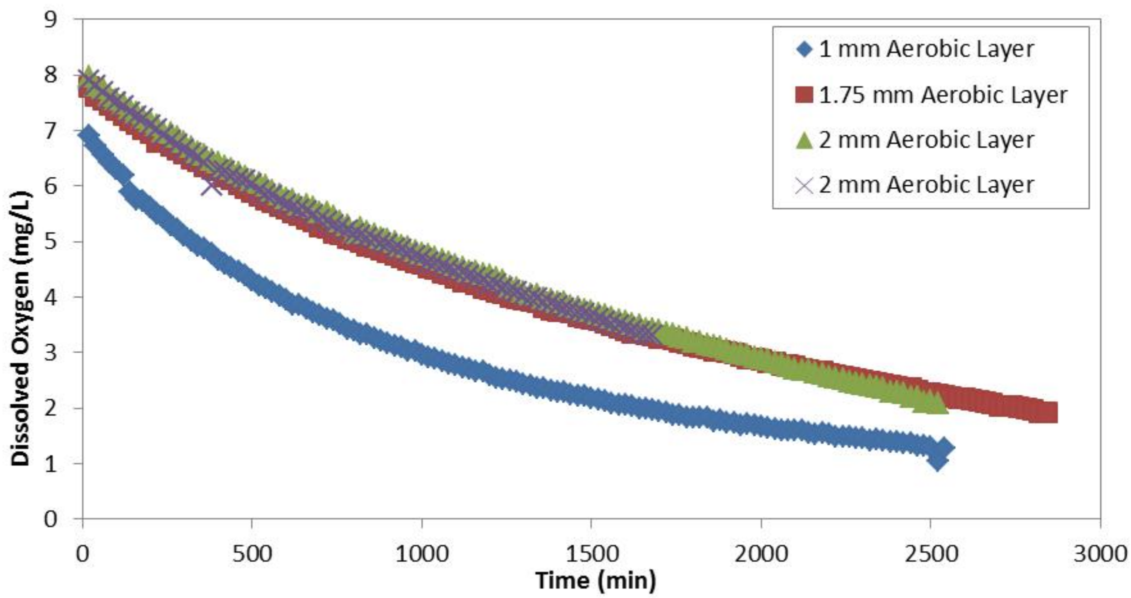

Figure 30. Sediment Oxygen Demand Test for County Road 3 Aerobic Layer Formation

Initial SOD testing shows a greater SOD rate for the first test with no initial aerobic layer formation at the beginning of the test to a 1mm aerobic layer at the end of the test. The first SOD test was not used for SOD rates for County Road 3 because the aerobic layer had not yet formed completely. Aerobic layer formation will actively decompose the existing organics within the layer and can affect SOD results. Results allowed following experiments to form the aerobic layer before SOD tests began as described in the procedure for SOD testing. A picture of the sediment after formation of the aerobic layer can be viewed in Figure 31.

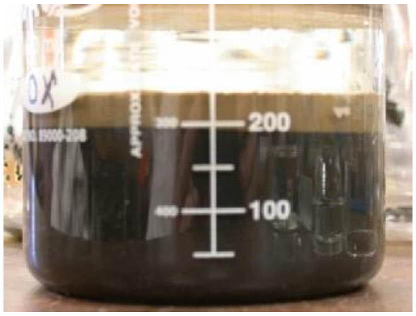

Figure 31. Aerobic Layer Formation Photo

4.4.4.   Electrical Interference of Dissolved Oxygen Probe Readings

SOD testing uses a paddle for mixing the water to simulate velocities found in natural waters. During SOD testing, it was noticed that the DO probe began to jump significantly in DO levels measured. The probe was calibrated and new filter ends were also installed on the probe with no change. A second DO meter was also used to rule out a defective DO meter. After some trial and error, it was found that the mixing unit was inducing an electrical current into the reactor water. The current in the water was causing the DO probe to measure erratic readings. Inaccurate DO readings caused by the electrical current from the mixer can be viewed in Figure 32. Calibration of the DO meter instrumentation occurred before and after nearly all experiment SOD individual tests as shown in Table 9 for the SOD test in Figure 32.

Table 9. Sediment Oxygen Demand Test for County Road 3 DO Meter Calibration

Experiment	Time (Month/Day - Hr:Min)		Temperature	DO Meter Calibration	
No.	Start	End	^{o}C	Before	After
1	11/11 - 21:00	11/12 - 20:00	20	8.89	8.65
2	11/14 - 19:00	11/15 - 15:00	20	8.83	8.66

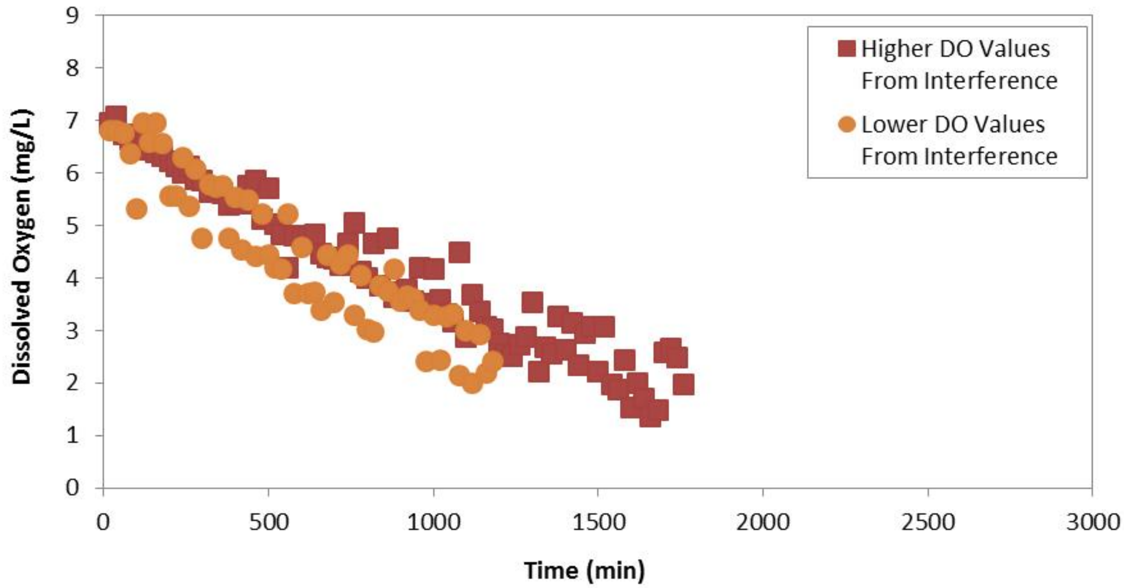

Figure 32. Sediment Oxygen Demand Test for County Road 3 Electrical Interference

A solution to help minimize the noise induced on the DO probe was to electrically isolate the mixing unit from the SOD reactor. This was accomplished with the addition of a stiff rubber hose clamped to two metal rods. One rod entered the SOD reactor and the other rod entered the mixer. An air gap filled with rubber between the two rods help prevent current transfer to the reactor. Noise still occurred, however, it was minor and allowed for accurate DO depletion rate measurements.

4.4.5. Temperature Variation

Previous studies and articles have stated that temperature plays a large role in SOD (DiTorro, 2001). Testing done on samples was in a controlled environment and temperature was recorded both inside the SOD reactor and in the temperature controlled water bath to assure that the temperature stayed the same inside the reactor. Temperature does play a role in oxygen depletion, however, testing showed that oxygen depletion still occurs very rapidly even at low temperatures. It was stated below 4°C, SOD would have little to no effect on the DO levels in the water (Thomann and Meuller, 1987). Results from varying temperature testing are shown in Figure 33 from sediment collected at site Bridge Crossing.

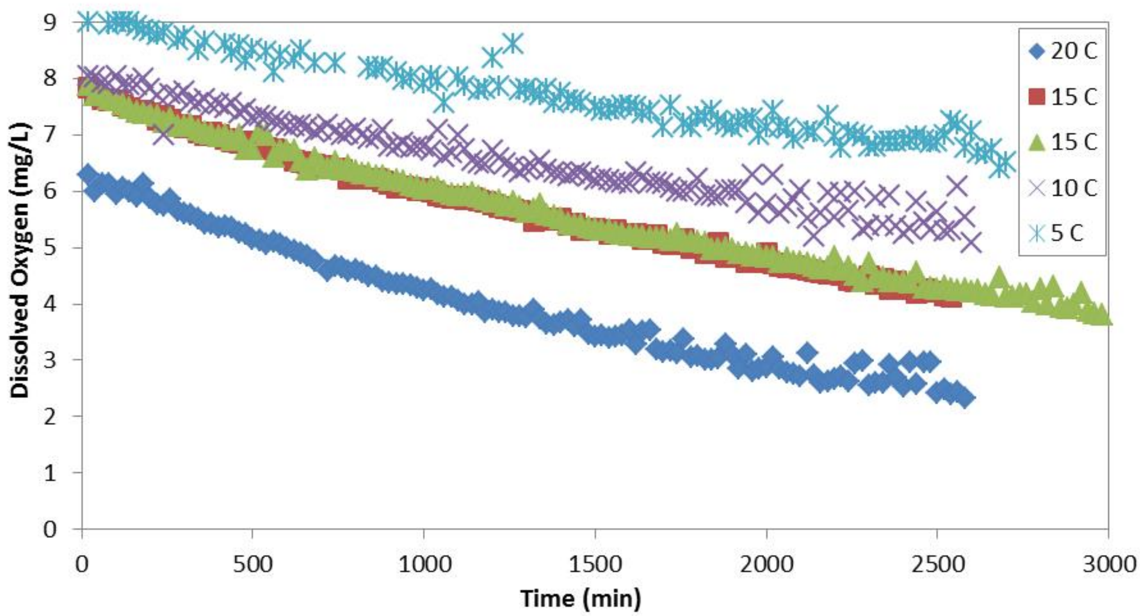

Figure 33. Sediment Oxygen Demand Test for Bridge Crossing Temperature Adjustment

As shown in the results, SOD rates are still significant even at low temperatures of 5°C. SOD rates were taken using the slope of the DO depletion curve from experiments taking into account reactor size and sediment surface area as described in Equation 5 of this thesis. Although temperature does play a role in SOD rates, effects are less significant than stated in literature. An equation was previously provided to convert SOD tests at 20°C to lower temperatures with a constant theta value of 1.047. This is not the case for the Souris River sediment where the theta value is approximately 1.035 or lower as shown in Table 10. Equation 6 of this thesis was used to determine theta for each temperature experiment.

Data confirms sediment as the leading source of oxygen depletion during winter months along the Souris River.

Table 10. Sediment Oxygen Demand Bridge Crossing Temperature Adjustment Theta Value

Temperature	SOD Rate	Theta Calculated
(^{o}C)	(g $O_2/m^2/d$)	(Θ)
20	0.33	NA
15	0.29	1.029
10	0.22	1.041
5	0.20	1.035
Theta Value Used for Modeling		1.035

4.4.6. Velocity Variation

Ex-situ tests were performed for the Souris River SOD testing. In order to mimic realistic river flows, the SOD reactor was stirred with a paddle. Calculations for river velocity conversions to paddle revolutions per minute are stated in Appendix G. In winter months, the velocity of the river is extremely low. Instrumentation brought to the field during site visits could not measure flow because of the low velocities during winter months. Table 11 compares impeller revolutions per minute to typical river velocities measured during the TMDL study. Figure 34 illustrates SOD results for different velocities at Bridge Crossing site.

Table 11. Sediment Oxygen Demand Reactor Impeller Velocities

Reactor Impeller Revolutions	Corresponding River Velocity
9 rpm	0.0279 m/s
17 rpm	0.0527 m/s
26 rpm	0.0806 m/s
34 rpm	0.1055 m/s

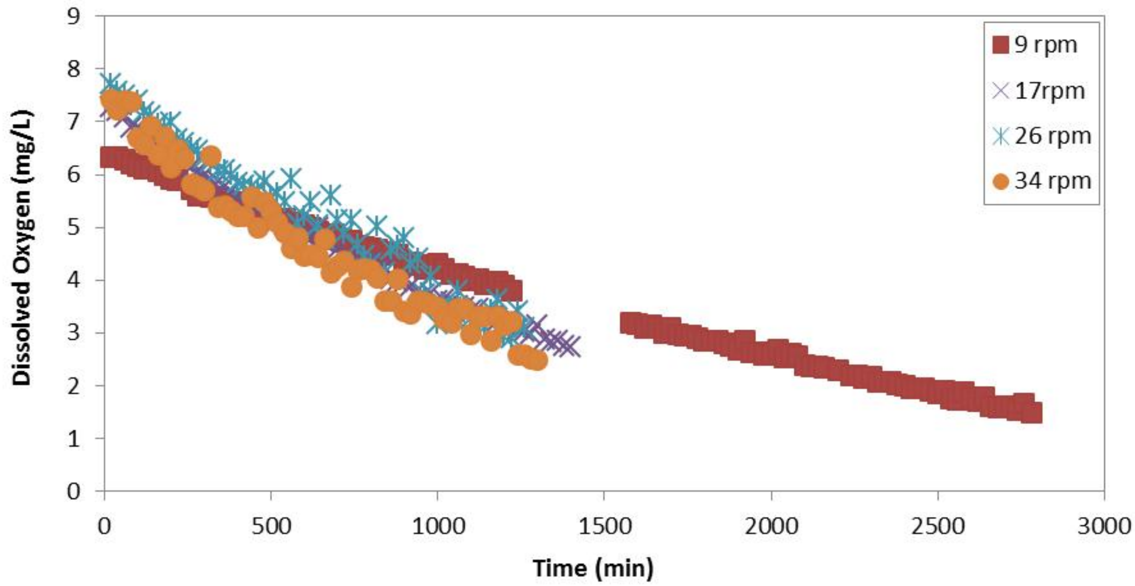

Figure 34. Sediment Oxygen Demand Test for Bridge Crossing Effects of River Velocity

Varying water velocity in the reactor simulates changes in river velocity throughout the course of the year. Conditions represented laminar flows in the river and do not reflect turbulent flows typically associated with storm events. Velocity SOD testing results provided information that an increase in river velocity will relate to higher SOD rates as originally predicted. See Table 12 for a table summarizing SOD rates for Bridge Crossing site shown previously. The SOD increase is more reflective of adequate stirring of the reactor water than a direct relation with velocity. SOD rates were drastically lower for the lowest velocity test but nearly the same for the remaining three velocity SOD tests. Similar results were seen with other sediments. Therefore, it is concluded that although velocity effects SOD rates, the effects are not as prominent as other factors. Modeling velocity effects on SOD can therefore be dismissed.

Table 12. Sediment Oxygen Demand Test for Bridge Crossing Velocity Impact Results

Impeller Tip Velocity (rpm)	SOD Rate ($g\ O_2/m^2/d$)
9	0.37
17	0.70
26	0.81
34	0.79

4.4.7. Results

Sediment oxygen demand test results for five sites at 20°C and an impeller speed of 17 rpm are shown in Figure 35. SOD tests for all five sites provided information to be used in the QUAL2K model for the Souris River TMDL project. SOD was established as the leading source of DO depletion during winter months. From the results presented, SOD can deplete DO levels significantly enough to create DO depleted waters and lead to fish kills. SOD rates from the chart shown in Figure 35 are summarized in Table 13.

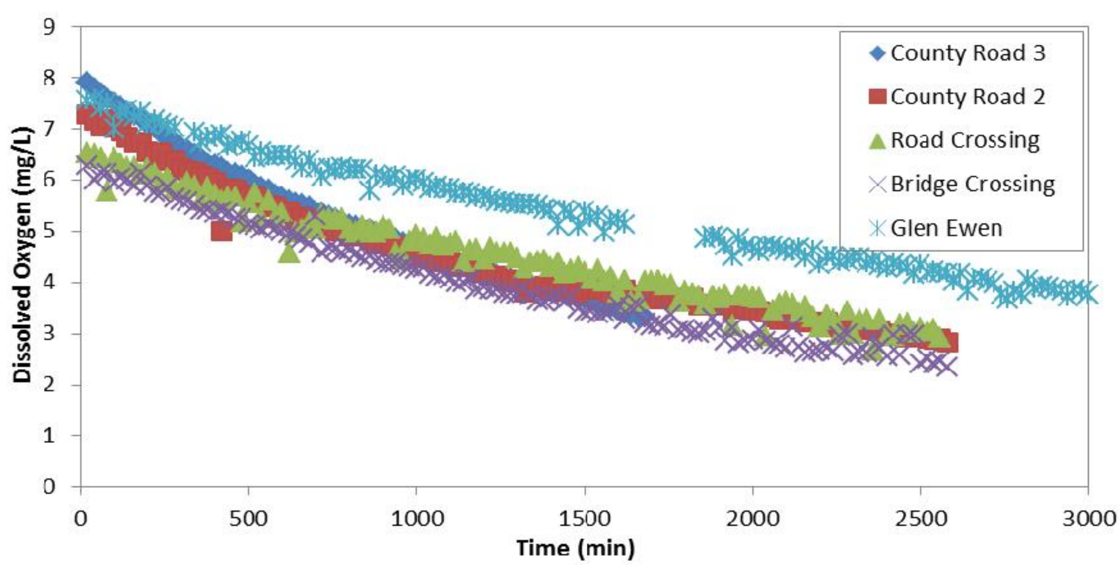

Figure 35. Sediment Oxygen Demand Test Results for Five Sampling Sites

Table 13. Sediment Oxygen Demand Test Results for Five Sampling Sites

Site	SOD Rate Initial	SOD Rate End	Average Percent Organics
	($g\ O_2/m^2/d$)	($g\ O_2/m^2/d$)	(%)
County Road 3	0.70	0.44	6.32
County Road 2	0.61	0.22	2.50
Road Crossing	0.40	0.26	1.64
Bridge Crossing	0.46	0.24	3.09
Glen Ewen	0.37	0.24	1.11

Results show that SOD rates for the five sediment sampling sites range from 0.22 g $O_2/m^2/d$ to 0.70 g $O_2/m^2/d$. The table also demonstrates that higher organic sediments produce higher SOD rates. As the majority of sediment sampling sites were at locations with shallow water depths, due to accessibility, the deeper portions have greater effects on SOD rates and further deplete DO levels during winter months than shallower river locations. It was previously stated in this thesis normal river sediment could have SOD rates in the range of .05-1 $g/m^2/d$ for mineral soils and 0.2-1 $g/m^2/d$ for sandy soils. It appears that the Souris River sediments are within this range. However, in deeper portions of the river where the organic material settles out, SOD rates are near the higher end of this range rather than the lower end.

4.4.8. Discussion

Sediment oxygen demand testing results have provided rates for modeling input as well as adjustments for varying velocity and temperature. Results showed temperature has a less effect on SOD rates compared to review of previously published information. An increase in velocity also increases SOD rates slightly. SOD rates at many of the sites were fairly similar. SOD results show slightly higher SOD rates at County Road 3 where the percent organics were also higher in concentration. County Road 3 also has a deeper and wider cross section. SOD rates decreased the further upstream the sediment samples were gathered. These sites had shallower water levels and increased river velocity which prevented the settling of organic matter and also the increase in organic matter decomposition.

4.5. QUAL2K Modeling

As part of the Souris River TMDL Study, the QUAL2K model was required for analysis of the impaired river reach. Surveyed river cross sections, site sampling data, field observations, standard and site specific model input constants, and modeling restriction parameters were entered to provide an accurate model for relating sediment organics and SOD rates to DO depletion along the Upper Souris River.

4.5.1. Model Input Parameters

Input parameters for the QUAL2K model primarily consisted of water quality sampled data, surveyed data, lab sediment oxygen demand results, regional weather, and standard model input parameters.

Values entered as input parameters for "Headwater Data" are water quality sample results from the Souris River TMDL sampled at Glen Ewen during initial river surface freeze over. Temperature, Conductivity, Dissolved Oxygen, and pH were field sampled values. Nitrogen and phosphorus values were lab sampled data. Miscellaneous water quality constituents that were unknown were not entered. Aeration rates under "Water Column Rates" were specified as zero because of the complete freeze over of the river as confirmed by site visits. The remaining rates listed were kept as standard model input parameters.

The QUAL2K model input "Reach Data" parameters were entered based on field surveyed results further adjusted as stated in previous sections of this thesis to fit model input parameter requirements. SOD rates were input based on SOD testing results and graphed correlation to sediment organic material later discussed in this section. Shade and cloud cover was also input as one hundred percent because ice and snow cover prevented light penetration.

Groundwater flow was not calculated as part of the QUAL2K model for the Upper Souris River TMDL. Groundwater flow data was not available for the river reach area. Also, groundwater dissolved oxygen samples were gathered during the winter site visit and illustrated DO concentrations of groundwater were significantly higher than river water DO concentrations. River water sampling sites showed DO levels near 0 mg/L and groundwater DO samples greater than 2 mg/L. Lack of groundwater flow data and field sampling DO concentrations confirmed low DO from groundwater was not a major cause to river DO depletion.

4.5.2. Sediment Percent Organics Relationship to Sediment Oxygen Demand

Percent organics and SOD were previously found in this thesis to have a correlation with higher organic sediment producing higher SOD rates. SOD rates were tested for five sites along the study area. Sediment percent organics compared to SOD rates are illustrated in Figure 36. The equation shown in Figure 36 was developed to provide SOD rates for sites sampled for organic material and not SOD tests conducted in the lab. Table 14 shows SOD rates for all sites that obtained sediment organic material tests. These SOD rates were input into the QUAL2K model for each site listed.

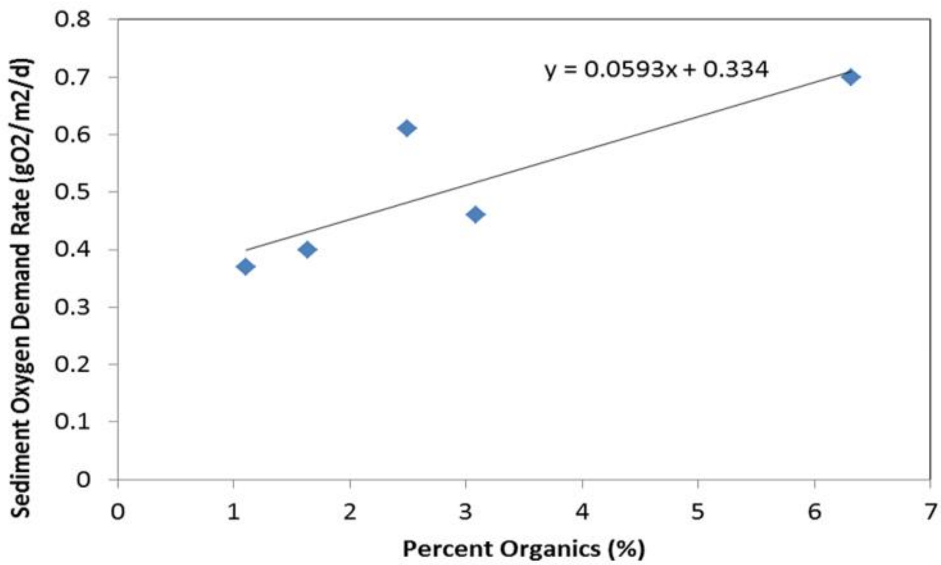

Figure 36. Sediment Organic Content Correlation to SOD Rates

Table 14. QUAL2K SOD Rate Values

Segment Name	Organic Content (%)	SOD Rate ($gO_2/m^2/d$)**
Glen Ewen	1.11	0.37*
Bridge Crossing	3.09	0.46*
Road Crossing	1.64	0.40*
USGS	6.11	0.70
County Road 2	2.50	0.61*
Stafford Bridge	13.32	1.12
Cross Section 11	1.33	0.41
Johnson Bridge	14.91	1.22
Cross Section 12	1.33	0.41
County Road 3	6.32	0.70*

* SOD rates provided from lab testing.
** SOD rates calculated based on equation developed in Figure 36 unless otherwise noted.

4.5.3. Model Flow Calibration

QUAL2K model flow calibration was performed to obtain accurate physical characteristics of the Upper Souris River TMDL study reach. Flow calibration was performed after all input parameters were entered. The USGS gauging station flow rates and sampling sites water level depths were used to calibrate the model. Low head dams were used at Lake Darling and USGS gauging station to maintain water level depths measured at these two sites. USGS gauging station has a low head dam installed and Lake Darling is the furthest downstream location of the TMDL which is affected by the lake. For all other sites, Manning's n value was adjusted to best match QUAL2K simulated water levels to field measured water levels. Figure 37 shows flow calibration of the QUAL2K model for the Upper Souris River with field measured water levels observed on December 16, 2006.

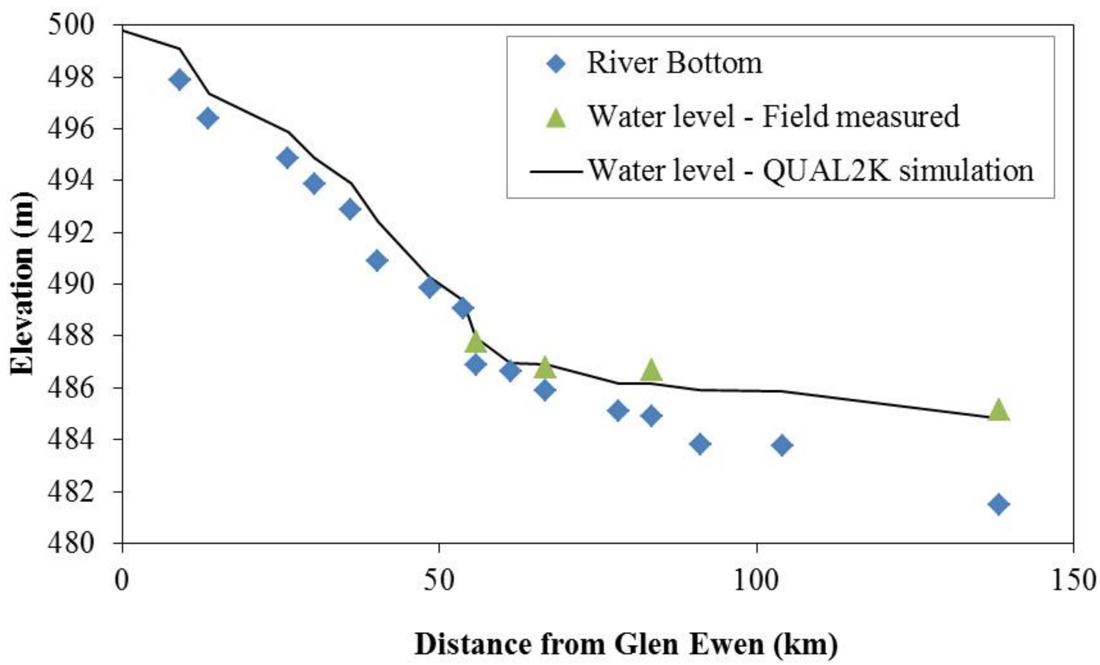

Figure 37. QUAL2K Model Calibration with Field Measured Water Levels

4.5.4. Dissolved Oxygen Calibration

After the QUAL2K model was calibrated for flow, calibration using field sampled DO concentrations was performed. Observed DO levels recorded at sampling sites on

January 14, 2007 were used to calibrate the model. An increase in DO concentration at the USGS gauging station was observed in during sampling. This increase in DO was simulated in the model through aeration at this location with an aeration rate of 0.5 day^{-1}. Figure 38 illustrates the DO profile of the model compared to observed DO concentrations from this calibration.

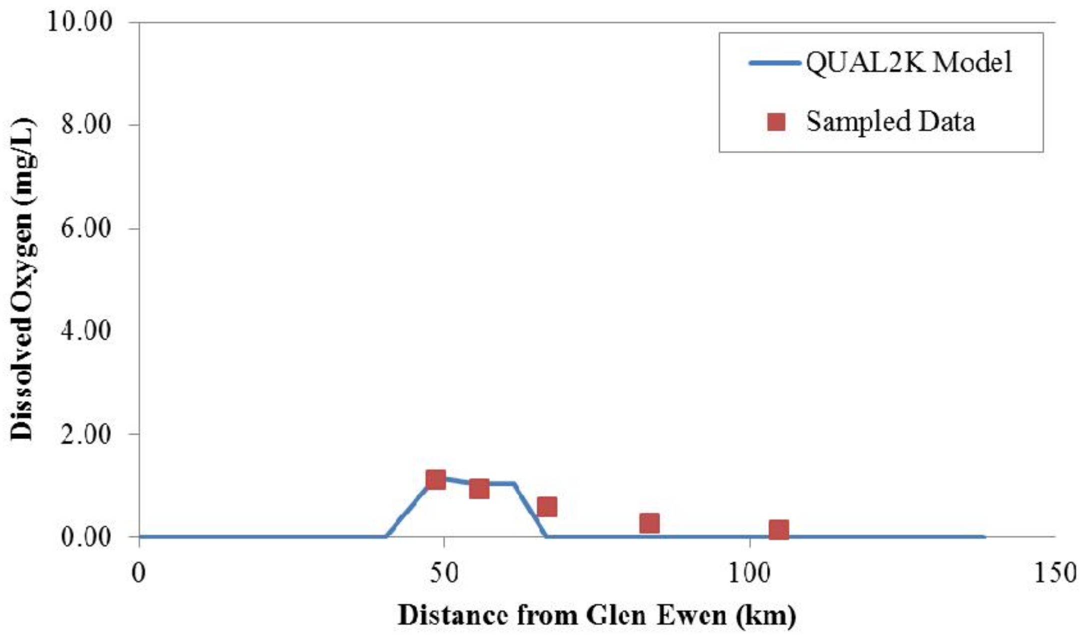

Figure 38. QUAL2K Model Calibration with Field Measured DO Concentrations

4.5.5. Reservoir Flushing

Reservoir flushing can be one method to improve water quality of a stream down river of a reservoir during low flow periods. Effects of short-term reservoir flushing are found to be quite different depending on the type of constituent being flushed. Although flushing can remove buildup of nitrogen and phosphorus, it tends to dramatically increase BOD of the river which can be from the re-suspension of sediment. (Chung, 2007) The increase of BOD can rapidly increase DO levels. Reservoir flushing is a temporary solution which may not be effective in increasing the quality of the water body to support life. Reservoir flushing can greatly harm the water body due to high solids loading associated with high velocities and erosion of embankments and re-suspension of contaminant laden sediment. Because of the short term positives and the long term negatives of reservoir flushing, this thesis work did not model reservoir flushing as a solution to increase dissolved oxygen levels.

4.5.6. Results

Improved DO levels during winter months are required to support aquatic life and bring the Upper Souris River out of impairment. Scenarios were established with the calibrated QUAL2K model to predict varying levels of DO from Glen Ewen to Lake Darling. A DO level of 5 mg/L was established as a minimum level to support aquatic life along the river reach. In order to improve DO levels during winter months SOD rates for each of the QUAL2K river reach segments requires reduction. A correlation for SOD to sediment organics was utilized to determine the reduction in sediment organic material both upstream of Glen Ewen and in the study reach to maintain DO levels of 5 mg/L or higher.

The first scenario analyzed the study area assuming that the river reach located in Canada was cleaned up and no action was taken for the Upper Souris River located in the United States. An assumption that influent DO levels at Glen Ewen reached 8 mg/L during winter months. Results for this first scenario are illustrated in Figure 39. This scenario shows that if no action is taken to reduce sediment organics in the TMDL river reach, the river would not be able to support aquatic life.

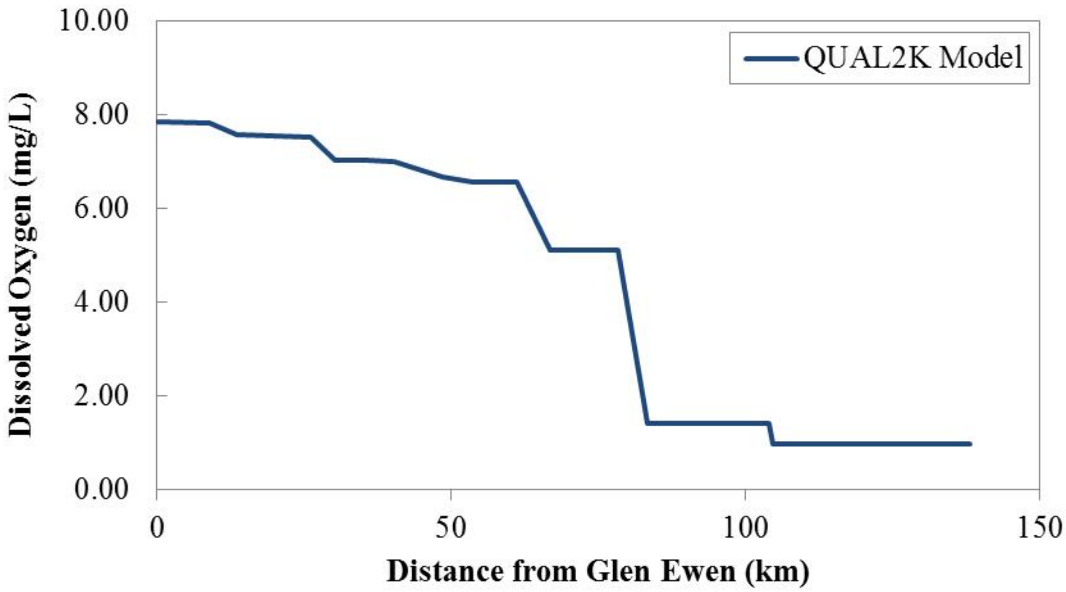

Figure 39. QUAL2K Simulation Results Assuming No United States River Cleanup

Once it was established that the United States river reach required reduction in sediment organics to maintain DO levels of 5 mg/L, three QUAL2K model simulations were performed. All three model simulations required a DO level of 5 mg/L at the furthest downstream site, Lake Darling. The three scenarios then established what percent of sediment organic material reduction is required if influent DO levels at Glen Ewen were 6 mg/L, 7 mg/L, or 8 mg/L. Results from these three model scenarios are shown in Figure 40.

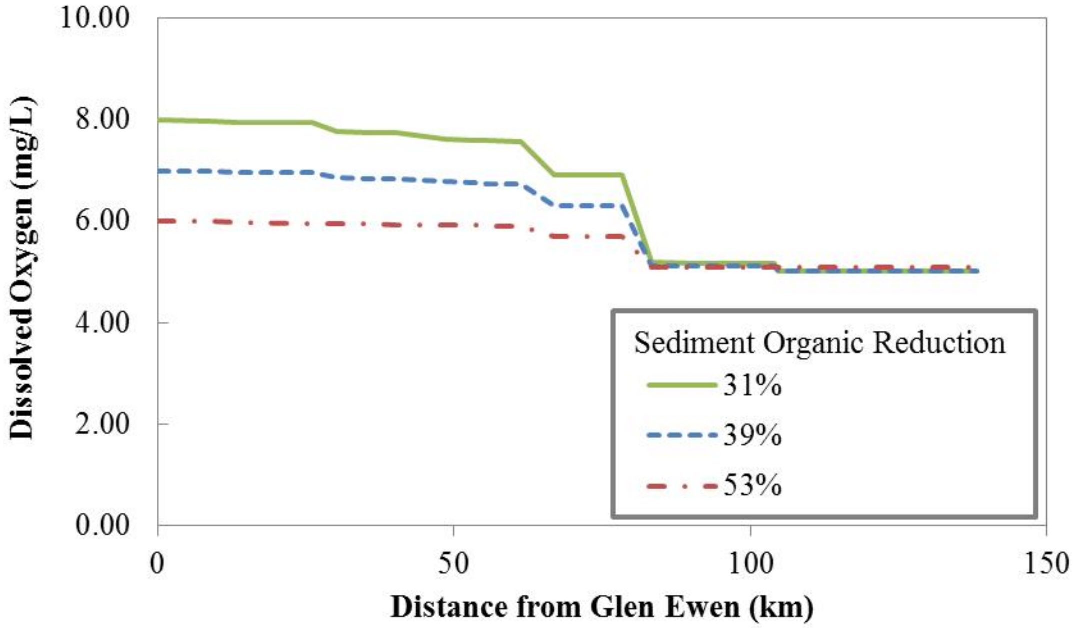

Figure 40. QUAL2K Simulation Results for Three United States Sediment Organic Reduction Scenarios

QUAL2K simulation results in Figure 40 provide three sediment organic reduction scenarios based on varying upstream influent DO concentrations. Results show that a 31% sediment organic material reduction is required if influent DO levels at Glen Ewen are 8 mg/L. If influent DO levels were as low as 6 mg/L at Glen Ewen, sediment organic reduction of 53% would be required to maintain DO levels of 5 mg/L at Lake Darling.

4.5.7. Summary

The following is a brief summary of the Upper Souris River QUAL2K model calibration and river cleanup scenarios:

1. SOD is currently reducing DO in the Upper Souris River to the point of not supporting aquatic life during winter months.

2. Reducing river sediment and organic loading in Canada provides a higher DO concentrated water at the United States and Canada border but cannot support life during winter months in the United States without some degree of sediment organic concentration reduction.
3. Reducing sediment organic material concentration between 31% and 53% is required to maintain DO levels greater than 5 mg/L throughout winter months in the Upper Souris River.
4. All QUAL2K model scenarios to maintain DO levels of 5 mg/L or greater require Canada to clean up the Souris River and maintain DO levels of 6 mg/L or higher at the United States and Canada border.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusion

Low DO levels were found to be the primary cause for impairment along the Upper Souris River. It was found that reduced DO levels are caused primarily from decay of algae and SOD during summer months and SOD during winter months. Both SOD and algae effects on DO levels are caused by increase in organics and nutrients to the river reach. Through site visits and observations along the river, it was determined that nonpoint sources, specifically cattle operations, along the river are the primary cause for high organic matter and nutrients. No point sources were identified along the study river reach. Nonpoint sources and implementation of best management practices will require addressing to bring the Souris River off the impaired waters list.

Sediment sampling showed many beneficial observations of the sediment in the Souris River. SOD demand tests provided DO depletion rates at varying temperatures, river velocities, and at multiple sample sites along the Souris River. An ex-situ sediment oxygen demand method was found to predict sediment oxygen demand rates. As predicted from winter DO testing, temperature influence on SOD rates was not as great as stated in literature. Testing also found a number of possible limitations in previous SOD rate tests in published research. Sediment analysis for percent organic and percent coarse material show how sediment varies along a river cross section and the river reach. Higher organics are found near the top layers of sediment and along the river’s edge likely caused by cattle operations, organics deposited from runoff, or river deposits along the river banks where river velocity is lower. Deeper river cross sections where river velocities are lower were found to have higher organic material than shallow river depth sites. The organic material settles out at these lower velocity areas to the sediment surface. Sediment oxygen demand reactor testing results showed higher organic sediment produced higher SOD rates.

The QUAL2K model was used for analysis of the river water quality and proved useful in determining the reduction in percent organics required to support aquatic life. The QUAL2K model also was a useful tool in analyzing steps to take in order to bring the Souris River out of impairment as part of the TMDL. River cross sections were surveyed along the river reach and analysis provided mathematically sound cross sections for input into the QUAL2K model. SOD rates, surveyed data, and sampled water quality were entered into the model. A correlation between SOD rates and sediment percent organics was established for the model. The model was calibrated and reductions in SOD rates established by reducing sediment organics by varying percentages. The QUAL2K model illustrated that reducing sediment organic material by 31% to 53% will provide DO levels to support aquatic life. These model results for the TMDL are dependent on influent DO at Glen Ewen is in the range of 6 mg/L to 8 mg/L. The United States and Canada will need to work together to bring the river out of impairment as both nations impact the Souris River's water quality. The TMDL and this thesis has provided a method to bring the Upper Souris River out of impairment for DO.

5.2. Recommendations for Future Studies

Understanding sediment of a water body is an important parameter for modeling a river reach. Dissolved oxygen levels and overall water quality are greatly affected by sediment and further research should be continued on SOD testing techniques and methods.

SOD testing takes considerable time for personnel to gather and evaluate each sample. In-situ versus ex-situ SOD testing should be performed and evaluated to maximize testing effectiveness and minimize sources of error as a side-by-side comparison. Both SOD testing techniques have their place, however, standardizing both techniques and creating a comparison between the two tests would allow organizations the opportunity to use either based on their available resources. Further testing for temperature and velocity effects on sediment oxygen demand can provide more accurate equations for modelers to use when modeling a river reach.

A key component to minimize time for running SOD tests is to create a more refined equation to compare SOD with percent organic content of the sediment. It is likely that each water body will have different SOD results for the same percent organics in sediment. However, it is likely that a similar relationship can be found along a stream where only one SOD test is required and the remainder of SOD testing results can be found by measuring the percent organics of sediment samples along the stream. SOD and percent organics for multiple streams in multiple regions require sampling to provide this equation and a means to understanding SOD in different soils and climate regions.

The QUAL2K model is a good tool for river water quality evaluation and stream modeling for point sources. A non-steady state model may be used to simulate scenarios for water quality improvement.

Nonpoint sources have been established as the leading cause for impaired United States waters by the EPA. However, restrictions on nonpoint sources are rarely enforced. Current point source reduction through discharge permit restrictions cannot solve the current water quality issue across the nation. A realistic approach needs to be enforced in order to prevent further contamination of the nation's water bodies. Current best management practices are a great start to furthering the nation's water body health and standardization towards a sustainable system.

REFERENCES

1. Bond, Trevor, et.al., "Estimating the contribution of in-stream cattle feces deposits to nutrient loading in an English Chalk stream." Agricultural Water Management 131 (2014): 156-162. Elsevier.
2. Caldwell, James M., and Micelis C. Doyle. Sediment oxygen demand in the lower Willamette River, Oregon, 1994. Portland, Or.: U.S. Dept. of the Interior, U.S. Geological Survey, 1995.
3. Chapra, Steven C. Surface water-quality modeling. New York: McGraw-Hill, 1997.
4. Chapra, Steven C. "QUAL2K Modeling Educational Seminar". EPA Division 7. July, 2007.
5. Chapra, Steven, Pelletier, G.J. and Tao, H. 2007. "QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality". Version 2.09: Documentation and Users Manual. Civil and Environmental Engineering Dept., Tufts University, Medford, MA., Steven.Chapra@tufts.edu. June 28, 2007.
6. Chau, K.W. "Field measurements of SOD and sediment nutrient fluxes in a land-locked embayment in Hong Kong." Advances in Environmental Research 6 (2002): 135-142. Elsevier.
7. Chaudhury, Rajat R, etc. "Dissolved Oxygen Modeling of the Blackstone River (Northeastern United States)." Water Resources Vol. 32, No. 8 (1998): 2400-2412. Elsevier.
8. Chung, Se. W., etc. "Effect of reservoir flushing on downstream river water quality." Journal of Environmental Management (2007): Elsevier.

9. Coutant, Charles. "Temperature-Oxygen Habitat for Freshwater and Coastal Striped Bass in a Changing Climate." Transactions of the American Fisheries Society 119 (1990): 240-53.

10. Crompton J. Barbra, etc. American Society of Agricultural Engineers. “Sediment Oxygen Demand of Coastal Plain Blackwater Streams”. Paper Number: 052101. July 2005.

11. Diplas, P. "Modeling of fine and coarse sediment interaction over alternate bars." Journal of Hydrology 159 (1994): 335-51. Elsevier. North Dakota State University.

12. Di, Toro Dominic M. Sediment flux modeling. New York: Wiley-Interscience, 2001.

13. “Dissolved Oxygen TMDL Protocols and Submittal Requirements.” Minnesota Pollution Control Agency. Minnesota Pollution Control Board, Minneapolis: 2008.

14. Duchscherer, Heather. “Dissolved Oxygen TMDL for the Souris River in Renville and Burke Counties, North Dakota.” North Dakota Department of Health Division of Water Quality. September, 2010.

15. Enz, John W. 2003. North Dakota Topographic, Climate, and Agricultural Overview. North Dakota State University. Available at http://www.soilsci.ndus.nodak.edu?Enz/enz/reports/ndclimate.htm

16. Fang, X. "Simulated climate change effects on dissolved oxygen characteristics in ice-covered lakes." Ecological Modeling 103 (1997): 209-29. Elsevier.

17. Hanson, Brent and Lin, Wei, “The use of channel characteristics for the calibration of index velocity ratings for acoustic doppler velocity meters.” North Dakota State University, Nov. 2008.

18. Hantush, Mohamed M. “Modeling nitrogen-carbon cycling and oxygen consumption in bottom sediments.” Advances in Water Resources April 2006 30, 59-79. Elsevier.

19. Higashino, Makoto, Stefan, Heinz. G. “Sedimentary microbial oxygen demand for laminar flow over a sediment bed of finite length.” Water Research Vol 39. (2005): 3153-3166. Elsevier.

20. Kellow, R. and Fewless, D. 2004. Souris River Bilateral Water Quality Monitory Group (SRBWQMG, 2004) in its report for year 2002. North Dakota Department of Health, Department of State. Regina, SK: Environment Canada.

21. Kim, Nag-Jong, and Choul-Gyun Lee. "A theoretical consideration on oxygen production rate in micro algal cultures." Biotechnology and Bioprocess Engineering 6 (2001): 352-58.

22. Lee, Joseph H. W., Kuang, C.P., Yung, K.S. “Analysis of three-dimensional flow in a cylindrical sediment oxygen demand chamber.” Applied Mathematical Modeling 24 (2000): 263-78. Elsevier.

23. Matlock, Marty D., Kasprzak, Kevin R., and Osborn, G. Scott. “Sediment Oxygen Demand in the Arroyo Colorado River.” Journal of the American Water Resources Association. April 2003.

24. Minnesota Pollution Control Agency. “Dissolved Oxygen TMDL Protocols and Submittal Requirements”. December 2008.

25. “National and Local Weather Forecast, Hurricane, Radar and Report.” The Weather Channel. Minot, ND. 13 June 2007 to 21 June 2007 www.weather.com.

26. NDASS. 2006. North Dakota Landcover Classification 2005. North Dakota Agricultural Statistics Service & North Dakota State University Extension Service, Fargo, North Dakota. CDROM.

27. "Nitrogen (N) and Water". Lenntech Water Treatment Solutions. 20 Jul. 2012. http://www.lenntech.com/periodic/water/nitrogen/nitrogen-and-water.htm.

28. North Dakota Century Code: 2001. Standards of Quality for Waters of the State. Chpt. 33-16-02.1, pg. 12. http://www.legis.nd.gov/information/acdata/pdf/33-16-02.1.pdf.

29. Price, Cynthia B., John C. Cerco, and Douglas Gunnison. Sediment oxygen demand and its effects on dissolved oxygen concentrations and nutrient release: Initial laboratory studies. Vicksburg, MS: U.S. Army Engineer Waterways Experiment Station, 1994.

30. Quality Criteria for Water. Washington: United States, Environmental Protection Agency, Office of Water Regulations and Standards. 1986.

31. "Sampling for Contaminants in Sediment and Sediment Pore Water." 15 Aug. 2012 http://clu-in.org/programs/21m2/sediment/. 26 Mar. 2004. United States Environmental Protection Agency.

32. "Sediment." Merriam-Webster. 15 Aug. 2012 http://www.merriam-webster.com/dictionary/sediment.

33. State of Ohio Environmental Protection Agency. Sediment Sampling Guide and Methodologies. 2nd Edition. November, 2001.

34. Thomann, Robert V., and John A. Mueller. Principles of surface water quality modeling and control. New York: Harper & Row, 1987.

35. United States Environmental Protection Agency. Standard Operating Procedures: Sediment Sampling. No.2016. November 1994.

36. United States Environmental Protection Agency. Water quality conditions in the United States: A profile from the 1994 national water quality inventory report to congress. Publication EPA 841-F-95-010. Office of Water, Washington, DC. 1995.

37. United States Environmental Protection Agency. "Water quality standards criteria summaries: a compilation of State/Federal criteria." Dissolved Oxygen. 1988.

38. United States Environmental Protection Agency. "Waterbody History Report for ND-09010001-001-S_00." http://ofmpub.epa.gov/tmdl_waters10/attains_wb_history.control?p_listed_water_id=ND-09010001-001-S_00&p_cycle. 2007.

39. Whipple, G.C. and Whipple, M.C. from measurements of Fox, C.J.J. Solubility of Oxygen in Sea Water. "Journal of the American Chemical Society", Vol.33, P. 362, 1911.

40. Whittemore, Raymond, C., et. al. "Handbook on Sediment Quality". Water Environment Federation. Pg. 171, 219-226. 2002.

41. Wood, Tamara M. Sediment oxygen demand in Upper Klamath and Agency lakes, Oregon, 1999. Portland, Or.: U.S. Dept. of the Interior, U.S. Geological Survey, 2001.

42. Yun, He and Cheng, Liu. "Optimizing the design of in situ sediment oxygen demand measurement chambers." International Journal of Sediment Research Vo. 26, Issue 2, June 2011. Elsevier.

APPENDIX A. SITE INFORMATION

Table A1. Site Coordinates and Water Elevation

Site	Latitude (Degrees)	Longitude (Degrees)	Elevation (meter)
Rafferty Dam	49.1469556	-103.0939056	164.3
Hwy 47	49.1168528	-102.9902667	163.1
Questionable	49.0760667	-102.8787167	160.9
Hwy 39	49.0756806	-102.7652778	160.3
Dirt Road	49.1012667	-102.5276500	158.2
Hwy 9	49.0743944	-102.2973833	156.5
Intersection	49.2148556	-102.2046389	156.1
Glen Ewen	49.1802000	-102.0275000	152.7
2	49.1510330	-102.0117170	152.1
3	49.1378500	-101.9952670	151.8
4	49.0819670	-101.9988500	151.3
Bridge Crossing (also 5)	49.0575830	-101.9917000	150.9
6	49.0452000	-101.9736670	150.6
Road Crossing (also 7)	49.0261000	-101.9755330	150.3
USGS	48.9921830	-101.9630330	149.7
9	48.9753830	-101.9541170	149.4
County Road 2	48.9663000	-101.9475000	149.1
10	48.9333830	-101.9314330	148.4
Stafford Bridge	48.9227000	-101.9264000	148.4
11	48.8934830	-101.8947830	148.1
Johnson Bridge	48.8792000	-101.8679000	147.9
12	48.8475170	-101.8627170	147.8
13	48.8078830	-101.8313500	147.5
North of Mouse River Park	48.7636670	-101.7759170	147.4
Lake Entrance	48.0000000	-101.0000000	146.8
Pool	49.0962083	-103.0206722	165.2
Alameda Dam	49.2591944	-102.2306639	164.6

Table A2. River Distance Between Sites

Site From	Site To	Distance (km)	Total Distance (km)	Location (km)	Distance (miles)	Total Distance from Lake Darling (miles)
Rafferty Dam	Hwy 47	12.2	12.2	343.4	7.6	213.4
Hwy 47	Questionable	24.1	36.3	319.3	15.0	198.4
Questionable	Hwy 35	22.3	58.6	297.1	13.8	184.6
Hwy 35	Dirt Road	44.5	103.1	252.6	27.7	156.9
Dirt Road	Hwy 9	39.0	142.1	213.5	24.3	132.7
Hwy 9	Intersection	33.3	175.4	180.2	20.7	112.0
Intersection	GE	41.9	217.3	138.3	26.1	85.9
GE	2	9.0	226.4	129.2	5.6	80.3
2	3	4.5	230.9	124.7	2.8	77.5
3	4	12.5	243.4	112.2	7.8	69.7
4	5	4.1	247.6	108.1	2.6	67.1
5	6	5.8	253.3	102.3	3.6	63.5
6	7	4.2	257.6	98.0	2.6	60.9
7	8	8.3	265.8	89.8	5.1	55.8
8	9	5.2	271.0	84.6	3.2	52.6
9	CR2	2.1	273.1	82.6	1.3	51.3
CR2	10	5.5	278.6	77.0	3.4	47.9
10	SB	5.6	284.1	71.5	3.5	44.4
SB	11	11.5	295.7	60.0	7.2	37.3
11	JB	5.1	300.7	54.9	3.2	34.1
JB	12	7.7	308.5	47.2	4.8	29.3
12	13	12.9	321.4	34.2	8.0	21.3
13	CR3	0.7	322.0	33.6	0.4	20.9
CR3	Lake Darling	33.6	355.6	0.0	20.9	0.0
Alamade Dam	Intersection	7.8	-	-	4.9	-
Pool	Hwy 47	5.4	-	-	3.4	-

Table A3. Site Visit Cattle Log During River Assessment

Picture #	Site Description	Visual	Latitude (Degrees)	Longitude (Degrees)
2418	Access	none	49.17393333	-102.02728333
2421	Crossing	cattle	49.16981667	-102.01835000
2423	Area	cattle	49.16743333	-102.01250000
2424	Area	none	49.16301667	-102.01145000
2427	Crossing	cattle	49.16066667	-102.01205000
2430	Access	cattle	49.15528333	-102.00870000
2432	Access	none	49.13798333	-101.99535000
2423	Crossing	cattle	49.12683333	-101.98668333
2445	Access	cattle	49.11751667	-101.98668333
2449	Access	cattle	49.11445000	-101.98848333
2453	Crossing	cattle	49.10516667	-101.99818333
2455	Crossing	cattle	49.10091667	-101.98641667
2457	Crossing	cattle	49.09646667	-101.98585000
2462	Crossing	cattle	49.08436667	-101.99035000
2466	Crossing	cattle	49.07808333	-101.99920000
2467	Crossing	cattle	49.07723333	-102.00036667
2468	Access	none	49.07638333	-102.00020000
2470	Access	cattle	49.07583333	-101.99990000
2472	Access	cattle	49.07320000	-101.99870000
2475	Access	cattle	49.07120000	-102.00090000
2479	Crossing	cattle	49.06938333	-101.99833333
2480	Access	cattle	49.06736667	-101.99673333
2482	Crossing	cattle	49.06206667	-101.99476667
2485	Access	cattle	49.06206667	-101.99476667
2491	Access	none	49.05505000	-101.99171667
2493	Access	none	49.05458333	-101.99225000
2501	Area	none	49.04328333	-101.98060000
2504	Access	none	49.04475000	-101.97436667
2505	Area	none	49.04365000	-101.97338333
2508	Crossing	cattle	49.04196667	-101.97476667
2510	Access	none	49.04018333	-101.97450000
2511	Crossing	cattle	49.03948333	-101.97316667
2513	Crossing	cattle	49.03871667	-101.97415000
2515	Crossing	cattle	49.03826667	-101.97561667
2517	Crossing	cattle	49.03785000	-101.97656667
2519	Crossing	none	49.03630000	-101.97636667

Table A3. Site Visit Cattle Log During River Assessment (Continued)

Picture #	Site Description	Visual	Latitude (Degrees)	Longitude (Degrees)
2521	Access	none	49.03561667	-101.97415000
2523	Area	cattle	49.03663333	-101.97340000
2526	Access	none	49.03466667	-101.97051667
2527	Crossing	cattle	49.03458333	-101.97045000
2531	Area	cattle	49.03181667	-101.96971667
2533	Access	cattle	49.03235000	-101.97183333
2535	Crossing	none	49.03303333	-101.97331667
2536	Crossing	cattle	49.03216667	-101.97418333
2538	Crossing	cattle	49.03113333	-101.97420000
2539	Area	cattle	49.03028333	-101.97375000
2541	Area	cattle	49.02935000	-101.97383333
2543	Crossing	cattle	49.02740000	-101.97551667
2546	Crossing	cattle	49.02728333	-101.97621667
2548	Crossing	cattle	48.99365000	-101.95973333
2554	Crossing	none	48.98501667	-101.95250000
2561	Crossing	cattle	48.96630000	-101.94750000
2572	Crossing	cattle	48.94436667	-101.93100000
2579	Area	cattle	48.93386667	-101.92918333
2589	Access	cattle	48.92576667	-101.92780000
2590	Access	cattle	48.92805000	-101.92586667
2603	Access	none	48.90896667	-101.90340000
2607	Area	none	48.90356667	-101.90691667
2612	Crossing	cattle	48.90458333	-101.89800000
2616	Access	none	48.90070000	-101.89380000
2630	Access	none	48.87171667	-101.98486667
2632	Crossing	cattle	48.86870000	-101.86681667
2637	Crossing	none	48.85953333	-101.85853333
2644	Area	cattle	48.82660000	-101.83631667

Table A4. Site Visit Log Jam Log from River Assessment

Picture #	Latitude (Degrees)	Longitude (Degrees)	Intensity
2506	49.04243300	-101.97375000	Small
2524	49.03605000	-101.97156700	Small
2544	49.02728300	-101.97621700	Large
2552	48.99365000	-101.95973300	Medium
2555	48.98030000	-101.95013300	Small
2571	48.94441700	-101.93100000	Medium
2579	48.93386700	-101.92918300	Large
2584	48.93016700	-101.92591700	Medium
2605	48.90808300	-101.90236700	Small
2619	48.89586700	-101.88913300	Medium

APPENDIX B. SURVEYED RIVER CROSS SECTIONS

Table B1. Surveyed Profiles of Sampling Sites

Site Number: 382020 - County Road 3
Site Location Latitude: N 48º48' 510"
Longitude: W 101º49' 514"

Point	Distance from East Bank	Profile of River Bottom
	(ft)	(ft)
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/mS/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

Table B1. Surveyed Profiles of Sampling Sites (Continued)

Site Number: 385402 - Johnson Bridge
Site Location: Latitude: N 48º52' 752"
Longitude: W 101º52' 071"

Point	Distance from East Bank	Profile of River	
	(ft)	(ft)	
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/mS/cm	2274
DO%:	86.5
DO / mg/L:	9.11
Depth/m:	1.265
pH:	8.58
Time:	6:00pm

Table B1. Surveyed Profiles of Sampling Sites (Continued)

Site Number: 485403 - Stafford Bridge
Site Location: Latitude: N 48º55' 362"
Longitude: W 101º55' 582"

Point	Distance	Profile of	
	(ft)	(ft)	
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/mS/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

Table B1. Surveyed Profiles of Sampling Sites (Continued)

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

Point	Distance from	Profile of	
	(ft)	(ft)	
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	

Souris River Water Data

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

Table B2. Surveyed Profiles of Sites

Cross Section 1

Site: GE Date: 5/26/2007

Latitude: 49.1802 Longitude: -102.0275

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Hor. Dist. Adj.
Bridge	5.46.15	16.05	158.432	159.239	0
TB	1.04.15	3.09	165.294	165.323	6.862
CV	358.25.15	-3.794	137.615	137.667	20.817
CC	355.44.15	-9.6	128.807	129.164	29.625
WE	355.02.05	-10.641	122.48	122.941	35.952
WB1	354.08.55	-11.891	116.033	116.641	42.399
WB2	353.21.45	-11.966	102.831	103.525	55.601
WB3	353.23.15	-11.197	83.725	84.52	74.707
WE	352.17.05	-10.601	78.246	78.961	80.186
TS	344.36.50	-7.437	27.026	28.031	131.406
CV	348.01.35	-3.18	14.992	15.326	143.44
Total Station Location		0	0		158.432

Cross Section 2

Site: 6 Date: 5/27/2007

Latitude: 49°09.062' Longitude: 102°00.703'

Insturment Height: 5.35 fee Pole Height: 4.7 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.	Hor. Dist. Adj.
TB	357.32.1	-4.425	102.785	102.88	-3.775	0
MP	354.02.50	-9.334	89.518	90.003	-8.684	13.267
CC	347.53.55	-16.173	75.431	77.146	-15.523	27.354
WE	345.16.10	-17.837	67.841	70.147	-17.187	34.944
WB	342.25.05	-18.724	59.091	61.987	-18.074	43.694
WB2	339.15.51	-18.955	50.042	53.512	-18.305	52.743
WB3	334.31.10	-19.471	40.858	45.26	-18.821	61.927
WB4	328.58.45	-19.841	32.991	38.498	-19.191	69.794
WE	321.22.25	-17.851	22.34	29.596	-17.201	80.445
MP	325.01.45	-8.3	11.865	14.48	-7.65	90.92
Total Station Location			0		0	102.785

Table B2. Surveyed Profiles of Sites (Continued)

Cross Section 3

Site: 10 Date: 5/27/2007

Latitude: 49°08.271' Longitude: 101°59.716'

Insturment Height: 4.25 fee Pole Height: 4.75 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	358.19.30	-3.84	131.32	131.376	-4.34
CV	355.01.15	-10.821	124.233	124.703	-11.321
MP	353.15.50	-13.883	117.537	118.354	-14.383
WE	351.52.05	-16.591	116.112	117.291	-17.091
WB1	350.31.45	-18.354	110.026	111.546	-18.854
WB2	346.58.50	-19.082	82.435	84.615	-19.582
WB3	343.18.10	-18.93	63.108	65.886	-19.43
WE	339.23.10	-16.655	44.277	47.306	-17.155
CV	344.16.55	-8.242	29.285	30.423	-8.742
CC	339.13.45	-4.942	13.032	13.938	-5.442
Total Station Location			0		0

Cross Section 4

Site: 16 Date: 5/27/2007

Latitude: 49°04.918' Longitude: 101°59.931'

Insturment Height: 4.35 fee Pole Height: 4.7 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	358.55.50	-2.293	122.807	122.828	-2.643
CV	356.14.00	-6.912	104.992	105.219	-7.262
MP	351.36.15	-13.938	94.435	95.458	-14.288
WE	347.12.25	-19.555	88.123	88.315	-19.905
WB1	343.15.15	-21.906	72.806	76.031	-22.256
WB2	338.05.00	-22.659	56.318	30.705	-23.009
WB3	333.13.15	-21.955	43.503	48.73	-22.305
WE	330.10.10	-19.547	34.089	39.296	-19.897
MP	333.01.10	-8.893	17.468	19.602	-9.243
Total Station			0		0

Table B2. Surveyed Profiles of Sites (Continued)

Cross Section 5

Site: BRIDGE CROSSING Date: 5/27/2007

Latitude: 49°03.455' Longitude: 101°59.502'

Insturment Height: 4.9 feet Pole Height: 4.75 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	359.31.45	-1.167	142.057	142.062	-1.017
MP	355.59.15	-9.439	131.808	132.145	-9.289
WE	351.27.30	-17.779	118.352	119.68	-17.629
WB1	348.56.10	-19.972	102.14	104.074	-19.822
WB2	346.13.35	-19.883	81.109	83.511	-19.733
WB3	342.11.15	-19.398	60.372	63.411	-19.248
WE	332.41.10	-17.51	33.905	38.159	-17.36
CC	325.50.10	-11.916	17.558	21.22	-11.766
Total Station Location			0		0

Cross Section 6

Site: Farms Area Date: 5/27/2007

Latitude: 49°02.712' Longitude: 101°58.420'

Insturment Height: 5.4 feet Pole Height: 4.75 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.	Hor. Dist. Adj.
TB	357.19.00	-7.306	156.202	156.373	-6.656	0
CC	352.25.20	-10.606	124.87	125.969	-9.956	31.332
CV	352.49.30	-13.991	111.167	112.084	-13.341	45.035
WE	346.41.55	-20.511	86.729	89.122	-19.861	69.473
WB1	343.07.50	-21.905	72.236	75.484	-21.255	83.966
WB2	338.20.00	-22.494	56.622	60.926	-21.844	99.58
WE	338.21.55	-17.328	43.692	47.003	-19.928	112.51
CV1	337.00.25	-14.234	33.535	36.431	-13.584	122.667
CV2	340.57.40	-8.449	24.486	25.903	-7.799	131.716
Total Station Location			0		0	156.202

Table B2. Surveyed Profiles of Sites (Continued)

Cross Section 7

Site: LOG XING Date: 5/27/2007

Latitude: 49°01.566' Longitude: 101°58.532'

Insturment Height: 5.4 feet Pole Height: 6.15 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	00.00.15	0.008	101.922	101.923	-0.742
CC	357.46.10	-3.573	91.745	91.814	-4.323
CV	353.07.50	-9.744	80.881	81.466	-10.494
WE	349.03.30	-13.918	71.992	73.325	-14.668
WB1	342.35.35	-17.47	55.719	58.394	-18.22
WB2	336.46.15	-18.389	47.337	50.783	-19.139
WB3	334.37.00	-17.805	37.526	41.535	-18.555
WE	329.36.10	-14.222	24.244	28.108	-14.972
MP	332.35.40	-9.535	18.391	20.716	-10.285
Total Station Location			0		0

Cross Section 8

Site: NUSGS Date: 5/27/2007

Latitude: 48°59.531' Longitude: 101°57.782'

Insturment Height: 4.2 feet Pole Height: 5.75 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	359.30.15	-0.959	110.779	110.783	-2.509
MP	335.06.30	-7.59	88.681	89.005	-9.14
WE	348.20.35	-14.249	69.066	70.52	-15.799
WB	343.06.30	-14.889	49.031	51.241	-16.439
WE	332.57.25	-14.367	28.145	31.6	-15.917
MP	331.07.00	-7.969	14.447	16.499	-9.519
Total Station Location			0		0

Table B2. Surveyed Profiles of Sites (Continued)

Cross Section 9

Site: N of CR2 Date: 5/27/2007

Latitude: 48°58.523' Longitude: 101°57.247'

Insturment Height: 4.35 fee Pole Height: 4.75 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
OS	358.43.45	-2.826	127.396	127.428	-3.226
MP	355.34.00	-8.626	111.255	111.589	-9.026
WE	349.11.40	-17.212	90.179	91.807	-17.612
WB1	346.31.00	-18.516	77.224	79.413	-18.916
WB2	343.23.55	-18.91	63.429	66.188	-19.31
WE	336.05.20	-17.134	38.646	42.274	-17.534
MP	333.01.55	-11.536	22.673	25.439	-11.936
CC	325.48.50	-7.849	11.557	13.97	-8.249
Total Station Location			0		0

Cross Section 10

Site: NEW DAY Date: 5/28/2007

Latitude: 48°56.003' Longitude: 101°55.886'

Insturment Height: 3.95 fee Pole Height: 4.7 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	01.37.20	2.873	100.429	100.47	2.123
MP	357.58.50	-2.946	83.673	87.725	-3.696
WE	351.52.36	-10.171	71.108	71.832	-10.921
WB	NA	3.5 FEET DOWN NO READING	43.534	NA	-14.5
WE	328.15.20	-10.34	15.96	19.016	-11.09
Total Station Location			0		0

Table B2. Surveyed Profiles of Sites (Continued)

Cross Section 11

Site: BM14 Date: 5/28/2007

Latitude: 48°53.609' Longitude: 101°53.687'

Insturment Height: 5.5 feet Pole Height: 4.7 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
MP1	357.59.30	-5.635	160.712	166.811	-4.835
MP2	355.55.55	-10.33	145.251	145.618	-9.53
WE	352.13.50	-17.568	128.757	129.95	-16.768
WB1	349.14.55	-21.623	113.878	115.913	-20.823
WB2	NA	Depth 5.5 feet at center of river	87.4715	NA	-22.456
WE	336.09.45	-17.756	46.186	43.934	-16.956
MP	338.23.05	-9.759	24.63	26.493	-8.959
Total Station Location			0		0

Cross Section 12

Site: BM16 Date: 5/28/2007

Latitude: 48°50.851' Longitude: 101°51.763'

Insturment Height: 4.2 feet Pole Height: 4.75 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	356.31.30	-6.079	100.101	100.285	-6.629
WE	354.15.20	-9.551	94.941	95.42	-10.101
WB1	NA	5 ft. below water level	78.721	NA	-15.026
WB2	NA	9 ft. below water level	62.501	NA	-19.026
WB3	NA	11 ft. below water level	46.281	NA	-21.026
WB4	NA	9 ft. below water level	30.061	NA	-19.026
WE	328.43.28	-9.401	13.831	16.182	-9.951
Total Station Location			0		0

Table B2. Surveyed Profiles of Sites (Continued)

Cross Section 13

Site: LAST Date: 5/28/2007

Latitude: 48°48.473' Longitude: 101°49.881'

Insturment Height: 4.1 feet Pole Height: 4.7 feet

Shot ID	Vertical Angle	Vertical Distance	Horizontal Distance	Slope Distance	Vert. Dist. Adj.
TB	358.53.55	-3.36	173.872	173.905	-3.96
MP	357.11.25	-6.866	139.904	140.072	-7.466
WE	355.31.10	-10.367	132.296	132.702	-10.967
WB	NA	12.5 ft. below water level	75.6785	NA	-23.418
WE	331.41.10	-10.269	19.061	21.652	-10.869
MP	338.11.40	-3.861	9.651	10.395	-4.461
Total Station Location			0		0

APPENDIX C. SAMPLING DATA

Table C1. On Site Sampling Data

CR3	**Flow Measurement**				**Field Monitoring Data**					
Sample Date	Sample Time	Stage	Flow Velocity	Water Depth	Ice	Sample Depth	Temp.	pH	DO	Cond.
m/d/y	hour	ft.	fps	ft.	ft.	ft.	^{o}C		mg/L	mS/cm
9/23/06	10:15						13.00	8.65	8.75	1835
11/5/06	9:30	14.6		10	0.5		3.70	8.61		
11/19/06	8:45	14.7		10	0.5		3.90	8.60	14.70	1336
12/3/06	9:00	14.5		5.6	0.6		4.33	8.21	7.63	1662
12/16/06	8:15	14.1	0.188	12.7	0.9		4.78	8.21	2.41	1553
1/7/07	8:15	14.8		12.3	1	4.00	4.30	8.00	0.80	1448
1/7/07						10.00	5.45	8.20	0.23	1843
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	4.38	8.14	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	5.7	8.09	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	Titrate

Table C1. On Site Sampling Data (Continued)

CR3	Flow Measurement				Field Monitoring Data					
Sample Date	Sample Time	Stage	Flow Velocity	Water Depth	Ice	Sample Depth	Temp.	pH	DO	Cond.
m/d/y	hour	ft.	fps	ft.	ft.	ft.	^{o}C		mg/L	mS/cm
1/28/07				11.9		7			0.3	Titrate
1/28/07				11		4			0.3	Titrate
2/11/07				11.6	1.3	7.5	5.54	8.1	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	5.33	8.2	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	5.05	7.96	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	0.9	7.85	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	2.18	8.11	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	4.19	8.64	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	11.37	8.63	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	14.01	8.63	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	17.3	8.33	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	16.65	8.36	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	16.19	8.44	8.35	1168

Table C1. On Site Sampling Data (Continued)

CR3	Flow Measurement				Field Monitoring Data					
Sample Date	Sample Time	Stage	Flow Velocity	Water Depth	Ice	Sample Depth	Temp.	pH	DO	Cond.
m/d/y	hour	ft.	fps	ft.	ft.	ft.	^{o}C		mg/L	mS/cm
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	11.33	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	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	10.23	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	8.96	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	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	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	3.47	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	6.76	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	6.43	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	8.77	1089
10/21/07	8:15	16.4		10.3	6.18		8.48	8.6	8.71	1082
9/23/06	18:00						12.60	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	1126
12/3/06	11:30	16.5		2.85	0.8		2.55	8.08	9.11	1229
12/15/06	9:30	17.2	0	4.3	0.7		1.92	7.82	5.99	1291
1/14/07	10:15			4.2	1.25	2.4	1.37	7.45	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	0.35	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

Table C1. On Site Sampling Data (Continued)

JB	Flow Measurement				Field Monitoring Data					
Sample Date	Sample Time	Stage	Flow Velocity	Water Depth	Ice	Sample Depth	Temp.	pH	DO	Cond.
m/d/y	hour	ft.	fps	ft.	ft.	ft.	^{o}C		mg/L	mS/cm
1/28/07				3.9	1.45	2.90			0.30	
1/28/07				3.9	1.45	3.70			0.30	
2/11/07	9:00	16.6		4.1	1.6	3.10	0.36	7.49	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	0.35	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	0.40	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	866
4/9/07	9:50	14.9		5.6		3.36	1.18	8.25	13.36	1046
4/14/07	8:10	14.6		6.1		3.66	5.15	8.71	14.54	1057
4/22/07	9:00	16.4		8		4.8	11.13	8.64	8.79	1079
4/28/07	8:35	15		5.6		3.36	14.25	8.4	7.84	1188
5/5/07	9:15	16	0.263	6		3.6	16.72	8.34	7.65	1071
5/13/07	7:10	16.7	0.105	5.3		3.18	15.85	8.36	8.29	1044
5/19/07	9:00	16.5		5.6		3	16.38	8.36	8.69	1197
5/28/07	15:20	16.7		5		3	15.1	8.26	10.19	1176
6/3/07	19:45	16.9		5.1		3.06	18.06	8.2	8.22	1096
6/10/07	19:30	16.3	0.146	5.7		3.42	20.52	8.35	8.12	1309
6/12/07	16:15	16.5	0.23	5.5		3.3	20.38	8.06	5.64	1433
6/24/07	8:20	17.4		5.5		3.12	24.36	8.62	7.8	1670
7/15/07	9:44	15.3	0.153	5.4		3.24	24.03	8.38	5.48	1109
7/30/07	8:16	15.3	0.106	5.7		3.42	25.77	8.31	6.24	1121
8/19/07	9:00	15.3	0.116	5.1		3.06	19.36	8.63	6.99	979
9/9/07	10:00	15.9		4.2		2.52	15.48	8.42	5.14	1006
10/21/07	9:00	16		4.5		2.7	7.66	8.59	10.53	1056

Table C1. On Site Sampling Data (Continued)

SB	Flow Measurement				Field Monitoring Data					
Sample Date	Sample Time	Stage	Flow Velocity	Water Depth	Ice	Sample Depth	Temp.	pH	DO	Cond.
m/d/y	hour	ft.	fps	ft.	ft.	ft.	^oC		mg/L	mS/cm
9/23/06	15:15						11.85	8.29	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	1193
12/3/06	12:30	23.3		2.8	0.9		0.31	8.11	10.87	1354
12/16/06	10:15	23	0.163	2.8	0.7		0.40	7.65	3.73	1459
1/14/07	11:46			2.7	0.8	0.6	0.23	7.49	1.89	1810
1/28/07	10:50			2.7	1	2.00	0.22	7.40	0.56	2146
2/11/07	10:00	23		2.8	1.5	2.00	0.30	7.49	0.21	2458
2/25/07	9;50	23		2.7	1.2	2.00	0.14	7.52	0.13	2709
2/25/07				2.7	1.2	2.30	0.13	7.52	0.24	2710
2/25/07				2.65	1	2.00	0.13	7.52	0.32	2710
3/10/07	13:00	23		2.8	1	1.72	0.27	7.41	0.35	2466
3/10/07				2.8	1	1.20	0.76	7.41	0.34	2594
3/10/07				2.5	0.5	1.70	0.83	7.39	0.57	2583
3/10/07				2.5	0.5	2.20	0.51	7.40	0.52	2600
4/1/07	9:30	22.1		3.4		2.00	1.53	8.10	11.66	905
4/9/07	10:30	22	1.27	1.8		1.80	1.27	8.45	14.06	889
4/14/07	9:10	22.4	0.603	3.2		1.92	4.96	8.73	13.66	1066
4/22/07	9:41	22.5	0.707	3		1.8	10.02	8.5	9.71	1070
4/28/07	9:40	22.5	0.707	3		1.8	11.8	8.44	8.5	13.95
5/5/07	10:10	22.5	0.66	3		2	16.45	8.36	7.38	1057
5/13/07	7:51	23	0.568	2.5		1.5	15.28	8.31	8.95	1084
5/19/07	10:00	23.7	0.2	1.3		0.78	15.81	8.11	6.02	1341
5/28/07	8:22	23	0.338	2.6		1.56	15.5	8.19	7.51	1158
6/3/07	19:18	23.3	0.3345	2.6		1.56	22	7.98	6.89	1097
6/10/07	18:30	22.6	0.8	3.1		1.86	21.65	8.37	7.49	1345
6/12/07	17:00	23	0.741	2.5		1.5	22.56	8.23	5.61	1413
6/24/07	8:50	23	0.187	2.2		1.32	25.48	8.63	4.48	1850
7/15/07	11:00	22.7	0.561	2.9		1.74	24.15	8.39	5.13	1129
7/30/07	9:00	22.9	0.383	2.9		1.74	25.32	8.26	4.6	1099
8/19/07	9:55	23	0.145	3.1		1.86	19.23	8.56	7.2	969
9/9/07	10:30	23.4	0.175	2.1		1.26	14.85	8.41	8.33	1058
10/21/07	9:30	23.2	0.101	2.2		1.32	7.43	8.48	12.82	1120

Table C1. On Site Sampling Data (Continued)

CR2	Flow Measurement				Field Monitoring Data					
Sample Date	Sample Time	Stage	Flow Velocity	Water Depth	Ice	Sample Depth	Temp.	pH	DO	Cond.
m/d/y	hour	ft.	fps	ft.	ft.	ft.	^{o}C		mg/L	mS/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	1193
12/3/06	13:30	30.8		1.4	0.6		0.00	8.01	9.57	893
12/16/06	10:50	32	0.125		0.9		0.01	7.62	4.37	1482
1/7/07	11:30	31.8		0.8	open		-0.4	7.54	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	0.4	0.15	7.32	2.99	1936
1/14/07	13:00					0.6	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	1.02	2294
2/11/07								Too shallow to sample		
2/25/07										
3/10/07										
4/1/07	10:00	29		2.9		1.74	1.01	8.10	11.66	928
4/9/07	11:50	27.4	17,1.75,2.(	3.4		2.00	1.13	8.40	13.99	985
4/14/07	11:00	28	0.946	3		1.80	4.44	8.67	12.86	1065
4/22/07	10:42	28.5	0.94	4		2.40	9.64	8.55	9.51	1072
4/28/07	10:20	28.5	0.94	3		1.80	13.17	8.44	8.66	1051
5/5/07	11:00	32	0.741	3		1.80	15.69	8.36	7.29	1055
5/13/07	8:39	26.3	0.237	2.3		1.38	15.04	8.33	8.93	1083
5/19/07	11:00	29.5	0.645	2		1.20	14.34	8.29	7.60	1354
5/28/07	6:23	29.5		1.8		1.00	15.72	8.28	7.60	1164
6/3/07	18:29	31.3	0.255	1.5		0.90	23.51	8.29	8.92	1163
6/10/07	18:00	31	0.8	3		1.80	21.86	8.36	7.95	1371
6/12/07	18:00	28	0.765	3.3		1.98	23.02	8.3	4.82	1436
6/24/07	9:36	28	0.475	1.8		1.08	25	8.64	4.79	1950
7/15/07	12:00	28.9	0.666	2.4		1.44	24.56	8.42	6.79	1116
7/30/07	10:00	29.3	0.546	2.1		1.26	25.87	8.37	4.4	1088
8/19/07	10:30	29.4	0.5	2		1.2	19.17	8.71	7.19	961
9/9/07	11:30	29.7	0.183	1.5		0.9	14.48	8.36	8.62	1045
10/21/07	10:30	29.8	0.183	1.4		0.84	7.52	8.62	12.28	1673

Table C1. On Site Sampling Data (Continued)

GE	Flow Measurement				Field Monitoring Data					
Sample Date	Sample Time	Stage	Flow Velocity	Water Depth	Ice	Sample Depth	Temp.	pH	DO	Cond.
m/d/y	hour	ft.	fps	ft.	ft.	ft.	^oC		mg/L	mS/cm
9/24/06	13:30						12.94	8.57	10.67	1053
11/5/06	13:30	26.8		-	0.17		2.00	8.56		
11/19/06	13:00	26.8		surf.	0.25		1.11	8.35	18.12	1833
12/3/06	15:47	26.5		2.6	0.8		0.02	7.75	3.71	1667
12/16/06	13:30	28	0.383	surf.	0.8		0.00	7.59	0.59	1990
1/7/07	13:30	29.7		4.8	1.3		-0.04	7.58	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	0.93	2958
1/28/07	15:09			8.8	1.7	5.90	0.41	7.50	0.37	3111
2/11/07	12:45			8.8	2.3	6.10	0.18	7.57	0.34	3191
2/25/07	12:30			8.5	2	6.00	0.97	7.69	0.16	2952
2/25/07				8.5	2	8.00	0.98	7.70	0.17	2945
2/25/07				8.5	2	4.00	0.74	7.70	0.07	2925
3/10/07	14:30			8.5	2.2	6.00	1.42	7.51	0.24	2663
3/10/07				8.5	2.2	8.00	1.42	7.51	0.16	2670
3/10/07				8.5	2.2	4.00	1.14	7.52	0.14	2803
4/1/07	11:30	26		3.6		1.56	0.47	7.99	11.62	1013
4/9/07	13:50	25.4	2.47	4		2.40	2.61	8.32	13.09	1041
4/14/07	12:30	25.5	1.17	4		2.40	5.39	8.48	12.42	1087
4/22/07	12:23	25.5	0.68	3.5		2.1	9.92	8.54	8.31	1068
4/28/07	12:30	26	0.68	4		2.4	13.11	8.42	10.33	1118
5/5/07	13:05	27	0.635	3		1.8	15.08	8.42	8.44	1003
5/13/07	11:00	26.3	0.271	3.4		2	14.63	8.64	9.14	1202
5/19/07	12:30	26	0.334	3.5		2.1	11.89	8.59	9.53	1276
5/27/07	7:15	29.6	0.28	2.9		1.8	13.52	8.78	10.99	1127
6/3/07	16:44	23.65	0.238	6		3.6	23.59	8.71	10.48	1268
6/10/07	15:30	25.5	0.8	4.5		2.7	20.79	8.67	9.75	1425
6/12/07	20:00	25.9	0.345	3.7		2.22	23.13	8.55	5.91	1929
6/24/07	11:00	26.9	0.168	2.9		1.74	25.25	8.84	6.41	1888
7/15/07	14:00	26	0.539	3.6		2.16	26.15	8.61	6.43	1134
7/30/07	12:35	26.1	0.442	3.6		1.56	26.15	8.49	4.38	1056
8/19/07	12:30	26.6	0.111	3		1.8	18.75	8.71	7.28	1012
9/9/07	14:30	26.9	0.15	1.8		1.8	15.06	8.2	7.21	1418
10/21/07	12:00	27.2	0.15	2.2		1.32	7.61	8.62	12.28	1673

Table C2. Nutrient Sampling Data

County Road 3

Sampling Date	pH	Acute Limit	Chronic Limit	Ammonia	Nitrate + Nitrite	TKN	Total Nitrogen	DP	TP
m/d/y		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
09/23/06	8.65	2.416	0.846	-	-	1.360	1.380	0.494	0.600
09/23/06	8.65	2.416	0.846	-	-	1.300	1.320	0.501	0.560
11/05/06	8.61	2.602	0.904	-	0.040	1.230	1.270	0.213	0.257
11/05/06	8.61	2.602	0.904	-	0.020	1.360	1.380	0.226	0.273
11/19/06	8.60	2.651	0.920	-	-	1.450	1.470	0.204	0.252
11/19/06	8.60	2.651	0.920	-	0.020	1.360	1.380	0.189	0.220
12/03/06	8.21	5.617	1.765	-	-	1.500	1.370	0.256	0.285
12/03/06	8.21	5.617	1.765	-	-	1.360	1.380	0.240	0.270
12/16/06	8.21	5.617	1.765	0.070	-	1.440	1.460	0.310	0.348
12/16/06	8.21	5.617	1.765	0.035	-	1.400	1.400	0.259	0.287
01/07/07	8.06	7.502	2.228						
01/14/07	8.11	6.816	2.065	0.209	-	1.460	1.490	0.484	0.531
01/14/07	8.11	6.816	2.065	0.203	-	1.410	1.440	0.453	0.482
01/28/07	8.02	8.095	2.364	0.295	-	1.650	1.680	0.631	0.658
01/28/07	8.02	8.095	2.364	0.271	-	1.740	1.770	0.638	0.657
02/11/07	8.09	7.083	2.129	0.362	-	1.660	1.690	0.597	0.642
02/11/07	8.09	7.083	2.129	0.442	-	1.870	1.900	0.777	0.777
02/25/07	8.20	5.727	1.793	0.326	-	1.760	1.790	0.756	0.575
02/25/07	8.20	5.727	1.793	0.401	-	1.890	1.920	0.546	0.775
03/10/07	7.91	9.946	2.760	0.527	-	1.790	1.820	0.665	0.690
03/10/07	7.91	9.946	2.760	0.429	0.03	1.68	1.71	0.481	0.513
04/01/07	7.85	11.098	2.988	0.304	0.570	1.570	2.140	0.184	0.234
04/01/07	7.85	11.098	2.988	0.303	0.570	1.570	2.140	0.210	0.240
04/09/07	8.11	6.816	2.065	0.092	0.36	0.99	1.35	0.108	0.164
04/09/07	8.1	6.948	2.097	0.094	0.38	1.06	1.44	0.112	0.169
04/14/07	8.64	2.461	0.860	-	0.05	0.917	0.967	0.033	0.095
04/14/07	8.64	2.461	0.860	-	0.04	0.909	0.949	0.025	0.094
04/22/07	8.63	2.507	0.875	-	-	1.2	1.23	0.044	0.081
04/22/07	8.63	2.507	0.875	-	-	1.2	1.23	0.044	0.09
04/28/07	8.63	2.507	0.875	-	-	1.17	1.2	-	0.121
04/28/07	8.55	2.912	1.001	-	-	1.15	1.18	0.096	0.13
05/05/07	8.33	4.448	1.450	-	0.03	1.11	1.14	0.15	0.174
05/05/07	8.36	4.196	1.379	-	0.1	1.03	1.13	0.148	0.171
05/13/07	8.36	4.196	1.379	-	-	1.11	1.14	0.177	0.203
05/13/07	8.37	4.115	1.356	-	0.03	1.07	1.1	0.178	0.195

Table C2. Nutrient Sampling Data (Continued)

County Road 3

Sampling Date	pH	Acute Limit	Chronic Limit	Ammonia	Nitrate + Nitrite	TKN	Total Nitrogen	DP	TP
m/d/y		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
05/19/07	8.44	3.594	1.206	-					
05/19/07	8.48	3.328	1.127	-	-	1.19	1.22	0.161	0.207
05/27/07	8.56	2.858	0.984	-	0.04	1.11	1.15	0.144	0.175
05/27/07	8.58	2.752	0.951	0.011	-	1.07	1.1	0.141	0.169
06/03/07	8.58	2.752	0.951	-	0.44	0.72	1.16	0.13	0.196
06/03/07	8.55	2.912	1.001	0.01	0.04	1.07	1.11	0.133	0.163
06/10/07	8.38	4.036	1.334	0.017	0.04	0.99	1.03	0.156	0.186
06/10/07	8.39	3.959	1.312	0.016	0.03	0.902	0.932	0.153	0.175
06/12/07	8.21	5.617	1.765	-	-	1.25	1.28	0.161	0.206
06/12/07	8.16	6.189	1.911	-	0.03	1.19	1.22	0.16	0.2
06/24/07	8.34	4.362	1.426	-	-	1.18	1.21	0.336	0.382
06/24/07	8.2	5.727	1.793	-	-	1.13	1.16	0.352	0.394
07/15/07	8.6	2.651	0.920	0.015	-	1.16	1.19	0.876	0.861
07/15/07	8.48	3.328	1.127	0.018	-	1.16	1.19	0.802	0.854
07/30/07	8.24	5.299	1.681	-	-	1.33	1.36	0.355	0.368
07/30/07	8.25	5.197	1.654	-	-	1.3	1.33	0.312	0.347
08/19/07	8.55	2.912	1.001	-	-	1.23	1.26	0.273	0.294
08/19/07	8.56	2.858	0.984	-	-	1.45	1.48	0.271	0.312
09/09/07	8.63	2.507	0.875	0.018	0.42	0.97	1.39	0.205	0.227
09/09/07	8.64	2.461	0.860	0.014	-	1.34	1.37	0.207	0.228
10/21/07	8.6	2.651	0.920	0.029	0.32	0.97	1.29	0.062	0.086

Table C2. Nutrient Sampling Data (Continued)

Johnson Bridge

Sampling Date	pH	Acute Limit	Chronic Limit	Ammonia	Nitrate + Nitrite	TKN	Total Nitrogen	DP	TP
m/d/y		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
09/23/06	8.58	2.752	0.951	-	0.040	1.730	1.770	1.040	1.200
11/05/06	8.59	2.701	0.935		0.030	1.060	1.090	0.111	0.105
11/19/06	8.29	4.807	1.549	-	0.020	1.090	1.110	0.072	0.090
12/03/06	8.08	7.220	2.162	0.015	0.030	1.280	1.310	0.098	0.094
12/15/06	7.82	11.714	3.104	0.073	0.040	1.240	1.280	0.101	0.105
01/07/07	7.45	21.406	4.552						
01/14/07	7.45	21.406	4.552	0.351	0.060	1.290	1.350	0.148	0.242
01/28/07	7.45	21.406	4.552	0.419	0.050	1.610	1.660	0.190	0.348
02/11/07	7.59	17.307	4.015	0.500	0.030	1.770	1.800	0.232	0.384
02/25/07	7.55	18.430	4.172	0.578	-	1.950	1.980	0.581	0.691
03/10/07	7.41	22.655	4.698	0.717	-	2.070	2.100	0.605	0.765
04/01/07	8.02	8.095	2.364	0.301	0.430	1.520	1.950	0.158	0.238
04/09/07	8.25	5.197	1.654	0.045	0.350	1.000	1.350	0.099	0.163
04/14/07	8.71	2.165	0.765	-	0.040	1.020	1.060	0.049	0.091
04/22/07	8.64	2.461	0.860	-	-	1.270	1.300	0.084	0.130
04/28/07	8.40	3.883	1.290	-	-	1.170	1.200	0.136	0.165
05/05/07	8.34	4.362	1.426	0.036	0.120	0.980	1.100	0.178	0.207
05/13/07	8.36	4.196	1.379	-	-	1.010	1.040	0.177	0.204
05/19/07	8.36	4.196	1.379	-	-	1.030	1.060	0.184	0.221
05/27/07	8.26	5.096	1.627	0.026	-	1.030	1.060	0.160	0.211
06/03/07	8.20	5.727	1.793	-	-	1.1	1.13	0.154	0.194
06/10/07	8.35	4.278	1.403	0.025	-	1.050	1.080	0.289	0.319
06/12/07	8.06	7.502	2.228	0.013	-	1.150	1.180	0.273	0.322
06/24/07	8.62	2.554	0.889	0.014	-	1.12	1.15	0.695	0.754
07/15/07	8.38	4.036	1.334	0.034	-	1.18	1.21	0.274	0.302
07/30/07	8.31	4.624	1.499	0.025	-	1.42	1.45	0.297	0.363
08/19/07	8.63	2.507	0.875	-	0.09	1.11	1.2	0.125	0.153
09/09/07	8.42	3.735	1.247	0.027	-	1.32	1.35	0.16	0.185
10/21/07	8.59	2.701	0.935						

Table C2. Nutrient Sampling Data (Continued)

Stafford Bridge

Sampling Date	pH	Acute Limit	Chronic Limit	Ammonia	Nitrate + Nitrite	TKN	Total Nitrogen	DP	TP
m/d/y		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
09/23/06	8.29	4.807	1.549	-	0.430	1.170	1.600	0.436	0.527
11/05/06	8.52	3.083	1.053	-	0.040	0.970	1.010	0.067	0.079
11/19/06	8.29	4.807	1.549	-	0.030	0.970	1.000	0.055	0.076
12/03/06	8.11	6.816	2.065	-	0.030	1.040	1.070	0.033	0.067
12/16/06	7.65	15.701	3.778	0.060	0.070	1.070	1.140	0.063	0.108
01/07/07									
01/14/07	7.44	21.716	4.589	0.369	0.150	1.400	1.550	0.073	0.131
01/28/07	7.44	21.716	4.589	0.462	0.110	1.890	2.000	0.087	0.155
02/11/07	7.49	20.189	4.402	0.801	-	2.380	2.410	0.131	0.233
02/25/07	7.52	19.299	4.288	1.320	-	2.720	2.750	0.179	0.353
03/10/07	7.40	22.972	4.734	1.340	-	2.920	2.950	0.130	0.423
04/01/07	8.10	6.948	2.097	0.321	0.390	1.540	1.930	0.160	0.237
04/09/07	8.45	3.525	1.185	-	0.120	0.847	0.967	0.058	0.121
04/14/07	8.73	2.088	0.741	-	0.030	1.060	1.090	0.059	0.110
04/22/07	8.50	3.203	1.089	-	0.080	1.140	1.220	0.097	0.141
04/28/07	8.44	3.594	1.206	-	-	1.090	1.120	0.134	0.164
05/05/07	8.36	4.196	1.379	0.018	0.030	1.060	1.090	0.172	0.202
05/13/07	8.31	4.624	1.499	-	-	1.000	1.030	0.173	0.212
05/19/07	8.11	6.816	2.065	0.012	0.040	0.970	1.010	0.187	0.302
05/27/07	8.19	5.839	1.822	0.078	-	1.050	1.080	0.142	0.204
06/03/07	7.98	8.730	2.504	0.073	0.04	1.03	1.07	0.135	0.176
06/10/07	8.37	4.115	1.356	0.046	-	0.921	0.951	0.242	0.288
06/12/07	8.23	5.403	1.709	0.034	0.030	0.990	1.020	0.317	0.370
06/24/07	8.63	2.507	0.875	0.045	0.04	1.07	1.11	0.632	0.729
07/15/07	8.39	3.959	1.312	0.026	-	1.12	1.15	0.205	0.247
07/30/07	8.26	5.096	1.627						
08/19/07	8.56	2.858	0.984	-	0.04	1.06	1.1	0.109	0.136
09/09/07	8.41	3.808	1.268	-	1.040	0.16	1.2	0.112	0.144
10/21/07	8.48	3.328	1.127	0.028	-	1	1.03	0.099	0.14

Table C2. Nutrient Sampling Data (Continued)

County Road 2

Sampling Date	pH	Acute Limit	Chronic Limit	Ammonia	Nitrate + Nitrite	TKN	Total Nitrogen	DP	TP
m/d/y		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
09/24/06				0.037	0.040	1.310	1.350	0.154	0.215
11/05/06	8.57	2.805	0.968	-	0.120	0.832	0.952	0.051	0.069
11/19/06	8.29	4.807	1.549	-	0.020	1.100	1.120	0.046	0.076
12/03/06	8.01	8.250	2.399	-	0.020	1.060	1.080	0.026	0.073
12/16/06	7.62	16.492	3.897	0.082	0.090	1.080	1.170	0.049	0.086
01/07/07	7.54	18.717	4.210						
01/14/07	7.35	24.577	4.909	0.356	0.180	1.560	1.740	0.064	0.122
01/28/07	7.41	22.655	4.698	0.605	0.490	1.810	2.300	0.071	0.132
02/11/07	7.44	21.716	4.589	0.845	0.060	2.640	2.700	0.083	0.178
02/25/07									
03/10/07									
04/01/07	8.10	6.948	2.097	0.335	0.350	1.550	1.900	0.165	0.235
04/09/07	8.40	3.883	1.290	-	0.300	1.010	1.310	0.092	0.137
04/14/07	8.67	2.329	0.818	-	-	1.190	1.220	0.067	0.131
04/22/07	8.55	2.912	1.001	-	-	1.270	1.300	0.100	0.154
04/28/07	8.44	3.594	1.206	-	-	1.080	1.110	0.135	0.162
05/05/07	8.36	4.196	1.379	-	0.040	1.080	1.120	0.174	0.206
05/13/07	8.33	4.448	1.450	-	-	0.980	1.010	0.191	0.239
05/19/07	8.29	4.807	1.549	-	-	1.320	1.350	0.211	0.324
05/28/07	8.28	4.902	1.575	0.039	-	0.990	1.020	0.144	0.207
06/03/07	8.29	4.807	1.549	0.023	-	1.01	1.04	0.152	0.194
06/10/07	8.36	4.196	1.379	0.038	-	0.964	0.994	0.246	0.289
06/12/07	8.30	4.715	1.524	-	-	0.980	1.010	0.335	0.376
06/24/07	8.64	2.461	0.860	-	-	1.07	1.1	0.476	0.531
07/15/07	8.42	3.735	1.247	0.033	-	1.2	1.23	0.189	0.225
07/30/07	8.37	4.115	1.356	0.102	0.04	1.36	1.4	0.225	0.265
08/19/07	8.71	2.165	0.765	-	-	1.04	1.07	0.105	0.131
09/09/07	8.36	4.196	1.379	0.011	0.050	1.21	1.26	0.127	0.155

Table C2. Nutrient Sampling Data (Continued)

Glen Ewen

Sampling Date	pH	Acute Limit	Chronic Limit	Ammonia	Nitrate + Nitrite	TKN	Total Nitrogen	DP	TP
m/d/y		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
09/24/06	8.57	2.805	0.968	-	0.240	0.940	1.180	0.082	0.111
11/05/06	8.56	2.858	0.984	-	0.100	0.990	1.090	0.036	0.062
11/19/06	8.35	4.278	1.403	-	0.070	0.990	1.060	0.019	0.057
12/03/06	7.75	13.253	3.380	0.054	0.100	1.290	1.390	0.035	0.066
12/16/06	7.59	17.307	4.015	0.146	0.030	1.640	1.670	0.057	0.107
01/07/07	7.58	17.584	4.054						
01/14/07	7.50	19.890	4.364	0.798	-	2.830	2.860	0.324	0.517
01/28/07	7.50	19.890	4.364	1.190	-	3.540	3.570	0.764	1.320
02/11/07	7.57	17.863	4.094	1.480	-	3.580	3.610	1.120	1.590
02/25/07	7.70	14.441	3.578	1.960	-	3.360	3.390	1.550	1.690
03/10/07	7.51	19.593	4.326	1.760	-	3.310	3.340	1.130	1.550
04/01/07	7.99	8.568	2.469	0.315	0.330	1.480	1.810	0.133	0.198
04/09/07	8.32	4.535	1.474	-	0.340	1.120	1.460	0.127	0.159
04/14/07	8.48	3.328	1.127	-	0.140	1.200	1.340	0.105	0.144
04/22/07	8.54	2.968	1.018						
04/28/07	8.42	3.735	1.247	-	-	1.190	1.220	0.128	0.153
05/05/07	8.42	3.735	1.247	-	0.340	0.790	1.130	0.157	0.182
05/13/07	8.64	2.461	0.860	-	-	1.070	1.100	0.210	0.255
05/19/07	8.59	2.701	0.935	-	-	1.290	1.320	0.268	0.305
05/27/07	8.78	1.911	0.683	0.029	0.040	1.090	1.130	0.202	0.262
06/03/07	8.71	2.165	0.765	0.014	-	1.12	1.15	0.33	0.374
06/10/07	8.67	2.329	0.818	0.041	-	0.967	0.997	0.190	0.212
06/12/07	8.55	2.912	1.001	-	-	1.030	1.060	0.281	0.314
06/24/07	8.84	1.721	0.620	-	-	1.21	1.24	0.654	0.716
07/15/07	8.61	2.602	0.904	0.025	-	1.21	1.24	0.158	0.214
07/30/07	8.49	3.265	1.108	0.013	-	1.27	1.3	0.178	0.227
08/19/07	8.71	2.165	0.765	-	0.13	1.01	1.14	0.159	0.219
09/09/07	8.2	5.727	1.793	0.133	0.880	0.72	1.6	0.104	0.163
10/21/07	8.62	2.554	0.889						

Table C3. Historical Precipitation Data

Precipitation Data for Mohall, ND

Year	Total Rainfall (inches)
1994	13.15
1995	12.89
1996	11.67
1997	8.2
1998	15.83
1999	17.66
2000	14.11
2001	9.29
2002	13.75
2003	11.8
2004	15.66
2005	12.45
2006	7.89
2007	11.07

Table C4. Site Sampling Visit Log

Date	Sampler	Sampling Start Time	Sites in order of sampling
09/23/06	Joe Super, Wei Lin, Bernhardt Saini-Eidukat	10:15	CR3, JB, SB, CR2, USGS, GE
11/05/06	Joe Super	9:30	CR3, JB, SB, CR2, USGS, GE
11/19/06	Joe Super	8:45	CR3, JB, SB, CR2, USGS, GE
12/03/06	Joe Super	9:00	CR3, JB, SB, CR2, USGS, GE
12/15/06	Joe Super	8:15	CR3, JB, SB, CR2, USGS, GE
01/07/07	Joe Super	8:15	CR3, JB, SB, CR2, GE, OX, HWY9
01/14/07	Joe Super	7:53	CR3, JB, SB, CR2, GE
01/28/07	Joe Super, Matt Baker, Wei Lin	8:45	CR3, JB, SB, CR2, USGS, GE, OX, HWY9
02/11/07	Joe Super	8:00	CR3, JB, SB, CR2, USGS, GE, OX, HWY9
02/25/07	Joe Super	7:50	CR3, JB, SB, GE, OX, HWY9
03/10/07	Joe Super	9:00	CR3, JB, SB, GE, OX, HWY9
04/01/07	Joe Super	8:00	CR3, JB, SB, CR2, GE
04/09/07	Joe Super	8:30	CR3, JB, SB, CR2, GE
04/14/07	Joe Super	7:10	CR3, JB, SB, CR2, GE
04/22/07	Joe Super	7:30	CR3, JB, SB, CR2, GE
04/28/07	Joe Super	7:00	CR3, JB, SB, CR2, GE
05/05/07	Joe Super	7:30	CR3, JB, SB, CR2, GE
05/13/07	Joe Super	6:00	CR3, JB, SB, CR2, GE
05/19/07	Joe Super	8:00	CR3, JB, SB, CR2, GE
05/27/07	Joe Super, Wei Lin, Matt Baker	7:15	GE
05/28/07	Joe Super, Wei Lin, Matt Baker	6:00	CR2, SB, JB, CR3
06/03/07	Joe Super	16:45	GE, CR2, SB, JB, CR3
06/10/07	Joe Super	15:30	GE, CR2, SB, JB, CR3
06/12/07	Joe Super	14:30	GE, CR2, SB, JB, CR3
06/19/07	Dora Abernathy	-	CR3
06/24/07	Joe Super	7:15	CR3, JB, SB, CR2, GE
06/26/07	Dora Abernathy	-	CR3
07/02/07	Dora Abernathy	-	CR3
07/05/07	Joe Super	8:30	CR3, JB, SB, CR2, GE
07/16/07	Dora Abernathy	-	CR3
07/30/07	Joe Super, Matt Baker	6:30	CR3, JB, SB, CR2, GE
07/31/07	Dora Abernathy	-	CR3
08/06/07	Dora Abernathy	-	CR3
08/13/07	Dora Abernathy	-	CR3

Table C4. Site Sampling Visit Log (Continued)

Date	Sampler	Sampling Start Time	Sites in order of sampling
08/19/07	Joe Super	8:00	CR3, JB, SB, CR2, GE
08/21/07	Dora Abernathy	-	CR3
09/04/07	Dora Abernathy	-	CR3
09/09/07	Joe Super	9:00	CR3, JB, SB, CR2, GE
09/10/07	Dora Abernathy	-	CR3
09/17/07	Dora Abernathy	-	CR3
09/24/07	Dora Abernathy	-	CR3
10/21/07	Joe Super	8:15	CR3, JB, SB, CR2, GE

Note: USGS, Oxbow, and Highway 9 were only tested for DO, Conductivity, pH, and Temp.

APPENDIX D. USGS CONTINUOUS SAMPLING

Table D1. USGS Continuous Flow Measurement

USGS 05114000 Gauging Station Data

Date	Flow
(year)	(ft^3/s)
1930	98.6
1931	2.12
1932	7.98
1933	76.3
1934	26.3
1935	12.1
1936	66.2
1937	1.56
1938	49.5
1939	97
1940	2.63
1941	49.1
1942	87.7
1943	286.5
1944	62.7
1945	13
1946	78
1947	202.5
1948	344.3
1949	84.9
1950	127.8
1951	244
1952	79.9
1953	235.1
1954	90.9
1955	344.5
1956	247.9
1957	55.9
1958	51.4
1959	20
1960	127.7
1961	5.91
1962	13.7
1963	25.7
1964	52.9

Date	Flow
(year)	(ft^3/s)
1965	111.3
1966	79.8
1967	48.6
1968	17.9
1969	411.3
1970	259.1
1971	135.2
1972	227.4
1973	17.1
1974	424.8
1975	524
1976	877.5
1977	15.1
1978	134.3
1979	526.8
1980	29.1
1981	17.1
1982	236.6
1983	200.9
1984	14.1
1985	50.9
1986	49.6
1987	54.1
1988	0.622
1989	21.6
1990	11.5
1991	24.6
1992	33.8
1993	23.1
1994	85.4
1995	88.8
1996	195.6
1997	234.1
1998	18.3
1999	372.5

Historic Flows

Date	Flow
(year)	(ft^3/s)
2000	19
2001	347.7
2002	23.5
2003	41.6
2004	41
2005	103.9
2006	19.8

Table D1. USGS Continuous Flow Measurement (Continued)

USGS 05114000 Gauging Station Data TMDL Flow

Date	Flow	Date	Flow	Date	Flow	Date	Flow	Date	Flow
(m/d/y)	(ft³/s)	(m/d/y)	(ft³/s)	(m/d/y)	(ft³/s)	(m/d/y)	(ft³/s)	(m/d/y)	(ft³/s)
11/13/06	3.40	12/19/06	1.4	1/24/07	1.2	3/1/07	0.5	4/6/07	55
11/14/06	3.7	12/20/06	1.5	1/25/07	1	3/2/07	0.49	4/7/07	59
11/15/06	3.8	12/21/06	1.5	1/26/07	0.95	3/3/07	0.48	4/8/07	64
11/16/06	4.2	12/22/06	1.5	1/27/07	0.92	3/4/07	0.47	4/9/07	70
11/17/06	4.4	12/23/06	1.5	1/28/07	0.88	3/5/07	0.46	4/10/07	78
11/18/06	4.6	12/24/06	1.5	1/29/07	0.86	3/6/07	0.45	4/11/07	87
11/19/06	4.8	12/25/06	1.5	1/30/07	0.85	3/7/07	0.47	4/12/07	94
11/20/06	4.7	12/26/06	1.5	1/31/07	0.84	3/8/07	0.5	4/13/07	96
11/21/06	4.5	12/27/06	1.5	2/1/07	0.8	3/9/07	0.55	4/14/07	94
11/22/06	4.5	12/28/06	1.4	2/2/07	0.8	3/10/07	0.85	4/15/07	93
11/23/06	4.3	12/29/06	1.4	2/3/07	0.75	3/11/07	1.8	4/16/07	92
11/24/06	4.3	12/30/06	1.4	2/4/07	0.7	3/12/07	4.5	4/17/07	90
11/25/06	4.2	12/31/06	1.4	2/5/07	0.65	3/13/07	25	4/18/07	88
11/26/06	3.7	1/1/07	1.4	2/6/07	0.6	3/14/07	90	4/19/07	87
11/27/06	3	1/2/07	1.5	2/7/07	0.55	3/15/07	150	4/20/07	88
11/28/06	2.5	1/3/07	1.6	2/8/07	0.51	3/16/07	175	4/21/07	90
11/29/06	2.2	1/4/07	1.5	2/9/07	0.49	3/17/07	170	4/22/07	87
11/30/06	2	1/5/07	1.5	2/10/07	0.47	3/18/07	160	4/23/07	84
12/1/06	1.7	1/6/07	1.5	2/11/07	0.45	3/19/07	150	4/24/07	84
12/2/06	1.5	1/7/07	1.5	2/12/07	0.42	3/20/07	140	4/25/07	84
12/3/06	1.4	1/8/07	1.5	2/13/07	0.37	3/21/07	130	4/26/07	84
12/4/06	1.3	1/9/07	1.5	2/14/07	0.37	3/22/07	120	4/27/07	81
12/5/06	1.3	1/10/07	1.5	2/15/07	0.35	3/23/07	110	4/28/07	80
12/6/06	1.3	1/11/07	1.4	2/16/07	0.36	3/24/07	100	4/29/07	79
12/7/06	1.3	1/12/07	1.3	2/17/07	0.38	3/25/07	94	4/30/07	80
12/8/06	1.3	1/13/07	1.2	2/18/07	0.39	3/26/07	88	5/1/07	79
12/9/06	1.4	1/14/07	1.1	2/19/07	0.42	3/27/07	82	5/2/07	76
12/10/06	1.4	1/15/07	0.95	2/20/07	0.48	3/28/07	73	5/3/07	75
12/11/06	1.4	1/16/07	0.91	2/21/07	0.51	3/29/07	70	5/4/07	80
12/12/06	1.4	1/17/07	0.93	2/22/07	0.53	3/30/07	64	5/5/07	73
12/13/06	1.4	1/18/07	0.94	2/23/07	0.54	3/31/07	60	5/6/07	83
12/14/06	1.5	1/19/07	0.95	2/24/07	0.53	4/1/07	57	5/7/07	119
12/15/06	1.5	1/20/07	0.96	2/25/07	0.52	4/2/07	54	5/8/07	111
12/16/06	1.5	1/21/07	0.98	2/26/07	0.52	4/3/07	53	5/9/07	83
12/17/06	1.4	1/22/07	1	2/27/07	0.51	4/4/07	50	5/10/07	45
12/18/06	1.4	1/23/07	1.1	2/28/07	0.5	4/5/07	51	5/11/07	34

Table D1. USGS Continuous Flow Measurement (Continued)

USGS 05114000 Gauging Station Data TMDL Flow

Date	Flow	Date	Flow	Date	Flow	Date	Flow	Date	Flow
(m/d/y)	(ft^3/s)	(m/d/y)	(ft^3/s)	(m/d/y)	(ft^3/s)	(m/d/y)	(ft^3/s)	(m/d/y)	(ft^3/s)
5/12/07	31	6/17/07	34	7/23/07	44	8/28/07	4.5	10/3/07	1.6
5/13/07	30	6/18/07	35	7/24/07	43	8/29/07	4.2	10/4/07	1.9
5/14/07	31	6/19/07	31	7/25/07	43	8/30/07	3.9	10/5/07	2.1
5/15/07	30	6/20/07	26	7/26/07	41	8/31/07	3.5	10/6/07	2.8
5/16/07	29	6/21/07	20	7/27/07	40	9/1/07	3.5	10/7/07	2.5
5/17/07	39	6/22/07	17	7/28/07	39	9/2/07	3.3	10/8/07	2.8
5/18/07	40	6/23/07	16	7/29/07	39	9/3/07	3.2	10/9/07	2.9
5/19/07	28	6/24/07	14	7/30/07	38	9/4/07	3	10/10/07	2.9
5/20/07	26	6/25/07	16	7/31/07	37	9/5/07	2.8	10/11/07	2.8
5/21/07	30	6/26/07	15	8/1/07	38	9/6/07	2.8	10/12/07	3
5/22/07	33	6/27/07	14	8/2/07	37	9/7/07	3	10/13/07	3.1
5/23/07	36	6/28/07	13	8/3/07	34	9/8/07	2.8	10/14/07	3.2
5/24/07	37	6/29/07	17	8/4/07	34	9/9/07	2.7	10/15/07	3.4
5/25/07	35	6/30/07	40	8/5/07	35	9/10/07	2.5	10/16/07	3.4
5/26/07	31	7/1/07	43	8/6/07	36	9/11/07	2.1	10/17/07	3.4
5/27/07	25	7/2/07	44	8/7/07	37	9/12/07	2	10/18/07	3.4
5/28/07	18	7/3/07	44	8/8/07	40	9/13/07	1.9	10/19/07	3.3
5/29/07	14	7/4/07	43	8/9/07	40	9/14/07	1.8	10/20/07	3.3
5/30/07	13	7/5/07	42	8/10/07	37	9/15/07	1.8	10/21/07	3.4
5/31/07	16	7/6/07	42	8/11/07	35	9/16/07	1.9	10/22/07	3.3
6/1/07	15	7/7/07	44	8/12/07	37	9/17/07	1.9	10/23/07	3.2
6/2/07	14	7/8/07	43	8/13/07	43	9/18/07	1.8	10/24/07	3.1
6/3/07	14	7/9/07	46	8/14/07	40	9/19/07	2	10/25/07	3.1
6/4/07	14	7/10/07	51	8/15/07	38	9/20/07	1.9	10/26/07	3.1
6/5/07	14	7/11/07	51	8/16/07	36	9/21/07	2	10/27/07	3.1
6/6/07	85	7/12/07	51	8/17/07	28	9/22/07	2	10/28/07	3.1
6/7/07	127	7/13/07	48	8/18/07	19	9/23/07	2	10/29/07	3.1
6/8/07	112	7/14/07	48	8/19/07	14	9/24/07	2.2	10/30/07	3.1
6/9/07	95	7/15/07	48	8/20/07	12	9/25/07	2.2	10/31/07	3
6/10/07	89	7/16/07	47	8/21/07	10	9/26/07	2.2	11/1/07	3
6/11/07	73	7/17/07	45	8/22/07	8.3	9/27/07	2.1	11/2/07	2.9
6/12/07	62	7/18/07	46	8/23/07	7.1	9/28/07	2	11/3/07	2.9
6/13/07	55	7/19/07	44	8/24/07	6.4	9/29/07	1.9	11/4/07	2.8
6/14/07	45	7/20/07	42	8/25/07	5.7	9/30/07	1.9	11/5/07	2.6
6/15/07	39	7/21/07	41	8/26/07	5.6	10/1/07	1.9	11/6/07	2.4
6/16/07	34	7/22/07	43	8/27/07	4.8	10/2/07	1.8	11/7/07	2.6

Table D2. USGS Continuous Monitoring Data, Summer Months

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft^3/s)	(mg/L)	(uS/cm)	(^oC)
6/7/2007 0:30	3.14	125	5.7	1,390	18.6
6/7/2007 1:30	3.15	127	5.7	1,400	18.3
6/7/2007 2:30	3.16	129	5.6	1,400	18
6/7/2007 3:30	3.15	127	5.6	1,410	17.7
6/7/2007 4:30	3.15	127	5.6	1,410	17.4
6/7/2007 5:30	3.15	127	5.6	1,420	17.1
6/7/2007 6:30	3.16	129	5.7	1,420	16.8
6/7/2007 7:30	3.16	129	5.7	1,420	16.5
6/7/2007 8:30	3.16	129	5.8	1,420	16.3
6/7/2007 9:30	3.16	129	5.9	1,430	16.2
6/7/2007 10:30	3.16	129	6.1	1,430	16.2
6/7/2007 11:30	3.16	129	6.5	1,440	16.3
6/7/2007 12:30	3.16	129	6.9	1,440	16.6
6/7/2007 13:30	3.16	129	7.5	1,450	17.1
6/7/2007 14:30	3.16	129	8	1,460	17.4
6/7/2007 15:30	3.15	127	8.4	1,460	17.7
6/7/2007 16:30	3.15	127	8.7	1,470	17.8
6/7/2007 17:30	3.15	127	8.8	1,470	17.9
6/7/2007 18:30	3.15	127	8.8	1,470	17.8
6/7/2007 19:30	3.14	125	8.7	1,460	17.6
6/7/2007 20:30	3.14	125	8.4	1,450	17.4
6/7/2007 21:30	3.13	124	8	1,440	17.2
6/7/2007 22:30	3.13	124	7.6	1,420	16.9
6/7/2007 23:30	3.12	122	7.2	1,400	16.7
6/8/2007 0:00	3.12	122	7	1,390	16.6
6/8/2007 0:30	3.12	122	6.9	1,380	16.4
6/8/2007 1:30	3.11	120	6.7	1,360	16.2
6/8/2007 2:30	3.11	120	6.5	1,360	16
6/8/2007 3:30	3.1	119	6.4	1,340	15.8
6/8/2007 4:30	3.1	119	6.4	1,330	15.6
6/8/2007 5:30	3.09	117	6.4	1,320	15.4
6/8/2007 6:30	3.09	117	6.4	1,310	15.2
6/8/2007 7:30	3.08	115	6.5	1,310	15.1
6/8/2007 8:30	3.08	115	6.6	1,310	15

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft^3/s)	(mg/L)	(uS/cm)	(^oC)
6/8/2007 9:30	3.07	114	6.8	1,310	15.1
6/8/2007 10:30	3.07	114	7.1	1,310	15.3
6/8/2007 11:30	3.06	114	7.6	1,310	15.8
6/8/2007 12:30	3.06	114	8.2	1,310	16.3
6/8/2007 13:30	3.05	112	8.8	1,320	17
6/8/2007 14:30	3.05	112	9.4	1,320	17.7
6/8/2007 15:30	3.04	110	10	1,320	18.4
6/8/2007 16:30	3.04	110	10.4	1,330	18.8
6/8/2007 17:30	3.03	109	10.5	1,330	19.1
6/8/2007 18:30	3.03	109	10.5	1,340	19.2
6/8/2007 19:30	3.02	107	10.3	1,350	19.2
6/8/2007 20:30	3.01	105	9.9	1,360	18.9
6/8/2007 21:30	3.01	105	9.4	1,370	18.7
6/8/2007 22:30	3	104	8.7	1,370	18.4
6/8/2007 23:30	3	104	8.1	1,380	18.2
6/9/2007 0:00	3	104	7.8	1,390	18
6/9/2007 0:30	2.99	102	7.5	1,390	17.9
6/9/2007 1:30	2.98	101	6.9	1,400	17.7
6/9/2007 2:30	2.98	101	6.4	1,400	17.5
6/9/2007 3:30	2.98	101	6.1	1,410	17.4
6/9/2007 4:30	2.97	99	5.9	1,420	17.3
6/9/2007 5:30	2.97	99	5.8	1,420	17.2
6/9/2007 6:30	2.97	99	5.8	1,420	17
6/9/2007 7:30	2.96	98	5.9	1,430	17
6/9/2007 8:30	2.95	96	6	1,430	17
6/9/2007 9:30	2.95	96	6.2	1,430	17.1
6/9/2007 10:30	2.95	96	6.5	1,440	17.3
6/9/2007 11:30	2.94	95	7	1,440	17.8
6/9/2007 12:30	2.94	95	7.6	1,440	18.5
6/9/2007 13:30	2.94	95	8.4	1,440	19.2
6/9/2007 14:30	2.94	95	9.2	1,450	19.8
6/9/2007 15:30	2.93	93	9.8	1,450	20.3
6/9/2007 16:30	2.93	93	9.9	1,460	20.3
6/9/2007 17:30	2.93	93	9.8	1,460	20.4

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft^3/s)	(mg/L)	(uS/cm)	(^oC)
6/9/2007 18:30	2.93	93	9.7	1,460	20.7
6/9/2007 19:30	2.93	93	9.4	1,460	20.8
6/9/2007 20:30	2.93	93	8.9	1,460	20.6
6/9/2007 21:30	2.93	93	8.1	1,460	20.3
6/9/2007 22:30	2.93	93	7.5	1,460	20.1
6/9/2007 23:30	2.94	95	7	1,470	19.9
6/10/2007 0:00	2.94	95	6.8	1,470	19.8
6/10/2007 0:30	2.94	95	6.5	1,470	19.7
6/10/2007 1:30	2.94	95	6	1,470	19.5
6/10/2007 2:30	2.94	95	5.6	1,470	19.3
6/10/2007 3:30	2.94	95	5.3	1,480	19
6/10/2007 4:30	2.95	96	5.1	1,470	18.8
6/10/2007 5:30	2.95	96	5.1	1,480	18.7
6/10/2007 6:30	2.95	96	5.1	1,480	18.5
6/10/2007 7:30	2.95	96	5.1	1,470	18.4
6/10/2007 8:30	2.94	95	5.2	1,470	18.4
6/10/2007 9:30	2.94	95	5.4	1,470	18.4
6/10/2007 10:30	2.93	93	5.8	1,470	18.7
6/10/2007 11:30	2.92	92	6.1	1,470	18.8
6/10/2007 12:30	2.92	92	6.4	1,470	19.1
6/10/2007 13:30	2.91	91	7	1,470	19.6
6/10/2007 14:30	2.9	89	7.6	1,460	20.3
6/10/2007 15:30	2.89	88	8.4	1,460	20.9
6/10/2007 16:30	2.88	87	9.2	1,460	21.5
6/10/2007 17:30	2.87	85	9.8	1,460	22
6/10/2007 18:30	2.86	84	10	1,460	22.4
6/10/2007 19:30	2.86	84	10	1,460	22.5
6/10/2007 20:30	2.85	84	9.7	1,460	22.4
6/10/2007 21:30	2.84	83	9	1,470	22.3
6/10/2007 22:30	2.84	83	8.2	1,470	22
6/10/2007 23:30	2.83	82	7.4	1,470	21.7
6/11/2007 0:00	2.82	80	7	1,470	21.6
6/11/2007 0:30	2.82	80	6.5	1,470	21.4
6/11/2007 1:30	2.82	80	5.6	1,470	21

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft^3/s)	(mg/L)	(uS/cm)	(^oC)
6/11/2007 2:30	2.81	79	5	1,470	20.7
6/11/2007 3:30	2.81	79	4.5	1,460	20.4
6/11/2007 4:30	2.81	79	4.3	1,460	20.2
6/11/2007 5:30	2.81	79	4.1	1,460	20.1
6/11/2007 6:30	2.8	78	4	1,460	20
6/11/2007 7:30	2.8	78	4	1,460	19.9
6/11/2007 8:30	2.8	78	4.1	1,460	20
6/11/2007 9:30	2.8	78	4.4	1,460	20.2
6/11/2007 10:30	2.79	77	4.8	1,460	20.4
6/11/2007 11:30	2.78	76	5.5	1,460	21
6/11/2007 12:30	2.78	76	6.3	1,460	21.7
6/11/2007 13:30	2.77	74	7.2	1,450	22.4
6/11/2007 14:30	2.76	73	8.1	1,460	23
6/11/2007 15:30	2.75	72	8.9	1,450	23.7
6/11/2007 16:30	2.74	71	9.9	1,450	24.3
6/11/2007 17:30	2.73	70	10.5	1,450	24.9
6/11/2007 18:30	2.71	67	10.8	1,450	25.2
6/11/2007 19:30	2.7	66	10.6	1,450	25.2
6/11/2007 20:30	2.69	65	10	1,450	25
6/11/2007 21:30	2.69	65	9.1	1,450	24.8
6/11/2007 22:30	2.69	65	8.1	1,440	24.6
6/11/2007 23:30	2.69	65	7.1	1,450	24.3
6/12/2007 0:00	2.69	65	6.6	1,450	24.2
6/12/2007 0:30	2.69	65	6.2	1,450	24.1
6/12/2007 1:30	2.69	65	5.2	1,450	23.7
6/12/2007 2:30	2.68	64	4.3	1,450	23.4
6/12/2007 3:30	2.68	64	3.7	1,450	23.1
6/12/2007 4:30	2.68	64	3.5	1,440	22.8
6/12/2007 5:30	2.68	64	3.3	1,440	22.7
6/12/2007 6:30	2.68	64	3.2	1,450	22.5
6/12/2007 7:30	2.68	64	3.2	1,450	22.4
6/12/2007 8:30	2.68	64	3.1	1,450	22.3
6/12/2007 9:30	2.68	64	3.2	1,450	22.3
6/12/2007 10:30	2.68	64	3.6	1,450	22.5

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft^3/s)	(mg/L)	(uS/cm)	(^oC)
6/12/2007 11:30	2.67	63	4.3	1,450	22.8
6/12/2007 12:30	2.67	63	4.7	1,460	23
6/12/2007 13:30	2.66	62	5.2	1,460	23.1
6/12/2007 14:30	2.66	62	5.4	1,460	23.2
6/12/2007 15:30	2.65	61	5.7	1,460	23.2
6/12/2007 16:30	2.65	61	5.9	1,460	23.2
6/12/2007 17:30	2.66	62	6	1,460	23.1
6/12/2007 18:30	2.66	62	5.9	1,450	23
6/12/2007 19:30	2.66	62	5.5	1,460	23
6/12/2007 20:30	2.65	61	5.4	1,460	22.9
6/12/2007 21:30	2.64	61	5.1	1,460	22.7
6/12/2007 22:30	2.64	61	4.9	1,470	22.5
6/12/2007 23:30	2.63	60	4.7	1,470	22.3
6/13/2007 0:00	2.63	60	4.5	1,470	22.2
6/13/2007 0:30	2.63	60	4.4	1,470	22.1
6/13/2007 1:30	2.63	60	4.1	1,470	21.9
6/13/2007 2:30	2.62	59	4	1,480	21.7
6/13/2007 3:30	2.62	59	3.8	1,480	21.5
6/13/2007 4:30	2.62	59	3.6	1,490	21.4
6/13/2007 5:30	2.62	59	3.4	1,490	21.2
6/13/2007 6:30	2.62	59	3.4	1,500	21.1
6/13/2007 7:30	2.62	59	3.3	1,500	20.9
6/13/2007 8:30	2.61	58	3.4	1,500	20.8
6/13/2007 9:30	2.61	58	3.6	1,500	20.9
6/13/2007 10:30	2.61	58	4	1,510	21.1
6/13/2007 11:30	2.61	58	4.8	1,510	21.4
6/13/2007 12:30	2.6	57	5.8	1,510	22
6/13/2007 13:30	2.6	57	6.9	1,510	22.7
6/13/2007 14:30	2.6	57	8.3	1,520	23.4
6/13/2007 15:30	2.59	56	9.6	1,520	24.1
6/13/2007 16:30	2.58	55	11	1,520	24.9
6/13/2007 17:30	2.56	53	11.8	1,520	25.4
6/13/2007 18:30	2.55	52	12.2	1,520	25.7
6/13/2007 19:30	2.54	51	12.2	1,530	25.7

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft³/s)	(mg/L)	(uS/cm)	(^oC)
6/13/2007 20:30	2.54	51	11.6	1,540	25.5
6/13/2007 21:30	2.55	52	10.7	1,540	25.3
6/13/2007 22:30	2.55	52	9.6	1,540	24.8
6/13/2007 23:30	2.55	52	8.3	1,550	24.3
6/14/2007 0:00	2.55	52	7.7	1,550	24
6/14/2007 0:30	2.55	52	7.1	1,550	23.8
6/14/2007 1:30	2.54	51	5.9	1,550	23.3
6/14/2007 2:30	2.54	51	5	1,560	22.8
6/14/2007 3:30	2.53	50	4.2	1,560	22.4
6/14/2007 4:30	2.52	50	3.5	1,570	21.9
6/14/2007 5:30	2.52	50	2.9	1,570	21.5
6/14/2007 6:30	2.51	49	2.6	1,580	21.2
6/14/2007 7:30	2.51	49	2.4	1,580	21
6/14/2007 8:30	2.51	49	2.4	1,580	20.9
6/14/2007 9:30	2.5	48	2.6	1,580	21
6/14/2007 10:30	2.5	48	2.9	1,590	21.1
6/14/2007 11:30	2.5	48	3.5	1,590	21.4
6/14/2007 12:30	2.49	46	4.2	1,600	21.7
6/14/2007 13:30	2.49	46	4.9	1,600	21.9
6/14/2007 14:30	2.48	45	5.6	1,600	22.2
6/14/2007 15:30	2.48	45	6.3	1,600	22.5
6/14/2007 16:30	2.47	44	7	1,600	22.8
6/14/2007 17:30	2.47	44	7.7	1,610	23
6/14/2007 18:30	2.46	44	8.1	1,610	23.1
6/14/2007 19:30	2.45	43	8.4	1,620	23.1
6/14/2007 20:30	2.44	42	8.2	1,620	22.8
6/14/2007 21:30	2.45	43	7.9	1,610	22.5
6/14/2007 22:30	2.45	43	7.3	1,620	22.3
6/14/2007 23:30	2.45	43	6.7	1,620	22
6/15/2007 0:00	2.45	43	6.3	1,620	21.8
6/15/2007 0:30	2.45	43	6	1,620	21.7
6/15/2007 1:30	2.44	42	5.4	1,630	21.3
6/15/2007 2:30	2.44	42	4.8	1,630	20.9
6/15/2007 3:30	2.44	42	4.2	1,640	20.5

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft³/s)	(mg/L)	(uS/cm)	(°C)
6/15/2007 4:30	2.44	42	3.8	1,640	20.2
6/15/2007 5:30	2.44	42	3.5	1,640	19.9
6/15/2007 6:30	2.44	42	3.3	1,650	19.6
6/15/2007 7:30	2.44	42	3.2	1,650	19.4
6/15/2007 8:30	2.44	42	3.3	1,650	19.2
6/15/2007 9:30	2.44	42	3.6	1,660	19.2
6/15/2007 10:30	2.44	42	4.2	1,660	19.4
6/15/2007 11:30	2.44	42	5.2	1,660	19.9
6/15/2007 12:30	2.44	42	6.6	1,670	20.6
6/15/2007 13:30	2.44	42	8.1	1,670	21.5
6/15/2007 14:30	2.44	42	9.6	1,670	22.4
6/15/2007 15:30	2.43	41	11.1	1,680	23.1
6/15/2007 16:30	2.41	40	12.2	1,680	23.7
6/15/2007 17:30	2.39	37	13.2	1,680	24.3
6/15/2007 18:30	2.39	37	13.7	1,690	24.7
6/15/2007 19:30	2.39	37	13.7	1,680	24.9
6/15/2007 20:30	2.4	39	13.2	1,690	24.7
6/15/2007 21:30	2.4	39	12.2	1,700	24.4
6/15/2007 22:30	2.41	40	11.2	1,700	24
6/15/2007 23:30	2.41	40	9.9	1,700	23.6
6/16/2007 0:00	2.4	39	9.2	1,700	23.4
6/16/2007 0:30	2.4	39	8.5	1,710	23.1
6/16/2007 1:30	2.4	39	7.1	1,710	22.5
6/16/2007 2:30	2.4	39	6	1,710	22
6/16/2007 3:30	2.39	37	5	1,720	21.5
6/16/2007 4:30	2.38	37	4.2	1,720	21
6/16/2007 5:30	2.38	37	3.5	1,720	20.5
6/16/2007 6:30	2.38	37	3	1,720	20
6/16/2007 7:30	2.37	36	2.7	1,720	19.6
6/16/2007 8:30	2.37	36	2.7	1,720	19.3
6/16/2007 9:30	2.37	36	2.8	1,730	19.2
6/16/2007 10:30	2.37	36	3.3	1,730	19.4
6/16/2007 11:30	2.37	36	4.3	1,740	19.9
6/16/2007 12:30	2.37	36	5.8	1,740	20.7

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft^3/s)	(mg/L)	(uS/cm)	(^oC)
6/16/2007 13:30	2.37	36	7.6	1,740	21.7
6/16/2007 14:30	2.37	36	9.5	1,750	22.6
6/16/2007 15:30	2.36	35	11.3	1,750	23.5
6/16/2007 16:30	2.34	34	12.9	1,750	24.5
6/16/2007 17:30	2.32	33	14.1	1,740	25.3
6/16/2007 18:30	2.32	33	14.6	1,700	25.7
6/16/2007 19:30	2.33	33	14.7	1,760	25.9
6/16/2007 20:30	2.34	34	14.3	1,750	25.9
6/16/2007 21:30	2.35	35	13.5	1,760	25.8
6/16/2007 22:30	2.36	35	12.5	1,760	25.6
6/16/2007 23:30	2.36	35	11.2	1,760	25.2
6/17/2007 0:00	2.36	35	10.4	1,760	25
6/17/2007 0:30	2.36	35	9.7	1,770	24.8
6/17/2007 1:30	2.36	35	8.2	1,770	24.3
6/17/2007 2:30	2.35	35	6.8	1,770	23.7
6/17/2007 3:30	2.34	34	5.6	1,780	23.3
6/17/2007 4:30	2.34	34	4.7	1,780	22.7
6/17/2007 5:30	2.35	35	4.1	1,770	22.2
6/17/2007 6:30	2.36	35	3.5	1,770	21.8
6/17/2007 7:30	2.35	35	3.2	1,770	21.4
6/17/2007 8:30	2.36	35	3	1,780	21.2
6/17/2007 9:30	2.36	35	3	1,770	21
6/17/2007 10:30	2.38	37	3.6	1,760	20.8
6/17/2007 11:30	2.39	37	4.1	1,760	20.9
6/17/2007 12:30	2.39	37	5.1	1,760	21.4
6/17/2007 13:30	2.39	37	6.1	1,760	21.6
6/17/2007 14:30	2.39	37	6.8	1,760	21.7
6/17/2007 15:30	2.38	37	7.3	1,760	21.8
6/17/2007 16:30	2.38	37	7.5	1,760	21.9
6/17/2007 17:30	2.37	36	7.6	1,770	21.9
6/17/2007 18:30	2.37	36	7.6	1,770	22.1
6/17/2007 19:30	2.37	36	7.5	1,770	22.2
6/17/2007 20:30	2.36	35	7.3	1,780	22.3
6/17/2007 21:30	2.36	35	7	1,780	22.2

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft³/s)	(mg/L)	(uS/cm)	(°C)
6/17/2007 22:30	2.36	35	6.5	1,780	22
6/17/2007 23:30	2.36	35	6.1	1,790	21.8
6/18/2007 0:00	2.36	35	5.8	1,790	21.6
6/18/2007 0:30	2.36	35	5.5	1,790	21.4
6/18/2007 1:30	2.36	35	5	1,800	21.1
6/18/2007 2:30	2.36	35	4.6	1,800	20.8
6/18/2007 3:30	2.36	35	4.2	1,800	20.4
6/18/2007 4:30	2.36	35	3.9	1,800	20.1
6/18/2007 5:30	2.36	35	3.7	1,800	19.7
6/18/2007 6:30	2.36	35	3.5	1,790	19.3
6/18/2007 7:30	2.37	36	3.3	1,790	19
6/18/2007 8:30	2.37	36	3.4	1,790	18.7
6/18/2007 9:30	2.38	37	3.6	1,790	18.5
6/18/2007 10:30	2.38	37	4	1,780	18.4
6/18/2007 11:30	2.39	37	4.6	1,780	18.4
6/18/2007 12:30	2.39	37	5.5	1,790	18.7
6/18/2007 13:30	2.4	39	6.8	1,790	19.2
6/18/2007 14:30	2.4	39	8.2	1,800	19.8
6/18/2007 15:30	2.4	39	9.3	1,800	20.2
6/18/2007 16:30	2.41	40	10.2	1,790	20.4
6/18/2007 17:30	2.4	39	10.8	1,790	20.5
6/18/2007 18:30	2.4	39	11	1,800	20.3
6/18/2007 19:30	2.4	39	11	1,840	20.2
6/18/2007 20:30	2.4	39	10.7	1,830	20
6/18/2007 21:30	2.4	39	10.2	1,840	19.7
6/18/2007 22:30	2.4	39	9.6	1,840	19.4
6/18/2007 23:30	2.39	37	8.8	1,850	19.1
6/19/2007 0:00	2.39	37	8.5	1,850	18.9
6/19/2007 0:30	2.39	37	8.1	1,850	18.8
6/19/2007 1:30	2.38	37	7.2	1,860	18.4
6/19/2007 2:30	2.37	36	6.5	1,860	18
6/19/2007 3:30	2.37	36	5.9	1,870	17.6
6/19/2007 4:30	2.36	35	5.3	1,870	17.3
6/19/2007 5:30	2.36	35	4.9	1,870	17.1

Table D2. USGS Continuous Monitoring Data, Summer Months (Continued)

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft³/s)	(mg/L)	(uS/cm)	(^oC)
6/19/2007 6:30	2.36	35	4.5	1,870	16.9
6/19/2007 7:30	2.35	35	4.2	1,870	16.7
6/19/2007 8:30	2.35	35	4.2	1,870	16.6
6/19/2007 9:30	2.35	35	4.4	1,870	16.6
6/19/2007 10:30	2.34	34	5	1,870	16.9
6/19/2007 11:30	2.34	34	5.9	1,870	17.4
6/19/2007 12:30	2.34	34	7.4	1,870	18.2
6/19/2007 13:30	2.34	34	9.1	1,870	19.1
6/19/2007 14:30	2.33	33	11	1,870	20.2
6/19/2007 15:30	2.32	33	12.7	1,870	21.1
6/19/2007 16:30	2.3	31	14.1	1,870	21.9
6/19/2007 17:30	2.29	30	15.1	1,880	22.6
6/19/2007 18:30	2.29	30	15.6	1,880	22.9
6/19/2007 19:30	2.3	31	15.7	1,880	23.2
6/19/2007 20:30	2.3	31	15.3	1,870	23.1
6/19/2007 21:30	2.31	32	14.5	1,880	23
6/19/2007 22:30	2.32	33	13.4	1,880	22.8
6/19/2007 23:30	2.32	33	12.2	1,870	22.4
6/20/2007 0:00	2.32	33	11.5	1,870	22.2
6/20/2007 0:30	2.32	33	10.8	1,870	22
6/20/2007 1:30	2.31	32	9.4	1,880	21.6
6/20/2007 2:30	2.31	32	8.1	1,880	21.1
6/20/2007 3:30	2.3	31	6.9	1,880	20.6
6/20/2007 4:30	2.3	31	5.9	1,890	20
6/20/2007 5:30	2.29	30	5.1	1,890	19.5
6/20/2007 6:30	2.29	30	4.5	1,890	19
6/20/2007 7:30	2.28	29	4	1,890	18.5
6/20/2007 8:30	2.28	29	3.7	1,890	18.1
6/20/2007 9:30	2.28	29	3.7	1,890	17.9
6/20/2007 10:30	2.28	29	4.1	1,900	18.1
6/20/2007 11:30	2.28	29	5	1,900	18.5
6/20/2007 12:30	2.27	29	6.2	1,900	19.2
6/20/2007 13:30	2.27	29	7.8	1,910	20.2
6/20/2007 14:30	2.26	28	9.7	1,910	21.2

Table D3. USGS Continuous Monitoring Data, Fall Month

USGS 05114000 Gauging Station Data

Date	Gauge Height	Stream Flow	Dissolved Oxygen	Specific Conductance Water Unfil.	Water Temp.
(m/d/y) hr:min	(ft)	(ft^3/s)	(mg/L)	(uS/cm)	(^oC)
10/7/2007 0:30	1.48	2.5	9.3	1,320	7.7
10/7/2007 1:30	1.48	2.5	9.3	1,320	7.7
10/7/2007 2:30	1.48	2.5	9.2	1,310	7.6
10/7/2007 3:30	1.48	2.5	9.1	1,320	7.6
10/7/2007 4:30	1.48	2.5	9	1,320	7.5
10/7/2007 5:30	1.48	2.5	8.9	1,320	7.4
10/7/2007 6:30	1.47	2.4	8.9	1,320	7.4
10/7/2007 7:30	1.47	2.4	8.7	1,320	7.3
10/7/2007 8:30	1.47	2.4	8.6	1,320	7.2
10/7/2007 9:30	1.47	2.4	8.5	1,330	7.1
10/7/2007 10:30	1.47	2.4	8.5	1,320	7.1
10/7/2007 11:30	1.47	2.4	8.5	1,330	7.2
10/7/2007 12:30	1.47	2.4	8.6	1,330	7.3
10/7/2007 13:30	1.47	2.4	8.7	1,330	7.4
10/7/2007 14:30	1.47	2.4	8.9	1,330	7.5
10/7/2007 15:30	1.47	2.4	9.1	1,320	7.7
10/7/2007 16:30	1.47	2.4	9.4	1,330	7.8
10/7/2007 17:30	1.47	2.4	9.4	1,330	7.8
10/7/2007 18:30	1.47	2.4	9.6	1,330	7.8
10/7/2007 19:30	1.48	2.5	9.7	1,330	7.8
10/7/2007 20:30	1.48	2.5	9.8	1,340	7.7
10/7/2007 21:30	1.48	2.5	10	1,330	7.8
10/7/2007 22:30	1.48	2.5	10	1,340	7.8

APPENDIX E. SEDIMENT PRELIMINARY JAR TESTS

Table E1. Highway 9 Preliminary Sediment Oxygen Demand Test

Coarse Material

Very little coarse material, little algae, small pieces of plants

Fine Material

Total Solid (mg/mL)	Organic (mg/mL)	Inorganic (mg/mL)	Organics (%)	Inorganic (%)
222.955	22.655	200.3	10.16	89.84

Concentration

	Temp 5°C	Temp 10°C	Temp 15°C	Temp 15°C	Temp 20°C
Time	DO	DO	DO	DO	DO
(min)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
0	7.57	7.94	9.1	8.72	9.06
10	6.82	7.27	8.22	7.82	8.13
20	6.42	6.84	7.52	7.23	7.38
30	5.92	6.55	6.99	6.71	6.71
40	5.61	6.2	6.48	6.28	6.16
50	5.33	5.94	6.09	5.85	5.71
60	5.11	5.7	5.74	5.49	5.28
70	4.95	5.47	5.46	5.15	4.87
80	4.71	5.21	5.1	4.86	4.55
90	4.51	5.03	4.77	4.61	4.26
100	4.33	4.83	4.51	4.36	3.99
110	4.16	4.66	4.26	4.18	3.73
120	4.04	4.53	4.01	3.91	
130	3.85	4.35	3.8	3.71	
140	3.73	4.18	3.58	3.53	
150	3.58	4.01	3.41	3.39	
160	3.48	3.91	3.23	3.22	
170	3.33	3.66	3.1	3.11	
180	3.21	3.53	2.95	2.93	
190	3.11	3.4	2.84	2.8	
200	3	3.33	2.69	2.67	
210	2.91	3.24		2.56	
220	2.8	3.1		2.52	
230	2.7	3.05		2.49	

Table E1. Highway 9 Preliminary Sediment Oxygen Demand Test (Continued)

Coarse Material

Very little coarse material, little algae, small pieces of plants

Fine Material

Total Solid (mg/mL)	Organic (mg/mL)	Inorganic (mg/mL)	Organics (%)	Inorganic (%)
134.54	12.72	121.82	9.45	90.55

Concentration

Time (min)	DO (mg/L)
0	8.04
10	7.41
20	7.03
30	6.95
40	6.7
50	6.32
60	5.71
70	5.08
80	4.67
90	4.33
100	4.08
110	3.89
120	3.69
130	3.55
140	3.39
150	3.27
160	3.17
170	3.06
180	2.96
190	2.86
200	2.82
210	2.75

Table E2. Johnson Bridge Preliminary Sediment Oxygen Demand Test

Coarse Material
Lots of Algae and Plantlife

Fine Material

Total Solid	Organic	Inorganic	Organics	Inorganic
(mg/mL)	(mg/mL)	(mg/mL)	(%)	(%)
160.77	23.97	136.8	14.91	85.09

Concentration

Time	DO
(min)	(mg/L)
0	7.05
10	5.12
20	3.65
30	2.62
40	1.83
50	1.24
60	0.78
70	0.43
80	0.04

Table E3. USGS Preliminary Sediment Oxygen Demand Test

Coarse Material

There was some plantlife retained but no coarse aggregates

Fine Material

Total Solid (mg/mL)	Organic (mg/mL)	Inorganic (mg/mL)	Organics (%)	Inorganic (%)
1.6532	0.1008	1.5524	6.10	93.90

Concentration

Time (min)	DO (mg/L)
0	7.09
10	6.7
20	6.45
30	6.23
40	5.99
50	5.84
60	5.71
70	5.57
80	5.46
90	5.37
100	5.28
110	5.21
120	5.13
130	5.06
140	4.97
150	4.93
160	4.87
170	4.8
180	4.76

Table E4. Stafford Bridge Preliminary Sediment Oxygen Demand Test

Coarse Material
No coarse material.

Fine Material

Total Solid (mg/mL)	Organic (mg/mL)	Inorganic (mg/mL)	Organics (%)	Inorganic (%)
129.98	17.2	112.78	13.23	86.77

Concentration

Time (min)	DO (mg/L)
0	7.45
10	6.58
20	6
30	5.52
40	5.11
50	4.75
60	4.43
70	4.16
80	3.91
90	3.71
100	3.5
110	3.32
120	3.17
130	3.03
140	2.9
150	2.76
160	2.65
170	2.55
180	2.45
190	2.36
200	2.27
210	2.18
220	2.1
230	2.01

Table E5. County Road 2 Preliminary Sediment Oxygen Demand Test

Coarse Material
Almost the entire sample is coarse material either clam shells or rocks

Fine Material

Total Solid	Organic	Inorganic	Organics	Inorganic
(mg/mL)	(mg/mL)	(mg/mL)	(%)	(%)
221.15	5.77	215.38	2.61	97.39

Concentration

Time	DO
(min)	(mg/L)
0	7.96
10	7.87
20	7.8
30	7.74
40	7.72
50	7.65
60	7.66
70	7.62
80	7.56
90	7.53
100	7.51
110	7.5
120	7.48
130	7.45

APPENDIX F. SEDIMENT MATERIAL ANALYSIS

Table F1. Sediment Sample Core Gathering Log

Site	Tube Number	Distance from Left Bank (ft)	Depth of Sample (ft)	Sediment Look/Feel	Core Gathering Ease
SB	1	2	2	Soft, Black	E
CR	2	5	1.5	Lighter on top, sandier	M
CR	3	15	2.4	Stiffer	M
CR	4	20	3.2	Stiffer	M
CR	5	33	2.5	sandy	M
CR	6	36	1.5	sandier	E
CR	Across	42			
GE	7	5	0.6	solid, clean top, black	H
GE	8	15	1.7		H
GE	9	25	2.2	smells	H
GE	10	32	1.9	black throughout	M
GE	11	38	1.1	cows come down here	M
GE	Across	42			
BX	12	68	1.4	algae area	M
BX	13	55	2.5	sandy	M
BX	15	41	2.9	muddy	E
BX	16	25.5	3	Soft, Black	E
BX	17	10	2.2	soft	E
BX	Across	76			
RD	18	53	1.7	clay and sand, gray	E
RD	19	41	3.5		E
RD	20	29	3.4	rocks, golf ball size	H
RD	21	19.5	2	coarse sandy	H
RD	22	8	0.8	sandy	E
RD	Across	58			

Table F2. Sediment Sample Percent Organic Data

Sediment Sample	Water Depth	LB[3]	Cup weight	after 103	after 550	Total Solid	Inorganic	Organic
(label)	(ft)	(ft)	(g)	(g)	(g)	(g)	(%)	(%)
Highway 9								
HW1A (aerobic layer)	9	40	43.61	44.47	44.40	0.85	92.44	7.56
HW1A (anaerobic layer)	9	40	38.65	40.18	40.08	1.53	93.33	6.67
County Road 3								
Mix[1]	2	5	43.53	44.82	44.74	1.29	93.68	6.32
Mix Aerobic			38.15	39.28	39.21	1.13	93.76	6.24
Mix Anaerobic			37.68	38.16	38.13	0.49	92.99	7.01
County Road 2								
Mix[1]			41.09	45.44	45.33	4.35	97.47	2.53
Mix[1]			38.15	41.01	40.95	2.86	97.69	2.31
Mix (aerobic layer)[2]			38.62	39.74	39.71	1.11	97.48	2.52
Mix (aerobic layer)[2]			40.51	41.44	41.41	0.93	96.98	3.02
Mix (anaerobic layer)[2]			38.19	40.86	40.80	2.67	97.82	2.18
Mix (anaerobic layer)[2]			40.22	42.81	42.76	2.59	98.02	1.98
CR1A	2	5	39.78	41.83	41.73	2.05	94.91	5.09
CR1B			41.61	45.07	44.95	3.46	96.67	3.33
CR1C			37.46	40.81	40.73	3.36	97.57	2.43
CR1D			48.35	52.13	52.04	3.78	97.67	2.33
CR2A	2	15	36.14	39.57	39.46	3.43	96.82	3.18
CR2B			42.42	44.98	44.91	2.56	97.29	2.71
CR2C			42.29	44.90	44.85	2.61	98.34	1.66
CR3A	3	20	40.27	44.41	44.32	4.14	97.98	2.02
CR3B			37.49	40.76	40.63	3.27	96.10	3.90
CR4A	3	33	36.22	40.18	40.09	3.95	97.81	2.19
CR4B			34.52	40.36	40.22	5.83	97.71	2.29
CR4C			74.75	78.08	78.00	3.33	97.61	2.39
CR4D			41.79	45.85	45.77	4.07	97.86	2.14
CR5A	2	36	35.05	40.01	39.92	4.96	98.22	1.78
CR5B			39.30	42.30	42.20	3.00	96.79	3.21
CR5C			43.69	48.81	48.71	5.12	98.07	1.93
CR5D			42.27	45.64	45.56	3.37	97.65	2.35

Table F2. Sediment Sample Percent Organic Data (Continued)

Sediment Sample	Water Depth	LB[3]	Cup weight	after 103	after 550	Total Solid	Inorganic	Organic
(label)	(ft)	(ft)	(g)	(g)	(g)	(g)	(%)	(%)
Stafford Bridge								
SB1A	2	2	41.74	43.54	43.45	1.80	95.36	4.64
SB1B			38.15	40.00	39.90	1.85	94.69	5.31
SB1C			38.19	40.46	40.34	2.27	94.55	5.45
SB1D			42.42	44.90	44.81	2.48	96.44	3.56
Road Crossing								
Mix[1]			36.89	41.25	41.18	4.37	98.20	1.80
Mix[1]			34.57	37.01	36.98	2.44	98.53	1.47
Mix (aerobic layer)[2]			38.19	39.14	39.13	0.95	98.86	1.14
Mix (aerobic layer)[2]			36.13	36.96	36.95	0.83	98.29	1.71
Mix (anaerobic layer)[2]			34.57	38.80	38.75	4.24	98.81	1.19
Mix (anaerobic layer)[2]			40.22	43.76	43.71	3.54	98.56	1.44
RD1A	1	8	36.13	39.76	39.74	3.62	99.58	0.42
RD1B			37.67	41.58	41.57	3.91	99.56	0.44
RD1C			34.57	37.53	37.51	2.96	99.41	0.59
RD2A	2	20	39.78	44.18	44.16	4.40	99.57	0.43
RD2B			42.29	45.24	45.22	2.95	99.45	0.55
RD2C			43.69	46.72	46.68	3.03	98.66	1.34
RD2D			40.27	45.64	45.60	5.37	99.24	0.76
RD3A	3	29	41.79	46.12	46.06	4.33	98.57	1.43
RD3B			42.27	46.99	46.93	4.73	98.60	1.40
RD3C			39.21	42.56	42.52	3.34	98.89	1.11
RD4A	4	41	42.76	47.27	47.13	4.51	97.01	2.99
RD4B			36.35	39.39	39.32	3.04	97.75	2.25
RD4C			34.55	36.27	36.23	1.72	97.77	2.23
RD5A	2	53	41.61	43.99	43.95	2.38	97.96	2.04
RD5B			35.05	40.83	40.72	5.78	98.01	1.99

Table F2. Sediment Sample Percent Organic Data (Continued)

Sediment Sample	Water Depth	LB[3]	Cup weight	after 103	after 550	Total Solid	Inorganic	Organic
(label)	(ft)	(ft)	(g)	(g)	(g)	(g)	(%)	(%)
Bridge Crossing								
Mix[1]			41.51	42.79	42.75	1.28	96.64	3.36
Mix[1]			37.60	39.95	39.89	2.35	97.17	2.83
Mix (aerobic layer)[2]			41.07	41.81	41.78	0.74	96.08	3.92
Mix (aerobic layer)[2]			36.04	37.64	37.60	1.61	97.08	2.92
Mix (anaerobic layer)[2]			40.08	42.99	42.92	2.91	97.27	2.73
Mix (anaerobic layer)[2]			36.35	38.73	38.66	2.39	96.91	3.09
BX1A	2	10	36.36	38.23	38.13	1.87	94.60	5.40
BX1B	2		51.55	53.04	52.99	1.49	96.72	3.28
BX1C	2		42.42	44.51	44.46	2.09	97.55	2.45
BX1D	2		37.50	39.80	39.76	2.30	98.03	1.97
BX2A	3	26	35.95	38.51	38.41	2.57	95.90	4.10
BX2B	3		35.06	36.63	36.58	1.57	96.77	3.23
BX2C	3		34.52	38.97	38.88	4.45	98.14	1.86
BX2D	2		42.03	46.23	46.19	4.21	99.08	0.92
BX3A	3	41	53.17	55.20	55.08	2.02	94.46	5.54
BX3B	3		39.29	41.74	41.68	2.45	97.76	2.24
BX3C	3		41.61	43.73	43.68	2.12	97.33	2.67
BX3D	2		42.17	45.18	45.13	3.01	98.61	1.39
BX4A	3	55	36.34	38.37	38.30	2.03	96.41	3.59
BX4B	2		41.79	44.32	44.28	2.54	98.22	1.78
BX4C	2		37.31	41.51	41.45	4.20	98.77	1.23
BX4D	2		42.47	46.31	46.27	3.84	98.89	1.11
BX5A	1	68	53.19	54.65	54.56	1.45	94.18	5.82
BX5B	1		42.53	44.67	44.57	2.13	95.68	4.32
BX5C	1		40.77	42.99	42.87	2.23	94.55	5.45
BX5D	1		39.07	41.22	41.14	2.16	96.10	3.90

Table F2. Sediment Sample Percent Organic Data (Continued)

Sediment Sample	Water Depth	LB[3]	Cup weight	after 103	after 550	Total Solid	Inorganic	Organic
(label)	(ft)	(ft)	(g)	(g)	(g)	(g)	(%)	(%)
Glen Ewen								
Mix[1]			36.13	41.61	41.56	5.48	99.01	0.99
Mix[1]			36.34	40.32	40.27	3.97	98.76	1.24
Mix (aerobic layer)[2]			38.19	39.14	39.13	0.95	98.86	1.14
Mix (aerobic layer)[2]			36.13	36.96	36.95	0.83	98.29	1.71
Mix (anaerobic layer)[2]			34.57	38.80	38.75	4.24	98.81	1.19
Mix (anaerobic layer)[2]			40.22	43.76	43.71	3.54	98.56	1.44
GE1A	1	5	40.18	42.36	42.34	2.18	99.25	0.75
GE1B		5	42.41	45.68	45.64	3.26	99.01	0.99
GE1C		5	42.03	45.93	45.90	3.90	99.22	0.78
GE1D		5	38.03	41.97	41.94	3.94	99.30	0.70
GE2A	2	15	41.85	45.44	45.42	3.59	99.44	0.56
GE2B		15	42.53	47.31	47.27	4.78	99.14	0.86
GE2C		15	37.19	40.46	40.42	3.27	98.67	1.33
GE3A	2	25	41.38	45.74	45.71	4.35	99.39	0.61
GE3B		25	40.51	45.02	44.93	4.50	98.12	1.88
GE3C		25	42.47	46.55	46.44	4.09	97.36	2.64
GE3D		25	40.49	43.62	43.51	3.13	96.41	3.59
GE4A	2	32	35.77	38.91	38.87	3.14	98.47	1.53
GE4B		32	37.60	40.16	40.10	2.56	97.54	2.46
GE4C		32	39.07	42.35	42.28	3.28	97.89	2.11
GE4D		32	39.78	42.61	42.54	2.83	97.44	2.56
GE5A	1	38	42.70	46.40	46.31	3.70	97.66	2.34
GE5B		38	43.53	45.58	45.52	2.05	96.87	3.13
GE5C		38	42.17	45.79	45.68	3.62	96.99	3.01
GE5D		38	40.76	44.30	44.21	3.53	97.45	2.55

Note:
1. Testing took place before SOD experiment
2. Testing took place after SOD experiment
3. Distance sediment sample was taken from left bank of river facing downstream.

Table F3. Sediment Sample Percent Fine and Coarse Material

				Fine			Coarse		
Sample Number	Sediment Sample	Water Depth	LB	Cup weight	after 103	after 550	Cup Weight	after 103	after 550
(#)	(label)	(ft)	(ft)	(g)	(g)	(g)	(g)	(g)	(g)
1	SB1A	2	2	41.458	44.019	43.935	42.141	42.387	42.366
2	SB1B			39.293	41.269	41.172	38.624	38.811	38.791
3	SB1C			35.945	37.501	37.436	39.469	39.683	39.659
4	SB1D			36.13	38.364	38.276	38.088	38.25	38.228
5	CR1A	1.5	5	38.71	42.149	42.041	39.214	39.327	39.303
6	CR1B			37.598	40.878	40.789	35.774	35.817	35.804
7	CR1C			53.183	56.273	56.178	51.552	51.592	51.582
8	CR1D			53.235	57.31	57.221	43.531	43.728	43.713
9	CR2A	2.4	15	43.528	46.06	45.98	36.618	36.666	36.665
10	CR2B			41.456	45.727	45.635	35.847	38.955	35.938
11	CR2C			39.467	43.293	43.201	40.196	40.537	40.522
12	CR3A	3.2	20	37.676	40.372	40.306	41.397	41.535	41.524
13	CR3B			36.88	41.912	41.716	40.217	40.483	40.438
14	CR4A	2.5	33	52.45	56.189	56.096	40.514	40.574	40.567
15	CR4B			42.786	45.511	45.445	42.702	42.767	42.761
16	CR4C			42.756	47.346	47.23	41.27	41.303	41.298
17	CR4D			38.813	43.028	42.95	36.134	36.189	36.188
18	CR5A	1.5	36	35.953	39.831	39.756	37.631	37.69	37.681
19	CR5B			37.484	42.242	42.111	38.626	38.776	38.771
20	CR5C			35.011	38.97	38.892	43.971	44.011	44.007
21	CR5D			38.147	42.407	42.338	38.089	38.158	38.152
22	RD1A	0.8	8	38.483	43.462	43.44	36.04	36.211	36.21
23	RD1B			37.483	42.003	41.976	41.766	41.956	41.954
24	RD1C			51.551	55.537	55.517	38.811	38.959	38.958
25	RD2A	2	20	38.649	41.862	41.85	41.412	41.706	41.705
26	RD2B			41.093	45.128	45.12	35.849	36.062	36.061
27	RD2C			41.269	45.168	45.099	38.147	38.535	38.52
28	RD2D			37.486	39.936	39.925	37.632	38.571	38.566
29	RD3A	3.4	29	43.531	45.675	45.64	37.456	37.753	37.741
30	RD3B			40.223	42.027	42.01	43.97	44.247	44.226
31	RD3C			36.703	38.731	38.704	74.747	75.776	75.77
32	RD4A	3.5	41	42.786	44.844	44.793	42.48	42.521	42.511
33	RD4B			36.222	38.486	38.425	53.181	53.276	53.269

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

				Fine			Coarse		
Sample Number	Sediment Sample	Water Depth	LB	Cup weight	after 103	after 550	Cup Weight	after 103	after 550
(#)	(label)	(ft)	(ft)	(g)	(g)	(g)	(g)	(g)	(g)
34	RD4C			40.565	44.532	44.487	53.202	53.388	53.354
35	RD5A	1.7	53	35.015	38.604	38.553	41.077	41.121	41.111
36	RD5B			41.863	45.11	45.056	40.198	40.222	40.216
37	BX1A	2.2	10	42.444	45.068	44.952	42.168	42.206	42.203
38	BX1B			43.904	48.5	48.31	38.147	38.227	38.221
39	BX1C			35.775	39.137	39.084	42.786	43.134	43.107
40	BX1D			35.951	38.051	37.996	37.599	37.789	37.776
41	BX2A	3	26	37.312	39.89	39.801	41.854	42.492	42.484
42	BX2B			52.447	56.453	56.378	37.673	39.418	39.353
43	BX2C			41.386	45.674	45.599	53.175	54.132	54.11
44	BX2D			36.613	44.279	44.022	53.194	55.342	55.328
45	BX3A	2.9	41	40.582	44.316	44.105	42.545	42.838	42.819
46	BX3B			39.215	42.325	42.244	38.714	38.991	38.983
47	BX3C			40.513	44.927	44.861	37.623	37.934	37.921
48	BX3D			51.551	54.976	54.939	43.525	43.728	43.694
49	BX4A	2.5	55	42.029	45.113	45.005	40.492	40.531	40.523
50	BX4B			36.34	39.953	39.912	41.511	41.599	41.584
51	BX4C			38.19	43.293	43.208	41.739	41.82	41.806
52	BX4D			40.559	44.799	44.709	38.648	38.72	38.716
53	BX5A	1.4	68	39.089	41.477	41.378	39.782	39.834	39.823
54	BX5B			40.217	42.377	42.286	37.71	37.762	37.754
55	BX5C			38.81	42.536	42.404	38.481	38.535	38.525
56	BX5D			39.084	41.47	41.4	39.701	39.822	39.822
57	GE1A	0.6	5	42.481	45.341	45.32	41.862	44.404	44.393
58	GE1B			36.704	38.739	38.706	38.486	40.97	40.951
59	GE1C			34.571	36.247	36.231	42.144	44.783	44.77
60	GE1D			41.769	43.558	43.539	37.484	40.124	40.108
61	GE2A	1.7	15	41.509	42.601	42.588	36.34	39.052	39.038
62	GE2B			38.65	40.628	40.588	38.189	41.015	40.992
63	GE2C			36.222	39.374	39.334	40.268	41.026	41.015
64	GE3A	2.2	25	36.352	38.908	38.849	41.786	44.165	44.139
65	GE3B			41.611	46.587	46.485	43.689	43.879	43.859
66	GE3C			35.055	38.772	38.699	39.294	39.438	39.428

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

				Fine			Coarse		
Sample Number	Sediment Sample	Water Depth	LB	Cup weight	after 103	after 550	Cup Weight	after 103	after 550
(#)	(label)	(ft)	(ft)	(g)	(g)	(g)	(g)	(g)	(g)
67	GE3D			41.077	43.421	43.356	36.137	36.308	36.3
68	GE4A	1.9	32	37.456	41.25	41.209	36.042	36.27	36.262
69	GE4B			34.517	37.19	37.129	41.74	41.85	41.846
70	GE4C			42.269	45.448	45.396	42.287	42.547	42.54
71	GE4D			48.35	52.72	52.62	39.778	40.091	40.086
72	GE5A	1.1	38	37.712	41.11	41.033	42.42	42.469	42.462
73	GE5B			40.086	45.544	45.409	74.749	74.805	74.793
74	GE5C			38.711	42.691	42.631	37.673	37.712	37.707
75	GE5D			36.612	41.639	41.54	39.214	39.272	39.269

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

	Fine Material						Coarse Material		
Sample Number	Inorganic	Organic	Total	Organic	Inorganic	% of Total Organic	Inorganic	Organic	Total
(#)	(g)	(g)	(g)	(%)	(%)	(%)	(g)	(g)	(g)
1	2.4775	0.0835	2.561	3.26	96.74	80.06	0.2244	0.0208	0.245
2	1.8797	0.0961	1.976	4.86	95.14	82.56	0.1666	0.0203	0.187
3	1.4915	0.065	1.557	4.18	95.82	73.20	0.1905	0.0238	0.214
4	2.146	0.0872	2.233	3.90	96.10	80.07	0.1402	0.0217	0.162
5	3.3309	0.1082	3.439	3.15	96.85	81.48	0.0885	0.0246	0.113
6	3.1913	0.0892	3.281	2.72	97.28	87.97	0.0305	0.0122	0.043
7	2.9944	0.0952	3.09	3.08	96.92	91.10	0.0301	0.0093	0.039
8	3.9856	0.0897	4.075	2.20	97.80	85.92	0.1822	0.0147	0.197
9	2.4517	0.0802	2.532	3.17	96.83	99.13	0.047	0.0007	0.048
10	4.1795	0.0918	4.271	2.15	97.85	2.95	0.091	3.0172	3.108
11	3.7337	0.0923	3.826	2.41	97.59	86.10	0.3257	0.0149	0.341
12	2.6305	0.0655	2.696	2.43	97.57	86.30	0.1272	0.0104	0.138
13	4.8357	0.1963	5.032	3.90	96.10	81.32	0.2205	0.0451	0.266
14	3.6457	0.0934	3.739	2.50	97.50	93.59	0.0532	0.0064	0.06
15	2.6583	0.066	2.724	2.42	97.58	92.70	0.0599	0.0052	0.065
16	4.474	0.1155	4.59	2.52	97.48	96.25	0.0286	0.0045	0.033
17	4.137	0.0783	4.215	1.86	98.14	98.86	0.0543	0.0009	0.055
18	3.8027	0.0748	3.878	1.93	98.07	89.37	0.0505	0.0089	0.059
19	4.6267	0.1313	4.758	2.76	97.24	96.26	0.1448	0.0051	0.15
20	3.8803	0.0788	3.959	1.99	98.01	95.28	0.0358	0.0039	0.04
21	4.1915	0.0683	4.26	1.60	98.40	92.30	0.0632	0.0057	0.069
22	4.957	0.0213	4.978	0.43	99.57	93.01	0.1697	0.0016	0.171
23	4.4934	0.0266	4.52	0.59	99.41	90.78	0.1879	0.0027	0.191
24	3.9658	0.0199	3.986	0.50	99.50	94.76	0.1469	0.0011	0.148
25	3.2008	0.0121	3.213	0.38	99.62	93.08	0.2931	0.0009	0.294
26	4.0265	0.0077	4.034	0.19	99.81	93.90	0.212	0.0005	0.213
27	3.8304	0.0694	3.9	1.78	98.22	81.94	0.3725	0.0153	0.388
28	2.4384	0.0111	2.45	0.45	99.55	65.29	0.9332	0.0059	0.939
29	2.1087	0.0354	2.144	1.65	98.35	75.32	0.2854	0.0116	0.297
30	1.7869	0.0168	1.804	0.93	99.07	44.33	0.2558	0.0211	0.277
31	2.0012	0.0275	2.029	1.36	98.64	81.85	1.023	0.0061	1.029
32	2.0068	0.0508	2.058	2.47	97.53	83.14	0.0306	0.0103	0.041
33	2.2033	0.0605	2.264	2.67	97.33	89.36	0.0884	0.0072	0.096

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

	Fine Material						Coarse Material		
Sample Number	Inorganic	Organic	Total	Organic	Inorganic	% of Total Organic	Inorganic	Organic	Total
(#)	(g)	(g)	(g)	(%)	(%)	(%)	(g)	(g)	(g)
34	3.9225	0.0446	3.967	1.12	98.88	57.25	0.1529	0.0333	0.186
35	3.5384	0.0508	3.589	1.42	98.58	83.97	0.0342	0.0097	0.044
36	3.1931	0.0541	3.247	1.67	98.33	89.42	0.0176	0.0064	0.024
37	2.5082	0.1163	2.625	4.43	95.57	97.08	0.0343	0.0035	0.038
38	4.4055	0.19	4.595	4.13	95.87	97.24	0.0747	0.0054	0.08
39	3.3091	0.0522	3.361	1.55	98.45	65.33	0.3205	0.0277	0.348
40	2.0457	0.055	2.101	2.62	97.38	81.72	0.1771	0.0123	0.189
41	2.489	0.0891	2.578	3.46	96.54	92.24	0.6297	0.0075	0.637
42	3.9304	0.0756	4.006	1.89	98.11	53.77	1.6805	0.065	1.746
43	4.2127	0.0756	4.288	1.76	98.24	77.86	0.9352	0.0215	0.957
44	7.4093	0.2568	7.666	3.35	96.65	94.83	2.1336	0.014	2.148
45	3.5228	0.2112	3.734	5.66	94.34	91.79	0.2735	0.0189	0.292
46	3.0289	0.0805	3.109	2.59	97.41	91.17	0.2698	0.0078	0.278
47	4.348	0.066	4.414	1.50	98.50	82.91	0.298	0.0136	0.312
48	3.3882	0.0373	3.426	1.09	98.91	52.39	0.1684	0.0339	0.202
49	2.976	0.1082	3.084	3.51	96.49	93.44	0.0307	0.0076	0.038
50	3.572	0.0408	3.613	1.13	98.87	73.91	0.0735	0.0144	0.088
51	5.0188	0.0844	5.103	1.65	98.35	85.95	0.0674	0.0138	0.081
52	4.1498	0.0901	4.24	2.13	97.87	95.55	0.0681	0.0042	0.072
53	2.289	0.0993	2.388	4.16	95.84	90.35	0.0412	0.0106	0.052
54	2.0691	0.0907	2.16	4.20	95.80	91.43	0.0443	0.0085	0.053
55	3.594	0.1322	3.726	3.55	96.45	93.03	0.0438	0.0099	0.054
56	2.3161	0.0703	2.386	2.95	97.05	99.58	0.1216	0.0003	0.122
57	2.8384	0.0212	2.86	0.74	99.26	66.04	2.531	0.0109	2.542
58	2.0017	0.0336	2.035	1.65	98.35	64.37	2.4653	0.0186	2.484
59	1.6601	0.0157	1.676	0.94	99.06	55.48	2.6255	0.0126	2.638
60	1.7696	0.0194	1.789	1.08	98.92	54.04	2.6232	0.0165	2.64
61	1.0786	0.013	1.092	1.19	98.81	48.33	2.6973	0.0139	2.711
62	1.938	0.0394	1.977	1.99	98.01	63.86	2.8038	0.0223	2.826
63	3.1117	0.0398	3.152	1.26	98.74	78.66	0.7465	0.0108	0.757
64	2.4979	0.0581	2.556	2.27	97.73	68.84	2.3525	0.0263	2.379
65	4.8745	0.1018	4.976	2.05	97.95	83.10	0.1693	0.0207	0.19
66	3.6443	0.073	3.717	1.96	98.04	87.64	0.1337	0.0103	0.144

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

	Fine Material						Coarse Material		
Sample Number	Inorganic	Organic	Total	Organic	Inorganic	% of Total Organic	Inorganic	Organic	Total
(#)	(g)	(g)	(g)	(%)	(%)	(%)	(g)	(g)	(g)
67	2.2781	0.0655	2.344	2.79	97.21	89.97	0.1638	0.0073	0.171
68	3.7538	0.0406	3.794	1.07	98.93	82.69	0.22	0.0085	0.228
69	2.6117	0.061	2.673	2.28	97.72	93.70	0.1059	0.0041	0.11
70	3.1267	0.0519	3.179	1.63	98.37	86.93	0.2524	0.0078	0.26
71	4.2697	0.1003	4.37	2.30	97.70	95.25	0.3079	0.005	0.313
72	3.3209	0.0768	3.398	2.26	97.74	91.65	0.0417	0.007	0.049
73	5.3229	0.1348	5.458	2.47	97.53	91.95	0.0443	0.0118	0.056
74	3.92	0.0603	3.98	1.51	98.49	91.23	0.0335	0.0058	0.039
75	4.9278	0.0987	5.027	1.96	98.04	96.48	0.0544	0.0036	0.058

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

	Coarse Material			Percent Material		Total % Organic from fine and coarse seperated material	% Organic from non-seperated material
Sample Number	Organic	Inorganic	% of Total Organic	Fine	Coarse		
(#)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
1	8.48	91.52	19.94	91.26	8.74	3.72	4.64
2	10.86	89.14	17.44	91.36	8.64	5.38	5.31
3	11.11	88.89	26.80	87.90	12.10	5.01	5.45
4	13.40	86.60	19.93	93.24	6.76	4.55	3.56
5	21.75	78.25	18.52	96.82	3.18	3.74	5.09
6	28.57	71.43	12.03	98.72	1.28	3.05	3.33
7	23.60	76.40	8.90	98.74	1.26	3.34	2.43
8	7.47	92.53	14.08	95.39	4.61	2.44	2.33
9	1.47	98.53	0.87	98.15	1.85	3.14	3.18
10	97.07	2.93	97.05	57.88	42.12	42.13	2.71
11	4.37	95.63	13.90	91.83	8.17	2.57	1.66
12	7.56	92.44	13.70	95.14	4.86	2.68	2.02
13	16.98	83.02	18.68	94.99	5.01	4.56	3.90
14	10.74	89.26	6.41	98.43	1.57	2.63	2.19
15	7.99	92.01	7.30	97.67	2.33	2.55	2.29
16	13.60	86.40	3.75	99.28	0.72	2.60	2.39
17	1.63	98.37	1.14	98.71	1.29	1.85	2.14
18	14.98	85.02	10.63	98.49	1.51	2.13	1.78
19	3.40	96.60	3.74	96.95	3.05	2.78	3.21
20	9.82	90.18	4.72	99.01	0.99	2.07	1.93
21	8.27	91.73	7.70	98.41	1.59	1.71	2.35
22	0.93	99.07	6.99	96.67	3.33	0.44	0.42
23	1.42	98.58	9.22	95.95	4.05	0.62	0.44
24	0.74	99.26	5.24	96.42	3.58	0.51	0.59
25	0.31	99.69	6.92	91.62	8.38	0.37	0.43
26	0.24	99.76	6.10	95.00	5.00	0.19	0.55
27	3.95	96.05	18.06	90.96	9.04	1.98	1.34
28	0.63	99.37	34.71	72.29	27.71	0.50	0.76
29	3.91	96.09	24.68	87.83	12.17	1.93	1.43
30	7.62	92.38	55.67	86.69	13.31	1.82	1.40
31	0.59	99.41	18.15	66.35	33.65	1.10	1.11
32	25.18	74.82	16.86	98.05	1.95	2.91	2.99
33	7.53	92.47	10.64	95.95	4.05	2.87	2.25

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

	Coarse Material			Percent Material			
Sample Number	Organic	Inorganic	% of Total Organic	Fine	Coarse	Total % Organic from fine and coarse seperated material	% Organic from non-seperated material
(#)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
34	17.88	82.12	42.75	95.52	4.48	1.88	2.23
35	22.10	77.90	16.03	98.79	1.21	1.67	2.04
36	26.67	73.33	10.58	99.27	0.73	1.85	1.99
37	9.26	90.74	2.92	98.58	1.42	4.50	5.40
38	6.74	93.26	2.76	98.29	1.71	4.18	3.28
39	7.96	92.04	34.67	90.61	9.39	2.15	2.45
40	6.49	93.51	18.28	91.73	8.27	2.94	1.97
41	1.18	98.82	7.76	80.18	19.82	3.00	4.10
42	3.72	96.28	46.23	69.65	30.35	2.44	3.23
43	2.25	97.75	22.14	81.76	18.24	1.85	1.86
44	0.65	99.35	5.17	78.12	21.88	2.76	0.92
45	6.46	93.54	8.21	92.74	7.26	5.71	5.54
46	2.81	97.19	8.83	91.80	8.20	2.61	2.24
47	4.36	95.64	17.09	93.41	6.59	1.68	2.67
48	16.76	83.24	47.61	94.42	5.58	1.96	1.39
49	19.84	80.16	6.56	98.77	1.23	3.71	3.59
50	16.38	83.62	26.09	97.62	2.38	1.49	1.78
51	17.00	83.00	14.05	98.43	1.57	1.89	1.23
52	5.81	94.19	4.45	98.32	1.68	2.19	1.11
53	20.46	79.54	9.65	97.88	2.12	4.50	5.82
54	16.10	83.90	8.57	97.61	2.39	4.48	4.32
55	18.44	81.56	6.97	98.58	1.42	3.76	5.45
56	0.25	99.75	0.42	95.14	4.86	2.81	3.90
57	0.43	99.57	33.96	52.94	47.06	0.59	0.75
58	0.75	99.25	35.63	45.04	54.96	1.16	0.99
59	0.48	99.52	44.52	38.85	61.15	0.66	0.78
60	0.63	99.37	45.96	40.40	59.60	0.81	0.70
61	0.51	99.49	51.67	28.71	71.29	0.71	0.56
62	0.79	99.21	36.14	41.17	58.83	1.28	0.86
63	1.43	98.57	21.34	80.63	19.37	1.29	1.33
64	1.11	98.89	31.16	51.80	48.20	1.71	0.61
65	10.89	89.11	16.90	96.32	3.68	2.37	1.88
66	7.15	92.85	12.36	96.27	3.73	2.16	2.64

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

	Coarse Material			Percent Material			
Sample Number	Organic	Inorganic	% of Total Organic	Fine	Coarse	Total % Organic from fine and coarse seperated material	% Organic from non-seperated material
(#)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
67	4.27	95.73	10.03	93.20	6.80	2.89	3.59
68	3.72	96.28	17.31	94.32	5.68	1.22	1.53
69	3.73	96.27	6.30	96.05	3.95	2.34	2.46
70	3.00	97.00	13.07	92.43	7.57	1.74	2.11
71	1.60	98.40	4.75	93.32	6.68	2.25	2.56
72	14.37	85.63	8.35	98.59	1.41	2.43	2.34
73	21.03	78.97	8.05	98.98	1.02	2.66	3.13
74	14.76	85.24	8.77	99.02	0.98	1.64	3.01
75	6.21	93.79	3.52	98.86	1.14	2.01	2.55

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

Sample Number	Difference	Difference squared
(#)		
1	-0.93	0.86
2	0.07	0.00
3	-0.43	0.19
4	0.99	0.98
5	-1.35	1.83
6	-0.28	0.08
7	0.91	0.82
8	0.11	0.01
9	-0.04	0.00
10		0.00
11	0.91	0.82
12	0.66	0.44
13	0.66	0.43
14	0.44	0.19
15	0.26	0.07
16	0.21	0.04
17	-0.28	0.08
18	0.35	0.12
19	-0.43	0.19
20	0.14	0.02
21	-0.64	0.42
22	0.03	0.00
23	0.18	0.03
24	-0.08	0.01
25	-0.06	0.00
26	-0.36	0.13
27	0.64	0.41
28	-0.26	0.07
29	0.50	0.25
30	0.42	0.18
31	-0.01	0.00
32	-0.08	0.01
33	0.62	0.39

Original vs. Separated Fine	
Description	**Value**
Average	-0.03
Median	-0.02
Minimum	-1.69
Maximum	1.84
Sum	-2.09
Number of Samples	75.00
Standard Deviation	0.65

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

Sample Number	Difference	Difference squared
(#)		
34	-0.36	0.13
35	-0.38	0.14
36	-0.14	0.02
37	-0.90	0.80
38	0.90	0.80
39	-0.29	0.09
40	0.97	0.94
41	-1.10	1.20
42	-0.79	0.62
43	-0.01	0.00
44	1.84	3.38
45	0.18	0.03
46	0.37	0.13
47	-0.98	0.96
48	0.57	0.32
49	0.12	0.01
50	-0.29	0.08
51	0.67	0.44
52	1.08	1.16
53	-1.31	1.72
54	0.16	0.03
55	-1.69	2.85
56	-1.08	1.18
57	-0.16	0.03
58	0.17	0.03
59	-0.12	0.01
60	0.11	0.01
61	0.14	0.02
62	0.43	0.18
63	-0.03	0.00
64	1.10	1.22
65	0.49	0.24
66	-0.49	0.24

Table F3. Sediment Sample Percent Fine and Coarse Material (Continued)

Sample Number	Difference	Difference squared
(#)		
67	-0.69	0.48
68	-0.31	0.10
69	-0.12	0.01
70	-0.38	0.14
71	-0.31	0.10
72	0.09	0.01
73	-0.48	0.23
74	-1.37	1.86
75	-0.54	0.29
		31.31

Table F4. Sediment Sample Variance Sampling

County Road 3 Sample Tests for Percent Organics

Test	Cup weight	After 103°C	After 550°C	Total Solid	In-organic	Organic	Differ-ence
(#)	(g)	(g)	(g)	(g)	(%)	(%)	(Diff^2)
1	43.530	44.819	44.737	1.289	93.68	6.32	0.01
2	38.476	39.596	39.526	1.120	93.75	6.25	0.00
3	38.425	39.385	39.321	0.961	93.24	6.76	0.28
4	38.106	39.154	39.084	1.048	93.32	6.68	0.20
5	39.251	40.271	40.201	1.021	93.14	6.86	0.39
6	43.129	44.422	44.340	1.294	93.63	6.37	0.02
7	43.199	44.086	44.041	0.887	94.92	5.08	1.34
8	41.518	42.718	42.648	1.200	94.17	5.83	0.16
9	46.874	48.234	48.154	1.359	94.11	5.89	0.12
10	38.419	39.529	39.459	1.110	93.70	6.30	0.01
							2.52

Description	Value
Average	6.23
Median	6.31
Minimum	5.08
Maximum	6.86
Sum	62.34
Number of Samples	10.00
Standard Deviation	0.27

Table F4. Sediment Sample Variance Sampling (Continued)

Stafford Bridge Sample Tests for Percent Coarse

			Fine			Coarse			
Test	Cup weight	After 103°C	Total Material	Cup Weight	After 103°C	Total Material	Fine	Coarse	Differ-ence
(#)	(g)	(g)	(g)	(g)	(g)	(g)	(%)	(%)	(Diff^2)
1	41.458	44.019	2.561	42.141	42.387	0.245	91.26	8.74	1.35
2	37.450	39.980	2.530	38.416	38.618	0.203	92.58	7.42	6.16
3	38.543	43.005	4.462	37.999	38.453	0.454	90.76	9.24	0.43
4	37.778	39.520	1.742	37.850	38.042	0.192	90.06	9.94	0.00
5	43.169	45.794	2.625	37.158	37.511	0.353	88.15	11.85	3.82
6	43.198	45.726	2.528	38.520	38.990	0.470	84.32	15.68	33.38
7	43.128	48.205	5.076	44.698	45.291	0.592	89.55	10.45	0.30
8	41.519	44.019	2.500	59.001	59.300	0.299	89.32	10.68	0.61
9	38.476	42.505	4.029	38.504	38.892	0.387	91.23	8.77	1.27
10	38.152	43.780	5.628	38.671	39.045	0.374	93.77	6.23	13.46
									60.78

Description	Value
Average	9.90
Median	9.59
Minimum	6.23
Maximum	15.68
Sum	99.00
Number of Samples	10.00
Standard Deviation	6.41

APPENDIX G. SEDIMENT OXYGEN DEMAND TESTING

Table G1. Sediment Oxygen Demand Reactor Velocity Configuration

Velocity of Water in a Reactor

Circumference (ft) 0.785425

Stirrer (rpm)	Stirrer (rps)	Stirrer Tip Velocity (ft/s)	Water Velocity[1] (ft/s)	Water Velocity[2] (ft/s)
6	0.10	0.08	0.03	0.06
7	0.12	0.09	0.03	0.07
8	0.13	0.10	0.03	0.08
9	**0.15**	**0.12**	**0.04**	**0.09**
10	0.17	0.13	0.04	0.10
11	0.18	0.14	0.05	0.11
12	0.20	0.16	0.05	0.12
13	0.22	0.17	0.06	0.13
14	0.23	0.18	0.06	0.14
15	0.25	0.20	0.07	0.15
16	0.27	0.21	0.07	0.16
17	**0.28**	**0.22**	**0.07**	**0.17**
18	0.30	0.24	0.08	0.18
19	0.32	0.25	0.08	0.19
20	0.33	0.26	0.09	0.20
21	0.35	0.27	0.09	0.21
22	0.37	0.29	0.10	0.22
23	0.38	0.30	0.10	0.23
24	0.40	0.31	0.10	0.24
25	0.42	0.33	0.11	0.25
26	**0.43**	**0.34**	**0.11**	**0.26**
27	0.45	0.35	0.12	0.27
28	0.47	0.37	0.12	0.29
29	0.48	0.38	0.13	0.30
30	0.50	0.39	0.13	0.31
31	0.52	0.41	0.14	0.32
32	0.53	0.42	0.14	0.33
33	0.55	0.43	0.14	0.34
34	**0.57**	**0.45**	**0.15**	**0.35**
35	0.58	0.46	0.15	0.36
36	0.60	0.47	0.16	0.37

1.Velocity of water for container that is two times the stirrer paddle diameter.

2.Velocity of water for our experiment where reactor is 1/3 of 2 times the paddle diameter.

Table G2. Sediment Oxygen Demand Testing Results at 20^{o}C

Time	County Road 3	County Road 2	Road Crossing	Bridge Crossing	Glen Ewen
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20	7.9	7.27	6.52	6.28	7.55
40	7.8	7.17	6.5	6	7.58
60	7.7	7.04	6.45	6.14	7.42
80	7.58	7.18	5.78	6.14	7.5
100	7.51	7.03	6.45	5.95	7
120	7.43	6.94	6.32	6.05	7.35
140	7.31	6.83	6.26	5.99	7.36
160	7.25	6.74	6.26	5.89	7.23
180	7.21	6.74	6.12	6.13	7.32
200	7.08	6.56	6.23	5.87	7.08
220	7.03	6.49	6.14	5.76	7.19
240	6.9	6.52	5.96	5.75	7.12
260	6.81	6.38	6.05	5.86	7.06
280	6.74	6.4	5.83	5.64	7.02
300	6.64	6.23	5.84	5.61	
320	6.59	6.18	5.94	5.58	
340	6.51	6.16	5.87	5.51	6.93
360	6.43	6.08	5.61	5.42	6.74
380	6	6.05	5.85	5.42	6.84
400	6.29	5.96	5.71	5.35	6.84
420	6.26	5	5.59	5.38	6.87
440	6.17	5.84	5.68	5.35	6.65
460	6.13	5.82	5.66	5.26	6.72
480	6.09	5.71	5.17	5.24	6.77
500	6.02	5.68	5.55	5.14	6.68
520	5.91	5.67	5.73	5.12	6.45
540	5.85	5.58	5.25	5.05	6.55
560	5.81	5.5	5.59	5.1	6.46
580	5.72	5.48	5.26	5.05	6.48
600	5.66	5.34	5.37	4.99	6.49
620	5.61	5.38	4.58	4.95	6.49
640	5.56	5.23	4.96	4.9	6.38
660	5.54	5.27	5.04	4.85	6.23
680	5.48	5.22	5.19	4.77	6.39
700	5.38	5.21	5.04	5.3	6.22
720	5.37	5.13	5.32	4.57	6.06
740	5.29	5.1	5.25	4.67	6.24

Table G2. Sediment Oxygen Demand Testing Results at 20^{o}C (Continued)

Time (min)	County Road 3 DO (mg/L)	County Road 2 DO (mg/L)	Road Crossing DO (mg/L)	Bridge Crossing DO (mg/L)	Glen Ewen DO (mg/L)
760	5.25	4.99	5.22	4.64	6.18
780	5.2	5.01	5.25	4.58	6.25
800	5.14	4.91	5.03	4.61	6.21
820	5.11	4.95	4.96	4.55	6.21
840	5.06	4.9	5.11	4.48	6.2
860	5.04	4.84	5.03	4.5	5.79
880	4.97	4.74	4.96	4.41	6.11
900	4.94	4.76	5.11	4.37	6.07
920	4.87	4.68	5.03	4.36	6.02
940	4.85	4.72	4.57	4.36	6.08
960	4.78	4.57	4.45	4.32	5.89
980	4.73	4.53	4.81	4.29	5.99
1000	4.69	4.52	4.92	4.25	6.01
1020	4.63	4.48	4.86	4.27	5.96
1040	4.59	4.45	4.73	4.16	5.84
1060	4.55	4.39	4.88	4.12	5.89
1080	4.51	4.39	4.71	4.13	5.83
1100	4.45	4.36	4.77	4.06	5.83
1120	4.43	4.29	4.8	3.99	5.73
1140	4.38	4.32	4.39	3.99	5.77
1160	4.35	4.29	4.61	4.03	5.75
1180	4.29	4.2	4.64	3.86	5.65
1200	4.23	4.18	4.43	3.89	5.69
1220	4.22	4.11	4.67	3.85	5.62
1240	4.16	4.13	4.58	3.85	5.58
1260	4.11	4.01	4.58	3.79	5.58
1280	4.09	4.04	4.58	3.79	5.56
1300	4.02	3.99	4.48	3.76	5.52
1320	3.98	3.8	4.26	3.9	5.52
1340	3.98	3.93	4.38	3.73	5.53
1360	3.91	3.9	4.42	3.65	5.5
1380	3.89	3.89	4.43	3.63	5.44
1400	3.83	3.82	4.3	3.68	5.41
1420	3.78	3.84	4.39	3.71	5.12
1440	3.76	3.87	4.19	3.61	5.41
1460	3.71	3.87	4.24	3.72	5.35
1480	3.7	3.79	4.29	3.47	5.09

Table G2. Sediment Oxygen Demand Testing Results at 20^{o}C (Continued)

Time	County Road 3	County Road 2	Road Crossing	Bridge Crossing	Glen Ewen
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1500	3.66	3.86	4.2	3.42	5.38
1520	3.61	3.9	4.07	3.44	5.25
1540	3.55	3.85	4.25	3.39	5.29
1560	3.52	3.85	4.01	3.41	4.96
1580	3.5	3.8	4.11	3.44	5.2
1600	3.44	3.79	3.81	3.54	5.22
1620	3.39	3.86	4.05	3.28	5.14
1640	3.36	3.76	3.63	3.51	
1660	3.32	3.76	3.67	3.54	
1680	3.31	3.73	4.01	3.2	
1700		3.73	4.02	3.15	
1720		3.67	4.05	3.18	
1740		3.66	3.95	3.12	
1760		3.68	3.95	3.37	
1780		3.67	3.62	3.05	
1800		3.61	3.84	3.08	
1820		3.68	3.79	3.02	
1840		3.54	3.73	3	
1860		3.55	3.57	3.03	4.86
1880		3.57	3.73	3.29	4.91
1900		3.56	3.69	3.11	4.87
1920		3.54	3.75	2.86	4.71
1940		3.49	3.16	3.1	4.51
1960		3.5	3.74	2.81	4.85
1980		3.5	3.76	2.85	4.7
2000		3.43	3.71	2.88	4.67
2020		3.43	3.69	3.06	4.6
2040		3.41	2.94	2.86	4.72
2060		3.32	3.45	2.78	4.71
2080		3.27	3.57	2.77	4.66
2100		3.33	3.63	2.72	4.63
2120		3.32	3.57	3.12	4.6
2140		3.27	3.41	2.73	4.67
2160		3.23	3.52	2.61	4.48
2180		3.23	3.31	2.63	4.63
2200		3.23	3.13	2.66	4.33
2220		3.23	3.37	2.71	4.5

Table G2. Sediment Oxygen Demand Testing Results at 20°C (Continued)

Time	County Road 3	County Road 2	Road Crossing	Bridge Crossing	Glen Ewen
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
2240		3.16	3.26	2.63	4.5
2260		3.13	2.96	2.95	4.38
2280		3.12	3.43	2.99	4.44
2300		3.09	2.99	2.56	4.47
2320		3.05	3.28	2.61	4.47
2340		3.08	3.27	2.61	4.37
2360		3.07	2.66	2.93	4.42
2380		3.03	3.28	2.7	4.32
2400		2.97	2.94	2.54	4.27
2420		2.99	2.94	2.97	4.36
2440		2.95	3.18	2.57	4.31
2460		2.93	3.2	2.97	4.29
2480		2.93	3.02	2.96	4.15
2500		2.92	3.1	2.41	4.34
2520		2.9	3.04	2.49	4.19
2540		2.87	3.08	2.4	4.23
2560		2.89	2.93	2.45	4.18
2580		2.83		2.33	4.19
2600					4.02
2620					4.18
2640					3.84
2660					4.07
2680					4.08
2700					4.01

Table G3. Bridge Crossing Sediment Oxygen Demand Tests

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(^{o}C)	Before	After	(mm)
1	11/29 - 16:00	12/1 - 12:00	20	8.64	8.64	2
2	12/5 - 21:00	12/7 - 16:00	15	8.69	8.58	2
3	12/7 - 22:00	12/9 - 22:00	15	8.66	8.63	2
4	12/10 - 23:00	12/12 - 20:00	10	8.72	8.66	2
5	12/13 - 22:00	12/15 - 23:00	5	8.57	8.54	2

(Italics illustrate interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	15°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20	6.28	7.83	7.88	8.03	8.99
40	6	7.69	7.7	8.01	9.05
60	6.14	7.63	7.7	7.92	9.34
80	6.14	7.62	7.63	7.9	8.95
100	5.95	7.61	7.6	8.04	9
120	6.05	7.52	7.55	7.88	8.99
140	5.99	7.47	7.47	7.88	8.99
160	5.89	7.42	7.4	7.88	8.92
180	6.13	7.42	7.39	8	8.85
200	5.87	7.38	7.38	7.81	8.83
220	5.76	7.26	7.33	7.69	8.78
240	5.75	7.34	7.22	7	8.81
260	5.86	7.26	7.29	7.72	
280	5.64	7.18	7.16	7.67	8.68
300	5.61	7.13	7.15	7.76	8.75
320	5.58	7.16	7.18	7.58	
340	5.51	7.05	7.08	7.57	8.5
360	5.42	6.99	7.05	7.63	8.65
380	5.42	7.04	7.02	7.52	
400	5.35	7	6.96	7.55	
420	5.38	6.92	6.99	7.47	8.61
440	5.35	6.87	6.91	7.57	8.46
460	5.26	6.86	7	7.38	8.58
480	5.24	6.88	6.75	7.46	8.32
500	5.14	6.85	6.74	7.3	8.52
520	5.12	6.81	7.07	7.34	
540	5.05	6.77	7	7.31	8.48

Table G3. Bridge Crossing Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(^{o}C)	Before	After	(mm)
1	11/29 - 16:00	12/1 - 12:00	20	8.64	8.64	2
2	12/5 - 21:00	12/7 - 16:00	15	8.69	8.58	2
3	12/7 - 22:00	12/9 - 22:00	15	8.66	8.63	2
4	12/10 - 23:00	12/12 - 20:00	10	8.72	8.66	2
5	12/13 - 22:00	12/15 - 23:00	5	8.57	8.54	2

(Italics illustrate interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	15°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
560	5.1	6.74	6.61	7.25	8.12
580	5.05	6.66	6.71	7.23	8.41
600	4.99	6.61	6.72	7.15	
620	4.95	6.53	6.71	7.16	8.34
640	4.9	6.51	6.53	7.18	8.49
660	4.85	6.5	6.37	7.13	
680	4.77	6.48	6.58	7.05	8.27
700		6.42	6.47	7.09	
720	4.57	6.44	6.4	7.18	
740	4.67	6.41	6.52	7.06	8.26
760	4.64	6.38	6.39	7	
780	4.58	6.21	6.45	7.01	
800	4.61	6.27	6.36	7.1	
820	4.55	6.22	6.32	6.99	
840	4.48	6.23	6.3	6.93	8.2
860	4.5	6.22	6.27	6.94	8.15
880	4.41	6.18	6.26	7.08	8.2
900	4.37	6.14	6.2	6.79	
920	4.36	6.07	6.19	6.78	8.11
940	4.36	6.09	6.17	6.85	7.98
960	4.32	6.05	6.11	6.77	8.01
980	4.29	6.02	6.08	6.79	
1000	4.25	6.03	6.04	6.78	7.91
1020	4.27	5.99	6.06	6.73	8.05
1040	4.16	5.93	6.05	7.09	7.94
1060	4.12	5.91	6	6.61	7.57
1080	4.13	5.88	5.95	6.68	

Table G3. Bridge Crossing Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(^oC)	Before	After	(mm)
1	11/29 - 16:00	12/1 - 12:00	20	8.64	8.64	2
2	12/5 - 21:00	12/7 - 16:00	15	8.69	8.58	2
3	12/7 - 22:00	12/9 - 22:00	15	8.66	8.63	2
4	12/10 - 23:00	12/12 - 20:00	10	8.72	8.66	2
5	12/13 - 22:00	12/15 - 23:00	5	8.57	8.54	2

(Italics illustrate interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	15°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1100	4.06	5.89	5.93	6.99	8.02
1120	3.99	5.85	5.95	6.75	7.85
1140	3.99	5.87	5.96	6.54	
1160	4.03	5.83	5.9	6.5	7.78
1180	3.86	5.8	5.85	6.48	7.81
1200	3.89	5.76	5.82	6.73	8.35
1220	3.85	5.73	5.83	6.58	7.87
1240	3.85	5.7	5.75	6.49	
1260	3.79	5.67	5.81	6.42	8.62
1280	3.79	5.65	5.72	6.34	7.8
1300	3.76	5.62	5.62	6.4	7.81
1320	3.9	5.48	5.68	6.43	7.75
1340	3.73	5.51	5.76	6.54	7.69
1360	3.65	5.52	5.58	6.37	7.82
1380	3.63	5.49	5.57	6.34	7.57
1400	3.68	5.51	5.51	6.31	7.75
1420	3.71	5.4	5.42	6.26	7.61
1440	3.61	5.42	*5.4*	6.31	7.62
1460	3.72	5.3	*5.4*	6.34	7.56
1480	3.47	5.3	*5.36*	6.26	
1500	3.42	5.34	*5.34*	6.2	7.5
1520	3.44	5.31	*5.32*	6.23	7.42
1540	3.39	5.23	*5.3*	6.2	7.44
1560	3.41	5.3	*5.27*	6.16	7.44
1580	3.44	5.25	*5.24*	6.16	7.51
1600	3.54	5.23	*5.22*	6.14	7.51
1620	3.28	5.24	*5.21*	6.34	7.5

Table G3. Bridge Crossing Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(^{o}C)	Before	After	(mm)
1	11/29 - 16:00	12/1 - 12:00	20	8.64	8.64	2
2	12/5 - 21:00	12/7 - 16:00	15	8.69	8.58	2
3	12/7 - 22:00	12/9 - 22:00	15	8.66	8.63	2
4	12/10 - 23:00	12/12 - 20:00	10	8.72	8.66	2
5	12/13 - 22:00	12/15 - 23:00	5	8.57	8.54	2

(Italics illustrate interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	15°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1640	3.51	5.16	*5.2*	6.24	7.38
1660	3.54	5.19	*5.18*	6.15	7.42
1680	3.2	5.21	*5.18*	6.16	
1700	3.15	5.08	5.17	6.12	7.13
1720	3.18	5.05	5.13	6.07	7.51
1740	3.12	5.09	5.23	5.99	
1760	3.37	5.14	5.12	5.99	7.21
1780	3.05	4.98	5.11	6.01	7.12
1800	3.08	5.02	5.11	6.22	7.31
1820	3.02	4.9	5.08	5.92	7.32
1840	3	4.89	4.97	5.93	7.42
1860	3.03	5.08	4.96	5.9	7.24
1880	3.29	4.83	4.98	6.02	7.18
1900	3.11	4.83	4.96	6.01	7.13
1920	2.86	4.84	4.89	6.02	7.23
1940	3.1	4.75	4.9	5.78	7.26
1960	2.81	4.75	4.86	6.29	7.29
1980	2.85	4.79	4.87	5.6	7
2000	2.88	4.91	4.83	5.77	7.12
2020	3.06	4.71	4.83	6.28	7.43
2040	2.86	4.67	4.75	5.61	7.14
2060	2.78	4.65	4.8	5.73	7.11
2080	2.77	4.67	4.74	5.85	6.93
2100	2.72	4.63	4.73	6.01	
2120	3.12	4.6	4.72	5.51	7.07
2140	2.73	4.58	4.68	5.19	7.05
2160	2.61	4.55	4.63	5.6	

Table G3. Bridge Crossing Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(^oC)	Before	After	(mm)
1	11/29 - 16:00	12/1 - 12:00	20	8.64	8.64	2
2	12/5 - 21:00	12/7 - 16:00	15	8.69	8.58	2
3	12/7 - 22:00	12/9 - 22:00	15	8.66	8.63	2
4	12/10 - 23:00	12/12 - 20:00	10	8.72	8.66	2
5	12/13 - 22:00	12/15 - 23:00	5	8.57	8.54	2

(Italics illustrate interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	15°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
2180	2.63	4.54	4.65	5.96	7.34
2200	2.66	4.53	4.82	5.54	6.98
2220	2.71	4.52	4.61	5.98	6.77
2240	2.63	4.42	4.65	5.64	7.04
2260	2.95	4.39	4.52	6	7
2280	2.99	4.41	4.41	5.3	6.97
2300	2.56	4.48	4.71	5.37	6.79
2320	2.61	4.35	4.47	5.87	6.79
2340	2.61	4.44	4.46	5.4	6.88
2360	2.93	4.27	4.4	5.92	6.87
2380	2.7	4.41	4.4	5.38	6.88
2400	2.54	4.29	4.41	5.25	6.91
2420	2.97	4.27	4.38	5.34	6.9
2440	2.57	4.19	4.55	5.8	6.96
2460	2.97	4.27	4.28	5.45	6.9
2480	2.96	4.21	4.29	5.3	6.85
2500	2.41	4.22	4.27	5.63	6.88
2520	2.49	4.15	4.31	5.29	7
2540	2.4	4.13	4.26	5.3	7.24
2560	2.45		4.25	6.08	7.17
2580	2.33		4.26	5.54	6.77
2600			4.21	5.09	7.06
2620			4.24		6.68
2640			4.16		6.66
2660			4.14		6.74
2680			4.46		6.4
2700			4.12		6.52

Table G3. Bridge Crossing Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(^{o}C)	Before	After	(mm)
9	12/19 - 19:00	12/21 - 17:00	20	8.97	9.04	2.5
17	12/31 - 16:00	1/1 - 15:00	20	8.94	9.02	2.5
26	1/1 - 17:00	1/2 - 14:00	20			2.5
34	1/3 - 15:00	1/4 - 12:00	20			2.5

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
20	6.34	7.29	7.72	7.43
40	6.34	7.2	7.58	7.22
60	6.28	7.08	7.49	7.39
80	6.21	6.9	7.31	7.38
100	6.17	6.88	7.39	6.7
120	6.1	6.8	7.19	6.57
140	6.1	6.69	7.12	6.91
160	6.05	6.6	6.96	6.38
180	5.98	6.53	6.88	6.73
200	5.91	6.41	6.99	6.13
220	5.89	6.35	6.68	6.48
240		6.23	6.59	6.31
260	5.71	6.14	6.49	5.81
280	5.6	6.06	6.45	5.76
300		6	6.31	5.69
320	5.58	5.92	6.23	6.35
340	5.57	5.87	6.05	5.38
360	5.48	5.76	6.08	5.4
380	5.48	5.68	6	5.31
400	5.42	5.56	5.84	5.21
420	5.32	5.51	5.8	5.22
440	5.32	5.46	5.78	5.58
460	5.2	5.35	5.7	4.99
480	5.24	5.15	5.86	5.48
500	5.21	5.22	5.57	5.3
520	5.15	5.11	5.66	5.1
540	5.16	5.05	5.48	4.9
560	5.06	4.99	5.92	4.59

Table G3. Bridge Crossing Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(^{o}C)	Before	After	(mm)
9	12/19 - 19:00	12/21 - 17:00	20	8.97	9.04	2.5
17	12/31 - 16:00	1/1 - 15:00	20	8.94	9.02	2.5
26	1/1 - 17:00	1/2 - 14:00	20			2.5
34	1/3 - 15:00	1/4 - 12:00	20			2.5

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
580	5.09	4.86	5.06	4.8
600	5.04	4.84	5.21	4.46
620	4.98	4.78	5.49	4.47
640	4.91	4.98	5.05	4.42
660	4.84	4.69	4.77	4.76
680	4.88	4.64	5.6	4.14
700	4.78	4.57	5.13	4.27
720	4.74	4.46	4.86	4.37
740	4.74	4.43	5.14	3.87
760	4.64	4.37	4.68	4.18
780	4.63	4.32	4.46	4.2
800	4.61	4.37	4.31	4.19
820	4.58	4.19	5.01	4.03
840	4.54	4.24	4.14	3.61
860	4.48	4.01	4.58	3.6
880	4.47	3.98	4.64	4.02
900	4.34	3.94	4.79	3.41
920	4.33	3.87	4.32	3.37
940	4.28	3.81	4.4	3.61
960	4.22	3.73	3.72	3.59
980	4.28	3.74	4.06	3.53
1000	4.3	3.61	3.17	3.48
1020	4.2	3.64	3.54	3.27
1040	4.11	3.59	3.47	3.19
1060	4.11	3.5	3.79	3.46
1080	4.07	3.47	3.39	3.45
1100	3.99	3.4	3.26	2.98
1120	4.01	3.46	3.24	3.3

Table G4. County Road 2 Sediment Oxygen Demand Tests

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	1/5 - 18:00	1/7 - 13:00	20	-	-	2
2	1/7 - 21:00	1/9 - 1:00	15	9.44	8.73	2
3	1/13 - 17:00	1/15 - 16:00	10	8.94	8.95	2
4	1/16 - 11:00	1/17 - 12:00	5	8.88	8.49	2.5
5	1/18 - 18:00	1/20 - 16:00	5	-	-	2.5

(Italics represent interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	5°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20	7.27	7.45	8.65	8.49	9.93
40	7.17	7.35	8.74	8.52	9.87
60	7.04	7.32			9.79
80	7.18	7.36	8.59	8.38	9.85
100	7.03	7.24	8.47		9.77
120	6.94	7.19		8.28	9.76
140	6.83	7.18	8.43	8.13	9.7
160	6.74	7.14	8.43	8.23	9.66
180	6.74	7.14	8.38	8.29	9.65
200	6.56	7.04	8.91	7.95	9.62
220	6.49	6.96	8.05	8.09	9.63
240	6.52	6.9	8.22	8.22	9.57
260	6.38	6.88	8.15	8.24	9.53
280	6.4	6.89	7.94	8.21	9.51
300	6.23	6.88	8.33	8.24	9.53
320	6.18	6.91	8.04		9.53
340	6.16	6.66	9.29	8.17	9.47
360	6.08	6.68	8.12	8.14	9.45
380	6.05	6.7	8.08		9.48
400	5.96	6.61	7		9.4
420	5	6	8.45	8.07	9.39
440	5.84	6.55	7.76	8.29	9.39
460	5.82	6.49	8.07	8.02	9.29
480	5.71	6.45	7.87	8.04	9.33
500	5.68	6.4	7.61	8.22	9.3
520	5.67	6.35	7.82	8.06	9.34
540	5.58	6.34	7.72	7.98	9.25

Table G4. County Road 2 Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	1/5 - 18:00	1/7 - 13:00	20	-	-	2
2	1/7 - 21:00	1/9 - 1:00	15	9.44	8.73	2
3	1/13 - 17:00	1/15 - 16:00	10	8.94	8.95	2
4	1/16 - 11:00	1/17 - 12:00	5	8.88	8.49	2.5
5	1/18 - 18:00	1/20 - 16:00	5	-	-	2.5

(Italics represent interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	5°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
560	5.5	6.41	7.63	8.08	9.24
580	5.48	6.4	7.72	7.9	9.24
600	5.34	6.24	7.83	8	9.25
620	5.38	6.21	7.87	7.87	9.13
640	5.23	6	7.86		9.27
660	5.27	6.05	7.81	7.68	9.07
680	5.22	6.05	7.6		9.02
700	5.21	5.99	7.61		9.01
720	5.13	5.89	7.63		9.1
740	5.1	5.89	9.1	7.62	8.96
760	4.99	5.94	8.05	7.76	8.99
780	5.01	6.33	7.53		8.92
800	4.91	5.87	7.53	7.53	9.02
820	4.95	5.86	7.73		8.9
840	4.9	5.88	7.47		8.85
860	4.84	5.87	7.94	7.58	8.83
880	4.74	5.84	7.69		8.89
900	4.76	5.78	7.95	8.35	9.62
920	4.68	5.71	7.26	7.53	8.87
940	4.72	6.04	7.64	7.49	8.74
960	4.57	5.84	7.61		8.97
980	4.53	5.6	7.01	7.57	9.19
1000	4.52	5.61	7.25	7.54	8.66
1020	4.48	5.48	7.04	7.38	8.6
1040	4.45	5.58	7.5	7.5	8.64
1060	4.39	5.52	7.19		8.64
1080	4.39	5.51	8.02	7.43	8.56

Table G4. County Road 2 Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	1/5 - 18:00	1/7 - 13:00	20	-	-	2
2	1/7 - 21:00	1/9 - 1:00	15	9.44	8.73	2
3	1/13 - 17:00	1/15 - 16:00	10	8.94	8.95	2
4	1/16 - 11:00	1/17 - 12:00	5	8.88	8.49	2.5
5	1/18 - 18:00	1/20 - 16:00	5	-	-	2.5

(Italics represent interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	5°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1100	4.36	5.28	6.92	8.09	9.4
1120	4.29	5.49	7.06	7.5	8.73
1140	4.32	5.46	7.03	7.24	9.08
1160	4.29	5.38	7.55	7.33	8.63
1180	4.2	5.36	7.04		8.38
1200	4.18	5.37	7.88		8.4
1220	4.11	5.33	7.96	7.34	
1240	4.13	5.29	6.81	7.33	
1260	4.01	5.27	7	8.5	
1280	4.04	5.22	6.69		
1300	3.99	5.2	6.51	7.16	
1320	3.8	5.03	7.24	7.07	
1340	3.93	5.07	7.6	6.94	
1360	3.9	5.31	7.28	7.26	
1380	3.89	5.15	7.63	7.3	
1400	3.82	5.12	6.36		
1420	3.84	5.11	6.73		
1440	3.87	5.07	6.4	*7.08*	
1460	3.87	5.06	7.69	*8.29*	
1480	3.79	5.02			8.31
1500	3.86	4.96	6.87		8.26
1520	3.9	4.96	7.6		8.17
1540	3.85	5.02	7.27		8.14
1560	3.85	4.94	6.31		8.21
1580	3.8	4.91	6.33		8.1
1600	3.79	4.9	6.24		8.12
1620	3.86	4.87	6.3		8.08

Table G4. County Road 2 Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	1/5 - 18:00	1/7 - 13:00	20	-	-	2
2	1/7 - 21:00	1/9 - 1:00	15	9.44	8.73	2
3	1/13 - 17:00	1/15 - 16:00	10	8.94	8.95	2
4	1/16 - 11:00	1/17 - 12:00	5	8.88	8.49	2.5
5	1/18 - 18:00	1/20 - 16:00	5	-	-	2.5

(Italics represent interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	5°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1640	3.76	4.8	7.09		8.01
1660	3.76	4.84	7.33		7.99
1680	3.73	4.83	6.87		8.03
1700	3.73	4.75	6.21		8.01
1720	3.67	4.75	6.09		7.96
1740	3.66	4.77	6.54		8.59
1760	3.68	4.64	6.77		7.85
1780	3.67	4.8	6.08		7.78
1800	3.61	4.65	6.31		7.88
1820	3.68	4.65	6.6		7.99
1840	3.54	4.64	7		7.87
1860	3.55	4.63	5.88		7.89
1880	3.57	4.59	7.01		7.92
1900	3.56	4.58	5.79		7.85
1920	3.54	4.56	6.97		7.78
1940	3.49	4.56	5.97		8.26
1960	3.5	4.55	5.99		7.77
1980	3.5	4.5	6.75		7.78
2000	3.43	4.48	6.27		7.93
2020	3.43	4.56	6.2		8.06
2040	3.41	4.35	6		7.69
2060	3.32	4.41	6.04		7.85
2080	3.27	4.35	6.36		7.6
2100	3.33	4.43	5.91		7.85
2120	3.32	4.4	5.47		7.63
2140	3.27	4.33	6.41		7.61
2160	3.23	4.28	5.86		7.68

Table G4. County Road 2 Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	1/5 - 18:00	1/7 - 13:00	20	-	-	2
2	1/7 - 21:00	1/9 - 1:00	15	9.44	8.73	2
3	1/13 - 17:00	1/15 - 16:00	10	8.94	8.95	2
4	1/16 - 11:00	1/17 - 12:00	5	8.88	8.49	2.5
5	1/18 - 18:00	1/20 - 16:00	5	-	-	2.5

(Italics represent interference)

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	5°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
2180	3.23	4.29	6.03		7.75
2200	3.23	4.4	5.77		7.74
2220	3.23	4.29	5.62		7.55
2240	3.16	4.22	5.65		7.59
2260	3.13	4.18	6.21		7.74
2280	3.12	4.23	5.45		7.49
2300	3.09	4.2	5.71		7.51
2320	3.05	4.17	5.79		7.45
2340	3.08	4.15	5.56		7.55
2360	3.07	4.08	5.74		7.46
2380	3.03	4.22	5.84		7.43
2400	2.97	4.09	5.54		7.46
2420	2.99	4.15	5.65		7.57
2440	2.95		5.71		7.68
2460	2.93		5.6		7.55
2480	2.93		6.08		7.35
2500	2.92		5.6		7.47
2520	2.9		5.65		7.37
2540	2.87		5.71		7.36
2560	2.89		6.21		7.33
2580	2.83		5.14		7.35
2600			5.46		7.35
2620			5.24		7.33
2640			4.97		7.31
2660			6.39		7.23
2680			5.95		7.27
2700			5.78		7.26

Table G4. County Road 2 Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
9	1/23 - 18:00	1/24 - 16:00	20		
17	1/21 - 20:00	1/23 - 10:00	20		
26	1/24 - 18:00	1/25 - 12:00	20	8.81	8.76
34	1/25 - 14:00	1/26 - 16:00	20	8.77	8.89

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
20	5.78	6.91	7.76	7.94
40	5.58	6.93	7.72	
60	5.64	6.78	7.64	
80	5.64	6.81	7.59	
100	5.56	6.71	7.57	
120	5.48	6.62	7.47	
140	5.42	6.57	7.37	
160	5.43	6.49	7.33	
180	5.34	6.47	7	
200	5.38	6	7.21	
220	5.3	6.36	7	
240	5.2	6.32	7.02	
260	5.09	6.23	7.06	
280	5.11	6.24	6.99	
300	5.04	6.08	6.94	7.08
320	5.07	6.05	6.85	7.08
340	4.95	5.99	6.8	7
360	4.97	5.98	6.72	6.94
380	4.97	5.91	6.7	6.93
400	4.87	5.92	6.64	6.84
420	4.83	5.79	6.54	6.76
440	4.81	5.68	6.56	6.73
460	4.79	5.73	6.53	6.71
480	4.64	5.67	6.43	6.65
500	4.59	5.72	6.38	6.61
520	4.57	5.63	6.3	6.57
540	4.53	5.49	6.26	6.59
560	4.6	5.38	6.25	6.61

Table G4. County Road 2 Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
9	1/23 - 18:00	1/24 - 16:00	20		
17	1/21 - 20:00	1/23 - 10:00	20		
26	1/24 - 18:00	1/25 - 12:00	20	8.81	8.76
34	1/25 - 14:00	1/26 - 16:00	20	8.77	8.89

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
580	4.49	5.45	6.21	6.44
600	4.47	5.38	6.12	6.41
620	4.41	5.28	6.07	6.39
640	4.39	5.28	6.02	6.36
660	4.38	5.21	6.01	6.31
680	4.27	5.16	5.96	6.25
700	4.24	5.18	5.88	6.27
720	4.12	5.14	5.86	6.12
740	4.11	4.98	5.8	6.09
760	4.16	5.02	5.78	6.08
780	4.09	4.92	5.76	6.02
800	3.99	4.89	5.66	5.98
820	3.92	4.82	5.64	5.95
840	3.9	4.79	5.57	5.85
860	3.86	4.7	5.57	5.88
880	3.91	4.74	5.5	5.84
900	3.86	4.7	5.51	5.78
920	3.79	4.65	5.49	5.73
940	3.74	4.54	5.44	5.71
960	3.74	4.53	5.4	5.65
980	3.69	4.47	5.35	5.62
1000	3.67	4.39	5.34	5.59
1020	3.6	4.38	5.25	5.48
1040	3.53	4.33	5.19	5.51
1060	3.63	4.28	5.19	5.47
1080	3.51	4.26		5.41
1100	3.46	4.19		5.38
1120	3.41	4.15		5.38

Table G4. County Road 2 Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
9	1/23 - 18:00	1/24 - 16:00	20		
17	1/21 - 20:00	1/23 - 10:00	20		
26	1/24 - 18:00	1/25 - 12:00	20	8.81	8.76
34	1/25 - 14:00	1/26 - 16:00	20	8.77	8.89

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
1140	3.42	4.08		5.29
1160	3.4	4		5.27
1180	3.32	4.06		5.21
1200	3.28	3.98		5.19
1220	3.33	3.94		5.14
1240	3.3	3.89		5.09
1260	3.18	3.82		5.09
1280	3.16	3.84		5.01
1300	3.18	3.74		5.03
1320		3.73		4.97
1340		3.7		4.89
1360		3.64		4.88
1380		3.58		4.16
1400		3.48		4.79
1420		3.5		4.77
1440		3.44		4.76
1460		3.42		4.71
1480		3.41		4.67
1500		3.32		4.67
1520		3.3		4.57
1540		3.26		4.56
1560		3.24		4.49
1580		3.17		4.45
1600		3.15		
1620		3.13		
1640		3.07		
1660		3.09		
1680		3.03		

Table G5. Glen Ewen Temperature Sediment Oxygen Demand Tests

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
2	2/1 - 12:00	2/3 - 16:00	20	8.87	8.98	2
3	2/3 - 18:00	2/6 - 11:00	20	8.92	8.89	2

Temperature Sediment Oxygen Demand Tests

Time	20°C	20°C
(min)	DO (mg/L)	DO (mg/L)
20	7.55	7.73
40	7.58	7.67
60	7.42	7.53
80	7.5	7.61
100	7	7.54
120	7.35	7.31
140	7.36	7
160	7.23	7.44
180	7.32	7.43
200	7.08	7.27
220	7.19	7.29
240	7.12	7.18
260	7.06	7.2
280	7.02	7.14
300		7.15
320		7.08
340	6.93	6.98
360	6.74	7.06
380	6.84	6.83
400	6.84	6.68
420	6.87	6.54
440	6.65	6.84
460	6.72	6.81
480	6.77	6.64
500	6.68	6.83
520	6.45	6.73
540	6.55	6.66
560	6.46	6.63
580	6.48	6.49
600	6.49	6.44

Table G5. Glen Ewen Temperature Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
2	2/1 - 12:00	2/3 - 16:00	20	8.87	8.98	2
3	2/3 - 18:00	2/6 - 11:00	20	8.92	8.89	2

Temperature Sediment Oxygen Demand Tests

Time	20°C	20°C
(min)	DO (mg/L)	DO (mg/L)
620	6.49	6.43
640	6.38	6.43
660	6.23	6.15
680	6.39	6.41
700	6.22	6.35
720	6.06	6.05
740	6.24	6.22
760	6.18	6.2
780	6.25	6.25
800	6.21	6.2
820	6.21	6.14
840	6.2	6.04
860	5.79	5.91
880	6.11	6.03
900	6.07	5.99
920	6.02	6.06
940	6.08	6.05
960	5.89	5.92
980	5.99	5.95
1000	6.01	5.88
1020	5.96	5.77
1040	5.84	5.86
1060	5.89	5.68
1080	5.83	5.44
1100	5.83	5.65
1120	5.73	5.43
1140	5.77	5.38
1160	5.75	5.7
1180	5.65	5.61
1200	5.69	5.62

Table G5. Glen Ewen Temperature Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
2	2/1 - 12:00	2/3 - 16:00	20	8.87	8.98	2
3	2/3 - 18:00	2/6 - 11:00	20	8.92	8.89	2

Temperature Sediment Oxygen Demand Tests

Time	20°C	20°C
(min)	DO (mg/L)	DO (mg/L)
1220	5.62	5.39
1240	5.58	5.54
1260	5.58	5.52
1280	5.56	5.48
1300	5.52	5.53
1320	5.52	5.34
1340	5.53	5.37
1360	5.5	5.45
1380	5.44	
1400	5.41	
1420	5.12	
1440	5.41	
1460	5.35	
1480	5.09	
1500	5.38	
1520	5.25	
1540	5.29	
1560	4.96	
1580	5.2	
1600	5.22	
1620	5.14	
1640		
1660		
1680		
1700		
1720		
1740		
1760		
1780		
1800		

Table G5. Glen Ewen Temperature Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
2	2/1 - 12:00	2/3 - 16:00	20	8.87	8.98	2
3	2/3 - 18:00	2/6 - 11:00	20	8.92	8.89	2

Temperature Sediment Oxygen Demand Tests

Time	20°C	20°C
(min)	DO (mg/L)	DO (mg/L)
1820		
1840		
1860	4.86	
1880	4.91	
1900	4.87	
1920	4.71	
1940	4.51	
1960	4.85	
1980	4.7	
2000	4.67	
2020	4.6	
2040	4.72	
2060	4.71	
2080	4.66	
2100	4.63	
2120	4.6	
2140	4.67	
2160	4.48	
2180	4.63	
2200	4.33	
2220	4.5	
2240	4.5	
2260	4.38	
2280	4.44	
2300	4.47	
2320	4.47	
2340	4.37	
2360	4.42	
2380	4.32	
2400	4.27	

Table G5. Glen Ewen Temperature Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
2	2/1 - 12:00	2/3 - 16:00	20	8.87	8.98	2
3	2/3 - 18:00	2/6 - 11:00	20	8.92	8.89	2

Temperature Sediment Oxygen Demand Tests

Time	20°C	20°C
(min)	DO (mg/L)	DO (mg/L)
2420	4.36	
2440	4.31	
2460	4.29	
2480	4.15	
2500	4.34	
2520	4.19	
2540	4.23	
2560	4.18	4.18
2580	4.19	4.12
2600	4.02	4.1
2620	4.18	4.04
2640	3.84	3.67
2660	4.07	4.05
2680	4.08	3.87
2700	4.01	3.93
2720	3.98	3.86
2740	3.75	3.83
2760	3.67	3.75
2780	3.83	3.87
2800	3.77	3.92
2820	4.04	3.72
2840	3.88	3.84
2860	3.93	3.81
2880	3.9	3.89
2900	3.85	3.81
2920	3.83	3.8
2940	3.71	3.77
2960	3.85	3.81
2980	3.84	3.78
3000	3.76	3.71

Table G6. Road Crossing Sediment Oxygen Demand Tests

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
A1	2/11 - 16:00	2/13 - 10:00	20		
A2	2/16 - 13:00	2/15 - 12:00	20	8.85	9
B1	2/19 - 19:00	2/20 - 20:00	20	9.24	8.98
B2	2/25 - 22:00	2/27 - 8:00	20		
C1	3/1 - 14:00	3/2 - 15:00	20	9.11	9.16

Temperature Sediment Oxygen Demand Tests

Time	20°C A	20°C A	20°C B	20°C B	20°C C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20	6.52	7.29	7.44	5.3	7.14
40	6.5	7.39	7.3	5.26	
60	6.45	7.21	7.23	5.21	
80		7.23	7.16	5.18	
100	6.45	6.93	7.11	5.08	
120	6.32	7.03	6.95	5.04	
140	6.26	7.1	6.77	5	
160	6.26	6.83	6.64	5.04	
180	6.12	7.03	6.77	5.03	6.7
200	6.23		6.62	4.94	6.71
220	6.14	6.7	6.54	4.79	6.51
240	5.96	6.69	6.49	4.79	6.61
260	6.05	6.61	5.78	4.77	6.62
280	5.83	6.81	6.27	4.58	6.59
300	5.84	6.67	6.24	4.32	6.53
320	5.94	6.6	6.18	4.54	6.57
340	5.87	6.11	6.03	4.49	6.39
360	5.61	6.16	5.99	4.54	6.47
380	5.85	6.41	5.95	4.26	6.33
400	5.71	6.22	5.88	4.3	6.26
420	5.59	6.29	5.85	4.28	6.03
440	5.68	6.42	5.68	4.28	6.28
460	5.66	6.31	5.62	4.16	6.16
480		6.2	5.56	3.98	5.95
500	5.55	6.18	5.51	4.1	6.09
520	5.73	6.21	5.46	4.03	6.01
540	5.25	6.03	5.32	4.03	6.11

Table G6. Road Crossing Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
A1	2/11 - 16:00	2/13 - 10:00	20		
A2	2/16 - 13:00	2/15 - 12:00	20	8.85	9
B1	2/19 - 19:00	2/20 - 20:00	20	9.24	8.98
B2	2/25 - 22:00	2/27 - 8:00	20		
C1	3/1 - 14:00	3/2 - 15:00	20	9.11	9.16

Temperature Sediment Oxygen Demand Tests

Time	20°C A	20°C A	20°C B	20°C B	20°C C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
560	5.59	6.21	5.18	3.86	6.03
580	5.26	6.05	5.38	3.87	5.82
600	5.37	5.94	5.16	3.86	5.81
620		6.02	4.84	3.5	5.73
640		5.48	4.9	3.79	5.56
660	5.04	5.99	4	3.54	5.78
680	5.19	5.81	5.02	3.59	5.61
700	5.04	5.12	4.95	3.63	5.64
720	5.32	5.64	4.81	3.42	5.75
740	5.25	5.77	4.91	3.52	5.68
760	5.22	5.81	4.66	3.47	5.5
780	5.25	5.51	4.82	3.42	5.36
800	5.03	5.66	4.61	3.4	5.38
820		5.4	4.62	3.32	5.46
840	5.11	5.48	4.57	3.28	5.29
860	5.03	5.26	4.54	3.33	4.98
880	4.96	5.46	4.31	3.21	5.35
900	5.11	5.14	4.39	3.11	5.23
920	5.03	5.37	4.33	3.14	5.27
940		4.88	4.3	3	5.34
960		5.07	4.19	2.92	5.08
980	4.81	5.32	4.23	2.98	5.11
1000	4.92	5.34	3.9	2.92	5.03
1020	4.86	5.32	4.01	2.87	5.14
1040	4.73	5.24	4.09	2.79	4.42
1060	4.88	5.26	4.11	2.82	4.94
1080	4.71	5.18	3.99	2.77	4.96

Table G6. Road Crossing Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
A1	2/11 - 16:00	2/13 - 10:00	20		
A2	2/16 - 13:00	2/15 - 12:00	20	8.85	9
B1	2/19 - 19:00	2/20 - 20:00	20	9.24	8.98
B2	2/25 - 22:00	2/27 - 8:00	20		
C1	3/1 - 14:00	3/2 - 15:00	20	9.11	9.16

Temperature Sediment Oxygen Demand Tests

Time	20°C A	20°C A	20°C B	20°C B	20°C C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1100	4.77	5.13	3.99	2.69	4.85
1120	4.8	5.08	3.98	2.52	4.85
1140		5.15	3.92	2.7	4.95
1160	4.61	4.67	3.82	2.5	4.79
1180	4.64	4.38	3.77	2.56	4.78
1200	4.43	5.05	3.76	2.43	4.76
1220	4.67	4.7	3.69	2.48	4.71
1240	4.58	4.97	3.61	2.37	4.71
1260	4.58	4.84	3.67	2.38	4.67
1280	4.58	4.66	3.57	2.2	4.47
1300	4.48	4.84	3.53	2.34	4.55
1320		4.83	3.41	2.23	4.56
1340	4.38	4.55	3.37	2.24	4.56
1360	4.42	4.72	3.38	2.21	4.47
1380	4.43	4.58	3.4	2.07	3.92
1400	4.3	4.66	3.33	2.05	4.48
1420	4.39	4.67	3.23	2.07	4.56
1440	4.19	4.4	*3.24*	2.02	4.45
1460	4.24	4.36	*2.91*	2.01	4.34
1480	4.29	4.03	*3.1*	1.84	
1500	4.2	4.45	*3.11*	1.96	
1520	4.07	4.23	*3.06*	1.81	
1540	4.25	4.33	*3.08*	1.88	
1560	4.01	4.25		1.87	
1580	4.11	4.17		1.82	
1600		4.29		1.66	
1620	4.05	4.19		1.82	

Table G6. Road Crossing Sediment Oxygen Demand Tests (Continued)

Temperature Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
A1	2/11 - 16:00	2/13 - 10:00	20		
A2	2/16 - 13:00	2/15 - 12:00	20	8.85	9
B1	2/19 - 19:00	2/20 - 20:00	20	9.24	8.98
B2	2/25 - 22:00	2/27 - 8:00	20		
C1	3/1 - 14:00	3/2 - 15:00	20	9.11	9.16

Temperature Sediment Oxygen Demand Tests

Time	20°C A	20°C A	20°C B	20°C B	20°C C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1640		4.21		1.72	
1660		4.21		1.54	
1680	4.01	4.27		1.64	
1700	4.02	4		1.66	
1720	4.05	3.69		1.6	
1740	3.95	3.96		1.59	
1760	3.95	3.96		1.36	
1780	3.62	3.96		1.56	
1800	3.84	3.77		1.48	
1820	3.79	3.76		1.52	
1840	3.73	3.88		1.46	
1860	3.57	3.76		1.41	
1880	3.73	3.71		1.01	
1900	3.69	3.43		1.41	
1920	3.75	3.65		1.41	
1940		3.66		1.26	
1960	3.74	3.61		1.34	
1980	3.76	3.66		1.1	
2000	3.71	3.43			
2020	3.69	3.44			
2040		3.58			
2060	3.45	3.55			
2080	3.57	3.48			
2100	3.63	3.61			
2120	3.57	3.33			
2140	3.41	3.52			
2160	3.52	3.41			

Table G6. Road Crossing Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
9	1/23 - 18:00	1/24 - 16:00	20		
17	1/21 - 20:00	1/23 - 10:00	20		
26	1/24 - 18:00	1/25 - 12:00	20	8.81	8.76
34	1/25 - 14:00	1/26 - 16:00	20	8.77	8.89

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
20	5.78	6.91	7.76	7.94
40	5.58	6.93	7.72	
60	5.64	6.78	7.64	
80	5.64	6.81	7.59	
100	5.56	6.71	7.57	
120	5.48	6.62	7.47	
140	5.42	6.57	7.37	
160	5.43	6.49	7.33	
180	5.34	6.47	7	
200	5.38	6	7.21	
220	5.3	6.36	7	
240	5.2	6.32	7.02	
260	5.09	6.23	7.06	
280	5.11	6.24	6.99	
300	5.04	6.08	6.94	7.08
320	5.07	6.05	6.85	7.08
340	4.95	5.99	6.8	7
360	4.97	5.98	6.72	6.94
380	4.97	5.91	6.7	6.93
400	4.87	5.92	6.64	6.84
420	4.83	5.79	6.54	6.76
440	4.81	5.68	6.56	6.73
460	4.79	5.73	6.53	6.71
480	4.64	5.67	6.43	6.65
500	4.59	5.72	6.38	6.61
520	4.57	5.63	6.3	6.57
540	4.53	5.49	6.26	6.59
560	4.6	5.38	6.25	6.61

Table G6. Road Crossing Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
9	1/23 - 18:00	1/24 - 16:00	20		
17	1/21 - 20:00	1/23 - 10:00	20		
26	1/24 - 18:00	1/25 - 12:00	20	8.81	8.76
34	1/25 - 14:00	1/26 - 16:00	20	8.77	8.89

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
580	4.49	5.45	6.21	6.44
600	4.47	5.38	6.12	6.41
620	4.41	5.28	6.07	6.39
640	4.39	5.28	6.02	6.36
660	4.38	5.21	6.01	6.31
680	4.27	5.16	5.96	6.25
700	4.24	5.18	5.88	6.27
720	4.12	5.14	5.86	6.12
740	4.11	4.98	5.8	6.09
760	4.16	5.02	5.78	6.08
780	4.09	4.92	5.76	6.02
800	3.99	4.89	5.66	5.98
820	3.92	4.82	5.64	5.95
840	3.9	4.79	5.57	5.85
860	3.86	4.7	5.57	5.88
880	3.91	4.74	5.5	5.84
900	3.86	4.7	5.51	5.78
920	3.79	4.65	5.49	5.73
940	3.74	4.54	5.44	5.71
960	3.74	4.53	5.4	5.65
980	3.69	4.47	5.35	5.62
1000	3.67	4.39	5.34	5.59
1020	3.6	4.38	5.25	5.48
1040	3.53	4.33	5.19	5.51
1060	3.63	4.28	5.19	5.47
1080	3.51	4.26		5.41
1100	3.46	4.19		5.38
1120	3.41	4.15		5.38

Table G6. Road Crossing Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration	
(#)	Start	End	(°C)	Before	After
9	1/23 - 18:00	1/24 - 16:00	20		
17	1/21 - 20:00	1/23 - 10:00	20		
26	1/24 - 18:00	1/25 - 12:00	20	8.81	8.76
34	1/25 - 14:00	1/26 - 16:00	20	8.77	8.89

Velocity Sediment Oxygen Demand Tests

Time	0.0916 ft/s	0.1731 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	9 rpm	17 rpm	26 rpm	34 rpm
1140	3.42	4.08		5.29
1160	3.4	4		5.27
1180	3.32	4.06		5.21
1200	3.28	3.98		5.19
1220	3.33	3.94		5.14
1240	3.3	3.89		5.09
1260	3.18	3.82		5.09
1280	3.16	3.84		5.01
1300	3.18	3.74		5.03
1320		3.73		4.97
1340		3.7		4.89
1360		3.64		4.88
1380		3.58		4.16
1400		3.48		4.79
1420		3.5		4.77
1440		3.44		4.76
1460		3.42		4.71
1480		3.41		4.67
1500		3.32		4.67
1520		3.3		4.57
1540		3.26		4.56
1560		3.24		4.49
1580		3.17		4.45
1600		3.15		
1620		3.13		
1640		3.07		
1660		3.09		
1680		3.03		

Table G7. County Road 3 Sediment Oxygen Demand Tests

Sediment Oxygen Demand Tests - Experiment Information

Run	Temperature	Aerobic
(#)	(°C)	(mm)
1	20	1
2	20	1.75
3	20	2
4	20	2

Sediment Oxygen Demand Aerobic Layer Tests

Time	1st Run	2nd Run	3rd Run	4th Run
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20	6.91	7.77	7.96	7.9
40	6.71	7.62	7.81	7.8
60	6.57	7.55	7.75	7.7
80	6.43	7.45	7.62	7.58
100	6.31	7.36	7.55	7.51
120	6.18	7.28	7.48	7.43
140	5.9	7.18	7.4	7.31
160	5.75	7.11	7.32	7.25
180	5.73	7.03	7.22	7.21
200	5.61	6.95	7.16	7.08
220	5.5	6.79	7.08	7.03
240	5.43	6.8	6.97	6.9
260	5.3	6.72	6.96	6.81
280	5.22	6.64	6.89	6.74
300	5.1	6.58	6.79	6.64
320	5.02	6.5	6.69	6.59
340	4.93	6.45	6.61	6.51
360	4.87	6.36	6.57	6.43
380	4.78	6.31	6.47	6
400	4.67	6.29	6.41	6.29
420	4.6	6.16	6.36	6.26
440	4.52	6.11	6.3	6.17
460	4.46	6.03	6.23	6.13
480	4.38	5.97	6.16	6.09
500	4.29	5.89	6.09	6.02
520	4.21	5.81	6.04	5.91
540	4.16	5.76	6	5.85
560	4.08	5.71	5.91	5.81

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Temperature	Aerobic
(#)	(°C)	(mm)
1	20	1
2	20	1.75
3	20	2
4	20	2

Sediment Oxygen Demand Aerobic Layer Tests

Time	1st Run	2nd Run	3rd Run	4th Run
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
580	4.02	5.64	5.85	5.72
600	3.96	5.59	5.78	5.66
620	3.86	5.53	5.76	5.61
640	3.85	5.48	5.67	5.56
660	3.8	5.4	5.65	5.54
680	3.73	5.35	5.61	5.48
700	3.67	5.26	5.53	5.38
720	3.61	5.24	5.51	5.37
740	3.58	5.16	5.44	5.29
760	3.52	5.14	5.37	5.25
780	3.43	5.07	5.3	5.2
800	3.41	5.03	5.16	5.14
820	3.34	4.99	5.24	5.11
840	3.32	4.91	5.17	5.06
860	3.26	4.89	5.14	5.04
880	3.21	4.86	5.06	4.97
900	3.17	4.81	5.03	4.94
920	3.13	4.76	5	4.87
940	3.1	4.71	4.91	4.85
960	3.04	4.66	4.9	4.78
980	3.03	4.62	4.84	4.73
1000	2.97	4.59	4.78	4.69
1020	2.92	4.52	4.77	4.63
1040	2.9	4.5	4.72	4.59
1060	2.84	4.44	4.67	4.55
1080	2.81	4.42	4.63	4.51
1100	2.77	4.34	4.58	4.45
1120	2.74	4.28	4.52	4.43

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Temperature	Aerobic
(#)	(°C)	(mm)
1	20	1
2	20	1.75
3	20	2
4	20	2

Sediment Oxygen Demand Aerobic Layer Tests

Time	1st Run	2nd Run	3rd Run	4th Run
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1140	2.71	4.28	4.46	4.38
1160	2.66	4.22	4.47	4.35
1180	2.65	4.15	4.41	4.29
1200	2.59	4.13	4.38	4.23
1220	2.55	4.09	4.34	4.22
1240	2.52	4.07	4.3	4.16
1260	2.5	4	4.19	4.11
1280	2.47	3.98	4.15	4.09
1300	2.42	3.96	4.1	4.02
1320	2.41	3.93	4.05	3.98
1340	2.37	3.9	4.05	3.98
1360	2.36	3.82	3.98	3.91
1380	2.32	3.77	3.95	3.89
1400	2.3	3.75	3.9	3.83
1420	2.29	3.75	3.9	3.78
1440	2.25	3.71	3.84	3.76
1460	2.22	3.66	3.81	3.71
1480	2.22	3.63	3.77	3.7
1500	2.17	3.6	3.74	3.66
1520	2.15	3.58	3.69	3.61
1540	2.12	3.54	3.67	3.55
1560	2.09	3.5	3.64	3.52
1580	2.07	3.44	3.58	3.5
1600	2.05	3.41	3.56	3.44
1620	2.04	3.35	3.52	3.39
1640	1.99	3.37	3.49	3.36
1660	2	3.34	3.43	3.32
1680	1.96	3.31	3.42	3.31

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Temperature	Aerobic
(#)	(°C)	(mm)
1	20	1
2	20	1.75
3	20	2
4	20	2

Sediment Oxygen Demand Aerobic Layer Tests

Time	1st Run	2nd Run	3rd Run	4th Run
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1700	1.94	3.27	3.39	
1720	1.93	3.25	3.35	
1740	1.88	3.23	3.32	
1760	1.87	3.19	3.28	
1780	1.84	3.16	3.26	
1800	1.84	3.12	3.19	
1820	1.83	3.11	3.18	
1840	1.82	3.08	3.14	
1860	1.77	3.04	3.13	
1880	1.78	3.03	3.1	
1900	1.73	3	3.05	
1920	1.74	2.98	3.01	
1940	1.7	2.94	2.98	
1960	1.72	2.9	2.96	
1980	1.69	2.88	2.92	
2000	1.67	2.86	2.9	
2020	1.64	2.83	2.86	
2040	1.63	2.83	2.82	
2060	1.61	2.78	2.8	
2080	1.6	2.77	2.76	
2100	1.59	2.75	2.71	
2120	1.59	2.7	2.68	
2140	1.56	2.69	2.69	
2160	1.54	2.66	2.63	
2180	1.55	2.65	2.62	
2200	1.53	2.62	2.57	
2220	1.49	2.58	2.54	
2240	1.48	2.56	2.53	

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Temperature	Aerobic
(#)	(°C)	(mm)
1	20	1
2	20	1.75
3	20	2
4	20	2

Sediment Oxygen Demand Aerobic Layer Tests

Time	1st Run	2nd Run	3rd Run	4th Run
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
2260	1.48	2.55	2.48	
2280	1.45	2.53	2.46	
2300	1.46	2.51	2.44	
2320	1.42	2.47	2.41	
2340	1.43	2.46	2.38	
2360	1.41	2.44	2.36	
2380	1.4	2.4	2.3	
2400	1.39	2.38	2.28	
2420	1.36	2.37	2.26	
2440	1.36	2.35	2.21	
2460	1.32	2.31	2.2	
2480	1.32	2.27	2.11	
2500	1.31	2.26	2.12	
2520	1.04	2.24	2.08	
2540	1.28	2.22		
2560		2.19		
2580		2.18		
2600		2.18		
2620		2.15		
2640		2.12		
2660		2.1		
2680		2.08		
2700		2.04		
2720		2.03		
2740		2.03		
2760		2.01		
2780		1.99		
2800		1.96		

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	Not Recorded	10/3-12:00	20			2
2	10/5-16:00	10/7-13:00	15	12.23	8.01	
3	10/7-22:00	10/9-17:00	10	8.75	9.03	
4	10/9-23:00	10/11-15:00	10	9.16	8.92	
5	10/12-10:00	10/14-10:00	5	8.96		

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20	7.9	7.47	8.21	8.02	8.73
40	7.8	7.23	8.12	7.92	8.6
60	7.7	7.13	8.27	7.85	8.51
80	7.58	7.12	8.03	7.8	8.37
100	7.51	6.98	7.88	7.65	8.37
120	7.43	6.94	7.78	7.81	8.26
140	7.31	6.84	7.74	7.57	8.19
160	7.25	6.73	7.19	7.43	8.32
180	7.21	6.66	7.33	7.39	8.15
200	7.08	6.58	7.2	7.32	8.08
220	7.03	6.45	7.09	7.25	7.96
240	6.9	6.36	7.11	7.19	7.84
260	6.81	6.27	7.04	7.05	7.89
280	6.74	6.19	6.88	7.02	7.83
300	6.64	6.18	6.9	6.94	7.74
320	6.59	6.04	6.85	6.87	7.71
340	6.51	6.01	6.77	6.78	7.83
360	6.43	5.93	6.67	6.72	7.5
380	6	5.89	6.6	6.66	7.59
400	6.29	5.83	6.47	6.6	7.64
420	6.26	5.72	6.51	6.52	7.38
440	6.17	5.67	6.38	6.49	7.2
460	6.13	5.62	6.33	6.42	7.19
480	6.09	5.54	6.18	6.32	7.15
500	6.02	5.45	6.21	6.27	7.07
520	5.91	5.42	6.17	6.24	7.46
540	5.85	5.33	6.14	6.12	7.17

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	Not Recorded	10/3-12:00	20			2
2	10/5-16:00	10/7-13:00	15	12.23	8.01	
3	10/7-22:00	10/9-17:00	10	8.75	9.03	
4	10/9-23:00	10/11-15:00	10	9.16	8.92	
5	10/12-10:00	10/14-10:00	5	8.96		

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
560	5.81	5.26	5.99	6.05	7.1
580	5.72	5.18	5.9	6	7.06
600	5.66	5.16	5.76	5.91	6.96
620	5.61	5.08	5.79	5.95	6.85
640	5.56	5.02	5.76		6.9
660	5.54	4.96	5	5.74	6.71
680	5.48	4.93	5.55	5.75	6.63
700	5.38	4.73	5.59	5.58	6.76
720	5.37	4.78	5.55	5.57	6.65
740	5.29		5.03	6.45	6.48
760	5.25	4.64	5.38	5.45	6.42
780	5.2	4.6	5.34	5.31	6.39
800	5.14	4.55	5.29	5.55	6.53
820	5.11	4.46	5.25	5.21	6.47
840	5.06	4.44	5.16	5.2	6.44
860	5.04	4.38	5.03	5.1	7.02
880	4.97	4.31	5.05	5.03	6.9
900	4.94	4.28	4.96	5.06	6.23
920	4.87	4.19	4.93	4.94	6.3
940	4.85	4.15	4.87	4.96	6.2
960	4.78	4.1	4.81	4.86	6.2
980	4.73	4.04	4.81	4.77	6.1
1000	4.69	4.04	4.72	4.74	6.09
1020	4.63	3.93	4.63	4.72	6.15
1040	4.59	3.88	4.56	4.58	5.49
1060	4.55	3.84	4.71	4.84	5.95
1080	4.51	3.8	4.52	4.5	5.84

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	Not Recorded	10/3-12:00	20			2
2	10/5-16:00	10/7-13:00	15	12.23	8.01	
3	10/7-22:00	10/9-17:00	10	8.75	9.03	
4	10/9-23:00	10/11-15:00	10	9.16	8.92	
5	10/12-10:00	10/14-10:00	5	8.96		

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1100	4.45	3.74		4.47	5.88
1120	4.43	3.66	4.39	4.36	5.91
1140	4.38	3.63	4.21	4.34	5.95
1160	4.35	3.59	4.3	3.85	5.82
1180	4.29	3.54	4.19	4.12	5.76
1200	4.23	3.48	4.17	4.45	
1220	4.22	3.4	4.09	3.99	5.51
1240	4.16	3.35	4.07	3.94	5.67
1260	4.11	3.32	4.04	3.94	5.63
1280	4.09	3.29	4.67	3.83	5.5
1300	4.02	3.23	4.02	4.15	5.48
1320	3.98	3.17	3.89	3.79	5.5
1340	3.98	3.14	3.83	3.7	5.39
1360	3.91	3.05	3.73	3.64	5.36
1380	3.89	3.02	3.71		5.29
1400	3.83	2.97	3.66	3.7	
1420	3.78	2.92	3.43	4	5.17
1440	3.76	2.86	3.56		5.25
1460	3.71	2.86	3.48	3.52	5.21
1480	3.7	2.8	3.69	3.47	5.24
1500	3.66	2.74	3.38	3.46	5.2
1520	3.61	2.7	3.38	3.56	5.18
1540	3.55	2.65	3.39	3.37	5.11
1560	3.52	2.61	3.24	3.28	4.91
1580	3.5	2.4	3.25	3.18	5.07
1600	3.44	2.53	3.59	3.17	5.24
1620	3.39	2.49	3.19		4.96

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	Not Recorded	10/3-12:00	20			2
2	10/5-16:00	10/7-13:00	15	12.23	8.01	
3	10/7-22:00	10/9-17:00	10	8.75	9.03	
4	10/9-23:00	10/11-15:00	10	9.16	8.92	
5	10/12-10:00	10/14-10:00	5	8.96		

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1640	3.36	2.44	3.01	3.13	4.94
1660	3.32	2.41	3.01	3.08	4.91
1680	3.31	2.37	2.98	2.9	4.89
1700		2.32	3.13		
1720		2.26	2.97	2.95	4.86
1740		2.26	2.83	2.9	4.73
1760		2.19	2.5		4.7
1780		2.15	3.77	2.81	4.6
1800		2.12	2.34	2.53	4.51
1820		2.08	2.54	2.63	4.54
1840		2.05	3.18	3.03	4.22
1860		1.99	2.58	2.4	4.5
1880		1.98	2.43	2.57	4.27
1900		1.88	2.46	2.53	4.22
1920		1.82	2.68	2.46	4.3
1940		1.85			4.23
1960		1.82	2.25	2.45	
1980		1.78	2.23	2.19	4.07
2000		1.75	2.11		4.08
2020		1.72		2.22	3.73
2040		1.6		2.22	4.22
2060		1.63		2.15	4.03
2080		1.6	2.37	2.2	4.36
2100		1.56	1.86	1.93	4.17
2120		1.46	2.11	2.24	4.21
2140		1.57	1.8	2.06	4.12
2160		1.59	2.45	1.97	3.99

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(#)	Start	End	(°C)	Before	After	(mm)
1	Not Recorded	10/3-12:00	20			2
2	10/5-16:00	10/7-13:00	15	12.23	8.01	
3	10/7-22:00	10/9-17:00	10	8.75	9.03	
4	10/9-23:00	10/11-15:00	10	9.16	8.92	
5	10/12-10:00	10/14-10:00	5	8.96		

Temperature Sediment Oxygen Demand Tests

Time	20°C	15°C	10°C	10°C	5°C
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
2180		1.47	1.76	1.94	3.98
2200		1.44	1.82	1.85	
2220		1.42	1.82	2.07	
2240		1.42	1.83	2.29	3.63
2260		1.46	1.78		3.79
2280		1.27	1.76	1.7	3.74
2300		1.36	1.71	1.62	3.83
2320		1.32	1.67	1.61	3.89
2340		1.28	1.58	1.31	
2360		1.28	1.6		3.88
2380		1.24	1.57	1.29	3.27
2400		1.23	1.56	1.42	3.75
2420		1.22	1.53		3.7
2440		1.1		0.96	3.27
2460		1.17	1.42	1.34	3.69
2480		1.1	1.42		3.63
2500		1.13	1.4	1.43	
2520		1.14	1.38	1.29	3.73
2540		1.07	1.6		3.54
2560		0.98	1.13		3.57
2580		1.06	1.3		3.59
2600		1.06	1.13		3.49
2620		0.98			
2640		1.02			3.44
2660					3.2
2680					
2700					3.25

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(rpm)	Start	End	(°C)	Before	After	(mm)
17	10/18 - 21:00	10/19 - 18:00	20			2.5
17 new water	10/31 - 14:00	11/01 - 21:00	20			
9 error	11/9 - 13:00	11/10 - 12:30	20	8.7	8.75	
9	11/10-15:00	11/11 - 11:00	20	8.49	8.7	
26	11/11 - 21:00	11/12 - 20:00	20	8.89	8.65	
34	11/14 - 19:00	11/15 - 15:00	20	8.83	8.66	

Velocity Sediment Oxygen Demand Tests

Time	0.1731 ft/s	0.1731 ft/s	0.0916 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	17 rpm	17 rpm	9 rpm	26 rpm	34 rpm
20	5.44	6.95	6.65	7.27	6.8
40	6.55	7.08	6.89	7.17	6.82
60	5.02	6.74	6.42	6.99	6.77
80	4.77	6.65	6.47	6.87	6.38
100	4.82	6.58	6.23	6.77	5.33
120	4.64	6.47	6.2	6.69	6.95
140	4.59	6.45	6.17	6.61	6.58
160	4.46	6.4	6.06	6.46	6.95
180	4.23	6.33	6.02	6.38	6.57
200	4.09	6.23	6.05	6.2	5.56
220	3.98	6.13	5.76	6.22	5.56
240	3.87	6.01	5.75	6.09	6.31
260	3.77	6.12	5.7	5	5.38
280	3.62	5.88	5.62	6	6.09
300	3.66	5.86	5.59	5.74	4.76
320	3.52	5.63	5.51	5.61	5.79
340	3.23	5.71	5.36	5.54	5.73
360	3.25	5.61	5.32	5.11	5.76
380	3.23	5.4	5.21	4.79	4.75
400	2.92	5.45	5.21	5.84	5.53
420	2.67	5.42	5.07	6.29	4.54
440	2.41	5.77	5.12	5.61	5.48
460	2.3	5.85	4.99	5.01	4.41
480	2.82	5.12	4.9	4.96	5.23
500	2.09	5.71	4.89	4.87	4.45
520	2.31	5.02	4.8	4.76	4.19

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(rpm)	Start	End	(°C)	Before	After	(mm)
17	10/18 - 21:00	10/19 - 18:00	20			2.5
17 new water	10/31 - 14:00	11/01 - 21:00	20			
9 error	11/9 - 13:00	11/10 - 12:30	20	8.7	8.75	
9	11/10-15:00	11/11 - 11:00	20	8.49	8.7	
26	11/11 - 21:00	11/12 - 20:00	20	8.89	8.65	
34	11/14 - 19:00	11/15 - 15:00	20	8.83	8.66	

Velocity Sediment Oxygen Demand Tests

Time	0.1731 ft/s	0.1731 ft/s	0.0916 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	17 rpm	17 rpm	9 rpm	26 rpm	34 rpm
540	2.58	4.84	4.71	5.48	4.17
560	1.77	4.2	4.66	5.51	5.21
580	1.54	4.81	4.52	5.36	3.7
600	1.72	4.79	4.58	4.47	4.59
620	2.47	4.78	4.48	4.47	3.71
640	2.66	4.84	4.42	5.09	3.73
660	1.02	4.46	4.35	4.28	3.4
680	1.12	4.38	4.22	4.81	4.44
700	1.75	4.37	4.2	3.73	3.54
720	1.37	4.25	4.19	4.07	4.27
740	1.06	4.67	4.17	4.01	4.44
760	1.54	5.06	4.08	3.79	3.28
780	1.38	4.11	4.03	4.67	4.04
800	0.93	4	3.9	3.83	3.02
820	1.18	4.67	3.9	3.73	2.98
840	0.96	3.85	3.83	3.52	3.85
860	0.93	4.76	3.78	3.65	3.76
880	0.99	3.63	3.75	3.56	4.17
900	0.91	3.73	3.64	3.45	3.56
920	0.87	3.79	3.62	3.34	3.66
940	0.75	3.57	3.56	3.21	3.62
960	0.77	4.2	3.51	3.07	3.4
980	0.72	3.5	3.44	3.91	2.4
1000	0.67	4.18	3.36	2.97	3.28
1020	0.66	3.58	3.35	2.92	2.43
1040	0.58	3.31	3.28		3.26

Table G7. County Road 3 Sediment Oxygen Demand Tests (Continued)

Velocity Sediment Oxygen Demand Tests - Experiment Information

Run	Time (Month/Day - Hr/Min)		Temperature	DO Meter Calibration		Aerobic
(rpm)	Start	End	(°C)	Before	After	(mm)
17	10/18 - 21:00	10/19 - 18:00	20			2.5
17 new water	10/31 - 14:00	11/01 - 21:00	20			
9 error	11/9 - 13:00	11/10 - 12:30	20	8.7	8.75	
9	11/10-15:00	11/11 - 11:00	20	8.49	8.7	
26	11/11 - 21:00	11/12 - 20:00	20	8.89	8.65	
34	11/14 - 19:00	11/15 - 15:00	20	8.83	8.66	

Velocity Sediment Oxygen Demand Tests

Time	0.1731 ft/s	0.1731 ft/s	0.0916 ft/s	0.2647 ft/s	0.3462 ft/s
(min)	17 rpm	17 rpm	9 rpm	26 rpm	34 rpm
1060	0.55	3.16	3.17		3.32
1080	0.51	4.5	3.16		2.14
1100	0.46	2.88	3.12		3
1120	0.45	3.69	3.04		1.99
1140	0.44	3.36	2.99		2.93
1160	0.39	3.07	2.94		2.19
1180	0.36	3.03	2.88		2.41
1200	0.41	2.76			
1220	0.32	2.55			
1240	0.3	2.52			
1260		2.73			
1280		2.87			
1300		3.53			
1320		2.22			
1340		2.68			
1360		2.55			
1380		3.27			
1400		2.63			
1420		3.14			
1440		2.33			
1460		2.96			
1480		3.07			
1500		2.22			
1520		3.07			
1540		1.96			
1560		1.87			

Table G8. Highway 9 Sediment Oxygen Demand Tests

Italic = Machine Problems

Sediment Oxygen Demand Test Trials with Aerated Water and Reactor Errors

Time	1st	2nd	3rd	4th	5th	6th
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20	6	8.84	6.5	6.48	*6.16*	6.25
40	5.91	8.64	6	6.49	*6.12*	6.17
60	5.78	8.45	6.37	6.44	*6.18*	6.04
80	5.7	8.23	6.34	6.33	*6.13*	5.94
100	5.56	8.02	6.27	6.18	*5.99*	5.83
120	5.45	7.84	6.21	6.17	*5.75*	5.71
140	5.38	7.64	5.99	6.02	*5.68*	5.64
160	5.26	7.47	5.95	5.98	*5.59*	5.59
180	5.24	7.3	5.85	5.83	*5.5*	5.44
200	5.12	7.16	5.69	5.78	*5.38*	5.36
220	5.05	7.01	5.7	5.7	*5.25*	5.31
240	4.89	6.87	5.56	5.67	*4.88*	5.19
260	4.85	6.74	5.41	5.58	*4.84*	5.09
280	4.76	6.62	5.35	5.52	*4.74*	5.04
300	4.69	6.51	5.2	5.46	*4.57*	5.03
320	4.58	6.4	5.16	5.38	*4.51*	4.94
340	4.53	6.3	5.05	5.31	*4.41*	4.91
360	4.45	6.22	4.94	5.27	*4.33*	4.83
380	4.37	6.13	4.78	5.17	*4.3*	4.77
400	4.31	6.04	4.76	5.1	*4.19*	4.76
420	4.18	5.95	4.65	5.06	*4.18*	4.67
440	4.12	5.88	4.52	4.9	*3.58*	4.6
460	4.03	5.78	4.45	4.89	3.5	4.54
480	3.97	5.71	4.35	4.85	3.42	4.47
500	3.89	5.63	4.27	4.82	3.39	4.44
520	3.84	5.55	4.19	4.79	3.31	4.38
540	3.72	5.48	4.07	4.75	3.29	4.36
560	3.66	5.44	3.97	4.69	3.24	4.27
580	3.62	5.38	3.96	4.65	3.2	4.25
600	3.52	5.33	3.87	4.6	3.14	4.15
620	3.44	5.28	3.81	4.52	3.09	4.07
640	3.4	5.23	3.77	4.48	3.01	4.02
660	3.33	5.19	3.73	4.44	2.99	3.98
680	3.28	5.15	3.72	4.44	2.93	3.92

Table G8. Highway 9 Sediment Oxygen Demand Tests (Continued)

Italic = Machine Problems

Sediment Oxygen Demand Test Trials with Aerated Water and Reactor Errors

Time	1st	2nd	3rd	4th	5th	6th
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
700	3.17	5.1	3.63	4.38	2.91	3.89
720	3.12	5.07	3.58	4.3	2.89	3.81
740	3.03	5.03	3.57	4.26	2.82	3.8
760	2.98	4.99	3.55	4.27	2.79	3.69
780	2.92	4.96	3.47	4.18	2.77	3.64
800	2.85	4.93	3.46	4.18	2.67	3.63
820	2.8	4.89	3.42	4.08	2.66	3.53
840	2.69	4.86	3.37	4.12	2.63	3.49
860	2.64	4.83	3.36	3.98	2.55	3.46
880	2.57	4.78	3.3	4.02	2.53	3.37
900	2.48	4.76	3.24	3.93	2.51	3.34
920	2.54	4.73	3.25	3.92	2.44	3.27
940	2.36	4.69	3.22	3.93	2.41	3.24
960	2.31	4.67	3.17	3.82	2.38	3.2
980	2.23	4.66	3.14	3.83	2.34	3.16
1000	2.19	4.62	3.1	3.76	2.28	3.15
1020	2.1	4.58	3.07	3.77	2.26	3.02
1040	2.07	4.57	3.05	3.66	2.17	2.97
1060	2	4.54	3	3.66		2.94
1080	1.99	4.51	2.96	3.61		2.88
1100	1.92	4.49	2.97	3.58		2.81
1120	1.9	4.47	2.88	3.52		2.79
1140	1.88	4.45	2.87	3.51		2.76
1160	1.86	4.41	2.86	3.45		2.7
1180	1.8	4.4	2.82	3.43		2.66
1200	1.8	4.38	2.78	3.34		2.61
1220	1.77	4.37	2.77	3.36		2.54
1240	1.72	4.37	2.79	3.35		2.51
1260	1.71	4.35	2.68	3.29		2.48
1280	1.68	4.31	2.63	3.28		2.38
1300	1.6	4.27	2.63	3.25		2.4
1320	1.61	4.24	2.57	3.19		2.35
1340	1.59	4.19	2.59	3.15		2.39
1360	1.56	4.15	2.55	3.15		2.24

Table G8. Highway 9 Sediment Oxygen Demand Tests (Continued)

Italic = Machine Problems

Sediment Oxygen Demand Test Trials with Aerated Water and Reactor Errors

Time	1st	2nd	3rd	4th	5th	6th
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1380	1.55	4.1	2.47	3.09		2.19
1400	1.52	4.06	2.45	3.05		2.13
1420	1.51	4	2.46	3.02		2.11
1440	1.49	3.96	2.43	3.06		2.1
1460	1.46	3.91	2.39	3.01		2.08
1480	1.45	3.87	2.37	2.97		2.07
1500	1.42	3.83	2.34	2.91		1.9
1520	1.41	3.78	2.31	2.83		1.87
1540	1.4	3.73	2.28	2.8		1.83
1560	1.37	3.69	2.24	2.81		1.84
1580	1.36	3.65	2.25	2.78		1.79
1600	1.34	3.6	2.2	2.73		1.76
1620	1.33	3.57	2.14	2.72		1.71
1640	1.31	3.52	2.13	2.7		1.67
1660	1.28	3.47	2.12	2.63		1.59
1680	1.27	3.42	2.09	2.65		1.57
1700	1.26	3.38	2.09	2.62		1.54
1720	1.22	3.33	2.06	2.55		1.5
1740	1.23	3.23	2.02	2.51		1.46
1760	1.21	3.13	2.03	2.47		1.41
1780	1.19	3.02	1.98	2.48		1.36
1800	1.16	2.88	1.94	2.41		1.32
1820	1.16	2.8	1.94	2.41		1.3
1840		2.7	1.92	2.38		1.26
1860		2.58	1.89	2.41		1.22
1880		2.53	1.85	2.34		1.22
1900		2.49	1.82	2.38		1.15
1920		2.42		2.3		1.12
1940		2.36		2.27		1.09
1960		2.36		2.23		1.05
1980		2.26		2.22		1.01
2000		2.22		2.18		1
2020		2.19		2.14		0.96
2040		2.2		2.09		0.92

Table G8. Highway 9 Sediment Oxygen Demand Tests (Continued)

Italic = Machine Problems

Sediment Oxygen Demand Test Trials with Deionized Water Replacement

Time	1st	2nd	3rd	4th	5th	6th
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
20						6.54
40						6.47
60						6.42
80					6.17	6.3
100					6.26	6.27
120					6.17	6.13
140		6.11	6.11		6.11	6.16
160		6.04	6.05		6.1	6.1
180		5.92	5.95		6	5.98
200		5.8	5.88	5.78	5.99	5.96
220		5.66	5.79	5.75	5.95	5.92
240		5.55	5.69	5.68		5.83
260		5.46	5.66	5.63		5.8
280		5.33	5.54	5.55		5.78
300		5.17	5.48	5.46		5
320		5.12	5.41	5		5.69
340		5.06	5.33	5.36		5.64
360	5.05	4.94	5.26	5.25		5.61
380	4.87	4.84	5.13	5.25		5.59
400	4.72	4.72	5.15	5.2		5.52
420	4.53	4.63	5.05	5.09		5.45
440	4.32	4.59	5.03	4.99		5.44
460	4.2	4.52	4.94	4.93		5.4
480	4.01	4.42	4.9	4.88		5.34
500	3.9	4.36	4.77	4.88		5.29
520	3.74	4.29	4.79	4.81		5.27
540	3.6	4.2	4.73	4.69		5.24
560	3.46	4.15	4.6	4.69		5.12
580	3.38	4.05	4.59	4.69		5.11
600	3.24	3.94	4.51	4.59		5.07
620	3.18	3.91	4.46	4.52		4.99
640	3.04	3.83	4.44	4.51		5.04
660	2.92	3.76	4.39	4.4		5.02
680	2.86	3.69	4	4.47		4.93

Table G8. Highway 9 Sediment Oxygen Demand Tests (Continued)

Italic = Machine Problems

Sediment Oxygen Demand Test Trials with Deionized Water Replacement

Time	1st	2nd	3rd	4th	5th	6th
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
700	2.78	3.67	4.28	4.37		4.91
720	2.7	3.58	4.21	4.34		4.86
740	2.57	3.54	4.19	4.28		4.83
760	2.52	3.47	4.14	4.28		4.76
780	2.41	3.41	4.09	4.22		4.78
800	2.34	3.33	4.02	4.16		4.77
820	2.24	3.28	3.98	4.15		4.68
840	2.19	3.22	3.95	4.01		4.66
860	2.14	3.18	3.92	4.03		4.61
880	2.06	3.1	3.89	3.97		4.58
900	1.97	3.06	3.82	3.89		4.56
920	1.94	3	3.77	3.88		4.53
940	1.89	2.97	3.71	3.83		4.48
960	1.82	2.93	3.68	3.8		4.41
980	1.78	2.85	3.66	3.77		4.4
1000	1.72	2.81	3.63	3.7		4.41
1020	1.68	2.77	3.52	3.69		4.35
1040	1.61	2.73	3.48	3.64		4.32
1060	1.55	2.66	3.49	3.6		4.29
1080	1.51	2.61	3.42	3.6		4.24
1100	1.49	2.58	3.42	3.54		4.2
1120	1.43	2.53	3.35	3.52		4.2
1140	1.39	2.5	3.32	3.5		4.17
1160	1	2.43	3.27	3.47		4.09
1180	1.28	2.41	3.52	3.42		4.09
1200	1.24	2.36	6	3.39		4.06
1220	1.22	2.31	6.54	3.35		4
1240	1.16	2.27	6.51	3.32		4
1260	1.13	2.22	6.32	3.29		3.95
1280	1.08	2.21	5.93	3.25		3.9
1300	1.04	2.15	5.63	3.26		3.88
1320	1.01	2.12	5.18	3.22		3.89
1340	0.98	2.07	3.84	3.21		3.82
1360	0.93	2.03	*3.66*	3.15		3.8

Table G8. Highway 9 Sediment Oxygen Demand Tests (Continued)

Italic = Machine Problems

Sediment Oxygen Demand Test Trials with Deionized Water Replacement

Time	1st	2nd	3rd	4th	5th	6th
(min)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)	DO (mg/L)
1380	0.92	2.01	*3.51*	3.13		3.77
1400		1.97	*3.48*	3.09		3.69
1420		1.94	*3.45*	3.07		3.71
1440		1.9	*3.43*	3.04		3.71
1460		1.86	*3.42*	3.03		3.69
1480		1.82	*3.37*	3.02		3.63
1500		1.78	*3.38*	2.96		3.6
1520		1.75	*3.32*	2.92		3.62
1540		1.72	*3.3*	2.92		3.55
1560		1.69		2.9		3.52
1580				2.9		3.54
1600				2.87		3.45
1620				2.78		3.44
1640				2.82		3.43
1660				2.78		3.36
1680				2.77		3.38
1700				2.74		
1720				2.71		
1740				2.66		
1760				2.68		
1780				2.65		
1800				2.63		
1820				2.58		
1840				2.57		
1860				2.55		
1880				2.53		
1900				2.52		
1920				2.48		
1940				2.47		
1960				2.44		
1980				2.44		
2000				2.42		
2020				2.41		
2040				2.38		

APPENDIX H. QUAL2K MODEL

Table H1. QUAL2K Model Flow Calibration

River Distance from Glen Ewen	QUAL2K Model Simulated Mannings Coefficient	QUAL2K Model Simulated Water Depth	Field Measured Water Elevation	Field Measured River Bed Elevation
(km)	(n)	(m)	(m)	(m)
0.00	0.065	499.77	499.79	498.87
9.04	0.065	499.11		497.87
13.57	0.05	497.36		496.37
26.08	0.08	495.88		494.87
30.22	0.09	494.88		493.87
36.01	0.02	493.88		492.87
40.23	0.065	492.40		490.87
48.49	0.01	490.27		489.87
53.67	0.01	489.38		489.07
55.72	0.01	487.93	487.79	486.88
61.24	0.01	486.94		486.63
66.81	0.009	486.93	486.79	485.88
78.33	0.05	486.17		485.12
83.41	0.05	486.19	486.70	484.88
91.12	0.05	485.91		483.81
104.04	0.01	485.87		483.77
138.28	0.02	484.84	485.15	481.49

Table H2. QUAL2K Model Scenarios

Distance from Glen Ewen	Dissolved Oxygen for Model Scenarios			
	No US Action	31% Reduction	39% Reduction	53% Reduction
(km)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
0.00	8.00	8.00	7.00	6.00
9.04	7.81	7.97	6.98	5.98
13.57	7.58	7.94	6.95	5.96
26.08	7.52	7.93	6.94	5.96
30.22	7.03	7.75	6.84	5.94
36.01	7.02	7.75	6.84	5.93
40.23	6.99	7.74	6.83	5.93
48.49	6.69	7.62	6.77	5.91
53.67	6.58	7.58	6.74	5.91
55.72	6.57	7.57	6.74	5.90
61.24	6.56	7.57	6.73	5.90
66.81	5.12	6.91	6.29	5.68
78.33	5.12	6.91	6.29	5.68
83.41	1.42	5.18	5.11	5.10
91.12	1.41	5.17	5.11	5.09
104.04	1.41	5.17	5.11	5.09
104.71	0.97	5.01	5.02	5.07
138.28	0.97	5.01	5.02	5.07