EFFECTS OF WASTEWATER EFFLUENT DISCHARGES ON THE WATER QUALITY OF THE BEAVER RIVER

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EXECUTIVE SUMMARY

Water quality surveys were conducted in the Beaver River in fall 1991 and in spring 1993 to 1) describe the effects of the spring and fall discharges from the Cold Lake/Grand Centre Regional Sewage System (CL/GC-RSS) and from the continuous treated municipal wastewater discharges from the Canadian Force Base-Cold Lake (CFB-WW); and 2) determine if the long-term PPWB monitoring site at Beaver Crossing is representative of the Beaver River water quality that enters Saskatchewan.

Water quality samples were collected during each of 14 surveys (8 in fall 1991, 6 in spring 1993) from four sites on the Beaver River (Ardmore, Beaver Crossing, Cherry Grove, Pierceland) and from three effluents (CL/GC-RSS, CFB-WW and CFB-SS a storm sewer on the Base).

As a result of the different treatment processes there were qualitative differences between the two municipal wastewater effluents and the quality of the CL/GC-RSS was generally inferior in spring. Phosphorus and nitrogen concentrations were consistently much higher in the wastewater effluents than in the Beaver River. Oxidized forms of nitrogen prevailed in the CFB-WW, whereas reduced forms of nitrogen prevailed in CL/GC-RSS. Bacteria counts were very low in the disinfected effluent from CFB-WW, but in spring they were high in the CL/GC-RSS. In fall, vanadium, chromium, cobalt, nickel, molybdenum cadmium, and arsenic were elevated in the CL/GC-RSS effluent. In the CFB-SS effluent zinc and copper were elevated in both spring and fall and high bacterial counts typified spring samples.

Concentrations of phosphorus, all forms of nitrogen, some major ions and associated variables, copper and arsenic were higher at the three Beaver River sites downstream of effluents than at Ardmore, the upstream site. Despite the poorer CL/GC-RSS effluent quality in spring, changes in Beaver River constituent concentrations were most noticeable in fall 1991 because river flows were exceptionally low. These low river flows are a result of the drought which has affected east central Alberta since the mid-1980's.

Concentration of many constituents did not meet Prairie Provinces Water Board Objectives, Alberta Interim Ambient Surface Water Quality Guidelines or Canadian Water Quality Guidelines in the Beaver River. For some (copper, chromium, total phosphorus and total nitrogen), non-compliance started or increased in frequency at Beaver Crossing, downstream of the discharges from the Canadian Forces Base. For others, (manganese, total nitrogen, total coliforms) non-compliance increased downstream of the CL/GC-RSS outfall. That effluent also contributed to the continued non-compliance of total phosphorus in the Beaver River. For other constituents (cadmium, iron, dissolved oxygen) non-compliance reflected natural background levels.

Flow frequency analysis indicated that flows in the Beaver River were exceptionally low during the fall 1991 surveys (October, November: 1 in 125 and 1 in 200 year low flows, respectively) and during the spring surveys (April, May: 1 in 24 and 1 in 11 year low flows, respectively). Under current effluent loads and average flow conditions non-compliance with water quality guidelines due to effluent discharges would be infrequent. Since low river flows are due to a local drought which in turn is due to unpredictable weather patterns, it is not known when or for how long average flow conditions will return in the Beaver River.

In order to ensure that data from the long-term PPWB monitoring site represent at all times of the year and under all flow conditions the quality of the Beaver River as it enters Saskatchewan, it would be advisable to move the monitoring site downstream of the CL/GC-RSS outfall. This advice is based on the following facts: 1) During the discharge of GL/GC-RSS wastewater, differences in Beaver River quality are quite noticeable between Beaver Crossing and sites downstream of the outfall, especially at low river flow; 2) CL/GC-RSS discharges often coincide with a PPWB sampling event. When this occurs, the PPWB data at Beaver Crossing misrepresent Beaver River water quality at Cherry Grove to a degree which depends upon the river's dilution capacity at that time; and 3) The Regional Planning Commission is currently planning the expansion of GL/GC-RSS to accommodate further population growth in the area. The wastewater load to the Beaver River is likely to increase and the timing of discharge could change.

ACKNOWLEDGEMENTS

Corporal Gary Delani and Sergeant Dave Hawkins from the Canadian Forces Base Cold Lake and Mr. Jim Wilder from the Cold Lake/Grand Centre Regional Sewage System facilitated the sampling of effluents by providing access to the sites and by keeping us informed of scheduled discharge dates.

Water quality sampling was carried out by Mike Bilyk, John Willis, Dave Allan, Doreen LeClair, and Treva Mailer. Water samples were analyzed at the Alberta Environmental Centre (Drs. F. Dieken and D. Smillie), the Alberta Provincial Laboratory of Public Health and the Millwoods facility of the Technical Services and Monitoring Division.

Andy DeBoer (Surface Water Assessment Branch) computed a discharge versus mean velocity relationship, provided an estimate of travel time and conducted a flow frequency analysis.

Bridgette Halbig provided technical support in the preparation of the report.

The report was reviewed by R. Bothe and D.O. Trew.

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1.0 INTRODUCTION

The Prairie Provinces Water Board (PPWB) has monitored the quality of the Beaver River at Highway #28 near Beaver Crossing on a monthly basis since 1974 (Figure 1). Because there were no known point source effluents between the long-term monitoring site and the Alberta/Saskatchewan border, data from the long-term site were expected to represent water quality of the Beaver River as it entered Saskatchewan.

The Canadian Force Base-Cold Lake has an extended aeration, secondary treatment plant (CFB-WW). It discharges treated and gas-chlorinated wastewater continuously (0.03 m^3/s) to Marie Creek which enters the Beaver River upstream of the long-term monitoring site. The base also has intermittent discharges of surface runoff to the creek via storm sewers. At least one of these storm sewers (CFB-SS) which discharges runoff into Marie Creek just upstream of the CFB-WW outfall, also drains hangars where planes are maintained and washed. Until 1984, the towns of Cold Lake and Grand Centre also discharged their wastewater into Marie Creek. In November 1984 the Cold Lake/Grand Centre Regional Sewage System (CL/GC-RSS) began discharging to the Beaver River, about 3 km downstream of the long-term monitoring site. The treatment system is a multi-cell, combination anaerobic/facultative lagoon system. Wastewater is discharged twice a year, in spring (April-May) and in fall (October-November), at a constant rate (0.17 m^3/s) during approximately 14 days.

In November 1987 a sampling program was conducted on the Beaver River during the discharges of CL/GC-RSS to determine the effects of the discharges on Beaver River water quality and to assess the validity of the long-term monitoring site as an indicator of water quality at the Alberta/Saskatchewan border. Flows in the Beaver River averaged 2.39 m^3/s in November 1987 (Environment Canada 1988). The study concluded that during the wastewater discharges increases in nutrient levels (N and P) at the border were small and did not justify moving the long-term monitoring site (Nelson 1988).

Since 1987 the towns of Cold Lake and Grand Centre have expanded slightly. As a result of drought conditions which have plagued eastern-central Alberta since the mid-1980's, flows and dilution capacity of the Beaver River have declined.

These changes justified the need to re-evaluate the effects of wastewater discharges on Beaver River water quality. Because wastewater effluent and river water quality vary over time, surveys were conducted in both seasons when municipal discharges occur.

Specific objectives were:

1) to describe effects of continuous and intermittent discharges of wastewater on Beaver River water quality in fall 1991 and spring 1993; and

2) to determine if, during the discharge of municipal wastewater, the long-term PPWB monitoring site at Beaver Crossing represents the quality of Beaver River water as it enters Saskatchewan.

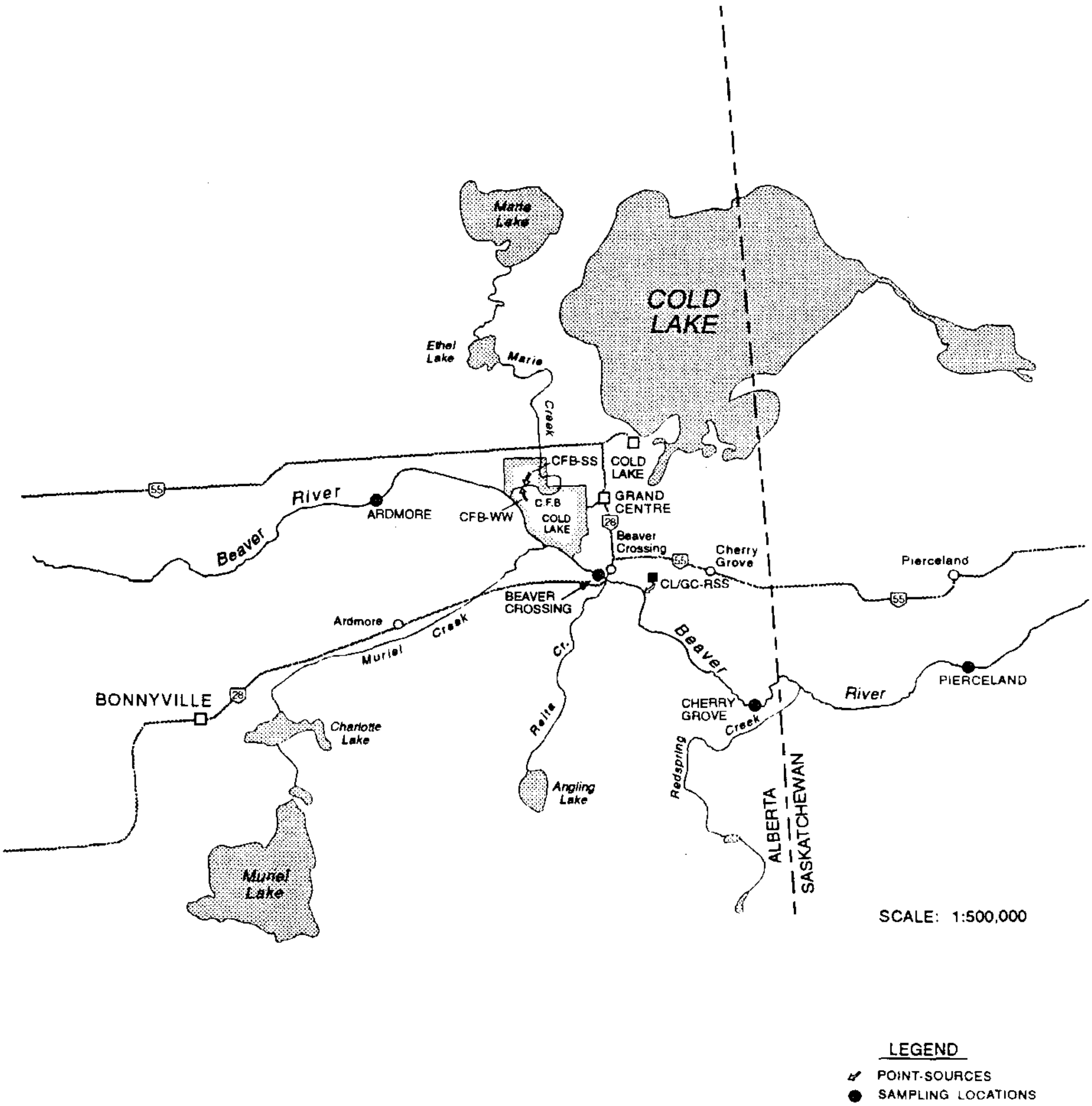


FIGURE 1. MAP OF THE BEAVER RIVER SHOWING RELATIVE LOCATION OF POINT-SOURCES AND SAMPLING LOCATIONS IN FALL 1991 AND SPRING 1993.

2.0 METHODS

2.1 FIELD METHODS

The four sampling sites on the Beaver River and the three effluents sampled in 1991 and 1993 are described in Table 1. The sampling schedule is summarized in Table 2.

2.2 LABORATORY METHODS

Water samples were processed by the Water Analysis and Research Branch, Alberta Environmental Centre, Vegreville.

Chlorophyll *a* was measured at the Technical Services and Monitoring Division field laboratory in Edmonton.

Bacterial samples were analyzed by the Provincial Laboratory of Public Health in Edmonton.

Table 3 lists water quality variables for which these samples were analyzed.

2.3 DATA ANALYSIS

Longitudinal changes in constituent concentration over successive surveys are presented in graphs which were inspected visually.

The Wilcoxon signed-rank test (Sokal and Rohlf 1969) was used to compare constituent concentrations measured at Beaver Crossing with those measured at the Cherry Grove site and at Pierceland.

For selected contaminants, in-stream concentrations were compared with concentrations predicted from effluent loads and in-stream loads at the upstream sampling site. The following formula were used in the calculations:

$$[\text{Beaver Crossing}_{\text{predicted}}] = \{[\text{Ardmore}_{\text{measured}}] \times (Q_{\text{dBeaver Crossing}} - \bar{Q}_{\text{CFB-WW}} - \bar{Q}_{\text{CFB-SS}}) + [\text{CFB-WW}_{\text{measured}}] \times \bar{Q}_{\text{CFB-WW}} + [\text{CFB-SS}_{\text{measured}}] \times \bar{Q}_{\text{CFB-SS}}\} / Q_{\text{dBeaver Crossing}}$$

$$[\text{Cherry Grove}_{\text{predicted}}] = \{[\text{Beaver Crossing}_{\text{measured}}] \times Q_{\text{dBeaver Crossing}} + [\text{CL/GC-RSS}_{\text{measured}}] \times \bar{Q}_{\text{CL/GC-RSS}}]\} / (Q_{\text{dBeaver Crossing}} + \bar{Q}_{\text{CL/GC-RSS}})$$

with [...] = concentration in mg/L
Qd = daily discharge in m^3/s
$\bar{Q}$ = average discharge in m^3/s

Note: $Q_{\text{dBeaver Crossing}}$ is actual discharge on a given day
$\bar{Q}_{\text{CFB-WW}}$ is average of daily discharges measured during the survey
$\bar{Q}_{\text{CFB-SS}}$ estimated average discharge

Table 1. List of Beaver River sites and effluents sampled in fall 1991 and spring 1993.

SITE NAME	NAQUADAT CODE	LOCATION
Beaver River at **Ardmore** - 3 point composite[1] - right bank[2] - centre channel[2,3] - left bank[2]	- 00AL06AC3490 - 00AL06AC3491 - 00AL06AC3500 - 00AL06AC3505	26.6 km u/s of Beaver Crossing and 13.2 km u/s of confluence with Marie Creek
Beaver River at Highway #28 Bridge near **Beaver Crossing** - 3 point composite[1] - right bank[2] - centre channel[2,3] - left bank[2]	- 00AL06AD3990 - 00AL06AD3991 - 00AL06AD4000 - 00AL06AD4005	13.4 km d/s Marie Creek confluence and 3.3 km u/s of CL/GC-RSS outfall
Beaver River at Gravel Pit near AB/Sask. **Cherry Grove** - 3 point composite[1] - right bank[2] - centre channel[2,3] - left bank[2]	- 00AL06AD4990 - 00AL06AD4991 - 00AL06AD5000 - 00AL06AD5005	21 km d/s of CL/GC-RSS outfall; 5.6 km u/s of AB/Sask. border
Beaver River at **Pierceland**, Sask. - 3 point composite[1] - right bank[2] - centre channel[2,3] - left bank[2]	- 00SA06AD0990 - 00SA06AD0991 - 00SA06AD1000 - 00SA06AD1005	51.6 km d/s of CL/GC-RSS outfall; 25 km d/s AB/Sask. border
Canadian Forces Base - Cold Lake storm sewer effluent at Marie Creek[1,2,3] (CFB-SS)	- 23AL06AC1000	
Canadian Forces Base - Cold Lake wastewater effluent at Marie Creek[1,2,3] (CFB-WW)	- 21AL06AC0500	
Cold Lake/Grand Centre Regional Sewage System outfall to Beaver River[1,2,3] (CL/GC-RSS)	- 21AL06AD4600	

1. Water chemistry
2. Field measurement
3. Bacteria

Table 2. Summary of sample collections carried out in fall 1991 and spring 1993.

SITE	COMPOSITE GRAB [1]	RIGHT BANK[2]	CENTRE [2,3]	LEFT BANK[2]	GRAB[1,2,3]
Ardmore	✓	✓	✓	✓	
Beaver Crossing	✓	✓	✓	✓	
Cherry Grove	✓	✓	✓	✓	
Pierceland	✓	✓	✓	✓	
CL/GC-RSS					✓
CFB-Cold Lake Wastewater					✓
CFB-Cold Lake Storm Sewer					✓[4]

1. Composite of equal volumes of water taken from left bank, right bank and centre channel or grab sample and analyzed for constituents listed in Table 3.
2. Field measurements of pH, temperature, conductivity and dissolved oxygen
3. Surface grab samples for bacterial counts
4. Hydrocarbons, extractable priority pollutants

Sampling dates: 1991: Oct 30, 31, Nov. 4, 5, 6, 7, 12, 13 and 19
1993: Apr 21, 29, May 5, 12, 19, and 26

Table 3. List of water quality variables.

VARIABLE NAME	ABBREVIATION	NAQUADAT CODE	UNITS(1)
Carbon, diss. organic	DOC	06101 L	
Carbon, diss. inorganic	DIC	06151 L	
Carbon, particulate	PC	06154 L	
Nitrogen, particulate	PN	07906 L	
Total phosphorus	TP	15421 L	
Diss. phosphorus	Diss. P	15101 L	
Total Kjeldahl nitrogen	TKN	07015 L	
Diss. ammonia	NH_3-N	07561 L	
Diss. nitrate+nitrite	(NO_2+NO_3)-N	07111 L	
Diss. nitrite	NO_2-N	07205 L	
Biochemical oxygen demand	BOD	08201 L	
Non-filterable residue	NFR	10401 L	
Turbidity		02074 L	NTU
Phenol		06536 L	
pH		10301 L	
Conductivity		02041 L	µS/cm
Total dissolved solids	TDS	00205 L	
Calcium	Ca	20105 L	
Magnesium	Mg	12102 L	
Total $CaCO_3$ hardness		10603 L	
Sodium	Na	11101 L	
Potassium	K	19101 L	
Fluoride	F	19107 L	
Sulphate	SO_4	16305 L	
Chloride	Cl	17201 L	
Reactive silica	SiO_2	14107 L	
Alkalinity, total	T. Alk	10101 L	
Bicarbonate	HCO_3^-	06202 L	
Chlorophyll *a*	Chl *a*	6715 L	mg/m^3
Aluminum, extr.	Al	13030 L	
Vanadium, total	V	23001 L	
Chromium, total	Cr	24004 L	
Manganese, total	Mn	25001 L	
Iron, total	Fe	26009 L	
Cobalt, total	Co	27009 L	
Nickel, total	Ni	28007 L	
Copper, total	Cu	29003 L	
Zinc, total	Zn	30030 L	
Molybdenum, total	Mo	42001 L	
Cadmium, total	Cd	48002 L	
Barium, total	Ba	56001 L	
Arsenic, total	As	33001 L	
Arsenic, diss.	As	33101 L	
Lead, extr.	Pb	82301 L	
Beryllium, diss.	Be	04101 L	
Selenium, total	Se	34003 L	
Mercury, total	Hg	8002 L	
Temperature	T	02061 F	°C
pH		10301 F	pH units
Conductivity		02041 F	µS/cm
Oxygen (meter)	DO	08101 F	
Oxygen (Winkler)	DO	08101 L	
Coliform, total		36001 L	No. per 100 mL
Coliform, fecal		36011 L	No. per 100 mL
Fecal Strep.		36101 L	No. per 100 mL

(1) Units are mg/L unless stated otherwise

Travel time was taken into consideration by choosing dates and corresponding sample data which matched predicted travel time as closely as possible (see Section 3.2). Note that in this simple steady state model, predicted concentration at Pierceland is the same as that predicted for the Cherry Grove site.

In-stream concentrations were compared with PPWB objectives (PPWBO, PPWB 1990), Alberta Surface Water Quality Interim Guidelines (ASWQG, Alberta Environment 1993) and Canadian Water Quality Guidelines (CWQG, CCREM 1987).

3.0 HYDROLOGICAL FEATURES

3.1 RIVER FLOWS AND EFFLUENT DILUTION

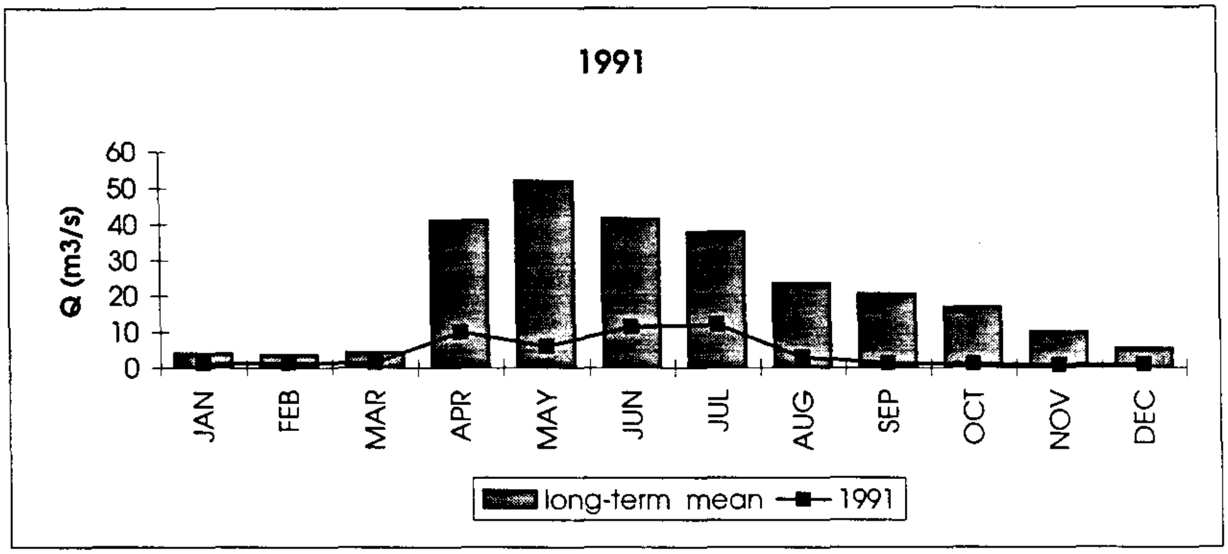
The quantity of water flowing in a river when effluent is discharged determines the degree of dilution and influences changes in the quality of the receiving stream. Stream flow varies from day-to-day, season-to-season and year-to-year and this variability must be taken into account when effects from effluent discharges on in-stream water quality are assessed.

Discharge in the Beaver River tends to peak in April and May as a result of snow melt and local runoff; it declines gradually over the open-water season and reaches a minimum in February (Figure 2). Spring discharges from the CL/GC-RSS generally coincide with high river flows in April and May, whereas in fall the effluent discharges occur in late October-November at much lower river flows. In 1991 average daily river discharge for November was 0.730 m^3/s; in 1993 average daily river discharge in May was 6.76 m^3/s. During the effluent release, daily river discharge ranged from 0.551 to 0.891 m^3/s in fall 1991 and from 4.55 to 10.0 in spring 1993 (Environment Canada (1992, 1994). These daily river discharge fluctuations imply that at a constant effluent release rate of 0.17 m^3/s, effluent dilution in the Beaver River ranged from 1:3 to 1:5 in fall 1991 and from 1:27 to 1:59 in spring 1993.

Discharge in the Beaver River fluctuates naturally from year to year, but as a consequence of the drought in the eastern part of the province, average annual discharge has dropped steadily since the early 1980's (Figure 3). The degree of impact from wastewater effluent discharges on water quality can be expected to change as river flows and the river's dilution capacity change over the years. It is important to note that all water quality surveys conducted on the Beaver River to measure the effects of wastewater discharges have been carried out in the last 10 years at lower than average river discharge. Consequently, and assuming higher flows return (see section 4.5), measured effects can be expected to be greater than 'average'.

3.2 TRAVEL TIME

A discharge versus mean velocity relationship was computed by the Hydrology Section (Surface Water Assessment Branch, Technical Services and Monitoring Division) from data presented in Environment Canada (1977). For a given discharge, the computed mean velocity was assumed to be applicable to the entire study reach. The discharge and velocity estimates are given in Table 4 for 2 dates during the fall 1991 and spring 1993 effluent release period. Travel time estimates are presented in Table 5.



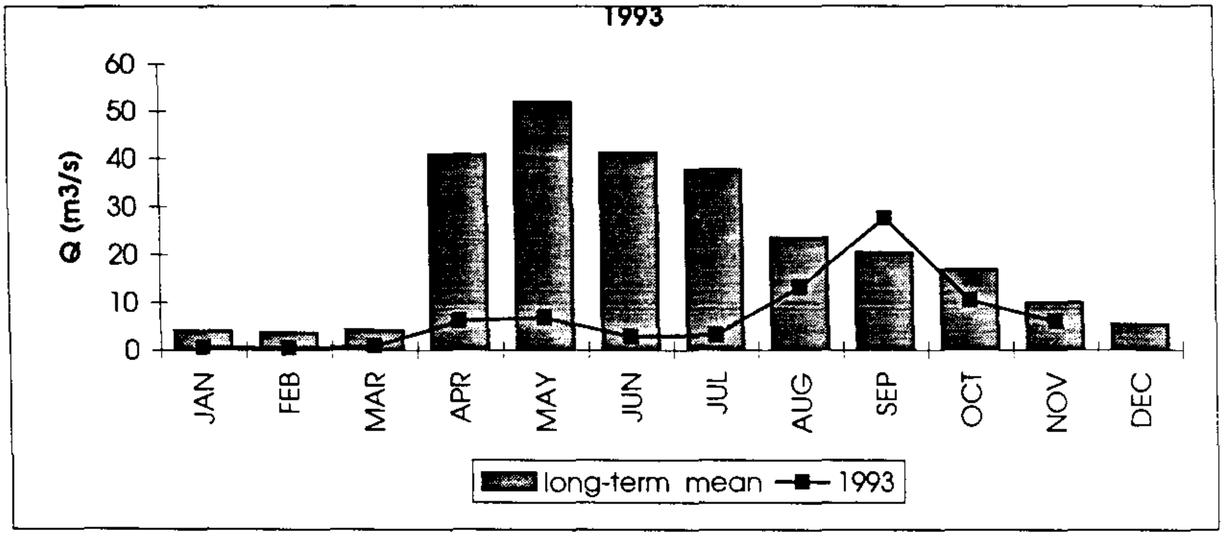


Figure 2. Comparison of long-term (1956-1990) mean monthly discharge in the Beaver River (Cold Lake Reserve - Station No. 06AD006) with mean daily discharge per month in 1991 and 1993
Source: Environment Canada (1992-1993)

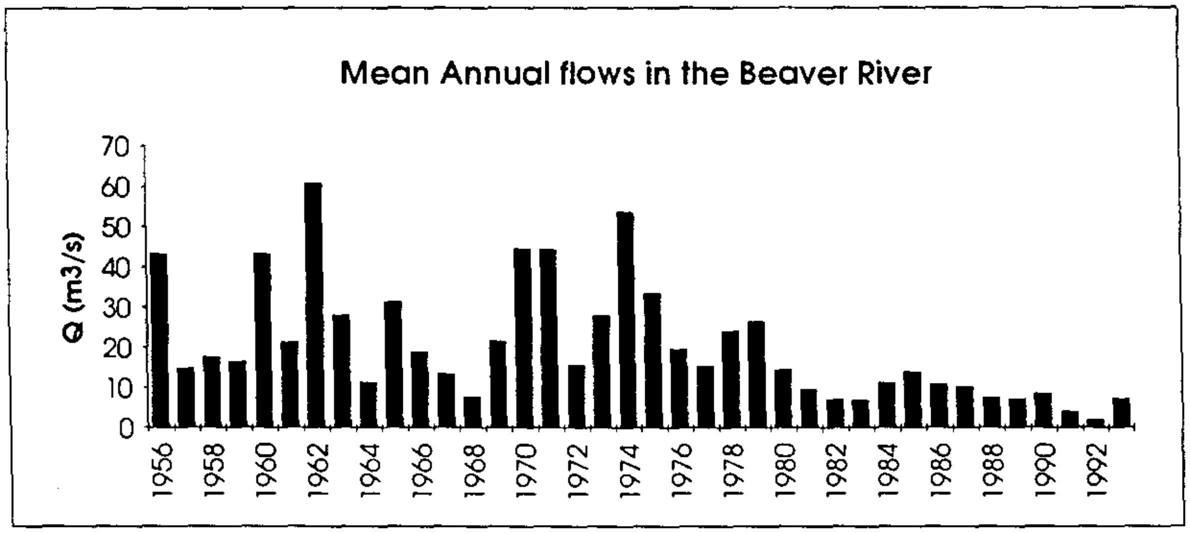


Figure 3: Long-term changes in mean annual flows in the Beaver River (Cold Lake Reserve - Station No 06AD006)
Source: Environment Canada (1992)

Table 4. Discharge and velocity estimates for the Beaver River at Cold Lake Reserve.

DATE	MEAN DAILY DISCHARGE (m^3/s)	MEAN VELOCITY (m/s)
Nov 1, 1991	0.552	0.143
Nov 15, 1991	0.730	0.158
Apr 26, 1993	7.06	0.339
May 5, 1993	4.55	0.293

Table 5. Travel time estimates.

LOCATION	DISTANCE (km)	TIME (h)			
		01/11/91	15/11/91	26/04/93	05/05/93
Ardmore	0.0	0.0	0.0	0.0	0.0
Beaver Crossing	26.6	51.5	46.9	21.8	25.2
CL/GC-RSS	29.9	57.9	52.7	24.5	28.4
Cherry Grove	50.9	98.6	89.7	41.6	48.3
Pierceland	81.5	157.8	143.6	66.7	77.4

4.0 RESULTS AND DISCUSSION

4.1 EFFLUENT CHARACTERISTICS

Table 6 presents average water chemistry for the Beaver River at Ardmore (i.e., above point-source discharges), the CFB-WW effluent, CFB-SS outfall and the CL/GC-RSS effluent during fall 1991 and spring 1993 surveys.

4.1.1 Comparison of Wastewater Effluents with Beaver River Water Quality

The most notable differences between wastewater effluent and the Beaver River quality are the much higher effluent phosphorus and nitrogen concentrations.

Total phosphorus concentrations in the CL/GC-RSS effluent are higher in spring than in fall, but the seasonal difference is much less pronounced in the CFB-WW. On average TP concentrations are 40 to 60 times higher than in the Beaver River and most of the phosphorus occurs as dissolved phosphorus. Average total phosphorus concentrations in the CL/GC-RSS are only slightly higher than in the CFB-WW.

As a result of differences in treatment process, there are certain differences in the quality of the two wastewater effluents, particularly as it relates to the dominant forms of nitrogen. The CFB-WW relies on extended aeration, secondary treatment and gas chlorination. The CL/GC-RSS is a multi-cell combination anaerobic/facultative lagoon system. The treatment of the CFB-WW breaks organic nitrogen compound down to oxidized forms of nitrogen. As a result (NO_2+NO_3)-N levels are very high (average >10 mg/L), but TKN and NH_4-N are relatively low. In the lagoon system where CL/GC-RSS wastewater is treated, oxidation is not as complete and TKN and NH_4-N tend to be much higher than (NO_2+NO_3)-N. TKN and NH_4-N are particularly high in spring lagoon effluent. Poorer effluent quality in spring compared to fall has been documented for many lagoon systems in Alberta (Beier 1987) and is attributed to the slower degradation and oxidation of organic matter under ice and the thermal mixing which occurs in the lagoon after ice melts.

Bacteria counts are another feature which distinguishes wastewaters from the Beaver River. Bacteria counts in individual samples from CL/GC-RSS were low in the fall of 1991 except for a single high count which boosted averages well above average counts for the Beaver River. In spring, bacteria counts in the effluent were consistently higher than in the river and contributed to the poorer effluent quality compared to fall. The CFB-WW is disinfected by gas chlorination before being released to Marie Creek. As a result of the chlorination process bacteria counts were lower (total coliforms) or comparable (fecal coliforms and fecal streptococci) to counts in the Beaver River.

Average concentration of several metals were higher in wastewater effluents than in the Beaver River. In particular, levels of Zn and Cu were higher in the CFB-WW effluent than in the river, but Fe and Mn concentrations were lower. Differences between spring and fall effluent quality were observed in the CL/GC-RSS with V, Cr, Co, Ni, Mo, Cd, and As being higher in fall than in spring and with effluent concentrations in fall being higher than concentrations in the Beaver River. Fe and Mn were an exception to this pattern as effluent

Table 6. Comparison of average river water quality at Ardmore with average effluent quality to the Beaver River.

SITE NAME	SEASON	CARBON DISS ORG 06101L	CARBON DISS INORG 06151L	CARBON PART 06154L	NITROGEN PART 07906L	P TOTAL 15421L	P DISS 15101L	N TKN 07015L	N DISS NH3 07561L	N DISS O2 NO3N 07111L	N DISS NO2 07205L	BOD 5 DAY 08201L	NFR 10401L	TURB NTU 02074L	PHENOL 06536L	PH 10301L	COND US/CM 02041L	TDS CALCD 00205L	Ca DISS 20105L	Mg DISS 12102L	HARDNESS TOTAL CaCO3 10603L	Na DISS 11101L
BEAVER R. AT ARDMORE	Average fall '91	16.05	102.19			0.036	0.011	0.76	0.097	0.022	0.002	1.1	3	5	0.007	7.98	811	471	83	33	345	60
	Average spring '93	11.38	44.48	1.55	0.21	0.071	0.018	0.66	0.010	0.002	0.001	2.1	7	5	0.005	8.33	346	223	43	16	173	22
CFB WW EFFLUENT	Average fall '91	9.69	32.25			2.490	2.264	1.80	0.391	12.722	0.023	2.3	2	2	0.005	7.44	515	291	37	13	144	44
	Average spring '93	9.20	33.10	1.39	0.20	2.903	2.020	1.16	0.040	11.473	0.001	1.3	3	2	0.006	7.55	584	322	41	15	165	50
CFB STORM SEWER	Average fall '91	6.40	59.50			0.158	0.119	0.49	0.064	0.985	0.028	4.2	6	5	0.002	8.12	545	294	67	24	267	15
	Average spring '93	5.60	55.00	0.55	0.06	0.081	0.050	1.60	0.582	6.487	0.118	2.1	2	1	0.003	8.11	605	328	70	26	280	15
CL/GC-WW ELLUENT	Average fall '91	20.47	75.57			2.188	2.057	4.98	3.198	0.403	0.123	2.6	2	5	0.013	7.96	803	456	63	29	276	65
	Average spring'93	21.15	73.43	14.10	2.51	4.123	3.633	17.00	12.650	0.074	0.032	16.4	27	20	0.017	7.97	617	338	53	24	231	64

SITE NAME	SEASON	K DISS 19101L	F DISS 09107L	SO4 DISS 16306L	Cl DISS 17201L	SILICA REACT SiO2 14107L	ALK TOTAL CaCO3 10101L	HCO3 LAB CALCD 06202L	Al EXT 13030L	V TOTAL 23001L	Cr TOTAL 24004L	Mn TOTAL 25001L	Fe TOTAL 26009L	Co TOTAL 27009L	Ni TOTAL 28007L	Cu TOTAL 29003L	Zn TOTAL 30030L	Mo TOTAL 42001L	Cd TOTAL 48002L	Ba TOTAL 56001L	As TOTAL 33001L
BEAVER R. AT ARDMORE	Average fall '91	3.4	0.21	30	11.9	9.7	416	507	0.02	0.004	0.004	0.115	0.473	0.001	0.005	0.002	0.002	0.002	0.002	0.089	0.0009
	Average spring'93	2.9	0.12	17	4.9	4.2	196	234	0.01	L.002	0.002	0.048	0.612	L.001	0.001	0.001	0.002	0.001	L.001	0.081	0.001
CFB WW EFFLUENT	Average fall '91	8.2	1.15	20	34.3	9.0	131	159	0.03	L.002	0.002	0.018	0.056	L.001	0.002	0.017	0.029	0.001	0.001	0.019	0.001
	Average spring '93	7.5	0.95	17	54.6	6.4	143	174	0.03	L.002	0.002	0.005	0.045	L.001	0.002	0.028	0.039	0.001	L.001	0.026	0.0009
CFB-SS EFFLUENT	Average fall '91	2.7	0.72	10	20.8	11.9	249	304	0.02	0.003	0.003	0.058	0.171	L.001	0.005	0.019	0.019	0.003	0.002	0.265	0.0016
	Average spring '93	2.6	0.52	12	29.6	9.4	240	293	0.01	0.002	0.002	0.072	0.205	L.001	0.002	0.017	0.029	0.002	L.001	0.234	0.0012
CL/GC-RSS EFFLUENT	Average fall '91	10.5	1.06	56	42.7	15.4	307	374	0.04	0.043	0.045	0.049	0.02	0.011	0.011	0.012	0.013	0.014	0.015	0.018	0.0047
	Average spring '93	10.5	0.91	33	42.1	13.7	329	399	0.08	0.003	0.001	0.305	0.611	0.001	0.004	0.013	0.01	0.001	L.001	0.044	0.003

SITE NAME	SEASON	As DISS 33101L	Pb EXT 82301L	Be DISS 04101L	Se TOTAL 34003L	Hg TOTAL 8002L	T DEG.C 020**F	PH 103**F	COND US/CM 020**F	DO METER O2 081**F	DO WINKLR O2 08101L	COLIF. TOTAL) per 100 r 36001L	COLIF. FECAL) per 100 r 36011L	FECAL STREP) per 100 r 36101L	CHL-A mg/m3 6715
BEAVER R. AT ARDMORE	Average fall '91	0.0005	0.002	L.001	L.0001	L.0001	0.03	7.32	773	6.16	5.37	20	6		
	Average spring '93		L.002	L.001	0.0001	L.0001	11.32	8.15	396	9.54	9.4	562	7	8	
CFC-WW EFFLUENT	Average fall '91	0.001	0.002	L.001	0.0001	L.0001	10.24	6.96	499	7.83	8.27	4	L10.		
	Average spring '93		0.002	L.001	0.0001	L.0001	11.84	7.11	580	7.18	7.99	63	10	4	
CL/GC-RSS EFFLUENT	Average fall '91	0.0014	0.002	L.001	0.0003	L.0001	1.95	7.72	789	12.2		4868	651		
	Average spring '93		0.001	L.001	0.0002	L.0001	13.61	8.31	783	9.83		21750	113	31	
CFB-SS EFFLUENT	Average fall'91	0.0035	0.001	L.001	0.0002	L.0001	8.9	7.3	533	10		7200	75		
	Average spring '93		0.002	L.001	0.0002	L.0001	6.01	7.86	587	11.12	11.15	37288	16357	155	295.9

NOTE: values below the detection limit were set to the detection limit for the calculation of averages; where all values were below the detection limit, the average was below the detection limit concentrations were lower in fall than in spring; in spring effluent concentrations equalled (Fe) or exceeded (Mn) river concentrations.

Cold Lake is the source of domestic water for the towns of Cold Lake, Grand Centre and for the Canadian Forces Base. The lake has rather low conductivity and low levels of TDS and major ions (Mitchell and Prepas 1991). The treated wastewater which is released by the towns and the base reflects these quality features of the source water. Although, average effluent concentrations of K^+, F^-, and Cl^- are 3 to 5 times higher in the effluents than in the Beaver River the wastewater tends to have relatively low conductivity and its TDS and major ion concentrations are comparable or only slightly higher than those in the Beaver River. This situation is quite different from that encountered in the Battle River drainage basin where many municipalities utilize ground water rich in TDS as a source of domestic water and where municipal discharges of wastewater contribute substantially to the TDS and major ion load in the river (Anderson 1994).

4.1.2 Comparison of Storm Sewer Effluent with Beaver River Water Quality

The CFB-SS also has elevated nutrient concentrations compared to the Beaver River. Cu, Zn, As and especially Ba concentrations were higher than in the river. Bacterial counts were unexpectedly high in the storm sewer effluent in spring 1993. The average total coliform and fecal coliform counts in excess of 37,000 and 16,000 per 100 mL, respectively, strongly suggest sewage contamination.

Because moderate foaming was noticed at the CFB-SS outfall, additional samples were collected for the analysis of surfactants, hydrocarbons and extractable priority pollutants. The results of these analyses are presented in Table 7. Hydrocarbons were not detected in the effluent. However, surfactants were measured in all samples and several extractable priority pollutants (such as phthalates) were measured, or tentatively identified in the effluent.

Surfactants, also called surface active agents or wetting agents, are organic chemicals that reduce surface tension in water and other liquids. They are used in household products (e.g., soaps, laundry detergents, dish-washing liquids) and they have industrial and agricultural applications (lubricants, emulsion polymerization). Surfactants available on today's markets are generally highly biodegradable and have low toxicity (CCREM 1987). Surfactants can cause foaming and their presence in samples from CFB-SS could explain the observed foaming of the effluent.

Phthalate esters represent a large group of chemicals widely used as plasticizers in polyvinyl chloride resins, adhesives and cellulose film coating. Other applications are found in cosmetics, rubbing alcohol, insect repellant, insecticides, tablet coating and solid rocket propellants (CCREM 1987). These compounds are often detected in field blanks (Noton and Shaw 1989, Anderson 1994, EQMB unpublished data). It is not possible to determine whether the phthalate esters detected in samples from the CFB-SS were the result of sample contamination in the field or in the laboratory or from contamination by products used at the base and containing these compounds.

Table 7. Organic compounds detected in the CFB-SS.

	EXTRACTABLE PRIORITY POLLUTANTS[1]								
	Surfactans (mg/L)	Bis(2-ethyl hexyl) phthalate	Butylbenzyl phthalate	Dibutyl phthalate	Diethyl phtalate	Aliphatic acid (C16)	TAAP-2-propanol, 1,3-Dichlorophosphate (3:1)	Polyethylene glycol polymers (3)	Alkyl phenoxy ethers
Oct. 31/91	0.52		1.x		1.x				300**
Nov. 6/91	0.58								
Apr. 29/93	2.44								
May 5/93	1.69								
May 12/93	2.22								
May 19/93	1.50	1	1.X	0.B		0.2**	0.3**		
May 26/93	1.14	2	1	1.B	0.X			6**	

(1) = Concentrations in µg/L unless indicated otherwise
NA = Not analyzed
B = Analyte found in blank as well as in sample
X = Estimated value. Target compound is less than MDL
** = Estimated concentrations for tentatively identified compounds

4.2 LONGITUDINAL AND TEMPORAL CHANGES IN BEAVER RIVER WATER QUALITY DURING THE CL/GC-RSS DISCHARGES

Results of the Wilcoxon signed rank test are shown in Table 8. The tests were performed on data collected during the CL/GC-RSS discharges and include the samples collected immediately after the end of the discharge, but exclude samples collected before the discharge. Figure 4 to 7 show temporal changes in constituent concentration at the four river sites for selected variables (i.e., variables for which concentration changes were visible).

4.2.1 Fall 1991

There was a significant (Wilcoxon Signed Rank test, $p<0.05$) increase in TP, DP, TKN, NH_3-N, (NO_2+NO_3)-N, NO_2-N, Mg, hardness, Na, K, F, Cl, and Zn concentrations between Ardmore and Beaver Crossing.

Although Zn, Ba and (NO_2+NO_3)-N concentrations declined between Ardmore and Cherry Grove, a further increase in the concentration of all other constituents was measured between the two sites. In addition, significant (Wilcoxon Signed Rank test, $p<0.05$) increases in DOC, conductivity, TDS, SO_4, SiO_2, dissolved and total As were recorded between the latter sites.

Results of statistical testing of concentration differences between Beaver Crossing and Pierceland are somewhat misleading because only a small number of samples (3 out of 7) were taken at Pierceland during the passage of the effluent plume. For example, the Wilcoxon Signed Rank test reveals no significant difference in TP, DP, NO_2-N or F whereas an inspection of graphs in Figure 4 to 6 shows a notable increase for the last three surveys when the effluent plume had reached Pierceland. Nevertheless, the Wilcoxon signed rank test identified significantly higher concentrations of DIC, NH_3-N, conductivity, TDS, Mg, Na, K, SO_4, Cl, and alkalinity at Pierceland (Table 8). In contrast, turbidity, Mn, Fe, Zn, and Ba levels were lower at Pierceland than at Beaver Crossing.

In fall 1991 in-stream total coliform (TC) and fecal coliform (FC) counts were low at all sites (i.e., TC <100 and FC <20 per 100 mL) with the exception of a sample collected at the Cherry Grove site on November 19 (Appendix 1). TC and FC counts in that sample were 900 and 111, respectively. These high counts at the Cherry Grove site were recorded on the same day as very high bacterial counts in the CL/GC-RSS effluent (TC: 34,000, FC: 4,500).

4.2.2 Spring 1993

Of the six surveys conducted in spring 1993, four were conducted during the passage of the effluent plume. This yielded an insufficient number of paired samples to obtain reliable statistical test results with the Wilcoxon Signed Rank test. Therefore, statistical testing was omitted; concentration differences among sites are only depicted graphically in Figures 4 to 7.

Because travel time was faster in spring 1993 than in fall 1991 most samples from the Cherry Grove site and Pierceland were taken during the passage of the effluent plume.

Table 8. Summary of results of Wilcoxon Signed Rank test comparing water quality characteristics of four sites on the Beaver River, fall 1991 surveys.

VARIABLE	ARDMORE VERSUS BEAVER CROSSING	BEAVER CROSSING VERSUS CHERRY GROVE	BEAVER CROSSING VERSUS PIERCELAND
DOC	ns	* (+)	ns
DIC	ns	ns	* (+)
TP	* (+)	* (+)	ns
Diss. P.	* (+)	* (+)	ns
TKN	* (+)	* (+)	ns
NH_3-N	* (+)	* (+)	* (+)
(NO_2-NO_3)-N	* (+)	* (-)	ns
NO_2-N	* (+)	* (+)	ns
BOD	ns	ns	ns
NFR	ns	ns	ns
Turbidity	ns	ns	* (-)
Phenols	ns	ns	ns
pH	ns	ns	ns
Conductivity	ns	* (+)	* (+)
TDS	ns	* (+)	* (+)
Ca	ns	ns	ns
Mg	* (+)	ns	* (+)
Hardness	* (+)	ns	ns
Na	* (+)	* (+)	* (+)
K	* (+)	* (+)	* (+)
F	* (+)	* (+)	ns
SO_4	ns	* (+)	* (+)
Cl	* (+)	* (+)	* (+)
SiO_2	ns	* (+)	ns
Alkalinity	ns	ns	* (+)
Cr	ns	ns	ns
Mn	* (-)	ns	* (-)
Fe	ns	ns	* (-)
Ni	ns	ns	ns
Cu	ns	ns	ns
Zn	* (+)	* (-)	* (-)
Cd	ns	ns	ns
Ba	ns	* (-)	* (-)
As	ns	* (+)	ns
Diss. As	ns	* (+)	ns

* = Significantly different or $P < 0.05$
ns = Not significant or $P < 0.05$

\- = Significant decrease
\+ = Significant increase

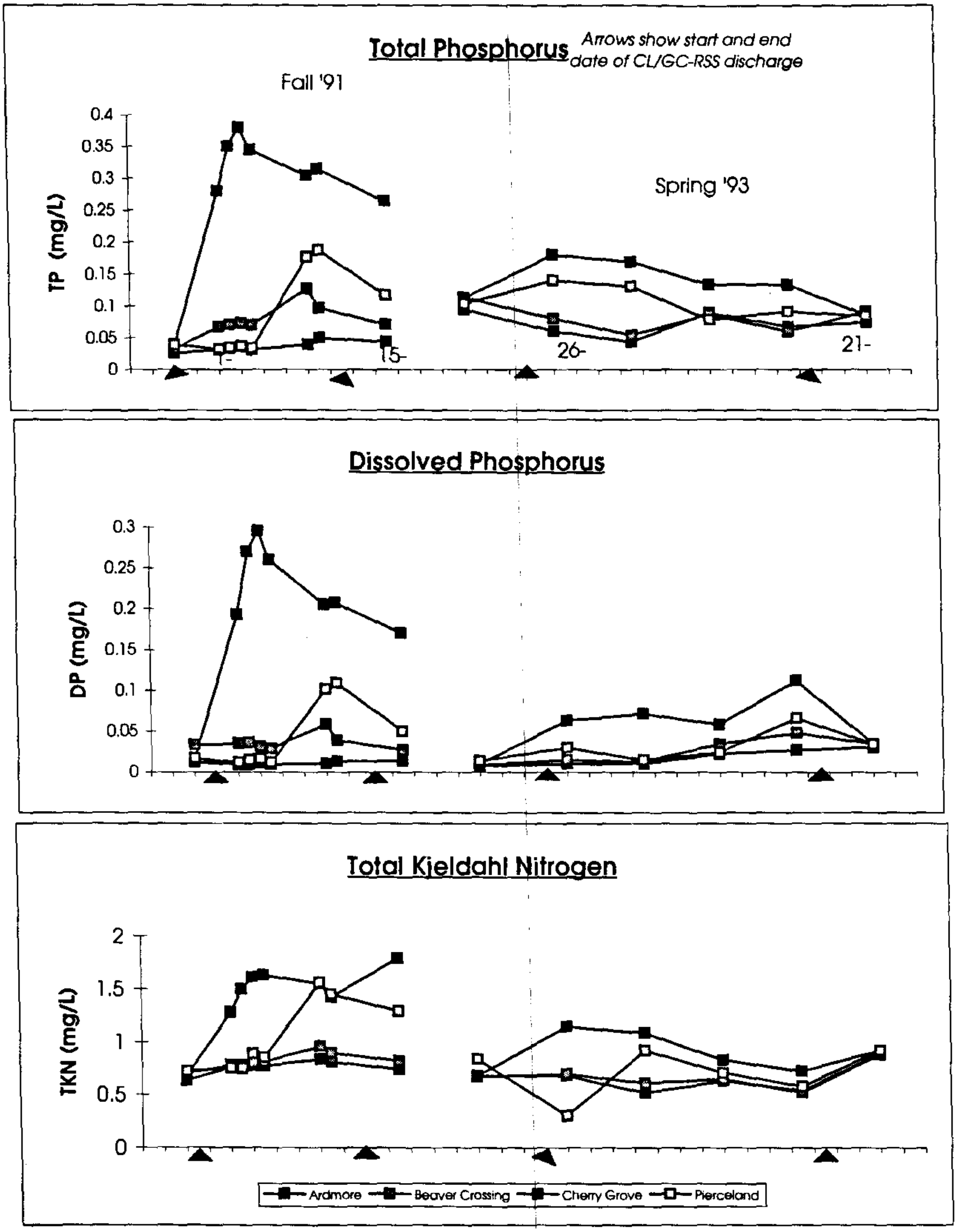


Figure 4. Longitudinal changes in phosphorus and Total Kjeldahl Nitrogen concentrations in the Beaver River during the discharge of effluent from CL/GC-RSS in fall 1991 and spring 1993

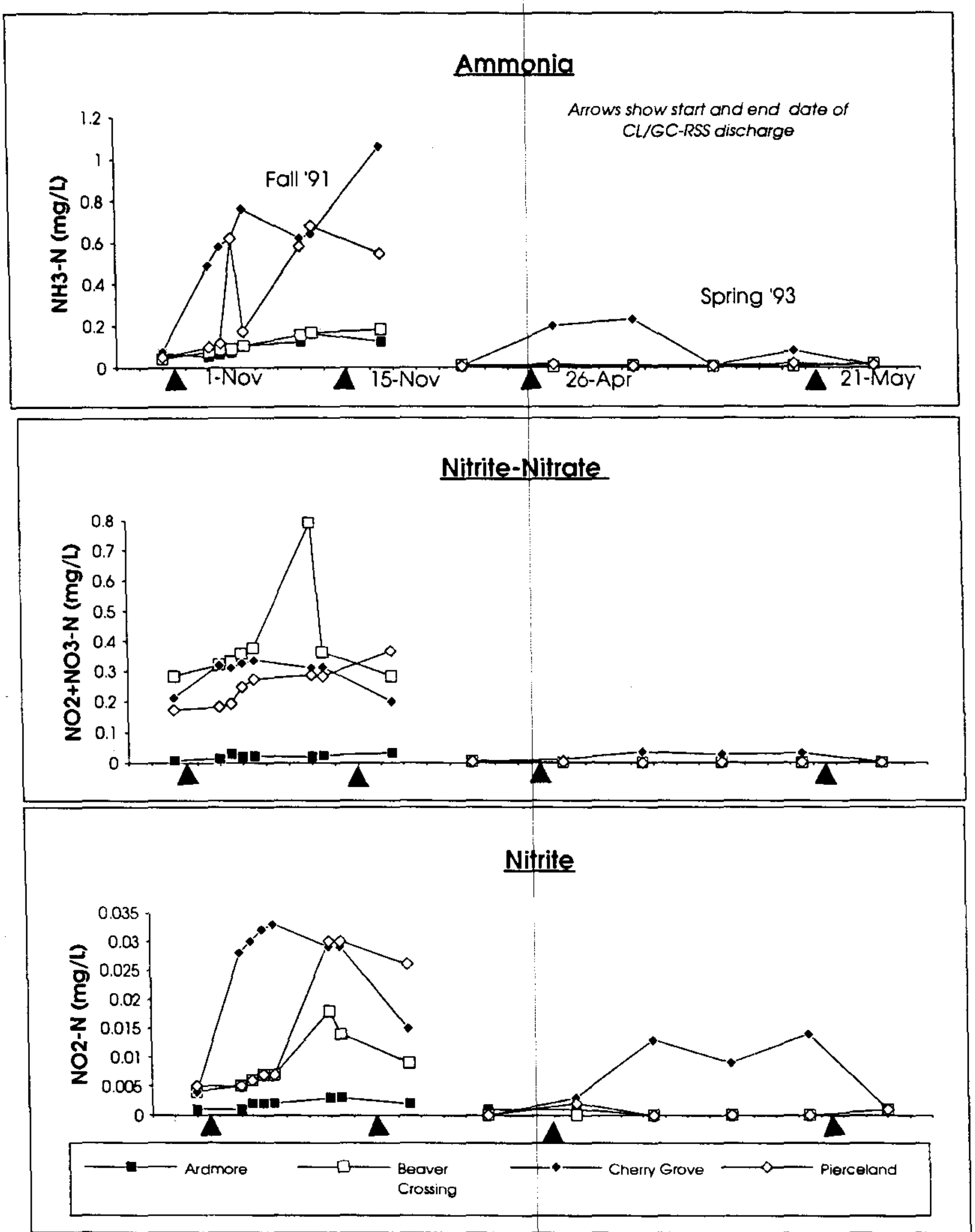


Figure 5: Longitudinal Changes in ammonia, nitrite and nitrate in the Beaver River during the discharge of effluent from CL/GC-RSS in fall 1991 and spring 1993

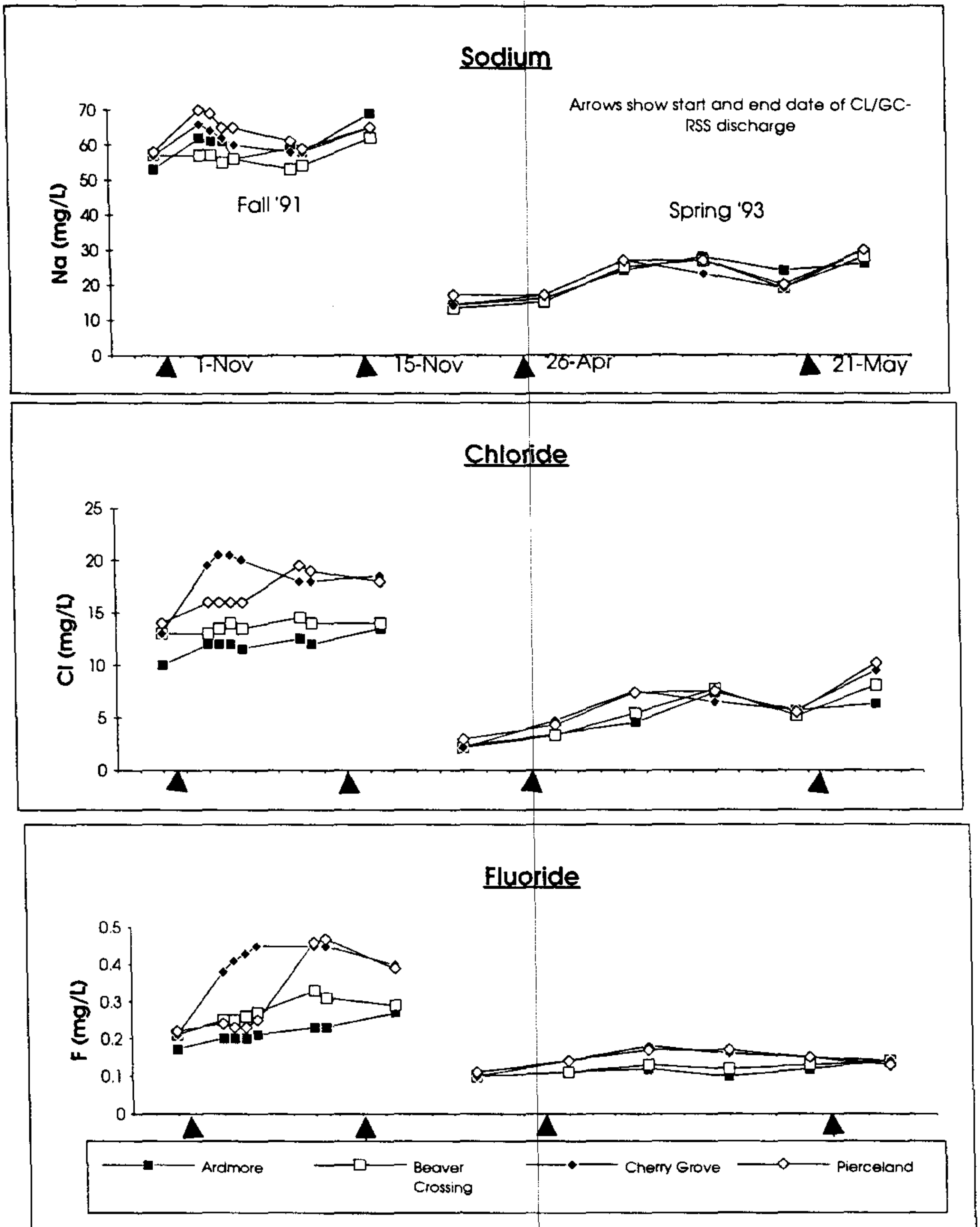


Figure 6. Longitudinal changes in sodium, chloride and fluoride in the Beaver River during the discharge of effluent from CL/GC-RSS in fall 1991 and spring 1993

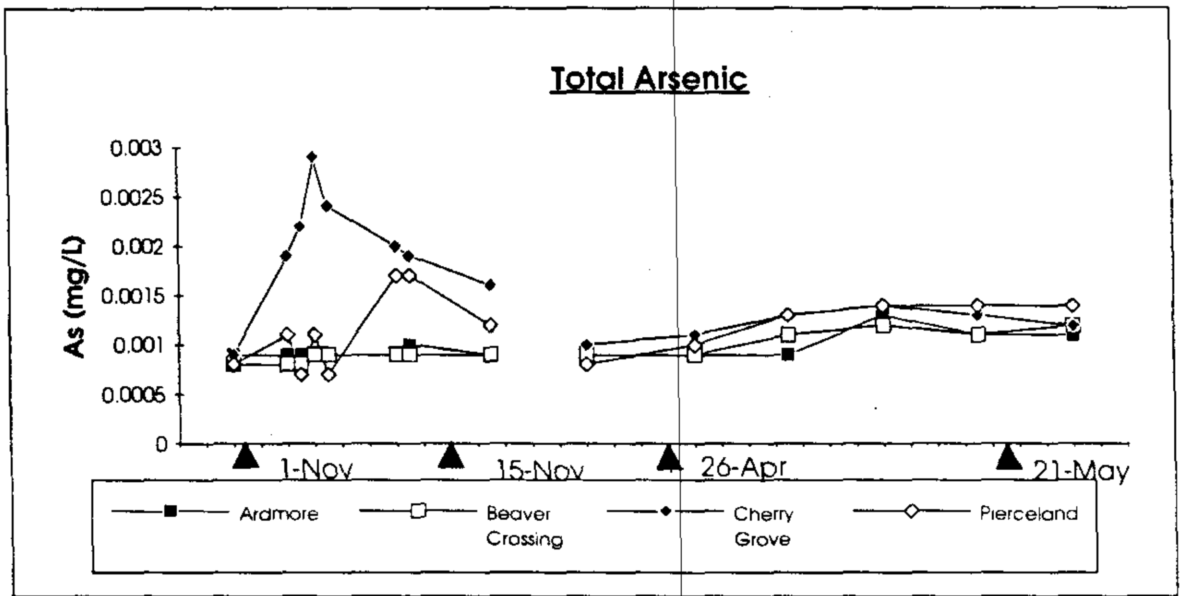


Figure 7: Longitudinal changes in Total Arsenic in the Beaver River during the discharge of effluent from GL/GC-RSS in fall 1991 and spring 1993

Although spring effluent was generally of poorer quality than fall effluent, effluent dilution was much greater in spring. As a result, longitudinal changes in river water quality were much less pronounced than in fall, although the concentrations of TP, DP, TKN, NH_3-N, (NO_2+NO_3)-N, NO_2-N and F were higher at the Cherry Grove site than at any other site; differences between Ardmore and Beaver Crossing or between Beaver Crossing and Pierceland were extremely slight.

In spring 1993 TC and FC counts were low in most samples from Ardmore and Beaver Crossing, except for TC counts in samples from May 19 which reached 3,200 and 2,100 TC per 100 mL at Ardmore and Beaver Crossing, respectively. Total coliform counts at the Cherry Grove site and at Pierceland were generally much higher than at the two other sites (maximum of 2,800 and 18,000 on May 19 at Cherry Grove and Pierceland, respectively). These high in-stream counts may be related to the discharge of CLGC/RSS wastewater which also contained high bacterial counts.

4.3 MASS LOAD CALCULATIONS

Several of the longitudinal changes in water quality observed in the Beaver River are the results of effluent discharges to the river. To illustrate this point concentrations of selected nutrients [TP and (NO_2+NO_3)-N] and ions (Na^+, Cl^-, and F^-) measured in the Beaver River were compared with concentrations calculated from instream loads and from effluent loads from wastewater (WW) and storm sewer (SS) discharges from the CFB-Cold Lake and from effluent loads from CL/GC-RSS (see section 2.3 for details). Travel time was taken into account by selecting sets of in-stream data which matched predicted travel time as closely as possible. In-stream concentrations were predicted for 2 series of data in fall 1991:

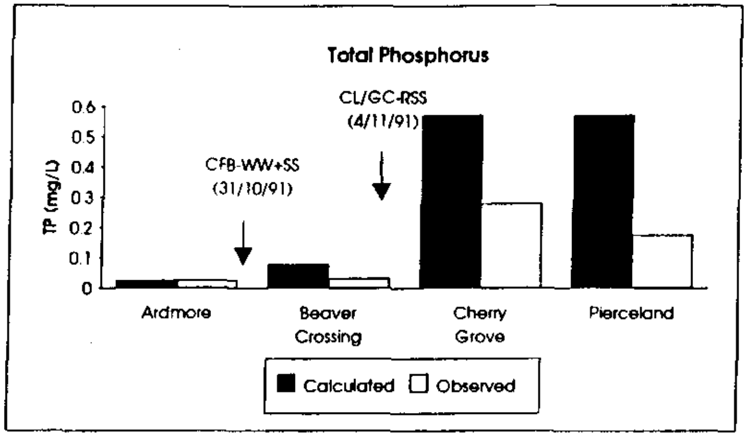
- CL/GC-RSS effluent discharged on Nov. 1 (closest match for effluent data: Nov. 4) was expected to reach the Cherry Grove site Nov. 3 (closest match for in-stream data: Nov. 4) and Pierceland Nov. 7 (closest match for in-stream data: Nov. 12).

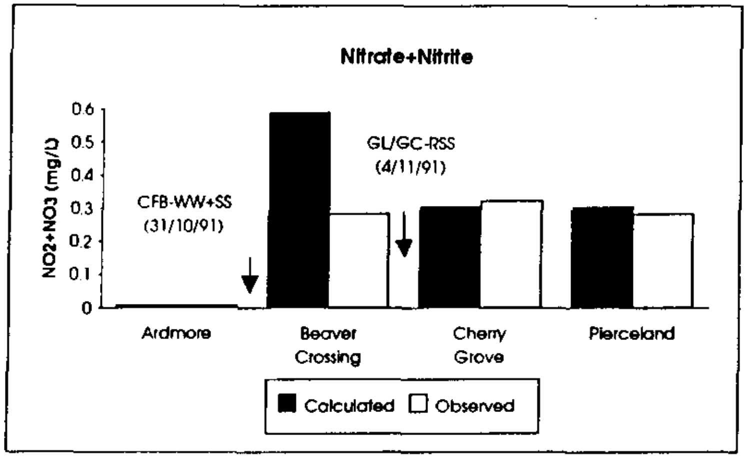
- CL/GC-RSS effluent discharged on Nov. 7 (effluent data: Nov. 7) was expected to reach the Cherry Grove site on Nov. 9 (instream data: Nov. 7) and Pierceland on Nov. 12 (instream data: Nov. 12).

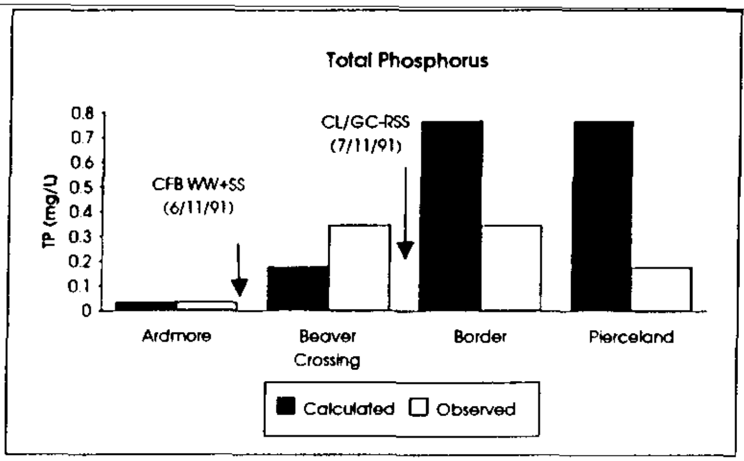
Results are shown in Figures 8 to 9. There is a close correspondence between predicted and measured concentrations for conservative elements (i.e., ions). The higher concentrations of Cl and F measured at Cherry Grove can be explained by ion loads from the CL/GC-RSS discharges. Although the increase in P and (NO_2+NO_3)-N can be attributed to loads from CFB and CL/GC-RSS, predicted concentrations are usually higher than measured concentrations, because the latter reflects some degree of instream processing and uptake. The CFB-WW outfall with its high (NO_2+NO_3)-N load explains the large increase in instream concentration of (NO_2+NO_3)-N, whereas both wastewater effluents and the CFB-SS account for the increase in instream TP.

4.4 COMPLIANCE WITH WATER QUALITY GUIDELINES AND OBJECTIVES

Table 9 lists all parameters which were monitored in the Beaver River during this study and which had at least one record which did not comply with the Prairie Provinces Water Quality Objectives (PPWBO), the Alberta Surface Water Quality Guidelines (ASWQG), or the Canadian Water Quality Guidelines (CWQG). The table also provides an indication of frequency of non-compliance.







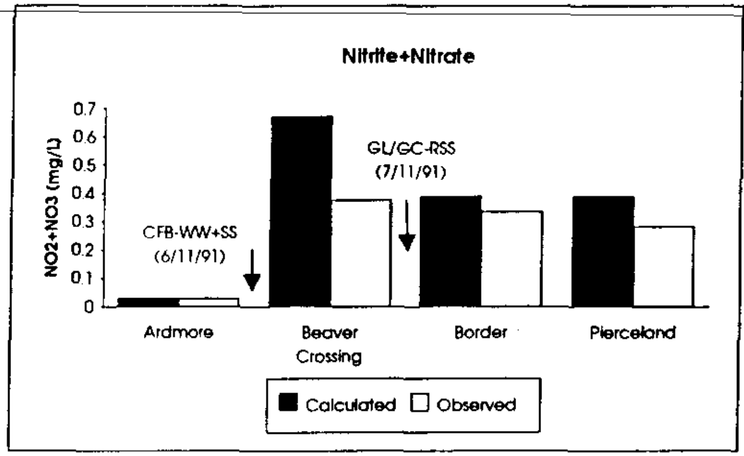


Figure 8 : Comparison of Total Phosphorus and Nitrite+Nitrate concentrations measured in the Beaver River with concentrations predicted from upstream loads and from effluent loads

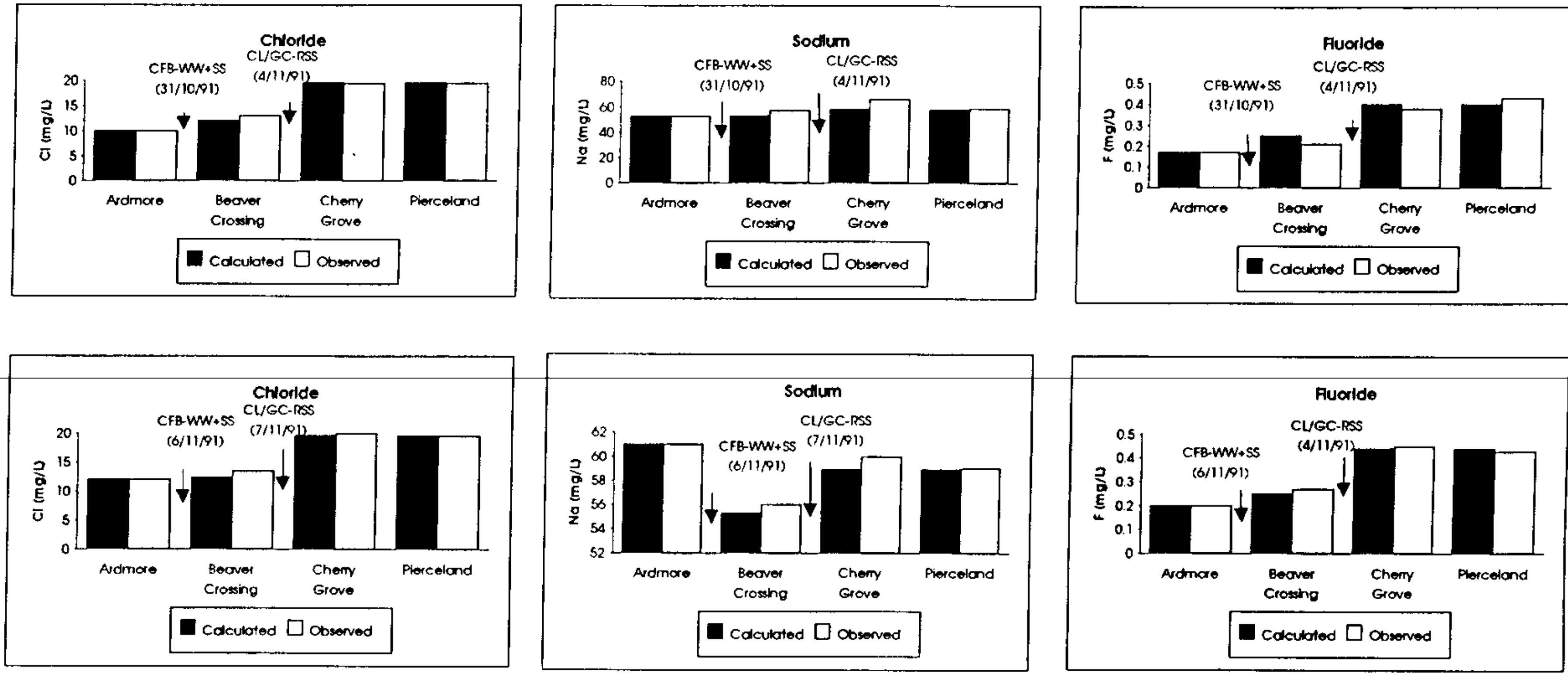


Figure 9. Comparison of chloride, sodium and fluoride concentrations measured in the Beaver River with concentrations predicted from upstream river load and effluent loads

Table 9. Summary of non-compliance with PPWBO, ASWQG and CWQG.

Water Quality Variable	Guideline / Objective value (mg/L)	Ardmore	Beaver Crossing	Cherry Grove	Pierceland	Maximum Levels (mg/L) recorded in river and effluents
Cd, Total	PPWBO[a] - 0.001 ASWQG[b] - 0.01 CWQG-PAL[c] - 0.0013[e] 0.0018[f]	2 0 2	2 0 2	2 0 2	2 0 2	- instream non-compliance in fall only - max river: 0.003 - max effluent: 0.003
Cr, Total	PPWBO - 0.011 ASWQG - 0.05 CWQG-PAL - 0.002	0 0 2	0 0 3	0 0 2	0 0 2	- instream non-compliance mostly in fall - max river: 0.006 at Beaver Crossing - max effluent: 0.007 in CFB-SS
Cu, Total	PPWBO - 0.004 ASWQG - 0.02 CWQG-PAL - 0.003[e] 0.004[f]	0 0 0	1 1 1	1 1 1	1 1 1	- instream non-compliance in fall and spring - max river: 0.077 at Border - max effluent: 0.039 CFB-WW
Fe, Total	PPWBO - 1.0 ASWQG - 0.3 CWQG-PAL - 0.3	1 3 3	1 3 3	0 3 3	0 3 3	- instream non-compliance in fall and spring - max river: 1.09 at Ardmore - max effluent: 0.789 in CL/GC-RSS
Mn, Total	PPWBO - 0.2 ASWQG - 0.05 CWQG-PAL - NA	1 2 -	0 2 -	0 3 -	0 2 -	- instream non-compliance in fall and spring - max river: 0.205 at Ardmore - max effluent: 0.457 CL/GC-RSS
Zn, Total	PPWBO - 0.03 ASWQG - 0.05 CWQG-PAL - 0.03	0 0 0	0 0 0	1 0 1	0 0 0	- instream non-compliance in spring - max river: 0.042 at Border - max effluent: 0.044 CFB-WW
TP	PPWBO - NA ASWQG - 0.045 CWQG-PAL - NA	- 2 -	- 3 -	- 3 -	- 3 -	- instream non-compliance in spring and fall - max river: 0.38 at Border - max effluent: 4.63 CL/GC-RSS
TN	PPWBO - NA ASWQG - 1.0 CWQG-PAL - NA	- 0 -	- 2 -	- 3 -	- 2 -	- instream non-compliance in spring and fall - max river: 1.99 at Border - max effluent: 16.43 at CL/GC-WW
Total Coliform	PPWBO - NA ASWQG - see (g) CWQG-REC[d] - see (h)	- 1 0	- 0 0	- 1 0	- 1 0	- instream non-compliance in spring - max river: 3200 at Ardmore - max effluent: 86,000 in CFB-SS
DO	PPWBO - 6.0< ASWQG - 5.0< CWQG-PAL - 6.0<	2 1 2	1 1 1	1 1 1	1 1 1	- instream non-compliance in fall - min river: 0 (many samples) - min effluent: 5.7 in CFB-WW, single non-compliance

a. PPWBO: Prairie Provinces Water Quality Objectives
b. ASWQG: Alberta Surface Water Quality Guidelines
c. CWQG-PAL: Canadian Water Quality Guidelines for the Protection of Aquatic Life
d. CWQG-REC: Canadian Water Quality Guidelines for Aesthetics and Contact Recreation
e. Value applies at hardness range of 120-180 mg/L
f. Value applies at hardness >180 mg/L
g. Geometric mean of 5 samples taken in less than 30 days should be less than 1000 total coliforms, less than 200 fecal coliforms <u>or</u> these numbers should not be exceeded in more than 20% of the samples <u>or</u> no total coliform count should exceed 2400
h. Geometric mean of not less than 5 samples taken in not more than 30 days should be less than 200 fecal coliforms per 100 mL.

'0' all samples comply with guidelines or objectives
'1' less than 20% of samples do not comply
'2' 20 to 70 % of samples do not comply
'3' more than 70% of samples do not comply
'NA' or '-' no guidelines or objectives

For some water quality variables such as Cu, Cr, TP, and TN, the frequency of non-compliance of river concentrations was higher at Beaver Crossing than at Ardmore. The increase in frequency of non-compliance was related to the high concentrations of these constituents in the CFB-WW or in the CFB-SS effluents.

The frequency of non-compliance of Mn, Zn, TN, and total coliforms was higher at the Cherry Grove site than at Beaver Crossing. Except for Zn, these increases were related to the high concentrations of these constituents in the CL/GC-RSS effluent. Non-compliance to surface water quality guidelines of Zn at Cherry Grove was not related to the effects of the CL/GC-RSS which had very low Zn concentrations. The cause of elevated zinc concentrations at Cherry Grove is not known. High total phosphorus concentrations in the CL/GC-RSS effluent contributed to the continued high level of non-compliance in the Beaver River.

Cadmium, Fe and DO concentrations in the Beaver River frequently did not meet surface water quality guidelines. Apparently this non-compliance is related to natural background conditions rather than to the effects of effluents. Dissolved oxygen in the ice-covered Beaver River in November 1991 complied more frequently with guidelines downstream than upstream of effluent discharges, probably because the open leads created by the effluents tend to improve aeration of the river.

4.5 LONG-TERM FLOW PATTERN IN THE BEAVER RIVER AND IMPLICATIONS ON NON-COMPLIANCES

Frequency analysis of monthly flows for October, November, April and May indicate that flows measured in the Beaver River during the monitoring of effects of effluent discharges were exceptionally low (A. DeBoer, Surface Water Assessment Branch, AEP, pers. comm.).

Following is the frequency of return for these flows:

October 1991:	1:125 year low flows
November 1991:	1:200 year low flows
April 1993:	1:24 year low flows
May 1993:	1:11 year low flows

Under these exceptionally low flow conditions, effluent discharges result in non-compliance of several water quality parameters. For a similar effluent load, but average flow conditions, concentrations of most, if not all parameters would comply with surface water quality guidelines. However, even under average flow conditions non-compliance could occur if effluent loads increased.

The anticipation that flows in the Beaver River will return to normal (i.e., long-term average) may reduce the urgency of improving existing wastewater treatment facilities or altering discharge patterns. However, no one can predict when flows will return to normal. The recent drought in east-central Alberta, which is the cause of low flows in the Beaver River, is attributed to unusual weather patterns. The occurrence or duration of such weather patterns cannot be predicted (R. Bothe, Surface Water Assessment Branch, AEP, pers. comm.).

5.0 SUITABILITY OF PPWB MONITORING SITE

Surveys conducted in the Beaver River in fall 1991 and spring 1993 indicate that during the discharge of wastewater from CL/GC-RSS there are differences in water quality between the current monitoring site at Beaver Crossing, and sites downstream of the wastewater effluent outfall. Concentrations of TP, DP, TKN, NH_3-N, Mg, hardness, Na, K, F, Cl, DOC, conductivity, TDS, SO_4, SiO_2 and total and dissolved As are elevated at Cherry Grove and at the Pierceland site during wastewater discharges from CL/GC-RSS. The CL/GC-RSS outfall induces a higher frequency of non-compliance to surface water quality guidelines in the Beaver River for TN, total coliforms and Mn and contributes to the high incidence of non-compliance of phosphorus.

Water quality differences between Beaver Crossing and sites downstream of the CL/GC-RSS outfall are most noticeable in data collected at very low river discharge (e.g., November 1991 with monthly average of 0.73 m^3/s), but they are only slight at higher river discharge (e.g., May 1993 with monthly average of 6.11 m^3/s). These findings are concordant with conclusions from the study conducted in 1987 at a river discharge of 2 m^3/s which is intermediate to that of fall 1991 and spring 1993 (Nelson 1988). These results indicate that data from the current PPWB long-term monitoring site are least representative of Beaver River water quality that enters Saskatchewan when CL/GC-RSS discharges at low river flows. Although flow conditions in the Beaver River were exceptional (i.e., 1 in 11 to 1 in 200 year low flows) during the monitoring of effects of effluent discharges, there is no way of predicting when, or how long flows will return to normal.

A comparison of PPWB sampling dates at Beaver Crossing with the dates where CLGC-RSS discharges occurred (Table 10) indicates that 6 of 8 PPWB sampling dates coincided with wastewater discharges. On these six dates differences may have occurred between the water quality measured at Beaver Crossing and the quality of water that enters Saskatchewan. Taking river discharge at the time of sampling into consideration one can expect that these differences would have been of the same magnitude as those reported in fall 1991 for 2 of the 6 dates; they would have been smaller for the other 4 sampling dates.

The Regional Planning Commission expects continued population growth in the Cold Lake Beaver River area and is currently planning to expand the existing lagoon system. The effluent volume discharged to the Beaver River is likely to increase and the timing and duration of discharge could change.

In view of these considerations and in order to ensure that data from the long-term PPWB monitoring site represent, at all times of the year and under all flow conditions, the quality of the Beaver River as it enters Saskatchewan, it would be advisable to move the current location to a site downstream of the GL/GC-RSS outfall.

Some practical aspects need to be considered if the PPWB site is to be moved:

- The Cherry Grove site and Pierceland are the two logical alternatives for the PPWB monitoring site. Access at the Cherry Grove site could be difficult in winter and in very wet weather. The likelihood that access difficulties could compromise the regularity of the sampling program should be assessed.

Table 10. Comparison of PPWB sampling dates at Beaver River Crossing with effluent discharge dates for CL/GC-RSS.

YEAR	SPRING		FALL	
	CL/GC-RSS DISCHARGE	PPWB SAMPLING	CL/GC-RSS DISCHARGE	PPWB SAMPLING
1989	Apr 3, for 2 to 3 weeks	Apr 26 * 9.51 m^3/s (1)	Oct 29 till Nov 19	Nov 8 * 3.49 m^3/s
1990	Apr 23 till May 11	May 9 * 11.2 m^3/s	Oct 29 till Nov 19	Nov 7 * 1.69 m^3/s
1991	Apr 15 till May 3	May 8 6.06 m^3/s	Nov 1 till Nov 15	no data 0.730 m^3/s
1992	Apr 20 till May 22	May 6 * 3.33 m^3/s	Oct 26 till Nov 16	Nov 4 * 1.30 m^3/s
1993	Apr 26 till May 21	Apr 17 6.11 m^3/s	Oct 22 till Nov 12	no date 6.02 m^3/s

Asterisk (*) identifies PPWB sampling dates which coincide with wastewater discharge
(1) Shows the mean monthly discharge in the Beaver River for that month

Note: Exact discharge dates for GL/GC-RSS were unavailable prior to 1989

- The land use between the Alberta/Saskatchewan border and the Pierceland site needs to be documented to ensure that water quality at Pierceland represents the quality of Beaver River water that leaves Alberta.

- Currently, Water Survey Canada monitors river flows at Beaver Crossing and it has been advantageous in water quality assessments to have accurate discharge records and water quality data at the same site. If the PPWB site is moved further downstream it would be desirable to determine how well discharge data from Beaver Crossing fit the new site.

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7.0 APPENDICES

APPENDIX I WATER QUALITY DATA : FALL 1991 AND SPRING 1993

SITE NAME NAQUADAT CODE	DATE	CARBON DISS ORG 06101L	CARBON DISS INORG 06151L	CARBON PART 06154L	NITROGEN PART 07906L	P TOTAL 15421L	P DISS 15101L	N TKN 07015L	N DISS NH3 07561L	N DISS O2 NO3N 07111L	N DISS NO2 07205L	BOD 5 DAY 08201L	NFR 10401L	TURB NTU 02074L	PHENOL 06536L	PH 10301L
BEAVER AT ARDMORE	31/10/91	14.4	88.5			0.026	0.017	0.63	0.07	0.008	0.001	1	2	4	0.007	8
00AL06AC3490	4/11/1991	16.7	107			0.051	0.009	0.76	0.054	0.016	0.001	1	2	4.6	0.006	8.09
	5/11/1991	17.1	109			0.053	0.009	0.74	0.065	0.03	0.002	0.7	3	4.9	0.006	8.04
	6/11/1991	19.5	109			0.086	0.011	0.77	0.072	0.02	0.002	1.2	6	5.9	0.007	8.16
	7/11/1991	15.5	106			0.081	0.009	0.77	0.105	0.023	0.002	0.9	3	5.4	0.006	7.96
	12/11/1991	14.7	102			0.039	0.01	0.84	0.123	0.019	0.003	0.8	2		0.008	7.82
	13/11/91	14.9	93.5			0.049	0.013	0.81	0.163	0.025	0.003	1.4	2	5	0.008	7.97
	19/11/91	15.6	102.5			0.044	0.014	0.74	0.124	0.032	0.002	1.4	2	4.6	0.007	7.85
	21/4/93	8.7	36.3	2.58	0.34	0.095	0.008	0.68	0.006	0.002	0.001	3.8	14	9.4	0.0007	8.5
	29/4/93	8.8	40	1.52	0.21	0.06	0.01	0.68	0.009	0.001	0.001	2.5	8	8.1	0.005	8.25
	5/5/1993	9.2	47.8	1.1	0.13	0.043	0.01	0.57	0.012	<0.001	<0.001	1	2	3.9	0.004	8.33
	12/5/1993	10.3	47.8	1.75	0.25	0.089	0.022	0.63	0.006	0.002	<0.001	2.6	11	5.4	0.006	8.33
	19/5/93	14.2	44	1.13	0.15	0.067	0.027	0.54	0.008	<0.001	<0.001	1.5	4	2.6	0.007	8.15
	26/5/93	17.3	51	1.21	0.16	0.074	0.03	0.89	0.02	0.003	0.001	1.2	4	2.2	0.019	8.47
BEAVER CROSSING	31/10/91*	13.9	92.5			0.033	0.033	0.7	0.044	0.284	0.004	1.3	2	4.6	0.007	8.02
00AL06AD3990	31/11/91*	13.8	92.5			0.036	0.036	0.76	0.036	0.292	0.004	1.2	1	4.9	0.007	8.04
	31/11/91*	13.9	88.5			0.032	0.037	0.71	0.066	0.287	0.004	1.6	3	4.8	0.007	8.04
	4/11/1991	16	109			0.067	0.035	0.78	0.077	0.323	0.006	0.8	2	4.7	0.007	8.01
	5/11/1991	16.2	109			0.07	0.036	0.78	0.09	0.332	0.006	1	2	5.3	0.007	8.15
	6/11/91	16.8	107			0.073	0.031	0.8	0.092	0.369	0.007	1.1	2	5	0.006	7.93
	7/11/1991	16	108			0.07	0.029	0.81	0.106	0.376	0.007	1	3	5.5	0.007	8.02
	12/11/1991	14	97.5			0.127	0.058	0.96	0.154	0.792	0.018	0.7	3	5.2	0.006	7.3
	13/11/91	14.2	93.5			0.097	0.009	0.9	0.166	0.364	0.014	1.7	3	5.6	0.006	7.92
	19/11/91	15.6	102.5			0.071	0.027	0.82	0.18	0.285	0.009	1.1	2	5	0.006	7.87
	21/4/93	8.6	34.8	2.8	0.36	0.114	0.009	0.67	0.012	0.004	<0.001	4.2	12	9.5	0.006	8.34
	29/4/93	8.4	42.2	1.69	0.25	0.08	0.015	0.7	0.006	0.001	<0.001	2.5	6	4.3	0.006	8.19
	5/5/1993	9.5	51.2	1.1	0.16	0.064	0.013	0.61	0.01	0.002	<0.001	1.6	3	3.9	0.005	8.42
	12/5/1993	10.6	47.3	1.64	0.23	0.086	0.034	0.65	0.007	0.001	<0.001	3.1	5	3.7	0.008	8.48
	19/5/93	13.4	42.5	0.96	0.13	0.069	0.048	0.52	0.009	<0.001	<0.001	1.2	3	2.3	0.007	8.28
	26/5/93	16.6	51.8	1.07	0.15	0.091	0.034	0.88	0.02	0.002	0.001	1.2	3	2.3	0.007	8.53
BEAVER AT BORDER	31/10/91	13.2	92.5			0.039	0.017	0.68	0.076	0.212	0.004	1.2	2	5	0.006	8.03
00AL06AD4990	4/11/1991	16.4	107			0.28	0.193	1.28	0.49	0.323	0.028	1.4	2	4.9	0.006	7.98
	5/11/1991*	17	102			0.35	0.27	1.5	0.58	0.312	0.03	1.5	2	5.1	0.009	8.12
	5/11/91*	17.6	104			0.355	0.255	1.49	0.6	0.31	0.08	1	3	5.1	0.009	8.14
	5/11/91*	16.6	103			0.345	0.255	1.5	0.58	0.311	0.031	0.9	2	5	0.009	8.14
	6/11/91	18.8	102			0.38	0.295	1.61	0.62	0.325	0.032	1.2	3	5.5	0.008	7.94
	7/11/91	16.5	102			0.345	0.26	1.63	0.76	0.336	0.033	1.2	3	5.6	0.007	8.07
	12/11/91	16	97.5			0.305	0.205	1.55	0.62	0.311	0.029	0.5	2	5.3	0.007	8.1
	13/11/91	15.3	93.5			0.315	0.207	1.42	0.639	0.313	0.029	2	1	4.9	0.007	8.03
	19/11/91	16.8	103.5			0.265	0.17	1.79	1.061	0.2	0.015	1.2	4	5.3	0.006	7.91
	21/4/93	9.1	35.8	2.86	0.36	0.112	0.01	0.68	0.006	0.007	<0.001	4.3	13	8.3	0.007	8.36
	29/4/93	9	40.8	1.76	0.36	0.18	0.063	1.15	0.2	0.011	0.003	2.6	8	7.2	0.006	8.28
	5/5/1993*	10.4	51	2.2	0.41	0.169	0.071	1.09	0.23	0.035	0.013	4.1	5	4.5	0.006	8.53
	5/5/1993*	10.4	51.5	2.23	0.44	0.169	0.07	1.08	0.23	0.036	0.014	3.5	5	4.7	0.006	8.57
	5/5/1993*	10.1	51.5	2.29	0.42	0.169	0.069	1.08	0.23	0.043	0.019	3.2	5	4.2	0.006	8.66
	12/5/1993	10.4	48	1.74	0.3	0.133	0.058	0.83	0.01	0.027	0.009	3.7	6	4.5	0.006	8.56
	19/5/93	12.9	42.5	1.46	0.23	0.133	0.112	0.72	0.081	0.032	0.014	2.4	5	2	0.007	8.38
	26/5/93	16.7	53.5	1.48	0.21	0.085	0.034	0.92	0.014	0.003	0.001	1.3	4	2.3	0.007	8.48
BEAVER AT PIERCELAND	31/11/91	14.2	88.5			0.039	0.017	0.72	0.052	0.172	0.005	1.1	2	3.9	0.007	8.08
00SA06AD0990	4/11/91	15.6	115			0.032	0.012	0.75	0.099	0.182	0.005	0.7	2	4	0.008	8.05
	5/11/91	15.8	109			0.034	0.015	0.75	0.116	0.194	0.006	1	2	4.2	0.008	8.12
	6/11/91	16.5	111			0.037	0.016	0.89	0.62	0.248	0.007	0.9	1	4.1	0.006	8.11
	7/11/91	14.9	111			0.034	0.012	0.85	0.173	0.274	0.007	1.3	2	4.2	0.007	8.21
	12/11/91*	15.5	101			0.176	0.101	1.56	0.58	0.286	0.03	1.5	2	4.6	0.007	7.91
	12/11/91*	15.3	101			0.178	0.103	1.56	0.58	0.282	0.029	1.5	2	4.5	0.007	8.08
	12/11/91*	15.6	102			0.183	0.11	1.56	0.59	0.283	0.03	1	2	4.6	0.007	7.92
	13/11/91	15.6	97.5			0.187	0.109	1.45	0.68	0.283	0.03	1.6	1	4.5	0.006	7.88
	19/11/91	17.5	109			0.117	0.05	1.29	0.546	0.366	0.026	1.1	2	4.1	0.006	7.93
	21/4/93	9.5	37.8	3.13	0.33	0.104	0.014	0.84	0.008	0.003	<0.001	4.7	8	7.2	0.007	8.42
	29/4/93	9.3	37.5	2.4	0.44	0.14	0.03	0.3	0.018	0.003	0.002	3.4	8	5.7	0.008	8.37
	5/5/1993	11	49.5	3.14	0.46	0.131	0.015	0.92	0.009	<0.001	<0.001	4.3	6	6	0.006	8.6
	12/5/1993	11.5	49.8	1.77	0.21	0.078	0.024	0.71	0.01	0.001	<0.001	3.3	3	3.2	0.007	8.87
	19/4/93*	13.7	44	1.32	0.19	0.091	0.066	0.58	0.019	0.002	<0.001	2.1	2	2.3	0.008	8.52
	19/4/93*	13.6	43.5	1.33	0.2	0.094	0.072	0.62	0.012	0.001	0.001	1.5	6	2.8	0.01	8.52
	19/4/93*	13.4	43.5	1.33	0.2	0.092	0.072	0.54	0.012	0.001	0.001	2.2	2	1.8	0.008	8.52
	26/4/93	16.6	52.3	1.57	0.23	0.084	0.034	0.97	0.014	0.002	0.001	1.3	2	2.4	0.007	8.66

SITE NAME NAQUADAT CODE	DATE	COND US/CM 02041L	TDS CALCD 00205L	Ca DISS 20105L	Mg DISS 12102L	HARDNESS TOTAL CaCO3 10603L	Na DISS 11101L	K DISS 19101L	F DISS 09107L	SO4 DISS 16306L	Cl DISS 17201L	SILICA REACT SiO2 14107L	ALK TOTAL CaCO3 10101L	HCO3 LAB CALCD 06202L	CHL-A mg/m3 6715
BEAVER AT ARDMORE	31/10/91	739	429	78	30	318	53	3	0.17	28	10	7	378	461	
00AL06AC3490	4/11/1991	836	489	88	36	368	62	3.3	0.2	30	12	9.3	429	523	
	5/11/1991	832	484	86	35	359	61	3.3	0.2	30	12	9.5	429	522	
	6/11/1991	843	493	90	34	365	61	3.4	0.2	32	12	10	435	530	
	7/11/1991	832	480	86	34	355	56	3.5	0.21	32	11.5	10.2	429	523	
	12/11/1991	790	459	79	33	333	59	3.4	0.23	30	12.5	10.2	403	492	
	13/11/91	775	446	77	31	320	58	3.5	0.23	27	12	10.4	396	483	
	19/11/91	844	491	83	33	343	69	3.9	0.27	33	13.5	11.2	427	520	
	21/4/93	325	171	34	12	134	14	1.8	0.1	8	2.3	5.3	164	189	
	29/4/93	356	188	39	14	155	16	2.1	0.11	8	3.4	4.7	177	215	
	5/5/1993	430	244	49	17	197	24	2.6	0.12	17	4.5	3.8	218	262	
	12/5/1993	440	242	44	16	176	28	3.4	0.1	19	7.4	4.1	208	250	
	19/5/93	390	215	41	15	164	24	3.5	0.12	13	5.7	2.9	189	231	
	26/5/93	466	278	50	22	215	26	4.2	0.14	38	6.3	4.4	220	258	
BEAVER CROSSING	31/10/91*	764	443	77	32	324	57	3.6	0.21	32	13	7.3	379	462	
00AL06AD3990	31/11/91*	771	447	78	32	327	57	3.6	0.21	32	13	7.3	383	467	
	31/11/91*	777	449	78	32	327	57	3.7	0.21	32	13	7.4	386	471	
	4/11/1991	843	487	87	37	370	57	3.8	0.25	31	13	9	429	523	
	5/11/1991	843	490	88	36	368	57	3.7	0.25	30	13.5	9.4	435	530	
	6/11/91	845	487	90	34	365	55	3.8	0.26	30	14	9.8	431	526	
	7/11/1991	852	497	90	36	373	56	4	0.27	34	13.5	10.2	436	532	
	12/11/1991	789	458	82	34	345	53	4.2	0.33	31	14.5	10.8	393	480	
	13/11/91	791	456	79	34	337	54	4	0.31	30	14	10.7	398	485	
	19/11/91	849	493	85	36	360	62	4.1	0.29	32	14	12.3	430	524	
	21/4/93	322	165	33	12	132	13	1.7	0.1	6	2.1	4.7	167	193	
	29/4/93	344	183	38	14	153	15	2	0.11	8	3.3	4.3	171	208	33.6
	5/5/1993	442	252	50	18	199	25	2.8	0.13	16	5.4	3.7	225	264	9.6
	12/5/1993	437	240	43	16	173	27	3.1	0.12	18	7.7	3.1	209	244	10.3
	19/5/93	361	207	41	15	164	19	2.9	0.13	12	5.1	2.5	186	227	6.9
	26/5/93	491	282	51	21	214	28	4.2	0.14	34	8.1	4	226	261	6.1
BEAVER AT BORDER	31/10/91	772	450	78	33	331	57	3.8	0.21	32	13	7.1	387	471	
00AL06AD4990	4/11/1991	858	500	82	38	361	66	5.3	0.36	38	19.5	9.8	415	506	
	5/11/1991*	850	495	83	34	347	64	5.4	0.41	39	20.5	10.1	412	502	
	5/11/91*	851	496	83	35	351	64	5.4	0.41	38	20.5	10.1	413	503	
	5/11/91*	852	497	82	36	353	64	5.4	0.41	39	20.5	10.1	413	504	
	6/11/91	852	492	85	34	352	62	5.5	0.43	35	20.5	10.3	413	504	
	7/11/91	863	498	84	35	354	60	5.5	0.45	38	20	10.7	420	512	
	12/11/91	829	479	82	34	345	58	5	0.45	36	18	11.5	407	496	
	13/11/91	820	471	78	34	335	58	4.9	0.45	36	18	11.5	401	488	
	19/11/91	873	509	86	36	363	65	5.3	0.4	37	18.5	12.6	431	525	
	21/4/93	328	172	34	13	138	14	1.8	0.1	7	2.1	4.3	165	197	
	29/4/93	362	193	40	14	154	17	2.3	0.14	8	4.7	4.5	179	218	31.1
	5/5/1993*	460	265	50	19	203	27	3.1	0.18	19	7.5	3	232	266	52.1
	5/5/1993*	459	263	49	19	201	27	3.2	0.18	18	7.5	3	232	263	55.9
	5/5/1993*	456	263	49	19	201	28	3.1	0.18	18	7.4	2.9	231	257	55.3
	12/5/1993	434	239	46	17	185	23	2.7	0.16	13	6.5	1	216	248	41.4
	19/5/93	383	205	40	14	158	19	2.9	0.15	11	5.7	0.9	187	222	27.6
	26/5/93	484	277	49	21	209	30	4.2	0.14	24	9.5	2.9	232	270	8.2
BEAVER AT PIERCELAND	31/11/91	757	440	74	33	321	58	4	0.22	31	14	5.6	376	459	
00SA06AD0990	4/11/91	877	513	84	37	362	70	4.3	0.24	37	16	7.3	440	536	
	5/11/91	885	519	88	37	372	69	4.3	0.23	38	16	7.8	447	545	
	6/11/91	878	515	89	37	375	65	4.3	0.23	36	16	8	443	540	
	7/11/91	894	521	88	38	368	65	4.2	0.25	37	16	8.3	455	555	
	12/11/91*	869	500	84	37	362	61	5.1	0.46	37	19.5	11.1	423	516	
	12/11/91*	859	499	85	37	365	58	5.2	0.43	37	19.5	11.1	427	520	
	12/11/91*	862	497	85	36	360	58	5.2	0.41	37	19.5	11.1	424	517	
	13/11/91	848	489	84	36	354	59	5.1	0.47	34	19	11.1	416	507	
	19/11/91	886	514	88	37	367	65	5.1	0.39	36	18	12.1	442	539	
	21/4/93	352	186	38	14	148	17	2.1	0.11	8	2.9	3.9	176	207	
	29/4/93	371	200	47	15	167	17	2.4	0.14	8	4.3	3.9	186	221	
	5/5/1993	453	260	49	19	201	27	3	0.17	17	7.4	1.1	220	258	26.5
	12/5/1993	454	258	46	20	197	27	3.3	0.17	17	7.5	0.5	231	244	55
	19/4/93*	394	208	42	15	167	20	2.9	0.15	7	5.5	1.2	194	223	23.4
	19/4/93*	393	211	42	15	167	20	2.9	0.15	10	5.4	1.2	194	222	11.7
	19/4/93*	395	215	42	16	171	20	2.9	0.16	12	5.5	1.2	194	223	11.6
	26/4/93	474	271	46	21	201	30	4.2	0.13	21	10.2	2.1	229	258	11.4

SITE NAME NAQUADAT CODE	DATE	CARBON DISS ORG 06101L	CARBON DISS INORG 06151L	CARBON PART 06154L	NITROGEN PART 07906L	P TOTAL 15421L	P DISS 15101L	N TKN 07015L	N DISS NH3 07561L	N DISS O2 NO3N 07111L	N DISS NO2 07205L	BOD 5 DAY 08201L	MPN 10401L	TURB NTU 02074L	PHENOL 06536L
CFB WW EFFLUENT 21AL06AC0500	31/10/91	9	33.6			1.05	1.05	1.54	0.029	11.485	0.001	1.1	2	1.9	0.006
	4/11/91	9.8	34			2.02	1.93	1.14	0.040	11.465	0.002	2.2	3	1.8	0.005
	5/11/91	9.4	31.3			3.35	3.3	1.6	0.178	13.458	0.013	2.2	2	1.6	0.006
	6/11/91	10	28.5			3.35	3.35	1.75	0.28	14.6	0.03	2.9	2	1.91	0.004
	7/11/91	10	31			2.56	2.45	1.5	0.17	13.882	0.009	2.5	2	1.8	0.006
	12/11/91	8.6	35			1.6	0.305	1.3	0.021	9.94	0.002	1.7	2		0.006
	13/11/91	10	34.4			3.45	3.275	3.7	2.01	12.412	0.101	2.7	2	1.7	0.006
	19/11/91	10.3	30.2			2.56	2.45	1.9	0.391	14.53	0.023	2.9	3	1.9	0.005
	21/4/93	10	30.8	1.11	0.15	3.05	0.45	1.2	0.03	12	0.002	0.9	2	0.98	0.005
	29/4/93	8.6	29.7	2.14	0.32	4.25	2.4	1.48	0.035	13.9	0.001	L2	4	2.4	0.005
	5/5/1993	8.4	32	1.04	0.14	2.4	2.3	0.95	0.034	10.8	0.001	L2	1	1.2	0.006
	12/5/1993	9.6	35	1.49	0.23	2.6	2.5	1.35	0.027	9.84	0.002	1.6	4	2.1	0.007
	19/5/93	9	34.8	1.07	0.14	2.62	2.12	0.75	0.025	11.4	0.001	L2	2	1	0.006
	26/5/93	9.6	36.8	1.51	0.22	2.5	2.36	1.25	0.07	10.9	L.001	L2	2	1.42	0.006
CFB STORM SEWER 23AL06AC1000	31/11/91	6.1	59.5			0.101	0.068	0.47	0.024	0.997	0.021	3.7	L1000	2.4	0.003
	6/11/91	6.7	59.5			0.215	0.17	0.5	0.1	0.973	0.035	4.6	6	7.8	0.001
	21/4/93	5.8	51.6	0.62	0.07	0.124	0.083	1.96	0.82	3.8	0.064	1.6	L1	1.12	0.003
	29/4/93	5.5	50.8	0.35	0.06	0.108	0.08	3.1	1.01	8.07	0.322	1.3	1	1.47	0.002
	5/5/1993	5.3	53.8	0.59	0.07	0.07	0.025	1.5	0.707	6.6	0.137	4.1	L1	0.95	0.003
	12/5/1993	5.1	56	0.56	0.06	0.04	0.022	1.03	0.306	6.45	0.076	1.8	L1	0.81	0.002
	19/5/93	5.5	58	0.49	0.04	0.05	0.028	0.63	0.184	6.43	0.046	L2	L1	0.8	0.002
	26/5/93	6.4	59.8	0.69	0.08	0.095	0.064	1.4	0.46	5.57	0.06	1.8	2	1.11	0.003
CL/GC WW ELLUENT 21AL06AD4600	31/10/91	7.4	88.5			0.014	0.014	0.42	0.038	0.366	0.015	0.7	L1000	0.3	0.002
	4/11/91	23	71			2.56	2.56	5.87	3.3	0.434	0.141	3	2	5.5	0.015
	5/11/91	22.2	71.4			2.6	2.5	5.3	3.4	0.449	0.146	2.3	2	6.4	0.015
	6/11/91	22.9	72.2			2.6	2.525	5.8	3.2	0.48	0.156	2.6	2	5.5	0.014
	7/11/91	22.3	72.7			2.56	2.275	5.4	3.4	0.448	0.203	2.7	4	5.9	0.014
	12/11/91	23.6	75.3			2.3	1.96	4.9	3.6	0.363	0.107	3.5	2	5.6	0.014
	13/11/91	21.9	77.9			2.7	2.676	7.46	5.46	0.302	0.092	3.5	2	5.6	0.015
	29/4/93	20.8	81.2	4.7	0.78	4.56	4.2	15.5	12.4	0.03	0.006	10.4	15	13.6	0.016
	5/5/1993	23	77	15.8	3.18	4.31	3.7	18	12.8	0.037	0.009	16.5	37	27	0.016
	12/5/1993	21.5	65	20.6	3.39	3	2.75	17.1	12	0.083	0.035	19	24	20	0.018
	19/5/93	19.3	70.5	15.3	2.7	4.63	3.88	17.4	13.4	0.147	0.077	19.8	32	20	0.016

SITE NAME NAQUADAT CODE	DATE	PH 10301L	COND US/CM 02041L	TDS CALCD 00205L	Ca DISS 20105L	Mg DISS 12102L	HARDNESS TOTAL CaCO3 10603L	Na DISS 11101L	K DISS 19101L	F DISS 09107L	SO4 DISS 16306L	Cl DISS 17206L	SILICA REACT SiO2 14107L	ALK TOTAL CaCO3 10101L	HCO3 LAB CALCD 06202L	CHL-A mg/m3 6715
CFB WW EFFLUENT 21AL06AC0500	31/10/91	7.34	507	285	37	13	146	44	7.5	1.12	19	33.5	9.1	134	163	
	4/11/91	7.26	527	297	36	13	143	50	7.6	1.15	21	37	8.9	136	166	
	5/11/91	7.56	526	298	37	13	146	46	8.5	1.13	21	35.5	9.5	130	158	
	6/11/91	7.56	525	297	37	12	142	44	8.4	1.14	19	37	9.2	124	151	
	7/11/91	7.42	518	292	38	13	143	43	8.6	1.15	20	36	9.2	123	150	
	12/11/91	7.5	498	280	37	12	142	43	7.5	1.2	20	33	8.7	139	170	
	13/11/91	7.52	511	287	35	13	141	41	8.9	1.19	19	30	9	138	168	
	19/11/91	7.39	508	289	37	13	146	41	8.3	1.09	21	32	8	121	147	
	21/4/93	7.57	568	309	38	14	153	47	7.9	0.99	18	49.5	8.3	137	167	
	29/4/93	7.38	552	304	40	15	162	43	7.4	0.94	13	47.4	8.2	128	156	
	5/5/1993	7.58	536	309	41	15	164	45	7.8	1	23	42.6	9.3	143	174	
	12/5/1993	7.62	540	296	42	16	171	40	7.4	0.93	13	42.2	6.7	153	186	
	19/5/93	7.53	555	300	41	15	164	41	7.3	0.88	17	40.8	6.2	146	178	
	26/5/93	7.6	751	413	43	16	173	86	7.3	0.93	17	105	7.6	151	184	
CFB STORM SEWER 23AL06AC1000	31/11/91	8.07	540	293	68	25	273	13	2.8	0.7	11	18	11.8	251	306	
	6/11/91	8.22	550	294	66	23	260	17	2.6	0.74	9	23.5	12	247	301	
	21/4/93	8.13	574	301	61	24	251	15	2.7	0.57	13	20.9	9.8	232	283	
	29/4/93	8.03	586	315	65	25	265	13	2.5	0.48	10	27.7	8.8	225	274	
	5/5/1993	8.07	605	336	73	27	293	16	2.8	0.52	14	30.8	9.6	239	292	
	12/5/1993	8.19	619	335	71	26	284	15	2.3	0.48	7	30.7	9	241	294	
	19/5/93	8.09	628	334	73	27	293	15	2.7	0.54	13	30	9.6	249	303	
	26/5/93	8.13	617	340	74	27	296	16	3	0.56	13	29.6	9.8	254	310	
CL/GC WW ELLUENT 21AL06AD4600	31/10/91	8.01	778	434	90	37	377	27	5.7	0.26	35	27	17.2	352	429	
	4/11/91	8.02	791	454	56	28	255	73	11.3	1.14	57	46	14.7	293	357	
	5/11/91	7.85	794	448	56	27	251	73	11.1	1.17	58	45	14.9	286	348	
	6/11/91	7.91	800	452	58	28	252	72	11.1	1.16	56	45.5	15	295	360	
	7/11/91	7.99	804	459	58	27	256	71	11	1.18	62	45.5	15.1	297	362	
	12/11/91	7.93	819	471	61	29	272	72	11.5	1.26	60	46	15.6	310	378	
	13/11/91	8.02	835	476	61	29	272	70	11.5	1.25	61	44	15.5	316	387	
	29/4/93	7.93	885	482	59	28	263	69	12.1	0.99	38	45.8	14.6	361	440	
	5/5/1993	8.09	830	473	56	26	247	69	10.5	0.96	45	43.9	14.7	342	417	368.6
	12/5/1993	8.33	7.33	4.11	49	21	209	60	9.7	0.86	28	40.6	12.9	313	375	360
	19/5/93	7.53	744	391	49	20	205	56	9.7	0.84	21	37.9	12.5	298	364	159

APPENDIX 1 : CONTINUED

SITE NAQUADAT CODE	DATE	DISCHARGE m3/s	Al EXT 13030L	V TOTAL 23001L	Cr TOTAL 24004L	Mn TOTAL 25001L	Fe TOTAL 26009L	Co TOTAL 27009L	Ni TOTAL 28007L	Cu TOTAL 29003L	Zn TOTAL 30030L	Mo TOTAL 42001L	Cd TOTAL 48002L	Ba TOTAL 56001L	As TOTAL 33001L	As DISS 33101L	Pb EXT 82301L	Se DISS 04101L	Se TOTAL 34003L	Hg TOTAL 8002L
Beaver River at Ardmore 00AL06AC3490	31 Oct 1991		0.02	0.004	0.004	0.044	0.33	L.001	0.004	0.002	L.001	0.002	0.002	0.078	0.0009	0.0006	0.002	L.001	L.0001	L.0001
	4 Nov 1991		0.02	0.004	0.003	0.081	0.407	0.001	0.003	0.001	0.002	0.002	0.002	0.093	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	5 Nov 1991		0.01	0.004	0.003	0.081	0.418	L.001	0.005	0.001	0.001	0.001	0.002	0.09	0.0009	0.0005	L.002	L.001	L.0001	L.0001
	6 Nov 1991		L.01	0.004	0.004	0.09	0.499	L.001	0.004	0.001	0.002	0.002	0.002	0.096	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	7 Nov 1991		0.03	0.004	0.004	0.093	0.484	0.001	0.006	0.002	0.004	0.002	0.003	0.091	0.0009	0.0005	L.002	L.001	L.0001	L.0001
	12 Nov 1991		0.01	0.006	0.005	0.199	0.558	0.002	0.006	0.003	0.004	0.003	0.003	0.087	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	13 Nov 1991		L.01	0.004	0.004	0.206	0.582	0.002	0.006	0.001	0.003	0.003	0.002	0.087	0.001	0.0006	L.002	L.001	L.0001	L.0001
	19 Nov 1991		L.01	0.005	0.006	0.13	0.504	0.002	0.006	0.002	0.002	0.002	0.003	0.088	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	21 Apr 1993		L.005	L.002	L.001	0.043	1.09	L.001	L.001	0.002	0.002	0.001	L.001	0.072	0.0009		L.002	L.001	L.0001	L.0001
	29 Apr 1991		L.006	L.002	L.001	0.037	0.704	L.001	L.001	0.001	L.001	L.001	L.001	0.071	0.0009		L.002	L.001	L.0001	L.0001
	5 May 1993		0.01	L.002	L.001	0.043	0.464	L.001	0.001	L.001	L.001	0.002	L.001	0.086	0.0009		L.002	L.001	L.0001	L.0001
	12 May 1993		0.03	L.002	L.001	0.078	0.626	L.001	0.001	0.001	L.001	0.001	L.001	0.097	0.0013		L.002	L.001	L.0001	L.0001
	20 May 1993		0.01	L.002	L.001	0.064	0.41	L.001	L.001	0.001	0.002	L.001	L.001	0.076	0.0011		L.002	L.001	L.0001	L.0001
	26 May 1993		0.01	L.002	0.004	0.034	0.377	L.001	0.003	L.001	0.002	0.001	L.001	0.081	0.0011		L.002	L.001	0.0001	L.0001
Beaver River at Beaver crossing 00AL06AD3990	31 Oct 1991*		0.02	0.004	0.003	0.046	0.42	0.001	0.006	0.002	0.002	0.003	0.003	0.079	0.0008	0.0006	L.002	L.001	0.0001	L.0001
	31 Oct 1991*		0.02	0.004	0.003	0.046	0.422	L.001	0.004	0.002	0.002	0.002	0.002	0.079	0.0008	0.0007	L.002	L.001	L.0001	L.0001
	31 Oct 1991*		0.02	0.004	0.005	0.046	0.432	0.001	0.005	0.002	0.002	0.002	0.002	0.079	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	4 Nov 1991		0.02	0.004	0.003	0.071	0.444	L.001	0.003	0.002	0.003	0.002	0.002	0.094	0.0008	0.0005	L.002	L.001	0.0001	L.0001
	5 Nov 1991		L.01	0.004	0.003	0.076	0.465	L.001	0.003	0.002	0.002	0.002	0.003	0.09	0.0008	0.0006	L.002	L.001	0.0001	L.0001
	6 Nov 1991		L.01	0.005	0.004	0.088	0.504	0.001	0.006	0.002	0.003	0.002	0.002	0.098	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	7 Nov 1991		0.03	0.006	0.006	0.086	0.499	0.002	0.006	0.002	0.004	0.002	0.002	0.093	0.0009	0.0005	L.002	L.001	0.0001	L.0001
	12 Nov 1991		0.02	0.006	0.004	0.126	0.566	0.001	0.006	0.003	0.006	0.003	0.003	0.095	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	13 Nov 1991		L.01	0.006	0.006	0.144	0.654	0.001	0.006	0.002	0.005	0.003	0.003	0.086	0.0009	0.0006	L.002	L.001	0.0001	L.0001
	19 Nov 1991		L.01	0.004	0.004	0.123	0.492	0.001	0.006	0.002	0.003	0.002	0.003	0.084	0.0009	0.0006	L.002	L.001	0.0001	L.0001
	21 Apr 1993		L.005	L.002	L.001	0.037	1.06	L.001	0.002	0.021	0.012	L.001	L.001	0.071	0.0009		L.002	L.001	L.0001	L.0001
	29 Apr 1991		0.02	L.002	L.001	0.035	0.646	L.001	L.001	L.001	L.001	L.001	L.001	0.068	0.0009		L.002	L.001	0.0001	L.0001
	5 May 1993		0.01	L.002	L.001	0.043	0.498	L.001	0.002	0.001	L.001	L.001	L.001	0.086	0.0011		L.002	L.001	L.0001	L.0001
	12 May 1993		0.03	L.002	0.001	0.079	0.438	L.001	0.001	L.001	L.001	L.001	L.001	0.094	0.0012		0.002	L.001	L.0001	L.0001
	20 May 1993		0.01	L.002	L.001	0.05	0.347	L.001	0.001	L.001	0.002	0.001	L.001	0.077	0.0011		L.002	L.001	0.0001	L.0001
	26 May 1993		0.02	L.002	0.006	0.04	0.387	L.001	0.004	L.001	0.002	0.001	L.001	0.085	0.0012		L.002	L.001	L.0001	L.0001
Beaver River at Cherry Grove 00AL06AD4990	31 Oct 1991		0.02	0.004	0.003	0.059	0.442	0.001	0.004	0.002	0.001	0.002	0.002	0.076	0.0009	0.0006	L.002	L.001	L.0001	L.0001
	4 Nov 1991		0.02	0.004	0.004	0.078	0.441	L.001	0.005	0.002	0.002	0.002	0.002	0.085	0.0019	0.0016	L.002	L.001	0.0001	L.0001
	5 Nov 1991*		0.04	0.004	0.003	0.078	0.419	0.001	0.006	0.002	0.002	0.002	0.002	0.077	0.0022	0.0018	0.002	L.001	0.0001	L.0001
	5 Nov 1991*		0.02	0.004	0.003	0.08	0.426	0.001	0.005	0.002	0.002	0.002	0.002	0.079	0.0024	0.0018	0.002	L.001	0.0001	L.0001
	5 Nov 1991*		0.02	0.004	0.003	0.08	0.421	0.001	0.006	0.002	0.001	0.002	0.002	0.078	0.0021	0.0017	L.002	L.001	0.0001	L.0001
	6 Nov 1991		L.01	0.004	0.004	0.093	0.471	0.002	0.005	0.002	0.002	0.003	0.003	0.082	0.0029	0.0025	L.002	L.001	L.0001	L.0001
	7 Nov 1991		0.03	0.006	0.004	0.092	0.446	0.001	0.005	0.002	0.003	0.003	0.003	0.078	0.0024	0.002	L.002	L.001	0.0001	L.0001
	12 Nov 1991		0.01	0.006	0.004	0.116	0.494	0.002	0.006	0.003	0.004	0.004	0.002	0.083	0.002	0.0012	L.002	L.001	L.0001	L.0001
	13 Nov 1991		0.01	0.006	0.005	0.112	0.478	0.002	0.006	0.002	0.003	0.003	0.002	0.076	0.0019	0.0014	L.002	L.001	0.0001	L.0001
	19 Nov 1991		L.01	0.004	0.004	0.126	0.501	0.001	0.006	0.001	0.002	0.002	0.002	0.081	0.0016	0.0013	L.002	L.001	0.0001	L.0001
	21 Apr 1993		L.005	L.002	L.001	0.037	0.929	L.001	0.002	0.016	0.01	0.001	L.001	0.067	0.001		L.002	L.001	L.0001	L.0001
	29 Apr 1991		0.02	L.002	0.001	0.041	0.653	L.001	0.001	0.066	0.039	L.001	L.001	0.065	0.0011		L.002	L.001	L.0001	L.0001
	5 May 1993*		0.01	L0.002	L.001	0.066	0.497	L.001	L.001	L.001	L.001	L.001	L.001	0.087	0.0013		L.002	L.001	L.0001	L.0001
	5 May 1993*		0.01	L.002	L.001	0.066	0.507	L.001	L.001	0.077	0.042	L.001	L.001	0.087	0.0013		0.005	L.001	L.0001	L.0001
	5 May 1993*		0.01	L.002	L.001	0.065	0.492	L.001	L.001	0.007	0.004	L.001	L.001	0.086	0.0013		L.002	L.001	L.0001	L.0001
	12 May 1993		0.02	0.002	0.001	0.037	0.426	L.001	0.003	L.001	L.001	0.001	L.001	0.086	0.0014		L.002	L.001	L.0001	L.0001
	20 May 1993		0.01	L.002	L.001	0.046	0.316	L.001	L.001	0.001	0.003	0.001	L.001	0.076	0.0013		L.002	L.001	L.0001	L.0001
	26 May 1993		0.02	L.002	L.001	0.043	0.348	L.001	L.001	L.001	0.002	0.002	L.001	0.064	0.0012		L.002	L.001	0.0001	L.0001

SITE / NAQUADAT CODE	DATE	DISCHARGE	Al EXT	V TOTAL	Cr TOTAL	Mn TOTAL	Fe TOTAL	Co TOTAL	Ni TOTAL	Cu TOTAL	Zn TOTAL	Mo TOTAL	Cd TOTAL	Ba TOTAL	As TOTAL	As DISS	Pb EXT	Se DISS	Se TOTAL	Hg TOTAL
		m3/s	13030L	23001L	24004L	25001L	26009L	27009L	28007L	29003L	30030L	42001L	48002L	56001L	33001L	33101L	82301L	04101L	34003L	80021L
Beaver River at Pierceland	4 Nov 1991		0.01	0.006	0.005	0.032	0.382	0.001	0.006	0.003	0.001	0.006	0.003	0.086	0.0011	0.0006	L.002	L.001	0.0001	L.0001
00SA06AD0990	5 Nov 1991		0.02	0.004	0.004	0.032	0.365	L.001	0.006	0.002	0.001	0.002	0.003	0.081	0.0007	0.0006	0.003	L.001	L.0001	L.0001
	6 Nov 1991		L.01	0.006	0.004	0.036	0.376	0.001	0.006	0.002	0.001	0.002	0.003	0.088	0.0011	0.0009	L.002	L.001	L.0001	L.0001
	7 Nov 1991		0.02	0.006	0.004	0.038	0.351	0.001	0.006	0.002	0.004	0.003	0.003	0.085	0.0007	0.0006	L.002	L.001	0.0001	L.0001
	12 Nov 1991*		0.02	0.006	0.005	0.063	0.404	0.002	0.006	0.002	0.003	0.004	0.003	0.082	0.0017	0.0012	L.002	L.001	0.0001	L.0001
	12 Nov 1991*		0.02	0.006	0.004	0.064	0.415	0.002	0.006	0.003	0.003	0.003	0.003	0.082	0.0017	0.0013	L.002	L.001	0.0001	L.0001
	12 Nov 1991*		L.01	0.006	0.004	0.059	0.386	0.002	0.006	0.002	0.003	0.003	0.003	0.076	0.0017	0.0014	L.002	L.001	L.0001	L.0001
	13 Nov 1991		L.01	0.006	0.005	0.062	0.402	0.002	0.006	0.003	0.003	0.003	0.003	0.074	0.0017	0.0012	L.002	L.001	0.0001	L.0001
	19 Nov 1991		L.01	0.004	0.005	0.062	0.393	0.001	0.006	0.002	0.002	0.002	0.002	0.078	0.0012	0.0008	L.002	L.001	0.0001	L.0001
	21 Apr 1993		L.006	L.002	L.001	0.036	0.69	L.001	0.002	0.037	0.022	0.002	L.001	0.07	0.0008		L.002	L.001	L.0001	L.0001
	29 Apr 1991		L.005	L.002	0.001	0.036	0.533	L.001	0.003	0.004	0.003	L.001	L.001	0.067	0.001		L.002	L.001	0.0001	L.0001
	5 May 1993		0.01	L.002	L.001	0.065	0.44	L.001	L.001	L.001	L.001	L.001	L.001	0.081	0.0013		L.002	L.001	L.0001	L.0001
	12 May 1993*		0.02	L.002	0.001	0.035	0.284	L.001	0.002	L.001	L.001	0.001	L.001	0.081	0.0014		0.002	L.001	L.0001	L.0001
	12 May 1993*		0.01	L.002	L.001	0.045	0.284	L.001	L.001	0.001	0.003	L.001	L.001	0.079	0.0014		0.002	L.001	0.0001	L.0001
	12 May 1993*		0.02	L.002	L.001	0.044	0.277	L.001	L.001	0.001	0.002	L.001	L.001	0.078	0.0014		L.002	L.001	0.0001	L.0001
	20 May 1993		0.02	L.002	L.001	0.046	0.282	L.001	L.001	0.001	0.002	0.001	L.001	0.076	0.0014		L.002	L.001	L.0001	L.0001
	26 May 1993		0.1	L.0002	L.001	0.047	0.289	0.002	L.001	L.001	0.002	0.001	L.001	0.081	0.0013		L.002	L.001	0.0001	L.0001
C18-Cold Lake Wastewater Effluent	31 Oct 1991		0.06	L.002	0.002	0.015	0.063	L.001	0.002	0.018	0.044	L.001	0.002	0.018	0.0009	0.0008	0.003	L.001	L.0001	L.0001
21AL06AC0600	4 Nov 1991		0.03	L.002	0.002	0.008	0.037	L.001	0.002	0.017	0.026	L.001	L.001	0.02	0.0012	0.0012	0.002	L.001	L.0001	L.0001
	5 Nov 1991		0.03	L.002	0.002	0.018	0.05	L.001	0.003	0.018	0.028	L.001	0.001	0.019	0.0012	0.0012	0.002	L.001	0.0001	L.0001
	6 Nov 1991		0.016	L.002	0.002	0.023	0.079	L.001	0.002	0.016	0.032	L.001	L.001	0.018	0.0011	0.0011	0.003	L.001	0.0001	L.0001
	7 Nov 1991		0.04	L.002	0.002	0.023	0.057	L.001	0.002	0.015	0.031	L.001	0.001	0.018	0.0011	0.001	0.002	L.001	L.0001	L.0001
	12 Nov 1991		0.02	L.002	0.002	0.021	0.049	L.001	0.003	0.014	0.02	L.001	L.001	0.02	0.0009	0.0009	L.002	L.001	L.0001	L.0001
	13 Nov 1991		0.01	L.002	0.002	0.028	0.074	L.001	0.002	0.018	0.026	0.001	0.001	0.019	0.001	0.001	L.002	L.001	0.0001	L.0001
	19 Nov 1991		0.02	L.002	0.002	0.008	0.042	L.001	0.003	0.016	0.026	L.001	L.001	0.016	0.0009	0.0009	0.002	L.001	0.0001	L.0001
	21 Apr 1993		0.01	L.002	L.001	0.01	0.039	L.001	L.001	0.039	0.044	0.001	L.001	0.023	0.0009		L.002	L.001	0.0001	L.0001
	29 Apr 1991		0.06	L.002	L.001	0.005	0.067	L.001	L.001	0.029	0.031	L.001	L.001	0.023	0.001		L.002	L.001	0.0001	L.0001
	5 May 1993		0.02	L.002	L.001	0.004	0.049	L.001	L.001	0.029	0.041	L.001	L.001	0.026	0.0009		L.002	L.001	L.0001	L.0001
	12 May 1993		0.03	L.002	L.001	0.003	0.042	L.001	L.001	0.026	0.036	L.001	L.001	0.028	0.0008		L.002	L.001	0.0001	0.0001
	20 May 1993		0.02	L.002	0.001	0.003	0.036	L.001	0.003	0.02	0.043	0.002	L.001	0.027	0.001		0.003	L.001	L.0001	L.0001
	26 May 1993		0.03	L.002	0.005	0.003	0.048	L.001	0.004	0.023	0.041	L.001	L.001	0.028	0.0009		L.002	L.001	0.0001	L.0001
C18-Cold Lake storm sewer	31 Oct 1991		0.02	0.003	0.003	0.068	0.164	L.001	0.003	0.02	0.016	0.002	0.002	0.256	0.0016	0.0013	L.002	L.001	0.0003	L.0001
23AL06AC1000	6 Nov 1991		L.01	0.003	0.003	0.048	0.177	L.001	0.006	0.018	0.021	0.003	0.002	0.276	0.0017	0.0016	L.002	L.001	0.0003	L.0001
	21 Apr 1993		L.005	L.002	L.001	0.074	0.217	L.001	0.002	0.034	0.039	0.001	L.001	0.234	0.0011		L.002	L.001	0.0001	L.0001
	29 Apr 1991		L.005	L.002	L.001	0.059	0.186	L.001	L.001	0.01	0.029	0.001	L.001	0.199	0.0009		L.002	L.001	0.0001	L.0001
	5 May 1993		L.005	L.002	L.001	0.069	0.166	L.001	0.001	0.012	0.031	0.001	L.001	0.221	0.001		0.002	L.001	0.0001	L.0001
	12 May 1993		0.02	L.002	L.001	0.082	0.153	L.001	L.001	0.013	0.037	L.001	L.001	0.195	0.0008		0.002	L.001	0.0001	L.0001
	19 May 1993		0.01	L.002	L.001	0.081	0.167	L.001	0.002	0.014	0.037	0.002	L.001	0.219	0.001		0.004	L.001	0.0001	L.0001
	26 May 1993		0.02	L.002	0.007	0.113	0.447	L.001	0.001	0.016	0.036	0.006	L.001	0.245	0.001		L.002	L.001	0.0001	L.0001
Cold Lake/Grand centre Wastewater effluent	31 Oct 1991		L.01	0.004	0.004	0.22	0.011	0.002	0.011	0.003	L.001	0.002	0.003	0.304	0.0002	0.0002	0.002	L.001	0.0002	L.0001
21AL06AD4600	4 Nov 1991		0.03	0.006	0.003	0.41	0.146	0.001	0.007	0.002	0.006	0.003	0.002	0.03	0.0095	0.009	0.002	L.001	0.0003	L.0001
	5 Nov 1991		0.04	0.006	0.003	0.387	0.167	0.001	0.007	0.002	0.006	0.003	0.002	0.028	0.0095	0.0094	0.004	L.001	0.0002	L.0001
	6 Nov 1991		0.01	0.006	0.003	0.412	0.128	0.002	0.008	0.002	0.003	0.004	0.002	0.031	0.0117	0.0114	L.002	L.001	0.0002	L.0001
	7 Nov 1991		0.06	0.006	0.004	0.396	0.13	0.003	0.007	0.003	0.006	0.007	0.002	0.03	0.0096	0.0096	L.002	L.001	0.0002	L.0001
	12 Nov 1991		0.03	0.007	0.004	0.457	0.131	0.003	0.01	0.003	0.006	0.004	0.003	0.039	0.0094	0.0086	L.002	L.001	0.0002	L.0001
	13 Nov 1991		0.02	0.006	0.004	0.42	0.197	0.002	0.008	0.004	0.02	0.004	0.002	0.037	0.0079	0.0079	L.002	L.001	0.0002	L.0001
	29 Apr 1991		0.06	0.002	L.001	0.36	0.438	0.001	0.006	0.011	0.012	L.001	L.001	0.04	0.0028		L.002	L.001	0.0001	L.0001
	6 May 1993		0.1	0.002	0.001	0.362	0.789	0.001	0.003	0.017	0.009	0.001	L.001	0.061	0.0029		0.002	L.001	0.0002	L.0001
	12 May 1993		0.06	0.003	L.001	0.268	0.467	0.001	0.005	0.01	0.004	L.001	L.001	0.036	0.0031		L.002	L.001	0.0002	L.0001
	19 May 1993		0.11	0.004	0.001	0.228	0.748	L.001	0.003	0.012	0.014	0.002	L.001	0.048	0.0033		L.002	L.001	0.0002	L.0001

APPENDIX 1 : continued

STATION NAQUADAT CODE	Date	TEMPERATURE DEG.C 02061F	PH 10301F	CONDUCTIVITY US/CM 02041F	OXYGEN METER O2 08101F	OXYGEN WINKLR O2 08101L	COLIFORM TOTAL No per 100 mL 36001L	COLIFORM FECAL No per 100 mL 36011L	FECAL STREP per 100 mL 36101L
Beaver River at Ardmore - Right Bank	31 Oct 1991	-0.1	7.1	662	10.7	10.6			
00AL06AC3491	4 Nov 1991	0.1	7.3	808	8.7				
	5 Nov 1991	0	7.2	813	7.1				
	6 Nov 1991	0	7.6	792	6.6				
	7 Nov 1991	-0.2	7.5	792	5.7				
	12 Nov 1991	0.1	7.2	758	1				
	13 Nov 1991	0	7.2	748	0				
	19 Nov 1991	0	7	855	3				
	21 Apr 1993	4.78	8.36	305	11.71				
	29 Apr 1993	7.33	8.09	342	10.41				
	5 May 1993	11.16	8.06	420	9.09				
	12 May 1993	17.23	8.06	439	8.01				
	19 May 1993	14.4	8.17	381	8.94				
	26 May 1993	12.81	8.19	488	9				
Beaver River at Ardmore - Centre	30 Oct 1991	0	7.2	732	11.9	11.7			
00AL06AC3500	31 Oct 1991	0	7.2	653	10.8		8	8	
	4 Nov 1991	0.1	7.4	801	8.6		29	L4.	
	5 Nov 1991	0	7.3	813	7.2	7	16	L4.	
	6 Nov 1991	0	7.7	793	6.6	6.41	16	L4.	
	7 Nov 1991	-0.1	7.6	791	5.9	5.76	16	L4.	
	12 Nov 1991	0.2	7.2	757	1.2	2.16	32	L4.	
	13 Nov 1991	0	7.3	760	0	1.67	32	9	
	19 Nov 1991	0.1	7	857	3.2	2.88	12	9	
	21 Apr 1993	4.82	8.36	306	11.72	11.36	69	L4.	8
	29 Apr 1993	7.37	8.09	342	10.43	10.3	27	L4.	L4.
	5 May 1993	11.16	8.06	420	9.07	8.98	57	L4.	L4.
	12 May 1993	17.28	8.05	440	8.04	8.04	40	4	24
	19 May 1993	14.45	8.17	382	8.96	8.97	3200	8	L4.
	26 May 1993	12.81	8.17	488	8.99	8.75	33	12	4
Beaver River at Ardmore - Left Bank	31 Oct 1991	-0.3	7.8	725	11				
00AL06AC3505	4 Nov 1991	0.4	7.4	798	8.6	8.86			
	5 Nov 1991	0	7.4	813	7.2				
	6 Nov 1991	0	7.8	788	6.5				
	7 Nov 1991	-0.1	7.6	788	6				
	12 Nov 1991	0.2	7.3	743	1				
	13 Nov 1991	0.2	7.4	750	0				
	19 Nov 1991	0.2	6.8	853	3.3				
	21 Apr 1993	4.87	8.36	306	11.75				
	29 Apr 1993	7.37	8.08	342	10.47				
	5 May 1993	11.16	8.04	420	9.1				
	12 May 1993	17.3	8.05	439	8.05				
	19 May 1993	14.46	8.17	382	9.08				
	26 May 1993	12.8	8.17	491	9.03				
Beaver River at Beaver Crossing - right bank	31 Oct 1991	0	7.4	752	10.5				
00AL06AD3991	4 Nov 1991	0	7.6	815	7.6				
	5 Nov 1991	0	7.3	816	6.7				
	6 Nov 1991	-0.3	7.4	800	6.5				
	7 Nov 1991	-0.2	7.5	812	5.3				
	12 Nov 1991	-0.1	7.2	770	0				
	13 Nov 1991	0	7.3	773	0				
	19 Nov 1991	-0.2	6.9	869	0				
	21 Apr 1993	6.51	8.42	302	11.93				
	29 Apr 1993	8.02	8.16	331	10.74				
	5 May 1993	14.91	8.18	436	10.22				
	12 May 1993	20.81	8.36	439	10.53				
	19 May 1993	15.01	8.22	373	9.46				
	26 May 1993	13.4	8.29	494	9.59				

STATION NAQUADAT CODE	Date	TEMPERATURE DEG.C 02061P	PH 10301P	CONDUCTIVITY US/CM 02041P	OXYGEN METER O2 08101P	OXYGEN WINKLR O2 08101L	COLIFORM TOTAL No per 100 mL 36001L	COLIFORM FECAL No per 100 mL 36011L	FECAL STREP per 100 mL 36101L
Beaver River at Beaver Crossing - Centre 00AL06AD4000	30 Oct 1991	-0.2	7.3	729	11.4	11.12			
	31 Oct 1991	-0.1	7.2	756	10.1		9	4	
	31 Oct 1991						L4.	4	
	31 Oct 1991						6	4	
	4 Nov 1991	0	7.4	819	7.5	7.3	16	L4.	
	5 Nov 1991	0	7.3	818	6.6	6.35	20	L4.	
	6 Nov 1991	-0.3	7.4	809	6.3	6.01	24	L4.	
	7 Nov 1991	-0.3	7.4	812	5	4.88	12	L4.	
	12 Nov 1991	-0.2	7.1	768	0	2.83	70	L4.	
	13 Nov 1991	-0.1	7.3	775	0	1.98	9	L4.	
	19 Nov 1991	-0.2	6.9	871	0	2.42	12	L4.	
	21 Apr 1993	6.46	8.42	302	11.87	11.51	33	L4.	L4.
	29 Apr 1993	7.97	8.17	331	10.68	10.59	33	L4.	L4.
	5 May 1993	14.93	8.19	437	10.21	10.26	54	L4.	4
	12 May 1993	20.79	8.35	438	10.4	10.36	30	8	12
	19 May 1993	15.05	8.21	379	9.4	9.5	2100	4	4
	26 May 1993	13.37	8.28	493	9.6	9.54	27	24	20
Beaver River at Beaver Crossing - Left Bank 00AL06AD4005	31 Oct 1991	-0.1	7.2	753	9.9	10.37			
	4 Nov 1991	0	7.3	820	7.5				
	5 Nov 1991	0	7.2	820	6.6				
	6 Nov 1991	-0.3	7.4	792	6.5				
	7 Nov 1991	-0.2	7.4	812	5.1				
	12 Nov 1991	-0.2	7.1	620	0				
	13 Nov 1991	-0.2	7.2	776	0				
	19 Nov 1991	-0.2	6.9	870	0				
	21 Apr 1993	6.51	8.43	303	11.87				
	29 Apr 1993	8	8.17	332	10.67				
	5 May 1993	15.08	8.19	436	10.21				
	12 May 1993	20.86	8.36	442	10.45				
	19 May 1993	15.08	8.22	377	9.42				
	26 May 1993	13.4	8.29	493	9.64				
Beaver River at Border - Right Bank 00AL06AD4991	31 Oct 1991	-0.3	7.5	707	10.7				
	4 Nov 1991	0	7.2	841	7.9				
	5 Nov 1991	0	7.3	818	7.1				
	6 Nov 1991	-0.3	7.4	816	6.7				
	7 Nov 1991	-0.3	7.5	826	5.9				
	12 Nov 1991	-0.1	7.2	813	3.4				
	13 Nov 1991	-0.2	7.1	796	3.8				
	19 Nov 1991	-0.2	7.1	904	3.3				
	21 Apr 1993	7.37	8.4	307	12.13				
	29 Apr 1993	8.43	8.16	351	10.91				
	5 May 1993	13.27	8.32	454	11.94				
	12 May 1993	19.49	8.47	436	11.6				
	19 May 1993	16.24	8.42	376	11.47				
	26 May 1993	13.5	8.27	490	9.7				
Beaver River at Border - Centre 00AL06AD5000	30 Oct 1991	-0.2	7.3	757	12	11.34			
	31 Oct 1991	-0.4	7.4	705	10.4	10.41	12	10	
	4 Nov 1991	0	7.2	840	7.9	7.63	28	L4.	
	5 Nov 1991*	0	7.3	824	7.1	6.9	6	4	
	5 Nov 1991*						12	12	
	5 Nov 1991*						28	4	
	6 Nov 1991	-0.3	7.4	815	6.7	6.32	16	L4.	
	7 Nov 1991	-0.3	7.4	826	5.8	5.82	20	L4.	
	12 Nov 1991	-0.1	7.3	812	3.5	3.24	15	L4.	
	13 Nov 1991	-0.1	7.2	795	3.7	3.73	32	16	
	19 Nov 1991	-0.2	7.1	903	3.4	3.05	900	111	
	21 Apr 1993	7.35	8.46	307	12.15	11.72	63	L4.	L4.
	29 Apr 1993	8.42	8.15	352	11.01	11.18	110	L4.	L4.
	5 May 1993*	13.29	8.33	454	11.92	11.7	430	L4.	L4.
	5 May 1993*						340	L4.	L4.
	5 May 1993*						530	L4.	L4.
	12 May 1993	19.45	8.46	433	11.6	11.53	410	L4.	9
	19 May 1993	16.24	8.42	377	11.47	11.46	2800	12	L4.
	26 May 1993	13.5	8.27	490	9.64	9.61	G20.	20	L4.

STATION NAQUADAT CODE	Date	TEMPERATURE DEG.C 02061F	PH 10301F	CONDUCTIVITY US/CM 02041F	OXYGEN METER O2 08101F	OXYGEN WINKLR O2 08101L	COLIFORM TOTAL No per 100 mL 36001L	COLIFORM FECAL No per 100 mL 36011L	FECAL STREP per 100 mL 36101L
Beaver River at Border - Left Bank 00AL06AD5005	31 Oct 1991	-0.4	7.2	709	10.8				
	4 Nov 1991	0	7.2	840	7.9				
	5 Nov 1991	0	7.3	825	7				
	6 Nov 1991	-0.3	7.5	813	6.8				
	7 Nov 1991	-0.3	7.4	827	5.8				
	12 Nov 1991	0	7.3	810	3.5				
	13 Nov 1991	0	7.4	795	3.7				
	19 Nov 1991	-0.1	7.2	903	3.5				
	21 Apr 1993	7.38	8.45	307	12.19				
	29 Apr 1993	8.42	8.12	353	10.18				
	5 May 1993	13.29	8.32	454	11.97				
	12 May 1993	19.57	8.48	435	11.79				
	19 May 1993	16.24	8.43	377	11.6				
	26 May 1993	13.5	8.27	490	9.69				
Beaver River at Pierceland - Right Bank 00SA06AD0991	31 Oct 1991	-0.3	7.8	663	12.3				
	4 Nov 1991	0	7.3	862	8.7				
	5 Nov 1991	-0.2	8.1	835	7.6				
	6 Nov 1991	-0.1	7.4	832	7.1				
	7 Nov 1991	-0.1	7.5	847	5.6				
	12 Nov 1991	0	7.2	842	3.8				
	13 Nov 1991	0.3	8.2	817	3.3				
	19 Nov 1991	-0.2	7.1	915	4.4				
	21 Apr 1993	8.55	8.59	335	12.4				
	29 Apr 1993	9.06	8.36	358	12.31				
	5 May 1993	13.06	8.63	440	12.48				
	12 May 1993	20.34	8.74	456	12.36				
	19 May 1993	16.67	8.55	385	10.82				
	26 May 1993	14.18	8.5	480	10.74				
Beaver River at Pierceland - Centre 00SA06AD1000	30 Oct 1991	-0.2	7.4	711	12.8	12.33			
	31 Oct 1991	-0.3	7.8	656	12.4	11.58	20	4	
	4 Nov 1991	0	7.3	863	8.7	8.4	20	4	
	5 Nov 1991	-0.2	8.1	837	7.6	7.48	30	L4.	
	6 Nov 1991	-0.2	7.4	832	7	6.52	28	L4.	
	7 Nov 1991	-0.1	7.8	843	5.6	5.4	20	4	
	12 Nov 1991*	0	7.2	844	3.7	3.56	6	L4.	
	12 Nov 1991*						12	8	
	12 Nov 1991*						8	L4.	
	13 Nov 1991	0.2	8.2	816	3.6	3.1	32	L4.	
	19 Nov 1991	-0.2	7.1	916	4.4	4.39	32	L4.	
	21 Apr 1993	8.45	8.59	335	12.42	12.09	81	4	L4.
	29 Apr 1993	8.96	8.37	358	12.24	12.3	15	3	L4.
	5 May 1993	12.99	8.63	442	12.51	12.42	250	L4.	L4.
	12 May 1993	20.15	8.74	456	12.3	12.08	150	L4.	L4.
	19 May 1993*	16.61	8.55	386	10.83	11.01	1800	16	12
	19 May 1993*						1900	6	6
	19 May 1993*						1600	12	L4.
	26 May 1993	14.11	8.5	480	10.71	10.59	18	12	8
Beaver River at Pierceland - Left Bank 00SA06AD1005	31 Oct 1991	-0.4	7.9	702	12.4				
	4 Nov 1991	0	7.3	863	8.7				
	5 Nov 1991	-0.2	8	840	7.5				
	6 Nov 1991	-0.2	7.4	834	7.1				
	7 Nov 1991	-0.1	7.6	843	5.6				
	12 Nov 1991	0	7.2	841	4				
	13 Nov 1991	0	8.1	814	3.3				
	19 Nov 1991	-0.2	7.1	915	4.7				
	21 Apr 1993	8.6	8.61	333	12.42				
	29 Apr 1993	9.12	8.37	359	12.2				
	5 May 1993	13.11	8.64	441	12.51				
	12 May 1993	20.37	8.76	458	12.39				
	19 May 1993	16.71	8.57	385	10.89				
	26 May 1993	14.16	8.5	480	10.74				

STATION NAQUADAT CODE	Date	TEMPERATURE DEG.C 02061F	PH 10301F	CONDUCTIVITY US/CM 02041F	OXYGEN METER O2 08101F	OXYGEN WINKLR O2 08101L	COLIFORM TOTAL No per 100 mL 36001L	COLIFORM FECAL No per 100 mL 36011L	FECAL STREP per 100 mL 36101L
CFC Cold Lake Wastewater Effluent	31 Oct 1991	10.2	6.9	501	5.7		L10.	L10.	
21AL06AC0500	4 Nov 1991	10.8	7	507	8		4	L4.	
	5 Nov 1991	10.3	6.9	508	8		L10.	L10.	
	6 Nov 1991	9.7	7.1	498	8.4	8.32	L10.	L10.	
	7 Nov 1991	9.5	7	491	8.2	8.22	L10.	L10.	
	12 Nov 1991	10.4	6.9	482	8.2		L10.	L10.	
	13 Nov 1991	10.8	7	494	7.6		L10.	L10.	
	19 Nov 1991	10.2	6.9	514	8.5		L10.	L10.	
	21 Apr 1993	10.14	7.42	555	8.52	7.9	10	L10.	L10.
	29 Apr 1993	10.34	7.2	549	8.67	8.18	10	L10.	4
	5 May 1993	11.8	7.1	531	7.9	7.89	60	10	L4.
	12 May 1993	14.41	7	530	5.98		260	10	L4.
	19 May 1993	11.9	6.93	549	5.72		L30.	L10.	L4.
	26 May 1993	12.44	6.98	768	6.3		10	L10.	L4.
Cold Lake /Grand Centre Wastewater Effluent	31 Oct 1991						24	10	
21AL06AD4600	4 Nov 1991	1.9	7.7	777	11.9		L10.	L10.	
	5 Nov 1991	1.7	7.7	781	12.1		10	L10.	
	6 Nov 1991	1.8	7.8	772	11.3		L10.	L10.	
	7 Nov 1991	1.9	7.9	773	12.7		10	L10.	
	12 Nov 1991	2.4	7.6	807	11.8		L10.	L10.	
	13 Nov 1991	2	7.6	821	11.4		34000	4500	
	21 Apr 1993	8.28	7.95	875	10.84		3800	60	10
	29 Apr 1993	12.54	8.11	819	10.16		60000	320	60
	5 May 1993	17.25	8.68	698	9.47		8200	40	10
	12 May 1993	16.37	8.48	740	8.83		15000	30	44
	19 May 1993								
CFC Cold Lake Storm Sewer	31 Oct 1991	8.9	7.3	533	10		7000	100	
21AL06AC1000	6 Nov 1991						7400	50	
	21 Apr 1993	5.53	8.08	548	11.33	11	58000	11000	720
	29 Apr 1993	5.27	7.83	568	11.29	11.36	7900	2000	60
	5 May 1993	5.54	7.79	584	11.2	11.42	70000	60000	63
	12 May 1993	6.45	7.83	597	11.05	11.19	86000	25000	36
	19 May 1993	6.53	7.82	608	11.03	11.38	1400	110	12
	26 May 1993	6.74	7.83	614	10.83	10.56	430	33	40