WATER QUALITY OVERVIEW OF ATHABASCA RIVER BASIN

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ATHABASCA RIVER BASIN

PREPARED FOR

ALBERTA ENVIRONMENT
PLANNING DIVISION

BY

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August 23, 1985

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Planning Division
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Attention: Jim Snidal

RE: ATHABASCA RIVER WATER QUALITY OVERVIEW
CONTRACT NO. 85-0769

Dear Jim;

We are pleased to transmit our final report on the Athabasca River Water Quality Overview. We trust this document satisfies the terms of reference and provides a basin wide perspective on Athabasca River water quality conditions. It should serve as a valuable reference for subsequent work on water quality planning in the basin.

Nanuk Engineering appreciates the opportunity afforded us by Planning Division, Alberta Environment to undertake this assignment.

Yours truly,

M. V. Thompson, P.Eng.
Chief Engineer

MVT:lc
enclosure

EXECUTIVE SUMMARY

This report overviews major water quality patterns and trends for the Athabasca River and its major tributaries. In doing so it compares water quality data with surface water quality objectives, identifies spatial and temporal patterns, defines major factors affecting water quality, characterizes the relationship between basin hydrology and water quality and identifies river reaches with similar water quality charateristics.

The data analyzed for this overview assessment include historical water quality records collected since 1970 at three fixed station network locations (Jasper, Town of Athabasca and Ft. McMurray), and the results of six basin wide synoptic sampling surveys done seasonally during 1984 and early 1985. The historical data define long term trends, whereas the synoptic surveys provide information on spatial patterns.

Results indicate that except for the St. Regis Pulp Mill at Hinton, point source effluents from municipal and industrial plants have no broadly based influence on river water quality. In almost all instances tributary streams account for 90% or more of all measured constituent loadings. At low river flows the Hinton Pulp Mill does affect river water quality for a distance of 50 to 75 km.

Many of the Alberta Surface Water Quality Objectives (ASWQO) are regularly exceeded, however most of these exceedances are not attributable to point or non-point source impacts. These provincial objectives do not account for regional variations in natural water quality. Comparison with Environment Canada's use specific water quality objectives indicate Athabasca River water can be used for all beneficial uses except contact recreation, which is limited much of the year by low water temperatures and high turbidity. Certain objectives for aquatic life and wildlife are occasionally exceeded, however, these violations are due to natural causes and pending further investigation are not thought to be significant.

Three water quality zones can be defined for the Athabasca River. The Foothills Reach, between Jasper Park boundary and Ft. Assiniboine, is characterized by fast flow and good overall water quality conditions. Alkalinity and hardness levels are elevated, reflecting the mountain origin of the water; yet the suspended solids, organic carbon and nutrient contents are low. The Hinton pulp mill is the only significant anthropogenic impact. Coal mining activity in the upper tributaries has no broad based effect on the mainstem river system. In contrast, very different water quality conditions are experienced in the river reach situated between Ft. McMurray and Lake Athabasca. Suspended solid levels are high much of the year, as are associated parameters like organic carbon, particulate nutrients and metals. These constituents are derived from upstream tributaries and channel re-suspension, rather than municipal or industrial effluents. The lower reach also has a unique major ion chemistry created by loadings from the Clearwater River. The intermediate reach between Ft. Assiniboine and Ft. McMurray is a transition zone. Along this stretch, alkalinity and hardness levels decrease, while most other constituent concentrations increase due to tributary loadings.

Based upon statistical analysis of the historical water quality database three distinct water quality seasons are defined. These include the ice cover interval, and two open water periods, from ice off to July 31 and August 1 to freeze-up. Water quality in the early openwater season is controlled by local and mountain snowmelt runoff and a rising hydrograph. The late openwater season is affected by a falling hydrograph, summer rainstorms in the Interior Plains and maximum instream biological activity.

Except for some tributaries the existing database adequately defines baseline water quality conditions throughout the basin. Future work should emphasize expansion of the fixed station water quality monitoring network, definition of river assimilation processes, development of basin specific water quality objectives, further work on trace organic compounds and more detailed definition of parameter inter-correlation and discharge dependence.

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I. INTRODUCTION

The Athabasca River drains one of the four major Alberta River Basins. It originates in the Columbia Icefields and then flows in a northeasterly direction across Alberta prior to draining into Lake Athabasca. The basin area is 157,000 km^2. This report overviews major water quality patterns and trends for the mainstem river and its major tributaries.

This overview is intended to provide part of the framework necessary for defining relevant water quality issues, identification of significant impacts, and characterization of the unique chemical, physical and biological attributes of the Athabasca River.

The data analyzed for this overview assessment includes historical water quality records from three mainstem locations (Jasper, Town of Athabasca and Ft. McMurray) collected since 1970, and the results of six synoptic sampling surveys done seasonally during 1984 and early 1985. These surveys encompassed twelve mainstem sites, nine tributaries and five effluents. The historical data define longterm trends, whereas the synoptic surveys provide information on spatial patterns.

Specific objectives of this basin water quality overview include:

- comparison of recent and historical water quality data with surface water quality objectives
- identification of longitudinal and seasonal patterns in water quality
- characterization of the relationship between basin hydrology and water quality
- assessment of the major factors affecting water quality, i.e. tributary streams, industrial and municipal effluents, non-point source impacts; and
- identification of river reaches with similar water quality characteristics.

Results of this study can also be used to refine the existing water quality model (Water Quality for River-Reservoir Systems) of the basin, gaps in the historical database, necessary revisions to water quality monitoring programs and provide the basis for development of basin specific river water quality objectives.

II METHODS

Water quality samples have been collected by both the Federal and Provincial governments at numerous Athabasca mainstem and tributary locations since the early 1960's. Unfortunately sampling sites and analytical methodologies have varied considerably over that interval. For this study provincial historic data were to be excluded from analysis and emphasis placed on interpreting the Federal database from four locations: Jasper, Hinton, Town of Athabasca and Ft. McMurray. Jasper and Town of Athabasca are the two current longterm network sampling locations. They are sampled monthly under the terms of a joint agreement between Alberta Environment and Environment Canada.

Scrutiny of the Federal database indicated a good water quality record at Jasper and Town of Athabasca, extending back to 1970. Little data existed for the station at Hinton so it was dropped from subsequent analysis. The Federal data record at a site upstream of Ft. McMurray, was moderately complete for the period 1970 to 1977. Since 1977, sampling was continued at this station by Alberta Environment in conjunction with the Alberta Oil Sands Environmental Research Program (AOSERP). For this analysis the two datasets were combined in order to provide record compatability with the upstream sites. The Ft. McMurray site is not influenced by the Clearwater River.

Prior to analysis, historic data were scrutinized and tape transferred from Alberta Environment's NAQUADAT database to the MTS computer system at the University of Alberta. Data from 1984 were entered directly into MTS from hardcopy provided by Water Quality Branch of Environment Canada. The water quality parameters for which historical data exist are listed in Table (1). Also indicated are corresponding NAQUADAT codes which provide information on the analytical method if compared with the NAQUADAT system dictionary.

The recent database included data from twelve mainstem river sites (Figure 1), nine tributary streams and five effluents. The effluents include the combined municipal waste and pulp mill effluent at Hinton, the final effluent from the Suncor Tar Sands Plant and municipal discharges at Whitecourt, Town of Athabasca and Ft. McMurray. The Syncrude Tar Sands Plant does not have a process effluent to the Athabasca River, however, mine drainage and depressurization water is discharged to

Poplar Creek. With the exception of the pulp mill, single grab samples were obtained from each river site, tributary, and effluent on six occasions. Twenty-four hour composite samples were obtained from the Hinton mill effluent. Samples for each survey were collected over a two to three day interval centered around May 15, June 12, July 11, September 11, and October 23, 1984. In addition, a winter sample was obtained between 3 and 5 February, 1985. The surveys were conducted by helicopter and grab samples were assumed representative of river cross section conditions. In addition to the 12 mainstem sites indicated above, samples were also obtained from two additional river sites located downstream of Hinton. At these locations, spaced less than five and twenty km below the pulp mill effluent, both right and left bank grab samples were obtained to compensate for possible lack of effluent mixing. Diurnal surveys for pH, temperature, conductivity and dissolved oxygen were done at Hinton in September and Town of Athabasca in October.

Chemical analyses for the synoptic survey samples were carried out by the Alberta Environmental Centre at Vegreville. The parameters and their appropriate parameter codes are listed in Table (1). Epilithic and phytoplanktonic chlorophyll samples were analyzed directly by Water Quality Control Branch of Alberta Environment. The epilithic chlorophyll samples were obtained by scraping defined areas of rocks from the river substrate; phytoplankton samples were obtained using grab samples from the water column. Microbiological samples were processed by the Alberta Public Health Laboratory in Edmonton. When required, the samples were properly preserved or iced at the time of collection to prevent degradation on route to the laboratory.

River discharge information was obtained from Water Survey of Canada when available. Longterm flow duration statistics and average discharge statistics were defined by Bothe (1982). Daily flows for the synoptic surveys were estimated for each mainstem and tributary sampling site by Hydrology Branch of Alberta Environment. Industrial and municipal effluent flows were obtained from Pollution Control Division of Alberta Environment.

All statistical analyses were undertaken with SPSSx (Spss Inc,1983) except the cluster and principal components analysis which were run on Clustan (Wishart,1978). Parameter distributions were evaluated using the Kolmogorov-Smirnov test and the appropriate transformation employed on non-normal distributions prior to conducting any parametric statistical procedures. The cluster and principal

TABLE 1 NAQUADAT WATER QUALITY PARAMETER CODES

PARAMETER		HISTORIC DATA	RECENT DATA
pH		10301L 01F	110301L 01F
Sodium		11103L 02L	11103L
Magnesium		12102L 01L 03L 02P	12102L
Calcium		20103L 01L	20110L
Potassium		19103L	19103L
Chloride		17206L 05L 03L	17203L
Sulphate		16306L 03L 04L	16306L
Bicarbonate		02061F 61S	06202L
Total dissolved solids		00202L	00205L
Conductivity		00205L	02041L 41F
Filterable Residue			10453L 52L 51L
Non-Filterable Residue		10401L 02L 01F 04L	10407L
Turbidity		02073L 72L 71L	02074L 73L 72L 71L
Hardness		10606L	10605L
Alkalinity		10603L	10101L
Temperature		02062L	02062L
Dissolved Oxygen		08101L 01P 01F	08102L 02F
Biochemical Oxygen Demand		08201L	08202L
Chemical Oxygen Demand		08304L 51L 49L 01L	08304L 51L 49L 01L
Cyanide		06605L	
Particulate Carbon		06902L 04L	06905L 02L 01L
Dissolved Organic Carbon		06104L 01L 04F	06107L
Total Organic Carbon		06101L 05L 51L	
Dissolved Inorganic Carbon		06104L 01L 04F	06154L
Phenols		06535L 35P 32L 3P	06537L
Tannins & Lignins			06551L
Oil & Grease			06524L
True Color		02021L	02021F
Apparent Color		02011L	
Phytoplanktonic chlorophyll a		06711L 17L	06715L
Epilithic chlorophyll a			06722L
Total Coliforms		36002L 01L 02F	36001L
Fecal Coliforms		36012L 12F 11L	36011L
Fecal Streptococci		36110L	
Silica		14102L 05L 01L	14102L
Fluoride		09105L 04L 03L 02L	09107L
Boron		05002L 01L	
Iron		26309L 06L	26309L
Manganese		25108L 07L	25108L
Total Phosphorus		15406L 13L 06F	15421L
Total Dissolved Phosphorus		15103L 03P 03F	15105L
Total Ortho Phosphorus		15257L 59L 56L 55L	15256L
Total Kjeldahl Nitrogen		07011L 02L 01L 11F	07021L
Particulate Nitrogen		07902L	07906L
Dissolved Nitrogen		07651L	
Nitrate + Nitrite		07110L 10F 06F 05L	07111L 05L
Nitrite			07206L 05L
Ammonia		07506L 51L 01L 06F	07562L
Aluminum	(dis.)	13104L 03L	
Aluminum	(ext.)	13305P 02P 05L 02L	13306L
Arsenic	(total)		33005L
Antimony	(total)	51101L 01P	
Barium	(total)	56020P 20L	
Barium	(ext.)	56301P 02P 01L 02L	
Beryllium	(ext.)	04304L	04304L
Cadmium	(total)	48020P 20L	48009L
Cadmium	(ext.)	48302P 01P 02L 01L	
Cadmium	(dis.)	48102L 02P 02L	
Chromium	(total)	24302P 02L	24009L
Cobalt	(total)	27102P 02L	27009L
Cobalt	(ext.)	27302P 01P 02L 01L	
Copper	(total)	29020P 20L	29009L
Copper	(ext.)	29305P 05L 06P 06L	
Lead	(total)	82020L 02P	
Lead	(ext.)	82301P 03P 02P 01L	82302L
Lead	(dis.)	82103L 02L 03P 02P	
Mercury	(total)	80011L 11P	80015L
Mercury	(ext.)	80313L 11L 13P 11P	
Molybdenum	(total)		42009L
Molybdenum	(ext.)	42302L 01L 01P 02P	
Nickel	(total)	28020L 20P	28009L
Nickel	(ext.)	28302L 01L	
Nickel	(dis.)	28102L 02P	
Silver	(ext.)	47301P 02P 01L 02L	
Selenium	(total)	34102L 01L 02F	34005L
Strontium		38301L 01P	
Vanadium	(total)	23020L 20P	23009L
Vanadium	(ext.)	23302L 02P 01P	
Zinc	(total)	30020L 20P	30009L
Zinc	(ext.)	30305P 05L 03L 04P	
Zinc	(dis.)	30105L 05P 04L 04P	

component analysis was implemented on a subset of 40 variables. This included a cross section of chemical, physical and biological constituents representative of natural and impacted water quality conditions within the basin. The entire 60 parameter dataset was not included in an attempt to eliminate covariates. The multivariate database was converted to standard scores prior to analysis, and Ward's hierarchical fusion method was used for clustering.

The definition of seasons for analysis of the historical database was based upon river freeze and thaw dates and the open water hydrograph. The average ice cover interval for the period 1975 to 1983 is presented in Table (2). These dates were used to define the overall open water and ice cover periods at each historical water quality site. Review of the historical river hydrograph indicated subdivision into two open water seasons might be desirable; an early season from ice off to July 31, and a late season from August 1 to freeze up. The majority of high river flow occurred in the early spring and summer. During August and September flows tend to recede towards the normal winter minimum. A non-parametric t-test on the historical database indicated these two proposed open water seasons were justified for a significant number of parameters (Table 3). The site specific seasons used in the analysis are summarized in Table (4).

TABLE 2 AVERAGE FREEZE AND THAW DATES FOR ATHABASCA RIVER FOR INTERVAL 1975 - 1983

	ATHABASCA AT JASPER	ATHABASCA AT ATHABASCA	ATHABASCA AT FT. MCURRAY
FREEZE-UP	NOVEMBER 14(15)	NOVEMBER 17(8)	NOVEMBER 9(7)
ICE OFF	MARCH 17(11)	APRIL 20(9)	APRIL 28(7)

( ) INDICATES STANDARD DEVIATION

TABLE 3 TEST FOR STATISTICALLY SIGNIFICANT OPEN WATER SEASONS IN HISTORICAL ATHABASCA RIVER WATER QUALITY DATABASE USING MANN-WHITNEY U ANALYSIS. SEASONS TESTED WERE ICE-OFF TO JULY 31 AND AUGUST 1 TO FREEZE-UP.

PARAMETER	N_1/N_2	JASPER	N_1/N_2	ATHABASCA	N_1/N_2	FT. MCMURRAY
SODIUM	38/34	-	37/49	-	40/43	-
CHLORIDE	38/34	*	37/49	*	40/43	-
SULFATE	38/34	-	37/49	**	38/41	-
DISSOLVED ORGANIC CARBON	28/27	**	22/27	**	16/16	-
PHENOL	30/29	-	25/32	-	29/32	-
CONDUCTIVITY	56/56	-	38/51	**	40/44	-
TURBIDITY	57/56	-	38/51	**	29/31	**
ALKALINITY	37/33	-	35/47	**	40/43	*
TOTAL PHOSPHORUS	57/55	**	25/36	**	25/33	**
DISSOLVED PHOSPHORUS	29/26	-	22/26	**	ND	
KJELDAHL NITROGEN	30/32	-	ND	-	18/23	-
AMMONIA	15/12	-	20/22	-	25/24	**
NITRATE & NITRITE	57/56	-	36/47	**	34/39	**

N_1 = SAMPLE SIZE FOR ICE-OFF TO JULY 31
N_2 = SAMPLE SIZE FOR AUGUST 1 TO FREEZE-UP

* = SIGNIFICANT DIFFERENCE AT P=0.05
** = SIGNIFICANT DIFFERENCE AT P=0.01
ND = INSUFFICIENT DATA

TABLE 4 DEFINITION OF SEASONS FOR HISTORICAL ANALYSIS OF ATHABASCA RIVER WATER QUALITY DATA

		OPEN WATER	
SITE	ICE COVER	HIGH FLOW	LOW FLOW
JASPER	15 NOVEMBER-15 MARCH	16 MARCH-31 JULY	1 AUGUST-14 NOVEMBER
ATHABASCA	15 NOVEMBER-20 APRIL	21 APRIL-31 JULY	1 AUGUST-14 NOVEMBER
FT. MCMURRAY	10 NOVEMBER-30 APRIL	1 MAY - 31 JULY	1 AUGUST-9 NOVEMBER

III BASIN CHARACTERISTICS

Natural river water quality is an integration of the chemical, physical and biological characteristics of the drainage basin. Observed water quality is in turn affected by man's activities in the watershed; expressed as both point and non-point impacts. Point source impacts include industrial and municipal discharges. Non-point impacts are those effects resulting from area wide changes in land use such as forestry, agriculture, mining and urbanization. In order to interpret water quality trends, some understanding of the natural and culturally induced characteristics of the drainage basin is required. A brief overview of the Athabasca River watershed is presented in this section.

1. Watershed Area and Channel Characteristics

The total area of the Athabasca River Basin is 157,000 km^2 (Figure 1). The Athabasca River originates in the Columbia Icefields and flows for 1464 km in a northeasterly direction to its point of discharge into Lake Athabasca. The proportion of the drainage area encompassed by each Water Survey of Canada (WSC) stream gauge is presented in Table (5). Approximately one-half the basin is situated upstream of the Town of Athabasca, and 85% is encompassed by the gauge located downstream from Ft. McMurray. The Clearwater, Lesser Slave, Pembina and McLeod rivers form the major tributary systems.

Total elevational drop from headwaters to mouth is 1254m, which results in an average channel slope of 0.86 m/km (Kellerhals et al., 1972)(Figure 2). The maximum slope approaches 4m/km in the reach upstream from Jasper. Between Jasper and Hinton the gradient is much reduced (0.7m/km) and then increases again to approximately 1.25 m/km between Hinton and Whitecourt. Upstream of the Town of Athabasca the gradient is only 0.3 m/km, which is only slightly higher than the minimum which occurs in the reach downstream from Ft. McMurray (0.12 m/km). The slope between Athabasca and Ft. McMurray is approximately 0.7 m/km. The river varies in width from an average of 60m at Jasper to 450m at Ft. McMurray.

2. Climate, Geology and Vegetation

Three major physiographic regions are included within the bounds of the Athabasca River Basin; the Cordillera, Interior Plains and the Canadian Shield. The Cordillera region includes the mountains and foothills in which the headwaters originate. It is underlain by both crystalline and steeply folded sedimentary rocks. The majority of the basin lies within the Interior Plains. They are

FIGURE 1   Map of Athabasca River Basin with 1984 Sampling Sites Indicated

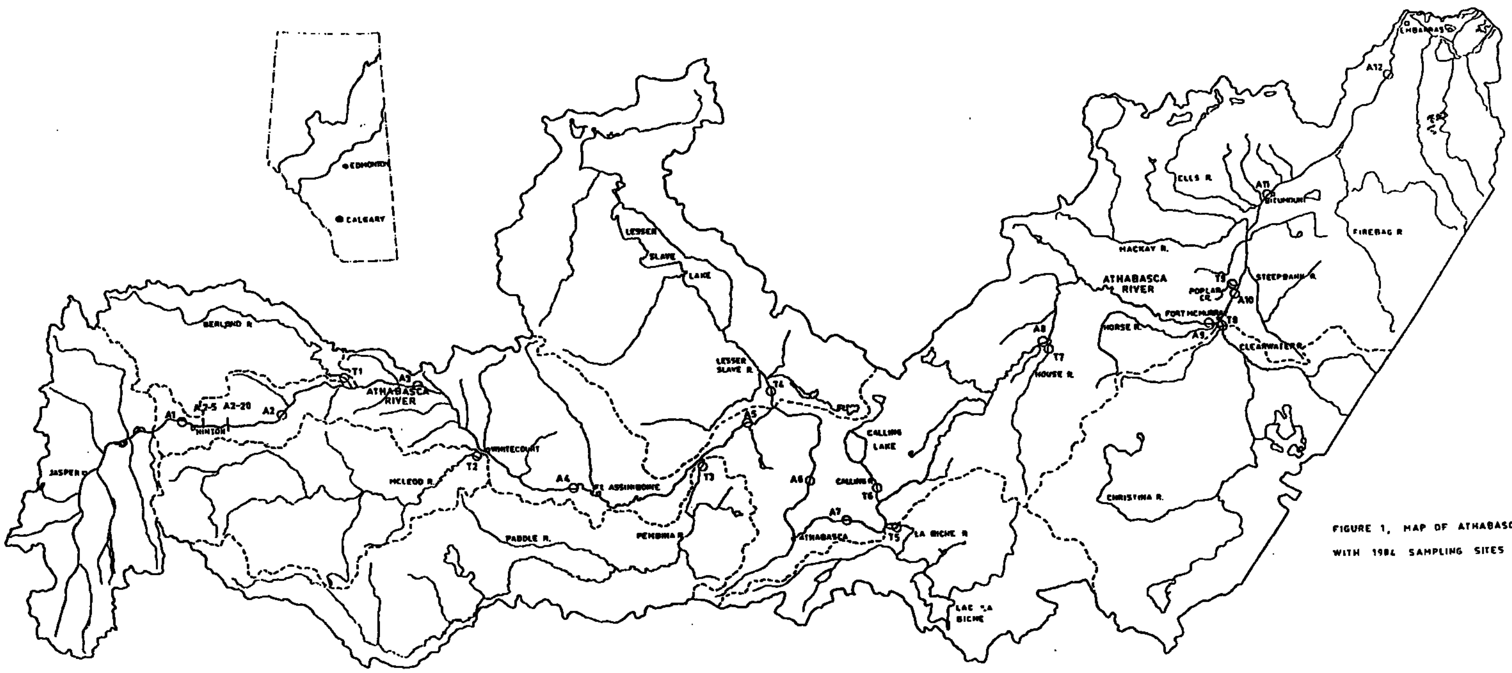

FIGURE 1, MAP OF ATHABASCA RIVER BASIN WITH 1984 SAMPLING SITES INDICATED.

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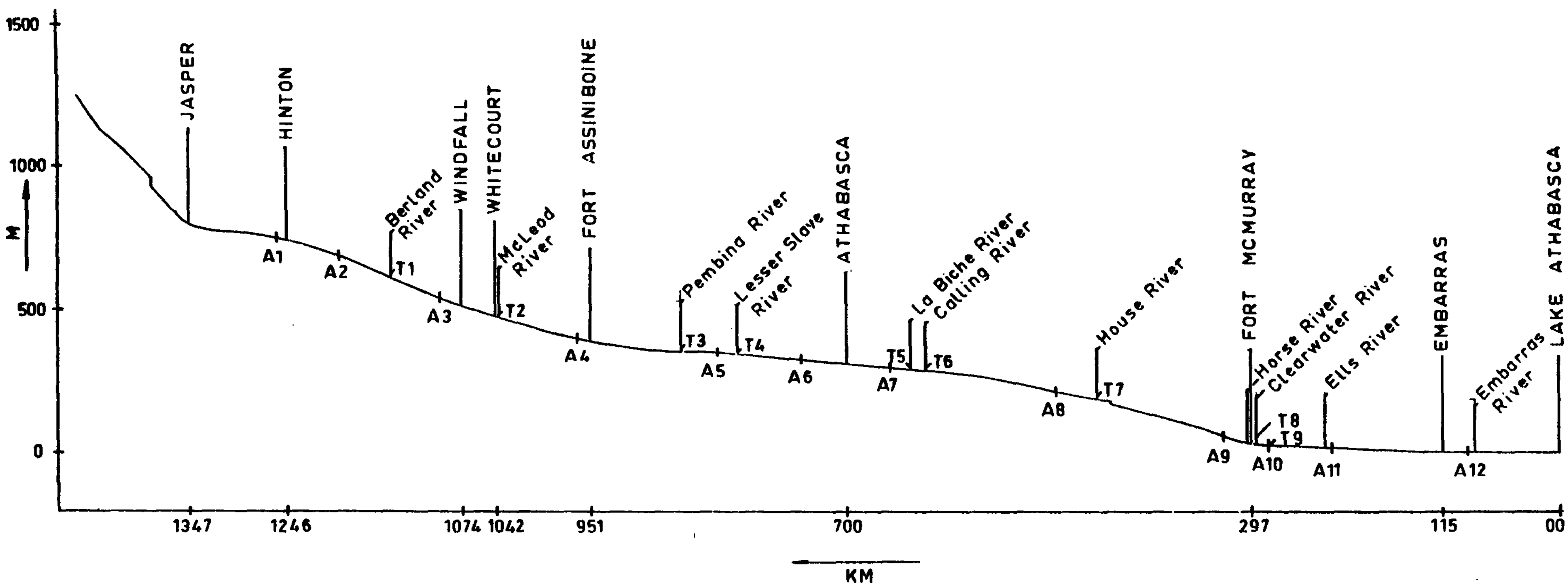
TABLE 5 AREA OF BASIN DRAINED BY EACH WATER SURVEY OF CANADA MAINSTEM GAUGE AND MAJOR TRIBUTARY

	AREA OF WATERSHED UPSTREAM OF WSC GAUGE (km^2)		AREA OF TRIBUTARY WATERSHED (km^2)
JASPER	3,877 (2.5)	MCLEOD R.	9,111 (5.8)
ENTRANCE	9,787 (6.2)	PEMBINA R.	13,097 (8.3)
WINDFALL	19,880 (13)	LESSER SLAVE R.	14,397 (9.2)
ATHABASCA	74,055 (47)	CLEARWATER R.	30,897 (20)
BELOW MCMURRAY	132,956 (85)	LABICHE R.	4,860 (3.1)
EMBARRAS AIRPORT	154,845 (99)		
TOTAL BASIN	157,000		

( ) INDICATE PERCENTAGE OF TOTAL WATERSHED AREA

FIGURE 2 :

LONGITUDINAL PROFILE OF ATHABASCA RIVER



underlain by flat sedimentary rocks and surficial deposits of glacial origin. The Canadian Shield section is located in the extreme northeast corner of the basin. It is a very small area with bedrock of ancient crystalline origin; drainage is often poor and lakes, ponds and muskegs are numerous.

Most of the basin located east of the Rockies experiences a continental climate (Longley and Janz, 1978). Winters are cold and prolonged, while the summers tend to be short and moderate in temperature. Mean January temperatures vary from -15°C in the mountain regions to -25°C in the extreme northeast corner of the basin (Supply and Services Canada, 1978). Average July temperatures vary from 10 to 15°C in the headwaters to between 15 and 18°C near Ft. McMurray. Only occasionally do temperatures exceed 30°C.

In the interior plains about two-thirds of the precipitation occurs in summer months, much in the form of major rainstorms (Longley and Janz, 1978). Average annual precipitation in the upper portions of the basin vary from 800mm in the mountains to between 500 and 600mm in the Edson and Whitecourt areas. Total precipitation is somewhat less in the northeast section, where it varies from 400 to 500mm. Average snowfalls of around 400cm occur along the continental divide; annual snowfalls approximate 140cm in most of the Athabasca Basin (Supply and Services Canada, 1978).

The oldest bedrock formations occur in the extreme northeast corner of the basin and consist of Precambrian sedimentary, igneous and metamorphic rocks (Hardy, 1967). As one moves southeasterly across the basin bedrock is formed by increasingly more recent sedimentary deposits. Upper and middle Devonian limestone shales occur in the area downstream of site A11 and along the Clearwater River. Lower Cretaceous sandstones and oil sands dominate the rest of the area north and east of Ft. McMurray. Bedrock between the Town of Athabasca and Ft. McMurray is dominated by dark grey upper Cretaceous marine shales. In the region between the Town of Athabasca and Whitecourt, upper Cretaceous sandstones, shale and coal of marine origin predominate. Bedrock in the region upstream of Whitecourt includes a mixture of Upper Cretaceous and Tertiary sandstone, shale and coal. A diversity of parent materials from the Tertiary, Upper Cretaceous, Lower Mesozoic and Upper Paleozoic periods occur in the foothill and mountain hardwater areas.

During the Pleistocene, the entire basin was covered by glaciers, consequently the areas unconsolidated surficial bedrock materials are of glacial origin (Supply and Services Canada, 1978). These glacial materials were deposited by ice, running water and standing meltwater. Particle size ranges vary from fine rock flour and clays, through sands and gravel to large rocks. Surficial material in the Athabasca Basin located south and west of the Town of Athabasca is largely glacial tills (a mixture of clays, silts and sands). Sands and gravel mixtures predominate in areas adjacent to the river channel and throughout that portion of the basin which lies between Athabasca Town and Ft. McMurray. (Alberta Government, 1969). Downstream of the junction with the Clearwater and to the immediate west of the Athabasca channel, lake deposited silts and clays are found. Still farther west these silts and clays give way to glacial till. River, lake and wind deposited sands and gravels form the surface layer in the northeast corner of the basin.

The two major soil types of the basin are grey wooded and organic (Alberta Government, 1969). Excepting the mountain regions, grey wooded soils predominate in that portion of the basin situated upstream from Athabasca Town. Some zones of dark grey and dark grey wooded soils are found in the south central agricultural area between the Town of Athabasca and Edson. Extensive tracts of muskeg occur in the intermediate portion of the basin between Athabasca and Ft. McMurray. Muskeg is an organic soil consisting of peat, formed by the growth of sphagnum moss. Muskeg soils tend to be acidic and have a high water holding capacity. Downstream from Ft. McMurray grey wooded soil is found interspersed with tracts of muskeg.

Most of the Athabasca River Basin is forested. Clearing has occurred in the south central region for agriculture, and to a lesser extent in the western and foothill areas due to logging and surface coal mining. Lodgepole pine, white spruce and Engelmann spruce are the major tree species in the mountains and foothills (Alberta Government, 1969). Moving northeast from Hinton the coniferous forests shift to stands of mixed aspen, poplar and white spruce. In the central area, around the Town of Athabasca, aspen poplar forests predominate. Tree growth is limited to predominately black spruce in the muskeg areas north of the mainstem river between Athabasca and Ft. McMurray. A greater diversity in vegetation occurs on the south side of the river. Muskeg, treed muskeg, aspen poplar and mixed jackpine and white spruce forests are interspersed throughout this region. To the north of Ft. McMurry, aspen poplar predominates west of the river, while a mixed vegetation of aspen poplar, jackpine, birch and muskeg is found on the east side.

3. Basin Development

A summary of existing and projected development in the Athabasca River basin is presented in Erxleben,(1982). This report emphasizes water demands but in doing so evaluates all major resource, municipal and agricultural activities.

The Athabasca River basin is sparsely populated. The total census in 1981 was 116,955, of which 65% was urban. The major city is Ft. McMurray and the larger towns include Hinton, Whitecourt, Athabasca, Edson, Westlock and Jasper. The only municipalities with continuous effluent discharge directly to the Athabasca River are Whitecourt, Edson, and Ft. McMurray. Hinton's sewage is combined with the pulp mill wastes for treatment and discharge as one effluent.

The Athabasca Basin is located on the fringe of the agricultural zone which extends through much of southern and central Alberta. Most existing agricultural activity in the basin occurs south of the mainstem river between the towns of Athabasca and Edson. The major watersheds included in the agricultural zone are the Pembina and to a lesser extent the LaBiche. The mainstay of the agricultural sector is mixed farming accompanied by livestock rearing and feed crop growing.

Resource development is the major cultural activity in the Athabasca River Basin. Supplies of timber, coal, petroleum, natural gas and oil sands are abundant. Logging is the dominant land use activity in the upper half of the watershed and a major kraft pulp mill is located at Hinton. This mill has a continuous discharge to the Athabasca River. Although numerous sawmills are located throughout the basin, none have a direct river effluent.

The basin contains abundant reserves of coal. Sub-bituminous coal beds suitable for thermal power generation exist in the Plains region, while metalurgical grade coals are found in the Foothills and Rocky Mountains. Coal mining activity in the McLeod and Pembina sub-basins have resulted in localized water quality impacts.

Conventional oil and gas development in the basin is extensive. The basin is estimated to contain 18% of Alberta's total gas reserve. As of 1982, there were 36 sour gas and 33 sweet gas processing plants operating in 244 producing areas. None of these plants have a direct effluent discharge to the Athabasca River. Approximately 36 conventional oil fields are located partially or wholly within the basin.

Surface mining and extraction of tar sands is the largest industrial activity. The evaluated oil sands area covers some 43,600 km^2 in the northeast corner of the basin. About 2000 km^2 is overlain by 75 meters or less of overburden and is therefore amenable to surface mining. There currently exist two mining extraction facilities downstream from Ft. McMurray. Both are located on the west bank of the river. Only the Suncor Plant has a process discharge to the Athabasca River. Syncrude holds its process effluent in a large tailings pond, but does discharge mine depressurization and runoff water to the Athabasca River via Poplar Creek.

IV RESULTS

1. Hydrologic Regime

The flow regime in the Athabasca River appears typical for a mountain fed stream, high flows in May, June and July with low flows predominant from November through March. In fact, the flows at Hinton constitute only 26% of the average annual flow of the Athabasca at Embarras. The annual hydrologic cycle is initiated in April by local runoff in the tributaries, then combines with snowmelt in the mountain headwaters, followed by appreciable summer rainstorm activity. The cycle is completed by recessive flows in the fall and winter.

The major tributaries of the Athabasca and their average annual contribution to the flow at Embarras are;

McLeod River	6.7%
Pembina River	4.6%
Lesser Slave River	6.4%
LaBiche River	6.7%
Clearwater River	18.5%
Berland River	5.6%
Total	48.5%

Peak flows in the tributaries occur in May except for the Lesser Slave River which is affected by the attenuation of Lesser Slave Lake.

a) 1984 Hydrology

The flows recorded in 1984 are compared to the long term hydrology in Figures (3) and (4). These figures provide several bases of comparison;

1. monthly mean flows in 1984 relative to the long term median flows.
2. 1984 monthly mean flows relative to the full range of flows.
3. exceedance probability of the 1984 monthly mean flows.
4. daily mean discharge on the sampling date compared to the long term and the 1984 monthly mean flows.

Figure 3 Discharge summary for Athabasca River mainstem gauging stations.

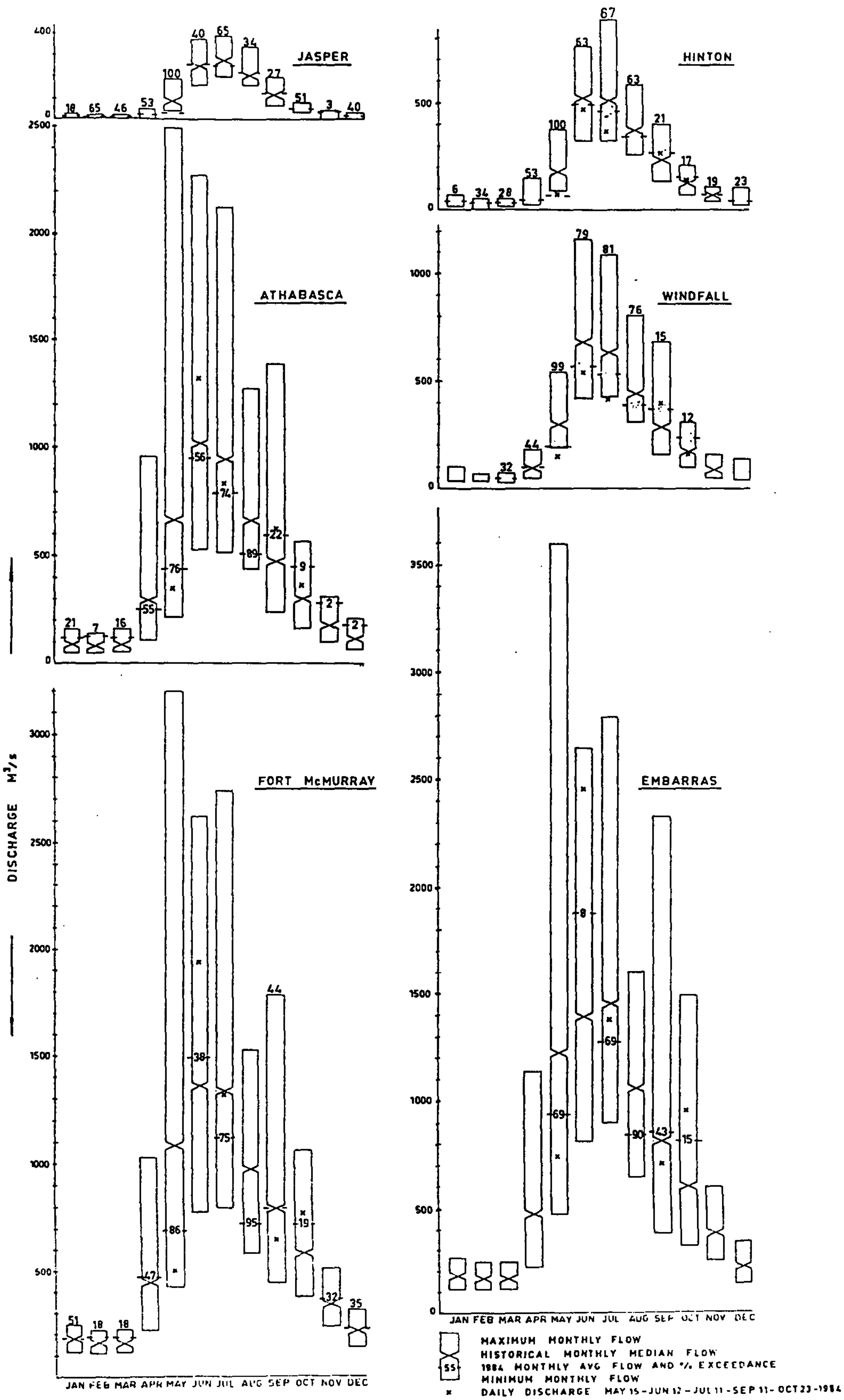
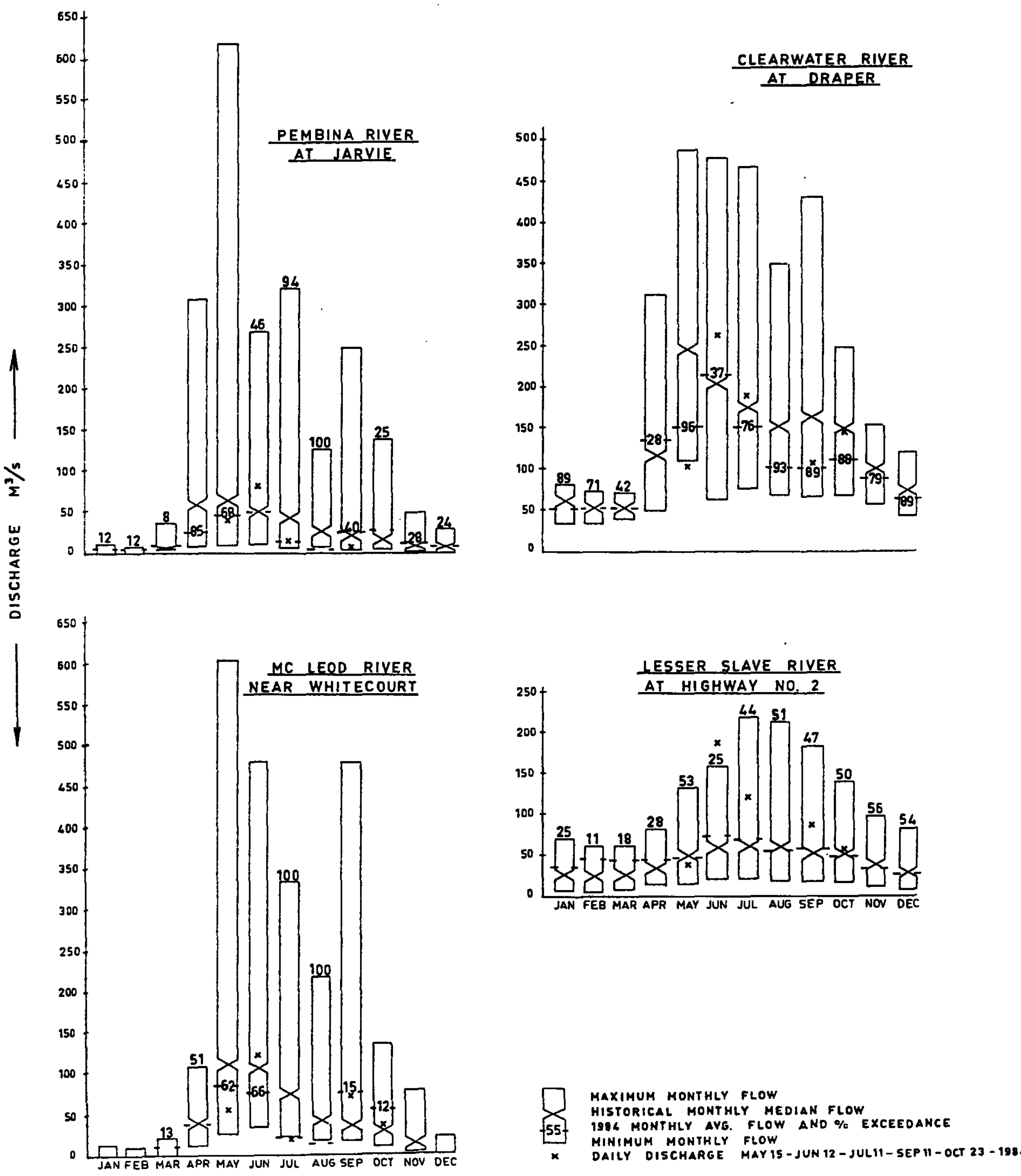


Figure 4 Discharge summary for Athabasca River tributaries that are gauged.



The graphs clearly indicate;

1. April was a near normal flow month

2. May was an exceptionally low month in the headwaters, with record low, monthly mean flows at Jasper and Hinton. Flows were well below expected values throughout the Basin. Only the Lesser Slave River which is regulated by the Lesser Slave Lake was close to normal.

3. Flows recovered in June with most tributaries registering greater than the median monthly flow. Headwater flows were generally lower than normal, except at Jasper where higher than normal flows were experienced.

4. July was a low flow month throughout the Basin, except for the Lesser Slave River. The other main tributaries experienced severe low flows with the mean flow in McLeod River less than the previous minimum.

5. Flows in August were also low. The monthly mean flow at Embarras was equal to its 90% exceedance value. The Pembina and McLeod Rivers experienced record minimum, monthly mean flows.

6. A comprehensive reversal of the low flow trend took place in September. Both headwaters and tributaries, except the Clearwater had higher than expected flows. This situation persisted throughout the remainder of the calendar year.

In summary, the 1984 hydrology was characterized by normal or above normal flows up to and including April. May through August were below normal except for June. Flows recovered in the fall to above normal values except those in the Clearwater. The annual flow in 1984 at Ft. McMurray was 92% of the long term average.

b) Synoptic Sampling Flows

Figures (3) and (4) indicate by an 'X' the daily mean discharge at the time of water quality sampling (May 15, June 12, July 11, Sept. 11 and Oct. 23, 1984).

On the first sampling date, May 15, flows were below the monthly mean flow and considerably below normal. At Windfall and Hinton, flows were close to the long term minimum for May.

The sampling in June was done at a time of relatively high flows in the lower portion of the Basin and below normal flows in the headwaters, with the division occurred near the gauge at Town of Athabasca.

July sampling occurred in a relatively low flow regime, with exceptionally low flows in the Pembina and McLeod Rivers and the mainstem at Windfall.

Sampling in September occurred at a time of generally above normal flows, and the daily discharge tended to be close to the monthly mean. At the most downstream points on the mainstem, the sampling date coincided with lesser than normal flows as the effects of upstream runoff had not been felt. The Clearwater River ran contrary to the Basin, showing very low flows at the time of sampling.

The October sampling was done in a month of above average flows, except in the Clearwater. On the sampling date discharges were higher than monthly mean except for the mainstem upstream of Athabasca Town and the McLeod River.

2. Spatial and Temporal Patterns in Water Quality

Longitudinal and seasonal trends in water quality of the Athabasca River, its major tributaries and effluents are presented in this section. Summary statistics for the database collected in 1984/85, and the historical database, are included in appendices (1) and (2), respectively. Seasonal and longitudinal plots of the recent data are presented in the text for key parameters. The section is subdivided according to major parameter groups for ease of interpretation and presentation.

a) Major Ions

The major ions present in surface waters include calcium, magnesium, sodium, bicarbonate and chloride. Collectively these major ions determine the overall salinity (salt content) of a waterbody. Total dissolved solids (TDS) is a measure of salinity, it incorporates the major ions and minor dissolved substances, i.e. nitrate, silica, potassium. Specific conductance (conductivity) is a measure of a water's ability to conduct electricity, which inturn is a direct function of its ionic composition. Total dissolved solids and conductivity are usually highly correlated, and conductivity is used as an indirect indicator of salinity.

Average 1984/85 TDS concentrations along the Athabasca River remained relatively constant near 150 mg/L (Figure 5). The TDS of Poplar Creek was considerably greater than any other mainstem or tributary site sampled. Salinity of the Lesser Slave and Calling Rivers were below average and showed little variance. The major cations include calcium, sodium and magnesium. Calcium dominates throughout the basin except in the Clearwater River (T8) and Poplar Creek (T9), where sodium is the major cation. Mainstem sodium concentrations increase with downstream distance, while magnesium concentrations decrease.

Calcium is one of the alkaline earth metals and is readily dissolved from sedimentary rocks, thereby explaining its significance in watersheds of sedimentary origin. Calcium levels of mainstem and tributary sites are higher in the upper reaches of the basin and decrease slightly towards the mouth. The highest average tributary concentrations occurred in the Berland, McLeod and Pembina Rivers.

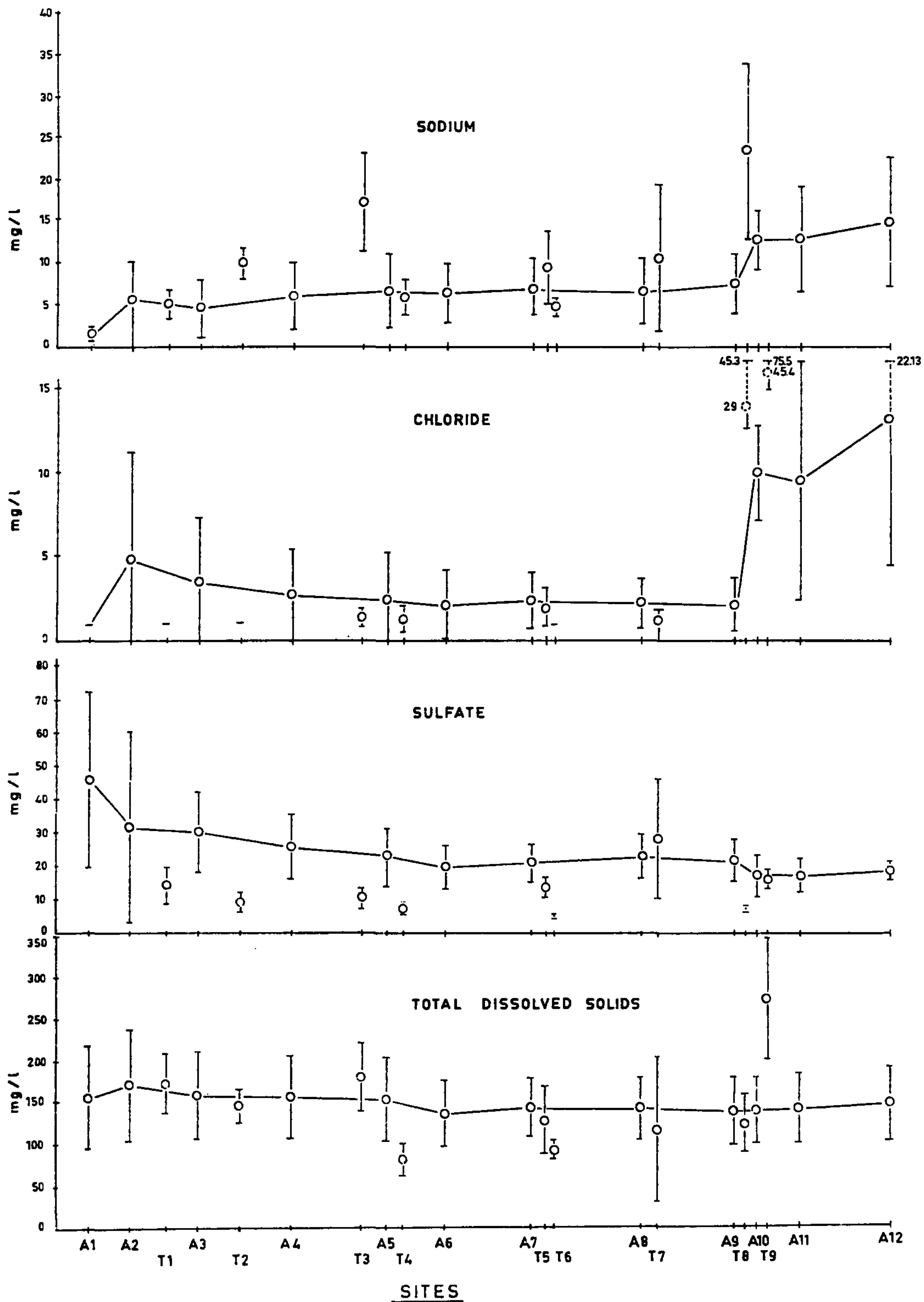
The 1984/85 average sodium concentrations for the mainstem river remained below 15 mg/L (Figure 5). Concentrations increased between A1 and A2 and then rose again downstream of Ft. McMurray. Elevated sodium levels were especially evident in Poplar Creek (T9), and the Clearwater (T8) and Pembina Rivers (T3). Moderately high levels were experienced in the McLeod (T2), LaBiche (T5) and House (T7) Rivers. Maximum seasonal concentrations in the Athabasca River, and most tributaries, occurred in February and May (Figure 6) and lows were measured in June and July.

Average magnesium concentrations varied between 4 and 11 mg/L. Like calcium, concentrations in the Athabasca River and tributaries decreased with distance from the headwaters. Magnesium is non-toxic and poses little concern to protection of public health or aquatic life (McNeely et al.,1979).

Bicarbonate was the dominant anion throughout the basin. Sulphate was of secondary importance at all sites except the Clearwater River and Poplar Creek, where concentrations were exceeded by chloride.

Bicarbonate is the major form of inorganic carbon in alkaline systems. Carbonate only occurs at very high pH levels, whereas significant free carbon dioxide is only found at pH values below 7. On the recent surveys average pH of the

Figure 5 Longitudinal trend in Sodium, Chloride, Sulphate and Total Dissolved Solids along the Athabasca River in 1984/85. Average values plus and minus 1 St.Dev.



mainstem Athabasca River ranged between 8.0 and 8.2. Among the tributaries ph values were highest in the Berland, McLeod and Pembina and were slightly less in the lower basin tributaries. Average pH of the House River was 7.5, and 7.8 for the Clearwater. In June a pH of 6.9 was recorded in the House River, which was the recent study minimum. Maximum bicarbonate concentrations in the Athabasca River occurred in the reach between Hinton and Athabasca. Lower average conditions prevailed in the upper and lower reaches of the river. Monitoring indicated bicarbonate concentrations in the Berland, McLeod and Pembina rivers exceeded those in the Lesser Slave, Calling, House and Clearwater rivers.

Sulphates may be leached from most sedimentary rocks, especially deposits like gypsum and anhydrite (McNeely et al 1979). Highest Athabasca River sulphate concentrations occurred at A1, and decreased from there downstream (Figure 6). Only House River and Poplar Creek concentrations exceeded those of the mainstem, all other tributaries were less. A maximum 1984/85 concentration of 88 mg/l was recorded at A1 in February. Elevated seasonal concentrations occurred at the upper mainstem sites and in the House River during February and May(Figure 7). Concentrations at all other sites showed little seasonal variation.

Average river chloride concentrations increased between A1 and A2, and then increased again downstream from Ft. McMurray. All tributaries upstream of A9 exhibited low concentrations, especially the Berland and McLeod Rivers. High chloride concentrations were evident in the Clearwater River and Poplar Creek. The 1984 seasonal distribution for chloride is presented in Figure (8). Maximum river concentrations occurred in February; highest open water levels were recorded in May. Seasonally, the concentration increase between A1 and A2 was only evident in May and February. Chloride concentrations remained low throughout the year at all tributary sites excepting the Clearwater River and Poplar Creek. The seasonal concentration pattern in these latter two streams was like the mainstem Athabasca.

The historical major ion data for sites at Jasper, Town of Athabasca and Ft. McMurray confirm the seasonal pattern evident from the recent database. Concentrations of all major ions are greatest during the ice cover period and for many, early summer median values exceed corresponding late summer concentrations. Major ion concentrations in most river systems tend to vary inversely with streamflow and surface runoff. Most major ion concentrations tend to increase between Jasper and Athabasca and then remain constant between there and upstream Ft. McMurray.

Figure 6   Seasonal Sodium distribution for Athabasca mainstem and tributary sites, 1984/85

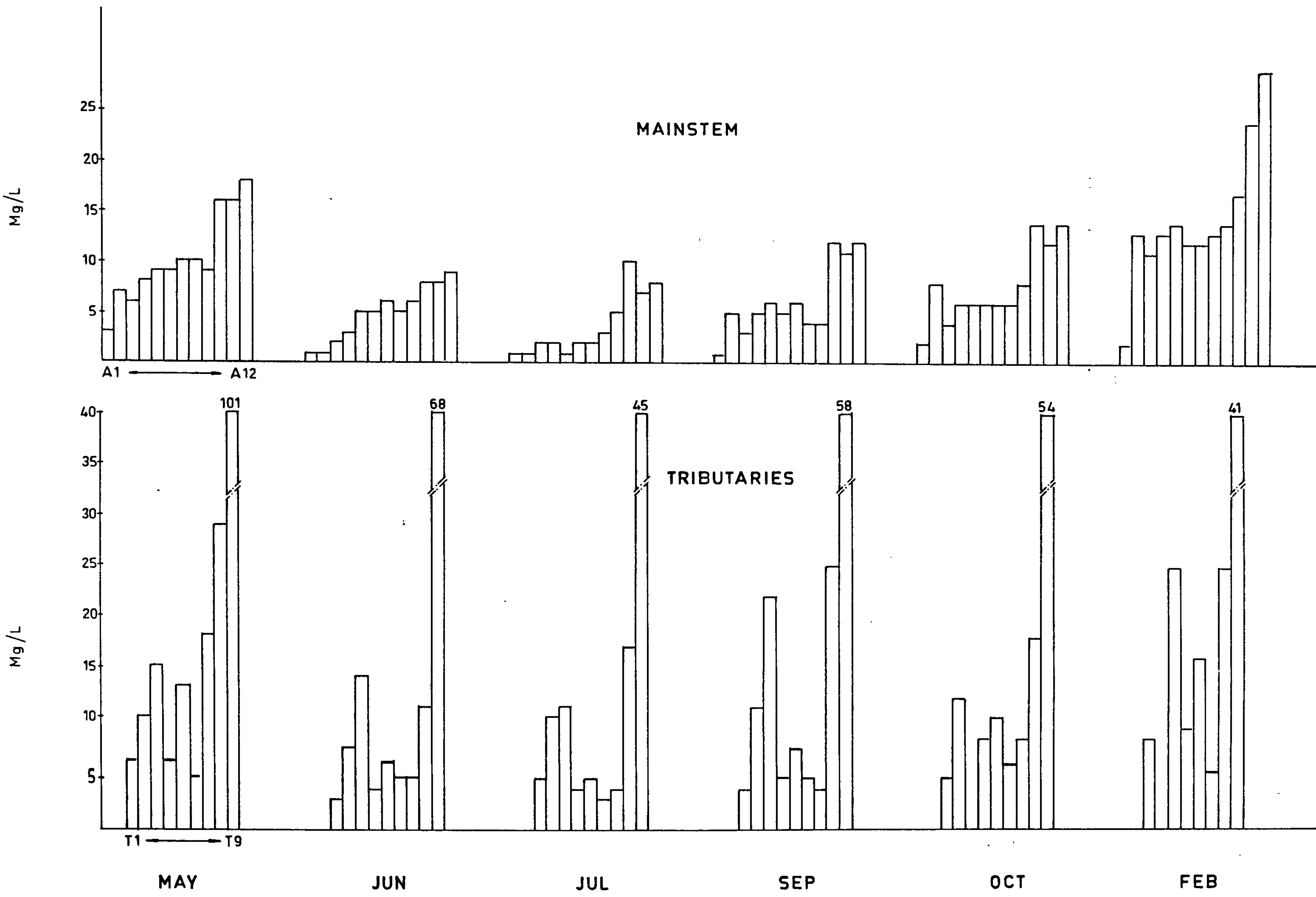


Figure 7 Seasonal Sulphate distribution for Atnabasca mainstem and tributary sites, 1984/85

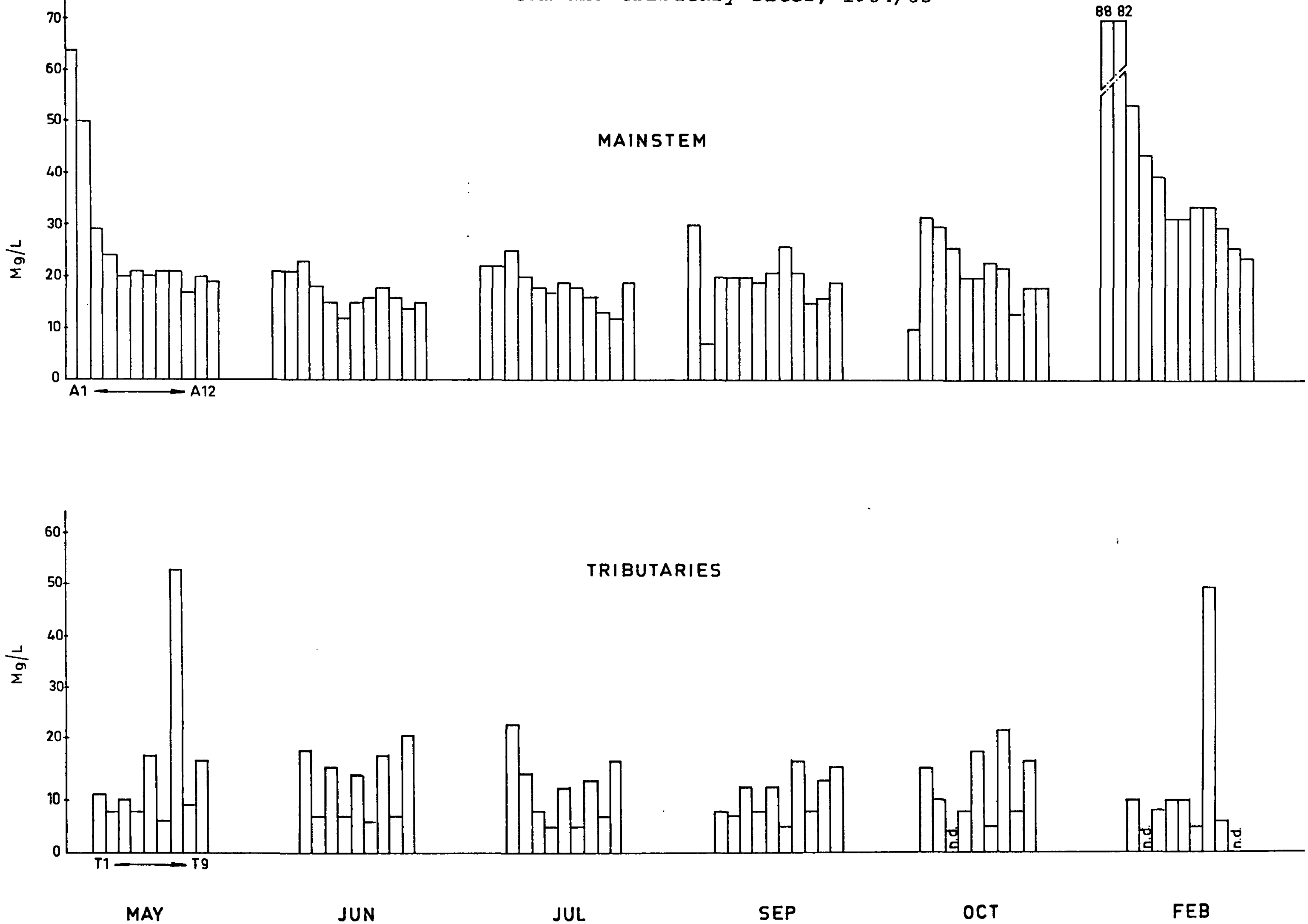


Figure 8   Seasonal Chloride distribution for Athabasca mainstem and tributary sites, 1984/85

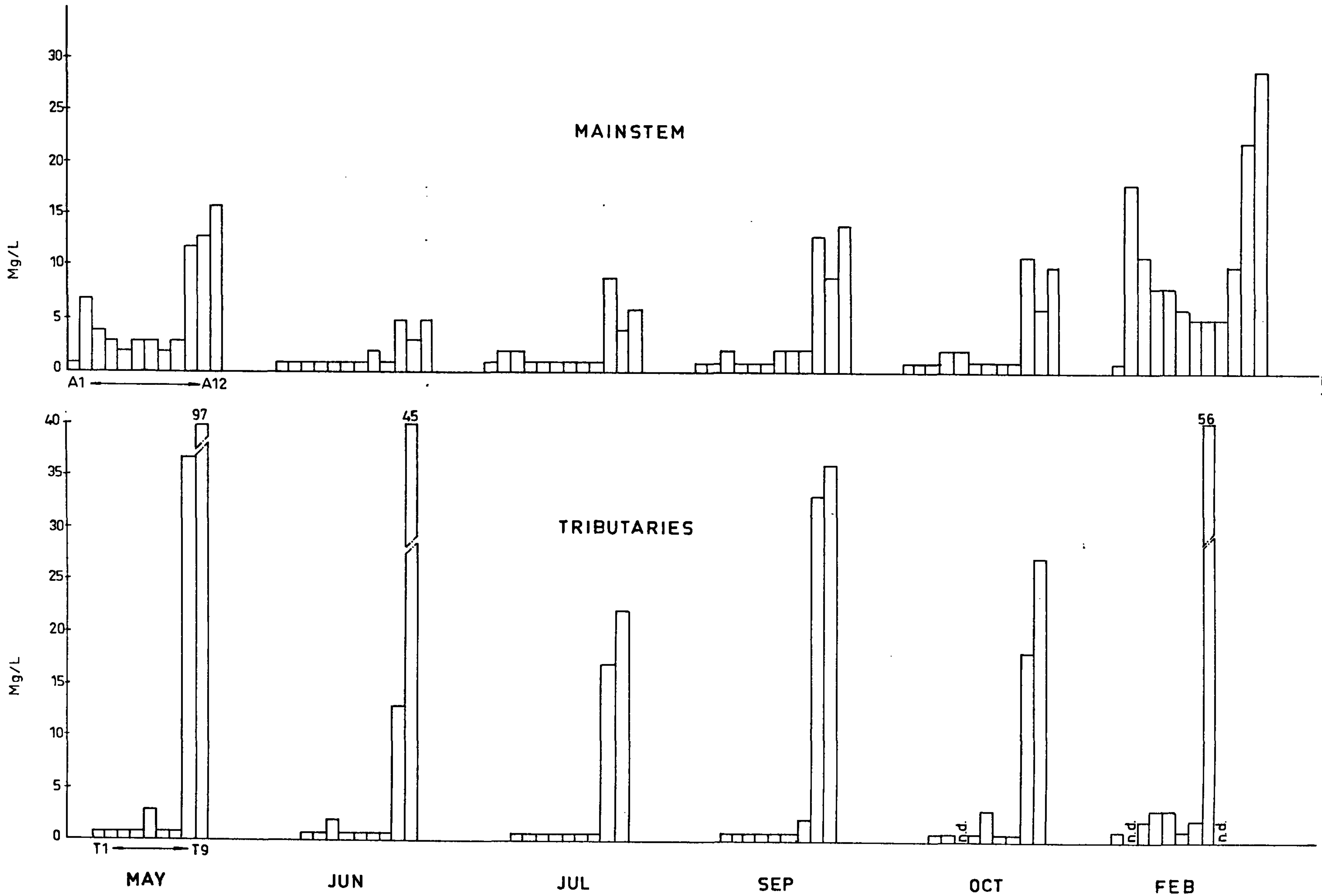
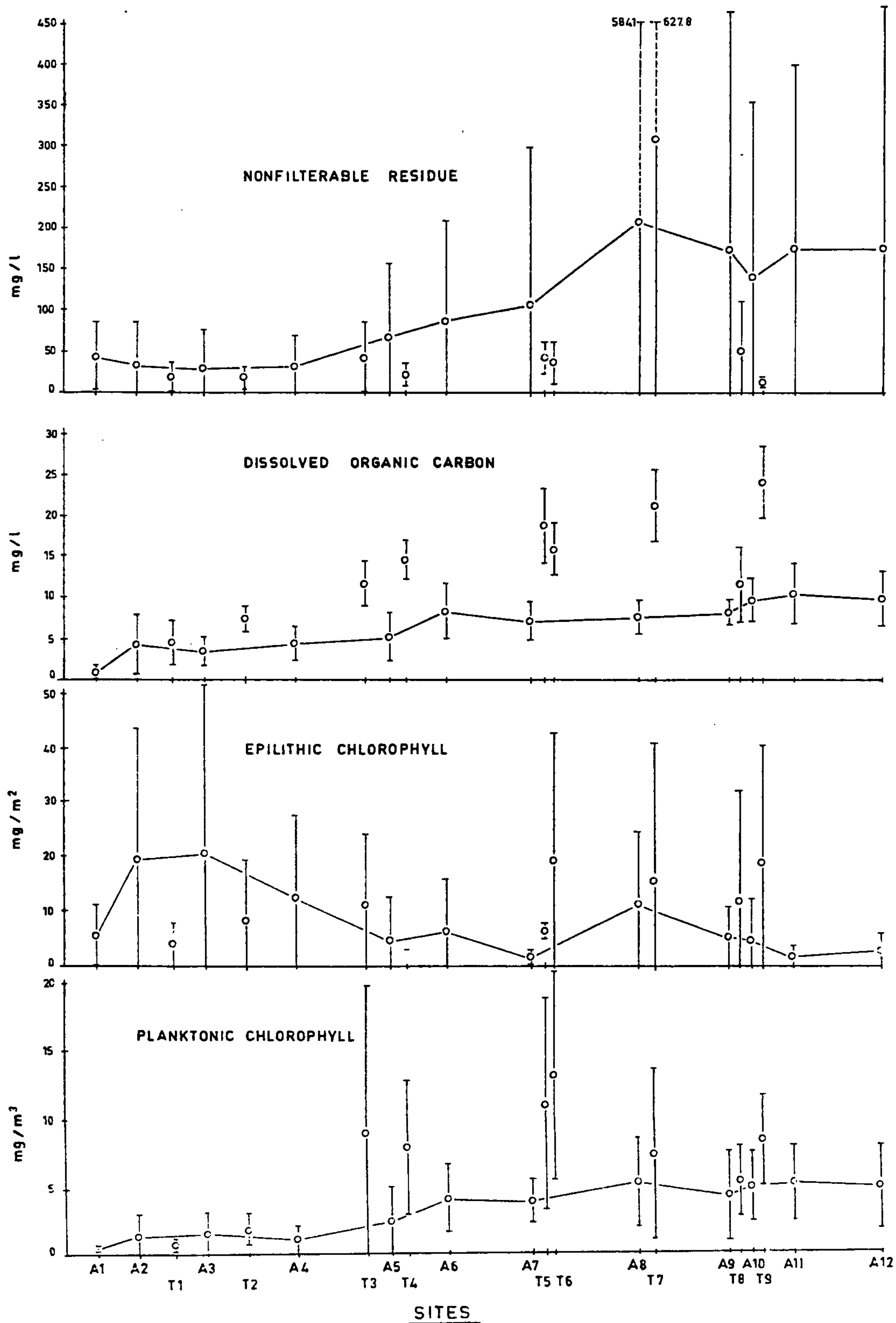


Figure 9 Longitudinal trend in Nonfilterable Residue, Dissolved Organic Carbon, Epilithic Chlorophyll and Planktonic Chlorophyll along the Athabasca River in 1984/85. Average values plus and minus 1 St.Dev.



Suspended solids varied seasonally, and maximum concentrations occurred during high flow conditions in June and July (Figure 10). Levels in May, September and October were similar, and only slightly exceeded the very low suspended solid conditions experienced under ice in February. Relative to the other tributary basins, NFR values for the House River were very high on four of the six sampling occasions.

Historically, maximum suspended solid concentrations occur in the early open water period. Median values for the late open water interval are substantially less at Jasper, Town of Athabasca and Ft. McMurray. As for the recent data, minimum NFR and turbidity occur under ice when both surface runoff and river discharge are low.

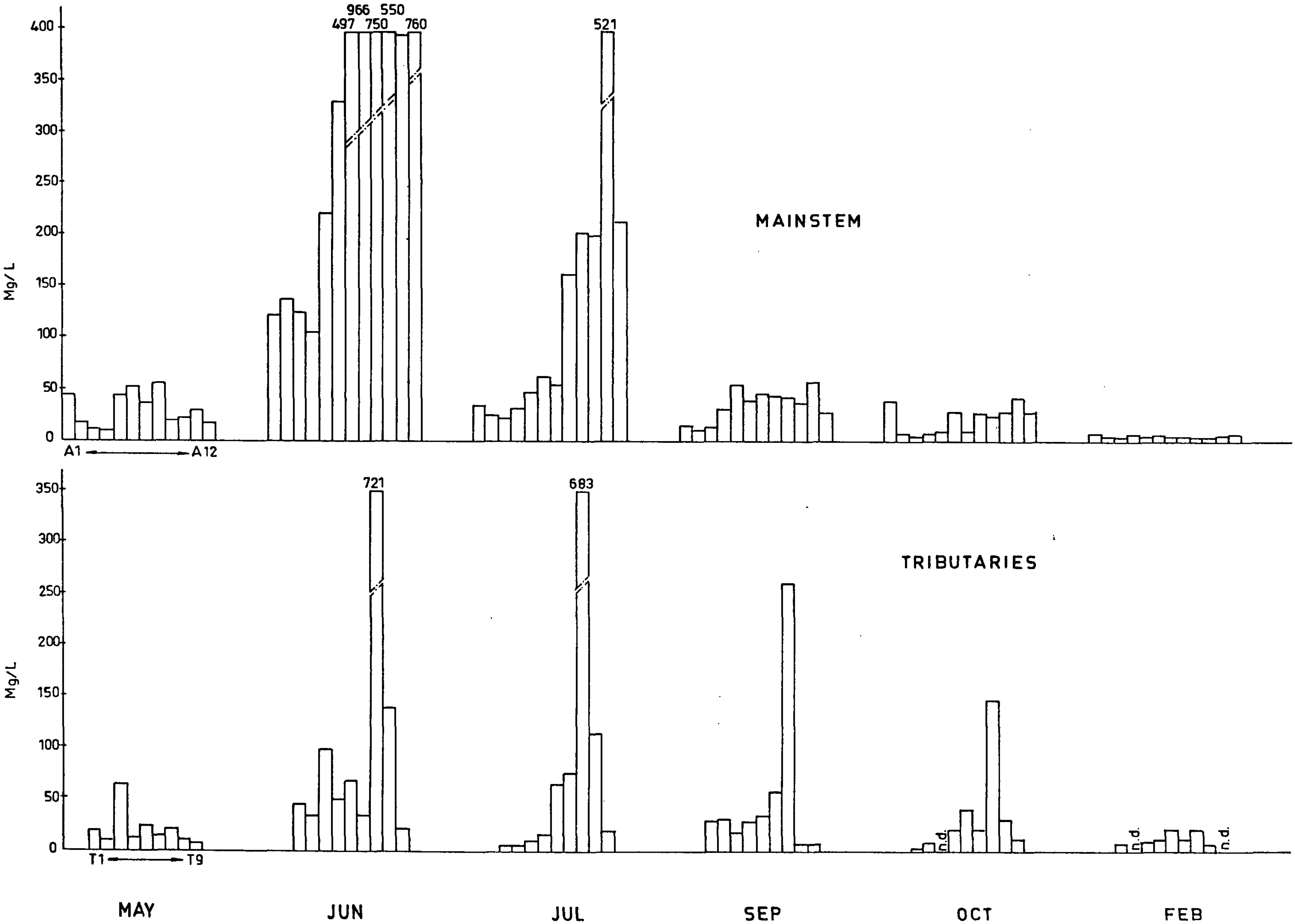
Average NFR concentrations in the sewage discharges and Suncor effluent varied between 9 and 33 mg/L. These are low and in line with surface water conditions in the upper part of the basin. Concentrations in the St. Regis effluent averaged 100 mg/l and reached 200 mg/L in an instantaneous grab sample.

c) Dissolved Oxygen and Biochemical Oxygen Demand

Average dissolved oxygen levels have remained high at all three historical sampling sites for both the open water and ice cover periods. The values imply that river oxygen has remained near the saturation level for most of the historic period. Unfortunately oxygen data is not available for all 25 river and tributary sites sampled in 1984/85. Diurnal data was only collected at A1 and A7 in the fall (Table 6). Oxygen values at that time were high and varied by no more than one mg/l in twenty four hours at either station.

Biochemical oxygen demand (BOD) remained near one mg/l at most river stations in 1984/85. Slightly higher values occurred at sites downstream of Hinton, yet the averages were still less than 2.0 mg/L. A maximum value of 3.7 mg/L was recorded at 5 km below Hinton in February 1985. There is no corresponding oxygen value to indicate the oxygen sag associated with this level, however, it is probably not large. There are no BOD records for the historical sites.

Figure 10 Seasonal Non-Filterable residue distribution for Athabasca mainstem and tributary sites, 1984/85



Chemical oxygen demand is a measure of the oxygen required to chemically oxidize organic matter using a mixture of chromic and sulfuric acids as digestors. It is another indicator of a water sample's total organic content. Chemical oxygen demand progressively increases with distance down the basin reflecting the overall longitudinal trend in organic content. Some site specific enhancement is apparent downstream from Hinton. The House River and Poplar Creek are both relatively high in COD.

d) Organic Carbon

In river systems organic carbon is derived from watershed runoff, anthropogenic inputs and instream river production. Natural sources include chemical and biological decay of plant and animal material. Effluents from pulp mills, petroleum refineries and sewage treatment plants often have a substantial organic carbon content. Total organic carbon includes complex mixtures of various dissolved and particulate compounds which vary in chemical composition depending upon their source of origin.

Organic carbon is a major component in the energy pathway of aquatic systems. Particulate carbon (POC), and associated bacteria and fungi, are often the primary food resource for benthic invertebrate communities. Dissolved organic carbon (DOC) can stimulate sediment bacteria, which in turn create an oxygen demand on the water column. Specific organic groups including phenols, tannin and lignin (T&L) and oil and grease(OG) have been monitored in the Athabasca River. Color is an indirect indicator of dissolved organic content as certain organic constituents can impart color to a water body, especially those associated with pulp mill discharges and drainage of muskeg soils.

No consistent longitudinal pattern in particulate carbon is evident from the recent surveys. Average mainstem values range from <1 to 5 mg/L. A maximum value of 13.6 mg/L was recorded upstream of the Lesser Slave River. Average tributary values range from 1 to 3 mg/L. Historical particulate carbon data only exist for Jasper and Town of Athabasca. AT those locations under ice POC values are low. Open water levels are higher at the Town of Athabasca than at Jasper, and early open water medians exceed late season values, especially at Athabasca Town.

Average dissolved organic carbon is higher in the lower reaches of the basin (Figure 9). A major increase occurs between A1 and A2, then again in the vicinity of the Lesser Slave River and downstream from Ft. McMurray. The DOC content of the tributary systems steadily increase with distance from the upper basin. Levels in the upper Athabasca River were greatest in the early spring, fall and winter when river flows were low (Figure 11). Conversely, maximum concentrations at the lower river sites occurred in June and July. The seasonal variation in DOC content of the Berland and McLeod rivers was slight. The DOC in tributaries T3 to T9 was high from June to October. The historical data indicate a major increase in DOC occurs between Jasper and Athabasca (5 to 6 fold), and again between Athabasca Town and upstream Ft. McMurray. At Jasper and Ft. McMurray there are no seasonal patterns in median concentrations. At Athabasca Town high DOC is observed both during the winter and the early open water period.

Phenolic substances include a group of organic compounds which are classified as monohydric, dihydric or polyhydric depending upon the number of hydroxyl groups attached to the aromatic benzene ring (McNeely et al.,1979). They are released by aquatic plants and decaying vegetation, and are found in municipal and some industrial discharges. At low concentrations they can impart taste and odor to chlorinated water supplies, and taint fish tissue. Average 1984/85 phenolic concentrations ranged from below detection at A1 to between 0.004 and 0.009 mg/L throughout the rest of the system (Figure 12). Highest values occurred at A2 and A8. Tributary concentrations were greatest in the Pembina, LaBiche, Calling and House Rivers and Poplar Creek. Mainstem and tributary phenolic concentrations were greatest in September, October and February (Figure 13). Low values occurred in June and July, while results from the May synoptic survey were only slightly higher. Historic median phenolic concentrations range between 0.001 and 0.003 mg/L at all three longterm sites except Athabasca Town during the early open water season (0.007 mg/L). Maximum recorded levels at Jasper, Town of Athabasca and Ft. McMurray are 0.009, 0.025 and 0.041 mg/L, respectively.

Tannins and lignins originate naturally from decay of terrestrial vegetation and are common constituents in pulp and paper discharges (Wallis et al.,1980). Tannins are polymers of flavinoid compounds, while lignin is a polymer of aromatic alcohols and comprises 25% of the dry weight of wood. Like DOC, 1984/85 mainstem tannin and lignin levels increased below Hinton, between A5 and A6 and downstream of Ft. McMurray (Figure 11). All mid-basin tributaries (T3 through T7 inclusive) had T&L levels greater than corresponding river concentrations. Concentrations in the House River were particularly high (average 1.5 mg/L).

Figure 11 Seasonal Dissolved Organic Carbon distribution for Athabasca mainstem and tributary sites, 1984/85

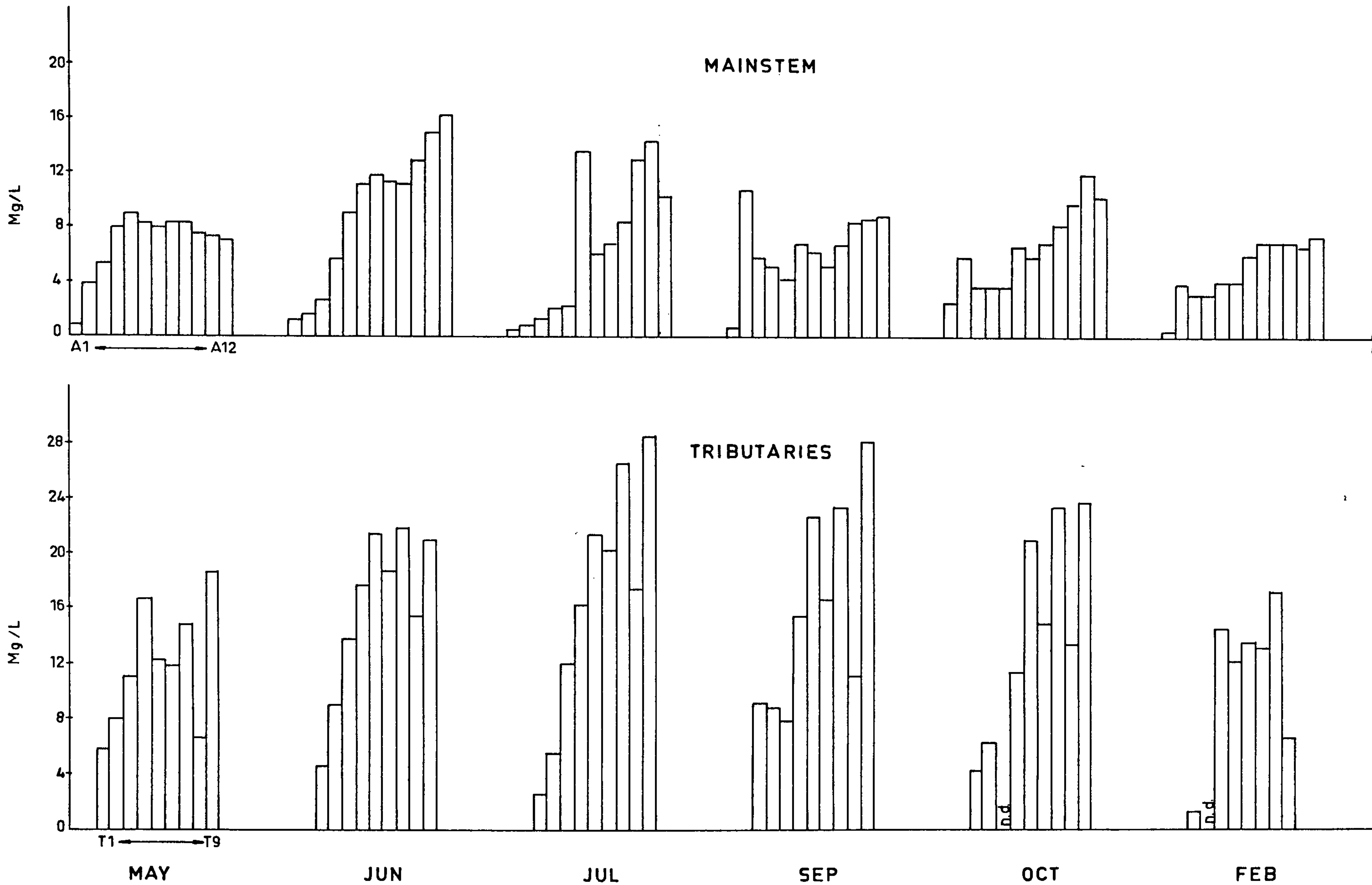


Figure 12 Longitudinal trend in Tannins and Lignins, True Colour, Phenols and Oil and Grease along the Athabasca River in 1984/85. Average values plus and minus 1 St.Dev.

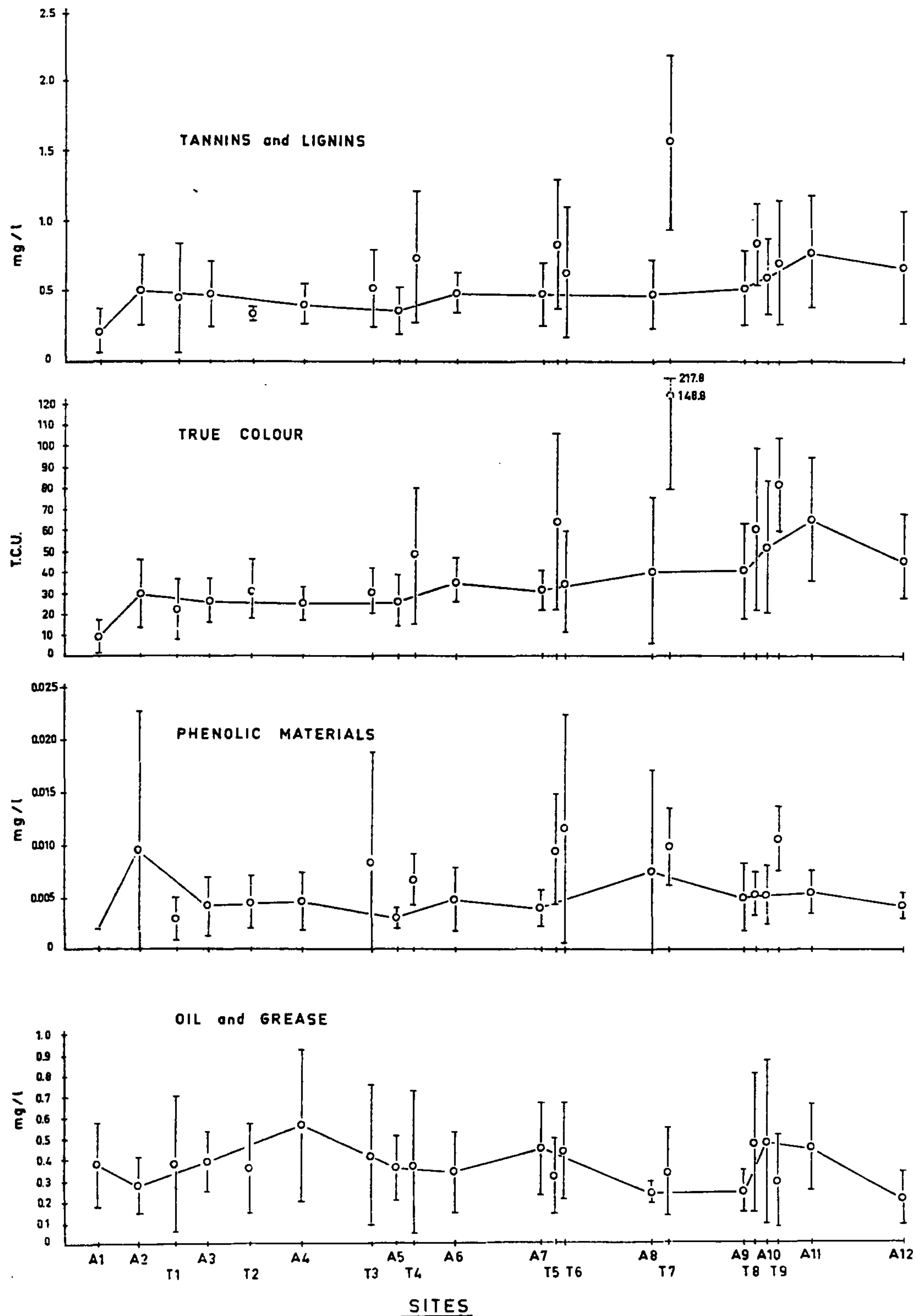
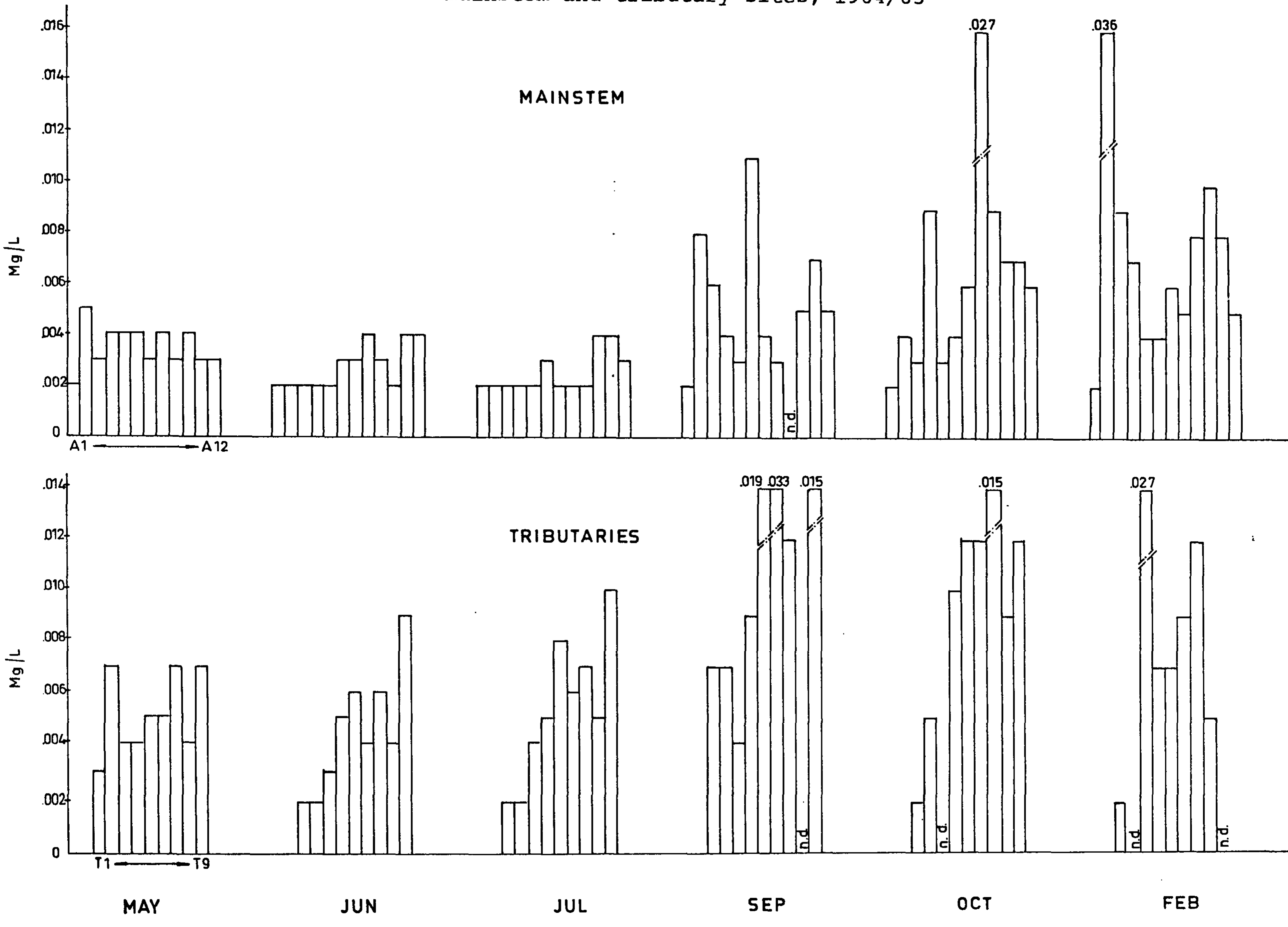


Figure 13 Seasonal Phenol distribution for Athabasca mainstem and tributary sites, 1984/85

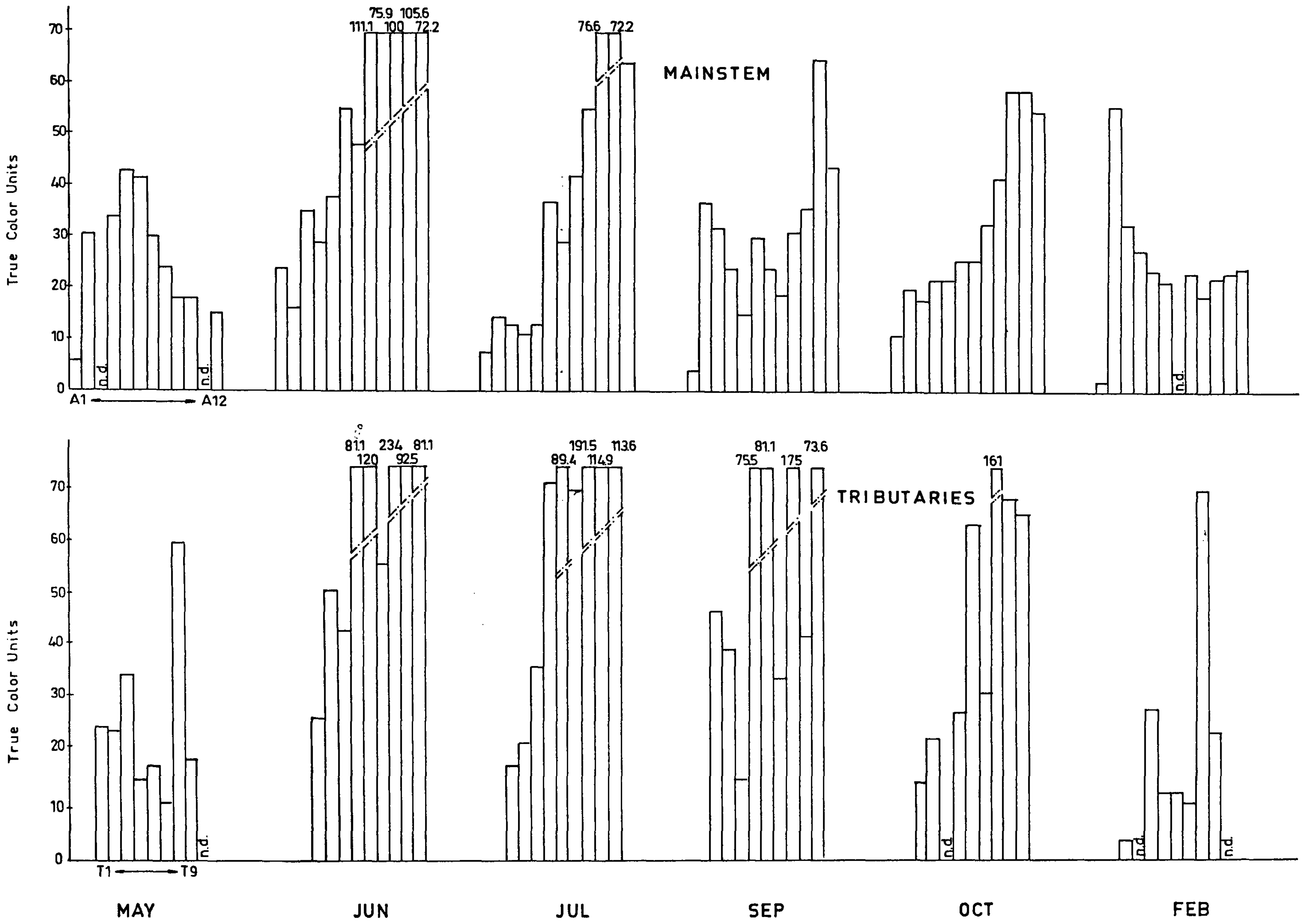


The 1984/85 longitudinal trend for true color was nearly identical to T&L (Figure 13). True color is a measure of dissolved coloring compounds, whereas apparent color is not prefiltered and is therefore affected by suspended material in the sample (McNeely et al 1979). In the upper Athabasca River during 1984/85 maximum true color levels occurred in September, October, November and to a lesser extent in May (Figure 14). Values were low in June and July. High color values were recorded in the lower half of the basin and the tributary streams in June and July when flows and runoff were high. Minimum values occurred in May and February. True color has only been measured at the historic sites since 1982, records prior to that only include apparent color. The apparent color at Jasper is low and seasonally non-variable. Median historic levels at the downstream sites are much higher (20 to 60 color units) and maximum during the early open water season.

Hydrocarbons are organic compounds that contain only hydrogen and carbon (McNeely, 1979). They include both petroleum compounds and hydrocarbons produced by biological activity. Natural gas and crude oil are mixtures of alkane hydrocarbons. Most natural gas is composed of straight chain alkanes, with one to four carbon atoms; gasoline has six to ten carbon atoms and lubricating oils are 17 to 22-carbon alkanes. Hydrocarbons with more than 22 carbon atoms are paraffins (grease and waxes). The oil and grease test reported here (06521L) involves a petroleum ether extraction. Surprisingly, maximum oil and grease concentrations do not occur in the tar sands area downstream from Ft. McMurray (Figure 12); similar levels are observed between A2 and A7. The overall confidence limits on the average values are wide, making trend identification difficult. The observed river pattern likely indicates the oil and grease test does not differentiate between naturally occurring and petroleum derived hydrocarbons. According to the 1984/85 synoptic surveys, there is no overt hydrocarbon increase in the Athabasca River near the tar sands extraction plant. There are insufficient data for historical oil and grease trend analysis.

The effluent from the Hinton pulp mill has high concentrations of most organic constituents including POC, DOC, phenol, and T&L. Concentrations in the treated sewage discharges and Suncor effluent are elevated relative to river concentrations, but are less than corresponding pulp mill values. Oil and grease concentrations at St. Regis exceed corresponding values in the Suncor Tar Sands effluent.

Figure 14 Seasonal True Color distribution for Athabasca mainstem and tributary sites, 1984/85



e) Biological Constituents

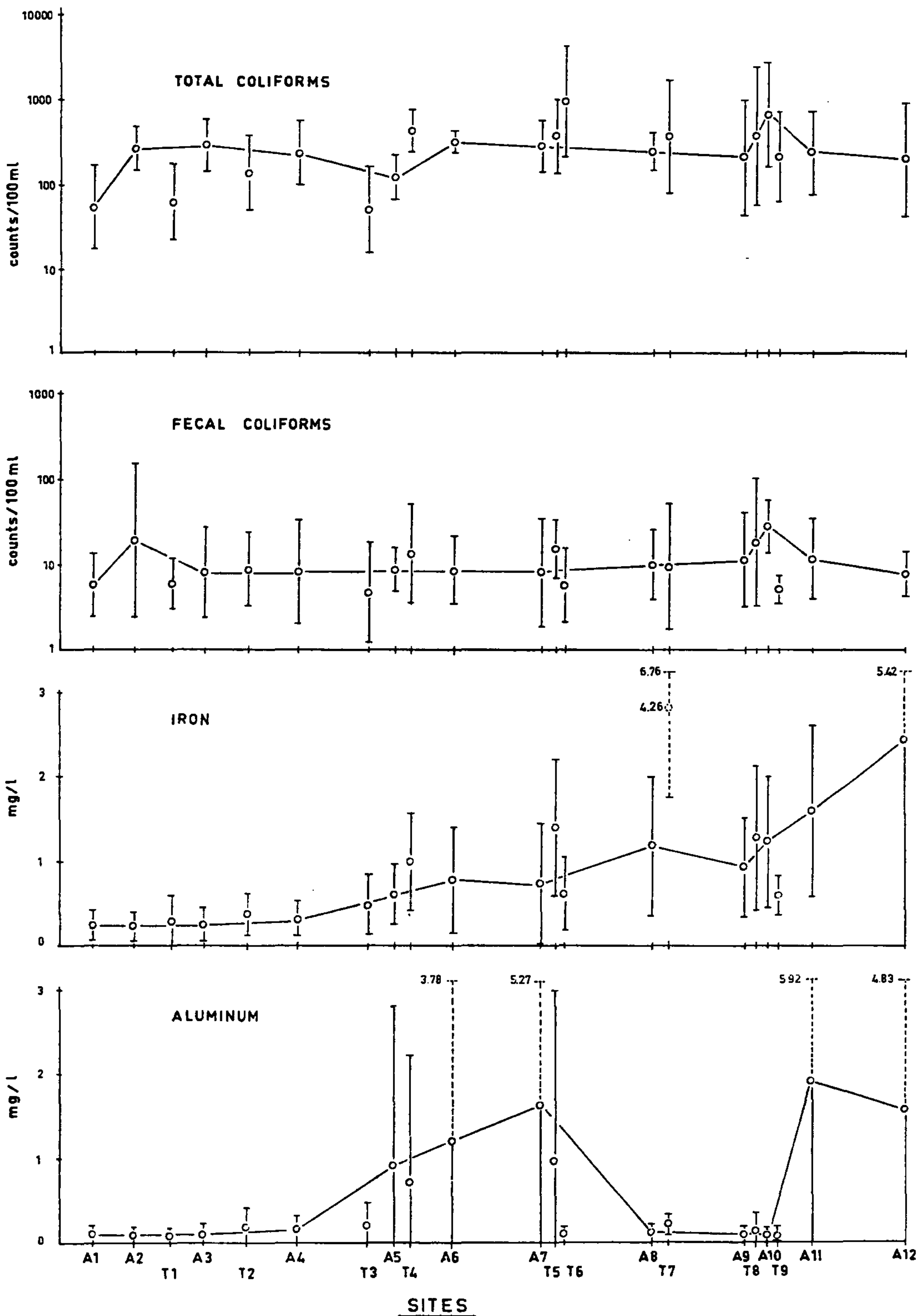
Biological data collected during the 1984/85 synoptic surveys include the microbiological indicators; total and fecal coliforms, and both phytoplanktonic and epilithic chlorophyll*a*.

The common pathogenic diseases transmitted through surface waters include dysentery, cholera, typhoid, gastroenteritis, infectious hepatitis, polyiomyelitis and diarrhea. Sources of the organisms are infected people and animals. Since direct monitoring of most pathogens in rivers and lakes is not feasible, indirect indicators of microbial safety are used. The philosophy of an indicator being that if it can be shown fecal contamination has occurred, then pathogenic organisms may be present. Members of the coliform group of bacteria are the most commonly used microbiological indicators. The total coliform test measures gram negative, non-spore forming, rod shaped bacteria which are prolific in the intestinal tract of warm-blooded animals. Fecal coliforms include only those bacteria which grow at 44.5^{o}C and are capable of fermenting sugar. Although both total and fecal coliform limits are often included in water quality objectives, the latter test is most significant as it does not include coliforms of non-fecal origin. The coliform *Enterobacter* often enters surface waters from surrounding soils and vegetation (Federal-Provincial Working Group on Recreational Water Quality 1983).

At the three historic monitoring locations median coliform counts have remained below 100 counts/100mL and fecal counts below 20 counts/100mL. These values represent normal background concen-trations for surface waters. There is no distinct between site trend in total coliform counts. Slightly enhanced fecal coliforms are evident at Ft. McMurray during winter and the early open water season.

During 1984/85 the geometric mean of total coliforms ranged between 100 and 1000 counts/100mL (Figure 15). Lower values were evident at A1, and in the Berlund and Pembina River tributaries. The site downstream of Ft. McMurray had the highest mean total coliform count of all mainstem river sites.

Figure 15 Longitudinal trend in Total and Fecal Coliforms, Iron and Aluminum along the Athabasca River in 1984/85. Average values plus and minus 1 St.Dev., except Coliforms which are geometric means.



Recent average fecal coliform counts remained near 10 counts/100mL at nearly all mainstem and tributary sites. Slightly higher geometric means occurred at A2, downstream Hinton, and A11 (Figure 15). Seasonally, fecal coliform densities upstream of Hinton remained low for five of the six synoptic surveys; a count near 30 occurred in July (Figure 16). High counts were observed downstream of Hinton in July and February, and in winter extended as far downstream as A4. The other notable mainstem Athabasca trend was relatively high fecal coliform densities at A9 and A10 in May, and A9 through A11 in July. Seasonal maximum counts in the tributaries tended to occur in June, July and August. During that summer period values were higher in the lower basin tributaries relative to the foothill and mountain drainages. In February the fecal coliform measurement in the Lesser Slave River exceeded that of all other tributaries which had very low under-ice densities.

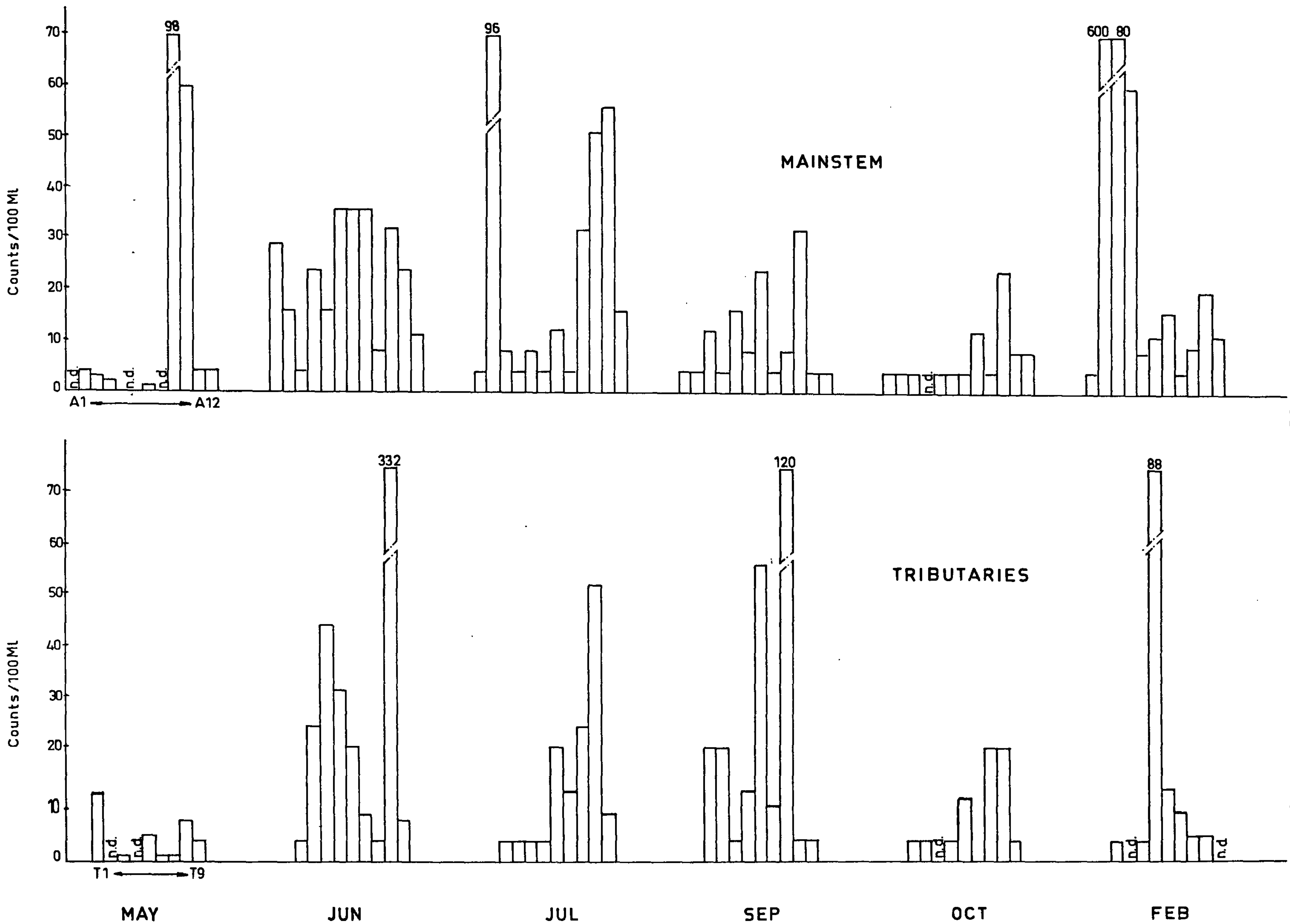
The sewage discharges had high total and fecal coliforms counts. This is anticipated since effluent chlorination is not practiced at any of the three locations. Bacteriological indicator levels in the Hinton Pulp Mill effluent were similar to those in sewage. No bacteriological data exist for the Suncor Tar Sands effluent, however, considering the nature of the discharge, counts are probably low.

Aquatic plants and algae form the primary producers in aquatic ecosystems. Like carbon, they are an important food web component. Their growth is determined by both the physical and chemical environment in the river. Under enriched conditions (i.e. high nutrient loads) extreme densities of plants or algae can result in water use limitation. Examples include extreme oxygen fluctuations, clogging of water intakes and taste and odor in drinking water.

Algae which grow suspended in the water column are called phytoplankton; periphyton are algae which grow attached to the stream bottom. Chlorophyll is the green pigment found in all plants and is commonly used as an indicator of algal biomass (density).

In 1984/85 phytoplankton chlorphyll *a* levels remained at or below 5 mg/m^3 in the mainstem Athabasca River (Figure 9). Very low levels were experienced upstream of A4. Concentrations increased between A4 and A8 and then levelled off from there downstream. Phytoplankton chlorophyll was high in tributary streams draining lakes, i.e. Lesser Slave (T4), LaBiche (T5) and Calling (T6) rivers. This is

Figure 16 Seasonal Fecal Coliforms distribution for Athabasca mainstem and tributary sites, 1984/85



understandable considering the high phytoplankton growth in their points of origin. The phytoplankton densities in the Pembina River, House River and Poplar Creek also exceeded levels in the mainstem. Along the upper Athabasca River phytoplankton chlorophyll was seasonally high in May and June, and low the rest of the year (Figure 17). Winter values were extremely low at all mainstem and tributary locations. At river sites A5 through A12 phytoplankton densities remained relatively constant throughout the open water interval, with only a slight tendency towards lower values in July and October. The seasonal pattern for the tributaries was the same as the adjacent mainstem river. This implies the tributary inputs largely account for the observed Athabasca River condition. Athabasca River phytoplankton chlorophyll levels are low relative to most Alberta lakes. Average chlorophyll densities of five mg/m^3 or less are classified as mesotrophic to oligotrophic (Vollenweider & Kerekes, 1980).

In contrast to the above pattern, attached algal densities were greater upstream and lower in the downstream reaches of the basin (Figure 18). Maximum average epilithic chlorophyll standing crops occurred between A2 and A4. Except for A8, reduced levels were observed downstream of A4. Benthic chlorophyll at A1 was low and approached the extremely low values recorded at Embarras and Bitumount. Tributaries with high average values include the Calling and House rivers, as well as Poplar Creek. With minor exceptions, highest 1984/85 epilithic chlorophyll levels, for both mainstem and tributary sites, occurred in September and October (Figure 18). Densities were extremely low during June and July when river flows, and therefore substrate scour, were high. Overall maximum densities occurred downstream of Hinton (A2, A3, A4) during October. An uncharacteristically high benthic chlorophyll was recorded in Poplar Creek during May. All other tributaries had low values at that time. Average benthic chlorophyll levels in the Athabasca River are considered to be low relative to values recorded in major southern Alberta Rivers. In those systems, average densities in the range of 100 to 200 mg/m^2 chlorophyll are not uncommon, and maximum values of 800 mg/m^2 have been recorded. (Charlton et al., 1985).

f) Nutrients

Carbon, nitrogen and phosphorus are the primary nutrients in aquatic systems. Of those, nitrogen and phosphorus most often regulate aquatic plant growth and are therefore of primary importance. At high levels, nitrogen and phosphorus can result in eutrophic water quality conditions.

Figure 17 Seasonal Phytoplankton Chlorophyll a distribution for Athabasca mainstem and tributary sites, 1984/85

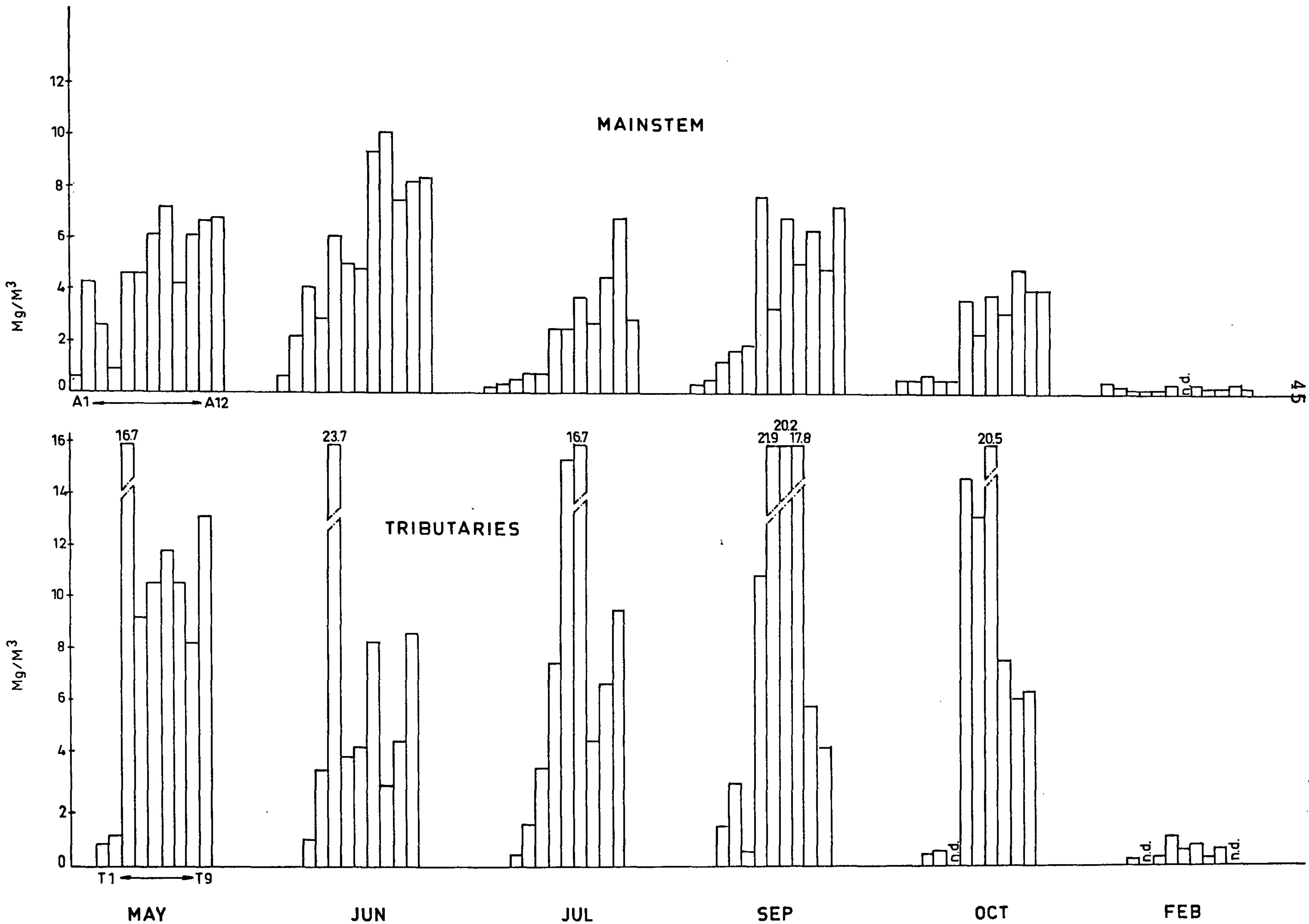
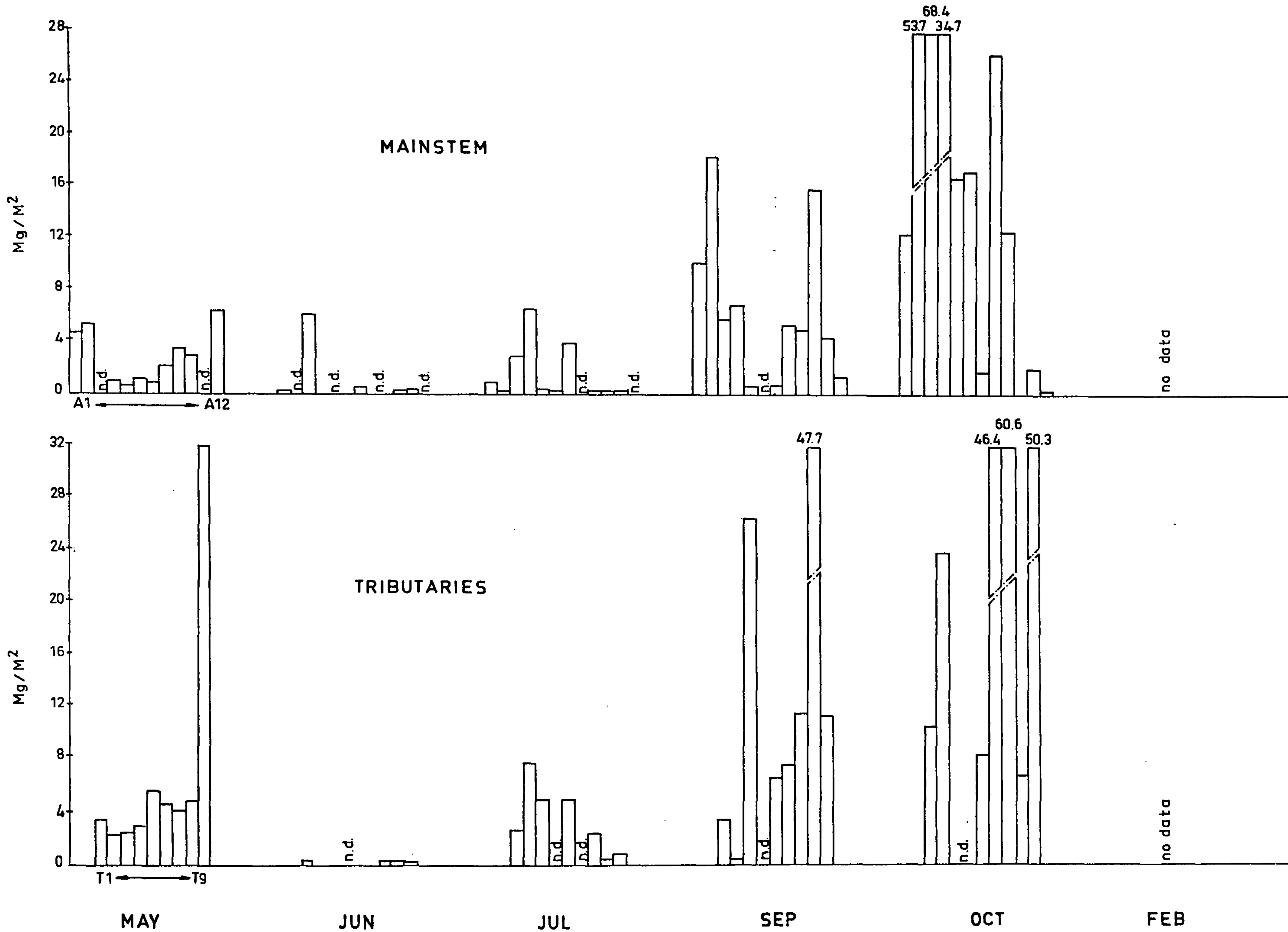


Figure 18   Seasonal Epilithic Chlorophyll a distribution for Athabasca mainstem and tributary sites, 1984/85



Total phosphorus (TP) occurs in numerous organic and inorganic forms, and can be present in waters as dissolved or particulate species (McNeely et al.,1979). Average total and dissolved phosphorus (TDP) levels for the recent survey increased greatly downstream of A4, and again downstream from Ft. McMurray (Figure 19). Upstream of A4 average mainstem TP was near 0.020 mg/L and TDP less than 0.005 mg/L. In contrast, average TP levels downstream from Ft. McMurray exceeded 0.100 mg/L. Most of the river basin increase in TP is due to particulate phosphorus. Lower reach TDP values remained low at 0.014 to 0.016 mg/L. Total phosphorus concentrations in the upper tributaries were low (i.e. Berland and McLeod rivers). Intermediate concentrations were observed in the Pembina, Lesser Slave and Calling Rivers, and Poplar Creek. High TP values were recorded in the LaBiche, House and Clearwater Rivers. The tributary TDP pattern was similar to that of total phosphorus, highest average concentrations occurred in the LaBiche and House Rivers. Along the mainstem river, total phosphorus concentrations were greatest in June and July when river and tributary flows were high (Figure 20). Minimum concentrations were experienced during winter throughout the basin.

At the historical sites, winter TP concentrations ranged from 0.009 mg/L at Jasper to 0.025 mg/L at Ft. McMurray. Maximum median values occur in the early open water season, with a substantial reduction evident in the late season. As was evident in the 1984/85 dataset, the longterm average concentrations longitudinally increase from Jasper to Ft. McMurray.

The longitudinal nitrogen pattern along the mainstem Athabasca River was the same as total phosphorus (Figure 21), increasing with distance from the headwaters. Tributary concentrations were greater in systems draining the plains region, as compared to mountain and foothill rivers like the Berland and McLeod. Except for the Clearwater River average concentrations in tributaries T3 to T9 were comparable to mainstem values. Seasonally, Athabasca River total nitrogen concentrations were similar in May, September, October and February (Figure 22). High values were recorded in June and July. Tributary concentrations did not vary substantially after May. At that time, nitrogen in the downstream tributaries was below average.

In 1984, the average nitrate + nitrite concentration of the Athabasca River remained constant (0.05 mg/L) throughout the basin. Only the average upstream Hinton concentration was greater at 0.063 mg/L. The standard deviation for nitrate

Figure 19 Longitudinal trend in Total Phosphorus and Total Dissolved Phosphorus along the Athabasca River in 1984/85. Average values plus and minus 1 St.Dev.

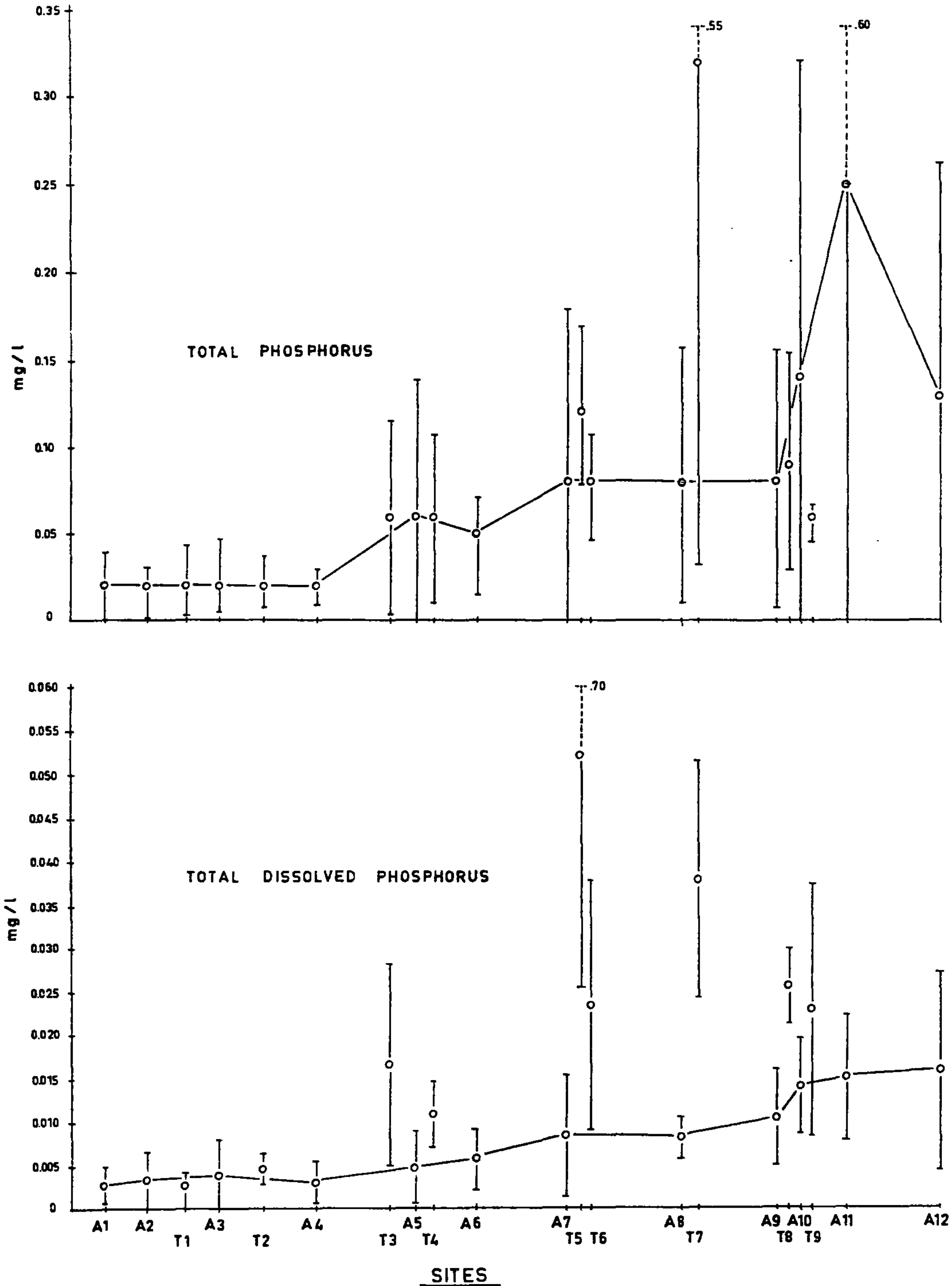


Figure 20 Seasonal Total Phosphorus distribution for Athabasca mainstem and tributary sites, 1984/85

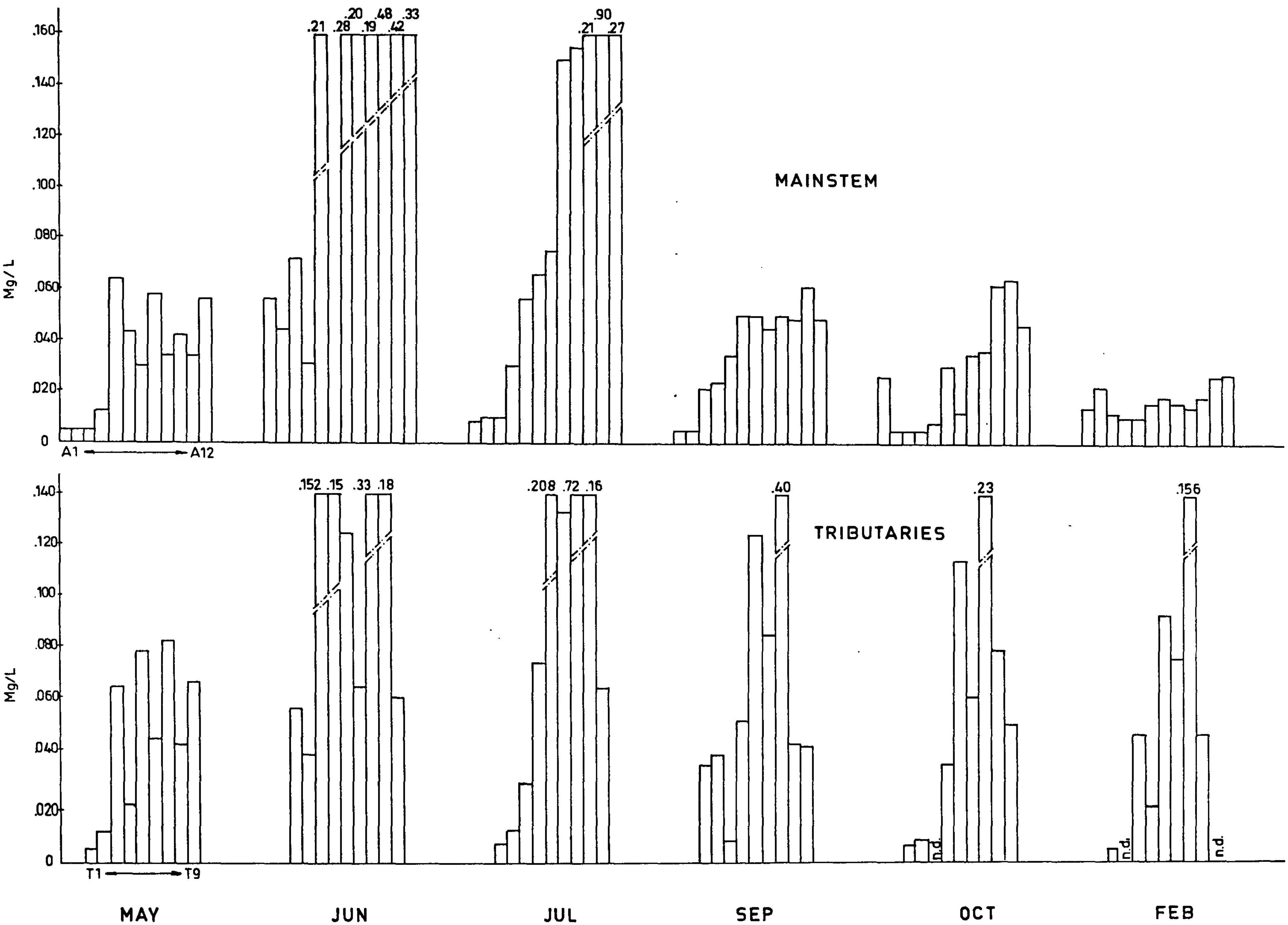


Figure 21 Longitudinal trend in Total Nitrogen, Nitrate + Nitrite and Ammonia along the Athabasca River in 1984/85. Average values plus and minus 1 St.Dev.

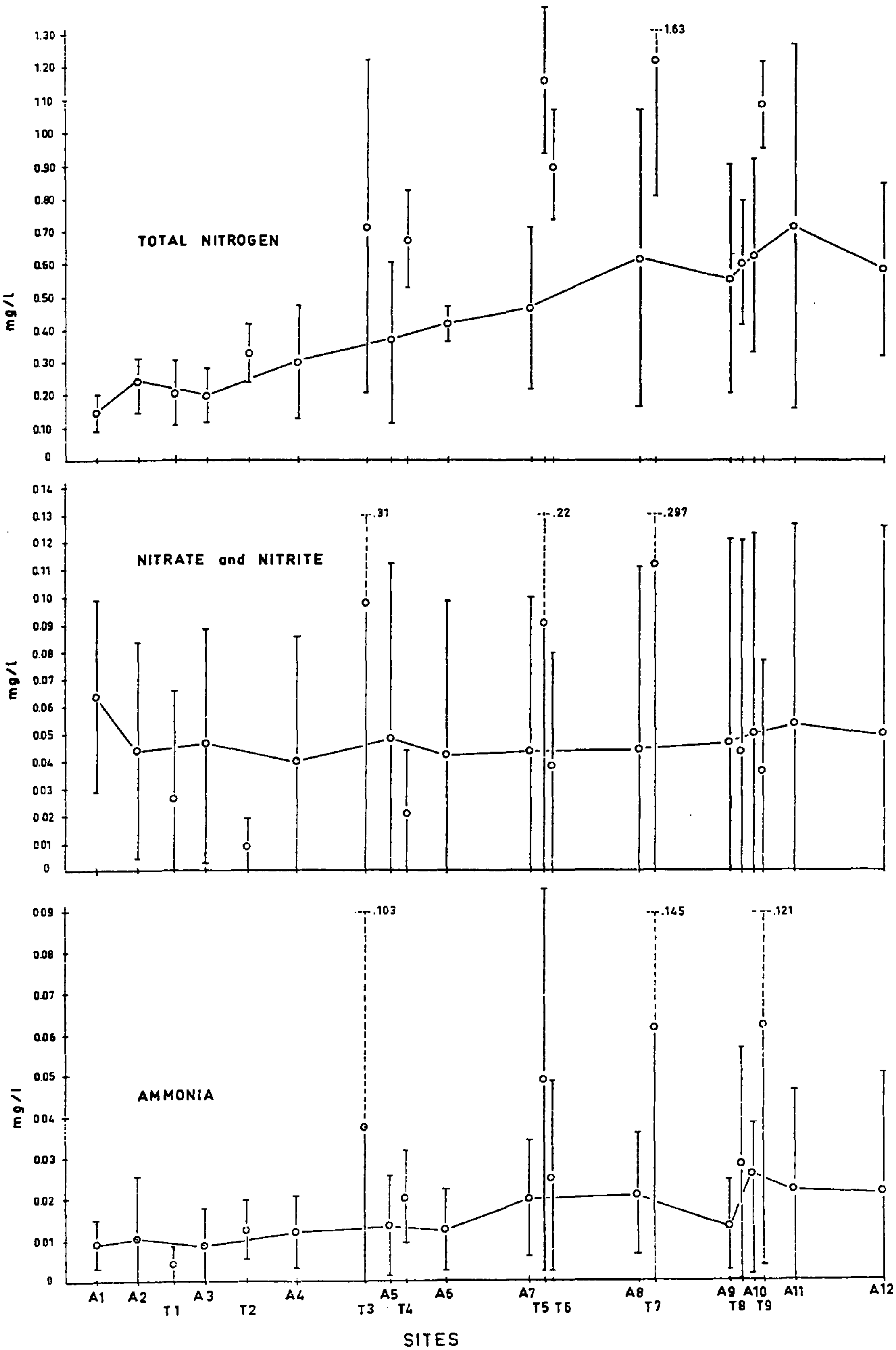
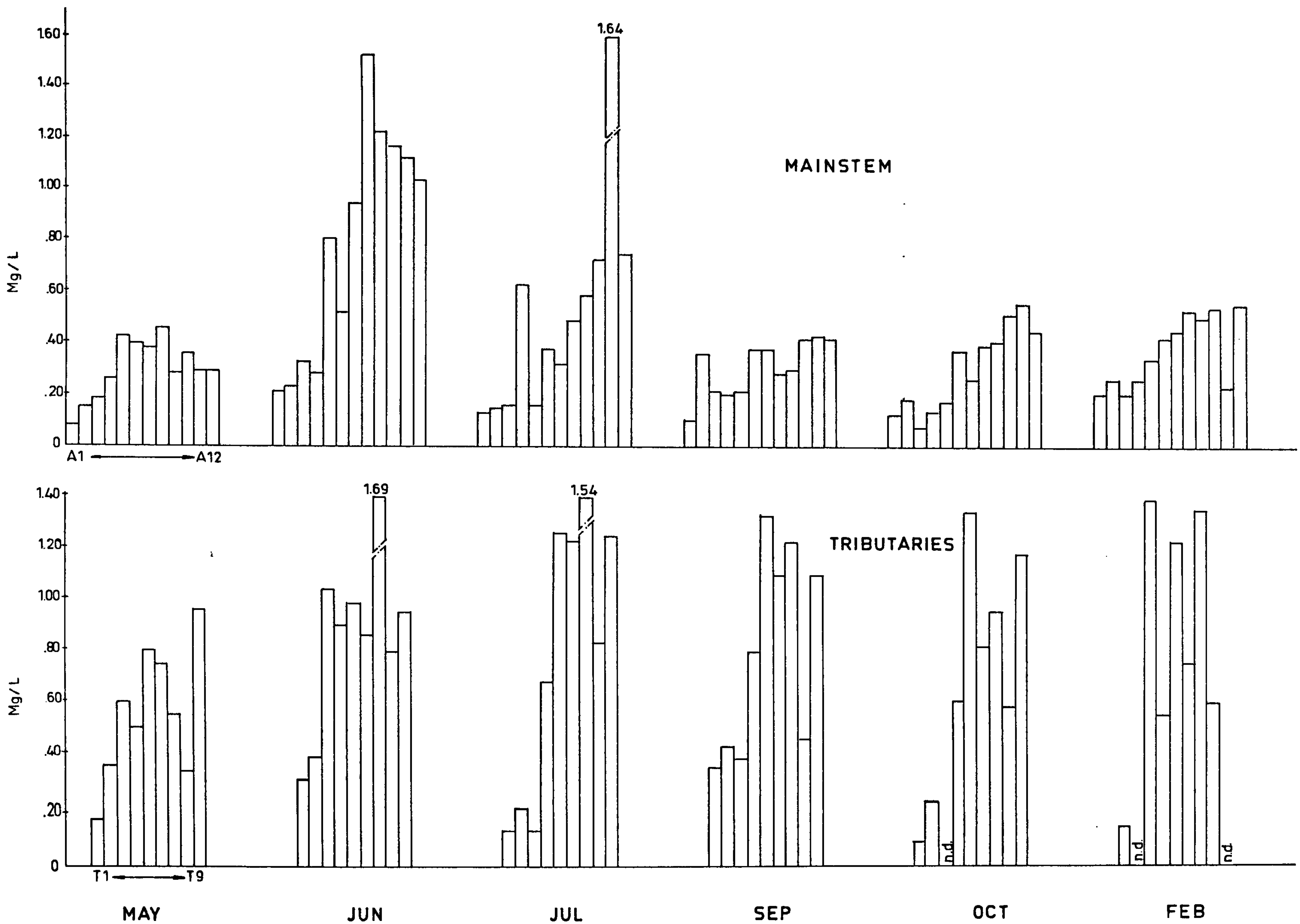


Figure 22 Seasonal Total Nitrogen distribution for Athabasca mainstem and tributary sites, 1984/85



+ nitrite was substantial at all sampling locations. Nitrate + nitrite concentrations in the Berland, McLeod and Lesser Slave rivers were below river average; whereas concentrations in the Pembina, LaBiche and House rivers were much greater.

Recent average ammonia concentrations remained near 0.01 mg/L upstream of Athabasca Town. Concentrations downstream of Athabasca were higher (0.020 to 0.030 mg/L). Very high ammonia concentrations were evident in the Pembina, LaBiche and House rivers, as well as Poplar Creek. Concentrations in the other tributaries approached background river concentrations.

The historical database includes information for dissolved and particulate nitrogen, as well as nitrate + nitrite and ammonia. Total nitrogen (sum of DN and PN) increases in the downstream direction. At Athabasca and Ft. McMurray early open water medians exceed similar values during other seasons. Maximum TN at Jasper occurs in winter. In all three seasons dissolved nitrogen at Athabasca exceeds corresponding values at Jasper and Ft. McMurray. The same occurs for particulate nitrogen, but only during the early open water period. Nitrate + nitrite values are greatest under ice and the winter medians at all three sites are similar. Nitrate + nitrite concentrations are low during the late open water season, especilly at Town of Athabasca and Ft. McMurray.

Effluent concentrations of particulate nitrogen (PN) were high in the pulp mill effluent and the Ft. McMurray sewage treatment discharge. Particulate nitrogen values in the Suncor effluent and Whitecourt STP were low. Ammonia concentrations in the Athabasca and Ft. McMurray sewage discharges were very high (15 to 22 mg/l) and nitrate levels correspondingly low. In contrast the major inorganic nitrogen form in the Whitecourt sewage effluent is nitrate, indicating that significant in plant nitrification is occurring. Ammonia levels in the Hinton discharge were high relative to river concentrations, but much lower than corresponding sewage values at Athabasca Town and Ft. McMurray. Inorganic nitrogen in the Suncor effluent was low for both forms.

g) **Metals**

Metals in surface waters can occur in both dissolved and particulate form. In waters of high pH and suspended solids the particulate forms usually dominate. The speciation of metals in aquatic systems is complex. In the dissolved phase metals can exist as free ions or be bound in colloidal particles. Particulate 'species' include metals adsorbed to organic particles, hydrous iron oxides, inorganic silts and clays. The toxicity and bioavailability of a metal depends greatly upon its form, and the other chemical and biological characteristics of the aquatic system. Reported here are data for total and extractable metal concentrations, and in a few instances, dissolved. The total measurement is a very rigorous test which measures all forms of the metal. The extractable test is less inclusive and was originally thought to estimate the bioavailable component. Due to the complex environmental chemistry of metals most recent water quality standards are based upon totals.

Iron, aluminum and manganese had the highest concentrations of all metals monitored. Under well oxygenated conditions iron exists in the ferric rather than ferrous form. It is naturally derived from weathering of sedimentary rock, and iron oxides and hydroxides may be leached from sandstone (McNeely et al.,1979). Results of the 1984/85 surveys indicate average iron concentrations increase in a downstream direction. Concentrations upstream of A4 were well below 1 mg/L, whereas downstream concentrations frequently exceeded that level (Figure 15). A major increase in iron content occurred downstream from Ft. McMurray. Tributaries high in iron include T4, T5 and T7. The historical database verified this recent longitudinal trend. Maximum concentrations occur in the early open water season at all three historic sites; minimums occurred under ice. Good dissolved iron data exists for Athabasca and Jasper only. At both sites average concentrations in all seasons were less than 0.1 mg/L.

Manganese is a metallic cation and is similar to iron in its chemical behaviour. Under oxygenated conditions it is usually found at concentrations below one mg/L. High iron and manganese levels can cause staining of plumbing fixtures and laundry. Like iron, average manganese concentration increased between A1 and the lower basin reaches. The maximum 1984/85 river average occurred at Bitumount (0.143 mg/L). The House River had the highest manganese content of all tributaries, low concentrations were recorded in the mountain and foothill tributaries. The historic pattern is for maximum manganese concentrations to occur during the early open water period, while late season and winter concentrations are lower. Median dissolved manganese concentrations are less than the detection limit of 0.01 mg/L.

Aluminum is the third most abundant element in the earth's crust. Surface water concentrations are often low as it tends to sorb to the sediments or precipitate from solution. Concentrations are higher in acidic systems (McNeely et al., 1979). Anthropogenic sources include acid mine drainage and discharge from water treatment plants which use alum. The recent longitudinal pattern for this metal was extremely variable (Figure 15). Mainstem and tributary concen-trations upstream of A4, and between Town of Athabasca and Bitumount, were low. High mainstem and tributary concentrations were observed between A4 and A8. The concentrations downstream from Ft. McMurray cannot be justified by levels in the House and Clearwater Rivers. It must be derived from re-suspension of channel sediments or unmonitored tributaries. Historic average concentrations at Athabasca Town and Ft. McMurray are similar; little data exist for Jasper.

Iron and manganese concentrations in the pulp mill effluent exceed corresponding values for the sewage treatment plants and the Suncor effluent. Only manganese concentrations for the St. Regis discharge exceeded surface water levels. Iron and manganese in all other effluents were equal to or less than river concentrations. Effluent aluminum concentrations ranged between 0.3 and 0.75 mg/L, except at the Whitecourt Sewage Treatment plant (0.129 mg/L).

In addition to the three major metals discussed above, recent or historic data exist for an additional 16 trace metals. Environmental overviews and guideline levels have recently been published by Environment Canada for 10 of the most important metals.

Arsenic is derived from natural and cultural sources. It is used in various industrial processes, some pesticides and hide tanning, and is also a byproduct of coal combustion (Demayo et al., 1979). Recent concentrations in the mainstem Athabasca River, its tributaries and effluents, were all low. Upper basin concentrations remained near 0.0005 mg/L, while concentrations downstream of Ft. McMurray ranged between 0.002 and 0.003 mg/L. Ninety percent of 5400 water samples collected from throughout Canada had concentrations less than 0.008 mg/L (Demayo et al.,1979).

Cadmium is one of the toxic metals and its major environmental pathway is atmospheric deposition (Reeder et al., 1979). Median historic total and extractable concentrations of cadmium in the Athabasca River have remained at the analytical detection limit (0.001 to 0.002 mg/L). The longest historic record is for extractable cadmium; and maximum historic concentrations have not exceeded 0.010 mg/L. Concentrations at all recent river and effluent sites were correspondingly low (0.002 mg/L or less).

Chromium has several oxidation states; chromium metal, chromic compounds and chromates (Taylor et al.,1979). Major anthropogenic sources include combustion of coal and oil, steel making, metal plating, cement production and chromate manufacturing. Unlike the other forms chromates are not strongly adsorbed to particulates and are therefore more mobile in aquatic systems. The historical record for extractable chromium does not include a record in exceedance of the detection limit (0.015 mg/L). The detection limit for the recent dataset is 0.001 mg/L. Average 1984/85 river values ranged from 0.003 mg/L (A2) to 0.010 mg/L (A1). The House River had the highest average tributary concentration (0.0125 mg/L), all others were below 0.006 mg/L. Maximum effluent levels were recorded at the Hinton Pulp Mill (0.152 mg/L).

Copper is a common heavy metal constituent of natural waters. When copper ions are introduced into alkaline waters they tend to precipitate and be removed by adsorption or sedimentation. This is one reason why average extractable copper concentrations ranged from only 0.002 to 0.006 mg/L throughout the Athabasca River in 1984/85. Maximum concentrations were less that 0.020 mg/L. Similar low values occurred in the tributaries, except for the House River, where the average and maximum were 0.021 and 0.046 mg/L respectively. Average effluent concentrations only exceeded 0.010 mg/L in the Whitecourt Sewage Treatment effluent and the pulp mill discharge. Historic median values of extractable copper ranged from 0.001 mg/L at Jasper to 0.003 mg/L at Ft. McMurray. There is no obvious seasonal distribution in the historic data.

Results of the synoptic surveys show no detectable lead in the Athabasca River upstream of Athabasca Town. The average concentration downstream of Ft. McMurray was 0.010 mg/L. A maximum recorded 1984/85 extractable lead of 0.037 mg/L occurred at Bitumount. Amongst the tributaries detectable lead concentrations were only recorded in the House River and Poplar Creek. The House River average was 0.019 mg/L. Considering the insignificant tributary loadings the observed mainstem levels likely reflect an instream source. Effluent concentrations ranged near 0.005 mg/L except for the St. Regis pulp mill (0.028 mg/L). The historic median values at all sites represent the detection limit for both total and extractable forms. A maximum recorded level of 0.056 mg/L occurred at Ft. McMurray under ice. Like copper, there is no seasonal trend in the historic lead data.

Mercury is of special interest in Alberta due to elevated fish tissue concentrations in some Alberta rivers. Inorganic mercury in natural waters is rapidly and efficiently transferred into the sediment (Reeder et al 1979). In the sediments, mercury can be neutralized by binding with sulphide ion, or be biologically transformed to methyl mercury. Methyl mercury is the toxic form and tends to biomagnify, hence the high fish tissue concentrations when ambient water concentrations are low. The provincial detection limit for mercury is 0.0001 mg/L. In 1984/85 values greater than the detection limit were only recorded immediately downstream of Hinton, upstream of Ft. McMurray and in the St. Regis effluent. Even then recorded values were only 0.0002 mg/L, except for the upstream Ft. McMurray location (0.010 mg/L). The historical detection limit for mercury has varied between 0.00002 and 0.00005 mg/L for extractable mercury and from 0.0001 to 0.00002 mg/L for total mercury. This variability is reflected in the median calculations. Actual greater than detection limit values for mercury have only been observed at the Ft. McMurray location, with the maximum being 0.0006 mg/L as total mercury.

Nickel concentrations in natural Canadian surface waters are less than 0.012 mg/L in 90% of samples (Taylor et al.,1979). Sediment concentrations are usually higher. The synoptic surveys indicate average Athabasca River concentrations for extractable nickel generally range from 0.004 mg/L at A1 to between 0.006 and 0.010 mg/L downstream from Ft. McMurray. A high mean value downstream of Athabasca Town (0.034 mg/L) was weighted by one high value (0.201 mg/L). Maximum values in the lower reaches of the basin were less than 0.035 mg/L. The maximum average effluent concentration was 0.017 mg/L and this occurred at Suncor. Average concentrations in all other discharges were below 0.010 mg/L. Tributary concentrations were all low, with only slightly elevated concentrations in the House River. Historic total nickel concentrations have not exceeded 0.015 mg/L at Jasper or Town of Athabasca. Maximum extractable concentrations of 0.035 mg/L have been recorded near Ft. McMurray in all three seasons. The only medians which exceed the historical detection limit are the open water values for Ft. McMurray.

Results of the recent surveys indicate increasing zinc concentrations downstream of Athabasca Town. Average values in the lower reach range between 0.014 and 0.024 mg/L. Upper basin values are less than 0.010 mg/L. The House and Clearwater rivers contain high zinc concentrations relative to all other monitored tributaries. Maximum effluent levels were recorded in the Hinton effluent. The Suncor effluent concentration was very low. The longtitudinal trend towards increasing zinc concentrations with downstream distance is verifed by the historic record. There is a slight seasonal pattern of higher levels during the early open water period. Zinc is easily mobilized by weathering of igneous and sedimentary rocks. The rate of weathering is less than that of nickel and mercury, but exceeds the rate for lead, arsenic and cadmium (Taylor & Demayo,1979).

Vanadium is naturally found in carbonaceous deposits and can be leached from oil sands (McNeely et al.,1979). This may explain why vanadium concentrations in the Athabasca River are greatest downstream from Ft. McMurray (0.020 to 0.030 mg/L). Concentrations upstream of Ft. McMurray were usually less than 0.005 mg/L, and seldom exceeded 0.010 mg/L. Higher than average tributary concentrations occurred only in the House River. The Suncor effluent concentrations were high relative to other effluents.

Athabasca River basin data also exist for cobalt, beryllium, molybdenum, selenium and silver. For all these metals the river and mainstem concentrations were consistently low, or showed little seasonal or longitudinal variance.

h) Trace Organics

Trace organic compounds including pesticides, herbicides and polychlorinated byphenols (PCB) have been monitored at the Environment Canada stations. This includes between thirty and forty separate compounds (Appendix III). Of this total only seven have ever been detected in river water samples, and none at problem concentrations.

In the pesticide group only alpha-BHC, lindane and picloram have been identified. Lindane was measured once at Jasper and twice at the Town of Athabasca. Two of the three records were at the detection limit, i.e. measurements of 0.001 mg/L rather than <0.001 mg/L. Picloram was positively recorded once at Jasper, also at a level equal to the detectable limit. Alpha-BHC has been commonly recorded at both river locations. Unlike lindane it has no insecticidal characteristics and is only present as an impurity in certain pesticide formulations (Gummer,1979). Prior to 1976 a pesticide of mixed BHC isomers containing 60% to 70% alpha was marketed, the current formulation only has 1% alpha. It's presence in surface waters is not considered to be of major environmental significance.

Herbicides tend to be more water soluble than most pesticides and occurance in the water phase is more likely. This enhanced solubility is counteracted by the fact they tend to degrade at a much faster rate, i.e. in days or weeks rather than years, as is the case for the organochlorine pesticide compounds. The herbicides 2,4-D; 2,4-DP and 2,4,5-T occur at trace levels in the Athabasca River. The most commonly used herbicide is 2,4-D, and it has occurred in measurable amounts (maximum 0.017 mg/L) in three of thirty-one total samples collected at the Town of Athabasca. There are two recorded occurences of 2,4-D at Jasper, both in 1978. The other two compounds 2,4,5-T and 2,4-DP have only been detected on rare occassions.

Hexachlorobenzene is the only other trace organic that has been detected by the routine monitoring program. On one occasion it was measured at 0.001 mg/L near Jasper. It is listed as a priority pollutant and is a member of the monocyclic aromatic group of compounds.

3. Variance Among Sites - Recent Data

Oneway analysis of variance (ANOVA) was used to statistically test for significant between site differences in the recent database. The analysis was performed on a subset of parameters which were log transformed if the Kolmogorov-Smirnov test indicated a significant deviation from the normal distribution. If the ANOVA indicated a significant difference between either mainstem or tributary locations a Student-Newman-Keuls (SNK) test was employed to define which specific sites deviated.

The ANOVA results for the mainstem Athabasca River are summarized in Table (7). There was no deviation amongst the twelve sites for TDS, however, there was for sodium, chloride and sulphate. Total and dissolved phosphorus concentrations were significantly different, as was total nitrogen, but not nitrate + nitrite or ammonia. Dissolved organic carbon and associated variables did vary amongst mainstem locations. The distribution of non-filterable residue, which is synonymous with suspended solids, was the same at all sites.

TABLE 7 ANALYSIS OF VARIANCE TO TEST FOR SIGNIFICANT DIFFERENCES BETWEEN MAINSTEM SITES IN 1984 (*DENOTES P<0.05; **DENOTES P<0.01)

PARAMETER	F RATIO	SIGNIFICANCE LEVEL
SODIUM	4.00	**
CHLORIDE	2.73	**
SULFATE	3.22	**
TOTAL DISSOLVED SOLIDS	0.28	--
NON-FILTERABLE RESIDUE	0.66	--
DISSOLVED ORGANIC CARBON	9.70	**
TANNIN & LIGNIN	1.99	*
COLOUR	2.75	**
EPILITHIC CHLOROPHYLL	0.80	--
PLANKTON CHLOROPHYLL	2.79	**
TOTAL COLIFORMS	1.32	--
FECAL COLIFORMS	1.44	--
TOTAL PHOSPHORUS	3.01	**
TOTAL DISSOLVED PHOSPHORUS	5.10	**
AMMONIA	1.22	--
TOTAL NITROGEN	4.58	**
NITRATE & NITRITE	0.90	--
IRON	3.93	**
ALUMINUM	0.52	--

TABLE 9 ANALYSIS OF VARIANCE TO TEST FOR SIGNIFICANT DIFFERENCES BETWEEN TRIBUTARY STREAMS IN 1984 (*DENOTES PLO.05; ** DENOTES PLO.01)

PARAMETER	F RATIO	SIGNIFICANCE LEVEL
SODIUM	25.4	**
CHLORIDE	70.8	**
SULPHATE	13.2	**
TOTAL DISSOLVED SOLIDS	7.88	**
NON-FILTERABLE RESIDUE	3.46	**
DISSOLVED ORGANIC CARBON	17.36	**
TANNIN & LIGNIN	2.18	*
COLOUR	6.96	**
EPILITHIC CHLOROPHYLL	0.28	--
PLANKTON CHLOROPHYLL	3.34	**
TOTAL COLIFORMS	3.08	*
FECAL COLIFORMS	0.94	--
TOTAL PHOSPHORUS	9.71	**
TOTAL DISSOLVED PHOSPHORUS	14.14	**
AMMONIA	3.93	**
TOTAL NITROGEN	13.85	**
NITRATE & NITRITE	1.36	--
IRON	6.84	**
ALUMINUM	0.67	--

TABLE 10 STUDENT-NEWMAN-KEULS ANALYSIS FOR STASTISTICALLY DIFFERENT MEANS, TRIBUTARY SITES, 1984/85

TOTAL COLIFORMS

T3	*	
T1	*	
T2	*	*
T9	*	*
T7	*	*
T8	*	*
T5	*	*
T4	*	*
T6		*

PHYTO CHLA

T1	*	
T2	*	*
T3	*	*
T8		*
T7		*
T4		*
T5		*
T9		*
T6		*

NFR

T9	*	
T1	*	
T2	*	
T4	*	
T8	*	
T3	*	
T6	*	
T5	*	
T7		*

IRON

T1	*		
T2	*	*	
T3	*	*	
T6	*	*	
T9	*	*	
T4	*	*	
T8		*	
T5		*	
T7			*

TOTAL PHOSPHORUS

T1	*			
T2	*	*		
T3		*	*	
T4		*	*	
T9			*	
T6			*	
T8			*	
T5			*	*
T7				*

TOTAL DISSOLVED PHOSPHORUS

T1	*			
T2	*			
T4		*		
T3		*	*	
T9		*	*	
T6		*	*	*
T8		*	*	*
T7			*	*
T5				*

TOTAL NITROGEN

T1	*			
T2		*		
T3			*	
T8			*	*
T4			*	*
T6			*	*
T9				*
T5				*
T7				*

NH_3

T1	*	
T2		*
T3		*
T4		*
T6		*
T8		*
T5		*
T7		*
T9		*

TDS

T4	*			
T6	*	*		
T7	*	*		
T8	*	*	*	
T5	*	*	*	
T2		*	*	
T1			*	*
T3			*	*
T9				*

CHLORIDE

T1	*	
T2	*	
T6	*	
T4	*	
T7	*	
T3	*	
T5	*	
T8		*
T9		*

SODIUM

T6	*		
T1	*		
T4	*		
T5	*	*	
T2	*	*	
T7	*	*	
T3	*	*	
T8		*	
T9			*

SO_4

T6	*				
T8	*	*			
T4	*	*			
T2		*	*		
T3		*	*	*	
T1			*	*	
T5			*	*	
T9				*	
T7					*

DOC

T1	*					
T2	*	*				
T8		*	*			
T3		*	*			
T4			*	*		
T6			*	*		
T5				*	*	
T7					*	*
T9						*

COLOR

T1	*	
T3	*	
T2	*	
T6	*	
T4	*	
T8	*	
T5	*	
T9	*	
T7		*

TANNIN & LIGNIN

T1	*	
T2	*	*
T3	*	*
T9	*	*
T6	*	*
T4	*	*
T8	*	*
T5	*	*
T7		*

concentration. Total phosphorus concentrations in the LaBiche and House Rivers exceeded levels in the upper tributaries, while the average TDP of the Berland and McLeod systems was less than tributaries located downstream of T4. Total nitrogen levels were also lower in the Berland and McLeod rivers.

Except for Poplar Creek, total dissolved solid concentrations in the upper tributaries exceeded those in the mid and lower reaches. Chloride and sodium were greatest in the Clearwater River and Poplar Creek. Average sulphate concentrations were highest in the House River and Poplar Creek, but were low overall in the Lesser Slave, Calling and Clearwater Rivers. Minimum dissolved organic carbon concentrations occurred in the Berland and McLeod rivers, and maximum levels in the Calling and House Rivers, and Poplar Creek. According to the color data the House River was more highly stained than any other tributary system. Total coliform counts in the Calling River statistically exceeded counts in the Berland and Pembina rivers.

It must be recognized that this analysis is based upon a sample size of five or six; which is a minimum for such statistical tests. The details of these results might vary somewhat with a larger sample size, nevertheless, the major patterns should be similar.

4. Flow Dependency and Correlation Between Water Quality Variables

Water quality in lotic systems is often dependent upon discharge. In systems unaffected by major effluent loadings, the suspended solids (NFR) content usually increases with river discharge, while an inverse flow dependance is often noted for salinity (TDS). Maximum TDS tends to occur at low river flows. At the same time particulate related parameters often correlate with the suspended solids content of the water, as do the major ions with TDS. Using the historic database possible discharge dependant TDS and suspended solid relationships were investigated for the Athabasca River. Inturn, significant interrelationships between major water quality parameters and suspended solids or TDS were tested.

Formal definition of discharge dependant relationships assist in explaining observed seasonal patterns in the database. Correlation amongst water quality parameters provides insight into the origin of certain constituents, and in turn might have implications for future monitoring. A more efficient water quality monitoring program could be achieved by eliminating tests for highly correlated parameters.

Conductivity is a surrogate parameter for TDS, and turbidity is an indicator of suspended solids. The correlation between conductivity and TDS was very high ($r=0.99$) and the slope was 0.99 indicating direct linearity (Table 11). A similar relationship exists between turbidity and NFR, although the Pearson's correlation coefficient was slightly lower ($r=0.90$). This can be attributed to variability in the composition of suspended solids, which includes both organic and inorganic materials. Conductivity was highly correlated with discharge at all three historic sampling locations, however, the regression relationship differed at Jasper as compared to the two downstream locations (Figure 23). Conductivity increases as discharge declines, however, for any given reduction in discharge a slightly greater increase in conductivity occurs at the lower two stations relative to Jasper. Variance in the Y axis intercept indicates lesser overall conductivity at Jasper, relative to Athabasca Town and Ft. McMurray.

The Town of Athabasca and Ft. McMurray turbidity versus discharge relationships were similar, and both deviated from that at Jasper (Figure 24). The discharge versus turbidity relationship is positive, indicating higher turbidity with increasing discharge. The correlation coefficient at each site exceeded 0.8, which infers that discharge explains at least 64% of the variance in the turbidity database. The regression slopes for Town of Athabasca and Ft. McMurray were identical. A lesser slope for Jasper indicates low flow turbidities at that station exceed corresponding downstream values.

In addition to a good relationship between turbidity and NFR; total phosphorus, iron and manganese also correlate well with turbidity. This indicates they are also discharge dependant. Total nitrogen does not relate well to turbidity, and therefore river discharge.

All major ions except potassium vary linearly with electrical conductance. Highest correlations exist for calcium and bicarbonate, which is understandable considering they are the major component of TDS in the Athabasca River. Slightly lower r values were observed for sodium, chloride and sulphate, possibly reflecting variance in the relative ion balance across the basin.

TABLE 11 CORRELATION AND LINEAR REGRESSION ANALYSIS BETWEEN WATER QUALITY VARIABLES AND DISCHARGE ON HISTORIC DATABASE

PARAMETER RELATIONSHIP	SITE	CORRELATION COEFFICIENT	REGRESSION EQUATION
DISCHARGE VS CONDUCTIVITY	COMBINED	-0.17	LOG(Y) = 2.47 - 0.043 LOG(X)
DISCHARGE VS CONDUCTIVITY	JASPER	-0.95	LOG(Y) = 2.58 - 0.182 LOG(X)
DISCHARGE VS CONDUCTIVITY	ATHABASCA T.	-0.85	LOG(Y) = 3.10 - 0.258 LOG(X)
DISCHARGE VS CONDUCTIVITY	FT. MCMURRAY	-0.87	LOG(Y) = 3.13 - 0.271 LOG(X)
DISCHARGE VS TURBIDITY	COMBINED	0.76	LOG(Y) = -0.85 + 0.850 LOG(X)
DISCHARGE VS TURBIDITY	JASPER	0.81	LOG(Y) = -0.80 + 0.935 LOG(X)
DISCHARGE VS TURBIDITY	ATHABASCA T.	0.84	LOG(Y) = -2.2 + 1.316 LOG(X)
DISCHARGE VS TURBIDITY	FT. MCMURRAY	0.83	LOG(Y) = -2.2 + 1.351 LOG(X)
TURBIDITY VS NFR	COMBINED	0.90	LOG(Y) = 0.10 + 1.014 LOG(X)
CONDUCTIVITY VS TDS	COMBINED	0.99	LOG(Y) = -0.21 + 0.990 LOG(X)
TURBIDITY VS TP	COMBINED	0.77	LOG(Y) = -2.29 + 0.609 LOG(X)
TURBIDITY VS TNIT	COMBINED	0.28	
TURBIDITY VS Fe(EXT)	COMBINED	0.88	LOG(Y) = -1.17 + 0.776 LOG(X)
TURBIDITY VS Mn(EXT)	COMBINED	0.84	LOG(Y) = -2.23 + 0.586 LOG(X)
CONDUCTIVITY VS Na	COMBINED	0.83	LOG(Y) = -60.0 + 27.54 (X)
CONDUCTIVITY VS Ca	COMBINED	0.96	LOG(Y) = -0.58 + 0.878 LOG(X)
CONDUCTIVITY VS K	COMBINED	0.46	LOG(Y) = -6.68 + 3.234 (X)
CONDUCTIVITY VS Cl	COMBINED	0.85	LOG(Y) = -5.64 + 2.434 LOG(X)
CONDUCTIVITY VS SO_4	COMBINED	0.88	LOG(Y) = -1.45 + 1.164 LOG(X)
CONDUCTIVITY VS HCO_3	COMBINED	0.94	LOG(Y) = -0.07 + 0.905 LOG(X)

Figure 23   Log normal relationships between discharge and conductivity at three longterm monitoring sites.

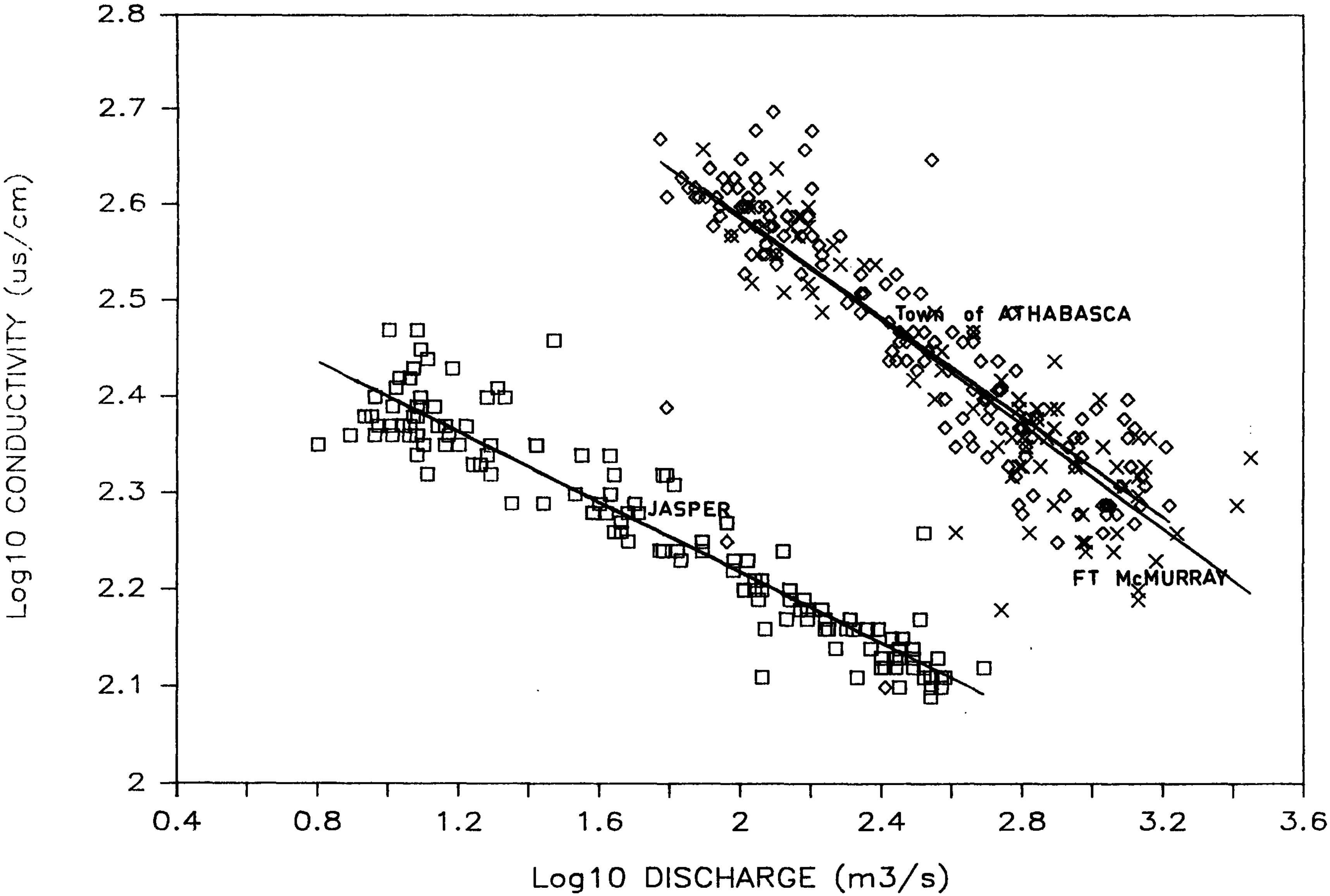
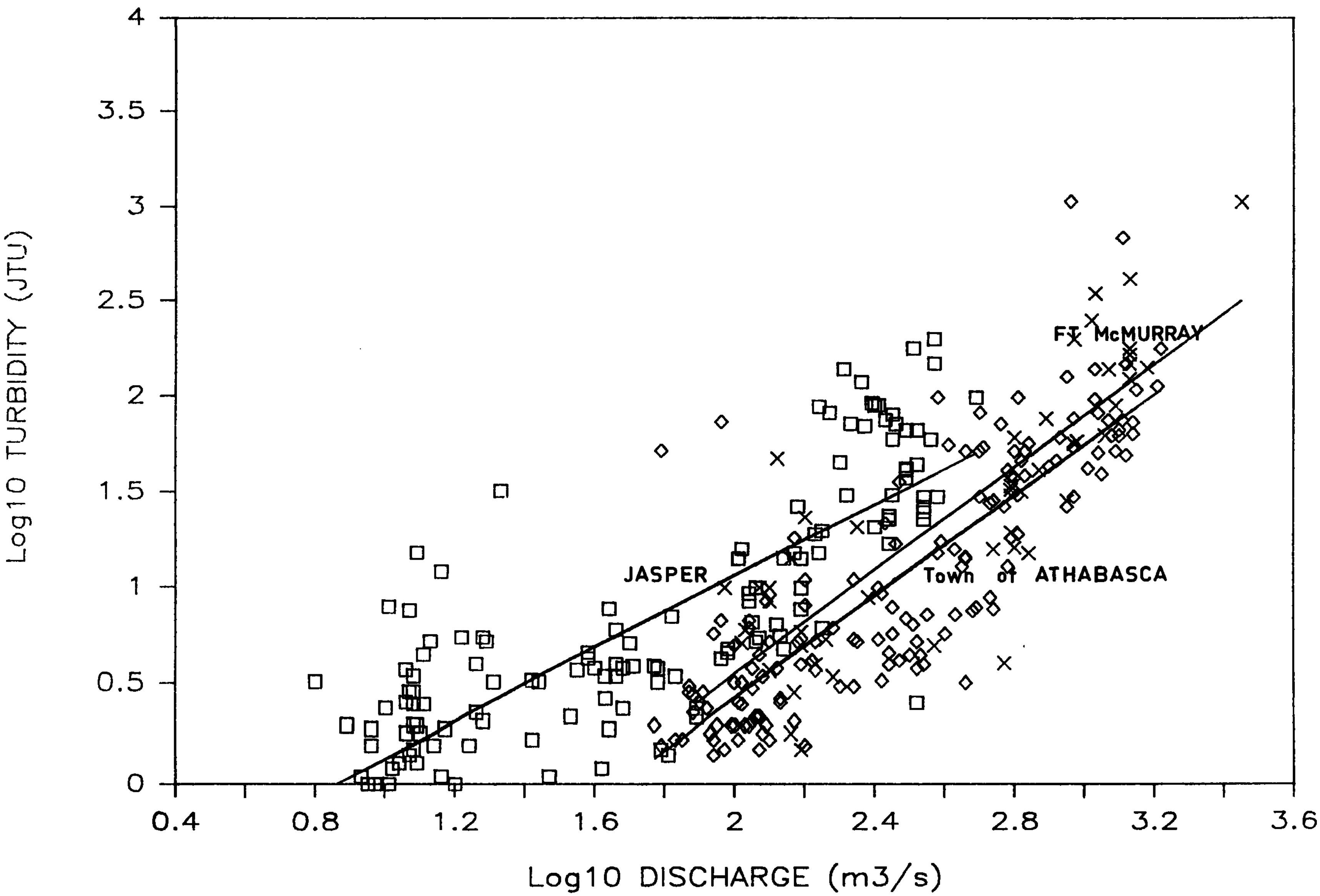


Figure 24 Log normal relationships between discharge and turbidity at three longterm monitoring sites.



5. Water Quality Comparison With Surface Water Objectives

The recent data collected in 1984/85, and the historic data from 1970 to 1984, were both compared against the Alberta Surface Water Objectives (ASWO) and use specific water quality criteria. The ASWO (Standards and Approvals Division, 1977) are general objectives which are intended to apply to all river systems and protect all uses, including the most sensitive (Table 12). The bacteriological indicator criteria in the ASWO are meant to be tested on datasets of no less than five samples in any consecutive 30 day period. Both the historic and recent data were not collected at this frequency; consequently, the objectives were applied to the long term or annual geometric mean values. The biochemical oxygen demand (BOD), suspended solids, temperature, colour and turbidity ASWO objectives are all based upon an increase above background. They are meant to pertain to sites below an effluent discharge where immediate upstream data is used as reference. These datasets did not lend themselves to this type of analysis, therefore these particular objectives were not tested.

The specific use objectives (Table 12) were integrated from three sources. The primary reference was McNeely et al (1979), which includes specific use objectives developed by Environment Canada for all major water uses. These were updated with the recently published guidelines for recreational water quality (Federal Provincial Working Group on Recreational Water Quality, 1983) and the more current guidelines for arsenic, zinc, cadmium, copper, mercury, lead, nickel, silver and selenium (Inland Waters Directorate, 1979).

For the historic database only those parameters which exceeded an objective concentration in the historic database five percent of the time are noted in the summary Table (13). This compensates for outliers in the dataset. Since the recent sample size was small (6), exceedance on any sampling date was considered a criteria violation (Table 14). The metal objectives frequently do not indicate the form to which they should be applied (i.e. dissolved, total, extractable). Unless specified as dissolved, the objectives for trace metals were tested against both total and extractable forms.

TABLE 12 WATER QUALITY OBJECTIVES TESTED AGAINST RECENT AND HISTORIC ATHABASCA RIVER WATER QUALITY, UNITS ARE mg/L UNLESS OTHERWISE INDICATED

	ALBERTA SURFACE WATER QUALITY OBJECTIVE	FEDERAL WATER QUALITY GUIDELINES				
		MUNICIPAL SUPPLY	RECREATION	LIVESTOCK	WILDLIFE	AQUATIC LIFE
ALKALINITY						<20
ALUMINUM				5.0		
ARSENIC	0.01	0.05(T)		0.05(T)		0.05(T)
TOTAL COLIFORMS+	^{A}5,000/^{B}1,000	100				
FECAL COLIFORMS+	^{A}1,000/^{B} 200	10	200			
BARIUM	1.0	N.D.				
BERYLLIUM						0.011
BORON	0.5			5.0	5.0	
CADMIUM	0.01	0.01(T)		0.02(T)		0.0002(T)
CALCIUM		75		1000	1000	
CHLORIDE		250				

TABLE 12 CONTINUED

		FEDERAL WATER QUALITY GUIDELINES				
	ALBERTA SURFACE WATER OBJECTIVE	MUNICIPAL SUPPLY	RECREATION	LIVESTOCK	WILDLIFE	AQUATIC LIFE
CHROMIUM	0.05	0.01(T)		1.0(T)		0.04(T)
COBALT				1.0	1.0	
COLOUR	30 UNIT INC.	5 TCU				
COPPER	0.02	0.05(T)		1.0(T)	0.002(T)	0.002(T)
CYANIDE	0.01	N.D.				0.005
FLUORIDE	1.5	1.2		2.0	2.0	
HARDNESS		120				
IRON	0.3	0.05(D)				0.30
LEAD	0.05	0.25(T)		0.5(T)	0.01(T)	0.01(T)
MAGNESIUM		50				
MANGANESE	0.05	0.01				
MERCURY	0.0001	0.001(T)		0.003(T)	0.003(T)	0.0001(T)
MOLYBDENUM				0.01	0.01	

TABLE 12 CONTINUED

	ALBERTA SURFACE WATER OBJECTIVE	FEDERAL WATER QUALITY GUIDELINES				
		MUNICIPAL SUPPLY	RECREATION	LIVESTOCK	WILDLIFE	AQUATIC LIFE
NICKEL		0.25(T)		5.0(T)	0.25(T)	0.25(T)
NITROGEN - AMMONIA		0.01				
- NITRATE+NITRITE				100.0	100.0	
- NITRITE				10.0	10.0	
- ORGANIC						
- KJELDAHL						
- TOTAL	1.0					
- AMMONIA UN-IONIZED						0.02
ODOUR(TON)	8.0					
OXYGEN	>5.0					>4.0
PH	6.5-8.5		6.5-8.5			6.5-9.0
PHENOL	0.005					0.001
PHOSPHORUS-P	0.050					0.100
POTASSIUM						0.001

TABLE 12 CONTINUED

	ALBERTA SURFACE WATER OBJECTIVE	FEDERAL WATER QUALITY GUIDELINES				
		MUNICIPAL SUPPLY	RECREATION	LIVESTOCK	WILDLIFE	AQUATIC LIFE
SELENIUM	0.01	0.05(T)		0.02(T)		0.01(T)
SILVER	0.05	0.05(T)				0.0001(T)
SULFATE		250		1000	1000	
SULFIDE	0.05	N.D.				0.002
SUSPENDED SOLIDS	10 INC.					25.0
SURFACTANTS		0.2				0.5
TEMPERATURE	3° INC		15-30°C			
TOTAL DISSOLVED SOLIDS		500		3000	3000	
TURBIDITY	25 JTU INC.	1	50			
URANIUM		0.02(T)		0.2(T)	0.30(T)	0.30(T)
VANADIUM				0.1	0.1	
ZINC	0.05	5.0(T)		50.0(T)	0.10(T)	0.10(T)

TABLE 12 CONTINUED

	ALBERTA SURFACE WATER OBJECTIVE	FEDERAL WATER QUALITY GUIDELINES: MUNICIPAL SUPPLY	RECREATION	LIVESTOCK	WILDLIFE	AQUATIC LIFE

A = WATERS TO BE WITHDRAWAN FOR TREATMENT AS A POTABLE WATER SUPPLY OR SECONDARY CONTACT RECREATION.

B = WATERS TO BE USED FOR VEGETABLE CROP IRRIGATION OR CONTACT RECREATION

INC = INCREASE ABOVE BACKGROUND

+ = COUNTS/100 ml

(T) = OBJECTIVES APPLY TO TOTAL CONCENTRATIONS

(D) = OBJECTIVES APPLY TO DISSOLVED FORM

GEOMTRIC MEAN VALUES APPLY TO ALL MICROBIOLOGICAL INDICATORS.

TABLE 13 COMPARISON OF HISTORICAL DATA AGAINST WATER QUALITY OBJECTIVES, PARAMETER IS INDICATED IF IT EXCEEDED THE GUIDELINE LEVEL IN GREATER THAN 5% OF SAMPLES.

	ALBERTA SURFACE WATER QUALITY OBJECTIVE	MUNICIPAL SUPPLY	RECREATION	LIVESTOCK	WILDLIFE	AQUATIC LIFE
JASPER						
ICE COVER	TP, Fe	TURB, HARD, COLOUR, Mn	°C		Cu	PHENOL, CU, Fe
EARLY OPEN WATER	PHENOL, TP, Fe, Mn	TURB, HARD, COLOUR, Mn	°C,TURB		Cu	NFR, PHENOL, AL, Cu, Fe
LATE OPEN WATER	TP, Fe, Mn	TURB, COLOUR, Mn	°C,TURB		Cu	NFR, PHENOL, TP, AL, Cu, Fe
ATHABASCA						
ICE COVER	PHENOL, TP	TURB, HARD, COLOUR, Fe, Mn	°C	Mo	Cu, Mo	NFR, PHENOL, Cu
EARLY OPEN WATER	PHENOL,TP,TN, Fe, Mn	TURB, COLOUR, Mn	°C,TURB	Mo	Cu, Mo	NFR, PHENOL, TP, AL, Cu, Fe
LATE OPEN WATER	PHENOL, TP, Fe, Mn	TURB, HARD, COLOUR, Mn	°C,TURB	Mo	Cu, Mo	NFR, PHENOL, TP, AL, Cu, Fe
FT. MCMURRAY						
ICE COVER	PHENOL, TP,TN, Fe	TURB, HARD, COLOUR, Mn	°C,TURB	Mo	Cu, Mo	NFR, PHENOL, TP, AL, Cu, Fe
EARLY OPEN WATER	PHENOL, TP, TN, Fe, Mn, Zn	TURB, COLOUR, Fe, Mn	°C,TURB	Al, Mo	Al,Cu,Mo	NRF, PHENOL, TP AL, Cu, FE
LATE OPEN WATER	PHENOL, TP, TN, Fe, Mn, Zn	TURB, HARD, COLOUR, Mn	°C,TURB	Mo	Cu, Mo	NFR, PHENOL, TP AL, Cu, Fe

TABLE 14 COMPARISON OF 1984/85 DATABASE AGAINST WATER QUALITY OBJECTIVES, PARAMETER IS INDICATED IF IT EXCEEDED THE GUIDELINE IN ANY OF THE SIX SAMPLES.

	ALBERTA SURFACE WATER QUALITY OBJECTIVE	MUNICIPAL SUPPLY	RECREATION	LIVESTOCK	WILDLIFE	AQUATIC LIFE
MAINSTEM SITES						
OLD ENTRANCE	Fe, Mn, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
A2-5-L	Fe, Hg, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR,Hg
A2-5-R	Fe, Mn, Hg, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL	AL,Cu	Cu,Fe,Hg,PHENOL, TP, K, NFR
A2-20-L	Fe, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
A2-20-R	Fe, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL	AL,Cu	Cu,FE,PHENOL,K,NFR
DOWNSTREAM HINTON	Fe, Mn, PHENOL	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
U/S WINDFALL	Fe, Mn, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
U/S FT. ASSINIBOINE	Fe, Mn, PHENOL	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
U/S LSR	Fe, Mn, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,TP,K,NFR
U/S ATHABASCA	AL, Fe, Mn, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
D/S ATHABASCA	AL, Fe, Mn, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu,Pb	Cu,Fe,Pb,PHENOL,TP, K,NFR
U/S HOUSE R.	ARS,Cu, Fe, Mn, TN, PHENOL, TP, ZN	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL	AL,Cu,Pb	Cu,Fe,Pb,PHENOL,TP, K,NFR
U/S FT.MCMURRAY	ARS, Fe, Mn, Hg, TN, PHENOL, TP, ZN	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL	AL,Cu,Pb	Cu,Fe,Hg,Pb,PHENOL, TP,K,NFR
U/S SUNCOR	Fe, Mn, TN, PHENOL, TP, ZN	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL	AL,Cu,Pb	Cu,Fe,Pb,PHENOL,TP, K,NFR
BITUMOUNT	AL,Fe,Mn,TN,PHENOL,TP	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL	AL,Cu,Pb	Cu,Fe,PHENOL,TP,K,NFR Pb,K,NFR
EMBARRAS	AL,Fe,Mn,TN,PHENOL,TP	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL,Mo	AL,Cu,Mo, Pb	Cu,Fe,PHENOL,TP,K,NFR
TRIBUTARY SITES						
BERLUND	Fe, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
MCLEOD	Fe, Mn, PHENOL	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,K,NFR
PEMBINA	Fe, Mn, TN, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,TP,K,NFR
LESSER SLAVE	Fe, Mn, PHENOL, TP	COLOUR, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,TP,K,NFR
LABICHE	AL, Fe, Mn, TN, PHENOL, TP	COLOUR, HARD, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,TP,K,NFR
CALLING	Fe, Mn, TN, PHENOL, TP	COLOUR, Mn, NH_3, TURB		AL	AL,Cu	Cu,Fe,PHENOL,TP,K,NFR
HOUSE	ARS, Cu, Fe, Pb, Mn, TN,PHENOL,ZN,TP	COLOUR, HARD, Mn, NH_3, TURB	TURB	AL,Mo	AL,Cu,Pb, Mo	Cu,Fe,PHENOL,TP,K,NFR
CLEARWATER	Cu, Fe, Mn, PHENOL, TP,ZN	COLOUR, Mn, NH_3, TURB	TURB	AL	AL,Cu	Cu,Fe,PHENOL,TP,K,NFR
POPLAR	AL, Mn, Fe, TN, PHENOL, TP	COLOUR, Mn, NH_3, TURB		AL	Al,Cu	CU,Fe,PHENOL,K,NFR

A total of 11 Alberta Surface Water Quality Objectives were exceeded in the combined historic and recent datasets. Total phosphorus, iron and manganese were violated at almost every location. Most other parameters were exceeded more frequently in the lower reaches of the basin. These include phenol, copper, zinc, total nitrogen, aluminum, arsenic and mercury. The mercury objective was exceeded immediately downstream from Hinton during the recent survey, and upstream of Ft. McMurray. This coincides with similar violations in the House River, which drains to that reach. Amongst the tributaries in general, there tended to be a greater level of exceedance in systems which drain the interior plains, relative to foothill watersheds. The maximum number of ASWQO violations occurred in the House River. That was also the only site where the ASWQO objective for lead was exceeded.

McNeely et al.(1979) list three sets of criteria for water to be withdrawn and treated for municipal supply; objective, acceptable and maximum permissible. The objective set are the most stringent and were the ones tested for this project. It must be noted these are not the Canadian drinking water standards, which apply to finished tap water. The objectives used here are for raw surface waters prior to conventional municipal water treatment. It is recommended by Alberta Environment that no surface water be directly ingested without prior treatment of an appropriate form.

Colour, hardness, manganese, ammonia and turbidity consistently exceeded objectives for municipal supply. Ammonia was not identified in the historic database as the analytical detection limit was greater than the objective concentration. Dissolved iron was exceeded but only under ice at Athabasca Town and during the early open water season at Ft. McMurray. The recent dataset did not include dissolved iron data. Color, manganese and turbidity levels in the Athabasca Basin exceed the objective concentrations by a substantial amount. There are no maximum permissible criteria for these parameters and violation of the objective levels does not mean the water cannot be used for municipal supply, it just dictates the level of treatment which is required. Average hardness in the basin varies between 140 and 230 mg/L, while the maximum permissible objective is 500 mg/L. Hard waters are undesirable as they have a reduced capacity to produce lather from soap. Water softening is a feasible water treatment technology. Average ammonia concentrations of the mainstem Athabasca River range between 0.009 and 0.026 mg/L, the municipal objective is 0.01 mg/L. Ammonia is not included in the drinking water objectives (Health and Welfare Canada,1978), but is likely included in the raw water objectives because it increases the chlorine demand during treatment.

The major water quality objectives for recreation are temperature, fecal coliforms, and turbidity. The criteria for temperature are not met due to the generally cold water conditions experienced throughout the basin. Temperatures likely do fall within the desirable range for short periods during mid summer. Coliforms are not a problem, but water clarity is. Turbid waters prevent recognition of individuals in distress. Like temperature, the turbidity criteria was seasonally tested yet there are probable periods when the turbidity objective is not violated.

The objectives for water to be consumed by livestock and wildlife were only exceeded for a few metals. Aluminum and molybdenum for both categories, and additionally copper and lead for wildlife. The wildlife criteria for copper is only one ppb greater than the analytical detection limit, and is significantly lower than the objective for municipal supply or the ASWO. The livestock objective for lead was only exceeded in the lower basin, and only on odd occasions; it is also less than comparable values for other water uses.

The objectives for protection of aquatic life apply to both the fishery and lower trophic levels. Other than metals, the objectives for total phosphorus, non-filterable residue, potassium and phenol were exceeded at most locations. Among the metals, copper and iron concentrations exceeded the objectives at all sites. Lead was exceeded only at sites downstream of Athabasca Town. Mercury violations occurred at the upstream Ft. McMurray location and immediately below Hinton. The trace metal objectives for aquatic life tend to be very low, and for copper, mercury and lead approached the analytical detection limit. The cadmium and silver objectives could not be tested as they are actually less than the detectable limit.

Although not tabulated in Table (12) there are also recommended objectives for trace organics, i.e. herbicides and pesticides (McNeely et al.,1979). The objective and acceptable levels for raw water to be used for municipal supply is no detection. Detailed herbicide and pesticide data only exist for the historic database. Amongst the 41 organic compounds monitored only seven have even been detected in the Athabasca River. Out of all tests Lindane, 2,4,5-T, picloram, hexachlorobenzene and 2,4-DP have only been recorded above the detectable limit once. Alphas-BHC is detected consistently at low levels, while 2,4-D has exceeded detection in less than 10% of samples (average concentration is 0.005 mg/L). Trace organic criteria are also recommended for aquatic life. Once again the recorded levels in the Athabasca River do not approach the recommended concentrations.

6. Mass Transport of Constituents

A primary purpose of the 1984 seasonal synoptic surveys was to quantify the relative significance of tributary and effluent loadings to the mainstem Athabasca River. Previous modelling of the river had indicated that up to 50% of certain river constituents could not be accounted for with known point and non-point inputs (Howard & Associates, 1984). Consequently 1984 sampling surveys emphasized tributary streams for which little or no historic data existed.

This section presents a mass balance of tributary and effluent inputs versus observed constituent transport in the mainstem river. Daily parameter loadings for each tributary and mainstem site were calculated using measured water quality concentrations and observed or calculated streamflows. The streamflows were provided by Hydrology Branch of Alberta Environment. Lack of streamflow data prevented loading calculations for the February survey. This analysis implies that the Athabasca River approached a steady state condition for the two to three day interval when the synoptic survey samples were collected. Based upon this assumption, loadings in the mainstem river should relate directly to upstream river and point source inputs. This assumption of steady state is reasonable considering the very large size of the river basin; such a system responds to changing environmental conditions more slowly than does a small watershed.

Mass balance data are presented in summary and detailed format. The summary Table (15) presents corresponding river loads at the upper boundary of the study area (A1) and near the mouth (A12). Total tributary and effluent loads are also presented, reflecting the sum of the nine tributaries and five municipal and industrial effluents. The values in brackets are the percentage ratio of that particular loading component over the total measured input load. The total input load is the sum of the tributary, effluent and headwater (A1) loads. Figures (25) to (33) present individual tributary and effluent loadings for a subset of parameters. On these figures the percentage values next to the mainstem river loadings indicate the percentage of that particular load accounted for by the upstream inputs. The upstream inputs include the loading at the preceeding river site plus all intervening tributaries and effluents. Parameters included on the summary table were excluded from detailed analysis if a significant number of the concentration values were measured at the detection limit. The unreliability of a detection limit concentration is magnified when it is multiplied by river discharge in the loading calculation. Figure (34) is a presentation of streamflow and effluent discharge using the same format.

TABLE 15 MASS BALANCE OF CONSTITUENT LOADINGS FOR EACH SYNOPTIC SAMPLING SURVEY IN 1984

HEAD indicates headwater loading as calculated at 1A; EXP indicates basin export loading as calculated at A12; TRIB is total tributary loading(T1-T9); and EFF is loading from the five continuous effluent discharges.
Units are Kg/day excepting colour, total coliforms and fecal coliforms which are relative units only.

	MAY				JUNE				JULY				SEPTEMBER				OCTOBER			
	HEAD LOAD	TRIB LOAD	EFF LOAD	EXP LOAD	HEAD LOAD	TRIB LOAD	EFF LOAD	EXP LOAD	HEAD LOAD	TRIB LOAD	EFF LOAD	EXP LOAD	HEAD LOAD	TRIB LOAD	EFF LOAD	EXP LOAD	HEAD LOAD	TRIB LOAD	EFF LOAD	EXP LOAD
Na^{1}	14 (3)	420(91)	29 (6)	1157 (250)	41 (6)	605(89)	31 (5)	1913 (283)	32 (7)	389(86)	34 (7)	947 (208)	23 (5)	390(87)	34 (8)	732 (164)	22 (6)	333(88)	23 (6)	1161 (307)
Cl^{1}	5 (1)	344(86)	50(13)	1029 (257)	41 (9)	383(82)	45(10)	1063 (227)	32 (8)	303(78)	54(14)	710 (183)	23 (6)	330(81)	54(13)	854 (209)	11 (4)	241(84)	35(12)	829 (289)
SO_4^{1}	300(52)	254(44)	20 (3)	1221 (213)	851(54)	703(45)	23 (1)	3188 (202)	701(69)	296(29)	19 (2)	2249 (221)	692(71)	261(27)	21 (2)	1159 (119)	549(70)	216(28)	16 (2)	1493 (191)
TDS^{2}	94(21)	346(76)	13 (3)	1040 (229)	404(37)	679(62)	13 (1)	2167 (197)	317(45)	380(53)	14 (2)	1385 (195)	275(41)	389(57)	14 (2)	870 (128)	183(39)	273(59)	99 (2)	1169 (251)
NFR^{1}	22(26)	61(72)	1 (2)	110 (131)	499(32)	1038(67)	1(.1)	16170(1051)	110(25)	330(75)	1(.3)	2550 (576)	38(27)	104(73)	1(.4)	172 (120)	46(42)	62(57)	1 (1)	232 (214)
DOC^{1}	4 (2)	237(98)	2 (1)	450 (185)	49 (4)	1060(96)	1(.1)	3443 (310)	13 (2)	569(96)	12 (2)	1196 (201)	14 (3)	381(94)	13 (3)	537 (131)	27 (9)	281(88)	9 (3)	854 (269)
$T\&L^{3}$	10 (6)	134(69)	50(26)	154 (79)	81 (9)	745(85)	54 (6)	2869 (326)	73(14)	399(74)	69(13)	875 (162)	30 (9)	222(70)	67(21)	268 (84)	56(19)	201(68)	39(13)	730 (246)
PHENOL	9 (6)	118(81)	19(13)	193 (132)	81(21)	287(75)	15 (4)	850 (222)	63(25)	172(67)	22 (9)	355 (138)	46(17)	192(72)	29(11)	305 (113)	22 (9)	201(82)	21 (9)	498 (204)
$COLOR^{1}$	27 (3)	590(75)	170(22)	971 (123)	977(13)	6292(85)	136 (2)	15345 (207)	235 (6)	3222(87)	245 (7)	7670 (207)	88 (4)	1782(86)	200(10)	2696 (130)	121 (8)	1206(84)	110 (8)	4611 (321)
$CHLA^{1}$	3 (1)	186(99)	-	437 (231)	24 (5)	428(95)	-	1764 (390)	5 (2)	232(98)	-	-	7 (3)	202(97)	-	445 (213)	5 (3)	173(97)	-	332 (186)
TC^{2}	8 (3)	222(97)	.01(.01)	128 (56)	1418(10)	12559(90)	42(.3)	4888 (35)	344 (6)	5287(93)	38(.7)	14204 (251)	110 (6)	1767(92)	47 (2)	317 (16)	22 (2)	1020(89)	107 (9)	3152 (274)
FC^{2}	-	13(17)	65(83)	25 (32)	114(11)	880(88)	2(.18)	255 (26)	13(11)	98(87)	1 (1)	189 (169)	9(14)	54(82)	3 (4)	24 (37)	4(12)	30(85)	1 (3)	66 (186)
TP	28 (3)	836(87)	100(10)	3600 (373)	2269(17)	10885(82)	124 (1)	70139 (528)	255 (5)	4869(92)	142 (3)	31959 (607)	138 (7)	1768(84)	187 (9)	2989 (143)	285(16)	1368(78)	107 (6)	3815 (217)
TDP	9 (2)	310(81)	65(17)	514 (134)	81 (4)	1700(93)	47 (3)	3401 (186)	63 (7)	749(84)	82 (9)	4498 (503)	46(10)	369(78)	59(13)	488 (103)	22 (4)	481(90)	30 (6)	995 (187)
$TNIT^{3}$	4 (3)	102(90)	8 (7)	186 (164)	85(12)	609(87)	9 (1)	2174 (309)	40(13)	263(84)	11 (3)	891 (284)	22(11)	179(84)	11 (5)	257 (121)	14 (9)	131(85)	9 (6)	376 (244)
NO_2NO_3	131(47)	100(36)	46(17)	597 (209)	2431(58)	1713(41)	32 (1)	4889 (117)	1498(81)	308(17)	47 (3)	6274 (339)	1084(71)	402(26)	34 (2)	122 (8)	799(61)	447(35)	46 (4)	1078 (85)
NH_3	80(10)	242(31)	453(58)	128 (17)	243(12)	1323(68)	393(20)	3613 (184)	63 (5)	794(64)	391(31)	1302 (104)	92(10)	484(52)	352(38)	244 (26)	121(12)	524(53)	337(34)	1576 (160)

$1 = 10^{-3}$
$2 = 10^{-4}$
$3 = 10^{-2}$

( ) indicates loading as percentage of total measured inputs from A1 to A12.

Review of the summary table indicates that for most water quality parameters tributary loadings dominate the inputs to the Athabasca River, followed by the headwater source and lastly effluents. The loadings upstream of A1 were significant for sulphate, TDS, nonfilterable residue (NFR) and nitrate + nitrite. Upstream phenols constitute greater than 20% of all measured inputs to the system in June and July only. The headwater loads for all parameters except those noted above are less than 20% of the total. Interestingly, between 50% and 70% of the sulphate transported in the Athabasca River originates upstream of Hinton.

The proportional significance of the effluent inputs varied depending upon streamflow conditions. They were of maximum significance in May and September, and least significant during the June high flow period. Only effluent chloride and ammonia accounted for greater than 10% of the total basin load for all five surveys evaluated. Effluent chloride loadings varied between 10% and 14% of total, while corresponding values for ammonia were 28% and 58%. At low river flows effluent inputs of tannin and lignin, phenol, colour, total dissolved phosphorus (TDP), fecal coliforms and nitrate + nitrite slightly exceeded the 10% loading ratio.

The percentage values beside the export loading column (Table 15) provide an approximation of the proportion of the export loadings which can be accounted for by headwater, tributary and effluent inputs. Values less than 100% indicate constituent retention within the basin, i.e. stream channel assimilation. Values greater than 100% imply significant sources were not included in the mass balance, or material was derived from the mainstem channel itself. Variation in percentage values must be assessed with caution and only interpreted for general trends. Even in a completely balanced steady state system, error variability associated with water quality sampling and analytical uncertainty, as well as error in the flow estimates, could result in appreciable variance away from 100%.

The loadings at Embarrass (A12) exceeded the measured inputs by two to three times (200% to 300%) for a number of parameters. This imbalance was more frequent at high flow conditions. These parameters included NFR and constituents which correlate with it, like total phosphorus and total nitrogen. Among the soluble parameters chloride, sulphate, sodium and dissolved phosphorus (TDP) are included in the 2 to 3 times export versus input category at high flows. Under low flow conditions in May and September many of these same parameters almost balanced.

Total and fecal coliforms tended to be assimilated within the basin, as indicated by percentages in the export column of less than 100%. At low flows, tannin and lignins, ammonia, nitrate + nitrite and phenols were also retained in the system relative to total inputs.

The detailed loading analysis for TDS indicates the major sources could be accounted for in most reaches (Figure 25). Exceptions include an unidentified source between A5 and A6 for all surveys except September, upstream of Ft. McMurray in October and the farthest downstream reach (A11 - A12) in May and June. On all five occasions the Clearwater River was the major contributor of TDS. Other significant tributary loadings include the McLeod, Berland and Lesser Slave Rivers. The Pembina was a significant contributor of TDS only during spring and summer.

Like TDS, sulphate (Figure 26) is largely accounted for by the measured inputs. Major anomalies include unaccounted for inputs upstream of the Town of Athabasca in May and June, and to a lesser extent during the fall surveys; also between the Town of Athabasca and Ft. McMurray in September and October. Major contributory streams include the Clearwater River, followed by the Berland, Lesser Slave, McLeod and Pembina Rivers. The extremely high percentage values at A2 in September and October brings into question the reliability of the datapoints.

Non-filterable residue is a measure of suspended particulate material (Figure 27). It is a complex parameter which in addition to being input by tributaries and effluents, can be derived from bank erosion and sediment resuspension during high flow intervals. At times of receding or low flow, it can be lost from the water column due to sedimentation. Major tributary sources of NFR in 1984 were the House, Clearwater and Lesser Slave Rivers. The Pembina, McLeod and Berland rivers were significant sources early in the year and in September. There was always a major increase in particulate river load with downstream distance, especially in June and July. The percentage values can be used as approximate indicators of sediment resuspension and deposition. During the June high flows unaccounted for sediment inputs occurred in the reach from upstream of Windfall to Ft. McMurray. Sediment deposition occurred below Ft. McMurray. The unaccounted for inputs upstream from Ft. McMurray likely reflect a combination of unmeasured tributaries and sediment resuspension. The same general pattern was repeated in July, however, sediment deposition was not apparent in the lower reaches. In October NFR transport down the Athabasca was minimal for the upper two thirds of the system and then increased marginally in the lower reaches.

FIGURE 25 SEASONAL TOTAL DISSOLVED SOLIDS MASS BALANCE ANALYSIS FOR THE ATHABASCA RIVER - 1984

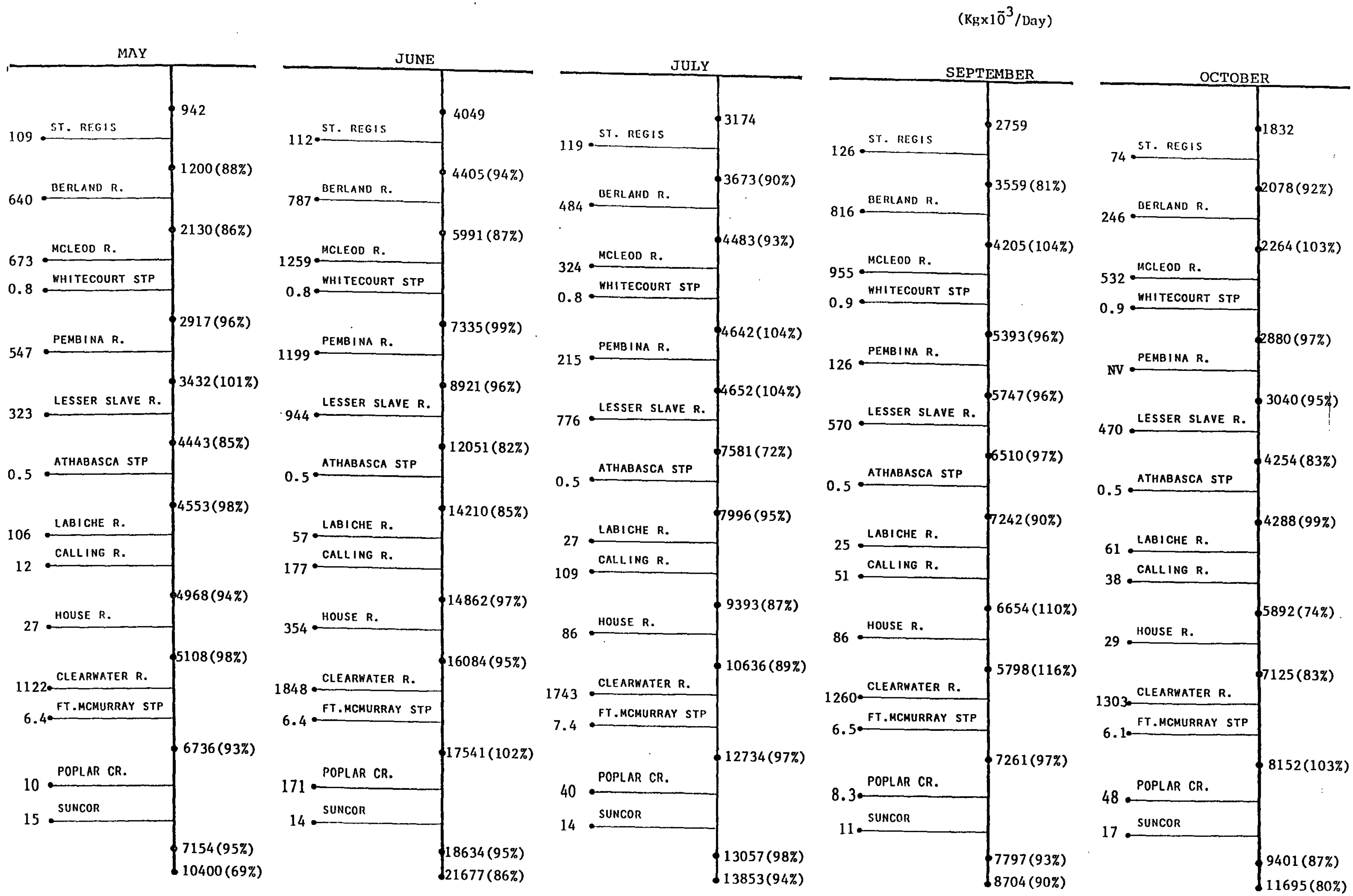


FIGURE 26 SEASONAL SULPHATE MASS BALANCE ANALYSIS FOR THE ATHABASCA RIVER - 1984

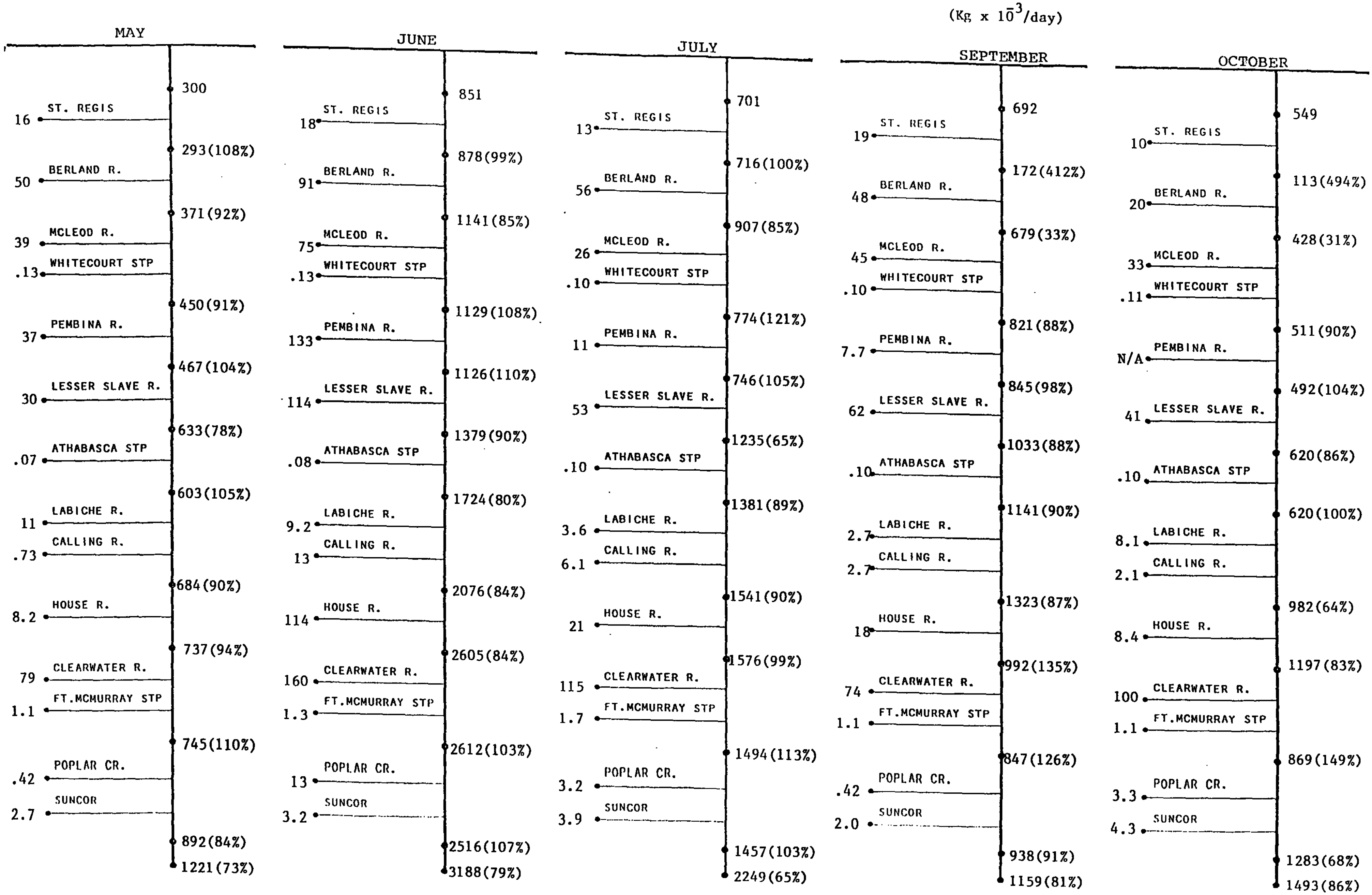
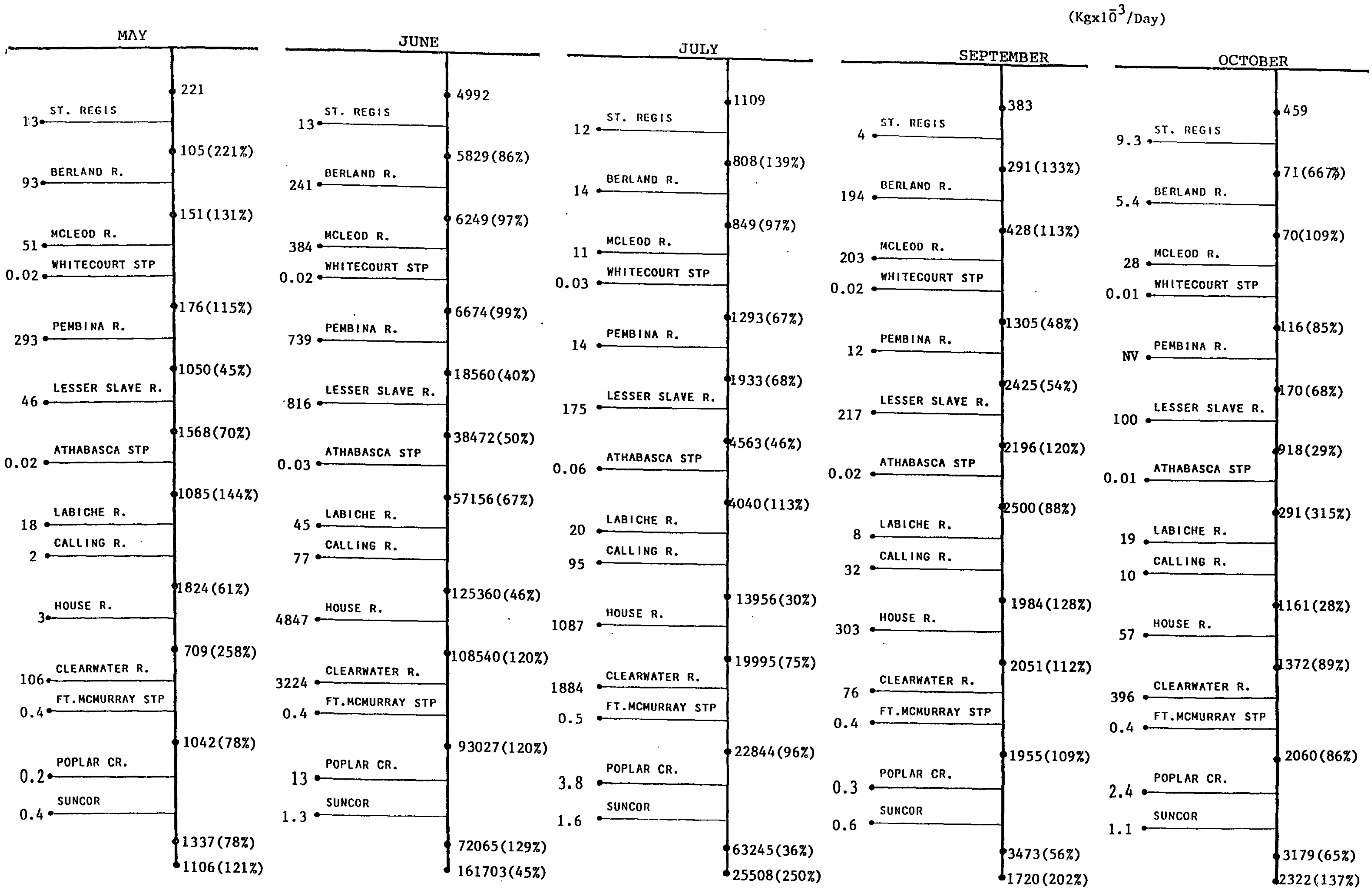


FIGURE 27 SEASONAL NON-FILTERABLE RESIDUE MASS BALANCE ANALYSIS FOR THE ATHABASCA RIVER - 1984



Major contributory sources of iron to the Athabasca River were the Clearwater, Lesser Slave and House rivers (Figure 28). The Berland and McLeod loadings were only significant in May and September. In most reaches the input sources accounted for 50% to 80% of the amount in transit, indicating unidentified sources or resuspension from the channel. Retention within the system occurred upstream of Ft. McMurray in May, June and September; upstream of Athabasca in July and September and downstream of Athabasca in May and October.

As for all parameters the maximum river transport of dissolved organic carbon (DOC) occurred in June (Figure 29). Minimum loadings coincide with reduced flows in May and September. The Clearwater and Lesser Slave rivers were the major tributary sources of DOC. The next major sources were the Berland and McLeod Rivers. For the lower reaches the mainstem loads balance well with inputs in May and June. Unaccounted for sources were evident in the upper reaches and between A11 and A12. With some exceptions, there was a general underestimation of DOC sources throughout the system in July. During September net retention of carbon occurred upstream of Ft. McMurray while the system was balanced in the lower reaches. On the last survey in 1984, carbon transport throughout the upper two thirds of the basin was low. River loadings increased downstream of the Clearwater River due to inputs from that sub-basin.

Except for June and July, the balance of inputs versus river transport of tannin and lignin was erratic (Figure 30). In June unaccounted for sources occurred throughout the basin. In July retention of tannin and lignin was evident in the upper reaches compared to a net input in the lower part of the basin. On all occasions except September, there was uptake of tannin and lignin downstream of Hinton. Major sources include the Clearwater and Lesser Slave rivers as well as the effluent discharge from the Hinton pulp mill.

Along with nitrogen and carbon, total phosphorus (TP) is one of the three major plant nutrients in both aquatic and terrestrial systems. The Clearwater, House and Lesser Slave rivers were the major sources of TP to the Athabasca System in 1984 (Figure 31). The Pembina, McLeod and Berland rivers were seasonally significant. During low river flows the St. Regis pulp mill contributes between three and seven percent of total measured inputs. In most surveys, a major increase in mainstem river loadings occurred between A4 and A6. The major tributary sources in this reach are the Pembina and Lesser Slave rivers, but they do not account for the entire increase. In June and July, other major increases in river load occurred downstream of Athabasca Town and Ft. McMurray.

FIGURE 30 SEASONAL TANNIN & LIGNIN MASS BALANCE ANALYSIS FOR THE ATHABASCA RIVER - 1984

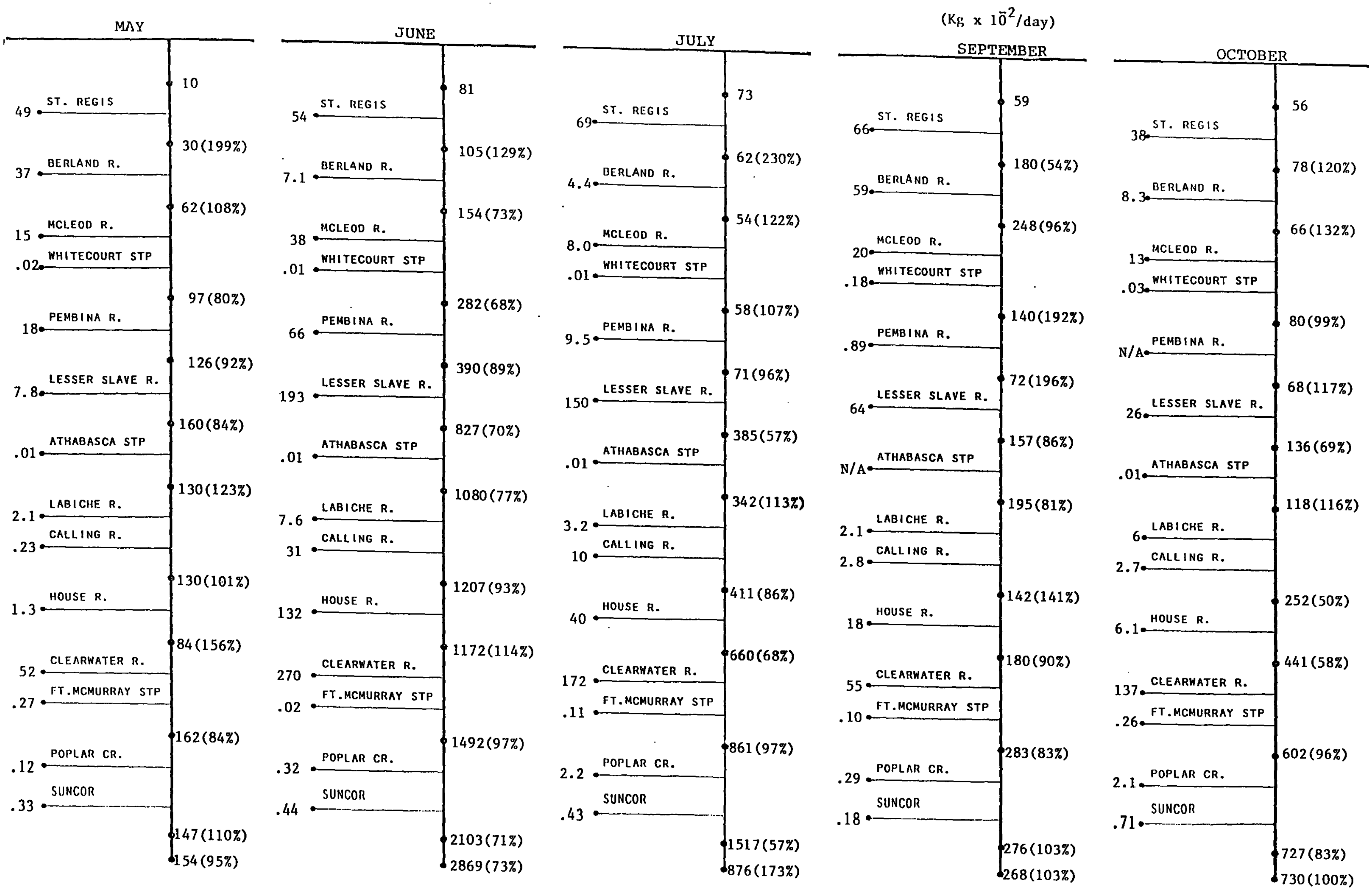


FIGURE 31 SEASONAL TOTAL PHOSPHORUS MASS BALANCE ANALYSIS FOR THE ATHABASCA RIVER - 1984

(kg x 10^{-2}/day)

	MAY	JUNE	JULY	SEPTEMBER	OCTOBER
(Athabasca River)	28	2269	255	138	285
ST. REGIS	37	76	103	143	60
(Athabasca River)	35(184%)	1840(127%)	326(110%)	148(191%)	68(510%)
BERLAND R.	27	283	17	206	8.1
(Athabasca River)	77(81%)	3571(59%)	363(94%)	713(50%)	80(95%)
MCLEOD R.	58	407	23	245	26
WHITECOURT STP	3.5	2.7	5.7	7.2	4.7
(Athabasca River)	244(57%)	1882(212%)	1161(34%)	985(98%)	102(109%)
PEMBINA R.	235	1148	38	5.1	N/A
(Athabasca River)	1493(32%)	15767(19%)	2322(52%)	1436(69%)	151(67%)
LESSER SLAVE R.	77	2449	780	395	175
(Athabasca River)	1297(121%)	9193(198%)	4796(65%)	2717(67%)	931(35%)
ATHABASCA STP	4.2	5.4	5.4	5.2	5.1
(Athabasca River)	905(144%)	32175(29%)	5450(88%)	2717(100%)	372(251%)
LABICHE R.	53	82	63	28	52
CALLING R.	5.3	138	164	46	25
(Athabasca River)	1889(51%)	25955(125%)	12843(44%)	2290(122%)	1494(30%)
HOUSE R.	13	2218	1145	453	89
(Athabasca River)	1193(159%)	27497(102%)	15267(92%)	2363(116%)	1960(81%)
CLEARWATER R.	367	4121	2627	388	983
FT.MCMURRAY STP	45	31	20	21	30
(Athabasca River)	1840(87%)	80456(39%)	24132(74%)	2769(100%)	4146(72%)
POPLAR CR.	1.7	38	13	1.3	10
SUNCOR	11	8.8	7.7	10	7.7
(Athabasca River)	1516(122%)	75479(107%)	109253(22%)	3579(78%)	4562(91%)
(Athabasca River)	3600(42%)	70139(108%)	31959(342%)	2989(120%)	3815(120%)

On all occasions major tributary sources of total nitrogen (Figure 32) were the Clearwater and Lesser Slave rivers. The McLeod and House rivers were of lesser importance. Changes in Athabasca River loadings tended to coincide with the major tributary sources.

Although tributaries were the major contribution of nitrate + nitrite (Figure 33), the sewage treatment plants at Athabasca and Whitecourt were of some significance at moderate to low river flows. Major tributary sources of nitrate include the Clearwater, Lesser Slave and House rivers. The Berland and McLeod tributaries were important early in the year. River assimilation of nitrate was evident in the upper reaches of the Athabasca River during May, while at the same time, there was an unaccounted for net input in the lower reaches. In June headwaters sources accounted for nearly 50% of the total river load, while tributary inputs made up most of the remainder.

7. Reach Characterization Based Upon Multivariate Analysis

As a primary objective of this report is to characterize patterns in water quality for the entire Athabasca River Basin, multivariate analysis techniques were employed to group sites with similar water quality characteristics. Each 1984 synoptic survey was analyzed using cluster and principal component analysis (PCA). Cluster analysis groups sites based upon simultaneous evaluation of all relevant water quality variables. The principal component analysis inturn defines which variables are of primary importance in defining each cluster.

Parameters included in the multivariate analysis are listed in Table (16). This includes forty of the sixty constituents measured. Parameters with a very high proportion of detection limit concentrations were excluded, as were likely covariates. The five municipal and industrial effluents were also excluded. Their unique quality would result in distinct classification apart from the surface waters, which inturn might mask relevant patterns in the surface water information.

The seasonal clusters and plots of the first two principal components are presented in Figures (35) to (40). Figure (41) represents a diagramatic summary of the major cluster groups. The cluster plot is a dendrogram in which the scale is a measure of decreasing similarity. In each instance the five or six major site groupings were extracted from each cluster analysis and superimposed on the bivariate PCA plot.

FIGURE 32 SEASONAL TOTAL NITROGEN MASS BALANCE ANALYSIS FOR THE ATHABASCA RIVER - 1984

(Kg x 10^{-2}/day)

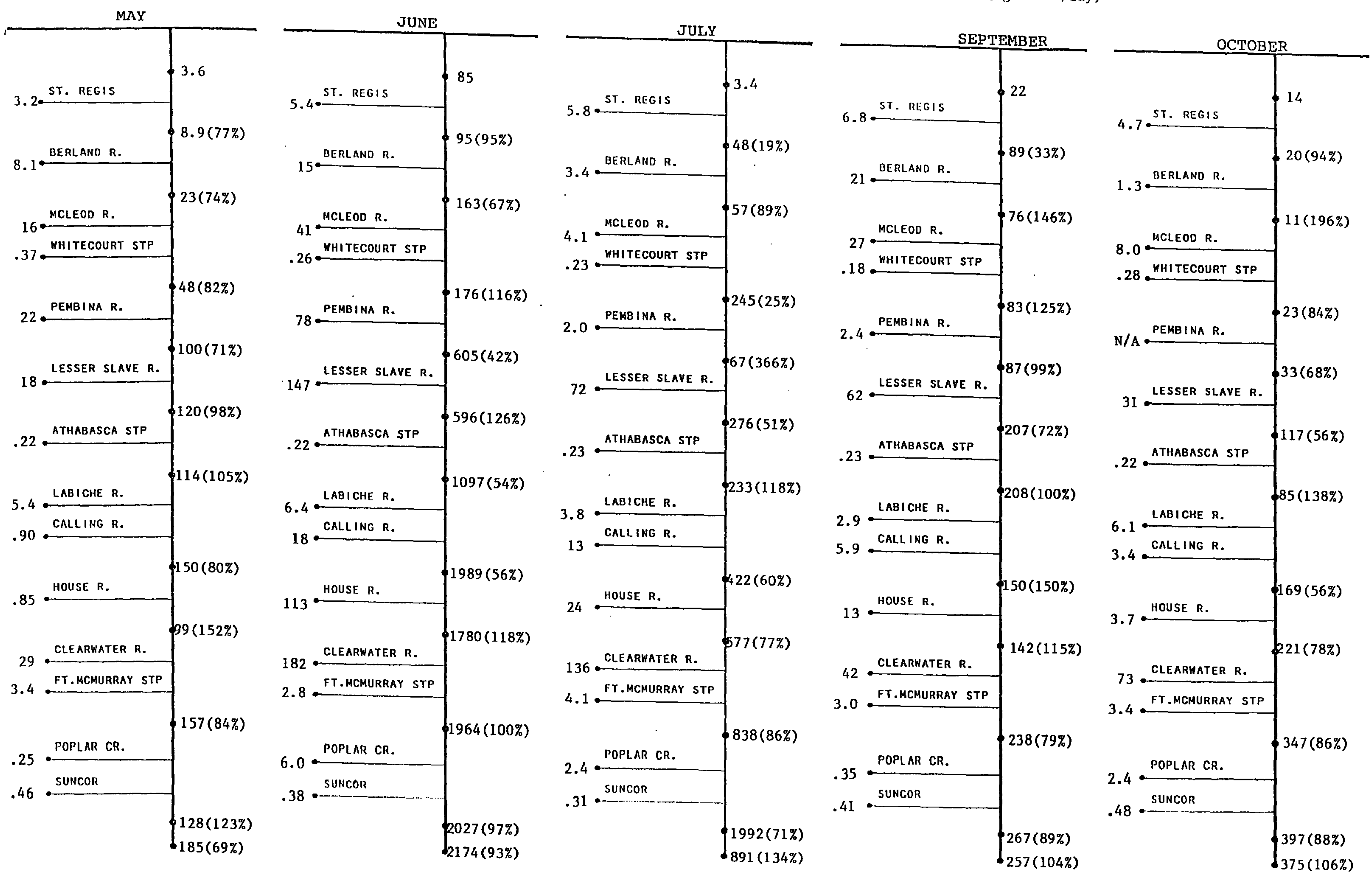


FIGURE 33 SEASONAL NITRATE + NITRITE MASS BALANCE ANALYSIS FOR THE ATHABASCA RIVER - 1984

(Kg /Day)

	MAY	JUNE	JULY	SEPTEMBER	OCTOBER
	131	2431	1498	1084	779
ST. REGIS	5	5	6	6	3
	70(194%)	2844(86%)	1563(96%)	123(885%)	226(346%)
BERLAND R.	4	383	5	12	1
	13(590%)	2430(133%)	1415(111%)	815(17%)	442(52%)
MCLEOD R.	43	279	2	39	7
WHITECOURT STP	35	23	21	16	26
	19(490%)	2572(106%)	1316(109%)	994(92%)	272(174%)
PEMBINA R.	7	30	3	1	L1
	23(112%)	2027(128%)	1783(74%)	1098(86%)	360(76%)
LESSER SLAVE R.	4	343	42	155	77
	30(90%)	3332(71%)	2180(84%)	1196(105%)	589(74%)
ATHABASCA STP	3	1	17	8	5
	30(112%)	4022(83%)	2325(94%)	1304(92%)	465(128%)
LABICHE R.	3	24	7	12	33
CALLING R.	2	11	6	53	2
	98(36%)	4283(95%)	2826(83%)	254(538%)	683(73%)
HOUSE R.	L1	249	60	91	25
	175(56%)	4342(104%)	4531(64%)	47(737%)	381(186%)
CLEARWATER R.	35	389	181	37	286
FT.MCMURRAY STP	1	1	1	1	10
	394(54%)	3688(128%)	3447(137%)	1243(7%)	1337(51%)
POPLAR CR.	L1	5	2	3	16
SUNCOR	2	2	2	3	2
	357(111%)	5032(73%)	4977(69%)	1643(76%)	1212(112%)
	579(61%)	4889(103%)	6274(79%)	122(1347%)	1078(112%)

FIGURE 34 ATHABASCA RIVER TRIBUTARY AND EFFLUENT DISCHARGES AT THE TIME OF THE 1984 SYNOPTIC SURVEYS (m^3/s)

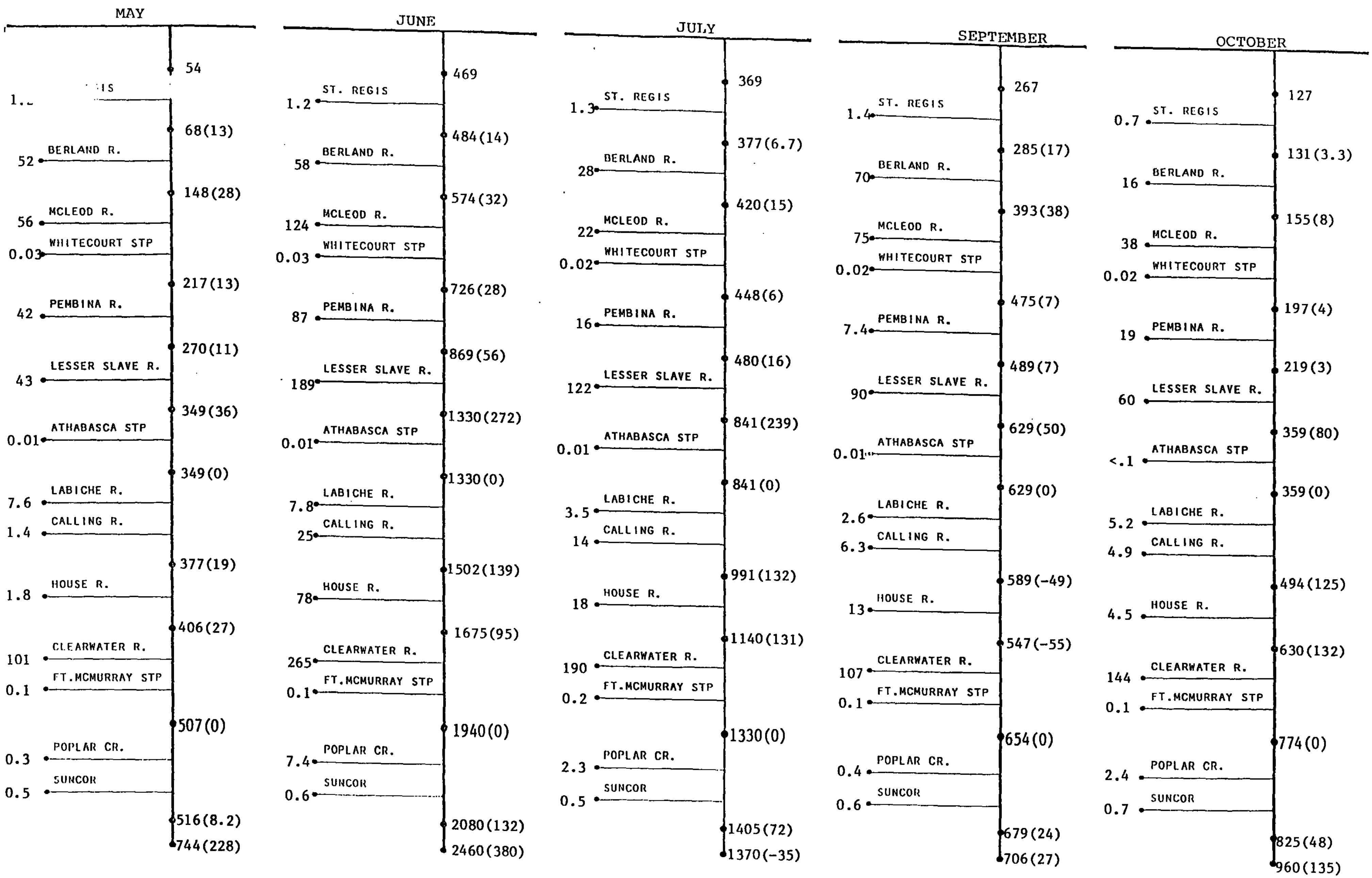
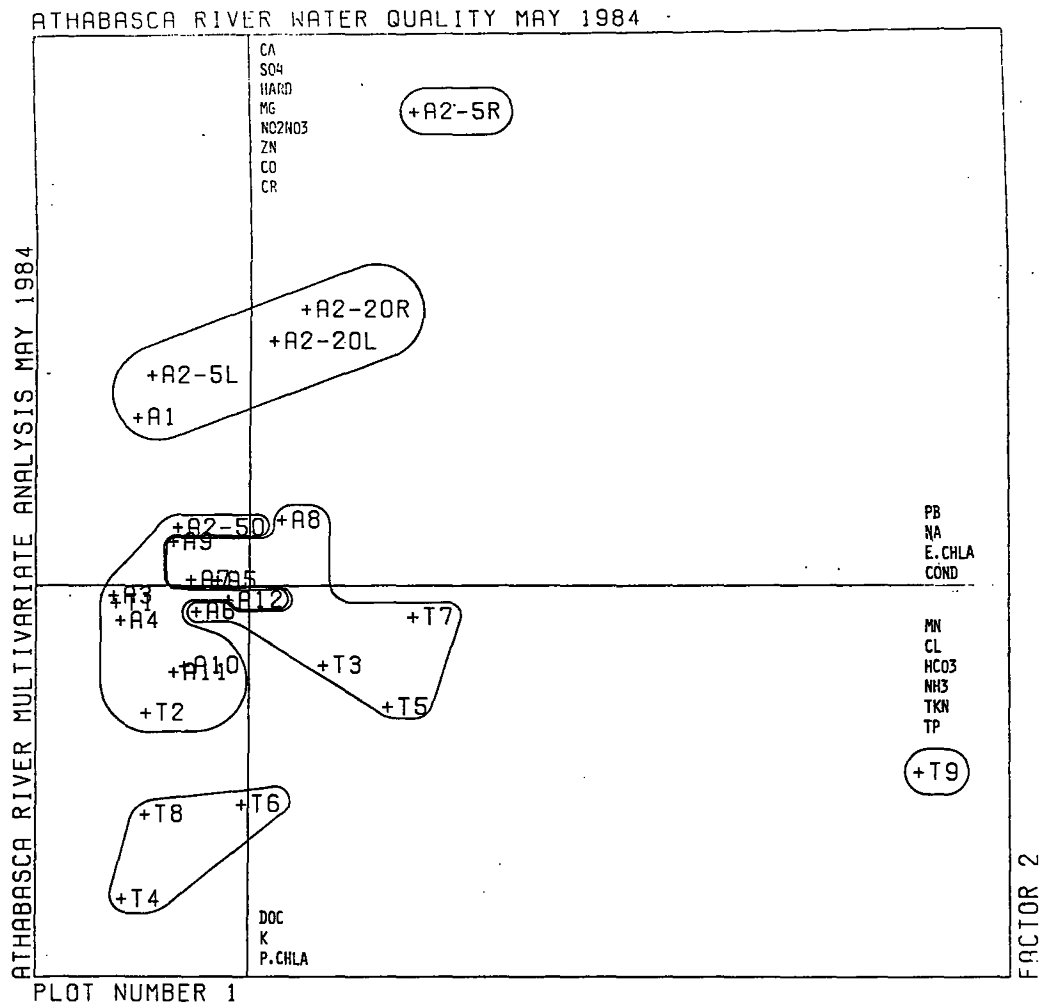


TABLE 16 PARAMETERS INCLUDED IN THE MULTIVARIATE CLUSTER AND PRINCIPAL COMPONENT ANALYSIS ON 1984 DATA.

(NA)	Sodium		Silica
(MG)	Magnesium	(FL)	Fluoride
(Ca)	Calcium	(TP)	Total Phosphorus
(K)	Potassium	(TDS)	Total Dissolved Solids
(Cl)	Chloride	(TKN)	Kjeldahl Nitrogen
(SO4)	Sulphate	(NO2NO3)	Nitrate & Nitrite
(HCO3)	Bicarbonate	(NH3)	Ammonia
(COND)	Specific Conductance		Cadmium
(NFR)	Nonfilterable Residue	(CO)	Cobalt
(HARD)	Hardness	(CU)	Copper
(ALK)	Alkalinity	(CH)	Chromium
(DOC)	Dissolved Organic Carbon		Iron
(PHENOL)	Phenol	(PB)	Lead
(T&L)	Tannin & Lignin	(MN)	Manganese
	Oil & Grease		Mercury
(COLOR)	Colour	(MO)	Molybdenum
(P.CHLA)	Phytoplankton Chlorphyll	(NI)	Nickel
(E.CHLA)	Epilithic Chlorophyll	(VN)	Vanadium
(TC)	Total Coliforms	(ZN)	Zinc
(FC)	Fecal Coliforms	(AR)	Arsenic

Figure 35 May Cluster and Principal Component Analysis



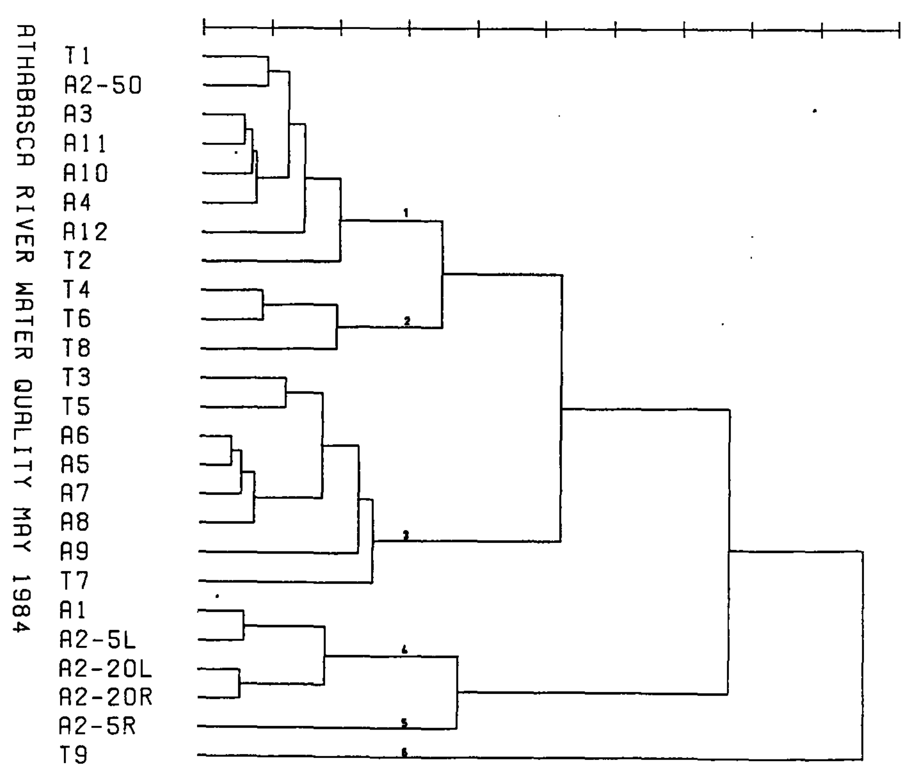
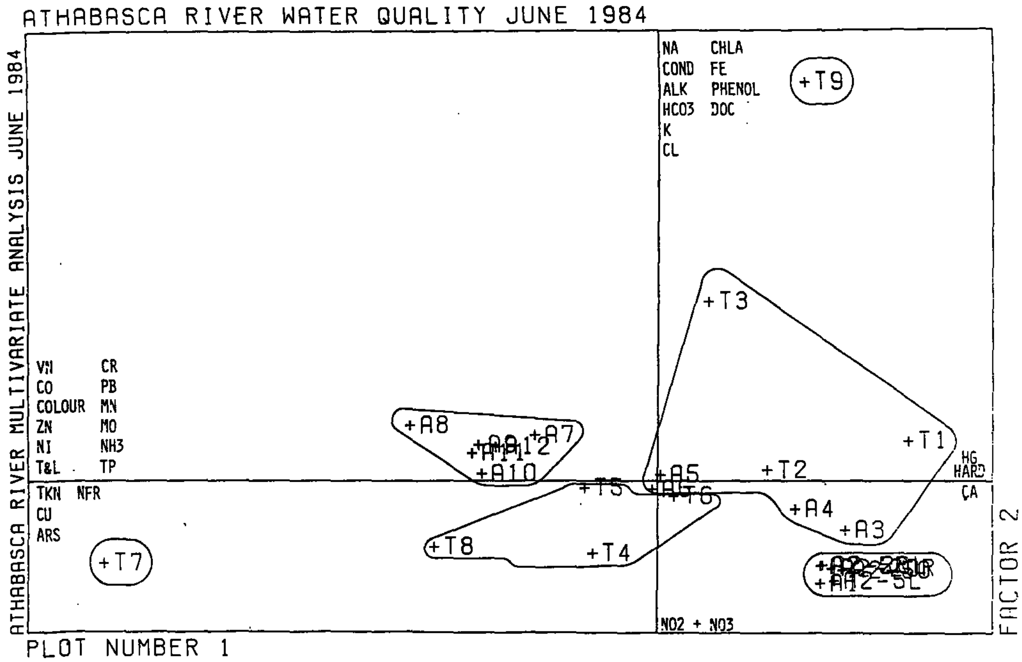


Figure 36 June Cluster and Principal Component Analysis



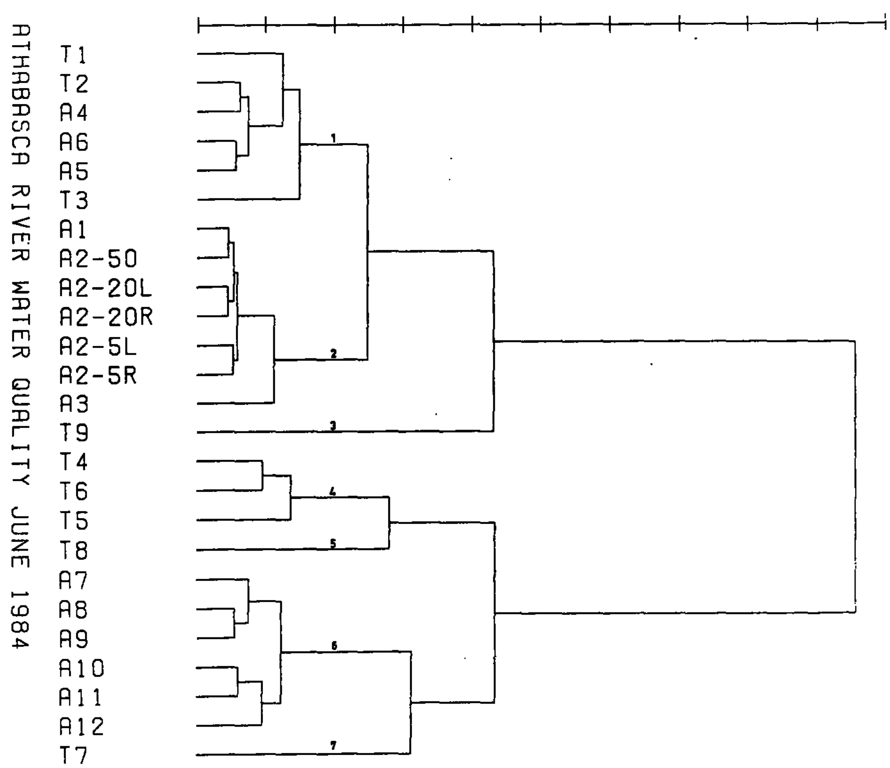
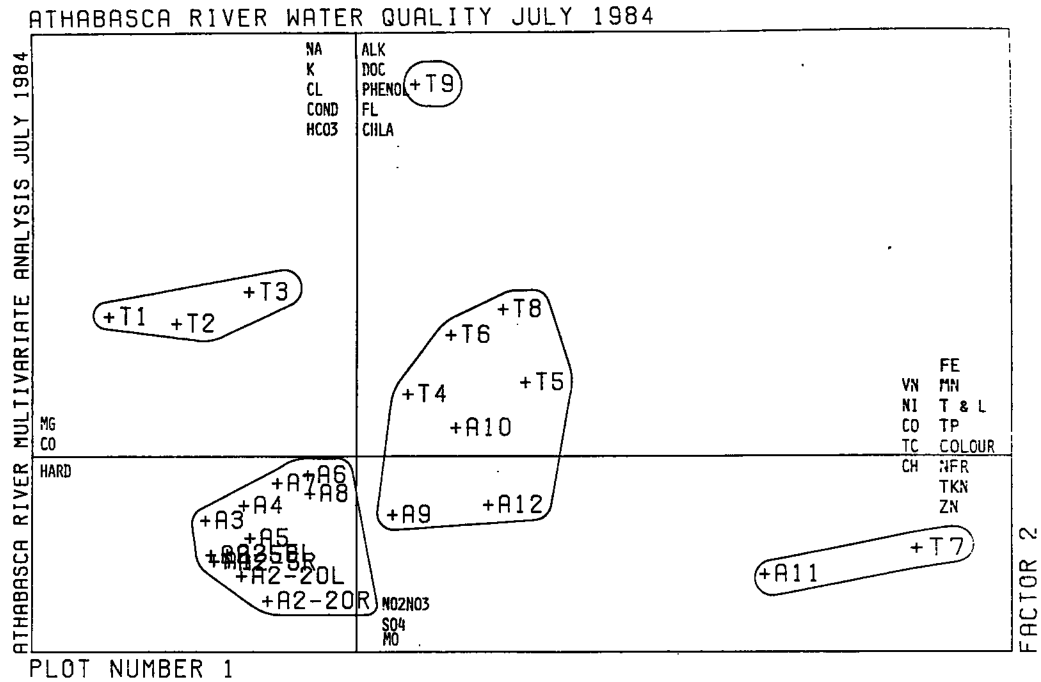


Figure 37 July Cluster and Principal Component Analysis



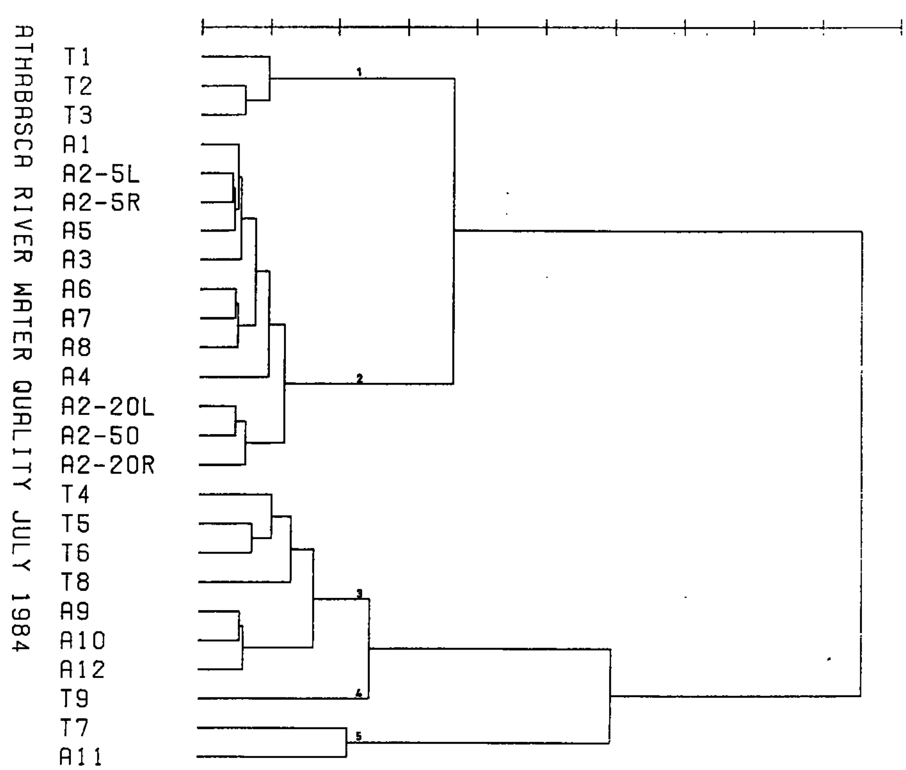
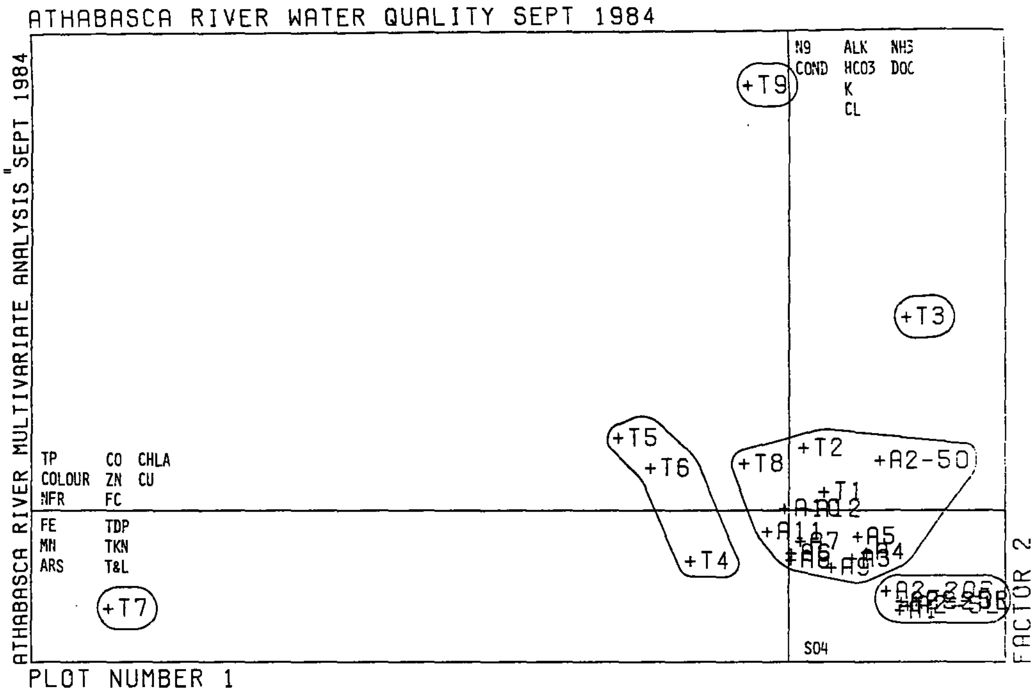


Figure 38 September Cluster and Principal Component Analysis



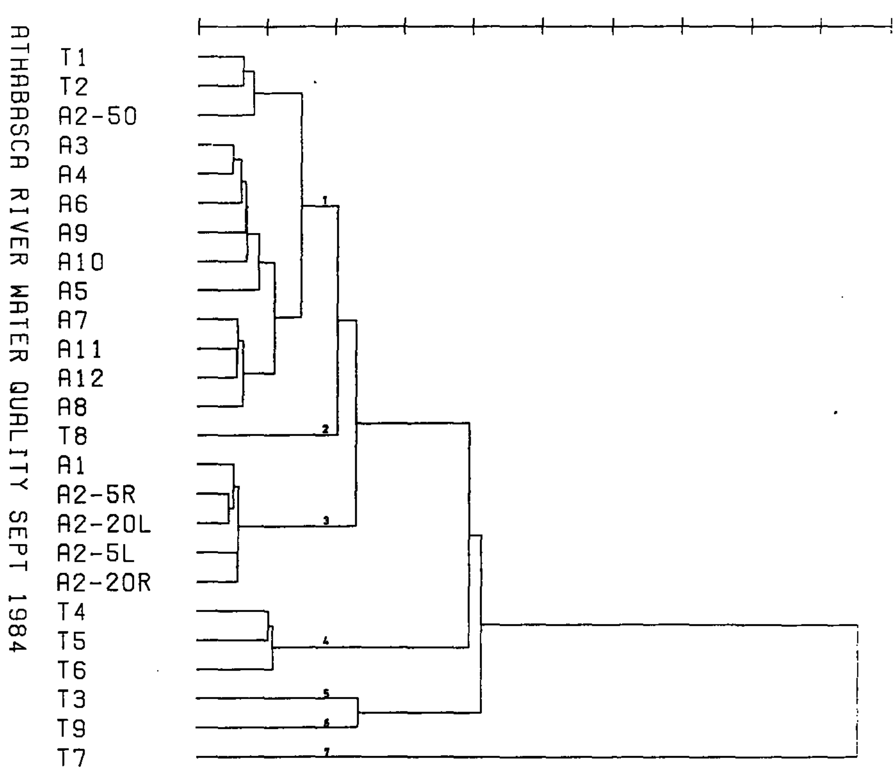
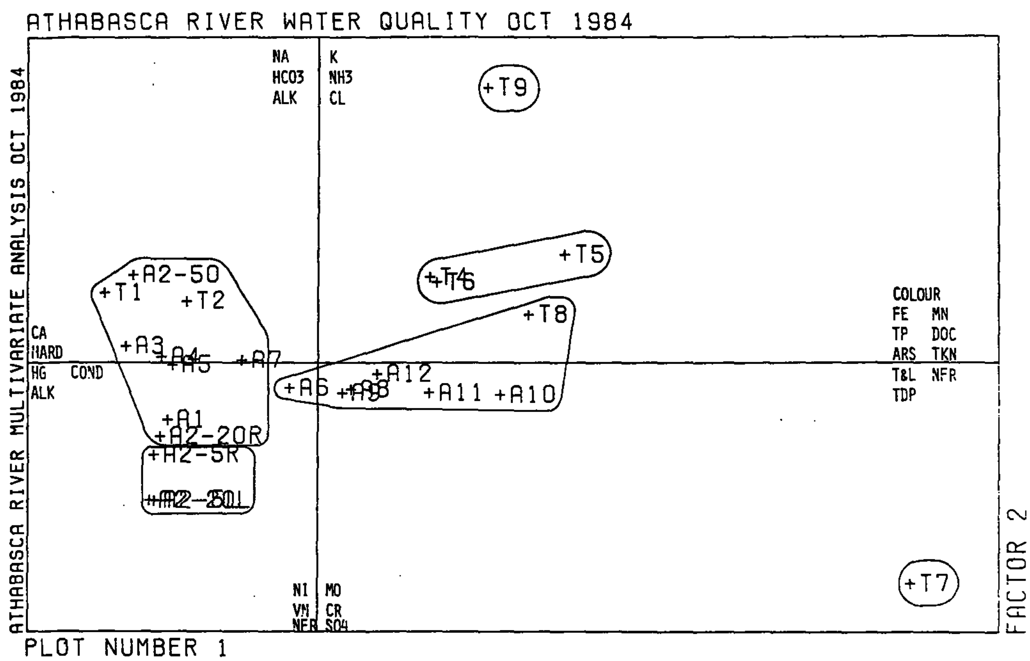


Figure 39 October Cluster and Principal Component Analysis



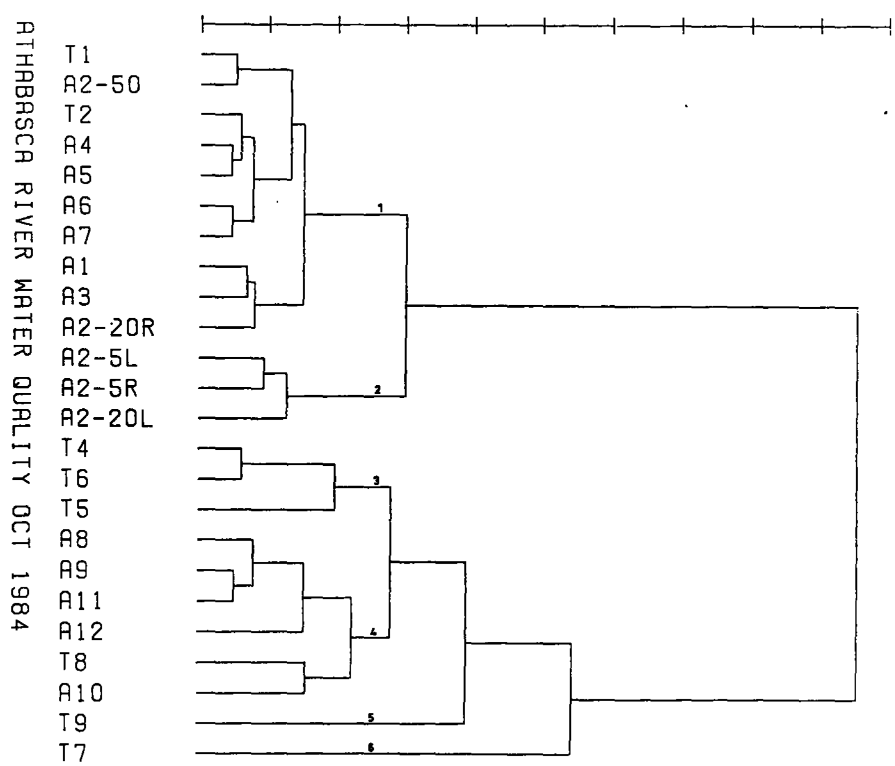
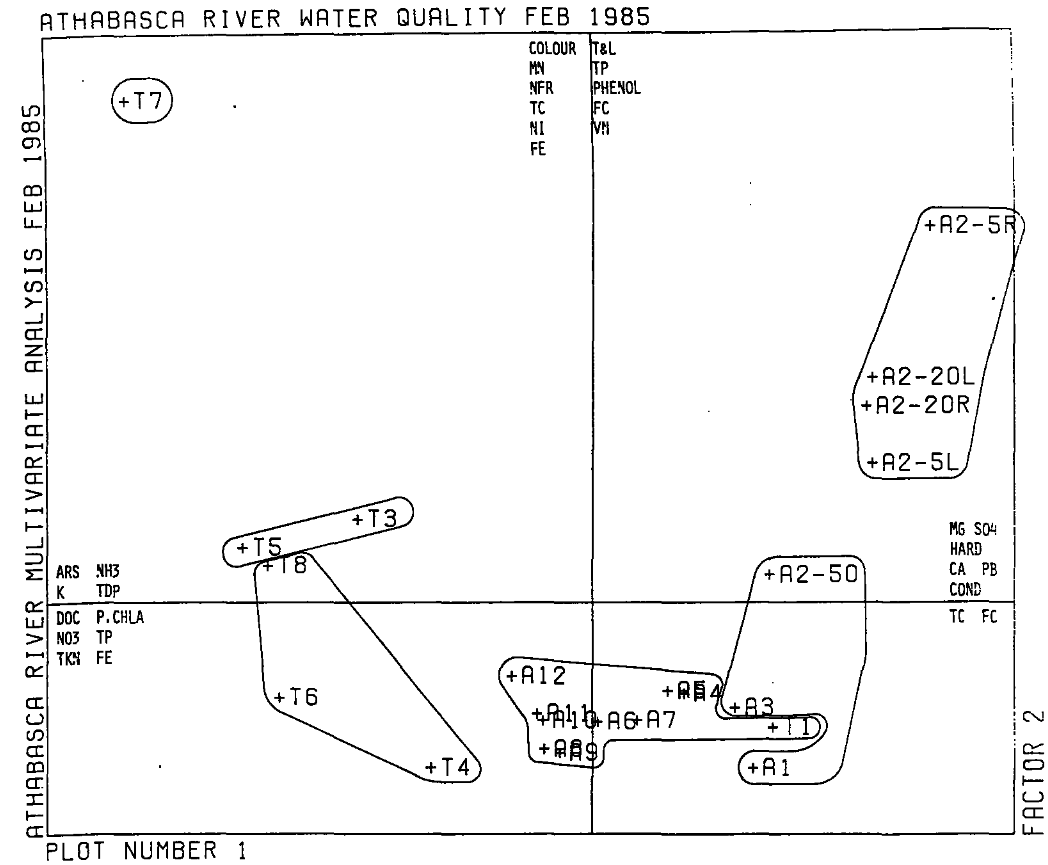


Figure 40 February Cluster and Principal Component Analysis



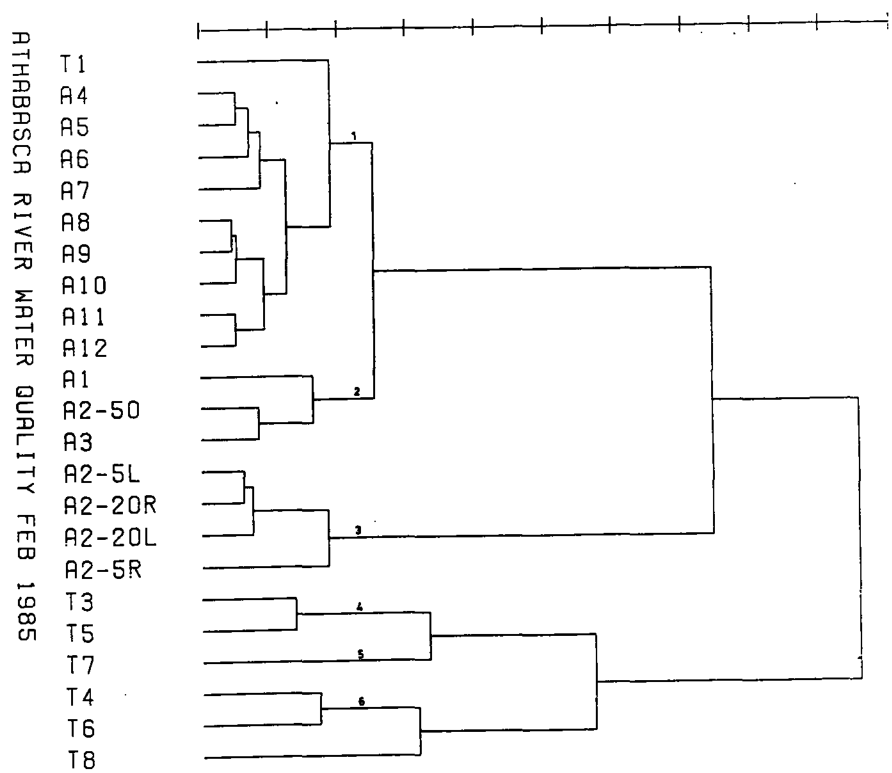
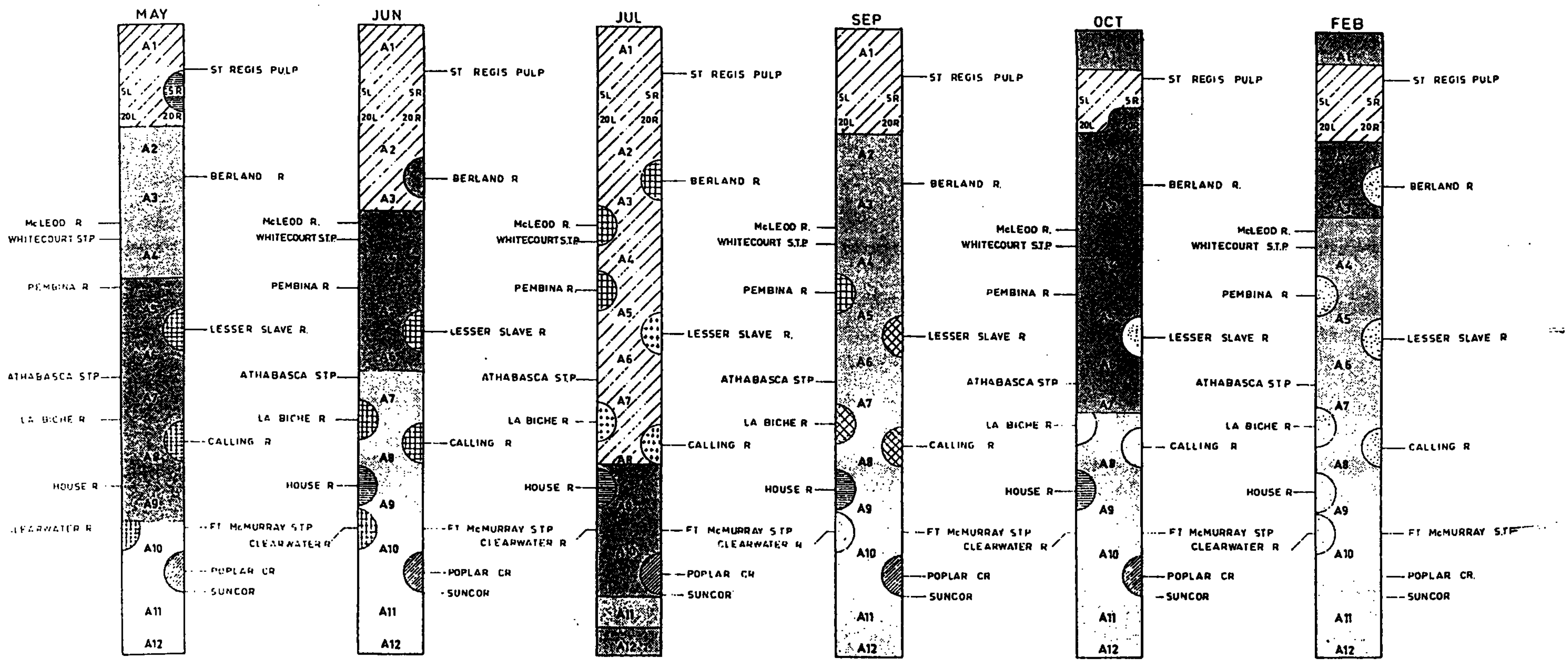


Figure 41 Seasonal Cluster Analysis Summary for Mainstem and Tributary Locations, 1984/85. Common Clusters are Indicated by Similar Shading.



Principal component analysis involves extraction of eigenvectors from a correlation matrix between all variables. The first two eigenvectors usually explain between 40 and 60% of the total variance in the dataset. Individual eigenvector values indicate the degree to which each water quality variable contributes to the total variance explained by that eigenvector. The significant positive variables for each of components one and two are indicated on the right and top sides of the PCA plot. The corresponding negative variables are indicated to the left and bottom respectively.

Some recurrent patterns emerged from the seasonal cluster analysis. In all instances the mainstem river sites tended to classify into two or three main groups. The upper sites were characterized by waters of higher relative alkalinity and hardness whereas increasing suspended solids, carbon content and nutrient levels resulted in clustering of the lower basin sites. The point of division between the mainstem groupings varied by season. Except for the river sites below the Hinton pulp mill, the industrial and municipal effluents did not effect instream quality enough that adjacent river sites classified on their own. Sites below Hinton were only differentiated during low flow conditions.

Poplar Creek and the House River usually clustered independently from all other tributary systems. Poplar Creek tended to be high in salinity and nitrogen, and the House River in suspended solids and associated variables. The upper tributaries of the basin, i.e. the Berland, McLeod and Pembina Rivers usually grouped together, as did the Lesser Slave, LaBiche, Calling and Clearwater rivers which drain the mid and lower reaches of the basin.

In May all sites upstream of A2 clustered together, except for the right bank site immediately downstream from the mill effluent. In addition to being high in hardness, these sites were characterized by elevated levels of sulphate, nitrate + nitrite, fecal coliforms and three metals. All mainstem sites downstream of A2 were quite similar, except for sub-grouping of sites between A5 and upstream Ft. McMurray. Water in the lower basin characteristically had higher DOC, phytoplankton and potassium. Conductivity, sodium chloride, nitrogen, phosphorus, and epilithic chlorophyll caused the distinct clustering of the mid reach Athabasca River locations along with the Pembina, LaBiche and House River tributaries. May water quality in the Berland and McLeod rivers was similar to that of the adjacent mainstem sites. Elevated DOC, potassium and phytoplankton set apart the Lesser Slave, Calling and Clearwater rivers.

High discharge conditions were experienced in June and July. During June the mainstem sites distinctly clustered into upper, middle and lower basin reaches. The middle reach included sites A4, A5 and A6, and adjacent tributaries like the Berland, McLeod and Pembina. Parameters characteristic of the lower basin sites include tannin and lignin, colour, NFR, TP, TKN and some of the sediment associated metals. Upper basin sites had lower overall values for these constituents, and higher concentrations of calcium, hardness and magnesium. The sites upstream of A4 were differentiated from their adjacent downstream sites and tributaries due to higher nitrate + nitrite concentrations. The tributary streams in the mid and lower parts of the basin had high concentrations of particulate parameters, carbon and nutrients. Their influence on the adjacent mainstem sites is apparent from their grouping within the same cluster.

Except for site A11, which clustered on its own with the House River, the mainstem sites clustered in two groups during July. All Athabasca River sites upstream of Ft. McMurray were characterized by high relative magnesium, calcium and hardness. Downstream of Ft. McMurray higher levels of nutrients, carbon, suspended solids and metals were significant. These parameters were particularly important at A11 and in the discharge from the Clearwater River. The mid basin tributaries all had similar water quality in July and contributed moderate levels of particulates, carbon and nutrients to the mainstem system. The second principal component differentiated Poplar Creek and the Berland, McLeod and Pembina rivers from the upstream Athabasca River sites due to elevated conductivity, NaCl, dissolved carbon parameters and phytoplankton; and lower relative nitrate + nitrite and sulphate concentrations.

September river and tributary flows were low except for the Berland and McLeod Rivers. For that synoptic survey all Athabasca River sites from A2 downstream clustered together. The sites upstream from A2 were differentiated by slightly higher sulphate concentrations. The trend towards higher suspended solid, nutrient and carbon concentrations with increasing downstream distance, apparent in all previous open water surveys, was not evident in September. These constituents were slightly elevated in the Lesser Slave, LaBiche and Calling Rivers, and only of major significance in the House River. At the time of the September survey the flows in the Pembina River were very low and conductivity, NaCl, DOC and ammonia were correspondingly high.

October was the last synoptic survey prior to ice cover. At that time the upstream downstream categorization evident during the first three surveys returned, with the subdivision occurring between Athabasca and Ft. McMurray. Within the upper basin group, the sites immediately below Hinton were differentiated by suspended solids, sulphate, vanadium, nickel and molybdenum. Quality of the upper tributaries tended to be similar to that in the adjacent mainstem rivers. Lesser Slave, LaBiche and Calling rivers clustered separately due to higher sodium chloride, alkalinity, potassium and ammonia. The House River once again was very high in NFR, nutrients and carbon.

The winter cluster groupings and their significant variables diverged from the general open water pattern indicated above. The major deviation for mainstem groupings occurred immediately downstream of Hinton. This was attributed to variables associated with the mill discharge; colour, tannin and lignin, phenol, coliforms, NFR and TP. Iron, nickel and vanadium also factored in the downstream Hinton cluster. Tributary water quality varied appreciably from that of the mainstem Athabasca, and three distinct clusters emerged. Six of the tributaries had higher concentrations of nitrogen, phosphorus, phytoplankton, DOC, arsenic and potassium compared to the mainstem. Amongst the six, the Pembina, LaBiche and especially House Rivers were differentiated from the Lesser Slave, Calling and Clearwater rivers due to colour, tannin and lignin, NFR, manganese, coliforms and a few minor metals.

V. DISCUSSION

The Athabasca River Basin is large, and drains a substantial portion of central and northern Alberta. River water quality conditions progressively change from the headwater in the mountains, through the foothills, and across the Interior Plains. This transition is largely due to natural factors rather than culturally induced impacts. Considering the low population base and the type of basin development which has occurred to date, one can understand why Athabasca River water quality is largely controlled by natural river continuum processes.

Results of this database analysis indicate three water quality zones; 1) a foothills zone located upstream of Ft. Assiniboine (A4); 2) an Interior Plains transition zone (A4 to A9); and 3) the lower basin reach between Ft. McMurray and Lake Athabasca (A4 to A9). Each region has a characteristic water quality which reflects tributary inputs, physiography and channel characteristics. There may indeed be a fourth mountain region zone located upstream of Hinton (A1), however, the detailed database for that reach was not considered here.

1. Foothills Reach

Water quality in the foothills region is characterized by high alkalinity and hardness and relatively low suspended solids. Hardness levels reflect the calcium and magnesium content, while elevated bicarbonate concentrations result in high alkalinity. Major tributaries in this region are the Berland and McLeod rivers, both of which have quality similar to that of the adjacent mainstem Athabasca River. Water entering this reach from the upstream mountain regions also contains high sulphate and nitrate + nitrite concentrations relative to the rest of the basin. Total phosphorus, total nitrogen and organic carbon contents are low in this river reach and the adjacent sub-basins. The stream gradient is sufficient to maintain a gravel and cobble sustrate, as opposed to a fine grained depositional stream bottom characteristic of lower reaches. This hard substrate, combined with adequate light conditions, means that epilithic (attached) algae rather than phytoplankton are the dominant primary producers. Except at elevated flow conditions in May, June and July water clarity is high due to a low suspended solids content. This contributes to the observed spring and fall maxima in benthic algal biomass.

Based upon the level of analysis carried out for this project, coal mining activities in the upper Pembina and McLeod basins are not having a detectable impact on either river or the mainstem Athabasca River. More detailed synoptic sampling might detect more subtle effects. Location of the existing long term network sites, at Jasper and Athabasca Town, will probably not allow for assessment of future coal mining related impacts.

The combined Hinton pulp mill and municipal sewage discharge affects river water quality of the foothills reach at low flows i.e. less than 100 m^3/sec, which tend to occur in fall and winter. Concentrations of sodium, chloride, dissolved organic carbon, phenol, tannin & lignin, bacteriological indicators and particulate nitrogen are elevated for a distance of approximately 50 kms. Based upon the 1984 data effluent mixing appears to occur within 20 kms of the outfall. Data were not obtained for other relevant pulp mill related parameters such as dimethyl-trisulfides, resin aids or Klebsiella (Bell et al.,1979), and from the synoptic surveys it is difficult to closely define the instream decay and transformation processs which occur within the impact zone. At high flows the dilution capacity provided by the river prevents any significant alteration in natural water quality.

2. Downstream Reach

Very different water quality conditions are experienced in the lower reach between Ft. McMurray and Lake Athabasca. Hardness and alkalinity are reduced relative to the uppermost reach and the major ion balance shifts. Enhanced levels of most particulate and carbon parameters are also observed. The suspended solids content remains high most of the year due to loading from the upstream reaches and tributaries. In addition the relative steep gradient and narrow channel upstream of Ft. McMurray causes bed scour and bank slumping. Downstream of Ft. McMurray the gradient drops and one would expect deposition of the suspended load. A study by Doyle (1977) confirms that suspended solid concentrations tend to be lower at Embarrass relative to Ft. McMurray, but only at flows greater than 1000 m^3/sec. Below 1000 m^3/sec concentrations at Embarrass can actually exceed those further upstream. This implies that larger sized particles do deposit in the lower reach, but smaller materials (less than 0.062mm) tend to be transported through to Lake Athabasca.

Total nitrogen and phosphorus content of the lower reach is high, and correlates strongly with suspended solids. This correlation implies much of the material is naturally derived from watershed runoff, bank erosion and scour. Dissolved phosphorus levels, the dominant form in municipal effluents, remains low throughout the year. Iron and manganese levels are high and also correlate with turbidity.

Maximum carbon concentrations are also observed in the lower portion of the basin. This is reflected in dissolved organic carbon and associated variables like phenols, tannin & lignin and colour. Particulate organic carbon levels remain relatively low. Loadings of these constituents can be traced to upstream tributary systems rather than point source discharges within the reach. These include the Suncor Tar Sands Plant effluent and the sewage discharge at Ft. McMurray.

The sodium chloride content of the Clearwater River and Poplar Creek are elevated relative to upstream portions of the basin. The high salt content of the Clearwater system is related to groundwater input from the Devonian formation (Hitchon et al, 1970). Poplar Creek levels result from mine depressurization water discharged to the Creek from the Syncrude facility. Flows from Poplar Creek are low enough that this discharge has no measureable effect on the Athabasca River. In contrast the Clearwater River is the largest single tributary and has a major influence on mainstem sodium chloride, and to a lesser degree, phosphorus and carbon levels.

Metals like copper, mercury, zinc and vanadium occur at maximum concentrations in the downstream reach. They correlate with the suspended inorganic load and are naturally derived. Effluent discharge loadings cannot account for the observed levels. These trace metals are associated with heavy mineral and organic materials, or are adsorbed on clays or fine mineral fractions (Allan & Jackson, 1978). They tend to be moderately to ultra-stable with regard to chemical weathering. The oil rich clays and sands of the Ft. McMurray area are thought to be a non-point source of certain trace metals (i.e. nickel and vanadium).

Unlike the upper basin, phytoplankton dominate relative to periphyton in reach three. River depth and turbidity restrict light penetration, and thereby inhibit periphyton production. Shifting of the depositional substrate also limits algal attachment. River phytoplankton are derived from tributaries draining lakes, channel erosion of periphyton and actual growth in the river itself.

3. Intermediate Reach/Transition Zone

The intermediate reach between Ft. Assiniboine and Ft. McMurray is a transition zone. In this stretch of river, water quality conditions gradually change from reach one, foothills typology to that of the lower basin. Most of the tributaries in the basin drain to the middle reach, and these loadings largely account for the observed water quality transition. Along this stretch, alkalinity and hardness levels decrease while the suspended solids, particulate metal, nutrient and carbon contents increase. For many constituents, a major change in quality occurs upstream of Athabasca Town, near the confluence with the Lesser Slave River. A second major change often occurs upstream of the Clearwater River, in the stretch which includes the confluence with the House River. Towards the upper end of this middle reach the stream gradient is reduced, i.e. between Ft. Assiniboine and A7. Below A7, the stream gradient increases quite markedly again. The slope is sufficient to maintain a series of rapids between A8 and Ft. McMurray.

The Clearwater and Lesser Slave systems are the dominant tributaries in terms of flow contribution and in many instances, the dominant constituent loadings. The quality of the Clearwater River and adjacent House River reflects the high proportion of organic soils (muskegs) in these sub-basins. Dissolved organic carbon, phenol and tannin & lignin concentrations are high, and hardness low, relative to much of the rest of the basin. In addition the House River is a major contributor of suspended solids to the lower mainstem Athabasca River.

Tributaries which drain lakes have unique water quality characteristics. Included in this group are the Lesser Slave, Calling and LaBiche tributaries, which all transport relatively high levels of carbon, tannin & lignin and particulate phosphorus. Pembina River water quality appears to be transitional. In many ways it is similar to the Berland and McLeod systems which drain the foothills, yet some parameter concentrations more closely approximate those of Interior Plain drainage systems.

4. Effects of Municipal and Industrial Effluents

Point source effluents from municipal and industrial plants in the basin have no broadly based influence on the river. Localized affects may be apparent immediately below the points of discharge for a very short distance. Except for ammonia and chloride, the data from 1984 indicate tributary loadings account for 90% of measured constituent inputs. It must be realized that only one year's data are available for many of these tributary systems, therefore annual variation in the significance of the tributary loads cannot be asessed. Similarly, the scale of sampling undertaken for this overview does not allow for fine definition of impact zones.

At low river flows the Hinton Pulp Mill does influence river tannin and lignin, phenol, colour, total dissolved phosphorus, fecal coliform and nitrate concentrations for a distance of 50 to 75 km downstream of Hinton. At this scale of assessment, tar sand plant discharges have no influence on river water quality. This includes both the process effluent from Suncor and the mine depressurization water drained to Poplar Creek by Syncrude.

One factor that was not considered in detail here, but has been raised elsewhere (Strosher and Peake, 1978; Wallis et al, 1980), is trace organic loadings related to tar sands development. Extractable trace organic concentrations in the river increase downstream from Ft. McMurray. These compounds are found naturally in the oil bearing McMurray formation but also comprise about 50% of the trace organic content of the Suncor effluent. It is not possible at this time to quantify the significance of point versus non-point extractable organic loadings to the system. Research is required to identify the chronic and acute lethality of these trace organics to aquatic organisms, potential impacts on downstream users and environmental pathways within the aquatic system. The latter is required if the fate of such compounds is to be modelled. The macro-organic parameters like oil and grease, phenolics and TOC are not good indicators of the trace organic compounds.

Some unaccounted for inputs occur between A5 and A6 (Athabasca Town), and upstream of Ft. McMurray. These loadings may be attributed to diffuse source inputs and small unmonitored streams. In both areas, drainage is poor. A flat topography and low gradient exists in the area around the confluence with the Lesser Slave River, while muskeg conditions predominate in the House River sub-basin.

Comparison of the Alberta Surface Water Quality Objectives (ASWQO) with historic and recent Athabasca River water quality indicates exceedance of many parameters on a regular basis. Considering the minor effect point source effluents have on the system one must conclude Athabasca water quality remains in a largely natural state; except for the stretch immediately below Hinton. This brings into question applicability of the ASWQO to this river system. The provincial objectives are based upon broad assumptions, and regional water quality patterns were not accounted for in their development.

The federal specific use objectives are exceeded for one or a few parameters in all instances. Non-compliance with the objectives for raw waters to be used for domestic supply just dictate the necessary level of treatment. Contact recreation is limited much of the year by low water temperatures and high turbidity. Many of the trace metal objectives for aquatic life and wildlife are exceeded along the lower Athabasca River. In most instances the levels are slightly exceeded, and at the same time, both the objective and ambient concentrations are near the analytical detection limit. Quantitative reliability of such data is questionable, and these objectives should be further refined. Objectives based upon sediment or tissue concentrations may be more appropriate. Considering the overall natural state of Athabasca River water quality, exceedance of non-metal aquatic life objectives also requires further evaluation. They may not apply to the indigenous river fauna of the Athabasca Basin.

The hydrologic regime is a primary controlling variable of Athabasca River water quality. The high flows in May, June and July create the major seasonal pattern in water quality. This overides the influence of point source discharges and instream biological effects. This explains why for the parameters tested here that concentrations correlate strongly with river discharge. The data exist to test for additional flow dependent relationships.

Runoff from the major tributary systems effect mainstem quality differentially. Maximum flow in the foothill systems coincides with the June mountain snowmelt. The flow pattern of interior basins is more variable, reflecting not only snowmelt, but also major summer rain events. Runoff related particulate parameters occur at maximum levels in spring and summer. Major ion and carbon concentrations are maximal during fall and winter low flow conditions.

Based upon statistical analysis of the historical water quality database three distinct water quality seasons are defined. These include the ice cover interval, and the open water periods from ice off to July 31 and August 1 to freeze-up. Water quality in the early openwater season is controlled by local and mountain snowmelt runoff and a rising hydrograph. The late openwater season is effected by a falling hydrograph, summer rainstorms in the interior plains and maximum instream biological activity.

Prior to 1984, intensive water quality studies have concentrated on the mainstem Athabasca River downstream of Ft. McMurray, and tributary rivers in the AOSERP region. Intensive sampling of the tar sands region has been halted and the information compiled in recent reports. In 1984, intensive impact oriented water quality sampling programs were undertaken on the Lovett and McLeod rivers relative to coal mine impacts, and along the mainstem river downstream from Hinton. The latter program was to quantify spatial and temporal patterns in pulp mill impacts. In conjunction with a strageticaly located fixed station monitoring network these intensive surveys provide an effective means of monitoring a large primarily natural river basin like the Athabasca. It is not necessary to undertake detailed sampling suveys along undisturbed mainstem reaches or sub-basins with minimal development.

VI RECOMMENDATIONS

1. Fixed Station Monitoring

Water quality monitoring in the basin has included maintenance of a fixed station network, currently consisting of two stations, one at Jasper and a second at the Town of Athabasca. To better assess long term trends additional fixed monitoring stations should be established on the mainstem Athabasca River at Embarras, and on the McLeod River at its mouth.

2. Synoptic Surveys

Detailed synoptic water quality monitoring surveys which complement the fixed station network should be conducted periodically, i.e. at three to five year intervals. These surveys should be restricted to the McLeod River sub-basin, the area downstream of Hinton and the river reach between Ft. McMurray and the Peace-Athabasca Delta.

3. Additional Data for Tributary Streams

Tributary streams contribute the majority of the basin export loading, yet very little historic data exist for many of these systems. An additional one year's baseline water quality data should be collected for all major tributaries to the mainstem Athabasca River.

4. Impact Zone Sampling Downstream of Hinton

In order to refine the WQRRS water quality model calibration of the Athabasca River it is recommended intensive sampling surveys be conducted in the vicinity of the Hinton discharge. Data collection should emphasize definition of; 1) instream decay and transformation, 2) mixing zones, 3) sediment oxygen demand, 4) carbon to chlorophyll ratios of benthic algae, 5) river patterns in dimethyl-trisulfides, resin acids and *Klebsiella*, 6) diurnal temperature and oxygen and 7) channel depth, velocity and width.

5. Intensive Studies Downstream from a Municipal Discharge

An intensive municipal effluent study should be done downstream from one of the three sewage outfalls. The Athabasca Town discharge is recommended due to preferred river mixing characteristics and effluent quality. The overall study format should be similar to that outlined for downstream Hinton.

6. Definition of Basin Specific Water Quality Parameters

Due to difficulties in applying the Alberta Surface Water Quality Objectives, and Environment Canada's specific water use criteria, basin specific objectives should be developed. These should account for natural water quality conditions and incorporate parameters appropriate to basin specific impacts, i.e. tar sands development.

7. Further Work on Trace Organics

Considering the current and future importance of the tar sands area, an effort should be made to refine sampling and analytical methods for extractable trace organic compounds. In addition their sources (point and non-point), environmental fate and effect should be researched and modelling capabilities developed.

8. Parameter Inter-Correlation and Discharge Dependence

Additional data analysis should be undertaken to develop empirical water quality relationships. These should emphasize variation with river discharge and inter-correlation among chemical and biological parameters. These could be used to assess non-point source impacts, set boundary conditions for simulation modelling projects and to streamline water quality monitoring programs.

REFERENCES

Alberta Government, 1969. Atlas of Alberta. Alberta Government Publication Services

Allen, R. & T. Jackson, 1978. Heavy metals in bottom sediments of the mainstem Athabasca River system in the AOSERP study area. Prep. for Alberta Oil Sands Environmental Research Program by Fisheries and Environment Canada, Freshwater Institute, AOERSP Report 34. 74 pp.

Bell, J.B., W. Macrae, J.F.L. Zaal & J. M. Vanderpost, 1979. Growth patterns of some enteric bacteria in a kraft pulp mill domestic sewage combined treatment system. Transactions Vol. 5 #2, TR26-TR32

Bothe, R.A., 1982. Athabasca River Basin Study: historical natural flows 1912 to 1980. Hydrology Branch, Alberta Environment. 61 pp.

Charlton, S.E.D., H.R. Hamilton & P.M. Cross, 1985. The Limnological characteristics of the Bow, Oldman and South Saskatchewan Rivers II The primary producers. Water Quality Control Branch, Alberta Environment. (In preparation).

Demayo, A., M.C. Taylor & S.W. Reeder, 1979. Guidelines for surface water quality Vol. 1. Inorganic substances - arsenic. Inland Waters Directorate, Environment Canada. Ottawa 13 pp.

Doyle, P.F., 1977. Hydrologic and hydraulic characteristics of the Athabasca River from Ft. McMurray to Embarras. Research Council of Alberta. Transportation and Surface Water Engineering Division, Edmonton. Report SWE 77-2, 47 pp.

Erxleben, J.P., 1982. Athabasca River Basin water use assessment. Planning Services Branch, Planning Division, Alberta Environment, 79 pp.

Federal-Provincial Working Group on Recreational Water Quality, 1983. Guidelines for Canadian recreational water quality. Minister of Supply and Services Canada. H46-20/1983E. ISBN 0-660-11478-X, 75 pp.

Gummer, W.D., 1979. Pesticide monitoring in the Prairies of Western Canada, water quality interpretive report #4. Environment Canada, Inland Waters Directorate, Water Quality Branch, Western & Northern Region. EN 36-518/4. 14 pp.

Hardy, W.G. (Ed), 1967. Alberta a natural history. M.G. Hurtig Publishers. Edmonton. 343 pp.

Health and Welfare Canada, 1978. Guidelines for Canadian drinking water quality. Federal-Provincial Working Group on Drinking Water Quality. Supply & Services Canada. H48 - 10/1978. ISBN 0-660:10429-6. 79 pp.

Hitchon, B., A.A. Kevinsen, S.W. Reeder, 1970. Regional variations of river water composition resulting from halite solution, MacKenzie River drainage basin, Canada. Water Resources Research. Vol. 5 #6: 1395 - 1402.

Howard, C.H. & Associates., 1984. Athabasca River Basin Implementation of the WQRRS model. Final Report. Produced for: Planning Division, Alberta Environment.

Kellerhals, R., C.R. Neill, & D.I. Bray, 1972. Hydraulic and geomorphic characteristics of rivers in Alberta. Research Council of Alberta. 54 pp.

Longley and Janz, 1978. The climatology of the Alberta Oil Sands Environmental Research Program study area. AOSERP Report ME 4.2.1, 64 pp.

McNeely, R.N., V.P. Neimanis & L. Dwyer, 1979. Water quality sourcebook, a guide to water quality parameters. Inland Waters Directorate. Environment Canada. EN 37-54/1979.

Reeder, S.W., A. Demayo, & M.C. Taylor, 1979. Guidelines for surface water quality. Vol. 1 Inorganic chemical substances - mercury & cadmium. Inland Waters Directorate, Environment Canada. Ottawa.

Smith, D.J., 1978. Water quality for river-reservoir systems. Documentation Manual U.S. Army Corps of Engineers. Hydrologic Engineering Centre. Davis. California. 288 pp.

Sokal, R.R. & F. J. Rolff, 1969. Biometry W.H. Freeman and Company, San Francisco, 776 pp.

SPSS Inc. 1983. SPSSX User's Guide, McGraw-Hill Book Comoany, Toronto, 805 pp.

Standards and Approvals Division, 1977. Alberta surface water quality objectives. Alberta Environment, 15 pp.

Strosher, M.T. & E. Peake, 1978. Characterization of organic constituents in waters and wastewaters of the Athabasca Oil Sands mining area. Prep. for the Alberta Oil Sands Environmental Research Program by the University of Calgary, Environmental Sciences Centre. AOSERP Report 20, 71 pp.

Supply and Services, Canada, 1978. Guidelines for Canadian drinking water quality. Federal-Provincial Working Group on Drinking Water Quality, Environment Canadda. H48-10/1978. 79 pp.

Taylor, M.C. & A. Demayo, 1979. Guidelines for surface water quality, Vol. 1. Inorganic chemical substances - zinc. Inland Waters Directorate, Environment Canada. Ottawa.

Taylor, M.C., A. Demayo & S.W. Reeder, 1979. Guidelines for surface water quality, Vol. 1. Inorganic chemical substances - nickel. Inland Waters Directorate, Environment Canada. Ottawa.

Vollenweider, R. A. & J.J. Kerekes, 1980. Organization for economic co-operation and development co-operative program on monitoring of inland lakes (eutrophication control): Synthesis report. 209 pp.

Wallis, P, E. Peake, M. Strosher, B. Baker and S. Telang, 1980. The assimilative capacity of the Athabasca River for organic compounds. Prep: for the Alberta Oil Sands Environmental Research Program by Kananaskis Centre for Environmental Research, University of Calgary. AOSERP WS 2.3.2. 106 pp.

Wishart, D., 1978. Clustan user manual. Third Edition Inter - University/Research Council, Series Report #47. 175 pp.

APPENDIX I

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS

1970 - 1983

STEM	PERIOD	Na mg/l	Mg mg/l	Ca mg/l	K mg/l	Cl mg/l	SO4 mg/l	HCO3 mg/l
JASPER	ICE COVER							
	MEDIAN	2	11	32	.4	.9	26	112
	COEF VAR	13	11	7	23	25	9	12
	MAX	2	15	41	.9	1.6	32	144
	CASES	33	26	33	33	33	33	33
	OPEN WATER E							
	MEDIAN	1	8	25	.4	.6	17	90
	COEF VAR	48	30	21	35	58	40	22
	MAX	2	11	34	.7	1.6	30	122
	CASES	38	30	38	38	38	38	36
	OPEN WATER L							
	MEDIAN	1	7	24	.3	.4	17	83
	COEF VAR	39	20	10	168	119	29	10
	MAX	2	10	29	4.3	4.0	26	101
	CASES	34	28	34	34	34	34	33
	TOTAL MEDIAN	1	9	28	.4	.7	22	96
ATHABASCA	ICE COVER							
	MEDIAN	12	14	51	1.8	5.1	38	188
	COEF VAR	19	20	16	74	31	24	15
	MAX	20	20	68	13.0	10.0	56	245
	CASES	62	39	62	62	62	62	58
	OPEN WATER E							
	MEDIAN	5	7	30	1.1	1.3	15	116
	COEF VAR	29	13	11	45	43	25	13
	MAX	9	10	38	3.0	4.1	25	152
	CASES	37	23	37	37	37	37	33
	OPEN WATER L							
	MEDIAN	6	9	37	1.0	1.6	21	134
	COEF VAR	30	18	15	30	39	27	15
	MAX	10	13	46	2.4	3.6	35	184
	CASES	49	30	49	49	49	49	46
	TOTAL MEDIAN	8	10	40	1.4	2.3	25	147
FT MCM	ICE COVER							
	MEDIAN	14	13	49	1.9	5.1	37	185
	COEF VAR	19	11	14	36	44	18	14
	MAX	21	16	62	4.0	19.0	51	238
	CASES	49	27	49	49	49	49	49
	OPEN WATER E							
	MEDIAN	6	8	31	1.1	1.6	19	115
	COEF VAR	41	12	12	61	144	23	10
	MAX	19	9	36	3.6	21.7	29	141
	CASES	40	28	40	40	40	38	39
	OPEN WATER L							
	MEDIAN	6	8	32	.8	1.9	20	123
	COEF VAR	26	14	15	45	63	28	14
	MAX	11	10	41	1.4	9.0	37	159
	CASES	43	30	43	43	43	41	42
	TOTAL MEDIAN	7	7	34	1.2	2.2	24	131

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS
1970 - 1983

STEM	PERIOD	TURBIDITY JTU	HARDNESS mg/l	ALKALIN. mg/l	TDS mg/l	CONDUCT. us/cm	NFR mg/l	pH pH units	TEMP deg.C
JASPER	ICE COVER								
	MEDIAN	2.0	199	92.0	131.0	236	3	8.0	.8
	COEF VAR	154	5	12	2	10	147	2	73
	MAX	32.0	133	118.0	133.0	294	45	8.2	2.5
	CASES	35	11	33	7	35	25	35	22
	OPEN WATER E								
	MEDIAN	8.0	94	78.0	127.0	150	12	8.1	8.9
	COEF VAR	139	40	22	20	27	178	2	45
	MAX	180.0	124	100.1	135.7	291	394	8.7	14.8
	CASES	57	10	37	7	56	31	57	46
	OPEN WATER L								
	MEDIAN	6.6	86	68.0	94.6	170	8	8.2	6.0
	COEF VAR	151	15	10	12	16	153	1	55
	MAX	205.0	104	83.0	111.9	233	165	8.4	15.0
	CASES	56	6	33	4	56	32	56	37
	TOTAL MEDIAN	5.0	111	79.0	128.0	183	7	8.1	6.3
ATHABASCA	ICE COVER								
	MEDIAN	2.8	181	154.0	231.0	396	2	7.7	.6
	COEF VAR	120	10	15	15	14	156	3	61
	MAX	36.0	213	201.0	266.0	501	45	8.2	2.5
	CASES	63	30	58	12	64	39	64	36
	OPEN WATER E								
	MEDIAN	62.0	105	95.0	120.0	220	129	8.0	14.0
	COEF VAR	180	10	13	5	14	143	2	34
	MAX	1100.0	116	125.0	130.6	294	1618	8.3	21.5
	CASES	38	16	35	5	38	30	38	41
	OPEN WATER L								
	MEDIAN	13.0	134	109.	135.0	269	13	8.2	10.5
	COEF VAR	99	13	15	13	16	135	3	61
	MAX	84.0	154	151.0	169.7	359	211	8.4	23.0
	CASES	51	20	47	5	51	37	51	47
	TOTAL MEDIAN	7.4	143	120.0	179.0	292	15	7.9	8.6
FT MCM	ICE COVER								
	MEDIAN	6.0	175	152.0		375	7	8.0	1.0
	COEF VAR	176	16	14	.	13	321	3	37
	MAX	150.0	215	195.0	.	454	788	8.4	1.5
	CASES	46	27	49	0	49	31	49	9
	OPEN WATER E								
	MEDIAN	73.0	104	94.2		222	198	7.9	16.1
	COEF VAR	149	9	10	.	14	115	3	25
	MAX	1100.0	112	116.0	.	308	1490	8.4	26.0
	CASES	29	18	40	0	40	35	40	31
	OPEN WATER L								
	MEDIAN	23.0	114	100.0		227	26	8.0	12.3
	COEF VAR	150	13	14	.	15	172	3	49
	MAX	355.0	136	131.0	.	312	648	8.5	22.0
	CASES	31	18	43	0	44	33	43	38
	TOTAL MEDIAN	21.5	119	106.0		248	40	8.0	12.6

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS

1970 - 1983

STEM	PERIOD	DO mg/l	BOD mg/l	CHLORO-PHYLL A mg/l	FECAL COLIFORMS no./100ml	TOTAL COLIFORMS no./100ml	FECAL STREP. no./dl
JASPER	ICE COVER						
	MEDIAN	12.3		.0010	2	14	4
	COEF VAR	8	.	76	189	200	209
	MAX	14.2	.	.0040	64	460	104.0
	CASES	32	0	13	26	27	26
	OPEN WATER E						
	MEDIAN	11.0		.0010	7	32	5
	COEF VAR	10	.	92	101	482	91
	MAX	14.0	.	.0060	49	11000	30.0
	CASES	34	0	15	59	56	61
	OPEN WATER L						
	MEDIAN	11.1		.0010	9	65	8
	COEF VAR	10	.	106	118	101	126
	MAX	14.2	.	.0090	98	650	90.0
	CASES	34	0	20	57	56	59
	TOTAL MEDIAN	11.7		.0010	7	36	6
ATHABASCA	ICE COVER						
	MEDIAN	10.9		.0010	3	23	6
	COEF VAR	21	.	174	137	306	238
	MAX	13.6	.	.0210	32	3600	426.0
	CASES	37	0	25	31	32	32
	OPEN WATER E						
	MEDIAN	9.4	.	.0061	17	81	65.3
	COEF VAR	11	.	88	126	153	133
	MAX	11.8	.	.0200	85	400	360.0
	CASES	24	0	16	22	14	21
	OPEN WATER L						
	MEDIAN	10.0		.0030	3	13	13
	COEF VAR	17	.	93	180	291	128
	MAX	13.7	.	.0150	65	2000	200.0
	CASES	33	0	21	20	17	23
	TOTAL MEDIAN	10.1		.0020	4	20	11
FT MCM	ICE COVER						
	MEDIAN	12.4	.	.0009	18	52	
	COEF VAR	7	.	185	52	101	.
	MAX	12.9	.	.0230	33	338	.
	CASES	4	0	8	8	10	0
	OPEN WATER E						
	MEDIAN	9.2	.	.0020	12	50	
	COEF VAR	12	.	128	136	137	.
	MAX	9.9	.	.0190	110	540	.
	CASES	3	0	8	15	15	0
	OPEN WATER L						
	MEDIAN	10.0	.	.0009	8	41	
	COEF VAR	6	.	155	178	171	.
	MAX	11.3	.	.0240	140	920	.
	CASES	6	0	13	16	17	0
	TOTAL MEDIAN	10.0	.	.0009	11	47	.

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS
1970 - 1983

STEM	PERIOD	TP mg/l	TDP mg/l	SRP mg/l	TOTAL NITROGEN mg/l	KJELDAHL NITOGEN mg/l	NO2 + NO3 mg/l	NH3 mg/l	DISSOLVED NITROGEN mg/l	PARTIC. NITROGEN mg/l
JASPER	ICE COVER									
	MEDIAN	.009	.006	.003	.27	.17	.11	.09	.14	.01
	COEF VAR	76	41	22	36	48	24	9	21	87
	MAX	.041	.012	.003	.60	.40	.20	.12	.22	.08
	CASES	35	25	7	15	15	35	12	25	24
	OPEN WATER E									
	MEDIAN	.017	.003	.002	.15	.09	.05	.09	.09	.03
	COEF VAR	97	39	63	59	48	88	5	43	470
	MAX	.140	.009	.007	.57	.30	.37	.10	.22	7.10
	CASES	57	29	8	30	30	57	15	30	30
	OPEN WATER L									
	MEDIAN	.008	.003	.002	.15	.10	.05	.09	.07	.01
	COEF VAR	274	42	23	69	87	83	5	53	96
	MAX	.600	.009	.003	.76	.70	.42	.10	.26	.08
	CASES	55	26	6	32	32	56	12	27	27
	TOTAL MEDIAN	.010	.003	.003	.17	.10	.06	.09	.10	.01
ATHABASCA	ICE COVER									
	MEDIAN	.013	.007	.003	.51	.38	.10	.09	.33	.03
	COEF VAR	279	60	339	20	25	66	11	87	129
	MAX	.580	.025	.400	.69	.60	.40	.15	2.30	.37
	CASES	43	33	15	15	16	61	36	35	35
	MEDIAN	.120	.006	.003	.49	.45	.04	.09	.25	.22
	COEF VAR	81	66	95	62	62	82	4	49	79
	MAX	.500	.021	.020	1.17	1.10	.21	.10	.61	.83
	CASES	25	22	9	6	6	36	20	22	22
	OPEN WATER L									
	MEDIAN	.024	.003	.002	.41	.40	.01	.09	.17	.09
	COEF VAR	137	73	37	46	48	193	5	28	77
	MAX	.330	.020	.005	.71	.70	.41	.10	.34	.36
	CASES	36	26	10	13	13	47	22	26	26
	TOTAL MEDIAN	.022	.006	.003	.47	.40	.05	.09	.27	.08
FT MCM	ICE COVER									
	MEDIAN	.025	.	.009	.70	.60	.14	.03	.14	.01
	COEF VAR	93	.	122	47	55	55	85	40	51
	MAX	.162	.	.090	1.57	1.46	.37	.12	.20	.01
	CASES	24	0	22	20	20	41	20	12	12
	OPEN WATER E									
	MEDIAN	.130	.	.013	.94	.90	.05	.05	.05	.01
	COEF VAR	183	.	80	75	70	177	243	158	87
	MAX	2.500	.	.057	3.85	3.19	.66	1.40	.40	.02
	CASES	25	0	27	18	18	34	25	20	20
	OPEN WATER L									
	MEDIAN	.047	.	.010	.68	.64	.01	.01	.01	.01
	COEF VAR	195	.	67	59	60	160	172	126	63
	MAX	1.300	.	.037	1.71	1.70	.18	.29	.04	.01
	CASES	33	0	27	23	23	39	24	17	19
	TOTAL MEDIAN	.048	.	.010	.75	.70	.04	.03	.03	.01

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS
1970 - 1983

STEM	PERIOD	PHENOL mg/l	APPARENT COLOR rel.units	TOTAL COLOR rel.units	CYANIDE mg/l	TOC mg/l	DOC mg/l	DIC mg/l	PC mg/l
JASPER	ICE COVER								
	MEDIAN	.0010	4.9	5	.0010	1.0	.90	21	.13
	COEF VAR	99	54	0	137	45	41	13	92
	MAX	.0080	20.0	5	.0190	3.0	1.00	25	.74
	CASES	24	28	7	26	11	25	9	24
	OPEN WATER E								
	MEDIAN	.0010	4.9	5	.0020	2.0	1.00	17	.34
	COEF VAR	103	137	37	70	63	128	36	158
	MAX	.0090	100.0	10	.0070	6.0	11.00	25	7.80
	CASES	30	43	14	28	13	28	8	28
	OPEN WATER L								
	MEDIAN	.0010	5.0	5	.0010	2.0	.80	16	.33
	COEF VAR	88	141	73	97	47	188	29	152
	MAX	.0060	100.0	20	.0100	3.0	12.00	19	5.00
	CASES	29	44	12	30	15	27	8	27
	TOTAL MEDIAN	.0010	4.9	5	.0010	2.0	.90	18	.25
ATHABASCA	ICE COVER								
	MEDIAN	.0020	20.0	30	.0010	9.0	6.25	35	.22
	COEF VAR	137	92	25	21	54	49	27	113
	MAX	.0200	160.0	40	.0070	26.0	25.00	49	2.41
	CASES	41	54	10	3	14	38	16	34
	OPEN WATER E								
	MEDIAN	.0020	60.0	30	.0049	11.0	7.05	20	3.55
	COEF VAR	125	75	65	0	57	44	21	70
	MAX	.0180	200.0	80	.0049	28.0	14.00	31	9.80
	CASES	25	25	11	2	9	22	6	20
	OPEN WATER L								
	MEDIAN	.0010	25.0	20	.0050	9.0	4.80	23	.73
	COEF VAR	177	54	70	45	52	42	11	110
	MAX	.0250	70.0	70	.0120	23.0	12.00	27	6.80
	CASES	32	39	12	5	17	27	8	26
	TOTAL MEDIAN	.0015	25.0	30	.0050	9.0	6.00	27	.70
FT MCM	ICE COVER								
	MEDIAN	.0025	25.0	20	.0030	10.0	10.00	33	.
	COEF VAR	99	100	77	73	32	32	12	.
	MAX	.0190	200.0	80	.0090	22.5	20.00	40	.
	CASES	26	34	13	21	30	20	4	0
	OPEN WATER E								
	MEDIAN	.0030	50.0	40	.0040	12.0	9.50	24	.
	COEF VAR	151	39	36	94	50	47	2	.
	MAX	.0410	80.0	60	.0210	30.0	23.50	25	.
	CASES	29	19	10	21	33	16	3	0
	OPEN WATER L								
	MEDIAN	.0020	35.0	35	.0040	10.3	9.25	18	.
	COEF VAR	108	51	99	77	54	60	.	.
	MAX	.0170	100.0	190	.0160	26.0	25.00	18	.
	CASES	32	23	10	24	36	16	1	0
	TOTAL MEDIAN	.0030	30.0	30	.0035	11.0	10.00	28	.

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS
1970 - 1983

STEM	PERIOD	SiO2 mg/l	Fl mg/l	B mg/l	Fe(ext.) mg/l	Fe(dis.) mg/l	Mn(ext.) mg/l	Mn(dis.) mg/l
JASPER	ICE COVER							
	MEDIAN	4.2	.08	.030	.12	.04	.010	.010
	COEF VAR	16	32	29	76	8	67	36
	MAX	7.2	.17	.040	.39	.05	.040	.019
	CASES	33	33	28	13	18	13	14
	OPEN WATER E							
	MEDIAN	3.5	.06	.020	.39	.04	.029	.010
	COEF VAR	25	31	29	106	9	107	29
	MAX	4.4	.13	.040	2.20	.05	.150	.019
	CASES	38	37	33	11	25	11	19
	OPEN WATER L							
	MEDIAN	2.9	.06	.020	.17	.04	.012	.009
	COEF VAR	26	24	38	114	9	79	26
	MAX	5.6	.10	.060	1.40	.05	.054	.020
	CASES	34	34	31	14	19	14	16
	TOTAL MEDIAN	3.6	.07	.020	.17	.04	.010	.010
ATHABASCA	ICE COVER							
	MEDIAN	5.3	.11	.080	.18	.07	.010	.010
	COEF VAR	21	30	36	30	45	36	54
	MAX	8.5	.26	.150	.26	.15	.022	.040
	CASES	57	42	31	9	28	10	27
	OPEN WATER E							
	MEDIAN	5.0	.07	.070	2.10	.07	.160	.010
	COEF VAR	20	73	46	116	62	119	284
	MAX	6.4	.33	.130	13.40	.27	.650	.420
	CASES	35	27	22	9	21	9	21
	OPEN WATER L							
	MEDIAN	4.1	.08	.050	0.57	.07	.034	.010
	COEF VAR	28	24	181	102	36	89	38
	MAX	7.7	.14	.900	3.70	.12	.170	.020
	CASES	48	39	29	17	22	19	21
	TOTAL MEDIAN	4.8	.09	.070	0.46	.07	.026	.016
FT MCM	ICE COVER							
	MEDIAN	5.7	.11	.060	.35	.12	.014	.009
	COEF VAR	14	45	44	53	59	88	5
	MAX	7.8	.23	.140	1.21	.17	.073	.010
	CASES	44	24	22	28	4	29	4
	OPEN WATER E							
	MEDIAN	4.8	.08	.060	2.45	.06	.118	.009
	COEF VAR	20	23	52	134	63	100	35
	MAX	7.0	.13	.110	28.00	.13	.740	.010
	CASES	32	17	18	27	8	29	8
	OPEN WATER L							
	MEDIAN	4.4	.09	.060	0.84	.07	.039	.010
	COEF VAR	32	23	61	152	53	107	5
	MAX	9.0	.12	.170	15.00	.15	.310	.010
	CASES	34	19	23	32	3	34	3
	TOTAL MEDIAN	5.1	.09	.060	0.82	.06	.040	.009

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS
1970 - 1983

STEM	PERIOD	Al(ext.) mg/l	Al(dis.) mg/l	Sb(total) mg/l	Ba(total) mg/l	Ba(ext.) mg/l	Cd(total) mg/l	Cd(ext.) mg/l	Cd(dis.) mg/l
JASPER	ICE COVER								
	MEDIAN	.026	.0005	.	.055	.050	.0009	.001	.
	COEF VAR	76	40	.	28	21	5	30	.
	MAX	.040	.0014	.	.090	.090	.0010	.002	.
	CASES	2	22	0	14	13	14	13	0
	OPEN WATER E								
	MEDIAN	.950	.0005	.	.050	.050	.0009	.001	.
	COEF VAR	.	131	.	26	32	64	0	.
	MAX	.950	.0049	.	.090	.099	.0040	.001	.
	CASES	1	25	0	20	13	20	11	0
	OPEN WATER L								
	MEDIAN	.030	.0005	.	.050	.049	.0009	.001	.
	COEF VAR	120	21	.	34	30	4	30	.
	MAX	.220	.0009	.	.100	.099	.0010	.002	.
	CASES	3	21	0	16	14	16	14	0
	TOTAL MEDIAN	.035	.0005	.	.050	.050	.0009	.001	.
ATHABASCA	ICE COVER								
	MEDIAN	.046	.0005	.	.090	.090	.0009	.001	.
	COEF VAR	72	145	.	9	23	6	149	.
	MAX	.099	.0060	.	.100	.120	.0010	.009	.
	CASES	9	24	0	4	9	4	9	0
	OPEN WATER E								
	MEDIAN	0.695	.0005	.399	.080	.090	.0009	.001	.
	COEF VAR	86	136	35	23	85	4	125	.
	MAX	2.600	.0049	.399	.090	.400	.0010	.009	.
	CASES	8	18	3	5	10	5	9	0
	OPEN WATER L								
	MEDIAN	.320	.0005	.399	.080	.090	.0009	.001	.
	COEF VAR	130	195	12	34	19	5	122	.
	MAX	2.900	.0140	.499	.110	.099	.0010	.009	.
	CASES	17	24	5	8	17	8	17	0
	TOTAL MEDIAN	.255	.0005	.399	.080	.090	.0009	.001	.
FT MCM	ICE COVER								
	MEDIAN	.105	.0005	.010	.	.060	.	.001	.001
	COEF VAR	70	50	1	.	19	.	103	.
	MAX	.350	.0015	.010	.	.090	.	.007	.001
	CASES	28	24	3	0	9	0	25	1
	OPEN WATER E								
	MEDIAN	0.750	.0009	.	.	.080	.	.001	.001
	COEF VAR	153	162	.	.	22	.	33	6
	MAX	11.400	.0210	.	.	.090	.	.002	.001
	CASES	27	22	0	0	6	0	21	3
	OPEN WATER L								
	MEDIAN	.290	.0006	.	.	.090	.	.001	.001
	COEF VAR	122	153	.	.	30	.	0	.
	MAX	3.300	.0100	.	.	.100	.	.001	.001
	CASES	32	27	0	0	9	0	25	1
	TOTAL MEDIAN	.270	.0007	.010	.	.065	.	.001	.001

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS
1970 - 1983

STEM	PERIOD	Cr mg/l	Co(total) mg/l	Co(ext.) mg/l	Cu(total) mg/l	Cu(ext.) mg/l	Pb(total) mg/l	Pb(ext.) mg/l	Pb(dis.) mg/l
JASPER	ICE COVER								
	MEDIAN	.015	.002	.002	.001	.001	.004	.004	.
	COEF VAR	18	77	16	214	130	62	24	.
	MAX	.015	.007	.003	.027	.011	.004	.005	.
	CASES	4	13	11	13	12	10	13	0
	OPEN WATER E								
	MEDIAN	.010	.002	.002	.001	.001	.004	.004	.
	COEF VAR	25	37	2	100	66	36	41	.
	MAX	.015	.004	.002	.009	.004	.004	.006	.
	CASES	3	20	9	20	11	11	11	0
	OPEN WATER L								
	MEDIAN	.015	.002	.002	.001	.001	.004	.004	.
	COEF VAR	13	21	0	64	68	54	22	.
	MAX	.015	.002	.002	.004	.004	.004	.004	.
	CASES	7	16	10	15	14	8	14	0
	TOTAL MEDIAN	.015	.002	.002	.001	.001	.004	.004	.
ATHABASCA	ICE COVER								
	MEDIAN	.015	.002	.002	.001	.002	.004	.004	.001
	COEF VAR	19	108	96	57	95	60	67	0
	MAX	.015	.009	.009	.003	.009	.004	.009	.001
	CASES	9	4	9	4	10	3	10	4
	OPEN WATER E								
	MEDIAN	.015	.002	.005	.003	.004	.004	.004	.001
	COEF VAR	21	38	72	47	105	60	104	93
	MAX	.015	.003	.013	.004	.019	.004	.014	.004
	CASES	9	5	9	5	9	3	9	3
	OPEN WATER L								
	MEDIAN	.015	.002	.002	.002	.002	.004	.004	.001
	COEF VAR	22	27	80	96	89	51	115	104
	MAX	.019	.002	.009	.010	.009	.005	.020	.005
	CASES	17	8	17	8	19	5	18	3
	TOTAL MEDIAN	.015	.002	.002	.002	.002	.004	.004	.001
FT MCM	ICE COVER								
	MEDIAN	.015	.	.002	.	.003	.	.004	.001
	COEF VAR	0	.	114	.	83	.	187	91
	MAX	.015	.	.013	.	.012	.	.056	.004
	CASES	8	0	24	0	29	0	28	3
	OPEN WATER E								
	MEDIAN	.015	.	.002	.	.004	.	.004	.004
	COEF VAR	15	.	165	.	112	.	97	55
	MAX	.015	.	.030	.	.040	.	.019	.006
	CASES	6	0	18	0	29	0	29	7
	OPEN WATER L								
	MEDIAN	.015	.	.002	.	.003	.	.004	.002
	COEF VAR	19	.	65	.	111	.	87	88
	MAX	.015	.	.006	.	.024	.	.017	.004
	CASES	9	0	23	0	35	0	34	2
	TOTAL MEDIAN	.015	.	.002	.	.003	.	.004	.004

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS
1970 - 1983

STEM	PERIOD	Hg(total) ug/l	Hg(ext.) ug/l	Mo(ext.) mg/l	Ni(total) mg/l	Ni(ext.) mg/l	Ni(dis.) mg/l	Si mg/l	Se mg/l
JASPER	ICE COVER								
	MEDIAN	.019	.019	.	.002	.	.	.006	.0005
	COEF VAR	3	52	.	100	.	.	56	34
	MAX	.020	.049	.	.012	.	.	.009	.0005
	CASES	18	9	0	14	0	0	2	26
	OPEN WATER E								
	MEDIAN	.019	.019	.	.002	.	.	.009	.0005
	COEF VAR	3	52	.	107	.	.	0	50
	MAX	.020	.049	.	.015	.	.	.009	.0017
	CASES	23	8	0	17	0	0	2	29
	OPEN WATER L								
	MEDIAN	.419	.534	.	.002	.	.	.005	.0004
	COEF VAR	3	47	.	58	.	.	49	30
	MAX	.020	.049	.	.006	.	.	.009	.0005
	CASES	20	10	0	15	0	0	4	29
	TOTAL MEDIAN	.019	.019	.	.002	.	.	.006	.0005
ATHABASCA	ICE COVER								
	MEDIAN	.019	.019	.099	.002	.	.	.004	.0005
	COEF VAR	70	48	32	35	.	.	45	37
	MAX	.100	.049	.099	.004	.	.	.009	.0007
	CASES	26	11	8	4	0	0	9	28
	OPEN WATER E								
	MEDIAN	.019	.019	.049	.002	.	.	.004	.0005
	COEF VAR	30	50	38	58	.	.	43	73
	MAX	.040	.049	.099	.006	.	.	.009	.0020
	CASES	19	7	7	4	0	0	11	21
	OPEN WATER L								
	MEDIAN	.019	.049	.049	.003	.	.	.004	.0005
	COEF VAR	22	42	36	93	.	.	43	37
	MAX	.040	.049	.099	.014	.	.	.009	.0005
	CASES	21	12	14	8	0	0	19	29
	TOTAL MEDIAN	.019	.034	.049	.002	.	.	.004	.0005
FT MCM	ICE COVER								
	MEDIAN	.100	.049	.099	.	.002	.005	.001	.0005
	COEF VAR	87	23	0	.	201	.	76	39
	MAX	.600	.049	.099	.	.035	.005	.005	.0005
	CASES	19	8	6	0	22	1	14	22
	OPEN WATER E								
	MEDIAN	.100	.049	.099	.	.004	.006	.001	.0005
	COEF VAR	69	48	25	.	114	63	103	179
	MAX	.200	.090	.099	.	.034	.009	.009	.0065
	CASES	20	6	5	0	24	3	8	19
	OPEN WATER L								
	MEDIAN	.100	.049	.074	.	.003	.005	.001	.0002
	COEF VAR	50	31	37	.	138	.	103	125
	MAX	.200	.049	.100	.	.033	.005	.009	.0028
	CASES	23	9	6	0	23	1	10	22
	TOTAL MEDIAN	.100	.049	.099	.	.003	.005	.001	.0004

ATHABASCA RIVER HISTORIC SUMMARY STATISTICS

1970 - 1983

STEM	PERIOD	Sr(ext.) mg/l	Vn(total) mg/l	Vn(ext.) mg/l	Zn(total) mg/l	Zn(ext.) mg/l	Zn(dis.) mg/l
JASPER	ICE COVER						
	MEDIAN	.31	.00099	.001	.002	.002	.
	COEF VAR	12	75	3	71	68	.
	MAX	.33	.00300	.001	.007	.006	.
	CASES	2	12	11	12	13	0
	OPEN WATER E						
	MEDIAN	.19	.00099	.001	.003	.001	.
	COEF VAR	.	100	5	99	155	.
	MAX	.19	.00700	.001	.018	.024	.
	CASES	1	20	9	17	11	0
	OPEN WATER L						
	MEDIAN	.19	.00099	.001	.002	.001	.
	COEF VAR	18	44	3	82	54	.
	MAX	.23	.00200	.001	.013	.003	.
	CASES	3	16	10	14	14	0
	TOTAL MEDIAN	.21	.00099	.001	.003	.001	.
ATHABASCA	ICE COVER						
	MEDIAN	.33	.00099	.001	.003	.002	.0020
	COEF VAR	25	174	160	53	60	115
	MAX	.46	.01800	.049	.005	.005	.0100
	CASES	8	4	7	4	9	4
	OPEN WATER E						
	MEDIAN	.17	.00100	.027	.008	.015	.0009
	COEF VAR	30	110	109	67	186	6
	MAX	.25	.00600	.090	.011	.080	.0010
	CASES	9	5	6	4	8	3
	OPEN WATER L						
	MEDIAN	.21	.00095	.007	.006	.003	.0030
	COEF VAR	33	89	116	65	80	67
	MAX	.51	.00500	.049	.018	.010	.0050
	CASES	17	8	12	8	17	3
	TOTAL MEDIAN	.23	.00099	.003	.005	.002	.0010
FT MCM	ICE COVER						
	MEDIAN	.33	.	.001	.	.007	.0030
	COEF VAR	10	.	0	.	118	33
	MAX	.38	.	.001	.	.071	.0040
	CASES	9	0	8	0	28	3
	OPEN WATER E						
	MEDIAN	.22	.	.002	.	.012	.0020
	COEF VAR	17	.	101	.	123	107
	MAX	.25	.	.009	.	.120	.0110
	CASES	6	0	7	0	29	7
	OPEN WATER L						
	MEDIAN	.20	.	.001	.	.004	.0009
	COEF VAR	38	.	59	.	143	0
	MAX	.44	.	.003	.	.082	.0009
	CASES	9	0	7	0	34	2
	TOTAL MEDIAN	.24	.	.001	.	.008	.0020

APPENDIX II

ATHABASCA RIVER SUMMARY STATISTICS-1984 DATA

SITE	TDS mg/l	COND us/cm	FR mg/l	NFR mg/l	TURB NTU	HARD mg/l	ALK mg/l
OLD ENRANCE							
MEAN	156.49	286	210	45.2	11.9	136	99.9
COEF.VARIATION	39	36	47	91	81	43	24
MAX	252.00	440	280	123.2	20.0	230	135.0
D/S HINTON 5KM LB							
MEAN	165.56	298	254	36.7	17.4	138	102.0
COEF.VARIATION	44	38	38	98	97	39	24
MAX	284.76	483	350	106.8	50.0	221	136.8
D/S HINTON 5KM RB							
MEAN	176.27	318	250	54.7	25.9	143	108.9
COEF.VARIATION	44	40	37	101	96	39	21
MAX	306.54	527	380	158.4	60.0	233	137.6
D/S HINTON 20KM LB							
MEAN	171.43	313	238	37.6	17.8	140	104.2
COEF.VARIATION	44	40	43	97	108	40	24
MAX	296.44	514	350	108.4	55.0	230	139.3
D/S HINTON 20KM RB							
MEAN	172.76	314	252	43.2	21.9	139	108.7
COEF.VARIATION	43	39	44	109	105	39	25
MAX	297.48	514	390	137.2	65.0	228	147.5
D/S HINTON 50KM							
MEAN	172.18	318	265	34.2	8.1	150	126.9
COEF.VARIATION	39	36	19	152	106	35	29
MAX	282.00	504	300	139.4	20.0	237	176.2
U/S WINFALL							
MEAN	159.97	299	220	30.5	7.3	139	119.9
COEF.VARIATION	32	31	19	155	79	33	24
MAX	256.00	466	250	126.0	15.0	224	169.0
U/S FT.ASSINIBOINE							
MEAN	157.35	295	240	32.3	10.6	132	125.2
COEF.VARIATION	32	30	18	119	79	33	25
MAX	251.00	459	270	106.4	20.0	215	183.0
U/S LSR							
MEAN	154.31	290	230	68.4	24.3	129	125.7
COEF.VARIATION	33	31	0	132	66	35	26
MAX	251.00	461	230	247.2	40.0	217	188.0
U/S ATHABASCA							
MEAN	137.41	260	215	87.8	22.9	113	112.8
COEF.VARIATION	29	28	3	140	61	32	23
MAX	211.00	392	220	334.8	30.0	182	160.0
D/S ATHABASCA							
MEAN	144.03	273	195	108.2	20.5	117	118.8
COEF.VARIATION	24	24	4	177	64	26	20
MAX	208.00	393	200	497.4	30.0	177	161.0
U/S HOUSE RIVER							
MEAN	142.75	272	205	209.4	33.1	116	114.1
COEF.VARIATION	26	26	10	179	100	26	23
MAX	211.00	406	220	966.0	80.0	173	161.0

ATHABASCA RIVER SUMMARY STATISTICS-1984 DATA

STEM	SITE	OIL mg/l	COLOR rel. units	PHYTO. CHL a mg/m3	EPILITH. CHL a mg/m2	TC mg/l	FC mg/l	SiO2 mg/l	F1 mg/l
MAINSTEM	OLD ENRANCE								
	MEAN	.37	9.0	.4	5.7	55	6	2.8	.10
	COEF.VARIATION	54	89	40	95	131	123	17	28
	MAX	.66	24.1	.6	12.3	350	28	3.4	.14
	D/S HINTON 5KM LB								
	MEAN	.38	11.5	.5	12.5	239	29	3.1	.11
	COEF.VARIATION	64	144	60	160	205	242	23	23
	MAX	.70	44.2	.8	42.4	8000	8000	4.4	.14
	D/S HINTON 5KM RB								
	MEAN	.55	31.6	.7	14.5	546	62	3.4	.11
	COEF.VARIATION	72	99	95	162	184	218	21	25
	MAX	1.20	87.8	1.7	54.6	8000	8000	4.5	.14
	D/S HINTON 20KM LB								
	MEAN	.43	22.1	1.4	18.1	462	79	3.1	.11
	COEF.VARIATION	83	86	115	85	195	214	29	23
	MAX	1.10	59.6	3.7	35.0	8000	5200	4.5	.14
	D/S HINTON 20KM RB								
	MEAN	.29	23.3	.9	26.7	402	81	3.4	.10
	COEF.VARIATION	25	63	89	139	202	238	25	23
	MAX	.40	50.0	2.1	89.2	8000	8000	4.8	.13
	D/S HINTON 50KM								
	MEAN	.28	29.4	1.3	19.4	267	20	4.6	.08
	COEF.VARIATION	46	54	122	124	76	197	46	22
	MAX	.50	56.6	4.3	53.8	800	600	7.2	.11
	U/S WINFALL								
	MEAN	.39	26.6	1.5	20.9	290	8	3.6	.10
	COEF.VARIATION	36	38	102	152	78	164	12	9
	MAX	.54	35.2	4.1	68.4	900	80	4.1	.11
	U/S FT.ASSINIBOINE								
	MEAN	.56	24.9	1.1	12.4	234	9	4.2	.09
	COEF.VARIATION	64	32	93	122	110	132	15	10
	MAX	1.00	34.0	2.9	34.7	1000	60	4.8	.11
	U/S LSR								
	MEAN	.36	26.2	2.4	4.6	124	9	4.3	.09
	COEF.VARIATION	42	47	108	175	71	52	17	8
	MAX	.60	43.4	6.1	16.7	340	16	5.0	.10
	U/S ATHABASCA								
	MEAN	.34	35.5	4.1	6.3	323	9	4.3	.09
	COEF.VARIATION	57	34	62	154	101	105	14	6
	MAX	.60	55.6	7.7	17.4	1300	36	5.2	.09
	D/S ATHABASCA								
	MEAN	.45	31.7	3.8	1.6	288	8	4.5	.08
	COEF.VARIATION	48	30	43	92	76	95	19	43
	MAX	.70	48.2	6.2	3.9	800	36	5.8	.10
	U/S HOUSE RIVER								
	MEAN	.24	41.9	5.2	11.3	248	10	3.7	.10
	COEF.VARIATION	23	84	62	117	52	91	30	13
	MAX	.30	111.1	9.4	26.5	500	36	5.3	.12

STEM	SITE	OIL mg/l	COLOR rel. units	PHYTO. CHL a mg/m3	EPILITH. CHL a mg/m2	TC mg/l	FC mg/l	SiO2 mg/l	F1 mg/l
	U/S FT.MCMURRAY								
	MEAN	.25	40.7	4.2	5.4	219	12	3.3	.10
	COEF.VARIATION	40	55	79	100	88	144	23	11
	MAX	.40	75.9	10.1	12.8	900	98	4.1	.12
	U/S SUNCOR								
	MEAN	.48	52.3	4.9	4.7	685	29	4.5	.11
	COEF.VARIATION	80	61	52	162	91	54	14	5
	MAX	.91	100.0	7.5	16.0	3000	60	5.6	.11
	BITUMONT								
	MEAN	.46	65.2	5.1	1.7	239	12	4.0	.10
	COEF.VARIATION	45	45	55	117	134	103	14	9
	MAX	.80	105.6	8.2	4.3	1600	56	4.9	.12
	EMBARRAS								
	MEAN	.21	46.1	4.9	2.7	201	8	4.2	.11
	COEF.VARIATION	64	49	63	123	107	52	17	9
	MAX	.40	72.2	8.3	6.4	1200	16	5.3	.12
TRIBUTARIES	BERLUND								
	MEAN	.38	22.2	.7	4.0	63	6	5.6	.10
	COEF.VARIATION	85	66	69	95	96	84	18	12
	MAX	1.00	47.2	1.5	10.4	220	20	7.6	.12
	MACLEOD RIVER								
	MEAN	.36	31.8	1.9	8.4	99	13	5.9	.09
	COEF.VARIATION	58	44	63	127	90	82	21	14
	MAX	.70	52.8	3.3	23.8	410	24	7.0	.11
	PEMBINA RIVER								
	MEAN	.42	31.5	8.9	5.1	50	11	2.9	.10
	COEF.VARIATION	78	34	120	118	118	161	47	12
	MAX	.90	43.4	23.7	26.1	260	44	4.0	.12
	LESSER SLAVE RIVER								
	MEAN	.37	47.5	7.9	3.0	430	14	2.9	.08
	COEF.VARIATION	99	67	62	.	59	127	67	5
	MAX	1.10	81.1	14.7	3.0	1010	88	5.2	.09
	LABICHE RIVER								
	MEAN	.32	64.4	11.0	6.3	386	16	3.9	.11
	COEF.VARIATION	56	66	70	23	120	87	47	8
	MAX	.60	120.8	21.9	8.3	2100	56	6.1	.12
	CALLING RIVER								
	MEAN	.44	35.9	13.0	19.5	964	6	2.0	.09
	COEF.VARIATION	52	66	59	120	86	53	62	8
	MAX	.70	70.2	20.5	46.4	3700	12	4.0	.10
	HOUSE RIVER								
	MEAN	.34	148.9	7.3	15.6	378	10	5.5	.14
	COEF.VARIATION	61	46	86	161	129	158	37	18
	MAX	.70	234.0	17.8	60.1	2600	120	7.8	.19
	CLEARWATER RIVER								
	MEAN	.48	60.5	5.3	12.0	379	19	6.3	.11
	COEF.VARIATION	68	64	49	168	142	185	21	13
	MAX	1.00	114.9	8.2	47.7	4700	332	7.7	.13

STEM	SITE	OIL mg/l	COLOR rel. units	PHYTO. CHL a mg/m3	EPILITH. CHL a mg/m2	TC mg/l	FC mg/l	SiO2 mg/l	Fl mg/l
	POPLAR CREEK								
	MEAN	.30	82.2	8.3	18.8	215	5	3.8	.14
	COEF.VARIATION	75	27	41	115	100	40	42	8
	MAX	.70	113.0	13.1	50.3	770	8	5.6	.16
EFFLUENTS	ST.REGIS-GRAB								
	MEAN	1.90	1724.0	.	.	18365	4570	6.0	.15
	COEF.VARIATION	113	17	.	.	100	107	18	10
	MAX	5.90	2149.0	.	.	90000	29000	7.3	.17
	ST.REGIS-COMPOSITE								
	MEAN	2.60	1704.6	.	.	.	.	6.0	.15
	COEF.VARIATION	68	17	.	.	.	.	17	9
	MAX	4.80	2128.0	.	.	.	.	7.1	.17
	WHITECOURT STP								
	MEAN	.82	23.4	.	.	6223	3890	11.8	.75
	COEF.VARIATION	125	14	.	.	81	58	5	6
	MAX	2.60	26.4	.	.	210000	8200	12.3	.80
	ATHABASCA STP								
	MEAN	.43	38.8	.	.	1849	99	8.4	1.10
	COEF.VARIATION	79	21	.	.	150	151	16	20
	MAX	1.10	46.3	.	.	70000	920	10.1	1.38
	FT.McMURRAY STP								
	MEAN	1.58	40.6	.	.	10641	2089	7.8	.77
	COEF.VARIATION	86	18	.	.	153	200	12	10
	MAX	3.70	48.1	.	.	80000	50000	9.2	.90
	SUNCOR FINAL EFF.								
	MEAN	1.36	.	.	.	.	.	5.1	.14
	COEF.VARIATION	72	.	.	.	.	.	29	10
	MAX	3.00	.	.	.	.	.	6.9	.16

ATHABASCA RIVER SUMMARY STATISTICS-1984 DATA

STEM	SITE	TP mg/l	TDP mg/l	SRP mg/l	TKN mg/l	PN mg/l	NO2NO3 mg/l	NO2 mg/l	NH3 mg/l
MAINSTEM	OLD ENRANCE								
	MEAN	.019	.003	.003	.08	.05	.063	.0027	.009
	COEF.VARIATION	101	72	47	48	96	55	136	66
	MAX	.056	.007	.005	.15	.11	.128	.0100	.017
	D/S HINTON 5KM LB								
	MEAN	.034	.007	.003	.15	.14	.060	.0010	.010
	COEF.VARIATION	95	72	46	50	51	36	4	52
	MAX	.100	.015	.005	.26	.23	.097	.0010	.018
	D/S HINTON 5KM RB								
	MEAN	.048	.005	.004	.21	.18	.059	.0015	.017
	COEF.VARIATION	82	94	52	67	66	36	84	81
	MAX	.105	.012	.006	.42	.35	.097	.0040	.041
	D/S HINTON 20KM LB								
	MEAN	.036	.005	.003	.28	.14	.060	.0011	.020
	COEF.VARIATION	71	76	43	78	31	37	37	53
	MAX	.084	.010	.005	.56	.21	.097	.0020	.036
	D/S HINTON 20KM RB								
	MEAN	.034	.004	.003	.24	.15	.065	.0013	.017
	COEF.VARIATION	81	66	43	61	31	45	41	67
	MAX	.086	.008	.005	.40	.22	.121	.0020	.037
	D/S HINTON 50KM								
	MEAN	.016	.003	.004	.18	.09	.043	.0013	.010
	COEF.VARIATION	97	98	41	51	63	91	39	143
	MAX	.044	.010	.006	.36	.16	.108	.0020	.041
	U/S WINFALL								
	MEAN	.021	.004	.004	.15	.16	.045	.0012	.009
	COEF.VARIATION	121	100	42	56	70	94	36	101
	MAX	.072	.012	.006	.28	.22	.126	.0020	.025
	U/S FT.ASSINIBOINE								
	MEAN	.019	.003	.004	.26	.08	.040	.0012	.012
	COEF.VARIATION	56	82	51	69	142	111	35	73
	MAX	.030	.008	.007	.60	.22	.128	.0020	.023
	U/S LSR								
	MEAN	.064	.005	.004	.31	.28	.048	.0012	.013
	COEF.VARIATION	118	89	48	83	116	131	35	91
	MAX	.210	.010	.007	.78	.65	.175	.0020	.037
	U/S ATHABASCA								
	MEAN	.047	.006	.005	.37	.30	.042	.0018	.012
	COEF.VARIATION	49	61	54	19	122	131	41	79
	MAX	.080	.010	.008	.49	.72	.154	.0030	.031
	D/S ATHABASCA								
	MEAN	.077	.008	.005	.42	.14	.044	.0017	.020
	COEF.VARIATION	131	85	61	60	88	128	49	70
	MAX	.280	.020	.010	.92	.26	.156	.0030	.039
	U/S HOUSE RIVER								
	MEAN	.084	.008	.005	.57	.14	.044	.0015	.021
	COEF.VARIATION	88	31	45	80	91	149	56	70
	MAX	.200	.012	.008	1.50	.28	.177	.0030	.045

STEM	SITE	TP	TDP	SRP	TKN	PN	NO2NO3	NO2	NH3
		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
	U/S FT.MCMURRAY								
	MEAN	.080	.010	.006	.51	.08	.047	.0017	.013
	COEF.VARIATION	92	53	84	70	129	157	49	82
	MAX	.190	.021	.017	1.20	.19	.193	.0030	.033
	U/S SUNCOR								
	MEAN	.143	.014	.011	.57	.22	.050	.0020	.026
	COEF.VARIATION	124	39	42	54	118	145	45	46
	MAX	.480	.020	.018	1.15	.52	.198	.0030	.041
	BITUMONT								
	MEAN	.251	.015	.010	.66	.31	.054	.0022	.022
	COEF.VARIATION	140	48	45	88	109	135	54	108
	MAX	.900	.028	.016	1.60	.70	.200	.0040	.069
	EMBARRAS								
	MEAN	.130	.016	.010	.53	.21	.050	.0018	.022
	COEF.VARIATION	103	72	41	50	124	151	41	131
	MAX	.330	.038	.016	1.00	.52	.200	.0030	.079
TRIBUTARIES	BERLUND								
	MEAN	.019	.003	.004	.18	.13	.027	.0010	.004
	COEF.VARIATION	111	62	60	55	79	146	0	105
	MAX	.056	.006	.007	.35	.22	.078	.0010	.013
	MACLEOD RIVER								
	MEAN	.022	.005	.004	.32	.07	.009	.0014	.013
	COEF.VARIATION	70	40	57	27	77	115	40	58
	MAX	.038	.007	.008	.42	.11	.026	.0020	.024
	PEMBINA RIVER								
	MEAN	.059	.017	.011	.62	.57	.098	.0012	.037
	COEF.VARIATION	94	69	72	60	53	218	39	175
	MAX	.152	.034	.020	1.04	.79	.480	.0020	.154
	LESSER SLAVE RIVER								
	MEAN	.058	.011	.005	.66	.19	.021	.0037	.020
	COEF.VARIATION	85	35	36	23	16	109	89	55
	MAX	.150	.014	.007	.88	.22	.064	.0100	.037
	LABICHE RIVER								
	MEAN	.124	.052	.025	1.07	.20	.090	.0043	.049
	COEF.VARIATION	37	52	59	21	27	143	45	95
	MAX	.208	.090	.053	1.28	.24	.350	.0070	.119
	CALLING RIVER								
	MEAN	.077	.023	.010	.87	.40	.036	.0065	.025
	COEF.VARIATION	40	62	37	19	83	123	116	90
	MAX	.133	.050	.013	1.12	.79	.098	.0200	.070
	HOUSE RIVER								
	MEAN	.320	.038	.028	1.10	.24	.117	.0035	.062
	COEF.VARIATION	71	36	34	37	52	154	44	135
	MAX	.720	.056	.040	1.65	.36	.480	.0050	.228
	CLEARWATER RIVER								
	MEAN	.091	.025	.019	.56	.12	.043	.0020	.028
	COEF.VARIATION	69	17	40	36	20	179	56	99
	MAX	.180	.033	.029	.82	.15	.200	.0030	.082

STEM	SITE	TP mg/l	TDP mg/l	SRP mg/l	TKN mg/l	PN mg/l	NO2NO3 mg/l	NO2 mg/l	NH3 mg/l
	POPLAR CREEK								
	MEAN	.056	.023	.010	1.05	.13	.037	.0056	.063
	COEF.VARIATION	19	64	29	12	25	108	93	94
	MAX	.066	.039	.015	1.24	.17	.081	.0140	.161
EFFLUENTS	ST.REGIS-GRAB								
	MEAN	.862	.154	.	6.12	3.06	.055	.0500	.717
	COEF.VARIATION	31	35	.	38	50	22	0	59
	MAX	1.290	.220	.	10.00	5.05	.080	.0500	1.420
	ST.REGIS-COMPOSITE								
	MEAN	.847	.198	.	5.77	2.41	.050	.0500	.918
	COEF.VARIATION	34	70	.	32	63	0	0	32
	MAX	1.220	.450	.	8.00	4.25	.050	.0500	1.270
	WHITECOURT STP								
	MEAN	2.298	2.147	2.415	1.59	.25	11.775	.2235	.318
	COEF.VARIATION	34	39	34	32	127	29	64	113
	MAX	3.540	3.440	3.380	2.50	.71	18.000	.4700	1.020
	ATHABASCA STP								
	MEAN	4.657	4.500	4.485	16.27	.94	5.186	1.1862	13.805
	COEF.VARIATION	13	23	6	45	40	103	72	58
	MAX	5.600	5.200	4.690	27.20	1.29	15.000	2.4800	24.900
	FT.McMURRAY STP								
	MEAN	2.260	1.703	.927	26.50	1.77	.181	.1502	21.733
	COEF.VARIATION	37	40	139	12	24	168	180	13
	MAX	3.500	2.800	1.840	30.00	2.17	.800	.7000	26.100
	SUNCOR FINAL EFF.								
	MEAN	.182	.120	.060	.78	.32	.069	.0362	.105
	COEF.VARIATION	21	39	32	19	77	74	57	64
	MAX	.250	.170	.074	1.00	.69	.172	.0500	.175

ATHABASCA RIVER SUMMARY STATISTICS-1984 DATA

STEM	SITE	Al(ext.) mg/l	Be(ext.) mg/l	Cd(total) mg/l	Co(total) mg/l	Cu(total) mg/l	Cr(total) mg/l	Fe(ext.) mg/l	Pb(ext.) mg/l
MAINSTEM	OLD ENRANCE								
	MEAN	.121	.0010	.0010	.0010	.0040	.0103	.25	.003
	COEF.VARIATION	84	0	0	0	150	142	68	0
	MAX	.312	.0010	.0010	.0010	.0160	.0400	.53	.003
	D/S HINTON 5KM LB								
	MEAN	.088	.0010	.0013	.0013	.0022	.0040	.22	.003
	COEF.VARIATION	62	4	39	63	68	39	54	1
	MAX	.187	.0010	.0020	.0030	.0050	.0050	.40	.003
	D/S HINTON 5KM RB								
	MEAN	.182	.0010	.0013	.0016	.0030	.0048	.40	.003
	COEF.VARIATION	114	4	39	64	70	46	88	1
	MAX	.580	.0010	.0020	.0030	.0060	.0070	1.05	.003
	D/S HINTON 20KM LB								
	MEAN	.092	.0010	.0013	.0013	.0028	.0057	.24	.003
	COEF.VARIATION	48	4	39	63	57	50	47	13
	MAX	.176	.0010	.0020	.0030	.0050	.0090	.44	.004
	D/S HINTON 20KM RB								
	MEAN	.115	.0010	.0013	.0013	.0030	.0048	.26	.003
	COEF.VARIATION	71	4	41	63	52	20	52	1
	MAX	.245	.0010	.0020	.0030	.0050	.0060	.40	.003
	D/S HINTON 50KM								
	MEAN	.103	.0010	.0010	.0010	.0025	.0032	.23	.003
	COEF.VARIATION	90	0	0	0	94	81	71	0
	MAX	.279	.0010	.0010	.0010	.0070	.0070	.55	.003
	U/S WINFALL								
	MEAN	.113	.0010	.0010	.0010	.0042	.0037	.26	.003
	COEF.VARIATION	111	0	0	0	121	59	76	0
	MAX	.362	.0010	.0010	.0010	.0140	.0060	.55	.003
	U/S FT.ASSINIBOINE								
	MEAN	.160	.0010	.0010	.0013	.0027	.0045	.32	.003
	COEF.VARIATION	106	0	0	62	46	50	66	1
	MAX	.490	.0010	.0010	.0030	.0040	.0080	.74	.003
	U/S LSR								
	MEAN	.913	.0010	.0013	.0018	.0038	.0058	.62	.003
	COEF.VARIATION	208	0	39	112	63	62	58	1
	MAX	4.790	.0010	.0020	.0060	.0080	.0130	1.14	.003
	U/S ATHABASCA								
	MEAN	1.194	.0010	.0010	.0022	.0053	.0058	.78	.003
	COEF.VARIATION	217	0	0	95	69	52	79	1
	MAX	6.470	.0010	.0010	.0060	.0120	.0120	1.82	.003
	D/S ATHABASCA								
	MEAN	1.620	.0012	.0013	.0025	.0045	.0070	.75	.007
	COEF.VARIATION	225	36	39	129	85	73	94	148
	MAX	9.070	.0020	.0020	.0090	.0120	.0170	1.95	.030
	U/S HOUSE RIVER								
	MEAN	.121	.0010	.0013	.0030	.0063	.0068	1.18	.009
	COEF.VARIATION	87	0	39	122	123	99	70	168
	MAX	.257	.0010	.0020	.0100	.0220	.0200	2.65	.042

STEM	SITE	Al(ext.) mg/l	Be(ext.) mg/l	Cd(total) mg/l	Co(total) mg/l	Cu(total) mg/l	Cr(total) mg/l	Fe(ext.) mg/l	Pb(ext.) mg/l
	U/S FT.MCMURRAY								
	MEAN	.100	.0010	.0012	.0030	.0062	.0068	.93	.008
	COEF.VARIATION	87	0	36	104	100	81	62	156
	MAX	.223	.0010	.0020	.0090	.0180	.0170	1.59	.034
	U/S SUNCOR								
	MEAN	.091	.0010	.0012	.0023	.0042	.0057	1.23	.008
	COEF.VARIATION	83	0	36	85	97	76	63	157
	MAX	.182	.0010	.0020	.0060	.0110	.0140	2.00	.035
	BITUMONT								
	MEAN	1.913	.0010	.0015	.0040	.0060	.0088	1.60	.009
	COEF.VARIATION	209	0	37	95	92	77	63	161
	MAX	9.080	.0010	.0020	.0100	.0140	.0180	2.80	.037
	EMBARRAS								
	MEAN	1.557	.0010	.0015	.0028	.0053	.0060	2.46	.007
	COEF.VARIATION	211	4	37	80	69	73	120	148
	MAX	7.420	.0010	.0020	.0060	.0090	.0130	8.15	.030
TRIBUTARIES	BERLUND								
	MEAN	.085	.0010	.0012	.0012	.0018	.0025	.30	.003
	COEF.VARIATION	101	0	36	36	64	79	99	0
	MAX	.240	.0010	.0020	.0020	.0040	.0060	.86	.003
	MACLEOD RIVER								
	MEAN	.177	.0010	.0010	.0014	.0030	.0054	.37	.003
	COEF.VARIATION	134	0	0	65	33	70	67	0
	MAX	.585	.0010	.0010	.0030	.0040	.0120	.68	.003
	PEMBINA RIVER								
	MEAN	.217	.0010	.0010	.0016	.0044	.0052	.49	.003
	COEF.VARIATION	121	4	4	86	44	53	72	1
	MAX	.652	.0010	.0010	.0040	.0070	.0100	.86	.003
	LESSER SLAVE RIVER								
	MEAN	.717	.0010	.0012	.0015	.0030	.0027	.99	.003
	COEF.VARIATION	210	0	36	82	87	121	58	0
	MAX	3.780	.0010	.0020	.0040	.0080	.0090	1.54	.003
	LABICHE RIVER								
	MEAN	.961	.0010	.0011	.0018	.0026	.0060	1.41	.003
	COEF.VARIATION	210	4	37	74	63	69	57	1
	MAX	5.080	.0010	.0020	.0040	.0050	.0130	2.65	.003
	CALLING RIVER								
	MEAN	.110	.0010	.0012	.0010	.0048	.0043	.62	.003
	COEF.VARIATION	72	4	36	4	134	78	69	1
	MAX	.236	.0010	.0020	.0010	.0180	.0100	1.19	.003
	HOUSE RIVER								
	MEAN	.220	.0010	.0020	.0058	.0153	.0100	4.26	.014
	COEF.VARIATION	57	5	32	79	113	76	59	192
	MAX	.366	.0010	.0030	.0140	.0460	.0240	7.07	.068
	CLEARWATER RIVER								
	MEAN	.144	.0010	.0017	.0038	.0063	.0037	1.28	.003
	COEF.VARIATION	147	4	49	137	153	75	66	1
	MAX	.519	.0010	.0030	.0140	.0260	.0070	2.73	.003

STEM	SITE	Al(ext.) mg/l	Be(ext.) mg/l	Cd(total) mg/l	Co(total) mg/l	Cu(total) mg/l	Cr(total) mg/l	Fe(ext.) mg/l	Pb(ext.) mg/l
	POPLAR CREEK								
	MEAN	.068	.0010	.0010	.0010	.0022	.0030	.60	.005
	COEF.VARIATION	62	0	0	0	60	41	39	95
	MAX	.120	.0010	.0010	.0010	.0040	.0040	.97	.014
EFFLUENTS	ST.REGIS-GRAB								
	MEAN	.651	.0010	.0020	.0010	.0220	.0128	.70	.017
	COEF.VARIATION	28	0	45	0	33	25	27	79
	MAX	.782	.0010	.0030	.0010	.0350	.0190	1.05	.033
	ST.REGIS-COMPOSITE								
	MEAN	.557	.0010	.0028	.0020	.0407	.0152	.72	.028
	COEF.VARIATION	26	0	61	84	26	32	34	62
	MAX	.659	.0010	.0050	.0050	.0550	.0220	1.20	.044
	WHITECOURT STP								
	MEAN	.129	.0010	.0015	.0018	.0100	.0048	.08	.005
	COEF.VARIATION	51	0	56	112	41	55	22	78
	MAX	.201	.0010	.0030	.0060	.0160	.0100	.10	.012
	ATHABASCA STP								
	MEAN	.744	.0010	.0010	.0010	.0063	.0025	.17	.004
	COEF.VARIATION	210	0	0	0	34	71	41	33
	MAX	3.540	.0010	.0010	.0010	.0090	.0050	.27	.006
	FT.McMURRAY STP								
	MEAN	.361	.0010	.0010	.0010	.0033	.0033	.20	.003
	COEF.VARIATION	40	0	4	4	45	78	29	1
	MAX	.529	.0010	.0010	.0010	.0060	.0080	.28	.003
	SUNCOR FINAL EFF.								
	MEAN	.319	.0010	.0011	.0016	.0033	.0037	.37	.007
	COEF.VARIATION	68	5	39	106	63	80	59	146
	MAX	.703	.0010	.0020	.0050	.0070	.0080	.78	.029

ATHABASCA RIVER SUMMARY STATISTICS-1984 DATA

STEM	SITE	Mn(dis.) mg/l	Hg(total) mg/l	Mo(total) mg/l	Ni(total) mg/l	Se(total) mg/l	Vn(total) mg/l	Zn(total) mg/l	As(total) mg/l
MAINSTEM	OLD ENRANCE								
	MEAN	.025	.00009	.0010	.004	.0002	.003	.006	.0007
	COEF.VARIATION	80	0	0	85	0	54	63	116
	MAX	.063	.00009	.0010	.011	.0002	.007	.011	.0022
	D/S HINTON 5KM LB								
	MEAN	.023	.00011	.0030	.003	.0002	.004	.004	.0006
	COEF.VARIATION	63	41	52	78	0	45	73	93
	MAX	.050	.00020	.0040	.006	.0002	.007	.010	.0016
	D/S HINTON 5KM RB								
	MEAN	.040	.00011	.0038	.004	.0002	.004	.008	.0008
	COEF.VARIATION	68	41	65	63	0	46	75	98
	MAX	.075	.00020	.0070	.007	.0002	.007	.018	.0020
	D/S HINTON 20KM LB								
	MEAN	.026	.00009	.0022	.004	.0002	.004	.007	.0005
	COEF.VARIATION	45	0	85	75	0	31	64	102
	MAX	.047	.00009	.0050	.007	.0002	.005	.013	.0015
	D/S HINTON 20KM RB								
	MEAN	.027	.00009	.0026	.004	.0002	.004	.006	.0005
	COEF.VARIATION	54	0	109	45	0	20	80	96
	MAX	.050	.00009	.0080	.006	.0002	.005	.013	.0014
	D/S HINTON 50KM								
	MEAN	.025	.00009	.0010	.003	.0002	.003	.004	.0006
	COEF.VARIATION	68	0	0	85	0	57	90	120
	MAX	.058	.00009	.0010	.008	.0002	.006	.010	.0021
	U/S WINFALL								
	MEAN	.024	.00009	.0010	.003	.0002	.002	.008	.0006
	COEF.VARIATION	102	0	0	62	0	82	87	126
	MAX	.073	.00009	.0010	.006	.0002	.006	.018	.0021
	U/S FT.ASSINIBOINE								
	MEAN	.029	.00009	.0025	.005	.0002	.004	.008	.0007
	COEF.VARIATION	82	0	94	36	0	53	85	100
	MAX	.072	.00009	.0060	.008	.0002	.008	.020	.0022
	U/S LSR								
	MEAN	.053	.00009	.0032	.007	.0002	.006	.009	.0013
	COEF.VARIATION	120	0	81	49	0	64	128	117
	MAX	.177	.00009	.0070	.013	.0002	.014	.031	.0044
	U/S ATHABASCA								
	MEAN	.063	.00009	.0018	.007	.0002	.007	.009	.0014
	COEF.VARIATION	105	0	112	45	0	80	82	104
	MAX	.192	.00009	.0060	.014	.0002	.018	.025	.0044
	D/S ATHABASCA								
	MEAN	.082	.00009	.0023	.006	.0002	.007	.011	.0019
	COEF.VARIATION	148	0	141	91	0	116	136	140
	MAX	.329	.00009	.0090	.017	.0002	.024	.042	.0073
	U/S HOUSE RIVER								
	MEAN	.120	.00009	.0037	.008	.0002	.009	.020	.0032
	COEF.VARIATION	152	0	97	94	0	123	108	161
	MAX	.486	.00009	.0100	.024	.0002	.030	.065	.0123

STEM	SITE	Mn(dis.) mg/l	Hg(total) mg/l	Mo(total) mg/l	Ni(total) mg/l	Se(total) mg/l	Vn(total) mg/l	Zn(total) mg/l	As(total) mg/l
	U/S FT.MCMURRAY								
	MEAN	.096	.00024	.0033	.007	.0002	.008	.019	.0029
	COEF.VARIATION	144	154	115	67	0	125	107	161
	MAX	.362	.00100	.0100	.020	.0002	.029	.059	.0125
	U/S SUNCOR								
	MEAN	.093	.00009	.0028	.006	.0002	.008	.024	.0022
	COEF.VARIATION	107	0	106	82	0	109	89	132
	MAX	.270	.00009	.0080	.013	.0002	.024	.058	.0079
	BITUMONT								
	MEAN	.143	.00009	.0042	.010	.0002	.011	.018	.0033
	COEF.VARIATION	123	0	120	91	0	111	111	118
	MAX	.464	.00009	.0120	.024	.0002	.028	.050	.0085
	EMBARRAS								
	MEAN	.096	.00009	.0033	.006	.0002	.008	.013	.0022
	COEF.VARIATION	79	0	82	95	0	92	105	115
	MAX	.195	.00009	.0070	.015	.0002	.020	.032	.0070
TRIBUTARIES	BERLUND								
	MEAN	.022	.00009	.0010	.003	.0002	.003	.008	.0006
	COEF.VARIATION	82	0	0	68	0	42	85	108
	MAX	.048	.00009	.0010	.006	.0002	.005	.021	.0019
	MACLEOD RIVER								
	MEAN	.033	.00009	.0010	.003	.0002	.004	.005	.0022
	COEF.VARIATION	89	0	0	77	0	73	71	128
	MAX	.074	.00009	.0010	.007	.0002	.010	.011	.0070
	PEMBINA RIVER								
	MEAN	.056	.00009	.0022	.007	.0002	.007	.015	.0016
	COEF.VARIATION	74	0	77	34	0	62	120	62
	MAX	.118	.00009	.0040	.011	.0002	.013	.046	.0029
	LESSER SLAVE RIVER								
	MEAN	.071	.00009	.0010	.003	.0002	.004	.006	.0013
	COEF.VARIATION	50	0	0	106	0	85	96	55
	MAX	.122	.00009	.0010	.008	.0002	.010	.018	.0028
	LABICHE RIVER								
	MEAN	.108	.00009	.0021	.005	.0002	.006	.011	.0018
	COEF.VARIATION	30	0	86	52	0	78	53	40
	MAX	.155	.00009	.0050	.007	.0002	.014	.021	.0031
	CALLING RIVER								
	MEAN	.073	.00009	.0010	.004	.0002	.004	.011	.0011
	COEF.VARIATION	36	0	4	81	0	58	92	38
	MAX	.104	.00009	.0010	.010	.0002	.008	.030	.0017
	HOUSE RIVER								
	MEAN	.268	.00009	.0058	.047	.0002	.014	.042	.0081
	COEF.VARIATION	38	0	107	162	26	89	80	152
	MAX	.391	.00009	.0150	.201	.0003	.037	.096	.0300
	CLEARWATER RIVER								
	MEAN	.067	.00009	.0032	.008	.0002	.004	.023	.0013
	COEF.VARIATION	62	0	81	131	0	67	156	95
	MAX	.142	.00009	.0070	.028	.0002	.010	.096	.0032

STEM	SITE	Mn(dis.) mg/l	Hg(total) mg/l	Mo(total) mg/l	Ni(total) mg/l	Se(total) mg/l	Vn(total) mg/l	Zn(total) mg/l	As(total) mg/l
	POPLAR CREEK								
	MEAN	.094	.00009	.0010	.003	.0002	.003	.011	.0010
	COEF.VARIATION	61	0	0	39	0	30	156	48
	MAX	.180	.00009	.0010	.004	.0002	.004	.043	.0018
EFFLUENTS	ST.REGIS-GRAB								
	MEAN	.715	.00013	.0035	.010	.0002	.005	.104	.0007
	COEF.VARIATION	18	45	57	24	0	29	25	64
	MAX	.889	.00020	.0050	.013	.0002	.007	.141	.0015
	ST.REGIS-COMPOSITE								
	MEAN	.734	.00011	.0042	.010	.0002	.005	.208	.0006
	COEF.VARIATION	20	41	64	30	0	26	24	60
	MAX	.924	.00020	.0070	.015	.0002	.007	.277	.0013
	WHITECOURT STP								
	MEAN	.021	.00009	.0018	.006	.0002	.003	.028	.0013
	COEF.VARIATION	86	0	113	61	0	67	30	26
	MAX	.049	.00009	.0060	.012	.0002	.008	.039	.0017
	ATHABASCA STP								
	MEAN	.062	.00009	.0018	.005	.0003	.004	.021	.0013
	COEF.VARIATION	43	0	112	23	37	99	35	35
	MAX	.103	.00009	.0060	.007	.0004	.012	.032	.0019
	FT.McMURRAY STP								
	MEAN	.070	.00009	.0010	.004	.0003	.003	.011	.0011
	COEF.VARIATION	35	0	4	69	20	32	57	40
	MAX	.107	.00009	.0010	.009	.0003	.004	.021	.0018
	SUNCOR FINAL EFF.								
	MEAN	.058	.00009	.0543	.017	.0004	.059	.006	.0026
	COEF.VARIATION	49	0	27	52	29	32	76	30
	MAX	.099	.00009	.0800	.028	.0006	.092	.015	.0040

APPENDIX III

NAQUADAT SUMMARY REPORT APR 24, 1985
FEDERAL FILE DATA

STATION 00AL07AA0023 LAT. 53D 2M 30S LONG. 118D 5M 15S PR 4 UTM 11 427100E 5877200N FOR JUN 13, 1973 TO NOV 07, 1983
ATHABASCA RIVER AT HWY 16 BRIDGE BELOW CONFLUENCE WITH SNARING RIVER,
JASPER NATIONAL PARK, ALBERTA

	SUBM ID	18075L ALPHA-BHC	18060L ALPHA-CHLORDANE	18065L GAMMA-CHLORDANE	18005L O,P-DDT	18010L P,P-DDD	18020L P,P-DDE	18000L P,P-DDT	18150L DIELDRIN
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0417	74(33)	68(68)	68(68)	64(64)	77(77)	77(77)	77(77)	77(77)
LOW	0003	L.001	L.003	L.002	L.001	L.002	L.001	L.004	L.002
HIGH		.010	L.003	L.002	L.001	L.002	L.001	L.004	L.002
AVERAGE		.002*							
STD.DEV.		.002*							
PERCNT:10TH		L.001	L.003	L.002	L.001	L.002	L.001	L.004	L.002
25TH		L.001	L.003	L.002	L.001	L.002	L.001	L.004	L.002
MEDIAN 50TH		.001	L.003	L.002	L.001	L.002	L.001	L.004	L.002
75TH		.002	L.003	L.002	L.001	L.002	L.001	L.004	L.002
90TH		.004	L.003	L.002	L.001	L.002	L.001	L.004	L.002
SECONDARY CODE									

	SUBM ID	18050L ALPHA-ENDO-SULFHAN	18055L BETA-ENDO-SULFHAN	18140L ENDRIN	18040L HEPTACHLOR	18045L HEPTACHLOR EPOXIDE	18070L GAMMA-BHC (LINDANE)	18030L P,P-METHOXY-CHLOR	18520P MCPA
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0417	77(77)	77(77)	69(69)	77(77)	77(77)	82(81)	77(77)	82(82)
LOW	0003	L.001	L.003	L.002	L.001	L.002	L.001	L.01	L.2
HIGH		L.001	L.003	L.002	L.001	L.002	.001	L.012	L.200
AVERAGE							.001*		
STD.DEV.							.000*		
PERCNT:10TH		L.001	L.003	L.002	L.001	L.002	L.001	L.01	L.2
25TH		L.001	L.003	L.002	L.001	L.002	L.001	L.01	L.2
MEDIAN 50TH		L.001	L.003	L.002	L.001	L.002	L.001	L.01	L.200
75TH		L.001	L.003	L.002	L.001	L.002	L.001	L.010	L.2
90TH		L.001	L.003	L.002	L.001	L.002	L.001	L.012	L.200
SECONDARY CODE									20L

	SUBM ID	18555P 2,4-DP	18500P 2,4-D	18510P 2,4,5-T	18550P 2,4-DB	18125L MIREX TOTAL	18164L ARCCLORS TOTAL (PCB'S)	18161L AROCLOR 1248 (PCB'S)	18160L AROCLOR 1254 (PCB'S)
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0417	82(82)	82(80)	82(80)	82(82)	65(65)	42(42)	47(47)	77(77)
LOW	0003	L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
HIGH		L.004	.013	.009	L.009	L.001	L.020	L.024	L.032
AVERAGE			.004*	.002*					
STD.DEV.			.001*	.001*					
PERCNT:10TH		L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
25TH		L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
MEDIAN 50TH		L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
75TH		L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
90TH		L.004	L.004	L.002	L.009	L.001	L.020	L.024	L.03
SECONDARY CODE		55L	00L	10L	50L				

* THESE STATISTICS INCLUDE VALUES FLAGGED WITH L,G OR Q

NAQUADAT SUMMARY REPORT APR 24, 1985
FEDERAL FILE DATA

STATION 00AL07AA0023 LAT. 53D 2M 30S LONG. 118D 5M 15S PR 4 UTM 11 427100E 5877200N FOR JUN 13, 1973 TO NOV 07, 1983
ATHABASCA RIVER AT HWY 16 BRIDGE BELOW CONFLUENCE WITH SNARING RIVER,
JASPER NATIONAL PARK, ALBERTA

	SUBM ID	18601L PICLORAM	18162L AROCLOR 1260 (PCB'S)	18190P GUTHION	18195P AZIN-PHOSETHYL	18205P IMIDAN	18215P DISULFOTON	18230P CRUFOMATE	18240P PARTHION
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0417	60(59)	77(77)						
LOW	0003	L.2	L.005						
HIGH		.20	L.06						
AVERAGE		.20*							
STD.DEV.		.00*							
PERCNT:10TH		L.20	L.005						
25TH		L.20	L.005						
MEDIAN 50TH		L.20	L.005						
75TH		L.20	L.005						
90TH		L.20	L.055						
SECONDARY CODE		01P							

	SUBM ID	18245P PARATHION-METHYL	18250P MALATHION	18260P FENCHLORPHOS (RONNEL)	18270P DIAZIONON	18300P PHORATE	18310P ETHION	18320P CARBO-PHENOTHION	18540P SILVEX
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0417								65(65)
LOW									L.004
HIGH									L.004
AVERAGE									
STD.DEV.									
PERCNT:10TH									L.004
25TH									L.004
MEDIAN 50TH									L.004
75TH									L.004
90TH									L.004
SECONDARY CODE									40L

	SUBM ID	17811L HEXACHLORO-BENZENE	18130L ALDRIN	18159L AROCLOR 1242 (PCB'S)	18521L MCPB	18530L DIACAMBA	18180L BARBAN
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0417	64(63)	77(77)	30(30)			
LOW	0003	L.001	L.001	L.002			
HIGH		.001	L.001	L.002			
AVERAGE		.001*					
STD.DEV.		.000*					
PERCNT:10TH		L.001	L.001	L.002			
25TH		L.001	L.001	L.002			
MEDIAN 50TH		L.001	L.001	L.002			
75TH		L.001	L.001	L.002			
90TH		L.001	L.001	L.002			
SECONDARY CODE							

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NAQUADAT SUMMARY REPORT APR 24, 1985
FEDERAL FILE DATA

STATION 00AL07BE0001 LAT. 54D 43M 21S LONG. 113D 17M 9S PR 4 UTM 12 352800E 6066100N FOR SEP 03, 1971 TO OCT 04, 1983
ATHABASCA RIVER AT ATHABASCA, ALBERTA

	SUBM ID	18075L ALPHA-BHC	18060L ALPHA-CHLORDANE	18065L GAMMA-CHLORDANE	18005L O,P-DDT	18010L P,P-DDD	18020L P,P-DDE	18000L P,P-DDT	18150L DIELDRIN
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0103	24(1)	25(25)	25(25)	22(22)	32(32)	32(32)	32(32)	32(32)
LOW	0003	L.001	L.003	L.002	L.001	L.002	L.001	L.004	L.002
HIGH	0479	.010	L.003	L.002	L.001	L.002	L.001	L.004	L.002
AVERAGE		.004*							
STD.DEV.		.003*							
PERCNT:10TH		.002	L.003	L.002	L.001	L.002	L.001	L.004	L.002
25TH		.002	L.003	L.002	L.001	L.002	L.001	L.004	L.002
MEDIAN 50TH		.003	L.003	L.002	L.001	L.002	L.001	L.004	L.002
75TH		.005	L.003	L.002	L.001	L.002	L.001	L.004	L.002
90TH		.008	L.003	L.002	L.001	L.002	L.001	L.004	L.002
SECONDARY CODE									

	SUBM ID	18050L ALPHA-ENDO-SULFHAN	18055L BETA-ENDO-SULFHAN	18140L ENDRIN	18040L HEPTACHLOR	18045L HEPTACHLOR EPOXIDE	18070L GAMMA-BHC (LINDANE)	18030L P,P-METHOXY-CHLOR	18520P MCPA
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0103	32(32)	32(32)	25(25)	32(32)	32(32)	32(31)	32(32)	29(29)
LOW	0003	L.001	L.003	L.002	L.001	L.002	L.001	L.01	L.2
HIGH	0479	L.001	L.003	L.002	L.001	L.002	.001	L.012	L.200
AVERAGE							.001*		
STD.DEV.							.000*		
PERCNT:10TH		L.001	L.003	L.002	L.001	L.002	L.001	L.01	L.2
25TH		L.001	L.003	L.002	L.001	L.002	L.001	L.010	L.2
MEDIAN 50TH		L.001	L.003	L.002	L.001	L.002	L.001	L.010	L.2
75TH		L.001	L.003	L.002	L.001	L.002	L.001	L.010	L.2
90TH		L.001	L.003	L.002	L.001	L.002	L.001	L.012	L.200
SECONDARY CODE									20L

	SUBM ID	18555P 2,4-DP	18500P 2,4-D	18510P 2,4,5-T	18550P 2,4-DB	18125L MIREX TOTAL	18164L ARCCLORS TOTAL (PCB'S)	18161L AROCLOR 1248 (PCB'S)	18160L AROCLOR 1254 (PCB'S)
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0103	30(29)	31(28)	30(29)	30(30)	22(22)	16(16)	19(19)	29(29)
LOW	0003	L.002	L.004	L.001	L.006	L.001	L.002	L.002	L.002
HIGH	0479	.025	.017	.007	L.009	L.001	L.020	L.024	L.032
AVERAGE		.005*	.005*	.002*					
STD.DEV.		.004*	.003*	.001*					
PERCNT:10TH		L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
25TH		L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
MEDIAN 50TH		L.004	L.004	L.002	L.009	L.001	L.002	L.002	L.002
75TH		L.004	L.004	L.002	L.009	L.001	L.011	L.02	L.002
90TH		L.004	L.004	L.002	L.009	L.001	L.020	L.024	L.032
SECONDARY CODE		55L	00L	10L	50L				

* THESE STATISTICS INCLUDE VALUES FLAGGED WITH L,G OR Q

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NAQUADAT SUMMARY REPORT APR 24, 1985
FEDERAL FILE DATA

STATION 00AL07BE0001 LAT. 54D 43M 21S LONG. 113D 17M 9S PR 4 UTM 12 352800E 6064100N FOR JUN 27, 1973 TO OCT 04, 1983
ATHABASCA RIVER AT ATHABASCA, ALBERTA

	SUBM ID	18601L PICLORAM	18162L ARCCLOR 1260 (PCB'S)	18190P GUTHION	18195P AZIN-PHOSETHYL	18205P IMIDAN	18215P DISULFOTON	18230P CRUFOMATE	18240P PARTHION
		UG/L	US/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0103	9(9)	28(28)	22(22)	16(16)	16(16)	15(15)	17(17)	17(17)
LOW	0003	L.2	L.005	L.1	L.2	L.2	L.02	L.2	L.01
HIGH	0479	L.20	L.06	L.5	L.20	L.20	L.020	L.20	L.02
AVERAGE									
STD.DEV.									
PERCNT:10TH			L.005	L.1	L.2	L.2	L.02	L.2	L.01
25TH		L.2	L.005	L.5	L.20	L.20	L.020	L.20	L.02
MEDIAN 50TH		L.2	L.005	L.5	L.20	L.20	L.02	L.20	L.02
75TH		L.20	L.005	L.5	L.20	L.20	L.020	L.20	L.02
90TH			L.055	L.5	L.20	L.20	L.020	L.20	L.02
SECONDARY CODE		01P		90L	95L	05L	15L	30L	

	SUBM ID	18245P PARATHION-METHYL	18250P MALATHION	18260P FENCHLORPHOS (RONNEL)	18270P DIAZIONON	18300P PHORATE	18310P ETHION	18320P CARBO-PHENOTHION	18540P SILVEX
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0479	18(18)	22(22)	17(17)	22(22)	16(16)	22(22)	22(22)	21(21)
LOW		L.01	L.01	L.02	L.02	L.02	L.01	L.02	L.004
HIGH		L.02	L.05	L.02	L.02	L.02	L.02	L.02	L.004
AVERAGE									
STD.DEV.									
PERCNT:10TH		L.02	L.01	L.02	L.02	L.02	L.01	L.02	L.004
25TH		L.02	L.05	L.02	L.02	L.02	L.02	L.02	L.004
MEDIAN 50TH		L.02	L.05	L.02	L.02	L.02	L.02	L.02	L.004
75TH		L.02	L.05	L.02	L.02	L.02	L.02	L.02	L.004
90TH		L.02	L.05	L.02	L.02	L.02	L.02	L.02	L.004
SECONDARY CODE		45L	50L	60L	70L	00L	10L	20L	40L

	SUBM ID	17811L HEXACHLORO-BENZENE	18130L ALDRIN	18159L AROCLOR 1242 (PCB'S)	18521L MCPB	18530L DIACAMBA	18180L BARBAN
		UG/L	UG/L	UG/L	UG/L	UG/L	UG/L
SAMPLES(FLAGS)	0103	22(22)	32(32)	10(10)			
LOW	0003	L.001	L.001	L.002			
HIGH	0479	L.001	L.001	L.002			
AVERAGE							
STD.DEV.							
PERCNT:10TH		L.001	L.001	L.002			
25TH		L.001	L.001	L.002			
MEDIAN 50TH		L.001	L.001	L.002			
75TH		L.001	L.001	L.002			
90TH		L.001	L.001	L.002			
SECONDARY CODE							

* THESE STATISTICS INCLUDE VALUES FLAGGED WITH L,G OR Q