CREEK WATER QUALITY IMPACTS: IRRIGATION TAILWATERS AND SEWAGE DISCHARGES

by

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ABSTRACT

The objective of this study was to determine the impacts of irrigation tailwater and sewage lagoon discharge on the water quality of Crowfoot Creek, Alberta, Canada. The monitored irrigation tailwater accounted for more than 55% of the water flow in the basin. With the exception of the early part of the 1997 irrigation season the irrigation tailwater only impacted the phosphate and total phosphorus levels in the creek. High values for all parameters were recorded in the early part of the 1997 irrigation season, due to irrigation source water quality or deposition of contaminants into the irrigation canals during the 1997 spring runoff. The impact of the sewage lagoon effluent on the water quality of the creek was minimal to insignificant. The primary sources of contamination in the watershed are thought to be direct cattle access to the creek, soil erosion and surface runoff.

RESUME

Le but de cette étude fut de déterminer l'impact de l'eau d'irrigation surabondante et des rejets de bassin de traitement d'effluents urbains sur la qualité de l'eau dans le bassin du ruisseau Crowfoot, en Alberta, Canada. Les eaux d'irrigation surabondantes furent responsables pour plus de 55% du débit du bassin. A l'exception du début de la saison d'irrigation en 1997, les eaux d'irrigation surabondantes n'eurent d'impacte que sur la teneur en phosphates et le phosphore total de l'eau du ruisseau. Au début de la saison d'irrigation de 1997 la contribution, aux niveaux élevés des divers paramètres de qualité de l'eau du ruisseau, de l'eau d'irrigation surabondante et des dépots de contaminants dans les canaux d'irrigation lors de l'écoulement printanier, fut noté. L'impacte des rejets du bassin de traitement sur la qualité de l'eau du ruisseau fut de minimale à insignifiante. Les principales sources de contamination dans le bassin versant semblent être l'accès direct du bétail au ruisseau, l'érosion du sol et le ruissèlement.

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ABBREVIATIONS

AAFRD	Alberta Agriculture, Food and Rural Development
Avg.	Average
°C	degrees Celsius
Ca	Calcium
CCREM	Canadian Council of Resource and Environmental Ministers
Cl	Chloride
CO_3	Carbonate
DP	Dissolved Phosphorus
F.Coli.	Fecal Coliform
HCO_3	Bicarbonate
H_2SO_4	Sulphuric Acid
JD	Julian Day
K	Potassium
kg	Kilogram
kg/ha	Kilograms per Hectare
km	Kilometre
m^3/s	cubic metres per second
Max.	Maximum
Mg	Magnesium
Mg	Megagram
mg/L	Milligrams per Litre
mm	millimetre
N	Nitrogen
N_2	Molecular Nitrogen
Na	Sodium
NAQUADAT	National Water Quality Data Bank
NH_3	Ammonia
NH_4	Ammonium

NO_2	Nitrite
NO_2-N	Nitrogen as Nitrite
NO_3	Nitrate
NO_3-N	Nitrogen as Nitrate
P	Phosphorus
PO_4	Ortho-phosphate
PP	Particulate Phosphorus
SO_4	Sulphate
TDS	Total Dissolved Solids
TKN	Total Kjeldahl Nitrogen
Total N	Total Nitrogen
Tot. N.	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
USA	United States of America
WID	Western Irrigation District
yr	year
μg/L	Micrograms per Litre

1.0 INTRODUCTION

Crowfoot Creek is a tributary of the Bow River, a major river in the Canadian province of Alberta. The Bow River Water Quality Task Force (1991) identified nutrients, coliform bacteria and metals as the major contaminants within the reach of the Bow River where Crowfoot Creek discharges. The Strategic and Support Division of Alberta Environmental Protection (1995) cautions that it will become increasingly difficult to maintain good water quality in the Bow River in the future if no action is taken. A surface water quality study conducted by Madawaska Consulting (1995) found that nutrients (particularly phosphorus) and fecal coliform bacteria usually exceeded water quality guidelines.

In 1996 the Irrigation Branch of Alberta Agriculture, Food and Rural Development (AAFRD) began a three year study to determine potential impacts on water quality of Crowfoot Creek by agricultural practices within the Crowfoot Creek watershed. McGill University was a partner in the study and this thesis is a major part of its contribution.

This thesis focuses on a sub-basin of the Crowfoot Creek watershed, the Larsen East basin. Irrigation takes place within the Larsen East basin and any excess irrigation water is discharged into the creek as an irrigation tailwater. The village of Standard is located within the Larsen East basin. Standard treats its municipal sewage in a sewage lagoon. Effluent from the lagoon is annually discharged into the creek over a one week period in late October. The decision to release the lagoon effluent during one week in the fall was taken by Alberta Environmental Protection and mentioned in the license granted to the village of Standard.

1.1 OBJECTIVES

The broad objective of this thesis is to determine the impacts of irrigation tailwater and sewage effluent on water quality of the Crowfoot Creek. The specific objectives are to:

- determine the impact on creek water quality by an irrigation tailwater,
- ascertain the effect of discharging effluent from the village of Standard's sewage lagoon on creek water quality,
- propose explanations for the fluctuations in parameters of interest: nitrogen as nitrite, nitrogen as nitrate, ammonium, total Kjeldahl nitrogen, total nitrogen, ortho-phosphate, total phosphorus, total dissolved solids, total suspended solids and fecal coliform, and
- identify sources of contamination with regard to the parameters of interest.

1.2 SCOPE

The objectives of the thesis were attained while limiting the scope of the study to the following. The Larsen East basin was delineated by AAFRD personnel. Sampling sites in the Larsen East basin (except one) were situated by AAFRD as part of their study. The flow, precipitation and water quality data were provided by AAFRD personnel. Sampling frequency was determined by AAFRD personnel, although the author did have input with regard to sampling frequency. The analysis is based on data collected during the 1996 and 1997 sampling seasons.

2.0 BACKGROUND

2.1 LARSEN EAST STUDY - PART OF THE CROWFOOT CREEK PROJECT

In 1996, the Irrigation Branch of Alberta Agriculture, Food and Rural Development (AAFRD) began an in-depth study on the Crowfoot Creek watershed (Figure 2.1) to determine the extent to which agricultural practices affect water quality. The Crowfoot Creek watershed is approximately 1360 km^2 in area. Twenty nine monitoring sites were located across the watershed to obtain water quality, flow and precipitation data. The project was designed to continue for three years starting in 1996. The partners in the study were the Irrigation Branch of AAFRD, Alberta Environmental Protection, Western Irrigation District, County of Wheatland, village of Standard, Ducks Unlimited Canada, McGill University and the University of Alberta. McGill University's contribution was to study a sub-basin of the Crowfoot Creek watershed in order to focus on water quality impacts within the sub-basin. The Larsen East basin of the Crowfoot Creek watershed was selected as the study site.

Data from 1996 and 1997 were collected from the Larsen East basin. Due to the time required to install the equipment, no data were collected until July 1996. Data from 1997 represent a complete sampling season; early spring through to October. A few sampling sites were relocated and some new ones were installed in 1997.

2.2 STUDY AREA

The Larsen East basin was chosen for two reasons. First, sampling of a significant discharge of excess irrigation water into the creek was possible. This provided an opportunity to study the impact of irrigation discharges on creek water quality. Second, the impact on water quality of the creek by the sewage effluent from the village of Standard's sewage lagoon needed to be determined. An understanding of the lagoon's impact on water quality of the creek would help explain water quality values observed downstream.

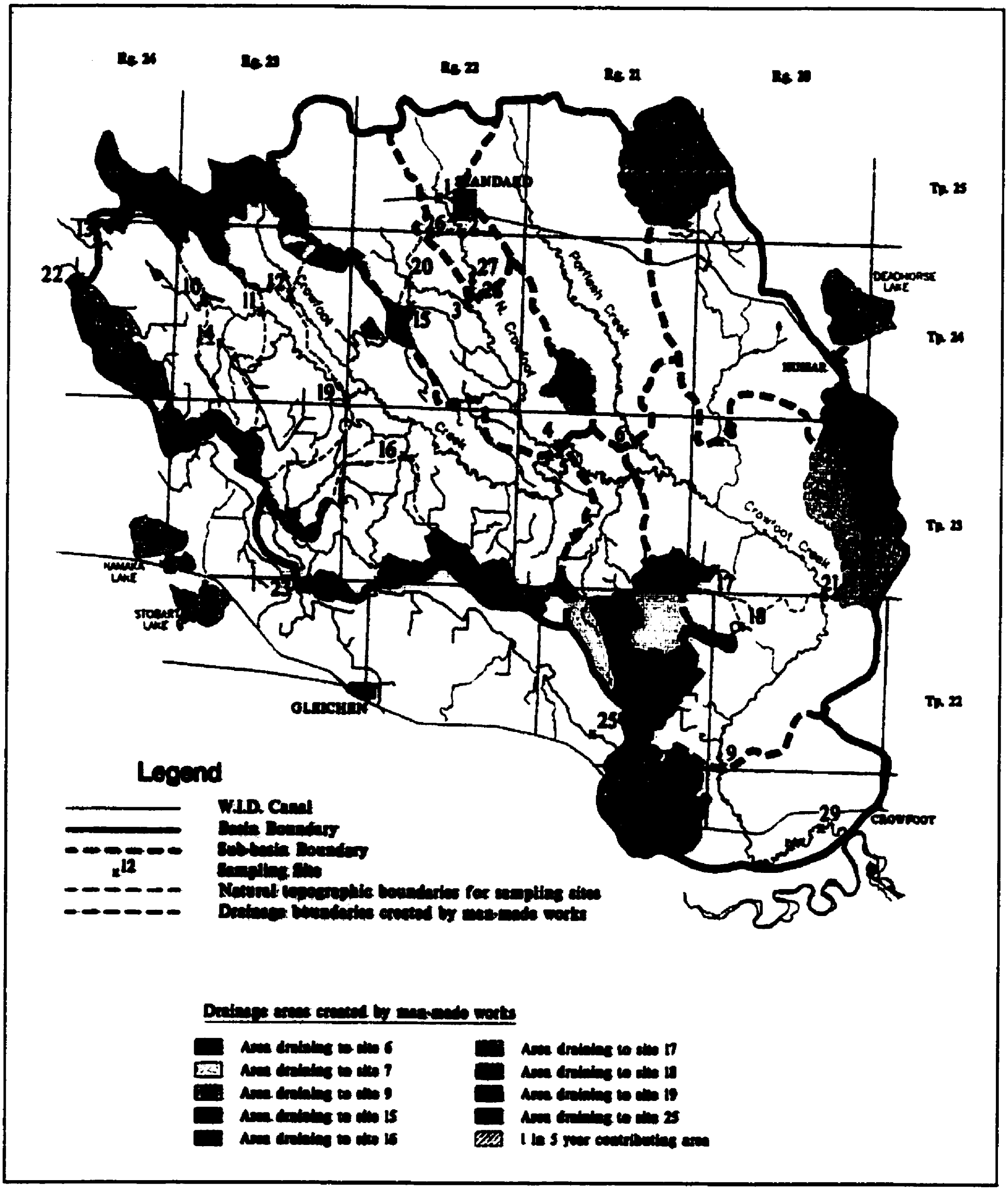

Figure 2.1 Map of the Crowfoot Creek watershed

The Larsen East basin (Figure 2.2) is approximately 169 km^2 in area. A smaller sub-basin (within which the village of Standard is located) is also part of the Larsen East basin. Hills on the northern boundary of the Larsen East basin result in some streams which account for the baseflow.

As can be seen in Figure 2.2 there are nine sampling sites in the Larsen East basin. Site #15 is located at the end of an irrigation canal. After the excess irrigation water passes by site #15 it is discharged into the creek downstream of site #20. Discharges of excess irrigation water are also known as "irrigation tailouts" or "irrigation tailwaters" or "irrigation return flows". In this thesis discharges of excess irrigation water shall be referred to as irrigation tailwaters. Irrigation water is supplied from early May until the end of September. Site #3 is not located on the creek between site #20 and #4 but on the eastern tributary of the creek. There is no flow past site #3 other than during spring runoff. It may be noted that in addition to the tailwater at site #15, three other discharges of excess irrigation water take place within the Larsen East Basin and are indicated by the "canal tailout without structure" icon in Figure 2.2. These tailouts do not form part of the analysis as they were not sampled or their flow recorded. The number of sampling sites was limited due to financial constraints. Site #26 is located at the discharge pipe where the sewage lagoon effluent enters the creek. Effluent from the sewage lagoon is released annually at the end of October. Downstream of site #2 there are two artificial reservoirs in series. By October the reservoirs have dropped due to evaporation and seepage losses. As a result, the lagoon effluent is stored in the reservoirs and does not flow past the second reservoir. Only during spring runoff do the reservoirs produce outflow. Sites #27 and #28 are situated at the outflow of each of the respective reservoirs. The reservoirs form part of a Ducks Unlimited Canada project. Site #4 is located at the Larsen East basin's outflow and it is at this site where the impact of the Larsen East basin on downstream water quality was quantified.

From the presence of irrigation canals in the south-west portion of the basin and field surveys it may be stated that irrigated agriculture occurs within the basin.

Dryland farming and livestock grazing also occurs within the basin. It should be noted that the pipeline shown in Figure 2.2 is used to supply water to a reservoir which is used as a water source for the village of Standard.

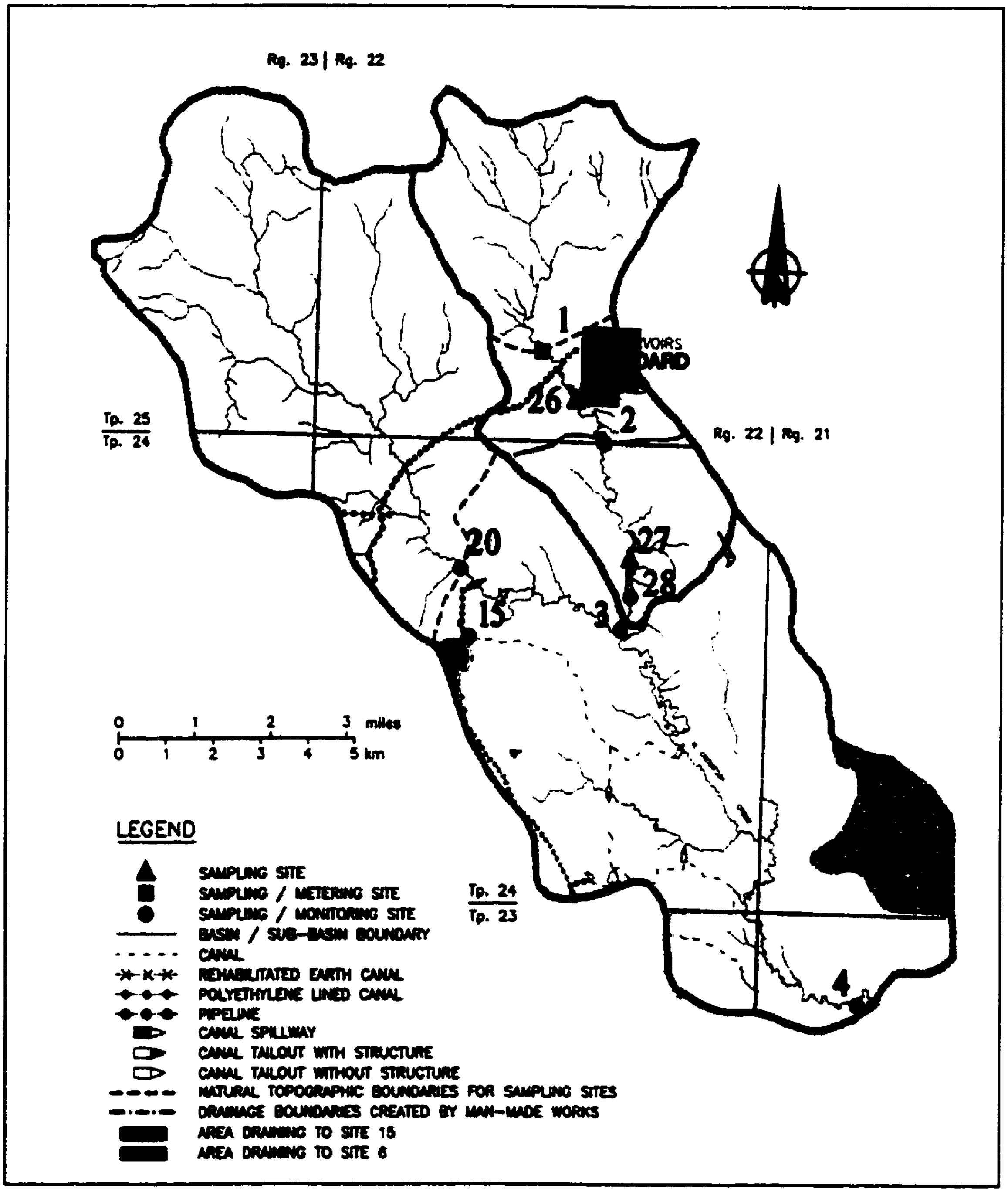

Figure 2.2 Study Area - Larsen East basin of Crowfoot Creek watershed

2.3 LITERATURE REVIEW

The following literature review includes a discussion on sources and mechanisms of movement of the parameters of interest. In addition a summary of the existing literature on the impact on creek water quality by irrigation, sewage lagoon discharges, grazing and agriculture practices is provided.

2.3.1 Nitrogen

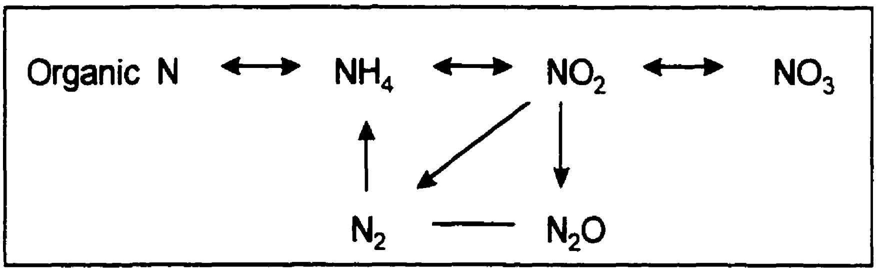

Figure 2.3 Biological Transformations of Nitrogen (CCREM 1987)

Nitrogen occurs in nature in inorganic and organic forms. The inorganic forms of nitrogen include nitrate (NO_3), nitrite (NO_2), ammonia (NH_3) and molecular nitrogen (N_2) (CCREM 1987). Major nitrogen species in the environment are interrelated by a complicated series of transformations known collectively as the Nitrogen Cycle (Figure 2.3).

2.3.1.1 Ammonia

Figure 2.3 shows that ammonia forms an essential link in the nitrogen cycle. Ammonia associated with clay minerals enters the aquatic environment through soil erosion (McNeely and others 1979a). Soluble ammonia and ammonium salts are contained in commercial fertilizers. If the concentration of ammonia or ammonium exceeds that of the immediate plant uptake, then transport via runoff from rainfall or irrigation waters can carry these compounds into aquatic systems (McNeely and others 1979a). Muchovej and Rechcigl (1995) state that ammonium fertilizers may be biologically transformed to nitrate which in turn is susceptible to leaching. Ammonia may also be discharged as a component of municipal wastewater (Pommen 1983, in CCREM 1987). Brezonik (1972) states that natural sources of ammonia include groundwater, gas exchange with the atmosphere, chemical and biochemical transformation of nitrogenous organic and inorganic matter in soil and water. The excretion of ammonia by biota and the nitrogen fixation processes of dissolved nitrogen gas in water (Brezonik 1972).

The environmental concentration range for ammonia in Western Canadian surface waters is 0.014 - 2.00 mg/L(NAQUADAT 1985, in CCREM 1987). Natural waters typically contain concentrations of less than 0.1 mg/L. Concentration levels greater than 0.1 mg/L may be indicative of anthropogenic activities (McNeely and others 1979a).

2.3.1.2 Nitrate

Most soluble nitrogen from agricultural land that reaches lakes, rivers and aquifers is in the form of nitrate (NO_3) (Muchovej and Rechcigl 1995). Muchovej and Rechcigl (1995) explain the mobility of nitrate compounds by their high solubility in soil solution and the ease by which they can be removed from anion exchange sites. As nitrates are mobile they infiltrate into the groundwater. Therefore, high NO_3 values frequently observed in streams draining agricultural lands originate predominately from groundwater (Muchovej and Rechcigl 1995). Nitrates tend to move down the soil profile with the initial, infiltrating rain, away from the zone of surface runoff removal. Consequently, nitrate in surface runoff is seldom closely associated with antecedent nitrate content in surface soils. Exceptions may occur when an intense rainstorm occurs shortly after surface application of a nitrate containing fertilizer, or when the soil horizon barrier in the profile results in interflow that reappears as surface runoff (Smith and others 1993; Legg 1982, in Muchovej and Rechcigl 1995).

Potential agricultural sources of nitrogen as nitrate (NO_3-N) contamination include nitrogen fertilizers, runoff from feedlots and manure storage facilities along with overloading of land with manure (Paterson and Lindwall 1992). USEPA (1976, in CCREM 1987) found that municipal/industrial wastewaters and septic tanks are significant principle anthropogenic point sources of nitrates. Human and animal waste are a major source of nitrates (McNeely and others 1979b).

Surface waters contain at least trace levels of nitrate, often less than 1 mg/L and rarely as high as 5 mg/L (CCREM 1987). Muchovej and Rechcigl (1995) cite Bachman (1984) on the concentrations of NO_3-N in natural surface water systems being rarely greater than 3 mg/L. Nitrate concentration levels in surface waters may fluctuate, being higher in the winter months, when groundwater input is proportionally greater, and in the spring, when contributions from overland runoff are substantial (McNeely and others 1979b).

2.3.1.3 Nitrite

The nitrite ion (NO_2^-) is less stable than the nitrate ion. Nitrites are oxidized to nitrates and are rarely found in significant concentrations (Health and Welfare Canada 1980, in CCREM 1987). Presence of nitrites in water indicates active biological processes influenced by organic contamination (McNeely and others 1979c). According to Health Canada (1996) nitrite is directly toxic. Therefore a maximum concentration of 3.2 mg/L (equivalent to 1.0 mg/L nitrogen as nitrite (NO_2-N)) is recommended in cases where nitrate and nitrite are determined separately. Industrial and municipal sewage plant discharges may contain nitrites. Nitrogen as nitrite concentrations are usually in the order of 1 µg/L and seldom exceed 1.0 mg/L (McNeely and others 1979c, in CCREM 1987).

2.3.1.4 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of ammonia and organic nitrogen. Ammonia and organic nitrogen contribute to nutrients in water leading to eutrophication making TKN a common parameter of interest. Ammonia and organic nitrogen are important for assessing available nitrogen for biological activities. Concentration of TKN in rivers that are not influenced by excessive organic inputs range from 0.1 to 0.5 mg/L (McNeely and others 1979d).

2.3.2 Phosphorus

Phosphorus (P) is an essential plant nutrient and is often considered a limiting factor for plant growth (CCREM 1987). Elevated concentrations of plant nutrients accelerate aquatic weed and algal growth in surface water leading to eutrophication which is a concern (Cross and Cooke 1996). As phosphorus is not soluble and binds to soil particles, the main mechanisms by which P is lost are runoff and erosion (Sharpley and others 1994). Domestic and industrial effluent along with agricultural drainage from fertilized land contribute phosphorus to surface waters (CCREM 1987). Sources of P in agricultural runoff include commercial fertilizers and manure (Sharpley and others 1994).

Generally, elemental phosphorus does not occur in the natural environment, but phosphorus in the form of orthophosphates, pyrophosphates, metaphosphates, polyphosphates and organically bound phosphorus are found in natural waters. Concentrations of the various forms of phosphorus are influenced by the exchange of phosphorus between sedimentary and aqueous compartments (CCREM 1987).

The two forms of phosphorus that were of interest in the study were total phosphorus (TP) and ortho-phosphate (PO_4). Total phosphorus is a measure of all the phosphorus (in any form) present in a water sample. Ortho-phosphorus includes inorganic dissolved phosphorus but not organic phosphorus (Thomann and Mueller 1987). Phosphorus found in surface runoff is in the form of dissolved phosphorus (DP) and particulate phosphorus (PP). Dissolved P is composed primarily of orthophosphates while particulate P includes P sorbed by soil particles and organic matter eroded during runoff. Particulate P normally constitutes the major portion (75-95%) of P found in runoff from conventionally tilled land (Sharpley and others 1994). As runoff from grasslands does not carry much sediment, DP is the primary form of P found in the runoff from these lands (Sharpley and others 1994).

Phosphorus binds to soil particles. Therefore, the main mechanisms by which P is lost from agricultural land are runoff and erosion. When rainfall or irrigation occurs the water interacts with a thin layer of surface soil before leaving the field as runoff. As the water passes over the soil desorption, dissolution and extraction of P from the soil, crop residue, surface applied fertilizer and manure takes place. The runoff also contains sediments picked up due to erosion along with dissolved P. Consequently, sorption or desorption with the runoff sediment may occur. The transformation of DP into PP and vice versa depends on the concentration of DP and PP in the runoff (Sharpley and others 1994). Phosphorus is transported to surface waters as dissolved phosphorus in runoff and as particulate phosphorus from eroding surface soil, streambanks and channel beds (Sharpley and Halvorson 1994). During detachment and movement of soil in runoff finer sized particles (clays, colloidal organic matter) are preferentially eroded. As these particles contain most of the P found in the soil profile it is possible for eroded material to possess a higher P concentration than the source soil (Sharpley and others 1994).

Phosphorus is rarely found in high concentrations in surface waters as it is actively taken up by plants (CCREM 1987). Phosphate concentrations between 0.01-0.05 mg/L are common for most natural surface waters in Canada (CCREM 1987). Observed values higher than these are usually an indicator of anthropogenic activity.

2.3.3 Total Dissolved Solids

The measurement of total dissolved solids (TDS) is an index of the amount of dissolved substances in water, and gives a general indication of the chemical quality of the water (CCREM 1987). Reid and Wood (1976) state that TDS usually refers to the inorganic substances that are dissolved in water. Faust and Aly (1981) assert that the concentration of TDS in water depends on the weathering characteristics of igneous and sedimentary rocks, runoff from soils and the influence of anthropogenic sources. The latter can include municipal, industrial effluent, agricultural runoff and atmospheric deposition. McNeely and others (1979e) also found that in periods of high surface runoff overland flow contributes dissolved materials to water. A significant source of salts in soil is irrigation. Salts are carried with the irrigation water onto the land. The portion of the water supplied that is consumed by the crop is essentially salt free. Therefore, salts brought into an area with the water supplied for irrigation leach into the soil. As the water moves through the soil it may pick up additional salts by dissolving weathered minerals or previously precipitated salts. This water may then be removed by subsurface drainage (Boone 1976). If there is no subsurface drainage then the water (and salts) ends up in the groundwater. In a surface water quality study (Madawaska Consulting, 1996) conducted on the County of Wheatland (within which the Crowfoot Creek flows) it was found that salinity was higher in May and June than in the remainder of the year. CCREM (1987) states that the range for TDS observed in western Canada was 0.002-5873 mg/L.

2.3.4 Total Suspended Solids

Total suspended solids (TSS) is a measure of the sediments in a water sample. Sediments become suspended in water and cause turbidity. Turbid waters can impair water treatment processes while excessive sediment deposition can degrade habitat for aquatic plants, aquatic organisms and ultimately influence the entire food chain (Cross and Cooke 1996). For this reason TSS is a common parameter of interest. The mechanism of transport of total suspended solids (TSS) is erosion of soil and subsequent runoff into the receiving water body along with channel erosion (Switzer-Howse and Coote 1984). Therefore, erosion enters any discussion on TSS.

About 75-80% of the suspended sediment transported annually by streams in Canada occurs in February, March and April. These months are usually characterized by snowmelt, runoff, rain with low impact energy and frozen soil or saturated layers near the soil surface (Switzer-Howse and Coote 1984). Erosion due to rainfall is commonly greatest during short-duration high-intensity thunderstorms, during snowmelt and periods when soils have high soil water content along with minimal vegetative cover (Cross and Cooke 1996). Soil erosion measurements on small upland watersheds, in Ohio, totaling 229 watershed-years found that most of the total erosion over a long term period of record comes from a few large storms (Edwards and Owens 1991). Menzel and others (1978) observed 900 - 3,900 kg/ha sediment in waters draining dryland wheat in Oklahoma.

2.3.5 Fecal Coliform

Bacteria occur naturally in freshwater and many are of no consequence to human health. Some types of bacteria enter aquatic environments as a result of human activity (e.g.. sewage input, agricultural and urban runoff) and may pose health threats. Coliform bacteria are commonly used as indicators of anthropogenic impacts on water quality (Saffran 1996). Greenberg and others (1992, in Saffran 1996) state that fecal coliform originate from the gastrointestinal tract of warm blooded animals. Total coliform on the other hand may originate from non-fecal sources such as organic matter and soil (Saffran 1996). Due to their origin fecal coliform, as opposed to total coliform, are a good indicator of contamination of the water source by animal feces. Doran and Linn (1979) also recommend fecal coliform as a good indicator of cattle activity in a watershed.

Animal wastes have been found to be a source of fecal coliform found in natural bodies of water. Clemm (1977) found that viable fecal coliform remain in animal wastes for up to one year. Consequently these may serve as potential sources for fecal coliform organisms into the streamwater, long after the animals have left the watershed. It also follows that the impact on water quality of removing the animals from the watershed may not be seen for up to a year. Similarly fecal coliform organisms may survive in soil for up to 2 weeks (Van Donsel and others 1976) and up to 6 weeks in surface waters (Clemm 1977). Howell and others (1995) found that deposition of fecal coliform in streams led to increased survival and regrowth of coliform in the streambed sediments. Subsequent resuspension may elevate fecal coliform concentrations in the absence of cattle and rainfall (Howell and others 1995).

Studies on water draining agricultural lands provide information on the range of fecal coliform values observed in such waters. Fecal contamination at any time is influenced by complex interactions which are dynamic and can cause the fecal bacteria concentration to vary dramatically with time at any given site (Howell and others 1995). Thelin and Gifford (1983) found that bovine fecal deposits that had not been rained on for 5 days yielded coliform in the million/100 mL range while fecal deposits that had not been rained on for 30 days yielded 40,000/100 mL coliform. From experiments conducted on grazed and ungrazed rangeland in southwest Idaho, Stephenson and Street (1978) found fecal coliform counts up to 2,500/100 mL at channel sites near cattle. Tiedemann and others (1987) found fecal coliform counts above 2,000/100 mL in waters near intensive livestock operations in Oregon (USA). In the study of Howell and others (1995) fecal coliform when present ranged from 350/100 mL - 20,000/100 mL in waters draining agricultural land in Kentucky (USA).

There have been a few studies of fecal coliform water contamination in Alberta which are of interest. In a study conducted on the Bow River and its tributaries by Sosiak (1996) high levels of fecal coliform were found in the Crowfoot Creek. Unfortunately, the extent to which this would affect mainstem coliform counts of the Bow River could not be determined. Madawaska Consulting (1995) conducted a surface water quality project for the County of Wheatland where Crowfoot Creek is situated. This project found that fecal coliform are impacting water quality. There were insufficient data to identify the specific sources but potential sources include feedlots, grazing areas or cattle watering.

2.3.6 Impact of Irrigation on Creek Water Quality

2.3.6.1 Irrigation Water Quality

Irrigated farming takes place within the Larsen East basin. Excess water not used for irrigation is discharged into Crowfoot Creek and may impact water quality of the creek. The irrigation water supplied to the farmers in the Crowfoot Creek basin is provided by the Western Irrigation District (WID). The WID in turn obtains the water from the Bow River within the City of Calgary. A report prepared by W-E-R AGRA (1994), on the WID headwaters, cautions that there were indications of problems with water quality relative to the water quality guidelines for irrigation, drinking water and livestock watering with respect to the following parameters: fecal coliform, total phosphorus and total dissolved solids. W-E-R AGRA (1994) did not identify the source of the contaminants, but stormwater from Calgary was considered a potential source. The report cautions however that this conclusion was made in light of the relatively good water quality in the Bow River near the intake of the WID canal. Greenlee and Lund (1995) cite Hamilton and others (1982) as observing the quality of water used in the irrigation district with respect to average TDS being 174-212 mg/L. A study by Madawaska Consulting (1996) for the WID found that irrigation canal water occasionally violated water quality guidelines for irrigation with respect to fecal coliform (i.e.. 100 counts/100mL). Also, total phosphorus was high in May at sampling sites on the irrigation canal network.

Studies by Alberta Agriculture prior to 1991 did not find that irrigation water quality was a serious problem (Paterson 1991). As water quality problems related to irrigation were not a serious problem in Alberta, not many studies have been conducted on irrigation water quality itself. There are more studies on return flow water quality issues discussed in the next section.

2.3.6.2 Irrigation Return Flow

Water diverted for irrigation but not used for irrigation is returned to natural bodies of water and the channels of such water are known as "return flows". Often overland runoff or subsurface drainage enters these "return flows" raising water quality concerns. Bolseng (1991) cites Barnetson (1985) as computing that on average 29% of the total volume diverted for irrigation in Alberta results in return flow. Irrigation return flows are of sufficient volume that they may have an impact on the water quality of receiving streams (Bolseng 1991). To the contrary Greenlee and Lund (1995) argue that the impact of irrigation return flow water on receiving rivers was diminished by dilution which ranged from a factor of 15 to greater than 600 times.

Many studies focusing on return flows have been conducted in Alberta, some of which are discussed. A "one-time only" sampling of 38 return flow channels in six irrigation districts in Alberta by Bolseng (1991) found the average NO_3-N of all samples to be 0.1 mg/L, well below the drinking water guideline of 10 mg/L. A study by Greenlee and others (1993) studied four irrigation return flow streams in southern Alberta and found a maximum value of 1.86 mg/L for NO_3-N, well below the drinking water guideline of 10 mg/L. With respect to TDS, 11% of the samples exceeded the drinking water guideline of 500 mg/L while no samples exceeded the livestock consumption and irrigation guidelines of 3,000 mg/L and 500-3,500 mg/L respectively. Greenlee and others (1993) comment that the elevated constituent levels in their study were closely related to surface runoff during and immediately following major precipitation events. Table 2.1, from Boone (1976), summarizes probable changes in return flow water quality as a result of irrigation.

Table 2.1: Irrigation Return Flow Quality (Boone 1976)

Quality Factors	Irrigation Return Flow	
	Surface Drainage	Sub-Surface Drainage
Salts (TDS)	Not greatly different from sources	Concentrations increased usually 5-7 times depending on the amount of salt in the supply, number of times reused, the amount of residual salts being removed and the amount of non-agricultural sources.
Nitrate	More likely a slight increase than a decrease, but highly variable.	Likely to decrease if the content in irrigation water is high and increase if amounts are low. Greatest hazard from heavily fertilized porous soils and irrigation.
Phosphate	Content may increase, but closely correlated with erosion of fertile topsoil.	Decrease if considerable in the source. Not likely to greatly increase
Sediment & Colloids	Often more than in source but may be less - highly variable.	Little or no sediment or colloidal material.
Pathogens and other organisms	Variable and may increase or decrease.	Low content with a likely reduction in most pathogens. Other organisms may increase or decrease.

Greenlee and Lund (1995) began a three year sampling program of the Lethbridge North Irrigation District in Southern Alberta in 1994. The results of the first year revealed some surprising results. High levels of total dissolved solids, nitrate-nitrogen, phosphate-phosphorus along with fecal coliform values as high as 150,000 counts/100 mL were observed at one of the three sites. Cattle with free access to the sampling site were suggested as the possible reasons for the high constituent levels.

A preliminary evaluation of the results from several synoptic surveys conducted on the Bow River by Sosiak (1996) concluded:

> "Irrigation return flow had higher levels of phosphorus, dissolved ammonia, coliform, suspended sediments and certain ions (sodium, potassium, sulphate, chloride) than streams, but lower levels of other variables (nitrate/nitrite, bicarbonate, silica, calcium, hardness). Loadings of most of these substances to the river from return flows were relatively small during the 1995 survey."

A more detailed explanation for the levels of various parameters is provided in a report by Madawaska Consulting (1997) on irrigation district water quality:

> "The data clearly indicate that there is a change in water quality as it moves from source water to return flow in the irrigation districts. For the most part, concentrations of salinity parameters, total phosphorus and pathogens increase, while nitrate+nitrite often decreases. Salinity parameters are most directly affected by runoff over saline soils or discharge of saline groundwater. The increase in total phosphorus can be attributed to the movement of soil particles and nutrient management practices. This despite the fact that phosphorus is removed from the water as it is incorporated into plant matter in the canal or stream. Because bacteria naturally decay (die) over time, any increase from source water to return flow can be attributed to additions by animal waste. The decrease in nitrate can be attributed to incorporation into biological material, but the process of denitrification also converts nitrate to nitrogen gas which is released into the atmosphere."

Another study on the water quality within the WID was initiated in 1996 by Madawaska Consulting. Their findings indicate that the water quality tended to deteriorate between main canal sites and the return flow sites, particularly when precipitation was high and inputs from runoff were higher.

2.3.6.3 Groundwater Discharges due to Irrigation

Groundwater discharges into Crowfoot Creek are a potential source of contamination within the Larsen East Basin. A significant portion of such groundwater discharges may be due to irrigation. Recently a groundwater study was conducted by Rodvang (1997) of AAFRD for part of the Crowfoot Creek watershed. The study area included part of the Larsen East basin. Findings of this study are presented below.

Rodvang (1997) explains that irrigation causes groundwater recharge which in turn causes groundwater discharge into surface waters. Simulations found that without irrigation, discharge rates would decrease by 55% to part of the Crowfoot Creek watershed. The results of the investigation show that canal seepage causes increased recharge rates at some locations, and that increased recharge will tend to increase the salinity of surface water and soils in the discharge area. Saline and wet soils found in low areas around Crowfoot Creek by Rodvang (1997) may be explained by such recharges. Rodvang (1997) computed that the ratio of water in the creek to groundwater discharge to the creek as being 11:1. Rodvang (1997) estimates that 73-161 mg/L of TDS is added to the creek from groundwater discharge.

The bedrock aquifer's water quality was determined using samples taken from domestic wells within the Crowfoot Creek basin. Of the 287 wells sampled only 7% had water which met the drinking water guideline for TDS of 500 mg/L, with levels mostly between 500 to 2,000 mg/L (Rodvang 1997). Approximately 40% of 198 wells sampled for nitrate contained more than 0.1 mg/L nitrate + nitrite, 20% contained more than 2 mg/L and 8% exceeded the Canadian drinking water guideline of 10 mg/L (Rodvang 1997). Lack of correlation between depth and nitrate occurrence suggested that the nitrate in domestic wells was derived in many cases from point sources of contamination, rather than non-point source agricultural contamination (Rodvang 1997). In contrast to the domestic wells, the evidence from piezometers suggested that nitrate in the study area was derived from agricultural sources. The levels of total dissolved solids, in the piezometers (depth ranging from 2-70 m below ground), exceeded the Canadian drinking water guidelines at all test sites in the Crowfoot Creek Basin (Rodvang 1997).

2.3.7 Standard Sewage Lagoon and Sewage Lagoon Effluent Water Quality

The village of Standard located within the Larsen East basin treats its municipal sewage in a sewage lagoon. Treated effluent is discharged to the creek which may impact the creek's water quality. Standard's sewage lagoon is of 4S-2L configuration (i.e. 4 cells with short residence time and 2 cells with long residence time) (Prince and others 1993). Prince and others (1993) comment that intermittent discharge lagoons are used to avoid effluent discharges during periods of poor effluent quality and low assimilative capacity of the receiving water that occurs in the winter due to ice cover. Standard's sewage lagoon is an intermittent discharge sewage lagoon, discharging the treated effluent only in October.

Using data collected from sewage lagoons across Alberta, Prince and others (1993) computed the average concentration of TSS, P, NH_3 and TKN of effluent from 4S-2L sewage lagoon discharges, which were 20.4, 2.2, 1.3 and 5.3 mg/L respectively. Based on daily monitoring of effluent quality from the village of Legal's (near Edmonton, Alberta) sewage lagoon's discharge Prince and others (1993) concluded that there was little variation in effluent quality over time with respect to total suspended solid and fecal coliform.

2.3.8 Influence of Cattle Grazing on Creek Water Quality

Along the Crowfoot Creek, the surrounding flood plain is used to graze cattle. Grazing may result in deposition of manure directly on the land in pastures and manure may become concentrated near feeding and watering areas (Sutton 1990, in Greenlee and Lund 1995). Deposited manure may be carried to a nearby water body with runoff. Kirchmann (1994) lists a number of studies which show that runoff from grazing lands contribute to the contamination of watersheds by bacteria. Cross and Cooke (1996) report that Robbins (1979) found that compaction of the soil from cattle's hooves and grazing practices caused high runoff from heavily grazed watersheds. Tiedemann and others (1988) stress the importance of the proximity of cattle to the severity of fecal coliform contamination. Gary and others (1983) comment that the intensity of grazing influences the fecal coliform concentration of nearby water bodies. In their study it was observed that cattle spent more than 65% of the day within 100 m of the stream. Gary and others (1983) explain the presence of the cattle near the stream due to the availability of water and the lush riparian vegetation. The cattle were in or adjacent to the stream 5% of the time and 5% of the cattle's defecation was directly into the stream. Tiedemann and others (1987) found that the fecal coliform counts in a stream, running through pastures in Oregon, increased six fold when cattle were allowed back into the pastures after a period of absence. For pastures in Oregon they observed that the loadings of fecal coliform varied seasonally as follows: winter < summer < snowmelt runoff. The snowmelt runoff was ten times the winter loading while the summer was five times the winter loading. Wintering grounds for cow-calf operations contain lower livestock densities than feedlots. However the higher densities during the winter can cause a localized accumulation (unlike summer grazing) of livestock waste that can be easily transported to surface water in spring runoff (Cross and Cooke 1996). Chichester and others (1979) found that winter feeding caused a high degree of soil and plant cover disturbance and an increase in runoff and erosion as compared with pastures grazed only in the summer. Feeding of cattle in a winter feeding area increased runoff that caused more nutrient and salt movement as compared to pastures only grazed in the summer (Cross and Cooke 1996). Livestock induced sediment loss is a potential impact from grazing. A study conducted by Owens and others (1996) on a pastured watershed, in Ohio, set out to observe the impact of fencing the cattle out of the stream. They do not mention the distance of the fencing from the stream. A 50% decrease in annual sediment concentration and a 40% decrease in average soil loss was observed. The view that animal grazing may be a threat to public health is not shared by all. Buckhouse and Gifford (1976) stated that cattle grazing on semi-arid watersheds in southeastern Utah posed no threat to public health. However, they caution that their conclusion was based on an experiment conducted on a small plot and cautioned that such conclusions may not be applicable for large areas.

2.9.9 Impact of Farming on Creek Water Quality

Irrigated and dryland farming takes place within the Larsen East basin and may affect creek water quality. Brichford and others (1993) caution that as nitrate is a mobile nutrient it is susceptible to leaching if excessive nitrogen fertilizer is applied prior to rain or irrigation. A study conducted by Burnett (1981) in Taber, in Alberta, found little evidence of nitrate from fertilizers leaching into the groundwater due to irrigation on sandy soils. Hodgkin and Hamilton (1993) comment that excessive application of phosphorus fertilizer had led to an accumulation of phosphorus in the soil in areas draining into the Harvey River in Australia. A decrease in application of super-phosphate to sandy soils in the study area resulted in a significant reduction of flow-weighted phosphorus. Brichford and others (1993) found that despite soil tests indicating high or very high levels of phosphorus in the soil farmers continued to add phosphorus fertilizer. Manure is a common source of nutrients for farming. Brichford and others (1993) state that manure contains nitrogen, phosphorus, inorganic salts, organic solids and microorganisms. All of these are potential contaminants of surface and groundwater. Ritter (1988) cautions that although manure application rates are recommended on the basis of N requirement of the crop the amount of P should be also taken into account. If the amount of P in the manure supersedes that required then P will accumulate in the upper layer of soil. This increased level of P in the upper soil layer leads to increased levels of P in runoff (Sharpley and others 1994). Quissenberry and others (1980) in Ritter (1988) state that manure applied in the fall may result in nitrate leaching. Agricultural activities such as tillage, crop harvesting, summer fallow etc. can leave the soil exposed. Exposed soil is susceptible to erosion by wind and rain. In this manner agriculture can contribute to the sediment load of surface waters (Brichford and others 1993).

In summary, this thesis focuses on the Larsen East basin which is part of the Crowfoot Creek watershed. The preceding literature review discussed sources and mechanisms of movement of the parameters of interest which are: ammonium, nitrogen as nitrate, nitrogen as nitrite, total Kjeldahl nitrogen, total phosphorus, dissolved phosphate, total dissolved solids, total suspended solids and fecal coliform. Existing literature on the impact on creek water quality by irrigation, sewage lagoon discharges, grazing and agriculture practices were also summarized.

3.0 METHODOLOGY

To meet the objectives set out in section 1.1 reliable, accurate and comprehensive information was required. This section will outline the procedures and equipment by which the information required for analysis was obtained.

3.1 SAMPLING SITES

Sampling sites were selected on the basis of basin boundaries. Individual purposes of sites #2, 4 and 15 were detailed in Buckland (1996) while sites #3, 20 and 26 were added after the study was initiated in response to the need for additional information. The location of the sampling sites can be seen in Figure 2.2. Table 3.1 describes the purpose of each sampling site.

Table 3.1 Larsen East Basin sampling site descriptions and purpose

Site #	Description of Site	Purpose
2	Located downstream of the Village of Standard's sewage lagoon and upstream of Ducks Unlimited reservoirs.	Determine and factor out, impact of annual sewage releases.
3	Situated 500 m downstream of the Ducks Unlimited reservoirs. The site was installed in the fall of 1996 after the study had begun and was an active sampling site for the 1997 sampling season.	Determine transformation of upstream loadings to the reservoirs and contribution of reservoirs to downstream water quality.
4	Outflow from the Larsen East basin and as such reflect the impact of the basin on the Crowfoot Creek watershed.	To integrate retention and loadings from north Crowfoot Creek.

15	Located at the end of an irrigation canal. After the water passes this site it enters a 1000 m pipeline from which the water exits into the creek 500 m downstream of site #20.	Monitor loadings from irrigation tailwater into Crowfoot Creek.
20	Situated near a cattle grazing operation and 500 m upstream of the irrigation tailwater discharges into the creek.	To gain an understanding of the baseline water quality before the addition of the irrigation tailwater.
26	Located at the outflow of the Village of Standard's sewage lagoon. Sampling was only conducted here during treated sewage discharge.	Provide information on the relative contribution of the sewage lagoon on water quality within the basin.

The equipment at each site used to obtain water quality, flow rate and rainfall information are listed in Table 3.2. Equipment at site #15 can be seen in Figure 3.1. After the 1996 sampling season there was some relocation of equipment and addition of sites as can be seen in Table 3.2.

Table 3.2 Equipment at Larsen East basin sampling sites

Site	1996				1997			
	Staff Gauge	Stilling Well	Automatic Sampler	Tipping Bucket Rain Gauge	Staff Gauge	Stilling Well	Automatic Sampler	Tipping Bucket Rain Gauge
1					✓			
2		✓	✓		✓	✓		
3	Installed in Fall 1996				✓	✓	✓	
4		✓	✓		✓	✓	✓	
15		✓			✓	✓	✓	✓
20		✓			✓	✓		
26								

The staff gauges were constructed of 1.5 m long snow fencing poles on which 0.91 m (3') sections of marked staff gauges were attached. In addition, precipitation data from a sampling site outside the Larsen East basin, approximately 500 m from site #4, were also used in the analysis.

Figure 3.1: Sampling Site #15 at the end of an irrigation canal with a rain gauge, stilling well and automatic sampler

3.2 WATER QUALITY SAMPLING

The water samples were collected with the intent to analyze for NO_2-N, NO_3-N, TKN, NH_4, TP, PO_4, TDS, TSS and fecal coliform. Water samples were only collected if the water was flowing in the creek/irrigation canal.

3.2.1 Water Quality Sampling Frequency

The sampling seasons of 1996 and 1997 can be characterized by four "types" of sampling: "Spring Runoff", "Routine", "Event" and "Lagoon Discharge". "Spring Runoff" was the sampling conducted early in 1997 during the snowmelt. Sampling was initiated after the snowmelt and concluded when the creek froze again in the fall. It consisted of a sample taken every Wednesday. Such sampling was termed "Routine". To gain more detailed information related to precipitation events, "Event" sampling was conducted. Finally, the impact of the effluent discharge from the village of Standard Sewage Lagoon was studied using "Lagoon Discharge" sampling. Table 3.3 summarizes the sampling frequency for the 1996 and 1997 sampling season along with the periods when various ("Spring Runoff", "Routine", "Event" or 'Lagoon Discharge") sampling was conducted.

Table 3.3 Sampling Frequency

Year	Purpose	Duration	Once a week	Daily	Twice a Day
1996	Routine sampling	Jul. 24-Oct. 30 (Julian day 206-304)	✓		
	Event Sampling	Sept. 20-21 (Julian day 263-264)		✓	
	Lagoon Discharge Sampling	Oct. 21-25 (Julian day 295-299)			✓
1997	Spring Runoff	Mar. 22-23 (Julian day 81-82), Mar. 25-Apr. 4 (Julian day 84-94), Apr. 9 (Julian day 99), Apr. 13-18 (Julian day 103-108)		✓	
	Routine sampling	Apr. 23-Oct. 29 (Julian day 82-)	✓		
	Event Sampling	May 27 (Julian day 147)		✓	
	Lagoon Discharge Sampling	Oct. 27-Nov 4 (Julian day 300-308)			✓

The sampling frequency for routine and event sampling was determined by AAFRD personnel. Sampling frequency for the lagoon discharge was recommended by the author after consultations with Dr. S. Barrington (McGill University, Personal Communication, 1997), A. Sosiak (Alberta Environmental Protection, Personal Communications, 1996) and Dr. R. Zytner (University of Guelph, Personal Communications, 1996). The result of this consultation was that the frequency of sampling was set at twice a day because this would provide adequate water quality data for the lagoon effluent.

3.2.2 Water Quality Sample Collection

The water samples from all sites were collected and then transported to the field laboratory in ice chests with freezer packs. Tables 3.4 and 3.5 summarize the sampling conducted in the 1996 and 1997 sampling seasons for all parameters except coliform. Descriptions of the sampling procedures are in section 3.2.3.

Table 3.4 1996 Sampling Procedure by Site

Sampling Type	Site #	Grab Sample	24 Hour Composite
Routine Sampling	2,15,20	✓	
	3	Site did not exist in 1996	
	4		✓
Event Sampling	2,4,15,20	✓	
	3	Site did not exist in 1996	
Lagoon Discharge Sampling	2,26	✓	

Table 3.5 1997 Sampling Procedure by Site

Sampling Type	Site #	Grab Sample	24 Hour Composite	Mixed (Grab or 24 Hour Composite)
Spring Runoff Sampling	2,3,4,15,20	✓		
	26	At lagoon outlet therefore not sampled		
Routine Sampling	2,20	✓		
	3,4,15		✓	
Event Sampling	2,4,15,20	✓		
	3			✓
	26	At lagoon outlet therefore not sampled		
Lagoon Discharge Sampling	2, 26	✓		

3.2.3 Sampling Procedure for All Parameters Except Coliform

The sampling procedure for all parameters except coliform mentioned in section 3.2.2 are described below. Three different methods of sampling were used: grab, 24 hour composite and mixed.

Grab sampling (Figure 3.2) used a 2 L plastic bottle which was attached to a 5 m pole by means of a clamp. The cap of the 2 L bottle was removed and the pole was extended into the flow of the channel. The bottle was submerged, with the neck pointing downstream, 30 cm (1') below the water surface and turned upstream and the bottle was partially filled. The bottle was brought back to the streambank and the lid was screwed on and the bottle was then shaken to rinse the inside of the bottle. In this manner the bottle was rinsed three times. Using the 2 L bottle a 500 mL sample bottle was filled and a thermometer was inserted into the 500 mL bottle and temperature of the water was noted (Figure 3.3). The 2 L bottle was filled for a final time, capped and stored in an ice chest with freezer packs until the sample was processed at the field laboratory. Temperature of the creek water in the 500 mL bottle was required in the laboratory analysis for ammonia (NH_3).

Figure 3.2: Manual grab sampling

Figure 3.3: Measuring the temperature of the creek water

The 24 Hour Composite sampling was conducted with ISCO[1] automatic samplers (Figure 3.4, 3.5) which were set on "time" sampling mode to sample every

[1]Disclaimer: Manufacturer's name is included for reader's information only and does not imply endorsement.

2 hours. After 24 hours a composite sample was collected and the sample bottle was shaken to mix settled sediments. A 2 L bottle was rinsed three times with the water from the automatic sampler bottle. The 2 L bottle was filled with water from the automatic sampler bottle and stored in an ice chest with freezer packs until it was processed at the field laboratory. A 500 mL bottle was dipped into the stream/canal and the temperature of the water in the bottle was measured. As with the grab sample, the creek water's temperature was required for the ammonia (NH_3) analysis procedure.

A mixed (grab or 24 hour composite) method of sampling was applied when rainfall events were anticipated. In this case the automatic samplers were changed from temporal to flow mode to collect up to 17 samples of 400-550 mL when triggered by the datalogger in the stilling well. The dataloggers triggered the automatic sampler after a preprogrammed change in water level. For 1997, the water level increment for each sampling site was site specific based on the 1996 hydrographs after precipitation events. An effort was made to choose water level increments in such a way as to collect water samples on the rising and falling limb of the hydrograph in a precipitation event. If sufficient water was collected by the automatic sampler then a 2 L bottle was rinsed three times with the sample water. After this the 2 L bottle was filled with the water to be analyzed. However, if insufficient water for a sample was collected by the sampler then a grab sample was collected, as described before. The temperature of the water was also measured.

For the 1996 sampling season the 2 L sample bottles used to collect the grab samples and transport the composite samples were cleaned in the following manner. Into each bottle 5 mL of Extran 300[2] (a phosphate free alkaline concentrate) liquid detergent was poured in each bottle after which the bottles were filled with deionized water and allowed to soak overnight. The lids were allowed to soak in an Extran 300 soap bath overnight. Bottles and lids were then washed in

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[2]Disclaimer: Manufacturer's name is included for reader's information only and does not imply endorsement.

an automatic dishwasher (Fisher Jet Clean Model 628[3]) for 4 washing cycles. The four wash cycles used: hot tap water, hot tap water with Extran 300, hot tap water and room temperature deionized water respectively. Finally, the bottles and lids were then rinsed twice by hand with room temperature double deionized water. In 1997 the procedure was modified to make the final wash cycle use room temperature double deionized water rather than deionized water and there was no hand rinsing after the dishwasher.

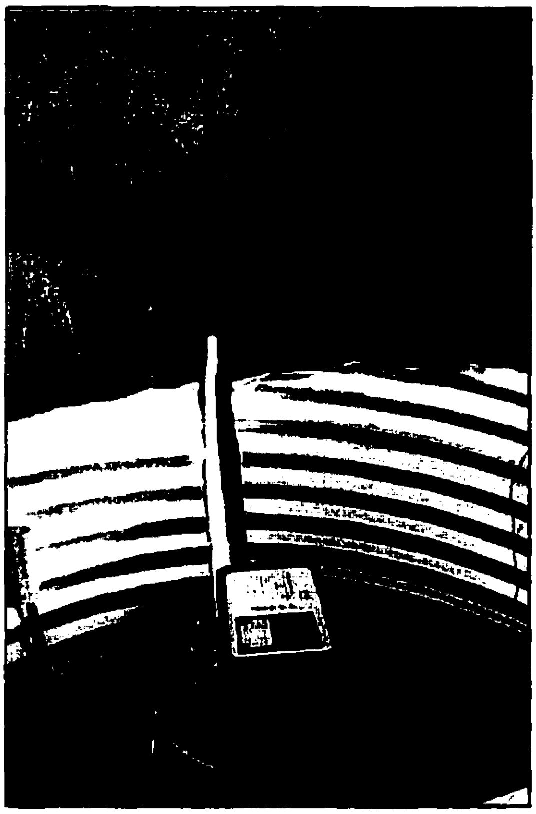

Figure 3.4: 3700 ISCO sampler and intake

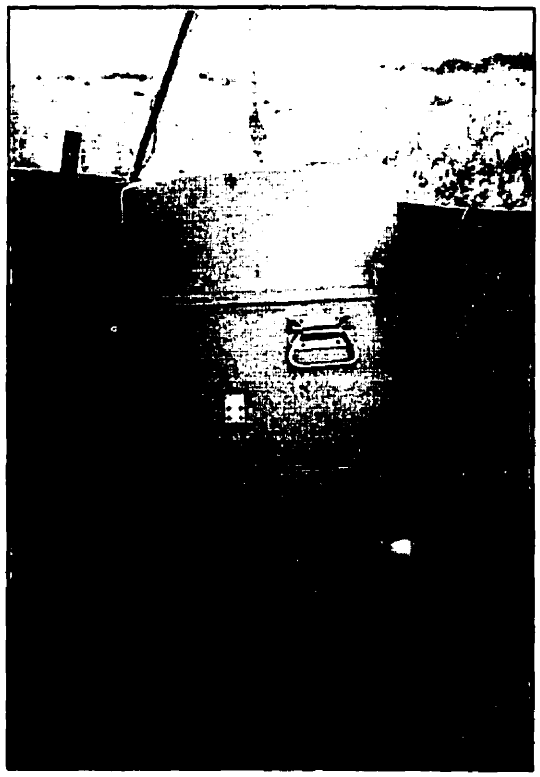

Figure 3.5: Sample bottle in ISCO automatic sampler surrounded by ice packs to preserve sample

In 1996 the sample bottles placed inside the ISCO automatic samplers were washed in the following manner. Into each bottle 2 mL of Extran 300 was poured. The bottles were then filled with deionized water and allowed to soak overnight.

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[3]Disclaimer: Manufacturer's name is included for reader's information only and does not imply endorsement.

Bottles and lids were rinsed ten times with hot tap water. Deionized water was then used to rinse the bottles and lids three times. Finally, the bottles and lids were rinsed twice with double deionized water. In 1997 the bottles for ISCO samplers were not washed, instead plastic bags were placed and used as liners in the bottles. A new plastic bag was used each time a composite sample was collected.

3.2.4 Sampling Procedure for Coliform

The water samples for coliform analysis were collected in bottles provided by the Provincial Laboratory of Public Health for Southern Alberta in Calgary. The 250 mL bottles had been sterilized and sodium thiosulphate powder was added to preserve the sample. Water samples were collected in one of three ways: i) the coliform bottle was attached to the end of a 5 m sampling pole by elastic bands and submerged in the flow until the bottle was filled; ii) after the 2 L bottle used in a grab sample was rinsed three times it was filled with water brought to the bank and the coliform bottle was filled; or iii) if the flow was high and could be reached by hand then the coliform bottle was held in the sampling individual's hand and submerged in the flow until it was filled. The coliform samples were stored at 4°C (in a fridge) until they were transported by courier to the Provincial Laboratory of Public Health for Southern Alberta (in Calgary) in an ice chest with a few freezer packs. All samples were delivered to the laboratory within 24 hours.

3.2.5 Water Quality Samples Processing for Laboratory in Lethbridge

After the water samples were collected from the sampling sites they were brought to the field laboratory in the town of Strathmore, located approximately 25 km west of the Larsen East Sub-basin. At the field laboratory the sample from each site was partitioned in the following manner. A 500 mL plastic bottle was triple rinsed with the sample water after which it was filled. This bottle was analyzed for Total Suspended Solids. Similarly, a 125 mL plastic bottle was triple rinsed with the sample water after which it was filled with the sample water. To preserve the sample until the samples were delivered to the laboratory 2 mL of 5% H_2SO_4 was added to the 125 mL bottle . This bottle was analyzed for TP, TKN and NH_4. Using a filter cup (0.45 µm filter paper) and a vacuum pump a quantity of the sample was filtered and with the filtrate a 125 mL bottle was triple rinsed. The bottle was then filled with the filtrate. This bottle was analyzed for NO_2-N, NO_3-N, TDS and PO_4. Using the same filter cup approx 150 mL of filtrate was obtained to triple rinse a 125 mL bottle and fill the bottle. A pipette was used to add 2 mL of 5% H_2SO_4 to the sample to preserve the sample until they were analyzed in the laboratory in Lethbridge. This sample was analyzed for DP. Finally, the bottles were stored at 4°C (in a fridge) until they were transported to the laboratory the following day in an ice chest with freezer packs.

3.3 PARAMETER ANALYSIS AND QUALITY CONTROL PROCEDURES

The water quality samples were analyzed by the AAFRD laboratory in Lethbridge for all parameters except coliform. Coliform samples were analyzed at the Provincial Laboratory of Public Health for Southern Alberta in Calgary. Table 3.6 describes the analysis procedures used for the various parameters.

Table 3.6 Laboratory analysis methods for various parameters

Parameter	Analysis Method (Greenberg and others 1992)
Nitrogen as Nitrite (NO_2-N)	Colorimetric Method
Nitrogen as Nitrate (NO_3-N)	Automated Hydrazine Reduction Method
Total Kjeldahl Nitrogen (TKN)	Semi-Micro-Kjeldahl Method and Automated Phenate Method
Ammonium (NH_4)	Automated Phenate Method
Total Phosphorus (TP)	Automated Ascorbic Acid Reduction Method
Ortho-phosphate (PO_4)	Automated Ascorbic Acid Reduction Method
Total Dissolved Solids (TDS)	Determined using the following equation[4]: $TDS=Ca+Mg+Na+K+Cl+SO_4+(0.6*(HCO_3+CO_3))+(4.43*NO_3\text{-}N)$
Total Suspended Solids (TSS)	Total Suspended Solids Dried at 103-105 C
Fecal Coliform	Membrane Filtration[5]

To ensure the reliability of the water sample analysis, quality control measures were undertaken. In 1996, a quality control sample was taken at every tenth site on each sampling day. As there were approximately 20 sites in the Crowfoot Creek watershed, two quality control samples were taken. Automatic samplers collected enough water to fill two 2 L bottles which were treated as two samples, the original and the "split". At sites where there were no automatic samplers two grab samples were taken from the same location, the original and the "duplicate". In 1997 two quality control samples, a split and a duplicate, were collected weekly from two sites within the Crowfoot Creek watershed. Unlike the previous sampling season a deliberate effort was made to pick the sites from which the split and duplicate were taken, to be from the east and west part of the Crowfoot Creek watershed. The duplicate and splits were also analyzed at the same

[4]Laboratory analysis procedures for the parameters used to compute TDS are outlined in Appendix H.

[5]Analysis procedure for fecal coliform as described in Greenberg and others (1995).

laboratories where the original samples were analyzed due to financial limitations. However, in the spring of 1997 a one time blind comparison was conducted with an independent laboratory for selected parameters. Results from this blind comparison were compared using a two tailed Students's t-test for paired samples. The equipment used to perform the analysis were calibrated prior to any analysis. It was decided by the project coordinator to not keep the laboratory "blind" (unaware of which duplicate or split was from each site) with respect to the duplicate and split samples as the laboratories calibrated their equipment before any analysis. The duplicate and split samples were compared using a two tailed Students's t-test for paired samples.

A second quality control measure was initiated in 1997. Double distilled water was bottled at the field laboratory in Strathmore and sent with the other samples to be analyzed by the laboratory in Lethbridge. This double distilled water "sample" was called a "blank". Maximum concentration of a parameter in the blank sample was compared with the average concentration for that parameter at all sites throughout the sampling season.

3.4 PROCEDURE FOR MASSLOAD CALCULATIONS

To quantify the impact of various sources the massload of various water quality parameters over different periods was used in the analysis. The massload was computed in the following manner. Using linear interpolation between weekly water sample parameter concentrations daily concentrations were obtained. The product of these daily concentrations and the daily flow resulted in the daily parameter massloads. The daily massloads for the period of interest were added to present the massload for the period of interest.

3.5 FLOW, PRECIPITATION AND LAND USE DATA

The measurement of flow passing by a site provided valuable information including runoff delay after precipitation events and mass loading of contaminants. For all the periods of flow, except spring runoff, the flow heights recorded by the datalogger, in the stilling wells, were calibrated to flow rates for each site by means of current flow meters (Figure 3.6) Model 1205 and 1210 (manufactured by Scientific Instruments, Wisconsin, U.S.A.[6]). In spring runoff, due to high water levels and ice in the stilling wells, the stilling wells were not used to record the water level. Instead when a sample was collected the staff gauge reading was recorded. The flow heights (i.e.. staff gauge reading) recorded were calibrated to flow rates for each site using a Model 3000 Datalogging Current Meter / Flowmeter (manufactured by Swoffer Instruments Inc., Seattle, U.S.A.[7]). The longer length of the rod allowed flow to be measured from bridges and temporary log bridges during spring runoff.

Figure 3.6: Measuring flow using a current meter

[6]Disclaimer: Manufacturer's name is included for reader's information only and does not imply endorsement.

[7]Disclaimer: Manufacturer's name is included for reader's information only and does not imply endorsement.

To gain information on rainfall within the basin, rainfall data using two tipping bucket rain gauges were recorded. When the tipping bucket rain gauge tipped a pulse was sent to the datalogger in the stilling well. After an interval of 20 minutes the accumulated pulses were stored in the datalogger data file. The 20 minute interval rainfall data were converted to millimeters (mm) of rainfall and daily rainfall was computed.

Land use data were gathered to help explain fluctuations of various parameters and locate potential sources of contamination. Information on the land use patterns within the Larsen East basin was obtained by field surveys, interviewing farmers and officials within the basin.

4.0 RESULTS AND DISCUSSION

Data collected in the 1996 and 1997 sampling seasons were analyzed. The data on which the analysis was based are presented in tabular form in Appendices B-F. Water quality guidelines against which the parameter levels were compared are listed in Appendix A. Most graphs present time in terms of Julian days and Appendix G contains tables of Julian days and the respective dates.

4.1 IMPACT OF IRRIGATION ON CREEK WATER QUALITY

To determine the impact on creek water quality by discharges of excess irrigation water (i.e. irrigation tailwaters), data from sites 4, 15 and 20 were analyzed. As irrigation water was supplied from early May to late September data from these dates were used. As mentioned previously:

- site #20 provides information on creek water quality upstream of the entrance of irrigation tailwaters into the creek;
- site #15 is located on an irrigation canal tailwater turnout; and
- the impact of irrigation tailwaters on creek water quality (along with other impacts) was observed at site #4.

4.1.1 Flow and Precipitation

Using the flow records from 1996 and 1997 it may be stated that during the irrigation season the major source of water at site #4 (basin outflow) is from the irrigation tailwater at site #15. Figures 4.1 and 4.2 display the flow and precipitation data for 1996 and 1997 respectively. Using average daily flows it was determined that site #15 (irrigation tailwater) accounted for 55% and 59% of the flow at site #4 for 1996 and 1997 respectively.

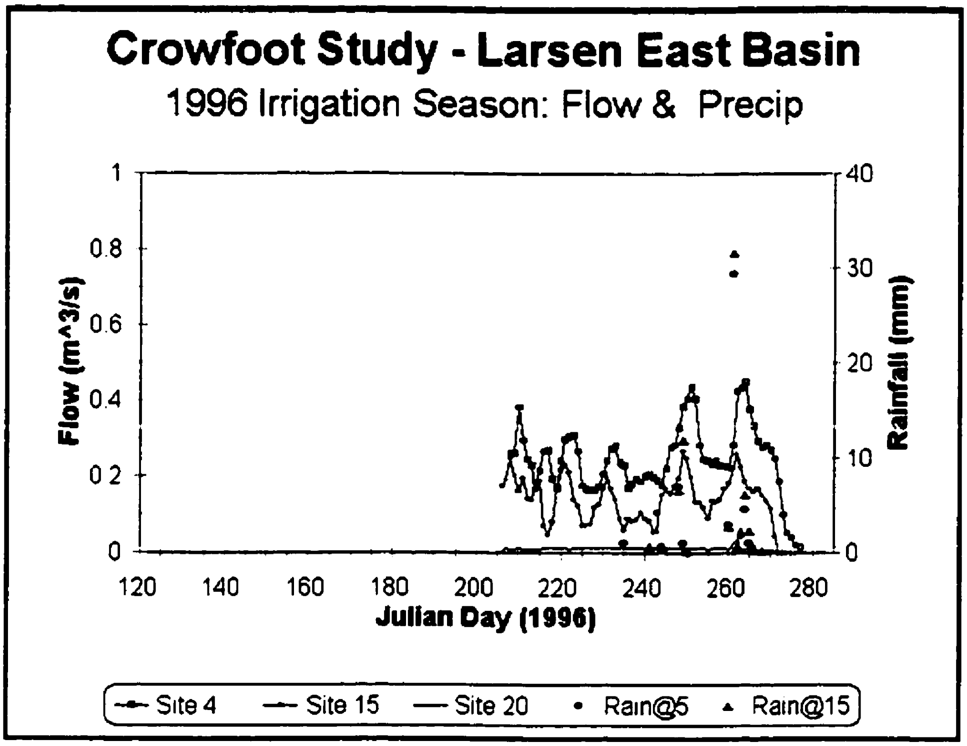

Figure 4.1 Flow / Precipitation for 1996

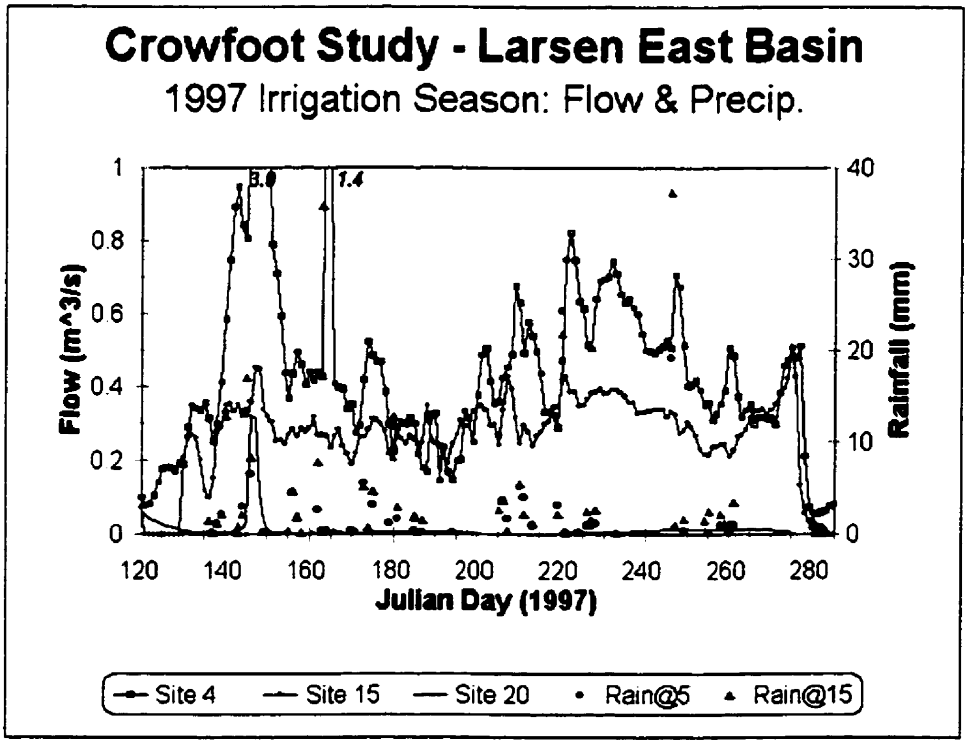

Figure 4.2 Flow / Precipitation for 1997

If the three additional tailwaters (described in section 2.2) were taken into account, the majority of water leaving the Larsen East basin can be accounted for by irrigation tailwaters. Therefore, it may be concluded that the irrigation tailwater has a major impact on creek water quality of the Larsen East basin. Whether the impact is positive or negative is discussed in following sections.

Since the majority of water within the basin is supplied for irrigation purposes, no clear relationship between precipitation and flow or precipitation magnitude and flow magnitude could be ascertained. Along with this, precipitation recorded at the two rain gauges (separated by 13 km) frequently varied substantially. This indicates that rainfall patterns within the Larsen East basin are highly variable and more than two rain gauges are required to gain proper precipitation data. Therefore, in the analysis, fluctuation of parameters were usually linked to flow events rather than precipitation events.

The Larsen East basin received less rainfall in 1997 than in 1996. As precipitation data are available from July of 1996 only rainfall data from Julian days 235-305 these were used to compare 1996 and 1997 rainfall amounts. Between Julian days 235-305 at site #5, just outside the Larsen East basin, 54.8 mm and 27.2 mm of rainfall were collected in 1996 and 1997 respectively. At site #15, for the same period, 67.2 mm and 54.6 mm rainfall were recorded in 1996 and 1997, respectively. During field visits farmers informed the researcher that they also considered 1997 a drier year. Site #15 is on an irrigation canal and as 1997 appears to be a drier year, more water would be needed for irrigation. This may explain the higher flow at site #15 in 1997 than 1996 during the irrigation season. As water flowing past site #15 is discharged into the creek, flow past site #4 is higher in 1997 than 1996 (Figures 4.1 and 4.2).

4.1.2 Nitrogen

4.1.2.1 Ammonium

Figures 4.3 and 4.4 present the fluctuations of ammonium for 1996 and 1997 respectively. As can be seen in Figure 4.3, the level of ammonium at site #20 rises after the rain event of Julian day 262. McNeely and others (1979a) found that ammonia associated with clay minerals enters the aquatic environment through soil erosion. There is substantial grazing around site #20 (Figure 4.5), therefore it is likely that the cattle cause compaction of the soil reducing infiltration and resulting in increased runoff and erosion. Robbins (1979) also found high runoff from heavily grazed watersheds due to compaction of soil from cattle's hooves and grazing practices. In addition, grazing would reduce the plant cover around site #20, further potentially contributing to runoff and erosion. Erosion after the 1997 spring runoff is a potential explanation for the high NH_4 values on Julian days 120-150. Deposition of contaminants over the fall and winter into irrigation canals may account for the rise in NH_4 at site #15 (irrigation tailwater) in the early parts of the 1997 irrigation season.

It can be seen in Figures 4.3 and 4.4 that the levels of NH_4 in 1996 are almost consistently higher than those observed in 1997 for the latter half of the irrigation season. As mentioned in the section on flow, there was less rainfall in 1997 than in 1996 for the latter part of the irrigation season. Less rainfall in 1997 would result in less runoff and thus less erosion. Sharpley and others (1994) state that during detachment and movement of soil in runoff finer sized particles (clays, colloidal organic matter) are preferentially eroded. Less erosion would explain less ammonia associated with clay particles entering the aquatic environment, as mentioned in McNeely and others (1979a), and thus explain lower NH_4 in 1997 than in 1996. However, no explanation can be found for the high values of NH_4 on Julian day 232 of 1997.

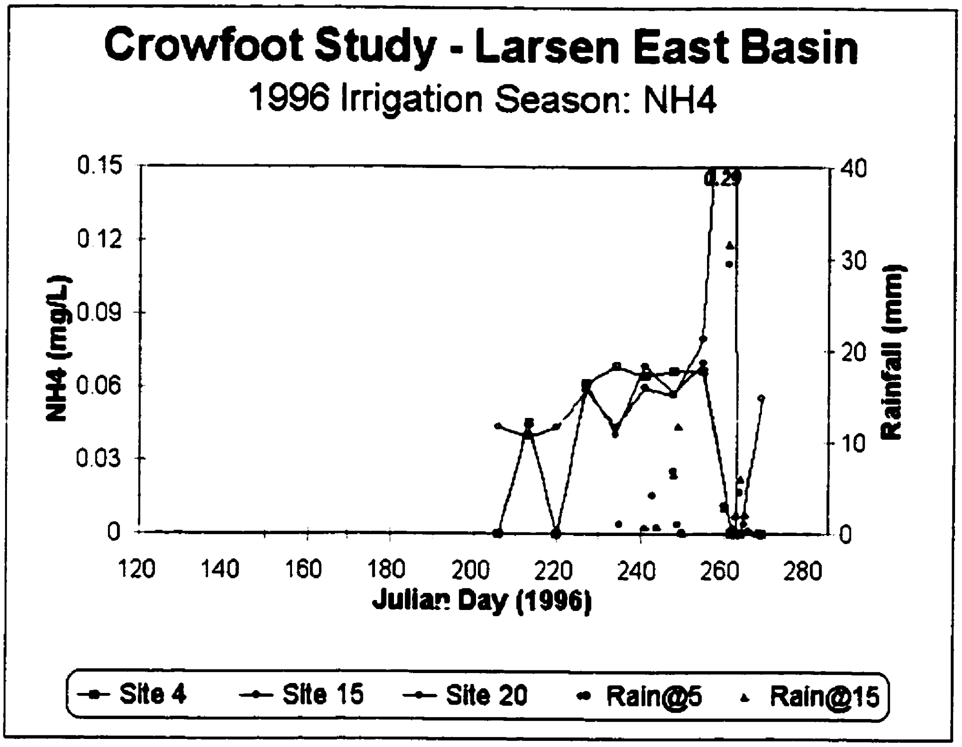

Figure 4.3 1996 Irrigation Season NH_4

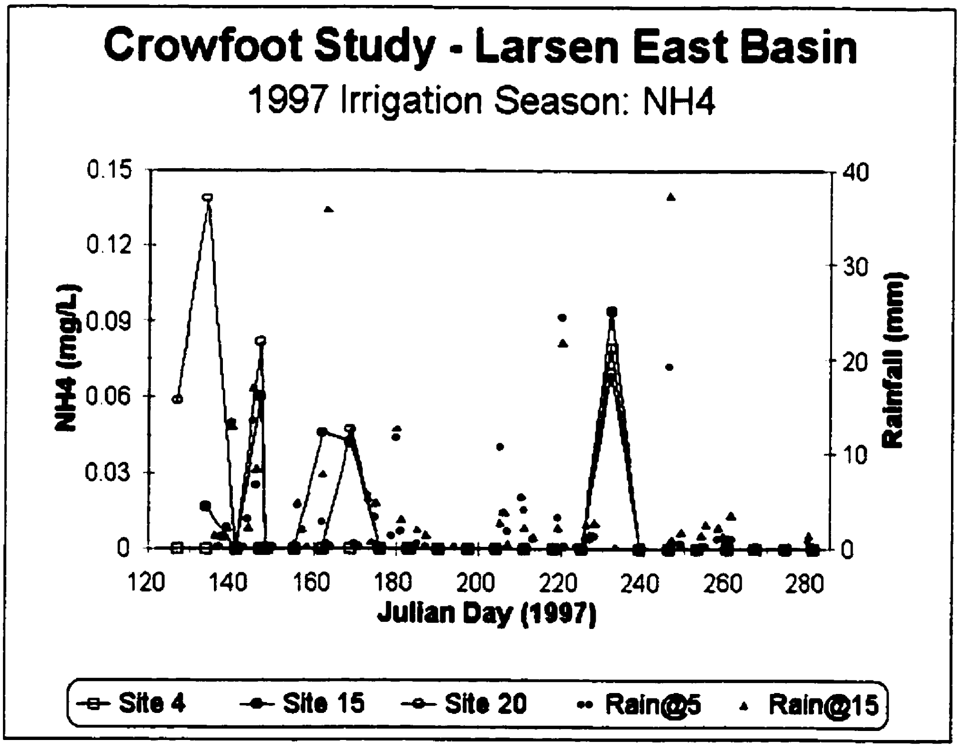

Figure 4.4 1997 Irrigation Season NH_4

Figure 4.5 Grazing around site #20

4.1.2.2 Nitrate

Nitrates are highly soluble and thus mobile. Nitrogen as nitrate concentrations for 1996 and 1997 are presented in Figures 4.6 and 4.7 respectively. It can be seen in Figure 4.6 that NO_3-N rose dramatically after a precipitation event at site #20 on Julian day 262 in 1996. As mentioned previously there is grazing around site #20. The grazing is expected to have resulted in compaction of the soil. McNeely and others (1979b) state that animal waste is a major source of nitrates. The compaction of the soil would reduce infiltration, the preferred pathway of nitrates according to the literature, and result in nitrates from manure being carried toward the creek in the runoff due to the precipitation. Thus, the peak of NO_3-N on Julian day 262 in 1996 for site #20 is likely due to runoff from the grazing area around the site. High values of NO_3-N are also observed at site #15 at the beginning of the irrigation season of 1997. An explanation of these high values may be that during the winter and early spring runoff events, contaminants were deposited in the unused irrigation canals. If this is the case then at the start of the 1997 irrigation season when water was supplied the canals are being flushed out resulting in high NO_3-N values.

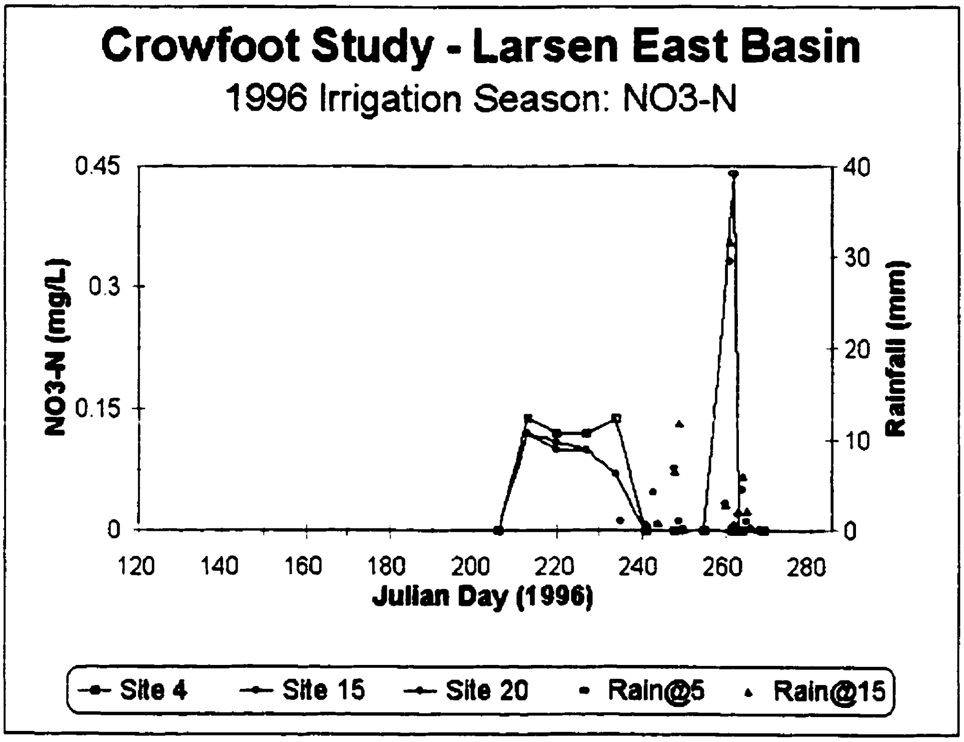

Figure 4.6 1996 Irrigation Season NO_3-N

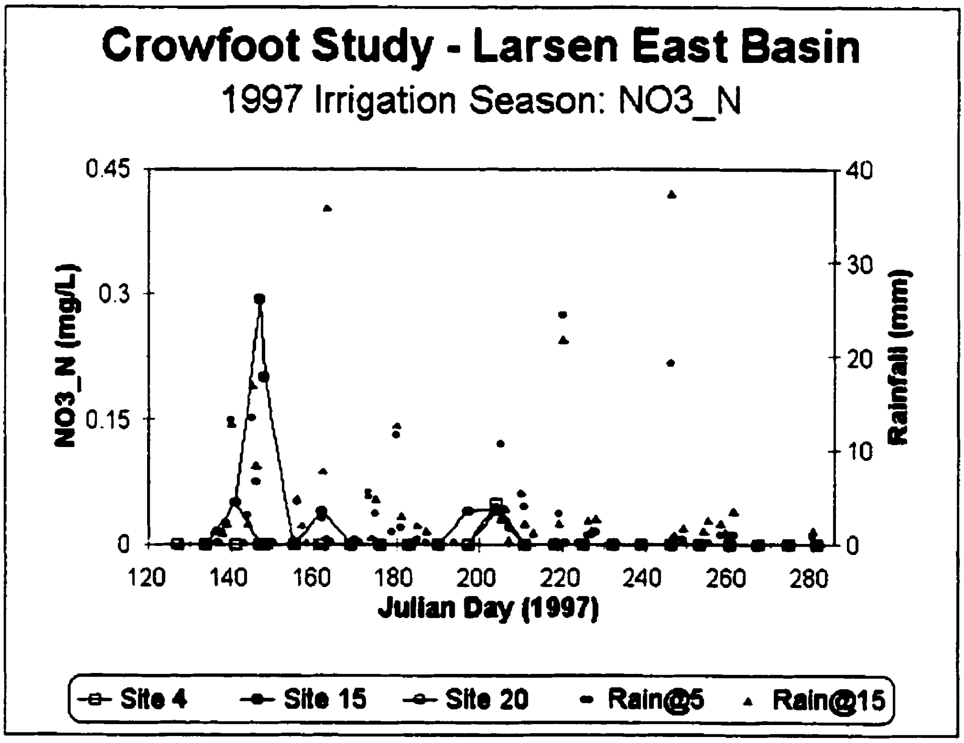

Figure 4.7 1997 irrigation Season NO_3-N

No explanation of the high NO_3-N values observed between Julian day 213-234 in 1996 could be found. The NO_3-N values observed in 1996 and 1997 were similar to those observed by CCREM (1987) for surface waters (0.001-1 mg/L). In addition, the NO_3-N values for site #4, #15 and #20 were below the Canadian Environmental Guideline for drinking water of 10 mg/L.

4.1.2.3 Nitrite

In the 1996 irrigation season no nitrogen as nitrite (NO_2-N) was observed at sites #4, 15 and 20. However, in the 1997 sampling season a sample (on Julian day 147) from site #15 (irrigation tailwater) was found to contain 0.07 mg/L of NO_2-N (Figure 4.8).

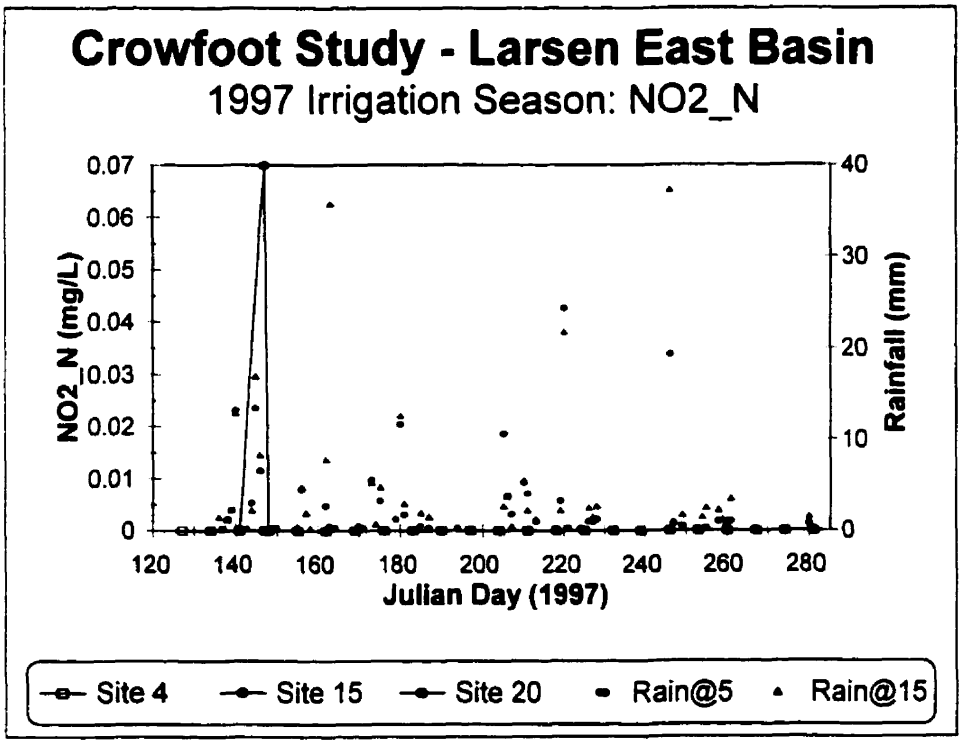

Figure 4.8 1997 Irrigation Season NO_2-N

No other samples from sites #4, 15 or 20 contained any detectable NO_2-N. The sample, from site #15 in 1997, which was found to contain 0.07 mg/L of NO_2-N was collected during a precipitation event. Levels of NH_4 and NO_3-N rose dramatically on during this precipitation event also. If the value observed is not due to experimental error then as mentioned in section 2.3.1.3 the presence of nitrite in water indicates active biological processes influenced by organic contamination. The organic contamination may have entered the irrigation canal due to surface runoff or groundwater discharges due to the rainfall on Julian days 143-146. From the water quality guidelines summarized in Appendix A it can be seen that the 0.07 mg/L of NO_2-N at site #15 violates the Canadian Environmental Quality guideline for freshwater aquatic life.

4.1.2.4 Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen (TKN) is a measure of ammonia and organic nitrogen (McNeely and others 1979d). Figures 4.9 and 4.10 illustrate the levels of TKN observed in 1996 and 1997 respectively. The rise in TKN after the rain event on Julian days 260-266 at site #20 can be seen in Figure 4.9. As with NO_3-N and NH_4 a potential explanation for this rise in TKN in the creek is runoff containing organic N and NH_4. Table 4.1 summarises the massload for TKN during the 1996 and 1997 sampling seasons.

Table 4.1 Ammonium accounts for small proportion of N in TKN by mass

Site	1996 Irrigation Season		1997 Irrigation Season	
	TKN (kg)	NH_4 (kg)	TKN (kg)	NH_4 (kg)
4	450.5	56.34	4294.6	32.34
15	253.4	28.24	1882.8	43.11
20	33.74	5.64	250.9	4.23

Note: Massloads were computed in the following manner. Using linear interpolating between weekly water sample TKN and NH_4 concentrations daily concentrations were obtained. The product of these daily concentrations and the daily flow resulted in the daily massload. Massload for the irrigation season (Julian days 206-304 and 127-281 for 1996 and 1997 respectively) were computed using daily massloads.

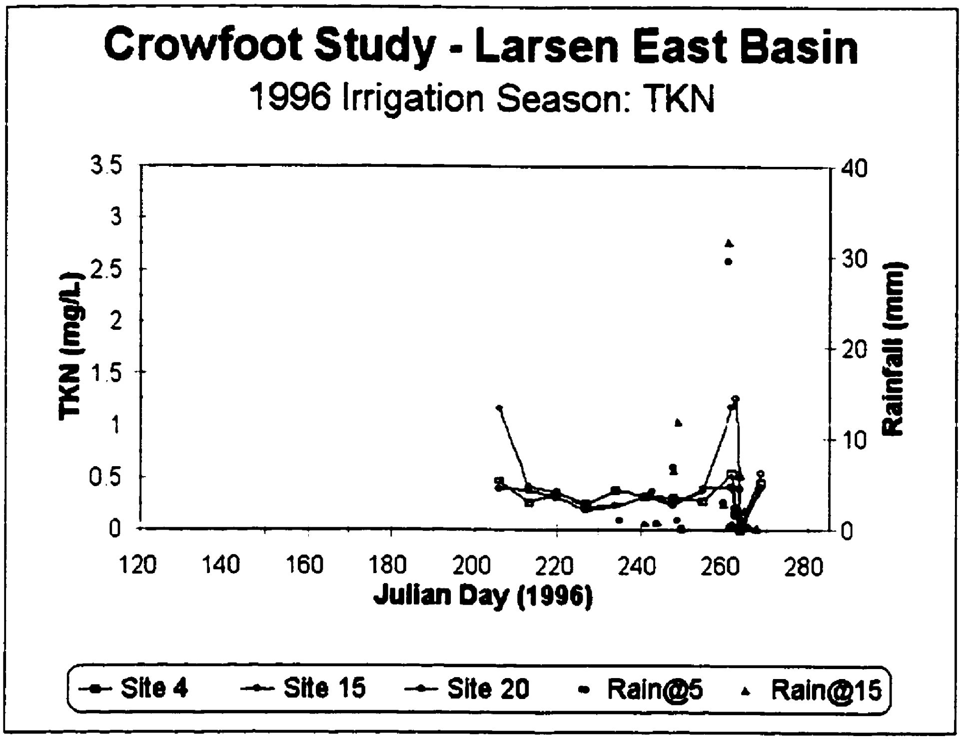

Figure 4.9 1996 Irrigation Season TKN

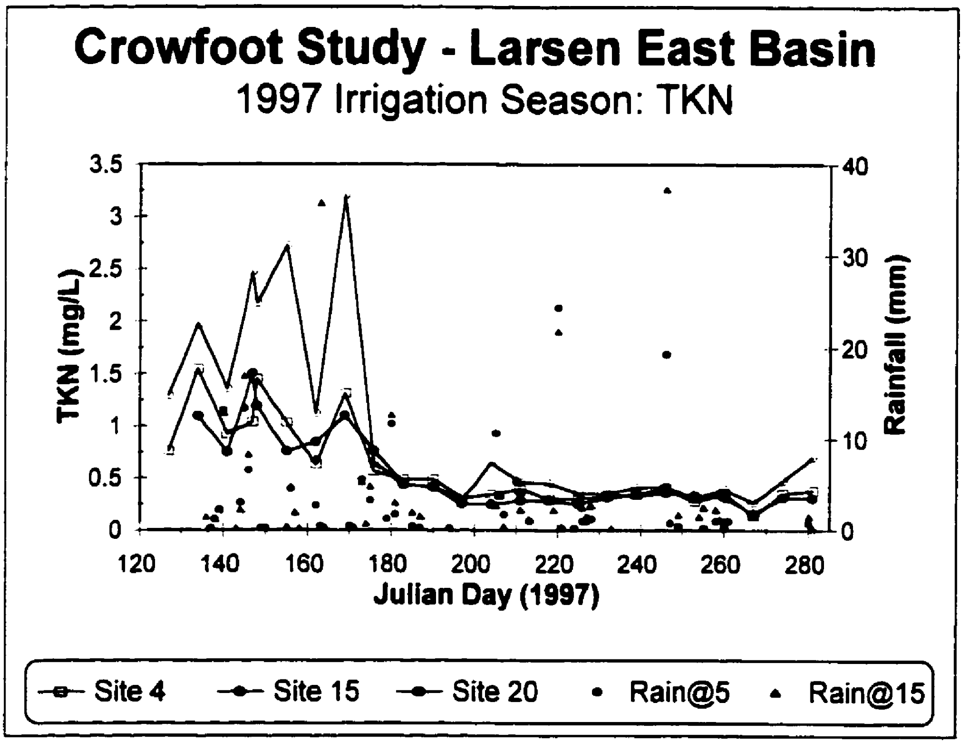

Figure 4.10 1997 Irrigation Season TKN

As can be seen in the table there is a substantial difference between the amount of TKN and NH_4. Thus, as TKN is a measure of ammonia and organic nitrogen, the difference must reflect the contribution of organic N. A potential source of the organic N might be runoff from lands with grazing near the creek. Areas with grazing with free access (cattle can enter the creek) to the creek are indicated in Figure 4.11. Another potential source of organic N may be runoff from fields where organic fertilizer has been applied.

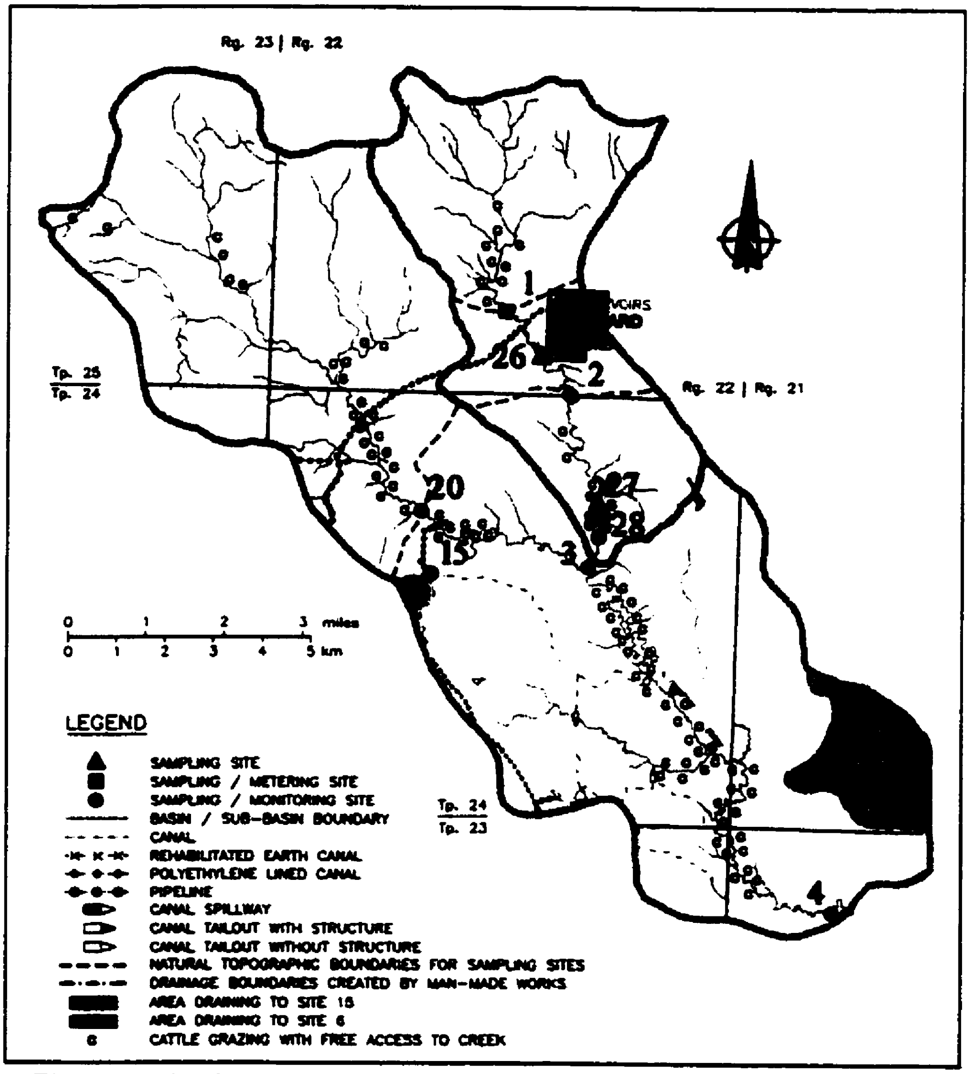

Figure 4.11 Areas with cattle grazing with free access to the creek

High values of TKN are also observed at the beginning of the 1997 irrigation season (Figure 4.10). As explained in the section on NH_4 it is possible that contaminants are deposited in the irrigation canal which would account for high values observed at site #15 (on an irrigation canal) at the beginning of the irrigation season when water is supplied into the irrigation network. Several cattle wintering sites exist along the creek (Phil Lund, Personal Communications, 1996). Cattle wintering sites are commonly near water bodies like creeks as they provide ready access to water. As the cattle are confined in small areas there is a concentration of solid and liquid animal waste. The specific locations of such wintering sites were not known. These wintering sites may explain the high values at sites #4 and #20 from Julian days 120-175. Another explanation of the high values from Julian days 120-175 at sites #4 and #20 could be runoff from fields on which organic or commercial fertilizer is applied. The high values at site #20 can be explained by a fertilizer spill. Early in 1997 a farm truck's fertilizer tank burst spilling fertilizer approximately 20 feet from site #20 (Figure 4.12). Any rainfall would both bring the fertilizer into solution and cause erosion of soil particles to which the fertilizer is attached. Thus, the fertilizer would enter the creek and be sampled at site #20.

Regardless of the source there was substantial TKN contribution during the beginning of the 1997 irrigation season. McNeely and others (1979d) indicate that the concentration of TKN in rivers which are not influenced by "excessive" organic inputs ranged from 0.1 to 0.5 mg/L. As can be seen in Figure 4.9 and 4.10 the TKN concentration for site #4 (basin outflow) and site #15 (irrigation tailwater) does not exceed 0.5 mg/L with the exception of the early part of the 1997 irrigation season. The Alberta Ambient Surface Water Quality Guideline for inorganic and organic N is 1.0 mg/L and this guideline was exceeded frequently, by up to 600%, in the early part of the 1997 irrigation season. No explanation could be found for the high TKN value at site #20 on Julian day 206 in 1996.

Figure 4.12 Fertilizer spill near site #20

4.1.2.5 Total Nitrogen

The Alberta Ambient Surface Water Quality Guideline for total nitrogen (inorganic and organic N) is 1.0 mg/L. This guideline was only exceeded by the water from site #4 (basin outflow) and site #15 (irrigation tailwater). This occurred in the early part of the 1997 irrigation season when it is expected that the watershed is being flushed out. Values as high as 3.67 mg/L were recorded at site #4 (Appendix F). Note, TKN was the form of N that accounted for most of the total nitrogen.

4.1.3 Phosphorus

The Alberta Ambient Surface Water Quality Guideline for phosphorus is 0.15 mg/L as phosphate or 0.05 mg/L as total phosphorus. Figures 4.13 and 4.14 graphically present the fluctuations of ortho-phosphate while Figures 4.15 and 4.16 pertain to total phosphorus for the 1996 and 1997 irrigation seasons respectively.

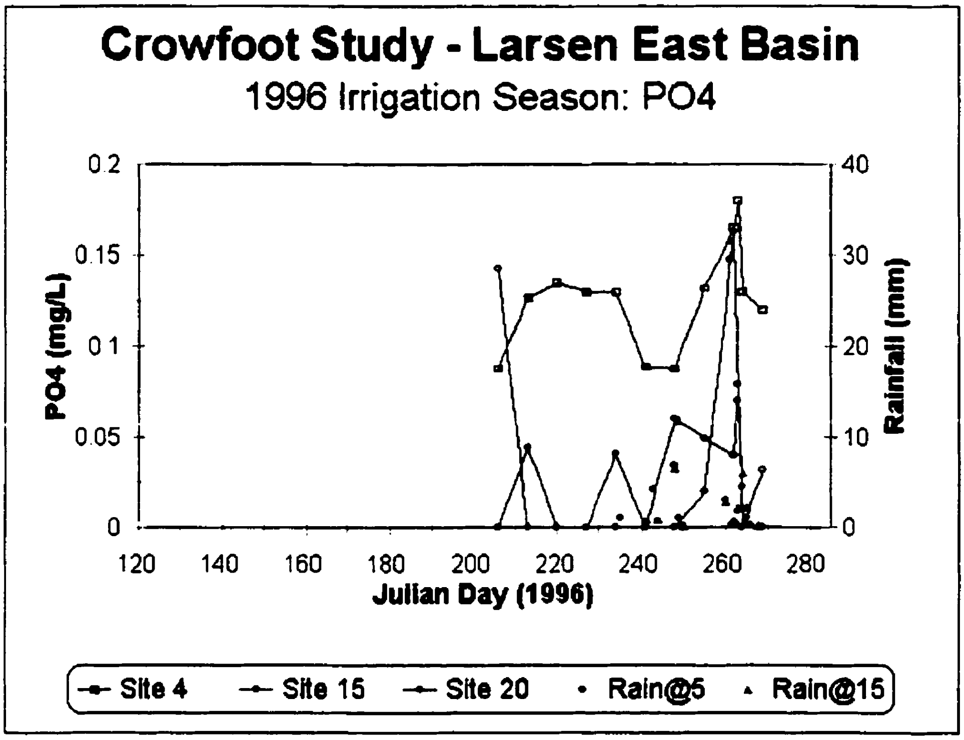

Figure 4.13 1996 Irrigation Season PO_4

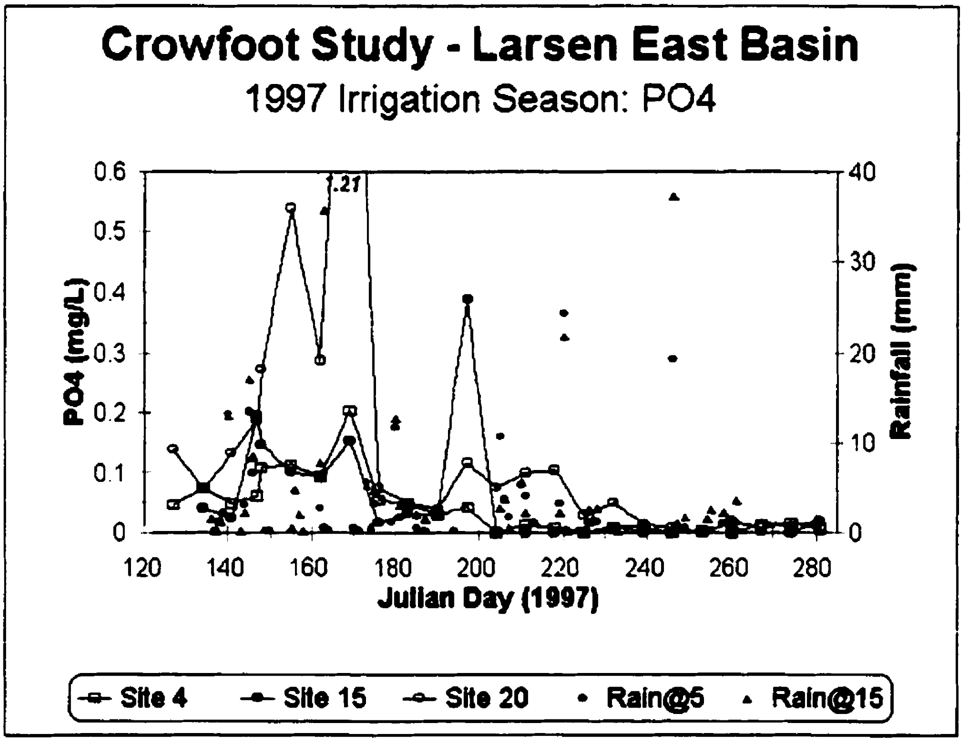

Figure 4.14 1997 Irrigation Season PO_4

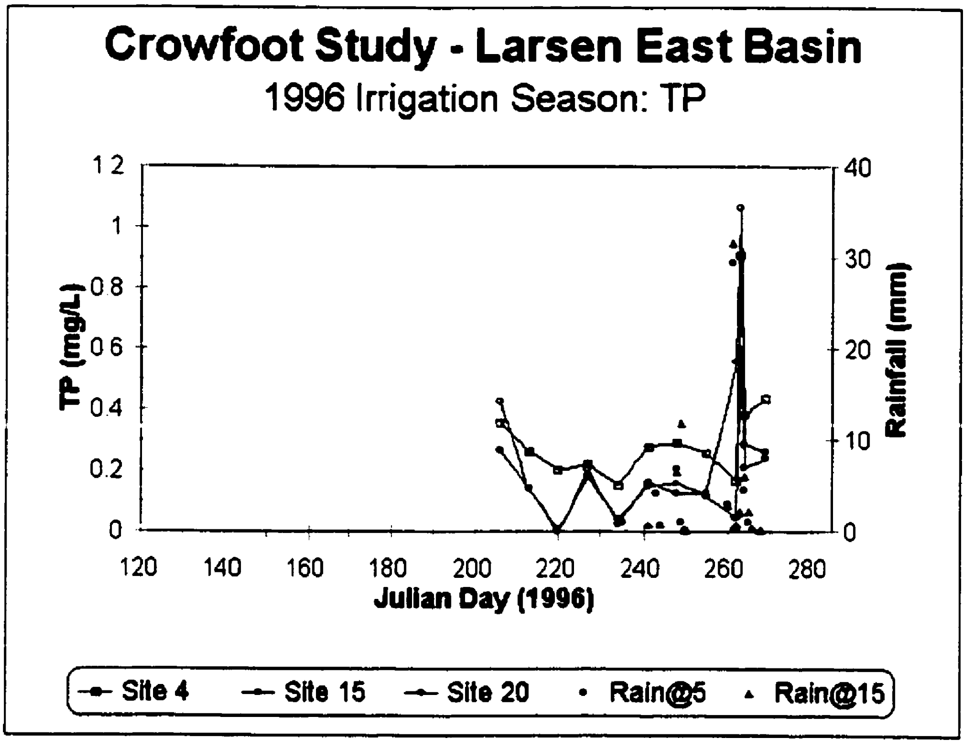

Figure 4.15 1996 Irrigation Season TP

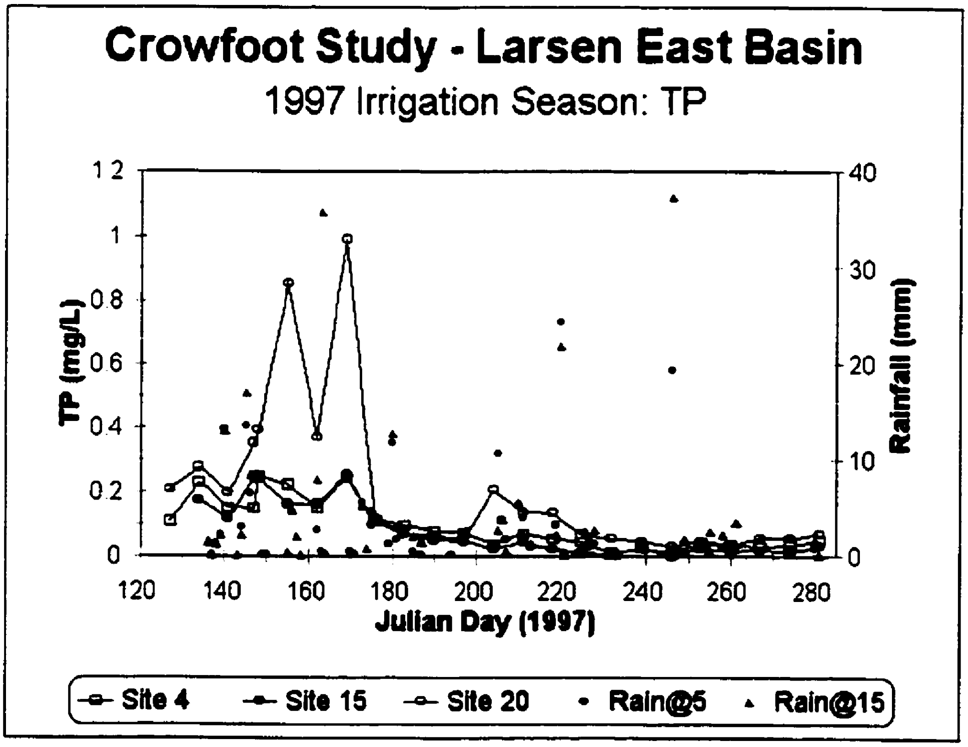

Figure 4.16 1997 Irrigation Season TP

In the 1996 irrigation season (Figure 4.13) the guideline for ortho-phosphate (PO_4) was exceeded on Julian days 262 and 263 in samples from sites #4 and #20 by about 20% and 6% respectively. A rise was also recorded at site #15, during the same period, but the above guideline was not exceeded. These samples were collected during a runoff generating precipitation event and it is expected that the runoff carried contaminants into the creek and irrigation canal. For the 1996 irrigation season (Figure 4.15) the total phosphorus in the water samples from sites #4, 15 and 20 almost consistently exceeded the TP guideline. As the PO_4 in the water samples was under guideline values the only plausible explanations for the high TP are I) a rise in particulate phosphorus; and/or ii) organic phosphorus contamination. Low TSS levels indicate that particulate phosphorus is not a problem. Thus, organic contamination must be occurring. Potential sources of organic pollution may be cattle access to the creek, runoff from grazing areas or runoff from fields on which organic fertilizer was applied.

In the early part of the 1997 irrigation season (Figures 4.14 and 4.16) for site #20 both PO_4 and TP were substantially higher than the guideline values. As mentioned in the section on Total Kjeldahl Nitrogen (TKN) a logical source of the phosphorus, at site #20, is the fertilizer spill (Figure 4.12). The high values of PO_4 and TP observed at site #15 (irrigation tailwater) early in 1997 may be due to the flushing out of the irrigation canal network after the spring runoff which may have deposited contaminants in the canals. There is some speculation that high phosphorus values in the irrigation water may be due to the turnover of Chestermere Lake which is part of the WID irrigation network. Runoff from grazing areas (most probably carrying manure and decaying cattle feed) around site #20 would also contribute to the phosphorus observed at site #20. Cattle wintering sites along the creek between site #20 and site #4 are probable sources of PO_4 and TP observed in the water at site #4 in the early part of the 1997 irrigation season. Another potential source of P observed at site #4 is runoff from fields on which commercial or organic fertilizer is applied. Cattle grazing around site #20 may be the explanation of the high TP values observed on Julian days 204-239 in 1997.

As the cattle are not fenced off from the creek it is highly possible that cattle enter the creek to drink water and stir up the sediment causing a dissolution of phosphorus.

In 1997 on Julian days 146-152 a flow event occurred due to heavy rainfall. This one flow event accounted for 68% of the irrigation season TP massload at site #20. The source of the TP was most possibly the fertilizer spill but the fact remains that runoff and erosion is a serious problem at site #20. A high PO_4 value is recorded on Julian day 197 in 1997 at site #15. There is no explanation for this high value. As the TP on the same date does not rise dramatically it is possible that the high PO_4 is due to experimental or analytical error.

4.1.4 Total Dissolved Solids

Low salinity is desired in irrigation water. Total dissolved solids (TDS) provides an idea of the dissolved substances (i.e. salts) in water. Figures 4.17 and 4.18 present the TDS levels observed in water samples from 1996 and 1997 respectively. As can be seen in Figure 4.18 salinity was higher in May and June than in the remainder of the year. Similar results were found in a surface water quality study (Madawaska Consulting, 1996) conducted on the County of Wheatland, within which the Crowfoot Creek flows. An explanation for the high TDS levels is that during the early part of the irrigation season the flow in the watershed is flushing out contaminants accumulated over the last fall or winter. On the other hand, it could represent the only time of the year when groundwater seepage is a major contributor to stream baseflow; being the only time of the year when the water table is high enough to do so. The Canadian Environmental Quality Guidelines for drinking water and irrigation with regard to TDS are 500 and 500-3500 mg/L respectively. The drinking water guideline was exceeded only: I) three times in the 1996 sampling season at site #20 by up to 146%; ii) in the early part of 1997 at sites #4,15 and 20 by up to 111%, and iii) on Julian day 281 in 1997 at site #4.

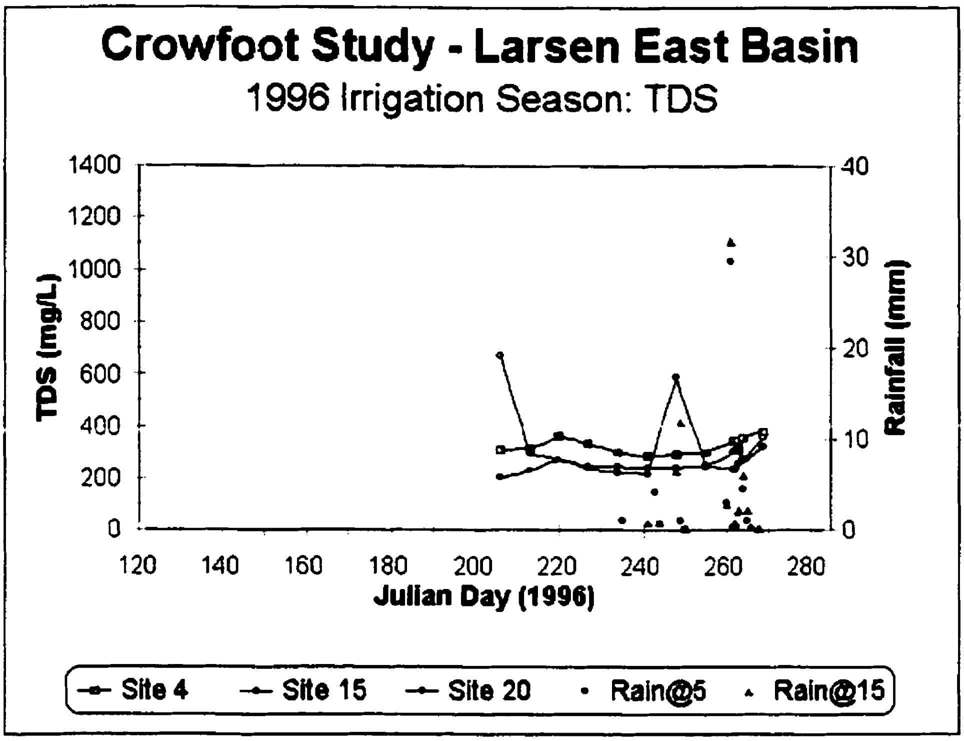

Figure 4.17 1996 Irrigation Season TDS

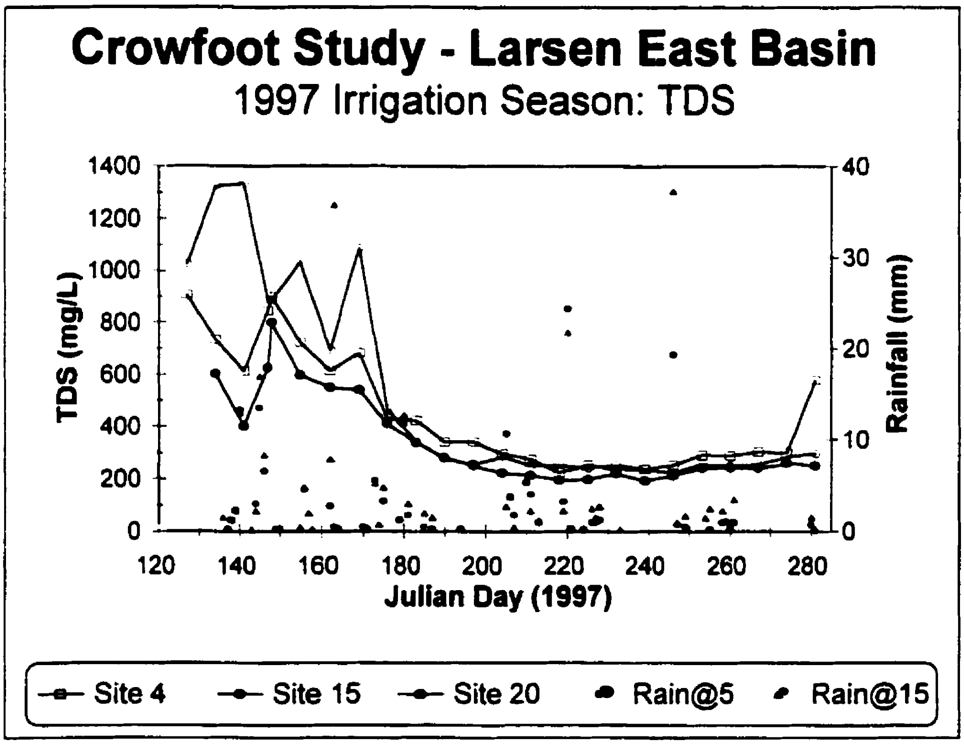

Figure 4.18 1997 Irrigation Season TDS

No explanations could be found for the high TDS values on: I) Julian day 206 in 1996 at site #20; ii) Julian day 246 in 1996 at site #15 and iii) Julian day 281 in 1997 at site #4. The high TDS value on Julian day 246 in 1996 at site #15 is suspect as on the same sampling date no rise in TDS was observed at site #4 or #20. Along with this the high TDS value is uncharacteristically high for the TDS values observed at site #15 during most of 1996.

4.1.5 Total Suspended Solids

Total suspended solids (TSS) is a measure of suspended sediments in a water body. Figures 4.19 and 4.20 present the TSS values for 1996 and 1997 respectively. Due to a precipitation event TSS values rose around Julian day 262 at sites #4 and #20 in 1996. It is suggested that runoff accounted for the rise in TSS values. For sites #4 (basin outflow) and site #15 (irrigation tailwater) TSS values remained below 30 mg/L in 1996 and 1997 with the exception of the early part of the 1997 irrigation season. It is suggested that a high water table led to less infiltration and subsequently more runoff and erosion during the early part of the 1997 irrigation season resulting in high TSS values. Not all TSS fluctuations in the creek correspond to precipitation events. Cattle grazing directly in the creek at various locations along the reaches, cause TSS loading which is independent of rainfall events. The cattle have access to the creek and thus destroy the streambanks and stir up sediment from the creek bottom. In addition, their grazing along the creek probably results in increased runoff and erosion. Although it is also possible that the soil along the creek near site #20 may be highly susceptible to erosion and thus natural erosion may be occurring which accounts for the TSS values.

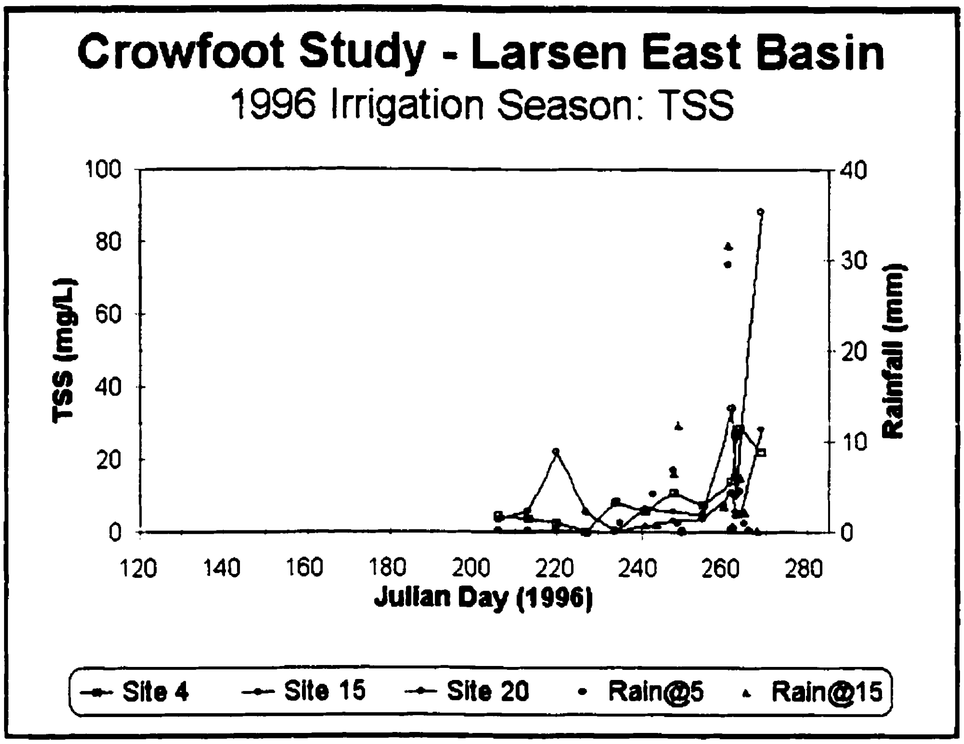

Figure 4.19 1996 Irrigation Season Total Suspended Solids

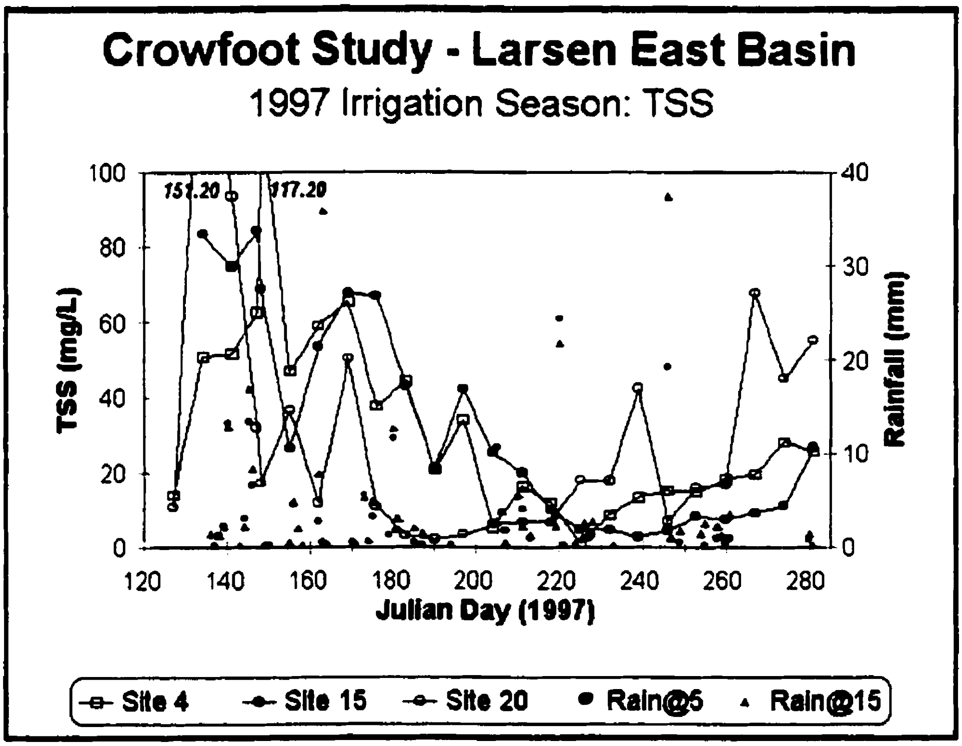

Figure 4.20 1997 Irrigation Season Total Suspended Solids

Soil erosion measurements on small upland watersheds (in Ohio) found that most of the total erosion occurs due to a few large storms (Edwards and Owens 1991). The Larsen East basin may not be a "typical" upland watershed as the majority of the water leaving the basin is due to irrigation tailwaters, as discussed earlier. Only in large rainfall events will runoff overtop the canal bank edges and enter the canal. Unless there is substantial runoff it is expected that the canal banks will prevent runoff from entering the canals. Runoff from areas downstream of the irrigation tailwater may also enter the creek in a rainfall event. Also, in the event of rain it is highly likely that the farmers will stop irrigating, resulting in more irrigation tailwater. Therefore it is difficult to differentiate the flow in the creek between runoff and tailwater. Regardless of the source of water, flow events do account for significant portions of the TSS massload observed, as can be seen in Table 4.2.

Table 4.2: Contribution of flow events to irrigation season TSS massload

Site #	1996	1997
4	56.8%	43.2%
15	52.3%	13.3%
20	41.3%	38.4%

Note: Massload percentages were computed in the following manner. Using linear interpolating between weekly water sample TSS concentrations daily concentrations were obtained. The product of these daily concentrations and the daily flow resulted in the daily TSS massload. Dramatic rises in flow were identified using Figures 4.1 and 4.2 as flow events. In 1996 Julian days 246-253 and 161-167 were considered as flow events while in 1997 Julian days 146-152 and 161-167 were considered as flow events. The daily massload for these days was summed and expressed as a percentage of the total massload.

The Alberta Ambient Surface Water Quality Guideline with regard to TSS is to not increase the TSS of the water more than 10 mg/L above a "background value." Ideally, a "background value" would be the natural quality of water untouched by direct human activity. An example would be the water from a natural forest or grassland in the upper reaches of a basin. This study's upper sites #15 and #20 were affected by irrigation water, irrigation tailwaters and/or cattle grazing.

Therefore no sites provided "background" values and it could not be determined if the guideline was met.

4.1.6 Fecal Coliform

Figures 4.21 and 4.22 present the levels of fecal coliform in water samples in 1996 and 1997 respectively. Fecal coliform values for site #20 in 1996 were as high as 6,100 / 100mL. The most probable explanation of such high values is the grazing of cattle around site #20. Doran and Linn (1979) recommend fecal coliform as an indicator of cattle activity in a watershed. As the cattle had access to the creek it is highly probable that there is some defecation occurring in the creek. Grazing along the creek between site #20 and site #4 may account for the fecal coliform entering the water after the irrigation tailwater. As can be seen in Figure 4.21 the fecal coliform of irrigation tailwater, at site #15, is below the irrigation water guideline of 100/100mL except after a major precipitation event in 1996 on Julian days 260-266. The high levels of fecal coliform on Julian day 262 in 1996 at site #4 and #15 indicate that runoff carrying fecal coliform is entering the irrigation canal and the creek downstream of the irrigation discharge. Runoff carrying fecal coliform entering the irrigation canal is of concern as the levels of fecal coliform exceed, by about 190%, the Canadian Environmental Quality Guideline for irrigation water of 100/100mL. As the primary purpose of the irrigation water is to irrigate the violation of the irrigation guideline is a concern.

Early in 1997 (Figure 4.22) high values of fecal coliform were observed at all sites, it is expected that the high values are due to the flushing out of the watershed in the early part of the 1997 irrigation season. In 1997 the fecal coliform values are highly variable. Howell and others (1995) comment fecal bacteria concentration can vary with time at any given site.

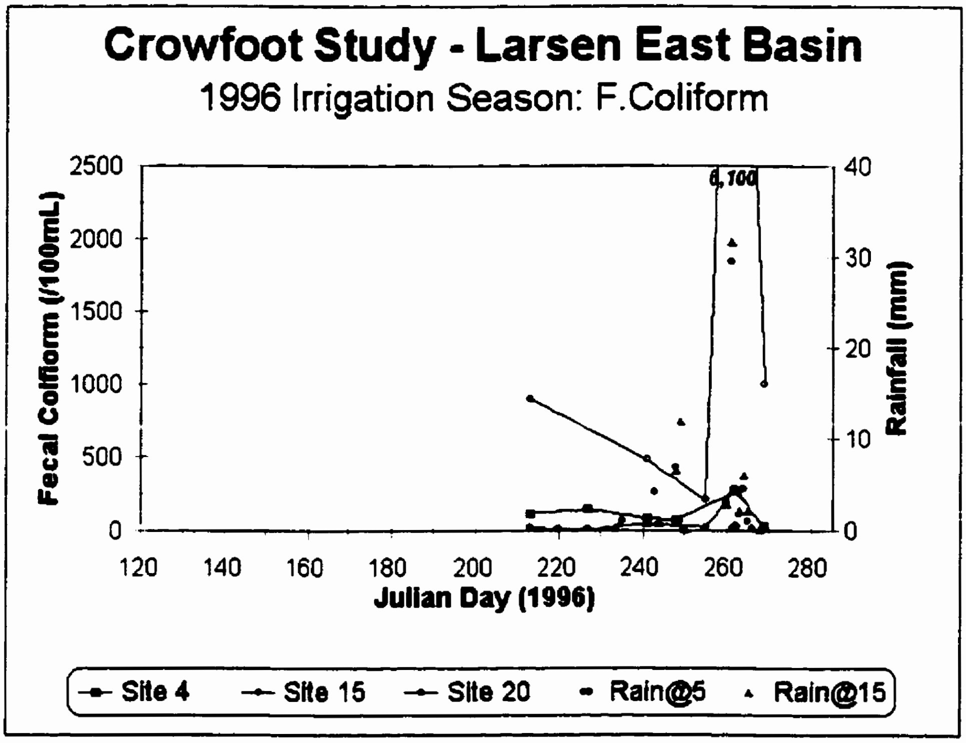

Figure 4.21 1996 Irrigation Season Fecal Coliform

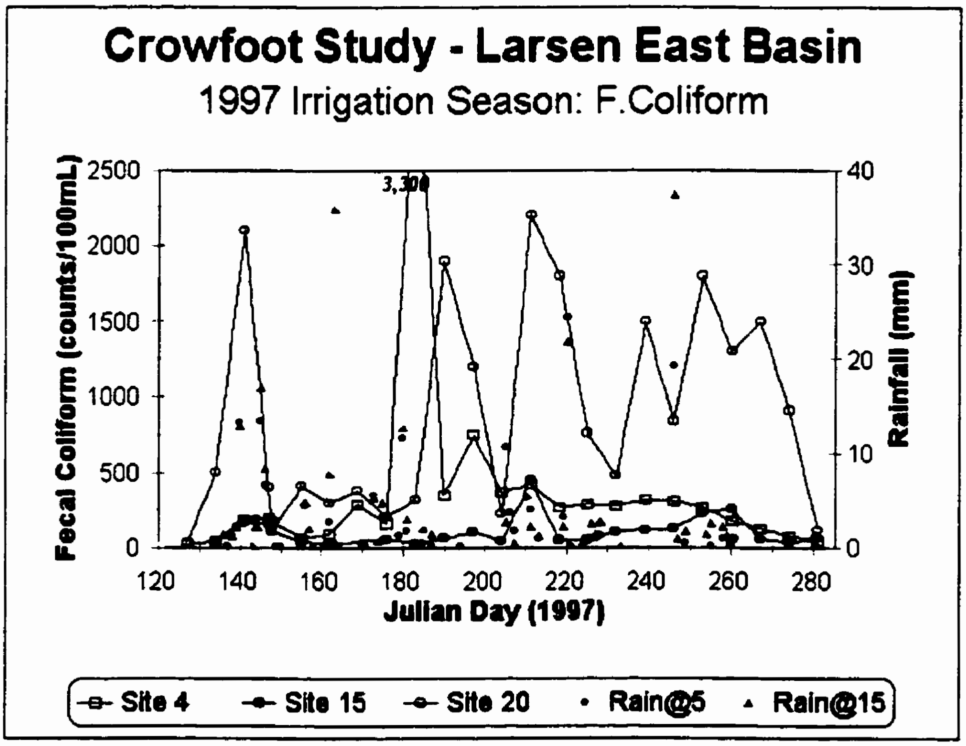

Figure 4.22 1997 Irrigation Season Fecal Coliform

Surprisingly in 1997 (Figure 4.22) high values of fecal coliform at site #15 (irrigation tailwater) frequently exceeded the irrigation water quality guideline by up to 350%. The high levels of fecal coliform did not consistently occur after precipitation events implying that besides runoff there are other sources of fecal coliform upstream of site #15. As in 1996 similar high fecal coliform values were observed in 1997 at sites #4 and #20 after rain events. The most probable source of the fecal coliform is the grazing along the creek with access to the creek.

4.1.7 SUMMARY: IRRIGATION TAILWATER IMPACTS ON CREEK WATER QUALITY

From the flow records of sites #4 (basin outflow) and #15 (irrigation tailwater) it may be concluded that the irrigation tailwater at site #15 accounted for 55% and 59% of the flow leaving the basin in 1996 and 1997 respectively. There are three other tailwater spill points located between the discharge from site #15 and the basin outflow at site #4. It is expected that if these were taken into consideration irrigation tailwaters would account for almost all the water leaving the basin during the irrigation season. As such the irrigation tailwaters play a major role in the water quality of the Crowfoot Creek in the Larsen East basin.

The Alberta Ambient Surface Water Quality guideline for total inorganic and organic nitrogen is 1.0 mg/L. In the sampling during the 1996 irrigation season, this guideline was met by water at sites #4 and #15. Similarly, in 1997 with the exception of the early part of the irrigation season water from sites #4, #15 and #20 did not exceed the guideline. Organic nitrogen was the primary form of nitrogen found in the water samples for both the 1996 and 1997 irrigation season.

Sampling during a precipitation event producing runoff in 1996 between Julian days 260-266 found that water from sites #4 (basin outflow) and #20 (upstream of irrigation tailwater) exceeded the Alberta Ambient Surface Water Quality Guideline for phosphorus as phosphate by 20% and 6% respectively. It is expected that runoff from surrounding areas is the major source of contaminants. The phosphorus as phosphate guideline can be expressed as 0.05 mg/L of total phosphorus. The total phosphorus values were frequently above 0.05 mg/L for all sites in 1996 and 1997. It is suggested that organic phosphorus contamination resulted in the guideline for total phosphorus being exceeded. Possible sources of organic pollution may have been cattle access to the creek, runoff from grazing areas or runoff from fields on which organic fertilizer was applied.

The total dissolved solids values were higher in May and June than in the remainder of the irrigation season. Two explanations are possible: I) spring flows flushed contaminants which have accumulated in late fall and winter and ii) May and June may be the only time of the year when groundwater seepage, typically high in salts, is a major contributor to stream baseflow.

Samples collected during a runoff producing precipitation event, in 1996, at sites #4 and #20 displayed high TSS values. It is expected that runoff accounted for the rise in TSS values. At sites #4 (basin outflow) and #15, TSS values were below 30 mg/L in 1996 and 1997 with the exception of the early part of the 1997 irrigation season. An explanation for this may be that a high water table led to less infiltration and subsequently more runoff and erosion. Not all TSS fluctuations at #20 correspond to precipitation events. It is possible that cattle grazing around site #20 causes erosion and streambank failure. A significant portion of the TSS massload in both the years occurred during periods of high precipitation.

In 1996 the irrigation tailwater (site #15) exceeded by about 190% the irrigation guideline with regard to fecal coliform only once, which was after a precipitation event producing runoff. However, in 1997 the irrigation guideline for fecal coliform was exceeded frequently by up to 350%. The high levels of fecal coliform did not consistently occur after precipitation events which would indicate that besides runoff there are significant sources of fecal coliform upstream of site #15 on the irrigation canal. Despite the irrigation tailwater (site #15) accounting for over half the flow at the basin outflow (site #4) the levels of fecal coliform at site #4 were frequently above those at site #15. Grazing along the creek upstream of site

#4 is a potential source of fecal coliform. There is grazing around site #20 which likely accounts for the high fecal coliform values at this site. In the early part of the 1997 irrigation season several high values for NH_4, NO_3-N, TKN, PO_4, TP, TDS and TSS were observed at site #15 (on irrigation canal prior to irrigation tailwater). It is likely that over the fall, winter and spring runoff contaminants were deposited into the irrigation canals. In the early part of the 1997 irrigation season these contaminants were being flushed out by the irrigation water leading to high parameter values at site #15.

Grazing of cattle occurs along the length of the creek. Several studies have found that grazing along water bodies such as creeks and rivers lead to contamination indicated by such parameters as nitrogen, phosphorus and fecal coliform bacteria (McNeely and others 1979b, Sharpley and others 1994, Sutton 1990 in Greenlee and Lund 1995, Kirchmann 1994, Tiedemann and others 1988). Grazing caused compaction of soil resulting in high runoff (Robbins 1979, in Cross and Cooke 1996). This runoff may cause erosion and carry animal waste into the creek. Animal wastes have been found to contain nitrogen, phosphorus and fecal coliform bacteria (Sharpley and others 1994, McNeely and others 1979b, Clemm 1977). Cattle also wintered near the creek but the exact locations of such operations is not known. Such wintering sites would also be sources of contaminants.

In the early part of the 1997 irrigation season a farm truck's fertilizer tank burst spilling fertilizer approximately 20 feet from site #20. It is expected that this may account for high nitrogen and phosphorus values at this site throughout the 1997 irrigation season at site #20.

4.2 SEWAGE LAGOON EFFLUENT IMPACTS ON CREEK WATER QUALITY

The village of Standard treats its municipal wastewater in a sewage lagoon. Effluent from the lagoon is released once a year in the fall, over a 4-6 day period. Site #26 is located at the sewage lagoon discharge point. The effluent then flows past site #2 (located 500 m downstream) and into the Ducks Unlimited reservoirs. Except during spring runoff, or during runoff producing precipitation events, the creek at site #2 is stagnant. Also, only during spring runoff is there flow from the reservoirs. That is, site #3 normally records no flow during the summer.

Flows and mass loads of individual parameters were examined at sites #26, 2, #3 and #4. Because individual forms of nitrogen (i.e. NH_4, NO_2-N, NO_3-N, TKN) and phosphorus (i.e. PO_4, TP) can alter with time, only TP and TN can be used when making comparisons between monitoring sites.

For computation of the mass load at site #26 the flow from site #2 was used. This was deemed acceptable for three reasons: I) there was no flow before the lagoon discharge at site #2 and thus any flow was a result of the lagoon discharge; ii) there were no sources of water entering the creek between site #26 and #2; and iii) there was no precipitation during the lagoon discharge which would have caused runoff.

It was assumed that the "lagoon effluent discharge-Duck Unlimited reservoirs" system had achieved steady state condition. The weirs, for the reservoirs, were built in 1980 and the Standard sewage lagoon has been operating since 1978. During the first years of operation one could expect a "build-up" of contaminants in the reservoir bed. Now, after 16 years of operation, one could expect that such sinks will be full and the system as a whole is in a steady state.

4.2.1 FLOW

Figures 4.23 and 4.24 present the flow observed at site #2 during the lagoon

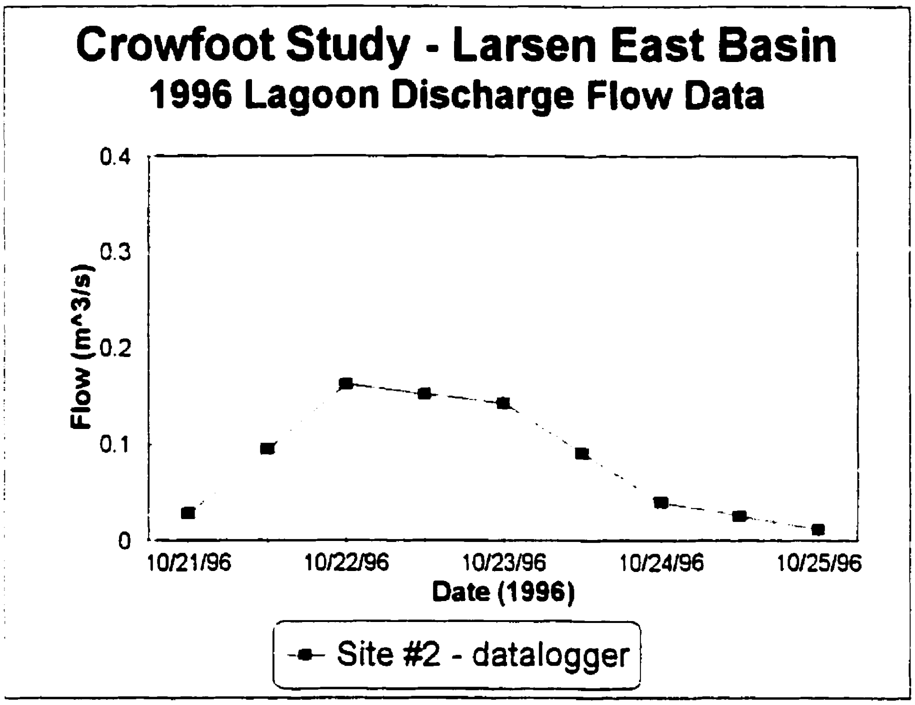

Figure 4.23 1996 Lagoon Discharge Flow Data

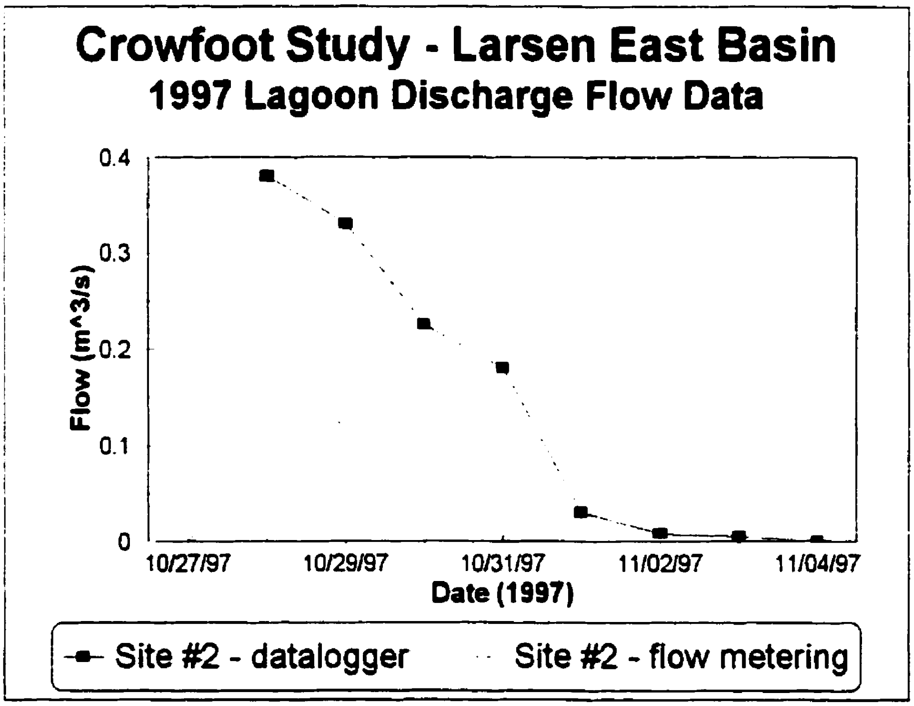

Figure 4.24 1997 Lagoon Discharge Flow Data

effluent discharge. The sewage lagoon accounts for essentially all the flow at site #2 during the lagoon discharge. The outlet structure from the lagoon is a pipe with a control valve. No flow data was obtained for Julian day 300 in 1997 due to equipment failure. The flow during the 1997 lagoon discharge differs dramatically from the flow in 1996. As the effluent in both years leaves the lagoon through a pipe the flow should be similar in 1996 and 1997. It is possible that the 1997 flow data is inaccurate as the datalogger recorded unsubstantiated voltage fluctuations. Extensive manual flow metering was conducted during the 1996 lagoon discharge. The 1996 discharge data are considered more reliable than the 1997 discharge data. Using the results of flow meterings at site #2 during the 1997 lagoon discharge an approximate hydrograph can be drawn (Figure 4.24). The volume of the lagoon discharge using this approximate hydrograph is the same order of magnitude as the lagoon discharge in 1996. Therefore, this approximate hydrograph is used in the following analysis.

4.2.2 Nitrogen

4.2.2.1 Total Nitrogen

Figures 4.25 and 4.26 present the levels of total nitrogen in the effluent from the Standard sewage lagoon for 1996 and 1997 respectively. The levels of total nitrogen for both years are of the similar order of magnitude. As will be seen below the various components of total nitrogen (NH_4, NO_2-N, NO_3-N, TKN) differed greatly. In 1996 NH_4 levels were an order of magnitude lower than those in 1997. Levels of TKN in 1997 were higher than those in 1996 while levels of NO_3-N dropped in 1997. The distribution of nitrogen between its various forms (NH_4, NO_2-N, NO_3-N, TKN etc.) depends on various factors (e.g. temperature, aquatic life).

The figures show that the sewage effluent flow causes a rise in total nitrogen of the creek at site #2. The contribution of the 1996 lagoon effluent on the total nitrogen in water leaving the Larsen East basin is summarised in Figure 4.27.

Contribution of the lagoon effluent is minimal (1.97%) with regard to total nitrogen of water leaving the basin.

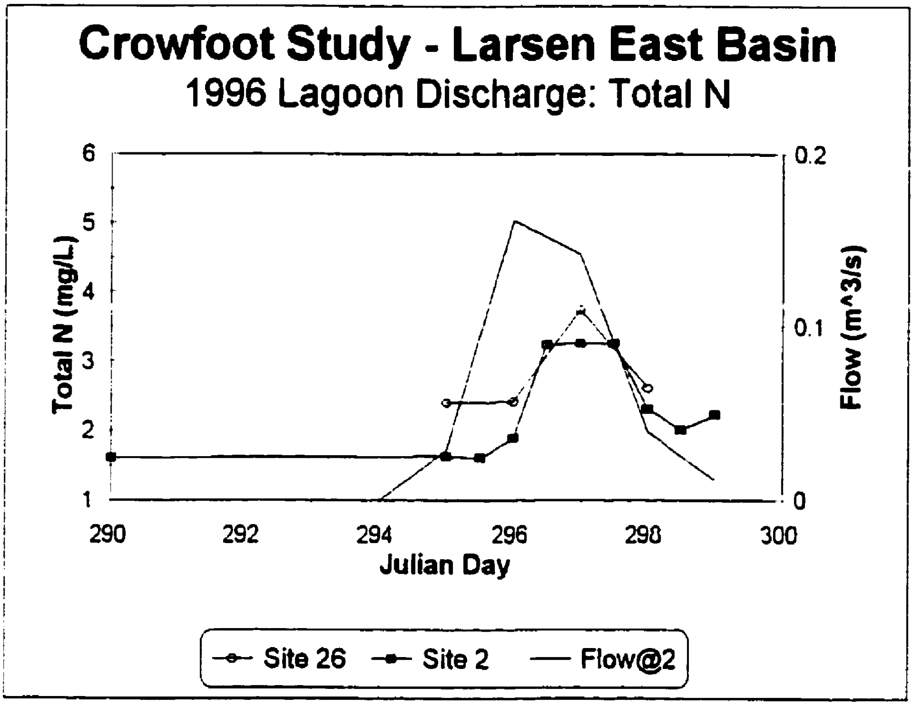

Figure 4.25 1996 Lagoon Effluent TN

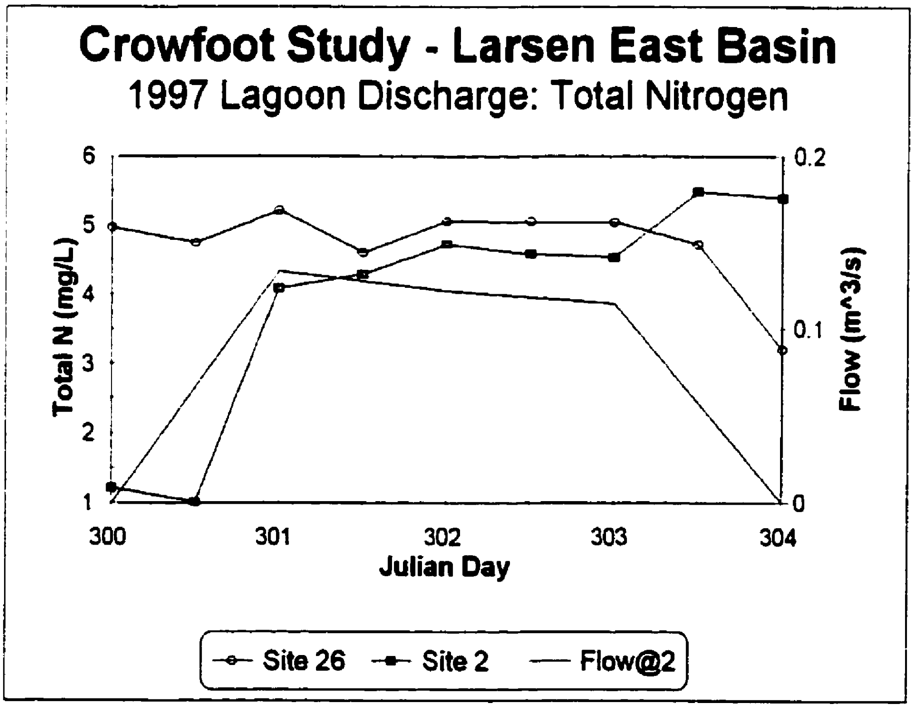

Figure 4.26 1997 Lagoon Effluent TN

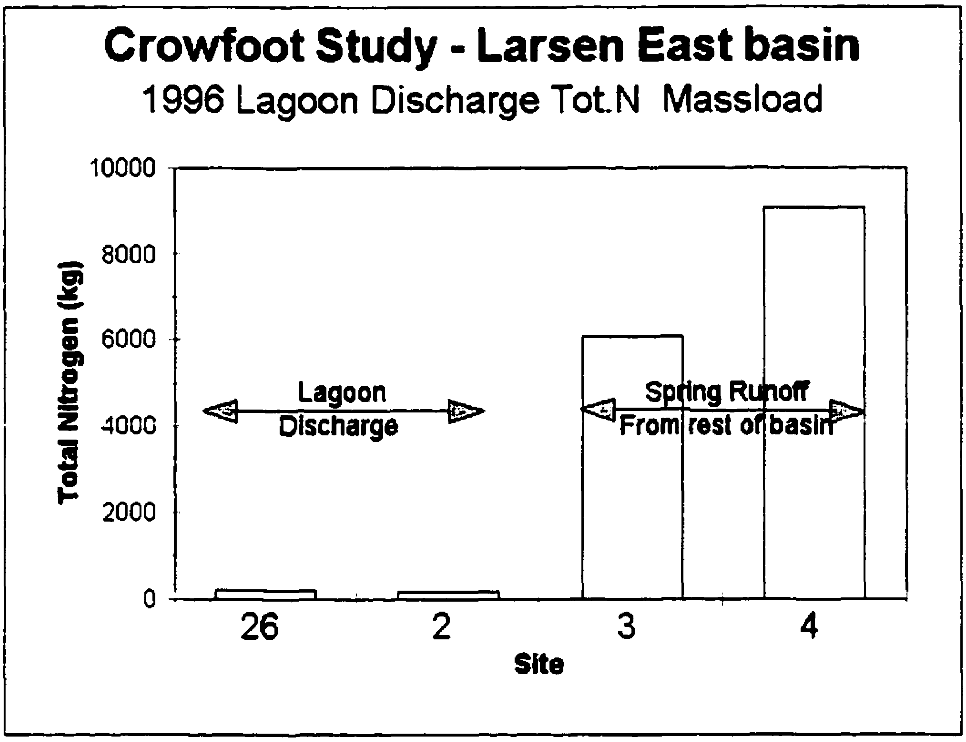

Figure 4.27 1996 Lagoon discharge contribution to 1997 Spring Runoff Total Nitrogen massload

Significant other sources of nitrogen exist within the Larsen East basin. Other sources of nitrogen within the Larsen East basin may have been: I) fall application of organic or inorganic fertilizer; ii) cattle wintering sites near the creek and iii) animal waste from cattle grazing close to or even in the creek.

4.2.2.2 Ammonium

Pommen (1983, in CCREM 1987) states that ammonia is often found in municipal wastewater discharges. Figures 4.28 and 4.29 present the levels of NH_4 in the lagoon effluent. Concentrations of NH_4 in 1996 and 1997 are different by an order of magnitude. The levels of NH_4 at site #2 are lower than those at site #26. This decrease may be due to conversion of ammonium to other forms of nitrogen or absorption of NH_4 by aquatic life between sites #26 and #2.

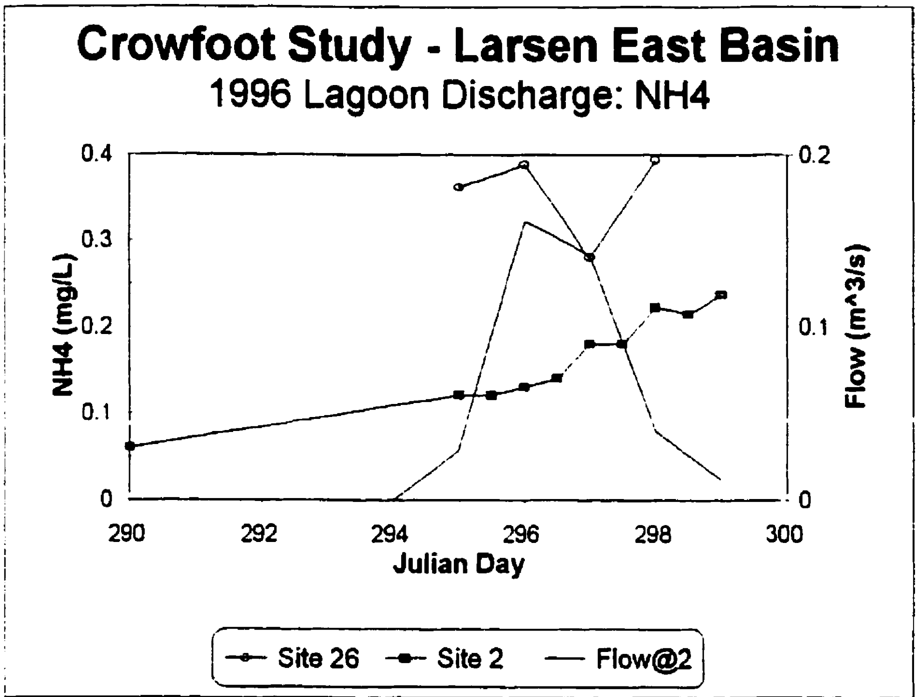

Figure 4.28 1996 Lagoon Effluent NH_4

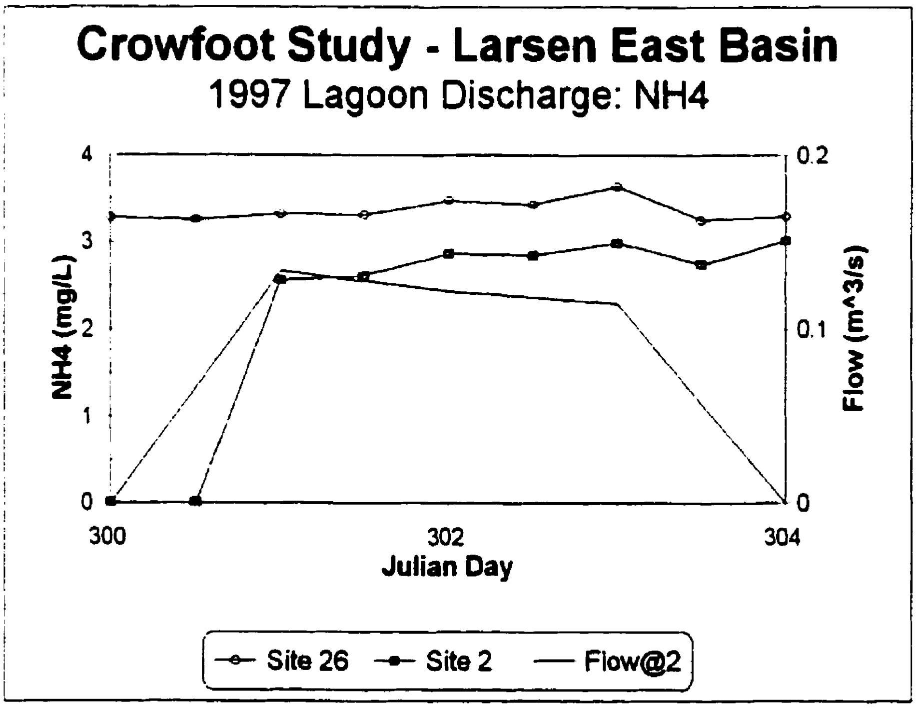

Figure 4.29 1997 Lagoon Effluent NH_4

4.2.2.3 Nitrate

The levels of NO_3-N in the 1996 and 1997 lagoon effluent can be seen in Figures 4.30 and 4.31.

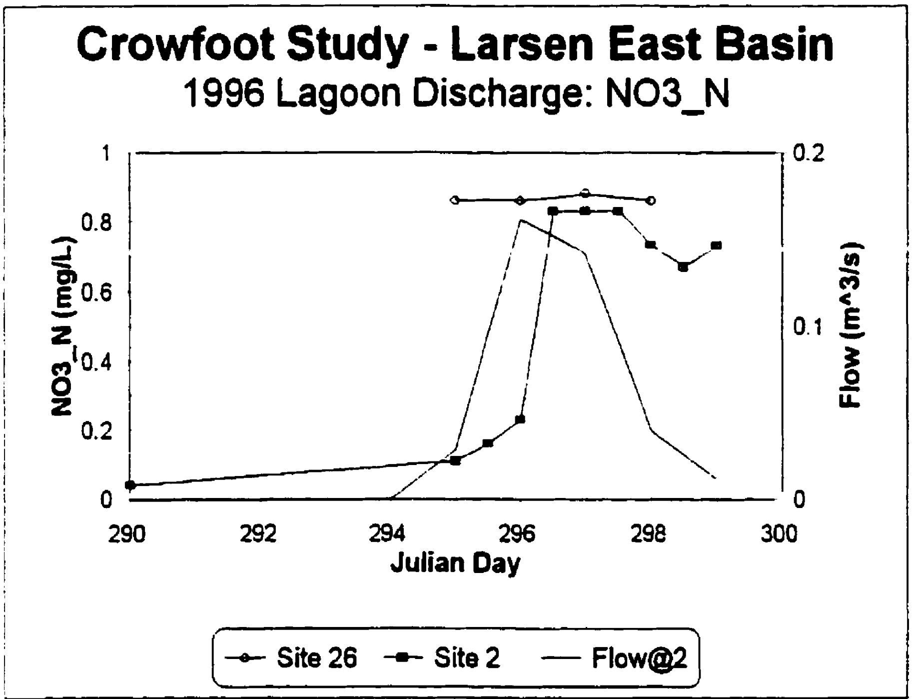

Figure 4.30 1996 Lagoon Effluent NO_3-N

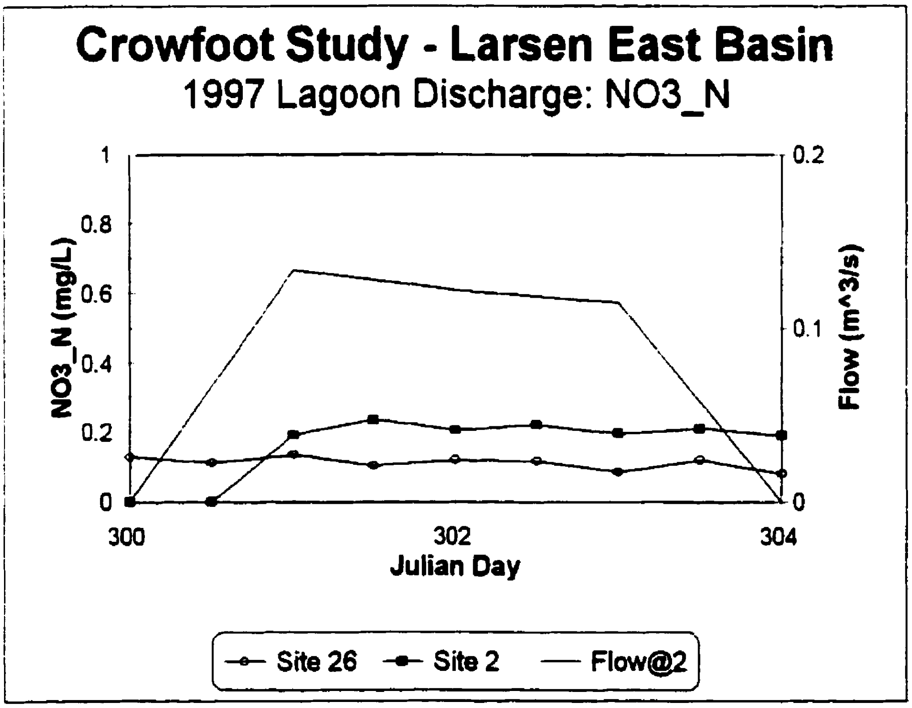

Figure 4.31 1997 Lagoon Effluent NO_3-N

USEPA (1976, in CCREM 1987) found that municipal wastewaters are significant anthropogenic point sources of nitrates. One can see that there is a time lag and/or absorption factor involved. High NO3-N levels from the lagoon discharge point (site #26) does not initially impact creek water quality at site #2. Levels of NO_3-N in 1996 and 1997 were different but of the same order of magnitude. It is expected that the nitrogen was in other forms of nitrogen.

4.2.2.4 Nitrite

McNeely and others (1979c) state that municipal sewage plant discharges may contain nitrites. Nitrites were found in the effluent from Standard's sewage lagoon (Appendices E and F). The Canadian Environmental Quality guideline for freshwater aquatic life of 0.019 mg/L was exceeded only once. On Julian day 297 in 1996 NO_2-N rose to 0.84 mg/L in the lagoon effluent. Nitrites are considered toxic to humans (Health Canada 1996) but, it is expected that the nitrites will oxidize to nitrates in the reservoirs. However, the resulting nitrates might contribute to some eutrophication of the Ducks Unlimited reservoirs.

4.2.2.5 Total Kjeldahl Nitrogen

The levels of TKN in the 1996 and 1997 lagoon effluent can be seen in Figures 4.32 and 4.33 respectively. It is worth noting that the TKN levels are substantially higher than NH_4 levels (Figures 4.28 and 4.29). This is expected as TKN is a measure of ammonia and organic N, and municipal sewage contains organic material. Prince and others (1993) found that the average concentration of TKN in effluent from 4S-2L sewage lagoons (same configuration as Standard's sewage lagoon) was 5.3 mg/L. As can be seen in Figures 4.32 and 4.33 the effluent from Standard's sewage lagoon has similar TKN concentrations.

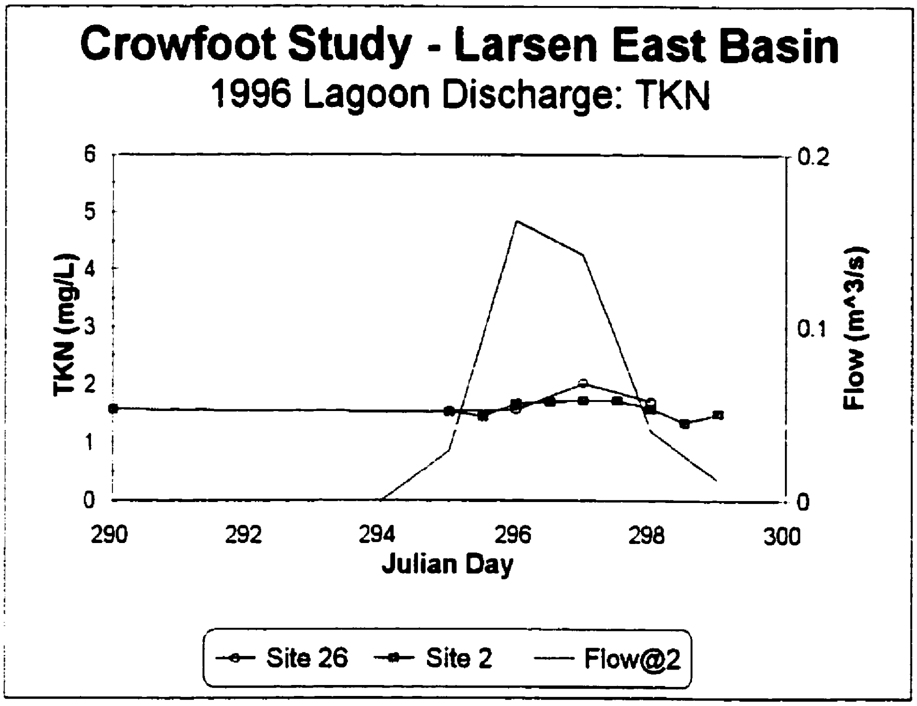

Figure 4.32 1996 Lagoon Effluent TKN

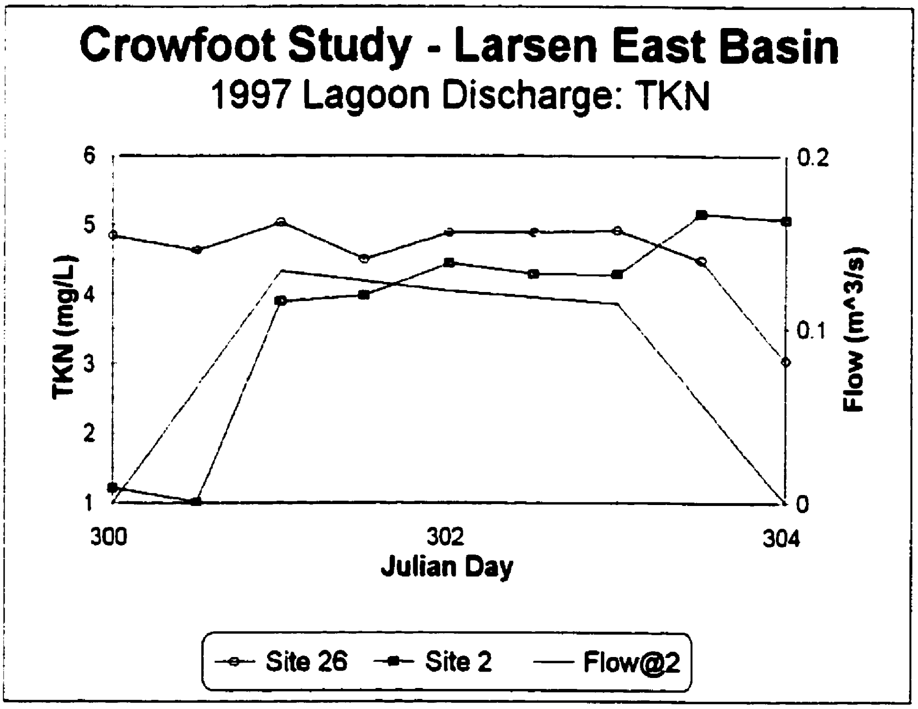

Figure 4.33 1997 Lagoon Effluent TKN

4.2.3 Phosphorus

Figures 4.34 and 4.35 present the levels of PO4 in the 1996 and 1997 lagoon discharges respectively. Total phosphorus levels are presented in Figures 4.36 and 4.37 for the 1996 and 1997 lagoon discharges. Phosphorus levels are slightly higher in the 1997 lagoon discharge than the 1996 lagoon discharge but the phosphorus values are of similar orders of magnitude. As with nitrogen, there is a time lag between the lagoon effluent and the concentration at site #2 rising. It is likely that during this time aquatic life between site #26 and #2 were absorbing the phosphorus and/or the phosphorus was being bound with sediment in the streambed. It can also be seen that the TP primarily consists of PO_4 in the 1996 and 1997 lagoon discharge. This is expected as the source of the phosphorus is the lagoon effluent and not erosion. If it were erosion then there would be a large discrepancy between TP and PO_4 indicating particulate phosphorus due to erosion.

As with total nitrogen it can be seen in Figure 4.38 that the lagoon effluent accounts for a minor part (8.86%) of the TP massload leaving the basin in the spring runoff. There is more TP by mass at site #3 than that at site #4 for the 1997 spring runoff. It is expected that this is due to degradation of phosphorus in the aquatic system and/or binding of phosphorus with sediment.

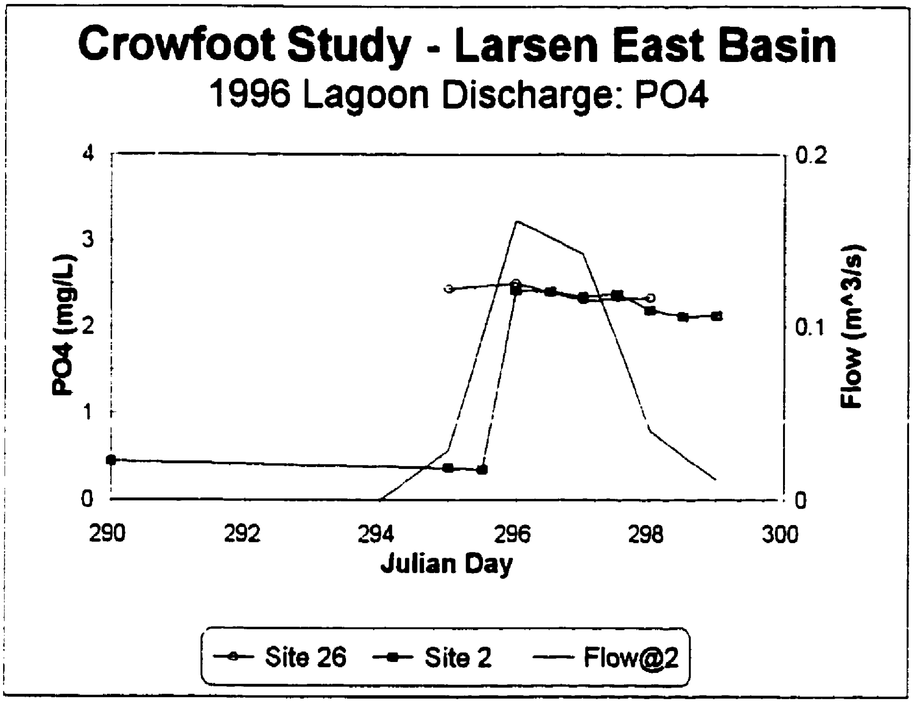

Figure 4.34 1996 Lagoon Effluent PO_4

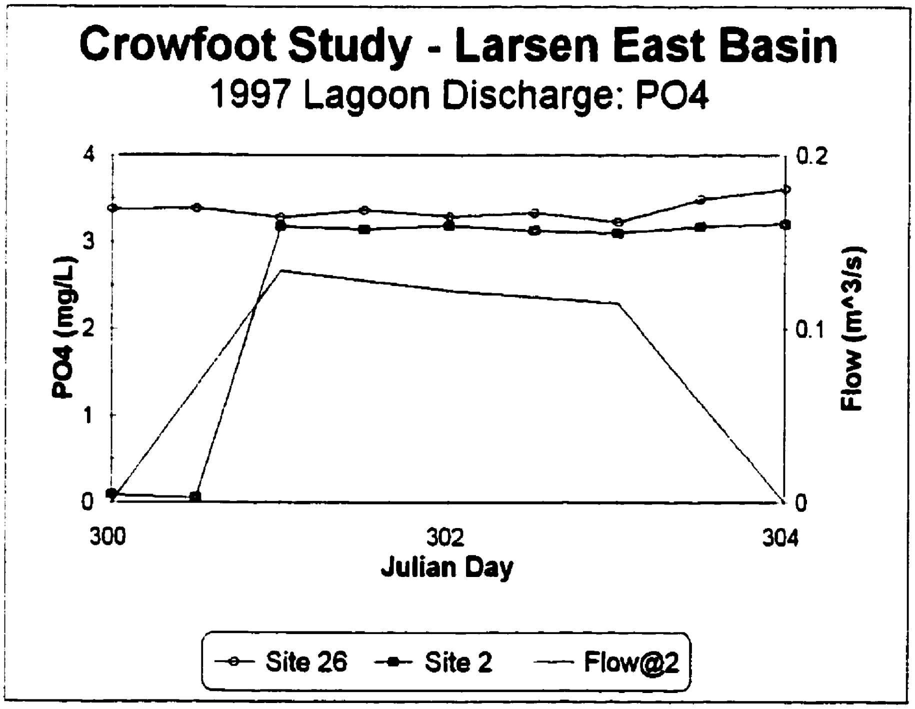

Figure 4.35 1997 Lagoon Effluent PO_4

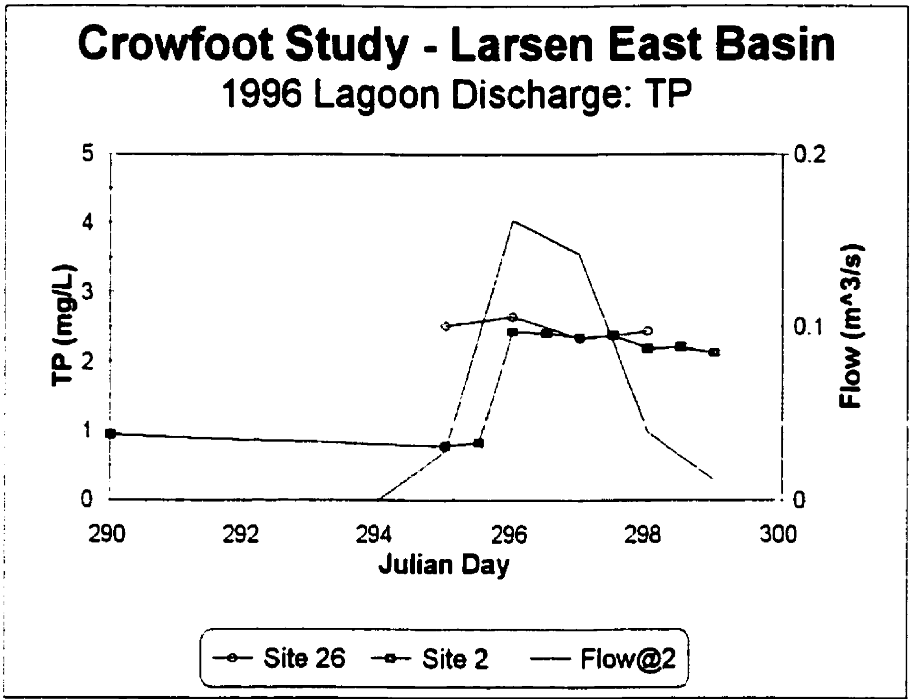

Figure 4.36 1996 Lagoon Effluent TP

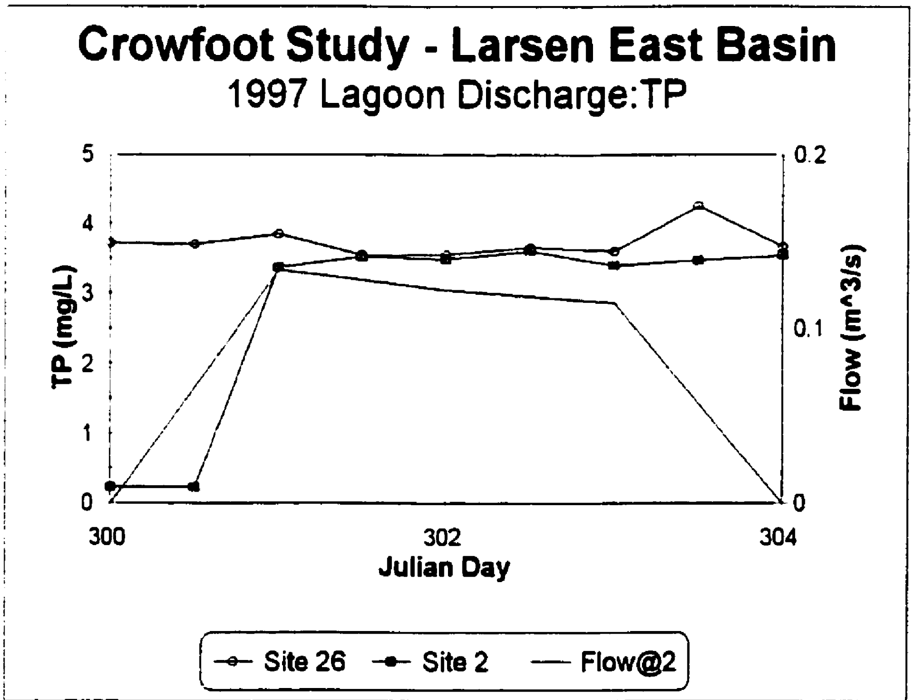

Figure 4.37 1997 Lagoon Effluent TP

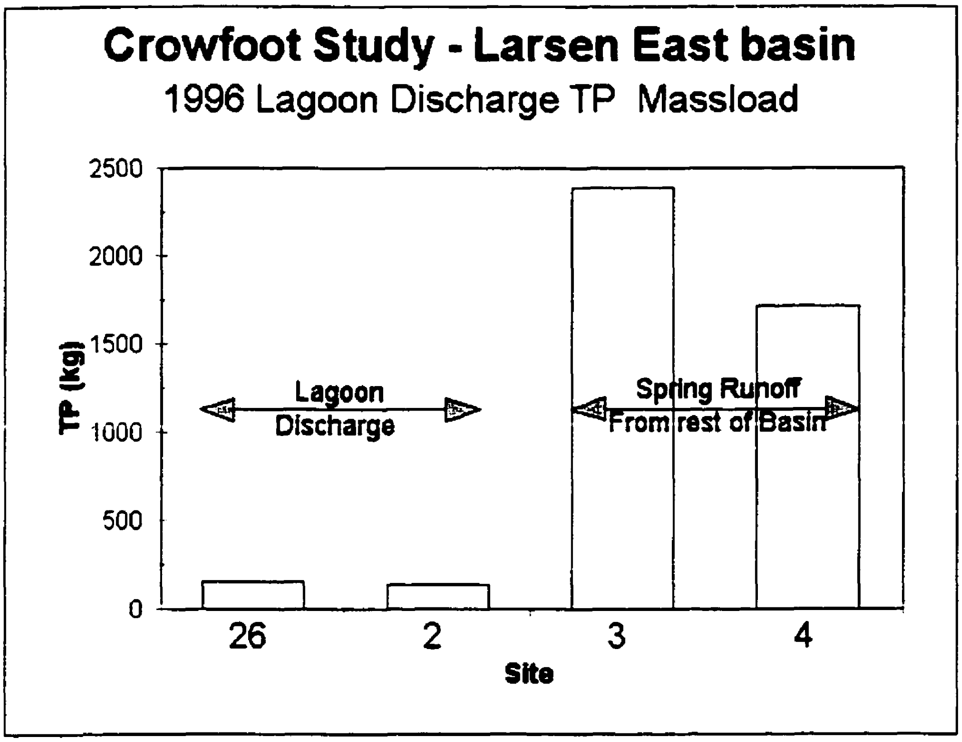

Figure 4.38 1996 Lagoon Discharge contribution to 1997 Spring Runoff Total Phosphorus massload

4.2.4 Total Dissolved Solids

As can be seen in Figure 4.39 and 4.40 the lagoon effluent is low in TDS compared to the creek water at site #2 before the effluent discharge. Thus, the sewage lagoon effluent dilutes the creek water. This actually improves creek water. Similar to the other parameters discussed, the lagoon effluent does not contribute the majority of the TDS mass leaving the basin (Figure 4.41) as it accounts for only 13.06% of TDS leaving the basin during spring runoff. The amount of TDS, by mass, during the 1997 spring runoff passing site #3 was 40% more than that observed at site #4. No explanation could be found for this reduction in TDS massload.

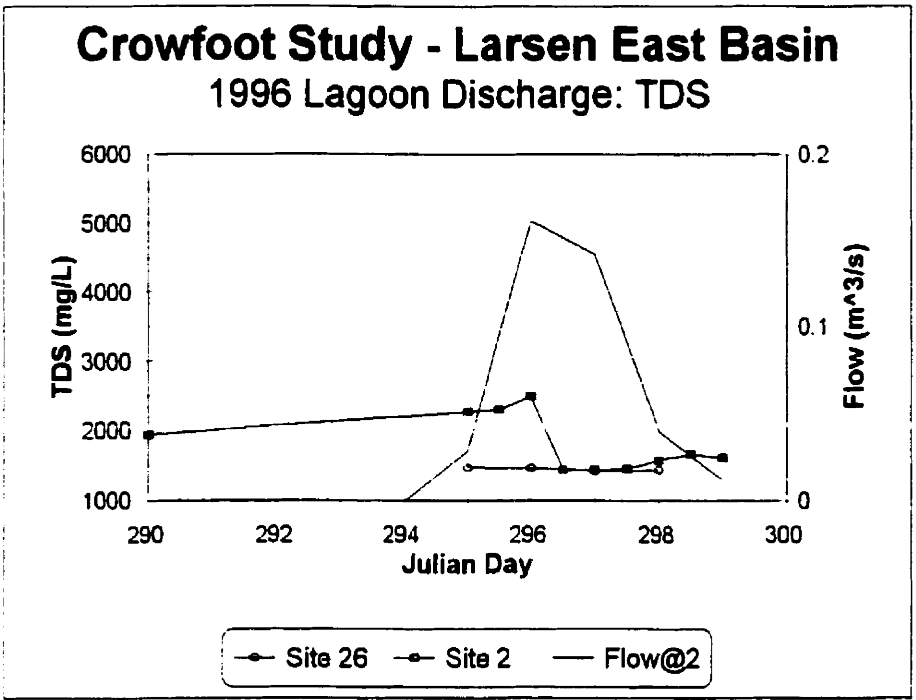

Figure 4.39 1996 Lagoon Effluent TDS

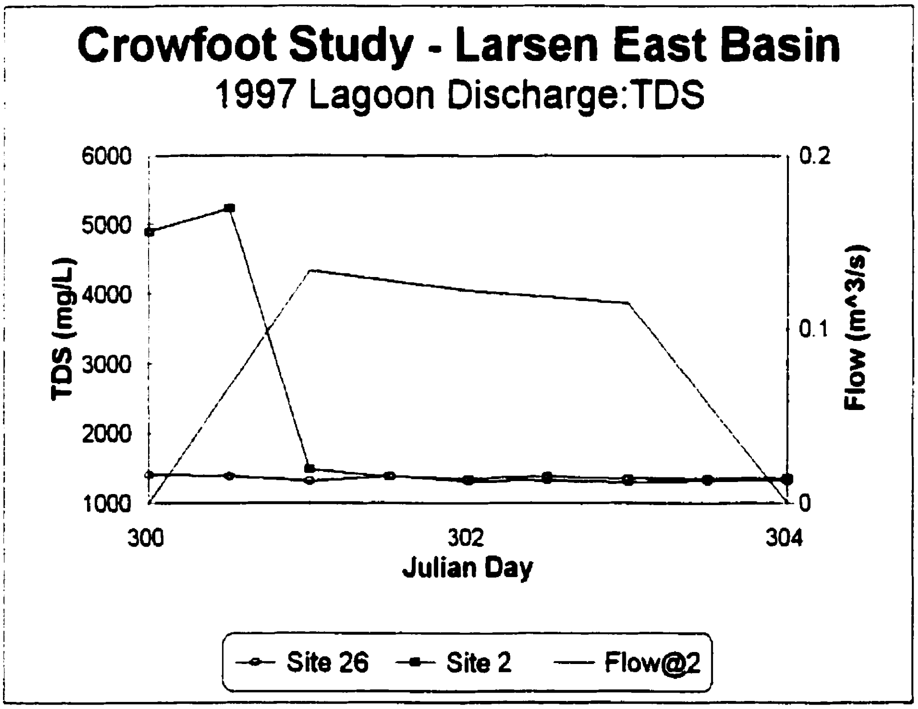

Figure 4.40 1997 Lagoon Effluent TDS

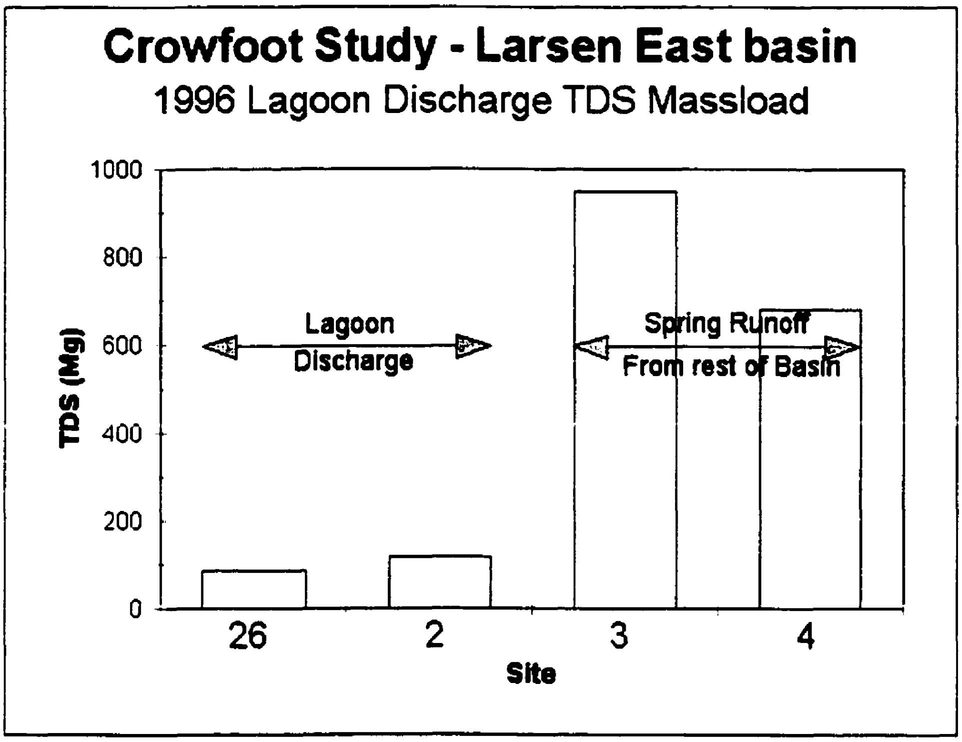

Figure 4.41 1996 Lagoon Discharge contribution to 1997 Spring Runoff TDS massload

4.2.5 Total Suspended Solids

One of the functions of a sewage lagoon is to settle out the solids, therefore it comes as no surprise that the sewage lagoon effluent is low with regard to TSS. Prince and others (1993) found that the average concentration of TSS in effluent from sewage lagoons similar to Standard's was 20.4 mg/L. As can be seen in Figures 4.42 and 4.43 the TSS concentrations in the effluent ranged from 1.2 to 24.6 mg/L, with one exception. On Julian day 303 in 1997, the TSS value for the sewage lagoon effluent rose to 162 mg/L. It is suggested that as this occurred near the end of the effluent release there may have been some scouring along the bottom of the lagoon resulting in this high TSS value.

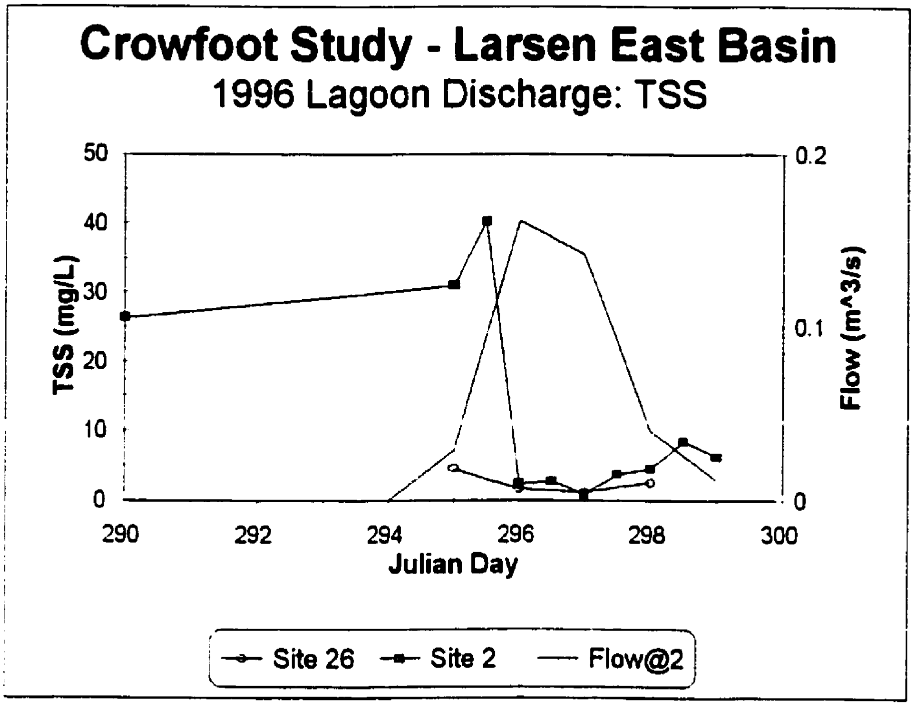

Figure 4.42 1996 Lagoon Effluent TSS

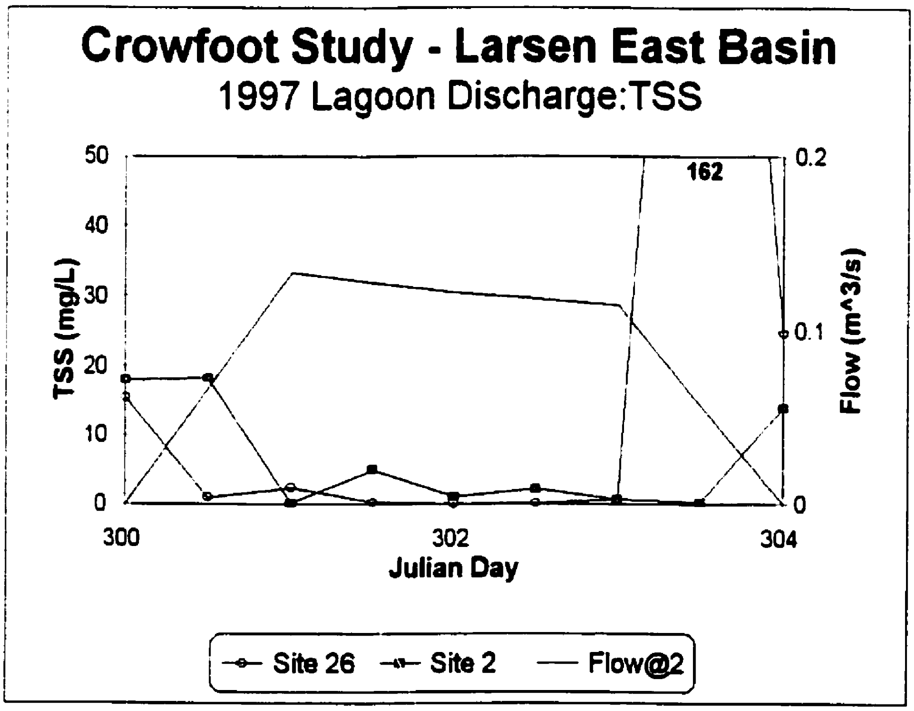

Figure 4.43 1997 Lagoon Effluent TSS

The TSS massload (Figure 4.44) for the 1996 lagoon discharge is minimal (0.05%) when compared with that at the basin outflow (site #4) during the 1997 spring runoff. Note that the 1996 lagoon effluent is stored in the Duck Unlimited reservoirs until the 1997 spring runoff event.

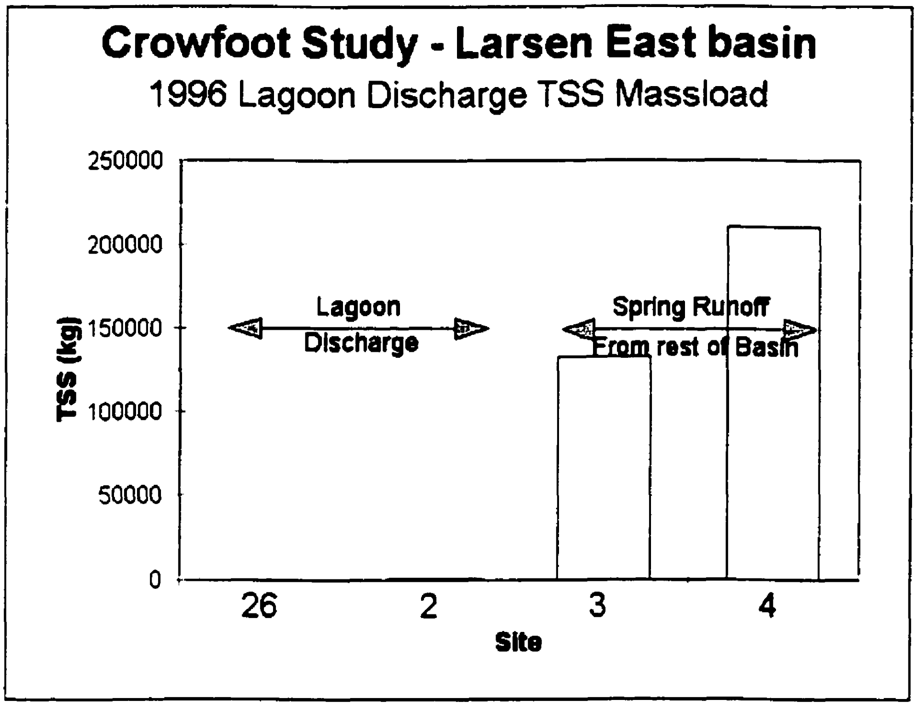

Figure 4.44 1996 Lagoon Discharge contribution to 1997 Spring Runoff TSS massload

4.2.6 Fecal Coliform

The fecal coliform levels in the lagoon discharge (Figure 4.45 and 4.46) are low (mean = 24, standard deviation = 23). They violate the drinking water guideline of 0/100mL but do not violate the irrigation guideline of 100/100mL. When compared with sampling at sites #4, #15 and #20 (mean = 490, standard deviation = 860) during the 1996 and 1997 irrigation seasons (Figures 4.21 and 4.22 respectively) the lagoon discharges were substantially lower in fecal coliform. Therefore, it may be stated that the sewage lagoon effluent is not a major source of fecal coliform in the Larsen East basin.

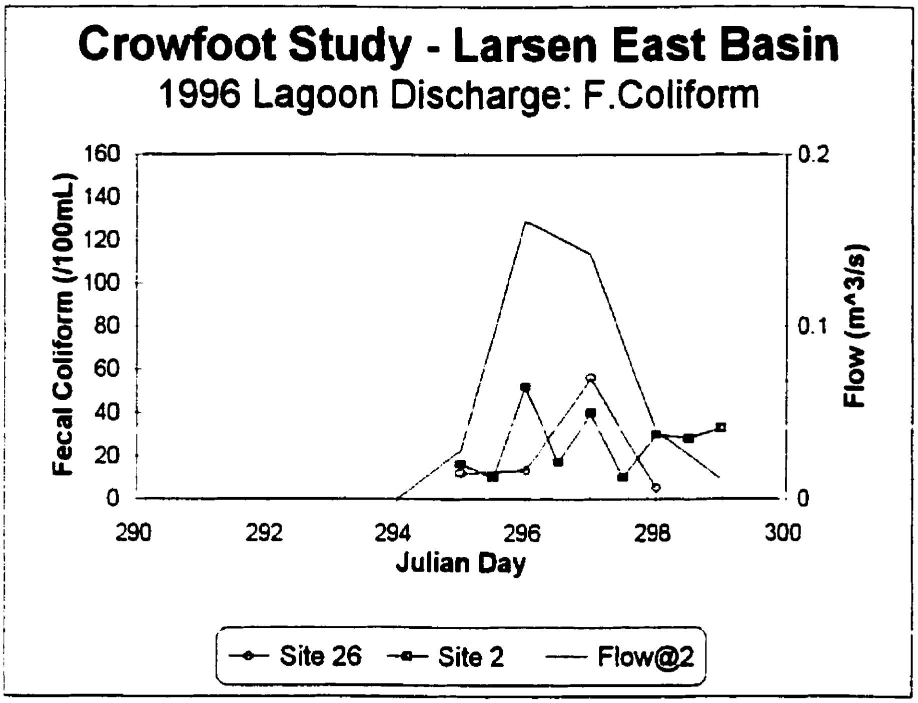

Figure 4.45 1996 Lagoon Effluent Fecal Coliform

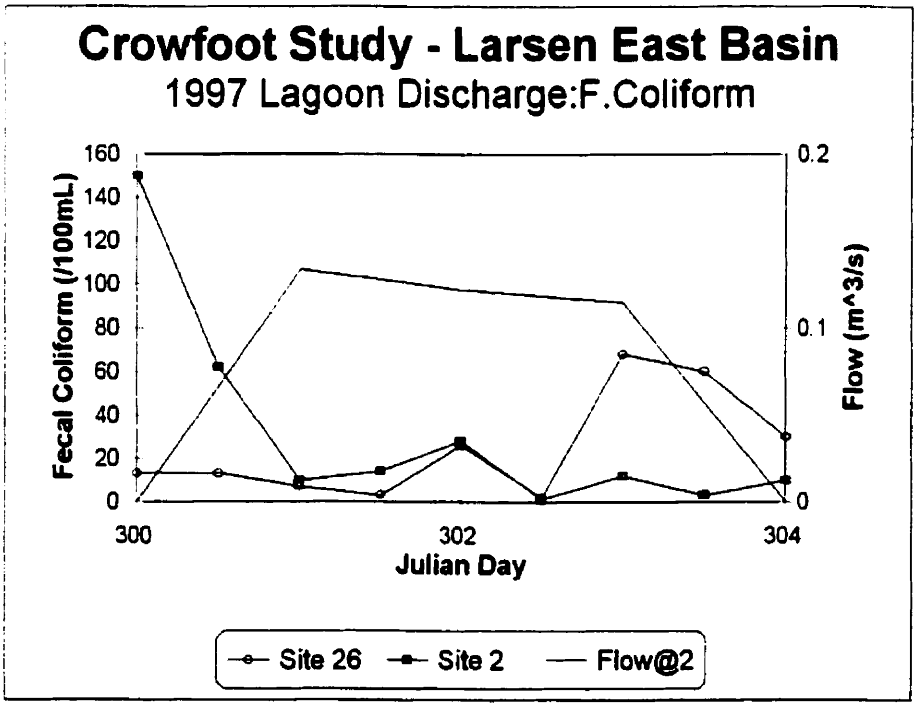

Figure 4.46 1997 Lagoon Effluent Fecal Coliform

4.2.7 SUMMARY: IMPACT OF SEWAGE LAGOON EFFLUENT ON WATER QUALITY OF CROWFOOT CREEK

The village of Standard treats its municipal wastewater in a sewage lagoon. Effluent from the lagoon is released in the late fall of each year into the creek about 3 km upstream of the Ducks Unlimited reservoirs. These reservoirs only experience outflow in the spring, thus the municipal effluent "winter" in the reservoirs. Analysis was based on I) the lagoon discharges in 1996 and 1997 ; and ii) flow downstream of the reservoirs (site #3) and the basin outflow (site #4) in the 1997 spring runoff.

Levels of NH_4, NO_3-N and TKN at Site #2, located 1 km downstream of the sewage lagoon outflow (site #26), are low for the first day of the effluent discharge and then the levels rise dramatically. It is likely that the levels are low initially due to I) adsorption of nutrients by aquatic life between sites #26 and #2 and/or ii) conversion to other forms of nitrogen. Presence of nitrogen as nitrite was detected in the effluent. The concentration of nitrogen as nitrite exceeded the Canadian Environmental Quality guideline for freshwater aquatic life by about 4300%. Nitrites are considered toxic to humans. The predominant form of nitrogen was organic nitrogen as anticipated since municipal sewage is organic waste.

As with nitrogen the concentration of ortho-phosphate and total phosphorus are low the first two days of the effluent discharge, after which time the concentrations rose. It is likely that there is adsorption of phosphorus during the initial two days. The total phosphorus primarily consisted of dissolved phosphorus ions from the effluent rather than erosion.

Total suspended solids values in the 1996 and 1997 lagoon effluent were less than 25 mg/L with one exception. The levels of total dissolved solids of the lagoon effluent (site #26) were substantially lower than those in the creek water at site #2. As a result the effluent actually dilutes these contaminants in the creek water at site #2 and improves the creek water quality with respect to these parameters.

Fecal coliform values of the lagoon effluent are lower than those observed at sites #4, #15 and #20 during the 1996 and 1997 irrigation seasons. It may be stated, therefore, that the sewage lagoon effluent is not a major source of fecal coliform in the Larsen East basin.

Contribution of the sewage lagoon to massload of total nitrogen, total phosphorus, total dissolved solids and total suspended solids leaving the basin in the spring runoff at site #4 were 1.97%, 8.86%, 13.06% and 0.05% respectively. These percentages indicate that the lagoon effluent does not account for the majority of the total nitrogen, total phosphorus, total dissolved solids and total suspended solids contamination within the Larsen East basin during spring runoff. The amount of sewage lagoon effluent, in terms of water volume, is substantially less than the flow during spring runoff. This low water volume resulted in the low massload from the sewage lagoon when compared with spring runoff.

4.3 QUALITY CONTROL

To check the reliability of the water quality data two quality control measures were undertaken. It was decided to conduct a two tailed Student's t-test for paired samples to determine the difference in the means of the original sample and the duplicates/splits. The t-test was carried out using Quattro Pro 7's @ttest function. The raw data and results can be found in Appendix B and Table 4.3 below summarizes the results. As can be seen in Table 4.3 all duplicates/splits (except TP in 1996) were 95% significant (i.e..t-test values above 0.05). On the basis of these results it can be said that the laboratory was able to replicate results for the same water sample. The only weakness in the procedure was that the laboratory was aware which samples were duplicates/splits. The laboratory that analysed the samples is a provincial laboratory that calibrates its equipment. However, for future sampling it is recommended that the laboratory be kept "blind" to the duplicates/splits. The results of a one time blind comparison with an independent laboratory were compared using a two tailed Student t-test for paired samples. Results of the t-test for NO3-N and TP were 0.95 and 0.046 respectively. The low significance (<0.95%) for TP is of concern.

Table 4.3 Results of t-test on the Duplicates and Splits

Year	Parameter									
	NO_2-N	NO_3-N	TKN	NH_4	Total N	PO_4	TP	TDS	TSS	F.Coli
1996	Note#1	0.45	0.41	0.4	0.38	0.25	***0.03***	0.3	0.9	Note#2
1997	0.34	0.44	0.65	0.3	0.62	0.09	0.61	0.9	0.5	0.567

Note#1: As the concentration in all duplicates/splits was 0.00 mg/L the T-test returned an error.

Note#2: There were insufficient duplicates of coliform samples in 1996 to perform a t-test.

As mentioned in the methodology section double distilled water was filled into a sample bottle in the field laboratory at Strathmore and sent for analysis along with the other samples. Such a sample was called a "blank". These samples were used as a further check on the laboratories analysis methods along with experimental error in pouring off samples at the field laboratory in Strathmore. Table 4.4 presents the comparison between the maximum concentration for parameters in the blanks with the average concentration for the same parameters from sites 2, 3, 4, 15, 20 and 26 for 1996 and 1997. As can be seen in Table 4.4 the concentration of the blank maximum value for various parameters is below the average concentration of the field samples. The only exception was the blank NO2-N values whose maximum concentration was 0.05 mg/L while the average of the field samples in 1997 was 0.02 mg/L. This comparison of blank maximums to field averages was conducted to determine the worst case scenario. Despite this, the detection of parameters in the blanks (double distilled water) is of concern. It would be of interest to isolate at what stage in the process the double distilled water or the measuring equipment becomes contaminated.

Table 4.4 Comparison of Blanks and Other Samples

	NO_2-N mg/L	NO_3-N mg/L	TKN mg/L	NH_4 mg/L	Tot.N mg/L	PO_4 mg/L	TP mg/L	TDS mg/L	TSS mg/L
% of Blank sample with non-zero conc.	2.1%	2.1%	4.2%	10.4%	8.3%	4.2%	6.3%	100%	2.1%
Avg. of Blank Samples	0.05	0.04	0.19	0.02	0.10	0.09	0.01	8.09	0.08
Max. in Blank Samples	0.05	0.04	0.3	0.03	0.3	0.26	0.02	28.18	0.08
Avg. for 1996 Field Samples	0.07	0.17	0.76	0.09	1	0.48	0.66	772	12.51
Avg. for 1997 Field Samples	0.02	0.37	1.47	0.37	1.86	0.59	0.71	600	41.28

5.0 CONCLUSIONS

5.1 SUMMARY OF PROJECT

Crowfoot Creek is a tributary of the Bow River, a major river in the Canadian province of Alberta. Various studies have found the reach of the Bow River, where the Crowfoot Creek discharges, polluted with respect to nutrients and coliform bacteria (Bow River Water Quality Task Force 1991, Madawaska Consulting 1995). The Irrigation Branch of Alberta Agriculture, Food and Rural Development began an in-depth water quality study of the Crowfoot Creek watershed in 1996. McGill University was a partner in the study and part of its contribution to the study is this thesis focussing on the Larsen East basin of the Crowfoot Creek watershed. The objectives of the thesis were to:

- determine the impact on creek water quality by irrigation tailwaters;
- ascertain the effect of discharging effluent from the Village of Standard's sewage lagoon on creek water quality;
- propose explanations for the fluctuations in: nitrogen as nitrite, nitrogen as nitrate, ammonium, total Kjeldahl nitrogen, total nitrogen, dissolved phosphate, total phosphorus, total dissolved solids, total suspended solids and fecal coliform; and
- identify sources of contamination with regard to the parameters of interest.

Water quality, precipitation and flow data were collected from Jul.-Oct. 1996 and Feb.-Oct. 1997. Data from Jul.-Sept. 1996 and May-Sept. 1997 were used to study the impacts by the irrigation tailwater at site #15 on creek water leaving the basin at site #4. Data from the lagoon discharge, in Oct. 1996, Oct.- Nov. 1997, along with spring runoff data, Feb. - Apr. 1997, were analysed to determine the effect of effluent from the Village of Standard's sewage lagoon on creek water quality.

5.2 CONCLUSIONS ON IRRIGATION TAILWATER IMPACTS ON CREEK WATER QUALITY

From the 1996 and 1997 irrigation season flow records, it was apparent that the irrigation tailwater at site #15 accounted for more than 55% of the water leaving the Larsen East basin. Therefore, irrigation tailwater may impact creek water quality in the basin.

In the early part of the 1997 irrigation season several high values for various parameters were observed at the irrigation tailwater site (site #15). It is suggested that over the fall, winter and spring runoff contaminants were deposited into the irrigation canals. In the early part of an irrigation season these contaminants are being flushed out by the irrigation water, thus leading to high parameter values in the tailwater.

The levels of total nitrogen in the irrigation tailwater and the basin outflow were both below the Alberta Ambient Surface Water Quality guideline except for the early part of the 1997 irrigation season. Total nitrogen contamination is not an issue within the Larsen East basin. In 1996 dissolved phosphate values of the irrigation tailwater rose during a precipitation event. Furthermore, there was substantial additional phosphate at the basin outflow from other sources. Phosphate content is usually the result of ambient soil erosion. However, in 1997 the phosphorus as phosphate values of the basin outflow was essentially the same as the irrigation tailwater. This indicates that a substantial amount of the phosphate contamination came from the irrigation tailwater. The Alberta Ambient Surface Water Quality guideline for total phosphorus was exceeded almost consistently by the irrigation tailwater and the basin outflow. Potential sources of organic pollution may have be cattle access to the creek, runoff from grazing areas or runoff from fields on which organic fertilizer was applied.

The values of total dissolved solids in the irrigation tailwater and the basin outflow were not above the Canadian Environmental Quality guidelines except in the early part of the 1997 irrigation season. Potential causes of the high values are:

I) flushing out of contaminants deposited during fall, winter and spring runoff into the irrigation canals; and/or ii) groundwater seepage into the creek and irrigation canals. As the intended use of this water is irrigation, the exceeding of the irrigation guideline in the early part of the 1997 irrigation season is of concern.

Levels of total suspended solids (TSS) were quite low for both the basin outflow and irrigation outflow in 1996. With the exception of the early part of the 1997 irrigation season, the TSS values at the basin outflow and the irrigation tailwater were also low. In the earlier part of the 1997 irrigation season the high levels of TSS in the irrigation tailwater indicate that: I) erosion is occurring in the irrigation canals; iii) irrigation canal banks are being eroded; and/or iii) runoff from eroded areas is entering the irrigation canal. Grazing in areas upstream of the basin outflow but downstream of the irrigation tailwater is expected to contribute to runoff and erosion raising TSS values at the basin outflow.

In 1996 high fecal coliform levels in the irrigation tailwater did not occur except after a runoff producing precipitation event. In 1997, however, frequent high levels of fecal coliform were observed at the irrigation tailwater suggesting contamination sources upstream. Levels of fecal coliform at the basin outflow were substantially higher than those at the irrigation tailwater suggesting contamination sources downstream of the tailwater, but upstream of the basin outflow. A probable source is cattle grazing with access to the creek upstream of the basin outflow.

There is substantial grazing along the creek with cattle having access to the creek. It is likely that this grazing causes compaction of the soil and reduces plant cover, especially riparian vegetation, leading to conditions susceptible to erosion. In the early part of the 1997 irrigation season a farm truck's fertilizer tank burst spilling fertilizer near the creek upstream of the irrigation tailwater discharge. As the flow at that point in the creek is insignificant the impact on the nitrogen and phosphorus values at the basin outflow is considered to be small but peaks were noted at site #20 following larger rainfall events.

5.3 CONCLUSIONS ON IMPACT OF SEWAGE LAGOON EFFLUENT ON WATER QUALITY OF CROWFOOT CREEK

The levels of total nitrogen and total phosphorus of the lagoon effluent exceed Alberta Ambient Surface Water Quality guidelines by about 420% and 8400% respectively. As there are no water users between the lagoon and the Ducks Unlimited reservoirs, where the effluent is stored over the winter, the risk to human health is considered minimal. It is expected that some nitrogen and phosphorus is adsorbed by the aquatic life between the lagoon and the reservoirs.

Effluent from the lagoon is quite low in total dissolved solids and total suspended solids. As a result, the lagoon effluent dilutes the water in the creek improving the creek water quality with regard to total dissolved solids. The total suspended solids concentration in the lagoon effluent was lower than the average for effluent from similar lagoons.

Similarly, fecal coliform values were low in the lagoon effluent, ranging from 5-56 counts/100mL. As creek and irrigation water frequently exceeded the irrigation guideline of 100/100mL for fecal coliform the sewage lagoon effluent is not a major source of fecal coliform contamination within the Larsen East basin.

Using daily water quality values and daily flow massloads of various parameters were computed for: I) the lagoon effluent; and ii) spring runoff immediately downstream of the reservoirs and at the basin outflow. It was found that the contribution of the lagoon effluent to total nitrogen, total phosphorus, total dissolved solids and total suspended solids leaving the basin during spring runoff were 1.97%, 8.86%, 13.06% and 0.05%. Therefore, it may be stated that the contribution by the lagoon was minimal to insignificant. Substantial other sources of contamination exist within the Larsen East basin. Cattle wintering sites, with a high density of cattle and as a result animal waste, are considered a likely source of contamination. Along with this, it is likely that spring runoff flushes accumulated contaminants out of the basin.

6.0 RECOMMENDATIONS

Based on the findings of this study some recommendations can be made on future work and reductions of contamination impacting creek water quality within the Larsen East basin. These recommendations are:

1. Organic nitrogen is the primary form of nitrogen found in the water of the Larsen East basin. Although nitrogen contamination is not a problem for the latter half of the irrigation season it may be beneficial to locate sources of organic nitrogen (grazing, wintering cattle, runoff of organic fertilizer applications etc.). If knowledge of such sources and their impacts is made known to farmers within the basin, they may voluntarily find ways to minimize contamination.
2. Particulate phosphorus is the primary form of phosphorus observed. The source of particulate phosphorus is erosion of streambanks, streambeds and runoff from eroded areas. Efforts to locate erosion prone areas and reduce erosion would improve water quality.
3. Levels of total dissolved solids in the irrigation tailwater were above the irrigation guideline (by about 9.5 times) in the early part of the 1997 irrigation season. As water in the irrigation canals is meant for irrigation the exceeding of the guideline is of concern. Further work to locate and reduce total dissolved solids in the irrigation water is needed.
4. There is fecal coliform contamination upstream of the irrigation tailwater outlet. As the irrigation water frequently exceeded the irrigation guideline, potential sources should be located and an effort made to bring irrigation water quality within irrigation guidelines. Perhaps with coliform and phosphorus in mind, structures should be maintained so as to eliminate surface runoff from entering the canals.
5. Substantial grazing along the creek takes place with cattle having access to the creek. It is expected that this grazing causes

compaction of the soil and a reduction of plant cover, especially riparian vegetation. Consequently, erosion highly impacts water quality in the creek. The runoff carries animal wastes into the creek. This study only suggests that such grazing may be impacting creek water quality. Additional work focussing on this topic may recommend certain measures be taken so that livestock agriculture may be carried on in the basin while maintaining good creek water quality.

6. To add to the above, it would be beneficial to protect and encourage riparian vegetation. Adequate riparian vegetation could act as a buffer filter strip reducing the amount of contaminants entering the creek.
7. There are cattle wintering sites located adjacent to the creek within the basin. It is expected that these sites impact creek water quality during spring runoff. Further work on the location of such sites, their impact on water quality and remedial actions would provide information on how to operate these sites in a manner so as to minimize creek contamination.
8. A study on the Ducks Unlimited reservoirs and how to maintain them in order to improve water quality may also prove beneficial in improving creek water quality.

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APPENDIX A: Water Quality Guidelines

Guideline		Parameter				
		N (mg/L)	P (mg/L)	TDS (mg/L)	TSS (mg/L)	Fecal Coliform (/100mL)
Canadian Environmental Quality (Environment Canada 1996)	Drinking Water	10.0 (NO_3-N), 1.0 (NO_2-N)		<=500		0
	Freshwater Aquatic Life	0.06 (NO_2)				
	Irrigation			500-3500		100
	Livestock Watering	100.0 (NO_3+ NO_2), 10.0 (NO_2)		3000		
Alberta Ambient Surface Water Quality (Alberta Environmental Protection 1997)		1.0[1]	0.15[2]		See note #1 below.	See note #2 below.

Note#1: Not to be increased by more than 10 mg/L over background value.

Note#2: With regard to Coliform the Alberta Ambient Surface Water Quality Guidelines (Alberta Environmental Protection 1997) states,

- In waters to be withdrawn for treatment and distribution as potable supply or used for outdoor recreation other than direct contact, at least 90% of the samples (not less than 5 samples in any consecutive 30 day period) should have a total coliform count of less than 5000 organisms per 100 mL and a fecal coliform count of less than 1000 organisms per 100 mL.
- In waters used for direct contact recreation or vegetable crop irrigation, the geometric mean of not less than 5 samples taken over not more than a 30 day period should not exceed 1000 organisms per 100 mL total coliform, nor 200 organisms per 100 mL fecal coliform nor exceed these numbers in more than 20% of the sample examined during any month, nor exceed 2400 organisms per 100 mL total coliform on any day.

[1] Total inorganic and organic nitrogen

[2] Total inorganic and organic Phosphorus as PO_4

APPENDIX B: Quality Control

A) FOR 1996

1) All parameters except Fecal Coliforms

Sample A (Original)

Site	Date	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L
2	10/16/96	0.00	0.04	1.57	0.07	1.61	0.44	0.94	1944	26.3
4	08/21/96	0.00	0.14	0.39	0.07	0.53	0.13	0.15	302	8.6
4	10/30/96	0.00	0.00	0.38	0.00	0.38	0.00	0.05	1699	13.5
15	08/28/96	0.00	0.00	0.24	0.07	0.24	0.00	0.18	214	0.7
20	07/24/96	0.00	0.00	1.17	0.04	1.17	0.14	0.43	673	3.6
20	09/20/96	0.00	0.00	0.00	0.00	0.00	0.00	0.29	275	27.5

Sample B (Duplicates/Splits)

Site	Date	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L
2	10/16/96	0.00	0.05	1.40	0.06	1.45	0.36	0.85	1914	24.6
4	08/21/96	0.00	0.07	0.21	0.05	0.28	0.10	0.10	293	11.9
4	10/30/96	0.00	0.00	0.37	0.00	0.37	0.00	0.02	1692	13.4
15	08/28/96	0.00	0.00	0.33	0.07	0.33	0.00	0.15	220	1.6
20	07/24/96	0.00	0.00	1.19	0.05	1.19	0.15	0.42	671	5.1
20	09/20/96	0.00	0.00	0.00	0.00	0.00	0.00	0.26	280	22.4

Results of 2 tailed T-test for paired sample									
	ERR	0.45	0.41	0.40	0.38	0.25	0.03	0.30	0.87

2) Fecal Coliform

Insufficient duplicates of coliform samples for T-test analysis.

B) FOR 1997

1) All parameters except Fecal Coliforms

Sample A (Original)

Site #	Date	NO2-N ppm	NO3-N ppm	TKN ppm	NH4 ppm	Tot. N ppm	PO4 ppm	TKP ppm	TDS mg/L	TSS mg/L
2	04/03/97	0.00	2.37	2.43	0.64	2.91	0.52	0.63	15.52	28.00
2	04/15/97	0.00	0.44	1.60	0.24	1.69	0.38	0.64	6.70	41.68
4	03/28/97	0.05	1.23	1.99	0.29	2.25	0.59	0.76	9.22	31.08
4	04/04/97	0.08	1.48	1.77	0.21	2.08	0.39	0.54	11.31	74.80
4	04/13/97	0.00	0.34	1.94	0.15	2.01	0.25	0.67	7.74	342.40
4	05/07/97	0.00	0.00	0.76	0.00	0.76	0.05	0.11	19.40	14.12
4	08/20/97	0.00	0.00	0.33	0.08	0.33	0.01	0.01	1.88	8.84
15	06/25/97	0.00	0.00	0.76	0.00	0.76	0.02	0.11	8.92	88.80
15	09/03/97	0.00	0.00	0.36	0.00	0.36	0.00	0.00	4.40	4.52
20	07/09/97	0.00	0.00	0.42	0.00	0.42	0.04	0.07	4.16	2.12
20	08/06/97	0.00	0.00	0.45	0.00	0.45	0.10	0.14	2.59	6.88
20	08/20/97	0.00	0.00	0.35	0.07	0.35	0.05	0.05	3.16	17.80
20	09/24/97	0.00	0.00	0.27	0.00	0.27	0.01	0.06	3.54	67.80

Sample B (Split/Duplicate)

Site #	SAM.DAT	NO2-N ppm	NO3-N ppm	TKN ppm	NH4 ppm	Tot. N ppm	PO4 ppm	TKP ppm	TDS mg/L	TSS mg/L
2	04/03/97	0.00	2.40	2.47	0.68	2.95	0.52	0.68	19.56	29.68
2	04/15/97	0.00	0.27	1.62	0.24	1.68	0.38	0.63	6.03	39.44
4	03/28/97	0.04	1.23	1.59	0.25	1.84	0.55	0.65	9.45	32.12
4	04/04/97	0.08	1.44	1.77	0.20	2.08	0.37	0.52	9.84	67.60
4	04/13/97	0.00	0.37	2.33	0.17	2.40	0.33	0.66	7.86	352.40
4	05/07/97	0.00	0.00	0.84	0.00	0.84	0.05	0.12	12.28	12.64
4	08/20/97	0.00	0.00	0.29	0.00	0.29	0.02	0.04	3.88	11.24
15	06/25/97	0.00	0.00	0.62	0.00	0.62	0.02	0.09	8.32	66.90
15	09/03/97	0.00	0.00	0.38	0.00	0.38	0.00	0.01	3.25	4.84
20	07/09/97	0.00	0.00	0.42	0.00	0.42	0.04	0.07	4.42	3.60
20	08/06/97	0.00	0.00	0.16	0.00	0.16	0.10	0.13	4.88	5.20
20	08/20/97	0.00	0.00	0.37	0.00	0.37	0.03	0.05	4.10	14.80
20	09/24/97	0.00	0.00	0.28	0.00	0.28	0.01	0.06	2.93	70.40

Results of 2 tailed T-test for paired sample	NO2-N	NO3-N	TKN	NH4	Tot. N	PO4	TKP	TDS	TSS
	0.337	0.425	0.650	0.296	0.618	0.909	0.610	0.856	0.509

2) Fecal Coliform

Sample A (Original)

Site #	Date	Dup/Sp	Coliform /100mL
2	04/03/97	D	64
2	04/15/97	D	116
4	03/28/97	D	
4	04/04/97	D	
4	04/13/97	D	45
4	08/20/97	s	280
4	05/07/97	D	20
20	07/09/97	D	1900
20	08/06/97	D	1800
20	08/20/97	D	390
20	09/24/97	D	1500

Sample B (Duplicate)

Site #	Date	Dup/Sp	Coliform /100mL
2	04/03/97	D	44
2	04/15/97	D	120
4	03/28/97	D	
4	04/04/97	D	
4	04/13/97	D	62
4	08/20/97	s	32
4	05/07/97	D	22
20	07/09/97	D	1900
20	08/06/97	D	1800
20	08/20/97	D	480
20	09/24/97	D	2000

Results of 2 tailed T-test for paired samples: 0.567

C) FOR "BLANKS"

Non 0 values as reported by laboratory for double distilled water bottled at field lab.

Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L
03/21/97	80				0.01				6.50	
03/22/97	81				0.03				0.76	
03/23/97	82								1.33	
03/24/97	83						0.01		6.50	
03/25/97	84			0.30		0.30			6.27	
03/26/97	85	0.05				0.01			3.03	
03/27/97	86								5.08	
03/28/97	87								3.27	
03/29/97	88		0.04			0.01	0.26		10.17	
03/30/97	89			0.08		0.08			7.11	
03/31/97	90								3.97	
04/02/97	92								4.69	
04/03/97	93								4.58	
04/04/97	94								6.07	
04/09/97	99								8.62	
04/13/97	103				0.01				2.78	
04/14/97	104				0.02				2.73	
04/15/97	105								2.96	
04/16/97	106				0.01				13.44	
04/17/97	107								5.89	
04/18/97	108								6.02	
04/23/97	113								6.69	
04/30/97	120								5.08	
05/07/97	127								5.70	
05/14/97	134								19.77	
05/21/97	141								21.55	
05/28/97	148								12.71	
06/04/97	155								28.18	
06/11/97	162								15.76	
06/18/97	169								10.54	
06/25/97	176								12.30	
07/02/97	183							0.02	10.38	0.08
07/09/97	190								7.64	
07/16/97	197							0.01	7.83	
07/23/97	204								5.16	
07/30/97	211								11.32	
08/06/97	218								4.35	
08/13/97	225								3.59	
08/20/97	232								7.87	
08/27/97	239								3.63	
09/03/97	246						0.01		6.42	
09/10/97	253								3.99	
09/17/97	260								3.79	
09/24/97	267								3.70	

Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L
10/01/97	274							0.01	4.21	
10/08/97	281								19.74	
10/22/97	295								18.79	
10/29/97	302								15.80	
Average		0.05	0.04	0.19	0.02	0.10	0.09	0.01	8.09	0.08
Maximum		0.05	0.04	0.30	0.03	0.30	0.26	0.02	28.18	0.08

As a means to compare maximum concentration values of blanks, average concentrations of parameters from all sampling sites are included below.

Year	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L
1996	0.07	0.17	0.76	0.09	1.00	0.48	0.68	772	12.51
1997	0.02	0.37	1.47	0.37	1.86	0.59	0.71	600	41.28

Percentage of Blank samples with non-zero concentrations

NO2-N	NO3-N	TKN	NH4	Tot. N	PO4	TKP	TDS	TSS
2.1%	2.1%	4.2%	10.4%	8.3%	4.2%	6.3%	100%	2.1%

D) BLIND LABORATORY COMPARISON

2 tailed t-test for paired samples used in the comparison.

		NO2-N		NO3-N		Total P	
Date	Site #	AAFRD	Cheme	AAFRD	Cheme	AAFRD	Cheme
97-04-13	3	<0.04	0.041	0.84	0.807	0.812	0.875
97-04-14	3	<0.04	0.026	0.70	0.541	0.670	0.770
97-04-13	4	<0.04	0.019	0.42	0.410	0.666	0.710
97-04-14	4	<0.04	0.031	0.56	0.519	0.599	0.644
97-04-13	7	<0.04	0.020	0.28	0.368	0.338	0.299
97-04-14	7	<0.04	0.036	0.56	0.676	0.445	0.617
97-04-13	9	<0.04	0.027	0.98	0.897	0.362	0.332
97-04-14	9	<0.04	0.026	0.98	1.030	0.321	0.445
97-04-13	28	<0.04	0.032	0.56	0.553	0.773	0.725
97-04-14	28	<0.04	0.028	0.56	0.622	0.582	0.720
97-04-13	Blank	<0.04	<0.003	<0.04	<0.003	<0.004	<0.02
97-04-14	Blank	<0.04	<0.003	<0.04	<0.003	<0.004	<0.02

Results of t-tests 0.95 0.046

Note: T-test computations did not include threshhold detection values (i.e. <0.04).

APPENDIX C: 1996 Flow & Precipitation Data

Date	Julian Day	Average Daily Flow (m^3/s)				Rainfall (mm)	
		Site #2	Site#4	Site #15	Site #20	Site#5	Site#15
07/08/96	190						
07/09/96	191			0.26			0
07/10/96	192			0.25			0
07/11/96	193			0.25			0
07/12/96	194			0.25			0
07/13/96	195			0.28			0
07/14/96	196			0.29			0
07/15/96	197			0.25			0
07/16/96	198			0.30			0
07/17/96	199			0.35	0.00		0
07/18/96	200			0.18	0.00		0
07/19/96	201	0.00		0.12	0.00		0
07/20/96	202	0.00		0.12	0.00		0
07/21/96	203	0.00		0.21	0.00		0
07/22/96	204	0.00		0.21	0.00		0
07/23/96	205	0.00		0.18	0.00		0
07/24/96	206	0.00		0.18	0.01		0
07/25/96	207	0.01		0.19	0.01		0
07/26/96	208	0.01	0.26	0.25	0.01		0
07/27/96	209	0.01	0.26	0.20	0.01		0
07/28/96	210	0.01	0.39	0.16	0.01		0
07/29/96	211	0.01	0.30	0.20	0.01		0
07/30/96	212	0.01	0.25	0.14	0.01		0
07/31/96	213	0.01	0.23	0.14	0.01		0
08/01/96	214	0.01	0.17	0.19	0.01		0
08/02/96	215	0.01	0.22	0.19	0.01		0
08/03/96	216	0.01	0.27	0.07	0.01		0
08/04/96	217	0.02	0.27	0.05	0.01		0
08/05/96	218	0.01	0.20	0.08	0.01		0
08/06/96	219	0.01	0.17	0.17	0.01		0
08/07/96	220	0.01	0.24	0.22	0.01		0
08/08/96	221	0.01	0.30	0.23	0.01		0
08/09/96	222	0.01	0.31	0.21	0.01		0
08/10/96	223	0.01	0.31	0.14	0.01		0
08/11/96	224	0.01	0.27	0.12	0.01		0
08/12/96	225	0.01	0.18	0.07	0.01		0
08/13/96	226	0.01	0.17	0.07	0.01		0
08/14/96	227	0.01	0.17	0.08	0.01		0
08/15/96	228	0.01	0.17	0.12	0.01		0
08/16/96	229	0.01	0.18	0.13	0.01		0
08/17/96	230	0.00	0.21	0.17	0.01		0
08/18/96	231	0.00	0.24	0.20	0.01		0
08/19/96	232	0.00	0.27	0.17	0.01		0
08/20/96	233	0.00	0.28	0.14	0.01		0
08/21/96	234	0.00	0.24	0.09	0.01		0

Date	Julian Day	Average Daily Flow (m^3/s)				Rainfall (mm)	
		Site #2	Site#4	Site #15	Site #20	Site#5	Site#15
08/22/96	235	0.00	0.23	0.06	0.01	1	0
08/23/96	236	0.00	0.17	0.09	0.01	0	0
08/24/96	237	0.00	0.18	0.08	0.01	0	0
08/25/96	238	0.00	0.20	0.09	0.01	0	0
08/26/96	239	0.00	0.19	0.11	0.01	0	0
08/27/96	240	0.00	0.20	0.09	0.01	0	0
08/28/96	241	0.00	0.21	0.08	0.01	0	0.8
08/29/96	242	0.00	0.20	0.06	0.01	0	0
08/30/96	243	0.00	0.19	0.06	0.01	4.3	0
08/31/96	244	0.00	0.18	0.15	0.01	0.8	0.8
09/01/96	245	0.00	0.22	0.17	0.01	0	0
09/02/96	246	0.00	0.28	0.16	0.01	0	0
09/03/96	247	0.00	0.29	0.18	0.01	0	0
09/04/96	248	0.00	0.33	0.20	0.01	6.9	6.6
09/05/96	249	0.00	0.39	0.27	0.01	1	11.9
09/06/96	250	0.00	0.41	0.25	0.01	0.3	0.3
09/07/96	251	0.00	0.44	0.20	0.01	0	0
09/08/96	252	0.00	0.41	0.14	0.01	0	0
09/09/96	253	0.00	0.29	0.13	0.01	0	0
09/10/96	254	0.00	0.25	0.12	0.01	0	0
09/11/96	255	0.00	0.24	0.09	0.01	0	0
09/12/96	256	0.00	0.24	0.14	0.01	0	0
09/13/96	257	0.00	0.24	0.13	0.01	0	0
09/14/96	258	0.00	0.23	0.14	0.01	0	0
09/15/96	259	0.00	0.23	0.17	0.01	0	0
09/16/96	260	0.00	0.23	0.18	0.01	3	2.8
09/17/96	261	0.00	0.29	0.22	0.03	29.5	31.7
09/18/96	262	0.00	0.43	0.26	0.04	0.3	0.8
09/19/96	263	0.07	0.44	0.23	0.01	1.8	2.3
09/20/96	264	0.02	0.45	0.19	0.01	4.6	6.1
09/21/96	265	0.01	0.38	0.17	0.01	1	2.3
09/22/96	266	0.00	0.33	0.16	0.01	0.3	0.5
09/23/96	267	0.00	0.29	0.17	0.01	0	0
09/24/96	268	0.00	0.28	0.15	0.01	0	0.3
09/25/96	269	0.00	0.28	0.14	0.01	0	0
09/26/96	270	0.00	0.27	0.12	0.01	0	0
09/27/96	271	0.00	0.25	0.05	0.01	0	0
09/28/96	272	0.00	0.19	0.00	0.00	0	0
09/29/96	273	0.00	0.10	0.00	0.00	0	0
09/30/96	274	0.00	0.05	0.00	0.00	0	0
10/01/96	275	0.00	0.04	0.00	0.00	0	0
10/02/96	276	0.00	0.02	0.00	0.00	0	0
10/03/96	277	0.00	0.02	0.00	0.00	0	0
10/04/96	278	0.00	0.01	0.00	0.00	0	0
10/05/96	279	0.00	0.02	0.00	0.01	0	0
10/06/96	280	0.00	0.01	0.00	0.00	0	0
10/07/96	281	0.00	0.01	0.00	0.00	0	0
10/08/96	282	0.01	0.01	0.00	0.00	0	0

Date	Julian Day	Average Daily Flow (m^3/s)				Rainfall (mm)	
		Site #2	Site#4	Site #15	Site #20	Site#5	Site#15
10/09/96	283	0.00	0.00	0.00	0.00	0	0
10/10/96	284	0.00	0.00	0.00	0.00	0	0
10/11/96	285	0.00	0.00	0.00	0.00	0	0
10/12/96	286	0.00	0.00	0.00	0.00	0	0
10/13/96	287	0.00	0.00	0.00	0.00	0	0
10/14/96	288	0.00	0.00	0.00	0.00	0	0
10/15/96	289	0.00	0.00	0.00	0.00	0	0
10/16/96	290	0.00	0.00	0.00	0.00	0	0
10/17/96	291	0.00	0.00	0.00	0.00	0	0
10/18/96	292	0.00	0.00	0.00	0.00	0	0
10/19/96	293	0.00	0.00	0.00	0.00	0	0
10/20/96	294	0.00	0.00	0.00	0.00	0	0
10/21/96	295	0.03	0.00	0.00	0.00	0	
10/22/96	296	0.16	0.00	0.00	0.00	0	
10/23/96	297	0.14	0.00	0.00	0.00	0	
10/24/96	298	0.04	0.00	0.00	0.00	0	
10/25/96	299	0.01	0.00	0.00	0.00	0	
10/26/96	300	0.00	0.00	0.00	0.00	0	
10/27/96	301	0.00	0.00	0.00	0.00	0	
10/28/96	302	0.00	0.00	0.00	0.00	0	
10/29/96	303	0.00	0.00	0.00	0.00	0	
10/30/96	304	0.00	0.00	0.00	0.00	0	
10/31/96	305	0.00	0.00	0.00	0.00	0	

APPENDIX D: 1997 Flow & Precipitation Data

	Date	Julian Day	Average Daily Flow (m^3/s)					Rainfall (mm)	
			Site #2	Site #3	Site#4	Site #15	Site #20	Site#5	Site#15
*	03/21/97	80	1.83	0.00	0.00	0.00	0.00		
*	03/22/97	81	1.83	0.00	0.00	0.00	1.99		
*	03/23/97	82	0.00	0.00	0.00	0.00	2.44		
*	03/24/97	83	0.00	0.00	0.03	0.00	1.56		
*	03/25/97	84	1.83	0.00	0.88	0.00	0.87		
*	03/26/97	85	3.40	0.00	0.32	0.00	1.19		
*	03/27/97	86	2.01	2.46	1.84	0.00	6.19		
*	03/28/97	87	1.64	1.88	4.76	0.00	0.00		
*	03/29/97	88	1.21	1.64	4.46	0.00	0.00		
*	03/30/97	89	1.21	1.44	4.76	0.00	5.13		
*	03/31/97	90	1.08	1.43	8.37	0.00	4.57		
*	04/01/97	91	0.82	1.40	4.76	0.00	2.94		
*	04/02/97	92	0.69	0.74	1.90	0.00	2.20		
*	04/03/97	93	0.80	0.74	2.84	0.00	2.23		
*	04/04/97	94	1.02	0.00	2.43	0.00	0.81		
*	04/05/97	95	0.00	0.00	0.00	0.00	0.00		
*	04/06/97	96	0.00	0.00	0.00	0.00	0.00		
*	04/07/97	97	0.00	0.00	0.00	0.00	0.00		
*	04/08/97	98	0.00	0.00	0.00	0.00	0.00		
*	04/09/97	99	0.00	0.00	0.00	0.00	0.00		
*	04/10/97	100	0.00	0.00	0.00	0.00	0.00		
*	04/11/97	101	0.00	0.00	0.00	0.00	0.00		
*	04/12/97	102	0.00	0.00	0.00	0.00	0.00		
*	04/13/97	103	0.42	0.62	0.01	0.00	0.93		
*	04/14/97	104	0.45	0.99	0.43	0.00	1.87		
*	04/15/97	105	0.41	0.99	1.23	0.00	1.61		
*	04/16/97	106	0.34	1.03	0.93	0.00	1.90		
*	04/17/97	107	0.31	1.17	0.89	0.00	1.81		
	04/18/97	108	0.17	0.33	0.05	0.00	0.35		
	04/22/97	112	0.00	0.00	0.40	0.00	0.00	0.0	
	04/23/97	113	0.00	0.83	0.31	0.00	0.19	0.0	0.0
	04/24/97	114	1.89	0.83	0.20	0.09	0.16	0.0	0.0
	04/25/97	115	1.87	0.83	0.18	0.16	0.13	0.0	0.0
	04/26/97	116	1.87	0.83	0.15	0.14	0.11	0.0	0.0
	04/27/97	117	1.86	0.83	0.11	0.12	0.09	0.0	0.0
	04/28/97	118	1.79	0.83	0.12	0.12	0.08	0.0	0.0
	04/29/97	119	1.74	0.83	0.10	0.15	0.07	0.0	0.0
	04/30/97	120	1.68	0.83	0.10	0.08	0.06	0.0	0.0
	05/01/97	121	1.64	0.83	0.08	0.00	0.05	0.0	0.0
	05/02/97	122	1.61	0.83	0.09	0.00	0.05	0.0	0.0
	05/03/97	123	1.58	0.83	0.11	0.00	0.04	0.0	0.0
	05/04/97	124	1.56	0.83	0.14	0.00	0.03	0.0	0.0
	05/05/97	125	1.52	0.83	0.18	0.00	0.03	0.0	0.0
	05/06/97	126	1.48	0.83	0.19	0.00	0.02	0.0	0.0

Date	Julian Day	Average Daily Flow (m^3/s)					Rainfall (mm)	
		Site #2	Site #3	Site#4	Site #15	Site #20	Site#5	Site#15
05/07/97	127	1.44	0.83	0.18	0.00	0.02	0.0	0.0
05/08/97	128	0.19	0.82	0.17	0.00	0.02	0.0	0.0
05/09/97	129	0.19	0.83	0.20	0.00	0.01	0.0	0.0
05/10/97	130	0.18	0.82	0.19	0.21	0.01	0.0	0.0
05/11/97	131	0.17	0.83	0.29	0.26	0.01	0.0	0.0
05/12/97	132	0.17	0.83	0.35	0.27	0.01	0.0	0.0
05/13/97	133	0.16	0.82	0.34	0.26	0.01	0.0	0.0
05/14/97	134	0.16	0.82	0.34	0.20	0.01	0.0	0.0
05/15/97	135	0.15	0.82	0.36	0.12	0.01	0.0	0.0
05/16/97	136	0.14	0.82	0.32	0.10	0.01	0.0	1.5
05/17/97	137	0.13	0.81	0.25	0.15	0.01	0.3	0.3
05/18/97	138	0.09	0.81	0.30	0.28	0.00	1.3	1.3
05/19/97	139	0.08	0.81	0.41	0.29	0.00	2.3	2.3
05/20/97	140	0.07	0.80	0.59	0.35	0.00	13.2	13.0
05/21/97	141	0.10	0.80	0.75	0.35	0.00	0.0	0.0
05/22/97	142	0.23	0.80	0.89	0.34	0.01	0.0	0.0
05/23/97	143	0.13	0.80	0.95	0.36	0.03	0.0	0.3
05/24/97	144	0.11	0.80	0.84	0.32	0.01	3.0	2.3
05/25/97	145	0.09	0.80	0.81	0.32	0.03	13.5	17.0
05/26/97	146	0.12	0.80	1.10	0.36	0.32	6.6	8.4
05/27/97	147	0.40	0.79	1.71	0.45	0.31	0.0	0.0
05/28/97	148	0.21	0.79	3.00	0.45	0.11	0.0	0.0
05/29/97	149	0.13	0.78	2.16	0.34	0.04	0.3	0.0
05/30/97	150	0.07	0.76	1.32	0.32	0.02	0.3	0.0
05/31/97	151	0.06	0.75	0.79	0.31	0.01	0.0	0.0
06/01/97	152	0.05	0.77	0.71	0.25	0.01	0.0	0.0
06/02/97	153	0.05	0.75	0.60	0.26	0.00	0.0	0.0
06/03/97	154	0.05	0.00	0.44	0.25	0.00	0.0	0.0
06/04/97	155	0.04	0.00	0.37	0.27	0.00	0.0	0.5
06/05/97	156	0.04	0.00	0.44	0.29	0.00	4.6	4.8
06/06/97	157	0.04	0.00	0.50	0.27	0.00	0.0	2.0
06/07/97	158	0.04	0.00	0.46	0.29	0.00	0.0	0.3
06/08/97	159	0.04	0.00	0.41	0.28	0.00	0.0	0.0
06/09/97	160	0.04	0.00	0.44	0.29	0.00	0.0	0.0
06/10/97	161	0.04	0.00	0.42	0.32	0.00	0.0	0.0
06/11/97	162	0.04	0.00	0.44	0.27	0.00	2.8	7.9
06/12/97	163	0.04	0.49	0.43	0.27	0.01	0.5	35.8
06/13/97	164	0.04	0.49	1.44	0.27	0.02	0.3	0.0
06/14/97	165	0.03	0.48	1.05	0.23	0.01	0.0	0.0
06/15/97	166	0.01	0.48	0.41	0.27	0.02	0.0	0.0
06/16/97	167	0.01	0.48	0.40	0.29	0.01	0.0	0.0
06/17/97	168	0.01	0.48	0.40	0.24	0.00	0.0	0.0
06/18/97	169	0.01	0.48	0.34	0.22	0.00	0.0	0.0
06/19/97	170	0.00	0.47	0.35	0.19	0.00	0.5	0.0
06/20/97	171	0.00	0.47	0.28	0.22	0.00	0.3	0.0
06/21/97	172	0.00	0.48	0.30	0.26	0.00	0.0	0.0
06/22/97	173	0.01	0.48	0.42	0.26	0.00	5.6	5.3

Date	Julian Day	Average Daily Flow (m^3/s)					Rainfall (mm)	
		Site #2	Site #3	Site#4	Site #15	Site #20	Site#5	Site#15
06/23/97	174	0.01	0.47	0.53	0.28	0.00	0.0	0.8
06/24/97	175	0.01	0.47	0.49	0.31	0.01	3.3	4.8
06/25/97	176	0.01	0.47	0.47	0.31	0.01	0.0	0.0
06/26/97	177	0.01	0.47	0.47	0.30	0.01	0.0	0.0
06/27/97	178	0.00	0.48	0.39	0.28	0.01	0.0	0.0
06/28/97	179	0.00	0.48	0.30	0.22	0.01	1.3	0.8
06/29/97	180	0.00	0.50	0.23	0.20	0.01	10.9	12.4
06/30/97	181	0.01	0.50	0.29	0.28	0.01	2.5	2.5
07/01/97	182	0.01	0.49	0.30	0.26	0.01	0.0	0.0
07/02/97	183	0.01	0.48	0.30	0.25	0.01	0.0	0.0
07/03/97	184	0.01	0.48	0.32	0.27	0.01	0.0	0.0
07/04/97	185	0.01	0.48	0.30	0.26	0.01	0.3	2.0
07/05/97	186	0.00	0.48	0.22	0.23	0.01	0.0	0.0
07/06/97	187	0.00	0.47	0.18	0.25	0.01	0.3	1.5
07/07/97	188	0.00	0.47	0.17	0.35	0.01	0.0	0.0
07/08/97	189	0.00	0.47	0.33	0.26	0.01	0.0	0.0
07/09/97	190	0.00	0.47	0.33	0.25	0.01	0.0	0.0
07/10/97	191	0.00	0.47	0.15	0.24	0.01	0.0	0.0
07/11/97	192	0.00	0.47	0.24	0.22	0.01	0.0	0.0
07/12/97	193	0.00	0.47	0.17	0.19	0.01	0.0	0.0
07/13/97	194	0.00	0.47	0.15	0.25	0.01	0.3	0.0
07/14/97	195	0.00	0.49	0.20	0.27	0.01	0.0	0.0
07/15/97	196	0.00	0.49	0.20	0.31	0.01	0.0	0.0
07/16/97	197	0.00	0.48	0.33	0.29	0.01	0.0	0.0
07/17/97	198	0.00	0.47	0.32	0.29	0.01	0.0	0.0
07/18/97	199	0.00	0.46	0.25	0.34	0.01	0.0	0.0
07/19/97	200	0.00	0.43	0.38	0.35	0.00	0.0	0.0
07/20/97	201	0.00	0.42	0.49	0.35	0.00	0.0	0.0
07/21/97	202	0.00	0.40	0.51	0.34	0.00	0.0	0.0
07/22/97	203	0.00	0.37	0.42	0.30	0.00	0.0	0.0
07/23/97	204	0.00	0.36	0.36	0.30	0.00	0.0	0.0
07/24/97	205	0.00	0.35	0.36	0.24	0.00	10.7	3.0
07/25/97	206	0.00	0.34	0.43	0.34	0.00	3.8	3.3
07/26/97	207	0.00	0.33	0.46	0.43	0.00	1.8	0.5
07/27/97	208	0.00	0.32	0.49	0.39	0.00	0.0	0.0
07/28/97	209	0.00	0.31	0.68	0.32	0.00	0.0	0.0
07/29/97	210	0.00	0.28	0.63	0.25	0.00	5.3	5.6
07/30/97	211	0.00	0.28	0.50	0.30	0.00	4.1	2.3
07/31/97	212	0.00	0.26	0.58	0.28	0.00	0.0	0.0
08/01/97	213	0.00	0.25	0.54	0.24	0.00	1.0	1.3
08/02/97	214	0.00	0.24	0.50	0.27	0.00	0.0	0.0
08/03/97	215	0.00	0.22	0.44	0.28	0.00	0.0	0.0
08/04/97	216	0.00	0.21	0.33	0.30	0.00	0.0	0.0
08/05/97	217	0.00	0.19	0.33	0.31	0.00	0.0	0.0
08/06/97	218	0.00	0.18	0.33	0.35	0.00	0.0	0.0
08/07/97	219	0.00	0.17	0.29	0.35	0.00	3.3	2.3
08/08/97	220	0.00	0.19	0.47	0.42	0.00	24.4	21.8

Date	Julian Day	Average Daily Flow (m^3/s)					Rainfall (mm)	
		Site #2	Site #3	Site#4	Site #15	Site #20	Site#5	Site#15
08/09/97	221	0.00	0.22	0.75	0.43	0.01	0.3	0.3
08/10/97	222	0.00	0.21	0.82	0.39	0.01	0.0	0.0
08/11/97	223	0.00	0.20	0.75	0.39	0.01	0.0	0.0
08/12/97	224	0.00	0.19	0.64	0.35	0.01	0.3	0.0
08/13/97	225	0.00	0.18	0.62	0.35	0.01	0.0	0.0
08/14/97	226	0.00	0.16	0.52	0.37	0.01	1.0	2.5
08/15/97	227	0.00	0.15	0.51	0.38	0.01	1.0	1.5
08/16/97	228	0.00	0.15	0.64	0.39	0.01	1.3	2.8
08/17/97	229	0.00	0.14	0.69	0.40	0.01	0.0	0.0
08/18/97	230	0.00	0.13	0.70	0.38	0.01	0.0	0.0
08/19/97	231	0.00	0.13	0.70	0.38	0.01	0.0	0.0
08/20/97	232	0.00	0.12	0.74	0.39	0.01	0.0	0.0
08/21/97	233	0.00	0.12	0.71	0.39	0.01	0.0	0.3
08/22/97	234	0.00	0.11	0.66	0.38	0.01	0.0	0.0
08/23/97	235	0.00	0.11	0.63	0.38	0.01	0.0	0.0
08/24/97	236	0.00	0.11	0.64	0.36	0.01	0.0	0.0
08/25/97	237	0.00	0.11	0.62	0.36	0.01	0.0	0.0
08/26/97	238	0.00	0.10	0.60	0.33	0.01	0.0	0.0
08/27/97	239	0.00	0.10	0.55	0.33	0.01	0.0	0.0
08/28/97	240	0.00	0.10	0.50	0.33	0.01	0.0	0.0
08/29/97	241	0.00	0.10	0.50	0.34	0.01	0.0	0.0
08/30/97	242	0.00	0.10	0.50	0.34	0.01	0.0	0.0
08/31/97	243	0.00	0.09	0.50	0.34	0.01	0.0	0.0
09/01/97	244	0.00	0.09	0.51	0.34	0.01	0.0	0.0
09/02/97	245	0.00	0.09	0.53	0.32	0.01	0.0	0.0
09/03/97	246	0.00	0.09	0.51	0.33	0.01	19.3	37.3
09/04/97	247	0.00	0.16	0.71	0.33	0.01	0.8	1.0
09/05/97	248	0.00	0.16	0.68	0.28	0.01	0.0	0.0
09/06/97	249	0.00	0.15	0.52	0.28	0.01	0.5	1.8
09/07/97	250	0.00	0.14	0.40	0.30	0.01	0.0	0.0
09/08/97	251	0.00	0.13	0.41	0.29	0.01	0.0	0.0
09/09/97	252	0.00	0.13	0.42	0.27	0.01	0.0	0.0
09/10/97	253	0.00	0.12	0.39	0.23	0.01	0.0	0.0
09/11/97	254	0.00	0.12	0.35	0.22	0.01	0.0	1.5
09/12/97	255	0.00	0.11	0.36	0.22	0.01	0.3	2.5
09/13/97	256	0.00	0.11	0.31	0.24	0.01	0.0	0.0
09/14/97	257	0.00	0.11	0.33	0.24	0.02	0.0	0.0
09/15/97	258	0.00	0.10	0.36	0.25	0.02	1.0	2.3
09/16/97	259	0.00	0.10	0.39	0.24	0.02	0.0	1.3
09/17/97	260	0.00	0.10	0.51	0.21	0.02	0.3	1.0
09/18/97	261	0.00	0.10	0.49	0.23	0.02	1.0	3.6
09/19/97	262	0.00	0.10	0.37	0.27	0.02	0.0	0.0
09/20/97	263	0.00	0.09	0.32	0.27	0.02	0.0	0.0
09/21/97	264	0.00	0.09	0.34	0.29	0.02	0.0	0.0
09/22/97	265	0.00	0.09	0.35	0.32	0.02	0.0	0.0
09/23/97	266	0.00	0.09	0.30	0.33	0.02	0.0	0.0
09/24/97	267	0.00	0.09	0.32	0.33	0.02	0.0	0.0

Date	Julian Day	Average Daily Flow (m^3/s)					Rainfall (mm)	
		Site #2	Site #3	Site#4	Site #15	Site #20	Site#5	Site#15
09/25/97	268	0.00	0.08	0.32	0.34	0.01	0.0	0.0
09/26/97	269	0.00	0.08	0.31	0.33	0.01	0.0	0.0
09/27/97	270	0.00	0.08	0.32	0.34	0.01	0.0	0.0
09/28/97	271	0.00	0.08	0.30	0.35	0.01	0.0	0.0
09/29/97	272	0.00	0.08	0.38	0.38	0.01	0.0	0.0
09/30/97	273	0.00	0.08	0.46	0.40	0.01	0.0	0.0
10/01/97	274	0.00	0.08	0.48	0.43	0.01	0.0	0.0
10/02/97	275	0.00	0.08	0.51	0.51	0.00	0.0	0.0
10/03/97	276	0.00	0.08	0.48	0.43	0.00	0.0	0.0
10/04/97	277	0.00	0.08	0.51	0.14	0.00	0.0	0.0
10/05/97	278	0.00	0.08	0.21	0.06	0.00	0.0	0.0
10/06/97	279	0.00	0.07	0.08	0.04	0.00	0.0	0.0
10/07/97	280	0.00	0.07	0.06	0.03	0.00	0.8	1.5
10/08/97	281	0.00	0.07	0.06	0.02	0.00	0.0	0.3
10/09/97	282	0.00	0.07	0.06	0.02	0.00	0.8	0.3
10/10/97	283	0.00	0.07	0.07	0.01	0.00	0.0	0.3
10/11/97	284	0.00	0.07	0.08	0.00	0.00	0.0	0.0
10/12/97	285	0.00	0.07	0.09	0.00	0.00	0.0	0.0
10/13/97	286	0.00	0.07	0.08	0.00	0.00	0.0	0.0
10/14/97	287	0.00	0.07	0.09	0.00	0.00	0.0	0.0
10/15/97	288	0.00	0.07	0.09	0.00	0.00	0.0	0.0
10/16/97	289	0.00	0.07	0.11	0.00	0.00	0.0	0.0
10/17/97	290	0.00	0.07	0.17	0.00	0.00	0.0	0.0
10/18/97	291	0.00	0.06	0.16	0.00	0.00	0.0	0.0
10/19/97	292	0.00	0.06	0.12	0.00	0.00	0.0	0.0
10/20/97	293	0.00	0.06	0.14	0.00	0.00	0.0	0.0
10/21/97	294	0.00	0.06	0.14	0.00	0.00	0.0	0.0
10/22/97	295	0.00	0.06	0.14	0.00	0.00	1.8	0.0
10/23/97	296	0.00	0.06	0.16	0.00	0.00	0.3	0.0
10/24/97	297	0.00	0.06	0.19	0.00	0.00	0.0	0.0
10/25/97	298	0.00	0.06	0.15	0.00	0.00	0.5	0.0
10/26/97	299	0.00	0.06	0.18	0.00	0.00	0.0	0.0
10/27/97	300	0.00	0.06	0.18	0.00	0.00	0.0	0.0
10/28/97	301	0.39	0.06	0.19	0.00	0.00	0.0	0.0
10/29/97	302	0.36	0.06	0.21	0.00	0.00	0.0	0.0
10/30/97	303	0.22	0.05	0.22	0.00	0.00	0.0	0.0
10/31/97	304	0.22	0.05	0.22	0.00	0.00	0.0	0.0
11/01/97	305	0.04	0.05	0.27	0.00	0.00	0.0	0.0
11/02/97	306	0.01	0.05	0.31	0.00	0.00	0.0	0.0
11/03/97	307	0.01	0.05	0.30	0.00	0.00	0.0	0.0
11/04/97	308	0.00	0.00	0.00	0.00	0.00		
11/05/97	309	0.00	0.00	0.00	0.00	0.00		

Date	Julian Day	Flow Metering Data (m^3/s)					Rainfall (mm)	
		Site #2	Site #3	Site#4	Site #15	Site #20	Site#5	Site#15
+ 10/28/97	301	0.13					0.0	0.0
+ 10/29/97	302	0.12					0.0	0.0
+ 10/30/97	303	0.11					0.0	0.0

- Note: Dramatic weather changes are normal in spring for this part of Alberta. Such changes lead to erratic freeze thaw cycles which explains the flow observed.

+ Note: These values were used in the analysis as the datalogger at site #2 appears to have malfunctioned from 10/27/98 onwards.

APPENDIX E: 1996 Water Quality Data

Site	Du	Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L	F.Coli /100m
2	S	10/16/96	290	0.00	0.04	1.57	0.07	1.61	0.44	0.94	1944	26.3	
2	S	10/16/96	290	0.00	0.05	1.40	0.06	1.45	0.36	0.85	1914	24.6	
2		10/21/96	295	0.00	0.11	1.52	0.12	1.64	0.36	0.77	2275	31.0	16
2		10/21/96	295	0.00	0.16	1.44	0.12	1.61	0.35	0.83	2296	40.3	10
2		10/22/96	296	0.00	0.23	1.67	0.13	1.90	2.41	2.42	2499	2.4	52
2		10/22/96	296	0.70	0.83	1.70	0.14	3.23	2.40	2.40	1436	2.7	17
2		10/23/96	297	0.70	0.83	1.72	0.18	3.25	2.34	2.34	1438	0.8	40
2		10/23/96	297	0.70	0.83	1.72	0.18	3.25	2.37	2.37	1452	3.8	10
2		10/24/96	298	0.00	0.73	1.58	0.21	2.31	2.18	2.18	1579	4.5	30
2		10/24/96	298	0.00	0.67	1.34	0.22	2.01	2.11	2.20	1660	8.4	28
2		10/25/96	299	0.00	0.73	1.50	0.24	2.23	2.12	2.12	1608	6.2	33
4		07/24/96	206	0.00	0.00	0.48	0.00	0.48	0.09	0.36	313	4.7	
4		07/31/96	213	0.00	0.14	0.27	0.05	0.41	0.13	0.26	317	3.9	124
4		08/07/96	220	0.00	0.12	0.36	0.00	0.48	0.14	0.20	362	2.8	
4		08/14/96	227	0.00	0.12	0.25	0.06	0.37	0.13	0.22	334	0.2	148
4	S	08/21/96	234	0.00	0.14	0.39	0.07	0.53	0.13	0.15	302	8.6	
4	S	08/21/96	234	0.00	0.07	0.21	0.05	0.28	0.10	0.10	293	11.9	
4		08/28/96	241	0.00	0.00	0.33	0.07	0.33	0.09	0.28	286	5.9	88
4		09/04/96	248	0.00	0.00	0.31	0.07	0.31	0.09	0.29	294	11.1	
4		09/11/96	255	0.00	0.00	0.28	0.07	0.28	0.13	0.26	303	7.5	78
4		09/18/96	262	0.00	0.00	0.54	0.00	0.54	0.17	0.17	345	14.4	270
4		09/19/96	263	0.00	0.00	0.21	0.00	0.21	0.18	0.91	311	27.1	
4		09/20/96	264	0.00	0.00	0.00	0.00	0.00	0.13	0.38	359	29.1	
4		09/25/96	269	0.00	0.00	0.45	0.00	0.45	0.12	0.44	384	22.1	33
4		10/02/96	276	0.00	0.00	0.50	0.05	0.50	0.12	0.31	620	30.4	
4		10/09/96	283	0.00	0.00	0.55	0.00	0.55	0.15	0.23	1148	20.4	25
4		10/16/96	290	0.00	0.00	0.50	0.04	0.50	0.15	0.34	1328	19.6	
4		10/23/96	297	0.00	0.00	0.45	0.04	0.45	0.14	0.35	1415	3.5	
4	S	10/30/96	304	0.00	0.00	0.38	0.00	0.38	0.00	0.05	1699	13.5	
4	S	10/30/96	304	0.00	0.00	0.37	0.00	0.37	0.00	0.02	1692	13.4	
15		07/24/96	206	0.00	0.00	0.40	0.00	0.40	0.00	0.27	204	0.8	
15		07/31/96	213	0.00	0.12	0.38	0.05	0.50	0.04	0.14	233	0.7	23
15		08/07/96	220	0.00	0.10	0.32	0.00	0.42	0.00	0.01	273	0.7	
15		08/14/96	227	0.00	0.10	0.19	0.06	0.29	0.00	0.18	238	0.1	10
15		08/21/96	234	0.00	0.07	0.23	0.04	0.30	0.04	0.04	225	0.4	
15	S	08/28/96	241	0.00	0.00	0.24	0.07	0.24	0.00	0.18	214	0.7	52
15	S	08/28/96	241	0.00	0.00	0.33	0.07	0.33	0.00	0.15	220	1.6	30
15		09/04/96	248	0.00	0.00	0.24	0.06	0.24	0.06	0.16	589	3.3	
15		09/11/96	255	0.00	0.00	0.41	0.07	0.41	0.05	0.12	248	3.8	27
15		09/18/96	262	0.00	0.00	0.41	0.00	0.41	0.04	0.05	236	11.1	290
15		09/19/96	263	0.00	0.00	0.14	0.00	0.14	0.08	0.60	261	5.8	
15		09/20/96	264	0.00	0.00	0.00	0.00	0.00	0.00	0.21	267	5.0	
15		09/25/96	269	0.00	0.00	0.41	0.00	0.41	0.00	0.24	322	28.7	16
20	D	07/24/96	206	0.00	0.00	1.17	0.04	1.17	0.14	0.43	673	3.6	
20	D	07/24/96	206	0.00	0.00	1.19	0.05	1.19	0.15	0.42	671	5.1	

Site	Du	Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L	F.Coli /100m
20		07/31/96	213	0.00	0.12	0.42	0.04	0.54	0.00	0.14	297	6.1	900
20		08/07/96	220	0.00	0.11	0.37	0.04	0.48	0.00	0.00	273	22.2	
20		08/14/96	227	0.00	0.10	0.23	0.06	0.33	0.00	0.20	247	5.6	
20		08/21/96	234	0.00	0.07	0.24	0.04	0.31	0.00	0.03	246	0.3	
20		08/28/96	241	0.00	0.00	0.33	0.06	0.33	0.00	0.16	239	6.4	480
20		09/04/96	248	0.00	0.00	0.27	0.06	0.27	0.00	0.13	242	5.8	
20		09/11/96	255	0.00	0.00	0.38	0.08	0.38	0.02	0.13	251	5.0	210
20		09/18/96	262	0.00	0.44	1.18	0.29	1.61	0.16	0.56	304	34.4	6100
20		09/19/96	263	0.00	0.00	1.26	0.00	1.26	0.07	1.06	304	10.1	
20	D	09/20/96	264	0.00	0.00	0.00	0.00	0.00	0.00	0.29	275	27.5	
20	D	09/20/96	264	0.00	0.00	0.00	0.00	0.00	0.00	0.26	280	22.4	
20		09/25/96	269	0.00	0.00	0.55	0.06	0.55	0.03	0.26	358	88.4	1000
20		10/16/96	290	0.15	0.18	2.27	0.38	2.60	0.16	0.76	1230	29.0	
20		10/23/96	297	1.50	0.24	3.41	0.51	5.15	0.06	0.73	1227	42.4	
26		10/21/96	295	0.00	0.86	1.54	0.36	2.40	2.43	2.51	1472	4.5	12
26		10/22/96	296	0.00	0.86	1.56	0.39	2.42	2.49	2.64	1467	1.6	13
26		10/23/96	297	0.84	0.88	2.02	0.28	3.74	2.30	2.32	1425	1.2	56
26		10/24/96	298	0.05	0.86	1.70	0.39	2.61	2.33	2.43	1442	2.5	5

APPENDIX F: 1997 Water Quality Data

Site	Du	Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L	F.Coli /100mL
2		03/21/97	80	0.00	0.00	2.26	0.20	2.26	1.67	2.39	3877	6.6	
2		03/22/97	81	0.00	0.05	1.52	0.00	1.56	1.33	1.94	3467	5.4	
2		03/23/97	82	0.00	0.04	1.12	0.24	1.16	1.37	1.25	3437	8.8	3
2		03/25/97	84	0.06	0.09	1.62	0.08	1.77	1.58	1.17	2667	8.6	22
2		03/26/97	85	0.05	0.55	1.63	0.39	2.23	0.52	0.55	291	28.9	130
2		03/27/97	86	0.00	0.73	1.95	0.87	2.68	0.41	0.49	148	28.5	
2		03/28/97	87	0.00	1.15	2.16	0.57	3.31	0.37	0.56	132	22.1	
2		03/29/97	88	0.00	1.57	2.01	0.40	3.58	0.28	0.59	123	30.6	
2		03/30/97	89	0.05	1.53	1.97	0.66	3.55	0.69	0.68	123	44.0	62
2		03/31/97	90	0.06	1.56	2.09	0.55	3.71	0.45	0.55	114	37.0	80
2		04/01/97	91	0.07	2.31	2.20	0.47	4.58	0.49	0.57	133	19.0	43
2		04/02/97	92	0.06	3.34	2.08	0.37	5.48	0.52	0.62	161	23.3	17
2	D	04/03/97	93	0.00	2.37	2.43	0.64	4.80	0.52	0.63	146	28.0	64
2	D	04/03/97	93	0.00	2.40	2.47	0.68	4.87	0.52	0.68	151	29.7	44
2		04/04/97	94	0.05	2.82	1.95	0.40	4.82	0.57	0.68	152	17.0	
2		04/13/97	103	0.00	0.47	1.98	0.32	2.45	0.54	0.73	138	44.3	40
2		04/14/97	104	0.00	0.64	1.72	0.20	2.36	0.46	0.48	118	47.2	220
2	D	04/15/97	105	0.00	0.44	1.60	0.24	2.04	0.38	0.64	114	41.7	116
2	D	04/15/97	105	0.00	0.27	1.62	0.24	1.89	0.38	0.63	113	39.4	120
2		04/16/97	106	0.06	0.54	1.53	0.24	2.13	0.37	0.55	126	28.6	120
2		04/17/97	107	0.00	0.55	1.42	0.27	1.97	0.38	0.47	164	21.6	47
2		04/18/97	108	0.00	0.28	1.50	0.09	1.78	0.41	0.57	204	11.1	
2		04/23/97	113	0.00	0.00	1.40	0.03	1.40	0.45	0.49	576	8.5	8
2		04/30/97	120	0.00	0.00	1.39	0.00	1.39	0.42	0.60	1001	6.0	2
2		05/07/97	127	0.00	0.00	1.35	0.00	1.35	0.35	0.50	1703	15.2	12
2		05/14/97	134	0.00	0.00	1.42	0.02	1.42	0.32	0.51	2431	13.9	58
2		05/21/97	141	0.00	0.00	1.51	0.00	1.51	0.35	0.57	3088	14.5	12
2		05/27/97	147	0.05	1.28	2.53	0.04	3.86	0.60	0.88	630	162.4	1400
2		05/28/97	148	0.05	0.61	2.34	0.00	3.00	0.59	0.82	775	42.9	58
2		06/04/97	155	0.00	0.00	2.26	0.00	2.26	0.67	1.03	1812	36.6	44
2		10/27/97	300	0.00	0.00	1.22	0.00	1.22	0.09	0.23	4969	18.0	150
2		10/27/97	300	0.00	0.00	1.01	0.00	1.01	0.05	0.23	5227	18.2	62
2		10/28/97	301	0.00	0.19	3.89	2.56	4.08	3.17	3.37	1516	0.1	10
2		10/28/97	301	0.08	0.24	3.98	2.61	4.29	3.14	3.53	1399	5.0	14
2		10/29/97	302	0.07	0.21	4.45	2.86	4.72	3.19	3.49	1359	1.0	28
2		10/29/97	302	0.07	0.22	4.29	2.84	4.58	3.13	3.61	1373	2.1	1
2		10/30/97	303	0.06	0.20	4.28	2.99	4.54	3.10	3.40	1370	0.6	12
2		10/30/97	303	0.12	0.21	5.16	2.74	5.49	3.17	3.47	1364	0.2	3
2		10/31/97	304	0.14	0.19	5.07	3.01	5.40	3.20	3.54	1370	13.9	10
3		03/22/97	81	0.12	0.18	4.32	0.29	4.62	4.50	4.82	2400	17.2	
3		03/23/97	82	0.15	0.24	3.42	1.26	3.81	4.57	3.03	2346	21.7	42
3		03/26/97	85	0.11	1.41	3.63	1.39	5.15	4.32	4.48	1937	23.0	120
3		03/27/97	86	0.05	0.22	0.23	1.85	0.49	3.84	3.38	2185	22.7	
3		03/28/97	87	0.00	0.81	2.49	0.81	3.30	0.56	0.79	253	33.8	

Site	Du	Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L	Coliform /100mL
3		03/29/97	88	0.00	1.39	2.06	0.50	3.45	0.39	0.77	189	51.0	
3		03/30/97	89	0.04	1.61	2.05	0.61	3.70	0.73	0.66	156	50.7	25
3		03/31/97	90	0.05	1.53	2.31	0.60	3.89	0.52	0.65	151	56.5	49
3		04/01/97	91	0.07	2.06	2.27	0.47	4.40	0.65	0.75	152	42.1	23
3		04/02/97	92	0.14	2.15	1.96	0.41	4.25	0.60	0.73	171	54.4	18
3		04/03/97	93	0.00	2.15	2.07	0.39	4.22	0.57	0.66	168	41.8	23
3		04/04/97	94	0.06	1.90	1.98	0.44	3.94	0.52	0.67	164	39.0	
3		04/13/97	103	0.00	0.79	1.93	0.25	2.72	0.69	0.81	278	38.2	22
3		04/14/97	104	0.00	0.70	1.96	0.21	2.66	0.52	0.67	163	53.0	92
3		04/15/97	105	0.00	0.44	1.79	0.24	2.23	0.47	0.72	132	55.4	84
3		04/16/97	106	0.07	0.51	1.65	0.27	2.23	0.47	0.67	136	59.2	66
3		04/17/97	107	0.00	0.47	1.78	0.29	2.25	0.41	0.60	170	70.8	96
3		04/18/97	108	0.00	0.41	1.67	0.20	2.08	0.35	0.60	134	56.8	
3		04/23/97	113	0.00	0.37	2.25	0.41	2.62	0.72	0.98	345	111.0	1
3		04/30/97	120	0.00	0.17	2.03	0.13	2.20	0.82	1.15	414	50.1	2
3		05/07/97	127	0.00	0.00	2.23	0.00	2.23	1.03	1.29	516	75.9	2
3		05/14/97	134	0.00	0.00	2.35	0.00	2.35	1.08	1.48	559	104.8	11
3		05/21/97	141	0.00	0.00	2.50	0.00	2.50	0.97	1.48	637	167.3	96
3		05/27/97	147	0.00	0.00	2.22	0.00	2.22	1.10	1.61	677	147.7	360
3		05/28/97	148	0.00	0.00	1.76	0.00	1.76	1.04	1.45	599	107.0	270
3		06/04/97	155	0.00	0.00	1.64	0.00	1.64	1.29	1.61	830	55.7	16
3		06/11/97	162	0.00	0.00	1.12	0.00	1.12	1.37	1.51	920	35.8	4
3		06/18/97	169	0.00	0.00	1.68	0.00	1.68	1.35	1.15	951	18.0	210
3		06/25/97	176	0.00	0.00	1.47	0.00	1.47	1.48	1.01	984	15.4	28
3		07/02/97	183	0.00	0.00	1.58	0.05	1.58	1.12	1.11	972	51.3	260
3		07/09/97	190	0.00	0.04	1.44	0.00	1.48	0.93	0.84	992	42.1	58
3		07/16/97	197	0.00	0.05	1.33	0.00	1.38	0.91	1.10	995	36.6	33
4		03/22/97	81	0.00	0.11	0.85	0.13	0.96	0.14	0.22	1059	18.5	
4		03/23/97	82	0.00	0.13	0.69	0.19	0.82	0.21	0.26	967	4.9	42
4		03/25/97	84	0.04	0.83	1.53	0.33	2.41	0.35	0.45	173	24.2	20
4		03/26/97	85	0.05	0.92	1.41	0.27	2.38	0.31	0.39	156	27.9	8
4		03/27/97	86	0.07	2.09	1.51	0.26	3.67	0.52	0.53	224	26.5	
4	D	03/28/97	87	0.05	1.23	1.99	0.29	3.27	0.59	0.76	255	31.1	
4	D	03/28/97	87	0.04	1.23	1.59	0.25	2.86	0.55	0.65	254	32.1	
4		03/29/97	88	0.00	0.97	1.93	0.30	2.90	0.43	0.73	269	24.3	
4		03/30/97	89	0.00	1.22	1.58	0.17	2.80	0.55	0.48	186	57.2	10
4		03/31/97	90	0.04	1.23	1.59	0.15	2.86	0.33	0.45	169	69.1	18
4		04/01/97	91	0.04	1.26	1.82	0.16	3.12	0.30	0.46	177	79.4	17
4		04/02/97	92	0.10	1.41	1.77	0.17	3.28	0.32	0.47	189	69.2	18
4		04/03/97	93	0.00	1.31	1.65	0.09	2.96	0.31	0.43	213	77.8	8
4	D	04/04/97	94	0.08	1.48	1.77	0.21	3.32	0.39	0.54	213	74.8	
4	D	04/04/97	94	0.08	1.44	1.77	0.20	3.29	0.37	0.52	214	67.6	
4		04/09/97	99	0.00	0.63	2.02	0.27	2.65	0.20	0.33	397	103.5	280
4	D	04/13/97	103	0.00	0.34	1.94	0.15	2.28	0.25	0.67	280	342.4	45
4	D	04/13/97	103	0.00	0.37	2.33	0.17	2.70	0.33	0.66	302	352.4	62
4		04/14/97	104	0.00	0.50	0.91	0.20	1.41	0.40	0.60	295	179.7	46
4		04/15/97	105	0.00	0.43	1.45	0.11	1.88	0.31	0.55	215	99.0	49

Site	Du	Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L	Coliform /100mL
4		04/16/97	106	0.04	0.23	1.54	0.10	1.81	0.28	0.51	182	89.2	10
4		04/17/97	107	0.00	0.14	1.54	0.06	1.68	0.25	0.40	229	75.6	29
4		04/18/97	108	0.00	0.16	1.34	0.04	1.50	0.20	0.39	201	65.5	
4		04/23/97	113	0.00	0.10	1.26	0.10	1.36	0.16	0.30	497	88.3	2
4		04/30/97	120	0.00	0.00	0.97	0.00	0.97	0.10	0.24	677	57.0	16
4	D	05/07/97	127	0.00	0.00	0.76	0.00	0.76	0.05	0.11	907	14.1	20
4	D	05/07/97	127	0.00	0.00	0.84	0.00	0.84	0.05	0.12	911	12.6	22
4		05/14/97	134	0.00	0.00	1.55	0.00	1.55	0.07	0.23	735	51.0	46
4		05/21/97	141	0.00	0.00	0.93	0.00	0.93	0.05	0.15	615	51.7	190
4		05/27/97	147	0.00	0.00	1.04	0.00	1.04	0.06	0.15	846	62.7	200
4		05/28/97	148	0.00	0.00	1.45	0.00	1.45	0.11	0.25	899	117.2	180
4		06/04/97	155	0.00	0.00	1.03	0.00	1.03	0.11	0.22	724	47.0	65
4		06/11/97	162	0.00	0.00	0.63	0.00	0.63	0.09	0.15	615	59.3	94
4		06/18/97	169	0.00	0.00	1.31	0.00	1.31	0.20	0.25	684	65.6	290
4		06/25/97	176	0.00	0.00	0.57	0.00	0.57	0.06	0.11	433	37.8	164
4		07/02/97	183	0.00	0.00	0.49	0.00	0.49	0.05	0.10	423	44.4	3300
4		07/09/97	190	0.00	0.00	0.49	0.00	0.49	0.03	0.08	341	21.0	350
4		07/16/97	197	0.00	0.00	0.31	0.00	0.31	0.04	0.08	342	34.1	750
4		07/23/97	204	0.00	0.05	0.35	0.00	0.40	0.00	0.04	297	5.3	370
4		07/30/97	211	0.00	0.00	0.40	0.00	0.40	0.01	0.07	274	16.3	420
4		08/06/97	218	0.00	0.00	0.30	0.00	0.30	0.01	0.06	226	11.8	270
4		08/13/97	225	0.00	0.00	0.30	0.00	0.30	0.00	0.05	254	1.1	290
4	S	08/20/97	232	0.00	0.00	0.33	0.08	0.33	0.01	0.01	237	8.8	280
4	S	08/20/97	232	0.00	0.00	0.29	0.00	0.29	0.02	0.04	234	11.2	32
4		08/27/97	239	0.00	0.00	0.34	0.00	0.34	0.01	0.03	238	13.5	320
4		09/03/97	246	0.00	0.00	0.40	0.00	0.40	0.00	0.01	254	15.2	310
4		09/10/97	253	0.00	0.00	0.28	0.00	0.28	0.00	0.04	292	14.9	270
4		09/17/97	260	0.00	0.00	0.35	0.00	0.35	0.00	0.04	289	18.2	180
4		09/24/97	267	0.00	0.00	0.14	0.00	0.14	0.02	0.03	305	19.6	130
4		10/01/97	274	0.00	0.00	0.35	0.00	0.35	0.02	0.03	300	28.3	80
4		10/08/97	281	0.00	0.00	0.38	0.00	0.38	0.01	0.05	578	25.7	42
4		10/15/97	288	0.00	0.00	0.46	0.00	0.46	0.01	0.05	1034	3.8	4
4		10/22/97	295	0.00	0.00	0.42	0.00	0.42	0.02	0.04	1145	5.0	7
4		10/29/97	302	0.00	0.00	0.43	0.00	0.43	0.01	0.03	1284	0.4	2
15		04/02/97	92	0.00	0.34	0.98	0.12	1.32	0.14	0.23	108	38.9	1
15		04/03/97	93	0.00	0.41	1.15	0.04	1.56	0.21	0.41	91	235.8	1
15		04/16/97	106	0.04	0.44	1.47	0.56	1.95	0.12	0.30	117	118.3	2
15		04/30/97	120	0.00	0.00	1.57	0.00	1.57	0.09	0.25	175	33.2	2
15		05/14/97	134	0.00	0.00	1.10	0.02	1.10	0.04	0.18	604	83.4	42
15		05/21/97	141	0.00	0.05	0.75	0.00	0.80	0.02	0.12	402	74.8	170
15		05/27/97	147	0.07	0.29	1.51	0.06	1.87	0.20	0.25	628	84.2	160
15		05/28/97	148	0.00	0.20	1.19	0.00	1.39	0.15	0.24	801	68.9	110
15		06/04/97	155	0.00	0.00	0.76	0.00	0.76	0.10	0.16	598	26.5	42
15		06/11/97	162	0.00	0.04	0.85	0.05	0.89	0.09	0.16	551	53.7	23
15		06/18/97	169	0.00	0.00	1.10	0.04	1.10	0.15	0.25	541	67.8	
15	S	06/25/97	176	0.00	0.00	0.76	0.00	0.76	0.02	0.11	411	88.8	
15	S	06/25/97	176	0.00	0.00	0.62	0.00	0.62	0.02	0.09	406	66.9	60

Site	Du	Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L	Coliform /100mL
15		07/02/97	183	0.00	0.00	0.44	0.00	0.44	0.03	0.07	338	43.0	28
15		07/09/97	190	0.00	0.00	0.42	0.00	0.42	0.03	0.05	281	21.1	64
15		07/16/97	197	0.00	0.04	0.25	0.00	0.29	0.39	0.05	252	42.3	110
15		07/23/97	204	0.00	0.04	0.25	0.00	0.29	0.00	0.03	223	25.3	50
15		07/30/97	211	0.00	0.00	0.29	0.00	0.29	0.00	0.05	215	19.9	450
15		08/06/97	218	0.00	0.00	0.29	0.00	0.29	0.00	0.02	197	9.8	52
15		08/13/97	225	0.00	0.00	0.25	0.00	0.25	0.00	0.01	198	4.7	51
15		08/20/97	232	0.00	0.00	0.32	0.09	0.32	0.01	0.00	222	4.8	110
15		08/27/97	239	0.00	0.00	0.34	0.00	0.34	0.00	0.03	195	2.9	120
15	S	09/03/97	246	0.00	0.00	0.36	0.00	0.36	0.00	0.00	215	4.5	
15	S	09/03/97	246	0.00	0.00	0.38	0.00	0.38	0.00	0.01	215	4.8	130
15		09/10/97	253	0.00	0.00	0.33	0.00	0.33	0.00	0.03	243	8.2	230
15		09/17/97	260	0.00	0.00	0.32	0.00	0.32	0.00	0.02	244	7.6	260
15		09/24/97	267	0.00	0.00	0.16	0.00	0.16	0.00	0.02	242	9.3	60
15		10/01/97	274	0.00	0.00	0.32	0.00	0.32	0.00	0.01	260	11.1	37
15		10/08/97	281	0.00	0.00	0.31	0.00	0.31	0.02	0.03	251	26.7	66
20		03/21/97	80	0.06	0.58	1.38	0.00	2.02	0.07	0.50	92	38.5	
20		03/22/97	81	0.05	0.25	1.24	0.00	1.54	0.03	0.55	97	79.9	
20		03/23/97	82	0.00	0.83	1.47	0.09	2.30	0.16	0.31	88	159.3	170
20		03/24/97	83	0.14	0.93	1.30	5.45	2.37	0.84	1.12	198	218.4	18000
20		03/25/97	84	0.05	1.38	1.57	0.28	3.00	0.25	0.42	167	185.2	15000
20		03/26/97	85	0.06	1.31	1.88	0.38	3.25	0.37	0.44	148	55.2	430
20		03/27/97	86	0.00	0.52	1.07	0.11	1.59	0.28	0.33	197	15.1	
20		03/28/97	87	0.00	0.69	1.50	0.11	2.19	0.29	0.40	174	13.4	
20		03/29/97	88	0.00	1.07	1.37	0.10	2.44	0.57	0.44	155	24.9	
20		03/30/97	89	0.04	0.91	1.47	0.10	2.42	0.40	0.45	156	35.2	46
20		03/31/97	90	0.00	0.94	1.65	0.13	2.59	0.29	0.42	166	32.9	92
20		04/01/97	91	0.00	0.88	1.63	0.09	2.51	0.27	0.38	145	40.2	29
20		04/02/97	92	0.00	0.99	1.57	0.00	2.56	0.27	0.37	185	29.9	25
20		04/03/97	93	0.00	0.75	1.42	0.05	2.17	0.28	0.37	194	26.0	40
20		04/04/97	94	0.00	0.55	1.45	0.07	2.00	0.26	0.36	196	23.5	
20		04/13/97	103	0.00	0.09	1.51	0.01	1.60	0.24	0.45	275	31.7	78
20		04/14/97	104	0.00	0.19	1.57	0.03	1.76	0.23	0.44	153	42.2	188
20		04/15/97	105	0.00	0.06	1.21	0.01	1.27	0.22	0.40	142	32.9	53
20		04/16/97	106	0.00	0.15	1.34	0.08	1.49	0.23	0.36	145	32.2	51
20		04/17/97	107	0.00	0.12	1.17	0.08	1.29	0.23	0.30	182	25.0	40
20		04/18/97	108	0.00	0.00	0.69	0.02	0.69	0.22	0.07	198	7.0	
20		04/23/97	113	0.00	0.00	1.23	0.02	1.23	0.16	0.23	502	4.7	10
20		04/30/97	120	0.00	0.00	1.45	0.00	1.45	0.17	0.25	740	3.0	150
20		05/07/97	127	0.00	0.00	1.30	0.06	1.30	0.14	0.21	1032	10.8	40
20		05/14/97	134	0.00	0.00	1.98	0.14	1.98	0.07	0.28	1305	151.2	500
20		05/21/97	141	0.00	0.05	1.36	0.00	1.41	0.13	0.20	1361	93.4	2100
20		05/27/97	147	0.00	0.00	2.47	0.08	2.47	0.19	0.35	898	32.0	400
20		05/28/97	148	0.00	0.00	2.17	0.00	2.17	0.27	0.39	898	17.2	120
20		06/04/97	155	0.00	0.00	2.73	0.00	2.73	0.54	0.85	1017	36.6	410
20		06/11/97	162	0.00	0.00	1.13	0.00	1.13	0.29	0.37	689	11.8	300
20		06/18/97	169	0.00	0.00	3.20	0.05	3.20	1.21	0.99	1068	50.5	380

Site	Du	Date	Julian	NO2-N mg/L	NO3-N mg/L	TKN mg/L	NH4 mg/L	Tot. N mg/L	PO4 mg/L	TKP mg/L	TDS mg/L	TSS mg/L	Coliform /100mL
20		06/25/97	176	0.00	0.00	0.65	0.00	0.65	0.07	0.12	451	10.8	209
20		07/02/97	183	0.00	0.00	0.43	0.00	0.43	0.05	0.07	349	3.2	320
20	D	07/09/97	190	0.00	0.00	0.42	0.00	0.42	0.04	0.07	286	2.1	1900
20	D	07/09/97	190	0.00	0.00	0.42	0.00	0.42	0.04	0.07	288	3.6	1900
20		07/16/97	197	0.00	0.00	0.29	0.00	0.29	0.12	0.05	249	3.4	1200
20		07/23/97	204	0.00	0.04	0.65	0.00	0.69	0.08	0.21	283	6.2	230
20		07/30/97	211	0.00	0.00	0.46	0.00	0.46	0.10	0.14	245	6.8	2200
20	D	08/06/97	218	0.00	0.00	0.45	0.00	0.45	0.10	0.14	257	6.9	1800
20	D	08/06/97	218	0.00	0.00	0.16	0.00	0.16	0.10	0.13	246	5.2	1800
20		08/13/97	225	0.00	0.00	0.35	0.00	0.35	0.03	0.07	235	18.0	760
20	D	08/20/97	232	0.00	0.00	0.35	0.07	0.35	0.05	0.05	245	17.8	390
20	D	08/20/97	232	0.00	0.00	0.37	0.00	0.37	0.03	0.05	246	14.8	480
20		08/27/97	239	0.00	0.00	0.41	0.00	0.41	0.01	0.05	234	42.6	1500
20		09/03/97	246	0.00	0.00	0.41	0.00	0.41	0.01	0.03	220	7.0	840
20		09/10/97	253	0.00	0.00	0.31	0.00	0.31	0.00	0.05	256	15.9	1800
20		09/17/97	260	0.00	0.00	0.39	0.00	0.39	0.02	0.04	252	16.8	1300
20	D	09/24/97	267	0.00	0.00	0.27	0.00	0.27	0.01	0.06	254	67.8	1500
20	D	09/24/97	267	0.00	0.00	0.28	0.00	0.28	0.01	0.06	249	70.4	2000
20		10/01/97	274	0.00	0.00	0.48	0.00	0.48	0.02	0.06	275	45.2	910
20		10/08/97	281	0.00	0.00	0.70	0.00	0.70	0.02	0.07	296	55.4	120
26		10/27/97	300	0.00	0.13	4.84	3.28	4.97	3.38	3.72	1405	15.4	13
26		10/27/97	300	0.00	0.11	4.63	3.25	4.74	3.38	3.70	1393	0.9	13
26		10/28/97	301	0.05	0.14	5.03	3.32	5.21	3.28	3.85	1338	2.4	7
26		10/28/97	301	0.00	0.10	4.50	3.31	4.60	3.36	3.54	1402	0.2	3
26		10/29/97	302	0.05	0.12	4.89	3.47	5.06	3.29	3.55	1340	0.0	26
26		10/29/97	302	0.05	0.12	4.89	3.43	5.06	3.33	3.65	1350	0.1	2
26		10/30/97	303	0.04	0.09	4.91	3.63	5.04	3.22	3.60	1332	0.6	68
26		10/30/97	303	0.12	0.12	4.48	3.25	4.72	3.49	4.26	1338	162.0	60
26		10/31/97	304	0.08	0.08	3.03	3.29	3.19	3.60	3.66	1346	24.6	30

APPENDIX G: JULIAN DAY - DATE CONVERSION

1996

Date	Julian	Date	Julian	Date	Julian	Date	Julian
07/01/96	183	08/01/96	214	09/01/96	245	10/01/96	275
07/02/96	184	08/02/96	215	09/02/96	246	10/02/96	276
07/03/96	185	08/03/96	216	09/03/96	247	10/03/96	277
07/04/96	186	08/04/96	217	09/04/96	248	10/04/96	278
07/05/96	187	08/05/96	218	09/05/96	249	10/05/96	279
07/06/96	188	08/06/96	219	09/06/96	250	10/06/96	280
07/07/96	189	08/07/96	220	09/07/96	251	10/07/96	281
07/08/96	190	08/08/96	221	09/08/96	252	10/08/96	282
07/09/96	191	08/09/96	222	09/09/96	253	10/09/96	283
07/10/96	192	08/10/96	223	09/10/96	254	10/10/96	284
07/11/96	193	08/11/96	224	09/11/96	255	10/11/96	285
07/12/96	194	08/12/96	225	09/12/96	256	10/12/96	286
07/13/96	195	08/13/96	226	09/13/96	257	10/13/96	287
07/14/96	196	08/14/96	227	09/14/96	258	10/14/96	288
07/15/96	197	08/15/96	228	09/15/96	259	10/15/96	289
07/16/96	198	08/16/96	229	09/16/96	260	10/16/96	290
07/17/96	199	08/17/96	230	09/17/96	261	10/17/96	291
07/18/96	200	08/18/96	231	09/18/96	262	10/18/96	292
07/19/96	201	08/19/96	232	09/19/96	263	10/19/96	293
07/20/96	202	08/20/96	233	09/20/96	264	10/20/96	294
07/21/96	203	08/21/96	234	09/21/96	265	10/21/96	295
07/22/96	204	08/22/96	235	09/22/96	266	10/22/96	296
07/23/96	205	08/23/96	236	09/23/96	267	10/23/96	297
07/24/96	206	08/24/96	237	09/24/96	268	10/24/96	298
07/25/96	207	08/25/96	238	09/25/96	269	10/25/96	299
07/26/96	208	08/26/96	239	09/26/96	270	10/26/96	300
07/27/96	209	08/27/96	240	09/27/96	271	10/27/96	301
07/28/96	210	08/28/96	241	09/28/96	272	10/28/96	302
07/29/96	211	08/29/96	242	09/29/96	273	10/29/96	303
07/30/96	212	08/30/96	243	09/30/96	274	10/30/96	304
07/31/96	213	08/31/96	244			10/31/96	305

1997

Date	Julian	Date	Julian	Date	Julian	Date	Julian
03/01/97	60	04/01/97	91	05/01/97	121	06/01/97	152
03/02/97	61	04/02/97	92	05/02/97	122	06/02/97	153
03/03/97	62	04/03/97	93	05/03/97	123	06/03/97	154
03/04/97	63	04/04/97	94	05/04/97	124	06/04/97	155
03/05/97	64	04/05/97	95	05/05/97	125	06/05/97	156
03/06/97	65	04/06/97	96	05/06/97	126	06/06/97	157
03/07/97	66	04/07/97	97	05/07/97	127	06/07/97	158
03/08/97	67	04/08/97	98	05/08/97	128	06/08/97	159
03/09/97	68	04/09/97	99	05/09/97	129	06/09/97	160
03/10/97	69	04/10/97	100	05/10/97	130	06/10/97	161
03/11/97	70	04/11/97	101	05/11/97	131	06/11/97	162
03/12/97	71	04/12/97	102	05/12/97	132	06/12/97	163
03/13/97	72	04/13/97	103	05/13/97	133	06/13/97	164
03/14/97	73	04/14/97	104	05/14/97	134	06/14/97	165
03/15/97	74	04/15/97	105	05/15/97	135	06/15/97	166
03/16/97	75	04/16/97	106	05/16/97	136	06/16/97	167
03/17/97	76	04/17/97	107	05/17/97	137	06/17/97	168
03/18/97	77	04/18/97	108	05/18/97	138	06/18/97	169
03/19/97	78	04/19/97	109	05/19/97	139	06/19/97	170
03/20/97	79	04/20/97	110	05/20/97	140	06/20/97	171
03/21/97	80	04/21/97	111	05/21/97	141	06/21/97	172
03/22/97	81	04/22/97	112	05/22/97	142	06/22/97	173
03/23/97	82	04/23/97	113	05/23/97	143	06/23/97	174
03/24/97	83	04/24/97	114	05/24/97	144	06/24/97	175
03/25/97	84	04/25/97	115	05/25/97	145	06/25/97	176
03/26/97	85	04/26/97	116	05/26/97	146	06/26/97	177
03/27/97	86	04/27/97	117	05/27/97	147	06/27/97	178
03/28/97	87	04/28/97	118	05/28/97	148	06/28/97	179
03/29/97	88	04/29/97	119	05/29/97	149	06/29/97	180
03/30/97	89	04/30/97	120	05/30/97	150	06/30/97	181
03/31/97	90			05/31/97	151		

1997 ctd -:

Date	Julian	Date	Julian	Date	Julian	Date	Julian
07/01/97	182	08/01/97	213	09/01/97	244	10/01/97	274
07/02/97	183	08/02/97	214	09/02/97	245	10/02/97	275
07/03/97	184	08/03/97	215	09/03/97	246	10/03/97	276
07/04/97	185	08/04/97	216	09/04/97	247	10/04/97	277
07/05/97	186	08/05/97	217	09/05/97	248	10/05/97	278
07/06/97	187	08/06/97	218	09/06/97	249	10/06/97	279
07/07/97	188	08/07/97	219	09/07/97	250	10/07/97	280
07/08/97	189	08/08/97	220	09/08/97	251	10/08/97	281
07/09/97	190	08/09/97	221	09/09/97	252	10/09/97	282
07/10/97	191	08/10/97	222	09/10/97	253	10/10/97	283
07/11/97	192	08/11/97	223	09/11/97	254	10/11/97	284
07/12/97	193	08/12/97	224	09/12/97	255	10/12/97	285
07/13/97	194	08/13/97	225	09/13/97	256	10/13/97	286
07/14/97	195	08/14/97	226	09/14/97	257	10/14/97	287
07/15/97	196	08/15/97	227	09/15/97	258	10/15/97	288
07/16/97	197	08/16/97	228	09/16/97	259	10/16/97	289
07/17/97	198	08/17/97	229	09/17/97	260	10/17/97	290
07/18/97	199	08/18/97	230	09/18/97	261	10/18/97	291
07/19/97	200	08/19/97	231	09/19/97	262	10/19/97	292
07/20/97	201	08/20/97	232	09/20/97	263	10/20/97	293
07/21/97	202	08/21/97	233	09/21/97	264	10/21/97	294
07/22/97	203	08/22/97	234	09/22/97	265	10/22/97	295
07/23/97	204	08/23/97	235	09/23/97	266	10/23/97	296
07/24/97	205	08/24/97	236	09/24/97	267	10/24/97	297
07/25/97	206	08/25/97	237	09/25/97	268	10/25/97	298
07/26/97	207	08/26/97	238	09/26/97	269	10/26/97	299
07/27/97	208	08/27/97	239	09/27/97	270	10/27/97	300
07/28/97	209	08/28/97	240	09/28/97	271	10/28/97	301
07/29/97	210	08/29/97	241	09/29/97	272	10/29/97	302
07/30/97	211	08/30/97	242	09/30/97	273	10/30/97	303
07/31/97	212	08/31/97	243			10/31/97	304

APPENDIX H: Analysis Methods for TDS Components

As mentioned in section 3.3 a value for total dissolved solids in a water sample was determined using the following equation:

$$TDS = Ca + Mg + Na + K + Cl + SO_4 + (0.6 * (HCO_3 + CO_3)) + (4.43 * NO_3\text{-}N)$$

Table H1 outlines the laboratory methods used to obtain values for the components used to determine total dissolved solids.

Table H1 Laboratory analysis methods for TDS components

Parameter	Analysis Method (Greenberg and Others 1992)
Ca	Atomic Absorption Spectrometric Method
Mg	Atomic Absorption Spectrometric Method
Na	Flame Emission Photometric Method
K	Flame Photometric Method
Cl	Automated Ferricyanide Method
SO_4	Turbidimetric Method
HCO_3+CO_3	Titration Method for Alkalinity
NO_3-N	Automated Hydrazine Reduction Method