A REVIEW OF EPILITHIC ALGAL BIOMASS, NUTRIENT, AND NONFILTERABLE RESIDUE DATA FOR MAJOR ALBERTA RIVER BASINS

A report prepared for

Alberta Environment, Environmental Assessment Division

by

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EXECUTIVE SUMMARY

The objectives of this review were to describe the river course variation of benthic algal biomass, nutrient and nonfilterable residue variables and their interrelationships in Alberta rivers. Trends in these variables were compared between river basins, and the physiographic zones and ecoregions through which these rivers flowed were also documented.

There were three categories of sampling sites: those located above major anthropogenic inputs, those immediately downstream of anthropogenic inputs, and those located well downstream in a zone of recovery. Based on water quality data, these three zones of water quality were recognizable within most river systems. Sampling sites on rivers located above major point source inputs had the lowest benthic algae, nutrient and nonfilterable residue concentrations. Sites downstream of these inputs were located in a zone of enrichment where algal and nutrient concentrations often increased dramatically. At sites that were located in a zone of recovery well downstream of inputs, there was a consistent decrease in algal chlorophyll concentrations.

Benthic algal biomass, nutrient and nonfilterable residues formed the basis for separating northern and southern rivers on the basis of water quality. Sites located on southern rivers, downstream of development inputs, were characterized by high chlorophyll a, high total dissolved phosphorus and low nonfilterable residue concentrations. Northern rivers were characterized by low chlorophyll a, low total dissolved phosphorus and high nonfilterable residue concentrations. Certain reaches of the South Saskatchewan, Red Deer, and North Saskatchewan rivers were intermediate or inconsistent with this separation.

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ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

The vegetation in a river is typically an assemblage of primary producers which varies both spatially and temporally. Aquatic plant communities may consist of microscopic algae, which either adhere to the surface of riverbed material (epilithic) or are free-floating (potamophytoplanktonic) and macroscopic algae and submerged macrophytes which are perennial, macroscopic plants rooted in the river substrate. Although aquatic plants are essential in aquatic ecosystems, when over abundant they can become a nuisance by being aesthetically unpleasant and having a significant impact on water use within a river basin.

The physical and chemical properties of river water change to some degree over the course of a river basin. Some variables change in a downstream direction due to natural causes, some are influenced by changes in flow and mixing regimes of the river system, and some by point and nonpoint source inputs. These changes ultimately affect the developmental patterns in primary producers along the course of a river as well as from one river to another. Because they remain fixed to the substrate, epilithic algae and macrophytes may in turn reflect changing conditions over a period of time.

Epilithic chlorophyll a is an important input variable in river trophic status evaluations and monitoring projects. Alberta Environment, through various survey, impact assessment and longterm monitoring programs, has assembled a comparatively large database describing chlorophyll a concentrations in provincial rivers, but no overview of provincial conditions had been compiled prior to this study. The principal objectives of this review were:

1. to summarize historical epilithic algal biomass and nutrient data in selected Alberta rivers;
2. to document the role of nonfilterable residues (ie. suspended solids), a discharge-related factor, as it affects epilithic algal biomass in each river;
3. to describe the river course variation in algal biomass, nutrient levels and nonfilterable

residues;

4. to compare and relate the trends in the above variables between river basins; and,

5. to document the physiographic zone and ecoregion differences between river basins and sampling sites.

2.0 METHODS

2.1 DATA BASE

Data for this review were obtained from a NAQUADAT summary report prepared by Alberta Environment, Environmental Assessment Division for all major Alberta rivers. Several water quality variables, monitored extensively by the Division for several years, were incorporated within this study (Table 1).

Table 1. Water quality variables measured in Alberta rivers.

Variable	Symbol	Units	NAQUADAT Code No.
Epilithic Chlorophyll a	Chl A	mg/m2	06722L
Total Phosphorus	TP	mg/l	15421L
Total Dissolved Phosphorus	TDP	mg/l	15105L
Nitrite and Nitrate	NN	mg/l	07111L
Total Kjeldahl Nitrogen	TKN	mg/l	07021L
Dissolved Ammonia	DA	mg/l	07562L
Nonfilterable Residue	NFR	mg/l	10401L

Epilithic chlorophyll a concentrations ([Chl A]) represent data that were collected from sampling sites on rivers on between 1980 and 1988, with several sites on specific rivers being monitored as far back as 1976. Similarily, the nutrient and nonfilterable residue values represent data that were collected from as far back as1954 to1988. Chlorophyll a was used in all analyses in this report because it is the pigment directly involved in photosynthesis and in this study it provided an estimate of the biomass of benthic algae growing on the surface of stones and rocks .

The two nutrient groups which most commonly limit aquatic plant growth or production are phosphorus and nitrogen. The main natural source of phosphorus is erosion due to weathering of rocks. Nitrogen is contributed by erosion of soils, atmospheric inputs, algal nitrogen fixation and conversion to specific forms by aquatic bacterial communities. Agricultural, municipal and industrial inputs are also important sources of both nutrients.

Total phosphorus [TP] is a measure of the the total pool of phosphorus in a water sample, of which a certain portion is directly available to algal communities. Total phosphorus may be organic or inorganic and may occur in dissolved or particulate form. In this report, total dissolved phosphorus [TDP] was also assessed because it provides a more precise estimate of biologically available phosphorus and can also reflect the degree of chlorophyll a production.

Dissolved ammonia [DA] is the total nitrogen in the forms of ammonium hydroxide, ammonium ion, and ammonia. Under certain conditions, [DA] is converted to nitrite and nitrate [NN] by nitrifying aquatic bacterial communities. [DA] and [NN] are both of the inorganic form. Total Kjeldahl Nitrogen [TKN] includes both [DA] and organic nitrogen. The organic nitrogen component may be obtained by subtracting [DA] from [TKN] whereas Total Nitrogen is obtained by adding [TKN] and [NN].

The Nonfilterable Residue [NFR] measurement represents the concentration of suspended solids in river water and frequently reflects variations in flow conditions. An appropriate current velocity data set, corresponding to the sampling period for variables at each sampling site, was not available. Consequently, [NFR] was used in this report as an index of variations in flow, which could be compared to algal biomass.

For each variable, median values for the entire study period from each sampling station on each river were used for comparative analyses. The median was used because it is generally more representative of the central tendency than the mean. Water quality data sets most frequently fall into skewed distributions due to the variable influences of numerous forces over time.

2.2 CLUSTER AND PRINCIPAL COMPONENT ANALYSES

A multivariate analysis program package called Clustan (Wishart 1987) was used for cluster and principal component analysis of the database for all river basins. Cluster analysis allowed grouping of river sampling sites on the basis of similarities in data. Principal component analysis was then used to confirm the identity of clusters and to distinguish the variables which were most important for defining each cluster.

For the first analysis, median values for [Chl A], [TDP] and [NFR] were used to cluster the data for the Milk, Oldman, Bow, Highwood, South Saskatchewan, Red Deer, North Saskatchewan and Athabasca rivers. Only the Oldman, Red Deer, North Saskatchewan and Athabasca River data set was complete for all variables. A second analysis using these data was performed to test whether variables other than the three used in the first analysis influenced the clustering. All analyses were performed on log-transformed data.

2.3 PHYSIOGRAPHIC ZONE AND ECOREGION DELINEATION

The physiographic zones and ecoregions through which the river systems examined in this report flowed were identified by using the Atlas of Alberta (1969) and a report on the Ecoregions of Alberta (Strong and Leggat 1981). Maps of Alberta physiographic zones and ecoregions are provided in Figures 1 and Appendix 4, respectively.

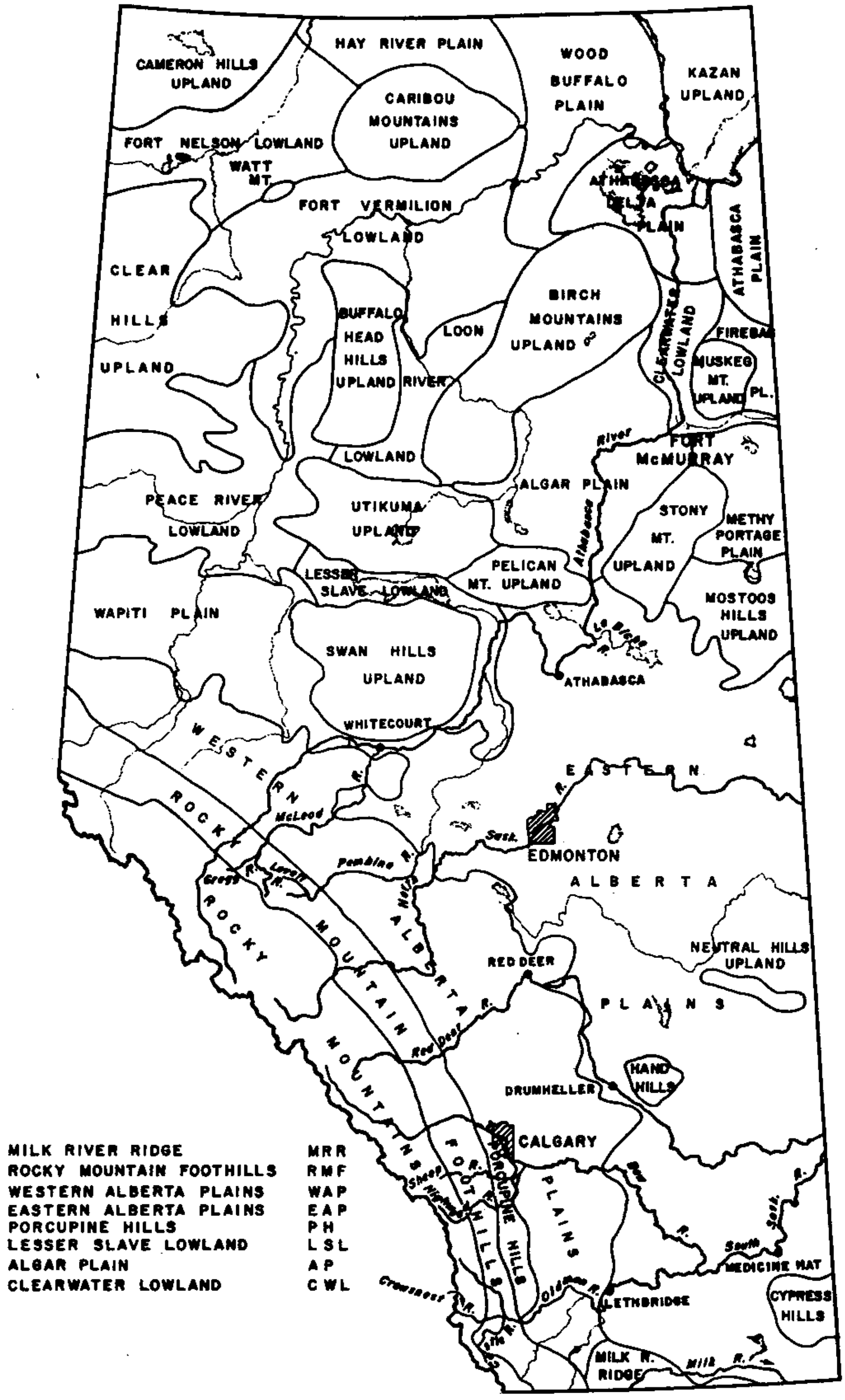

Figure 1. Physiographic Zones of Alberta

3.0 RESULTS AND DISCUSSION

Due to the large quantity of information consolidated in this review, most data have been tabulated or presented graphically in Appendices. A table which lists each sampling station with respect to its physiographic region and ecoregion is provided in Appendix 1. Median values for chlorophyll a, nutrients and nonfilterable residues are tabulated in Appendix 2, and histograms illustrating river course variation of each variable are provided in Appendix 3.

3.1 RIVER BASIN REVIEW OF CHLOROPHYLL A, NUTRIENT, AND NFR RELATIONSHIPS

Table 2 summarizes the range of chlorophyll a median values above and below development inputs and in the zone of recovery for each river. Reference is made to this Table in the discussion of each river basin.

TABLE 2. Range of median chlorophyll a concentrations (mg/m2) above and below major municipal and industrial discharges and within the zone of recovery of Alberta rivers.

River	Above Discharges	Below Discharges	Zone of Recovery
Milk	18.6*	6.1-176.5	—
Oldman	22.8-30.7	89.5-163.2	75.5*
Bow	23.5-39.3	111.9-393.9	23.9-57.1
Highwood	36.8-47.6	132.5-176.3	—
South Saskatchewan	1.9- 6.9	41.8*	18.6*
Red Deer	19.6*	54.8-224.9	11.4-48.7
North Saskatchewan	0.2-12.9	8.5-179.4	30.7-36.5
Pembina	—	23.5-70.4	4.8*
Lovett	8.3*	47.3-63.2	—
McLeod	4.1-42.8	50.4-201.7	4.9-9.4
Gregg	4.3*	110.4*	10.4-12.9
Athabasca		0.6-12.7	

*median for single station

3.1.1 MILK RIVER

The Milk River flows generally in an easterly direction through the Milk River Ridge (Ecoregion 2) and Western Alberta Plains along the U.S. and Alberta border (Ecoregion 1). In Alberta, the North Milk River originates at the western fringe of the Rocky Mountain Foothills (Ecoregion 3) and joins the mainstem within the Ridge (Ecoregion 2).

The [Chl A] in the upper reaches of the Milk and North Milk rivers ranged from 6.1 to 18.6 mg/m2 and were considerably lower than levels in the upper reaches of other southern rivers above development inputs. TDP concentrations along the total length of the river was comparable to those in the upper reaches of other southern rivers, whereas [NFR] increased downstream of the town of Milk River from 15.1 to 33.6 mg/l. These were similar to levels in the lower reaches of the South Saskatchewan and Red Deer rivers. The [Chl A] at the Hwy 878 sampling site increased dramatically to 176.5 mg/m2; this level was unexpected in relation to the relatively low [TDP] and high [NFR] found there. Generally, very little data are available on this river system.

3.1.2 OLDMAN RIVER

The Oldman River originates in the Rocky Mountains (Ecoregions 7 and 6) and flows in a southeasterly direction through the Rocky Mountain Foothills (Ecoregion 3) and then flows in a more eastwardly direction through the Western Alberta Plains (Ecoregions 3 and 2) to the confluence with the Bow River in the Eastern Alberta Plains (Ecoregions 2 and1).

The Oldman River changes from a mountain stream with clear, fast flowing waters to a larger and slower moving river with finer sediments and higher silt loads. The Oldman, unlike the Bow River which has regulated flow, is annually scoured to the extent that bed movement has been documented (Warner 1973). The water quality of this river is strongly influenced by inputs from tributaries, cities and irrigation return flows (Cross and Anderson 1986).

Generally, the best water quality in the Oldman River occured above the City of Lethbridge. The [Chl A] was lowest from Waldron's Corner to the sampling site near Fort Macleod and ranged from 22.8 to 30.7 mg/m2. Nutrient and NFR concentrations fell within the range of those in other southern rivers above development inputs. Chl A (89.5 to 163.2 mg/m2) and nutrient concentrations increased dramatically downstream of the City of Lethbridge to the site above the Town of Taber. Water quality generally improved at the mouth where [Chl A] declined to 75.5 mg/m2; nutrients fell also, but not back to their upper reach levels. [NFR] levels increased consistently from Waldon's Corner to a peak concentration of 23.0 mg/l at Taber and then dropped off at the mouth to a level equivalent to that upstream of Lethbridge.

Cross and Anderson (1986) reported that inputs from the Belly and St. Mary rivers were of good quality and maintained the quality of the Oldman above Lethbridge. The Crowsnest and Castle are two other tributaries which originate in the foothills and enter the Oldman above Lethbridge. The Crowsnest River was characterized by higher Chl A concentrations (245.7 mg/m2), nutrient and [NFR] than the Oldman stations above Lethbridge. Chl A in the Castle (94.1 mg/m2) was also higher, however, nutrients and [NFR] fell within the range found in the upper reaches of the Oldman. Based on data for the Oldman River site near Brocket, the inputs from these tributaries did not appear to alter the water quality of the mainstem.

3.1.3 BOW RIVER

The Bow River flows in a southeasterly direction from the Rocky Mountains near Banff, Alberta (Ecoregions 7,6 and 5) through the Rocky Mountain Foothills (Ecoregions 5 and 4) and then on through the Western and Eastern Alberta Plains to the confluence of the Oldman and South Saskatchewan rivers (Ecoregions 4,3,2 and 1). As in the Oldman, the Bow River evolves from a small clear river, uniform in flow and composition, to a large water course with its middle reaches enriched by development inputs. The Bow is a regulated river in which the effects of natural floods are dampened by dams and weirs.

Consequently, aquatic plants which establish themselves in this river are not subjected to the same degree of scouring as are those growing in the Oldman.

Based on Chl A and nutrient data, the Bow River can be subdivided into three zones. The first zone includes the reaches upstream of the City of Calgary (below Bearspaw Dam and upstream of 85th Street bridge), where [Chl A] was low and ranged from 23.5 to 39.3 mg/m2, and where [TDP] and [NFR] were within the range of those found in other southern rivers above major developments. The second zone includes the Calgary area (Inglewood Golf Course) to the site below the Bassano Dam, which can be described as the zone of enrichment. Chl A concentrations increased dramatically below Calgary with concentrations being the highest among all rivers which are impacted by development (111.9 to 393.9 mg/m2). The same trend occurred for nutrients. Cross et al. (1986) concluded that during the peak periods of growth, phosphorus in particular decreased in a downstream direction and that this reflected its relative uptake by plants. The third zone includes the lower reaches of the Bow (Bow City Bridge to the confluence of the Oldman and South Saskatchewan rivers), where values approached those in the first zone. Chl A in this zone ranged from 23.9 to 57.1 mg/m2 whereas [TDP] was relatively low, although slightly higher than in the first zone. NFR levels remained low and relatively constant except for an unusually high value at Fish Creek Location 11.

Cross et al. (1984) reported that physical variables associated with discharge may control algal production at high flows, even below Calgary where concentrations of nutrients are abundant. Only when river discharge declined below a critical level, did nutrients become the major controlling factor. This is best demonstrated In the zone of enrichment at the site of Fish Creek Location 11, where the [NFR] was very high compared to values at all other stations. The corresponding [Chl A] was one of the lowest in this zone, although nutrient concentrations remained high.

3.1.4 HIGHWOOD RIVER

The Highwood river flows in a northeasterly direction from its headwaters in the Rocky Mountains

(Ecoregions 7 and 6), through the Rocky Mountain Foothills and Porcupine Hills (Ecoregions 4 and 3), and briefly crossing the Western Alberta Plains to its mouth at the Bow river (Ecoregion 3).

Chl A concentrations remained low (although slightly higher than those upstream of municipal inputs on the Oldman, South Saskatchewan and Bow River) and ranged from 36.8 to 47.6 mg/m2. [TDP] was as low as in the upper reaches of other southern rivers. Chl A increased below the Town of High River and ranged from 132.5 to 176.3 mg/m2. Levels approached those below Lethbridge. Levels of the other variables remained relatively high to the mouth and consequently may have had some impact on the Bow itself. This may explain the high Chl A concentrations in the Bow below the confluence with this tributary (340.9 mg/m2).

3.1.5 SOUTH SASKATCHEWAN RIVER

The South Saskatchewan River originates at the confluence of the Bow and Oldman Rivers and flows in a northeasterly direction through the Eastern Alberta Plains to the Saskatchewan border (Ecoregion 1).

Chl A concentrations remained low from the confluence of the Oldman and the Bow to Medicine Hat (1.9 to 6.9 mg/m2) and then increased due to the effects of municipal inputs from the City of Medicine Hat (41.8 mg/m2). Levels recovered somewhat downstream at Highway 41 bridge (18.6 mg/m2). However [TDP] was relatively constant from reach to reach. Cross et al. (1986) concluded that the contribution of TDP from the Medicine Hat sewage effluent had little effect on the riverload and that TDP was probably used very rapidly by aquatic plants below its input. The increase in Chl A and nutrients below Medicine Hat municipal discharges were less than those observed below inputs from Lethbridge, Calgary and High River. Lower NFR values above Medicine Hat were probably governed by inputs from the Oldman and the Bow, whereas levels increased downstream of the City. Cross et al. (1986) found that the water chemistry in the South Saskatchewan River often showed trends which were intermediate or a combination of trends in the Oldman and the Bow. Charlton et al. (1986) concluded that the lower reaches of the Bow, Oldman and the entire South Saskatchewan River are chemically and biologically similar. The present analysis of the South Saskatchewan River was limited by infrequent sampling conducted at only four stations and the derivation of medians from such a small data base may explain some of the contradictions to information presented in other reports in which daily or some form of mean values for variables were used.

3.1.6 RED DEER RIVER

The Red Deer River originates in the Rocky Mountains (Ecoregion 6) and flows in a northeasterly direction through the Rocky Mountain Foothills (Ecoregions 10 and 9) and the Western Alberta Plains (Ecoregions 9 and 4) after which it flows in a southeasterly direction to the Saskatchewan Border through the Eastern Alberta Plains (Ecoregions 4,3,2 and 1).

The [Chl A] at the sampling site upstream of any developments on the Red Deer River was 19.6 mg/m2 and fell within the lower end of the range of values found for southern rivers. Chl A concentrations increased downstream of the site below the Glennifer Reservoir and peaked below the City of Red Deer (54.8 to 224.9 mg/m2), after which they declined to levels marginally above those upstream of the developments. The Chl A levels immediately below Red Deer were amongst the highest when comparing the impact of municipal effluents on southern rivers. Although nutrient concentrations in the Red Deer River followed the same general pattern as other southern rivers, [TDP] and [DA] concentrations decreased toward the Saskatchewan border, whereas [TP] and [TKN] increased dramatically. This coincides with the abrupt increase in NFR from the site above the City of Drumheller to the border site. Inputs from the City of Drumheller did not appear to impact the Red Deer greatly.

3.1.7 NORTH SASKATCHEWAN RIVER

The North Saskatchewan River originates in the Rocky Mountains (Ecoregions 7,6 and 5) and flows in a northeasterly direction passing through the Rocky Mountain Foothills (Ecoregions 10 and 9, Western Alberta Plains (Ecoregion 9) and the Eastern Alberta Plains (Ecoregion 9,8 and 4) to the Saskatchewan border.

[Chl A] remained very low from the headwaters to the City of Edmonton (0.2 to 12.9 mg/m2) at which point they increased substantially downstream due to development inputs (8.5 to 179.4 mg/m2). Although nutrient concentrations increased and remained higher downstream of Edmonton, some concentrations were highly variable from site to site, particularily [DA]. [Chl A] recovered to lower levels from the Lea Park to Lloydminster Ferry stations (30.7 to 36.5 mg/m2). [NFR] remained relatively constant from the headwaters to the Saskatchewan border and were generally higher than those found in more southern rivers.

3.1.8 LOVETT RIVER

The Lovett River flows southeast from the Rocky Mountain Foothills (Ecoregion 10) to its mouth at the Pembina River. All variables were relatively low above the Luscar Sterco Ltd coal mine, but increased thereafter. In terms of Chl A levels (63.2 mg/m2), the mine appeared to have the same level of impact on the river as did the City of Medicine Hat to the South Saskatchewan River, due to nutrient enrichment (Trew et el. 1988).

3.1.9 PEMBINA RIVER

The Pembina River originates in the Rocky Mountain Foothills (Ecoregion10) and flows in a northeasterly direction and passes through the Western Alberta Plains (Ecoregions 10 and 9) and Eastern Alberta Plains (Ecoregions 9 and 8) and through the Lesser Slave Lowland (Ecoregion 8) in its lower reaches before entering the Athabasca River.

Chl A concentrations were somewhat higher in the upper reaches of the Pembina River (23.5 to 70.4 mg/m2) than in other northern rivers. An increase in nutrients and Chl A downstream of the confluence of the Lovett River suggested some impact by coal mining activities in the Lovett watershed. The Chl A recovered at the confluence with the Athabasca River (4.8 mg/m2). As in the Lovett River, TKN and NN were the most prominent nutrient variables. NFR was low and relatively constant from station to station.

3.1.10 THE MCLEOD RIVER

The McLeod River originates in the Rocky Mountain Foothills (Ecoregion 10) and flows in a northeasterly direction through the Western Alberta Plains (Ecoregions 10, 9 and 8) while briefly passing through the Eastern Alberta Plains (Ecoregions 9 and 8). It enters the Athabasca River at Whitecourt.

Above the Edson municipal input, [Chl A] was high (4.1 to 42.8 mg/m2) and atypical of that found in the upper reaches of northern rivers. This was due to inputs of inorganic nitrogen from coal mines on Luscar Creek and the Gregg River (EQMB, unpubl. data) [Chl A] did, however, fall within the range of those in the upper reaches of southern rivers. [Chl A] increased below Edson (50.4 to 201.7 mg/m2) and fell between the values reported below Lethbridge and Red Deer. The last three sampling sites before Whitecourt were characterized by a considerable drop in Chl A levels (4.9 to 9.4 mg/m2). Nutrients, except for NN which decreases from the headwaters to its mouth, generally increase downstream of Edson. TKN was the most prominent nutrient variable. NFR concentrations in the upper reaches of the McLeod were as low as in southern river headwater reaches. They increased slightly below the Edson input.

3.1.11 GREGG RIVER

The Gregg River flows northeast through the Rocky Mountain Foothills (Ecoregion 10) to its confluence with the McLeod River. This is a subalpine river with a steep gradient and relatively high velocities. Chl A concentrations were low (4.3 to 12.9 mg/m2), except immediately below the Gregg River Resources coal mine (110.4 mg/m2). [NN] increased abruptly below the mine site and declined steadily to the mouth. Other nutrient levels were relatively constant, with elevated [TKN] reflecting relatively high organic inputs. [NFR] was as low as that measured in the upper reaches of the McLeod River, although there was a four-fold increase downstream of the Gregg River Resources mine site.

3.1.12 ATHABASCA RIVER

The Athabasca River originates in the Rocky Mountains (Ecoregions 6 and 5) and flows in a northeasterly direction through the Rocky Mountain Foothills (Ecoregion 9), Western Alberta Plains (Ecoregions 9 and 8) and Eastern Alberta Plains, and then north through the Lesser Slave Lowland back through the Eastern Alberta Plains, Algar Plain, Clearwater Lowland and through the Athabasca Delta Plain to Lake Athabasca (all in Ecoregion 8).

The range of Chl A concentrations was the lowest (0.643 to 12.7 mg/m2) of all rivers sampled in the province. Values were low from the first sampling site to the Obed Mountain Coals bridge (0.737 to 8.2 mg/m2), then generally increased from this point onward to Smith (5.0 to 12.7 mg/m2), and then decreased sharply from Smith to the furthest sampling point at Embarras airport (0.200 to 4.0 mg/m2). NFR concentrations followed the reverse pattern within these zones as did TP, TDP, NN, and TKN levels. Nutrients, with the exception of NN, gradually increased downstream to the last sampling station. Again most nitrogen was tied up in the organic form (TKN). The data from Smith to the last sampling site suggested that nutrients did not control production but that discharge related variables may have. Chl A concentrations that were measured in tributaries to the Athabasca also fell within this overall lower range characteristic of northern rivers. Nutrient and NFR levels for the tributaries were somewhat higher than in the Athabasca mainstem, particularily the House and La Biche Rivers.

3.2 CLUSTER AND PRINCIPAL COMPONENT ANALYSIS

The first cluster and principal component analysis was carried out on the Milk, Oldman, South Saskatchewan, Bow, Highwood, Red Deer, North Saskatchewan and Athabasca rivers, because those basins had the most complete data sets for [Chl A], [TDP], and [NFR]. Two major clusters were defined. The first cluster grouped all stations in rivers south of and including the Red Deer River, while the second cluster grouped stations in rivers north of the Red Deer River (Figure 2).

Several anomalies occured in this cluster separation (Figure 2). Stations downstream of the city of

Edmonton in the North Saskatchewan all fell within the cluster of southern river stations. Stations on the South Saskatchewan River, with the exception of the one below Medicine Hat and stations in the lower reaches of the Red Deer River, fell within the cluster of northern rivers.

The first principal component accounted for 55% of the sample variance. Differences in the relative concentrations of the three variables included in the analysis formed the basis for the separation between southern and northern rivers. Southern rivers were characterized by high [Chl A], high [TDP] and low [NFR] (Figure 3). Conversely, northern rivers were characterized by low [Chl A], low [TDP] and high [NFR] (Figure 3).

Rivers which exhibited characteristics of southern rivers (high [Chl A], high [TDP] and low [NFR]) were the Milk, Oldman, Bow, and Highwood. The Athabasca and the North Saskatchewan River (above Edmonton and in the zone of recovery) displayed typical northern river characteristics (low [Chl A], low [TDP] and high [NFR]). However the North Saskatchewan downstream of Edmonton behaved more like a southern river, although NFR remained relatively high. Red Deer River sites above the City of Red Deer shared features with both the southern and northern rivers, whereas sites influenced by the Red Deer municipal discharges were typical of southern rivers.

Despite high nutrient levels in the South Saskatchewan River, derived principally from the Bow and Oldman River inputs, Chl A concentrations were extremely low, and NFR concentrations were generally higher than for typical southern rivers. It did not appear that the South Saskatchewan River behaved as a combination of the Bow and Oldman waters. Discharge related physical factors, such as high turbidity from local erosion, may control production here, as occurs in northern rivers.

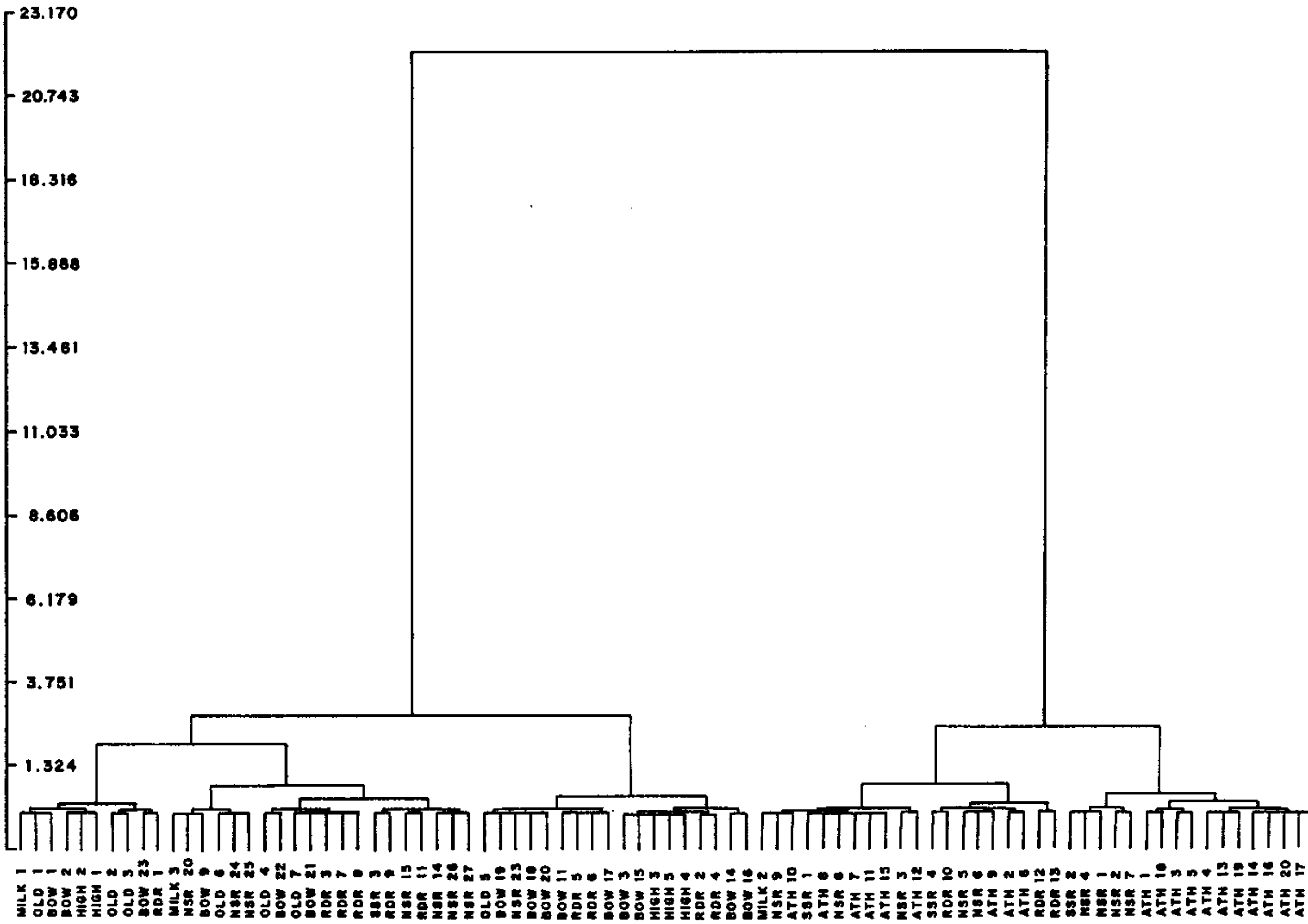

Figure 2. Cluster analysis using Chl a, TDP, NFR data

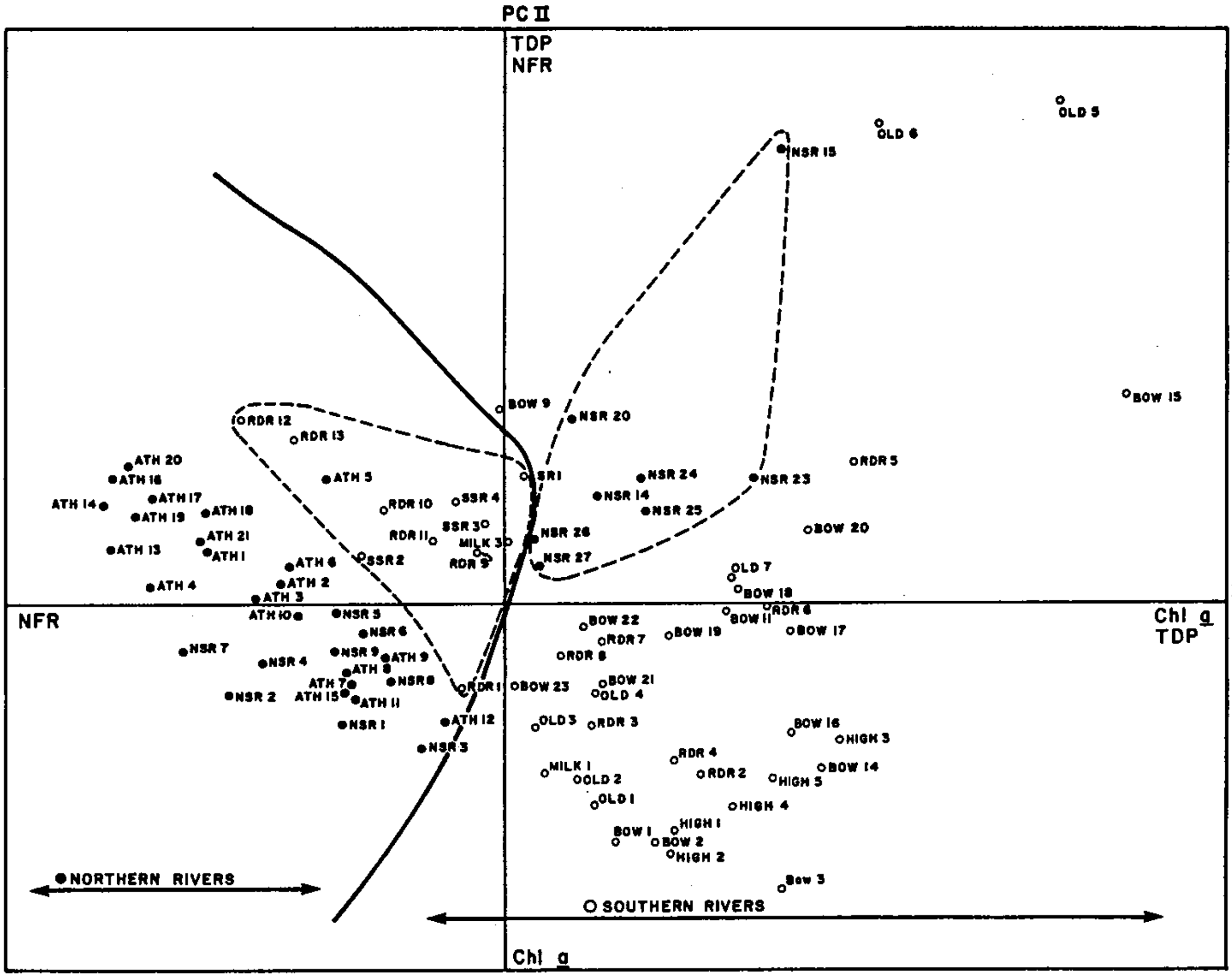

Figure 3. Principal component analysis using Chl a, TDP, and NFR data.

The second principal component accounted for 33% of the sample variance, and separated sites on the basis of low [Chl A], high [TDP] and high [NFR] (Figure 3). The clusters which were characterized by this trend were the three anomalous stations in the South Saskatchewan River, the lower Red Deer River stations, the last two sampling stations in the North Saskatchewan River (which typically represents a zone of recovery), and the lower reaches of the Athabasca River. All stations which were characterized by this trend fell within the Eastern Alberta Plains physiographic zone and into recovery reaches.

The third principal component accounted for 12% of the sample variance among the three variables, and separated the sites on the basis of low [Chl A], high [TDP], and low [NFR]. This component explained some of the outlying sites which did not fit the classification established by the first two components.

The second cluster and principal component analysis was performed on the Oldman, Red Deer, North Saskatchewan and the Athabasca rivers, using [Chl A], [TP], [TDP], [TNN], [TKN], [DA] and [NFR] as variables. These four rivers were the ones with complete data for the seven variables under evaluation. They represented a cross-section of Alberta river types the Oldman river being a typical southern river, the Athabasca a typical northern river, and in certain reaches the Red Deer and North Saskatchewan intermediate in nature. This analysis was performed in order to test whether variables other than the three used in the first analysis influenced the clustering.

This cluster analysis like the first separated the southern rivers (Oldman and Red Deer) from the northern ones (North Saskatchewan and Athabasca)(Figure 4).

In the principal component analysis (Figure 5), the first principal component accounted for 50% of the sample variance. It again tended to separate sites into southern and northern rivers, although separations were less clear. Southern rivers (Oldman and some Red Deer stations) had low [NFR] and high concentrations in all other variables, whereas northern rivers (middle reaches of Athabasca and

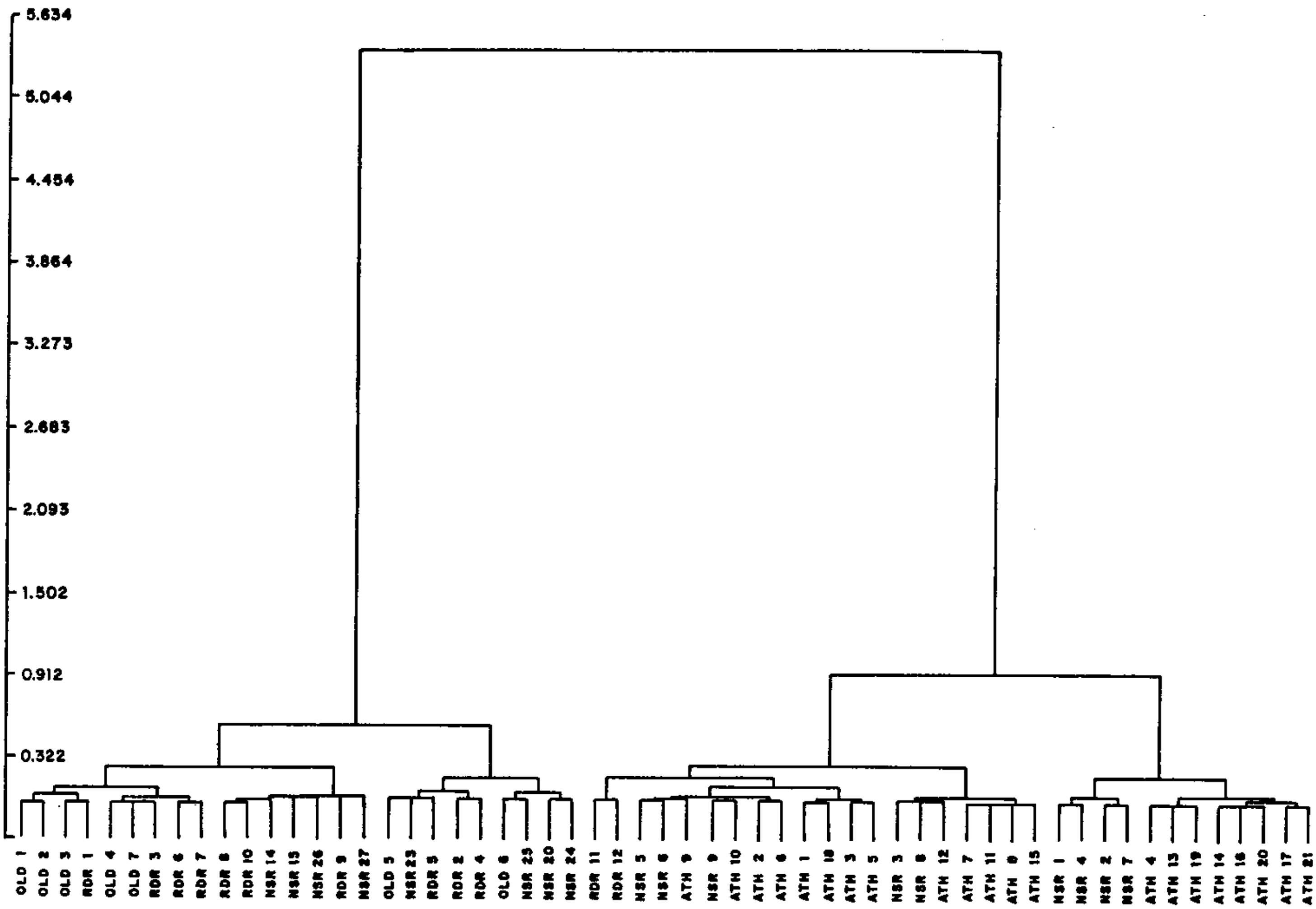

Figure 4. Cluster analysis using Chl *a*, TP, TDP, NN, TKN, DA and NFR data.

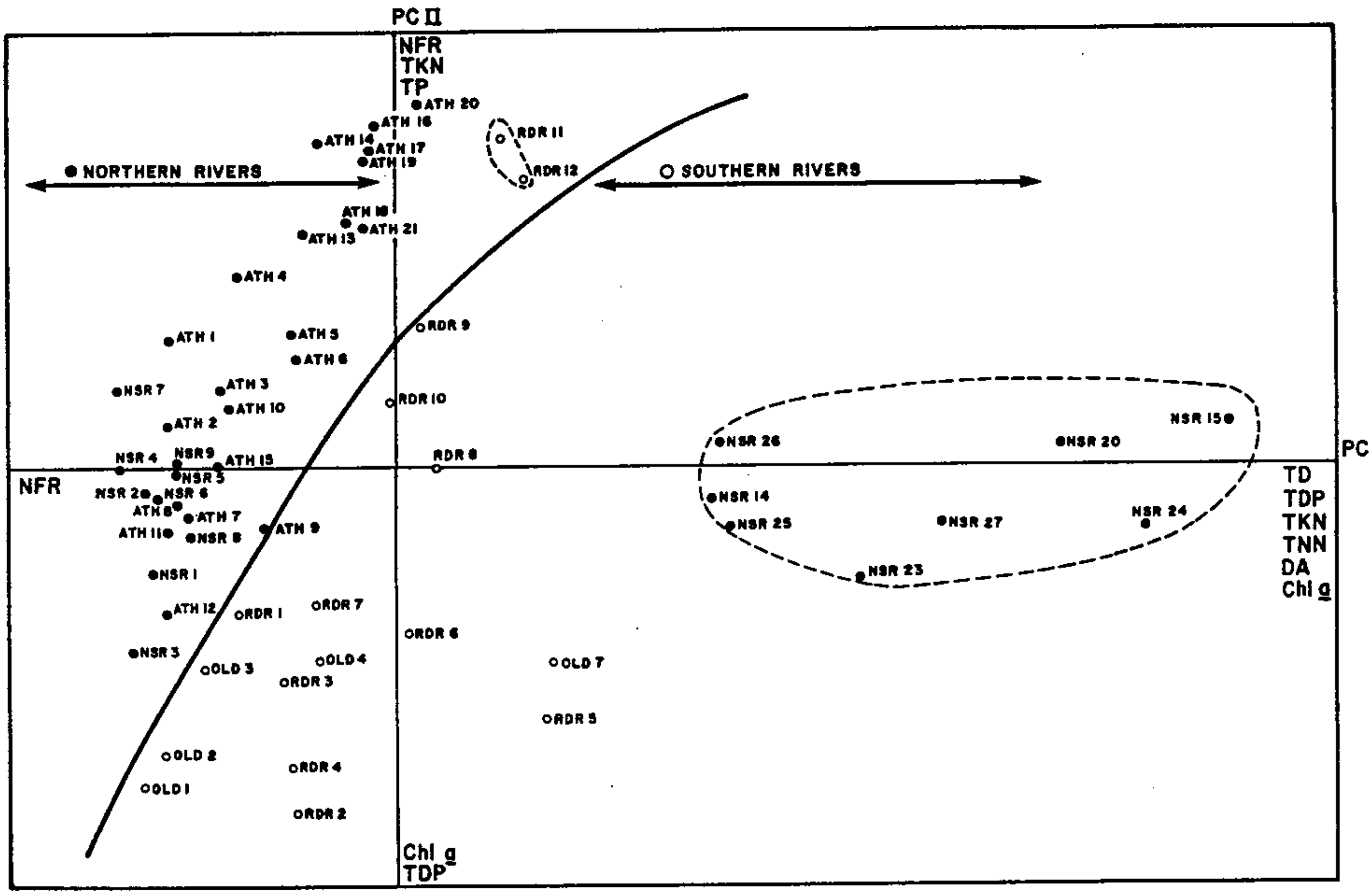

Figure 5. Principal component analysis using Chl $\underline{a}$, TP, TDP, NN, TKN, DA and NFR data.

upper reaches of North Saskatchewan) had high [NFR] and low concentrations in the remaining variables (Figure 5). As in the first cluster analysis, sites downstream of Edmonton on the North Saskatchewan were grouped with the southern rivers.

The second principal component accounted for 21% of the sample variance and separated sites with high [NFR], [TKN] and [TP], and low [Chl A] and [TDP]. The upper and lower reaches of the Athabasca River and two lower Red Deer sites were grouped on this basis (Figure 5). At the opposite end of the pole (high [Chl A] and [TDP] with low [NFR], [TKN], and [TP]) were several sites on the Oldman River and several sites on the Red Deer downstream from the city of Red Deer. The remaining sites on the lower reaches of the Red Deer were intermediate between these poles (Figure 5).

The third principal component accounted for 13% of the variance, and separated the sites on the basis of high [DA] and [NN], and low [Chl A], [TDP], [TP] and [TKN]. This component explained why some sites did not fit the classification established by the first two components.

In conclusion, adding variables to those used in the first cluster resulted in basically the same broad separation of northern and southern river stations with similar anomalies occuring.

4.0 SUMMARY

The major river systems examined in this study, with the exception of the Milk and South Saskatchewan, all originate in the Rocky Mountains and flow to the east through the Foothills, and Western and Eastern Alberta Plains to the Saskatchewan border. The Athabasca River flows north to the Athabasca Delta Plain through several additional physiographic zones, which include the Lesser Slave Lowland, Algar Plain, Clearwater Lowland, and the Athabasca Delta Plain. The Milk River flows east along the southern border of Alberta through the Milk River Ridge, and the South Saskatchewan River begins in the Eastern Alberta Plains at the confluence of the Oldman and Bow River.

The Alpine, Subalpine and Montane ecoregions are generally common to the rivers originating in the Rocky Mountains. It is after these headwater reaches that the major differences in ecoregions, through which the southern and northern rivers flow, become apparent. The Athabasca and the North Saskatchewan Rivers flow through the Boreal Uplands, Boreal Foothills, Boreal Mixedwood and Aspen Parkland ecoregions. With the exception of the Boreal Mixedwood, the Red Deer River also flows through these ecoregions, however, it veers south and passes through Fescue, Mixed and Short Grass ecoregions. The latter three ecoregions are common to the rivers south of the Red Deer River. The Bow River briefly passes through Aspen Parkland as does the Oldman River.

The climatic regime and the topography, vegetation, soil and river substrate characteristics may change from one physiographic zone and ecoregion to the next. These changes will ultimately affect the physical and chemical characteristics of a river and consequently the developmental patterns in primary producers along its course. In addition to natural inputs, development inputs such as agricultural runoff and municipal and industrial wastes also greatly affect the water quality of a river system.

Based on a comparative analysis of epilithic chlorophyll a, nutrients and non-filterable residues, the best separation of sites was obtained by grouping those above major development inputs, those downstream and obviously affected by these inputs, and those located well downstream of inputs in a zone of recovery. These separations, and those between river basins, were demonstrated with cluster and principal component analyses.

The best separation was obtained from analysis of Chl a, TDP and NFR data. Above development inputs, [Chl A], [TDP] and [NFR] were generally low in all rivers. Downstream, the degree of effect was dependent on the quantity and quality of municipal and industrial waste discharges and agricultural runoff, the background water quality, the volume of flow, and the assimilative capacity of the river. Most rivers were characterized by a zone of recovery well downstream of major development inputs where there was an obvious decrease in [Chl A].

[Chl A], [TDP] and [NFR] formed the basis for separating southern and northern river sampling sites. High [Chl A], high [TDP] and low [NFR] characterized southern rivers downstream of development inputs (Oldman, Bow, Highwood, and Red Deer rivers). Sites downstream of Edmonton on the North Saskatchewan River also fell into this southern river trend, although the effect of development inputs was less and was demonstrated by somewhat lower [Chl A] relative to the nutrient supply available. NFR concentrations in the North Saskatchewan were higher than in southern rivers, but lower than in the Athabasca River.

The lower reaches of the Red Deer River, and the South Saskatchewan River above Medicine Hat and below the zone of this city's impact, were characterized by low [Chl A] and high [TDP] and [NFR], which was more typical of northern rivers. For these sites, discharge-related physical factors may control primary production.

The South Saskatchewan River sites described above, the lower reaches of the Red Deer and Athabasca rivers, and the last two stations on the North Saskatchewan River (zone of recovery) are characterized by low [Chl A], and high [TDP] and [NFR]. These reaches all fall within the Eastern

Alberta Plains physiographic zone, and occur in areas which are generally not affected by development inputs.

Stations in the upper reaches of the Red Deer River above any developments were intermediate in characteristics between the same reaches of the remaining southern and northern rivers. Also, stations in the North Saskatchewan River above major developments were characterized by low [Chl A], low [TDP] and moderate [NFR].

Sampling sites along and between rivers which were clustered together were generally located in the same physiographic zones and ecoregions.

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APPENDIX 1. Table of sampling sites on each river, showing ecoregions and physiographic zones. Refer to Figures 1 and Appendix 4 for legend.

RIVER	SITE	LOCATION	ECOREGION NUMBER	PHYSIOGRAPHIC ZONE
Milk	1	Upstr confl N. Milk R.	2	MRR
	2	Dnstr Milk R. (town)	1	MRR
	3	Hwy878	1	MRR
North Milk	1	Upstr confl Milk R.	2	RMF
Crowsnest	1	Mouth	3	RMF
Castle	1	Hwy3 bridge near Cowley	3	RMF
Oldman	1	Waldon's Corner	3	RMF
	2	Near Brocket	3	RMF
	3	Near Fort Macleod	2	WAP
	4	Above Lethbridge, STP outfall	2	WAP
	5	Below Picture Butte	2	EAP
	6	Above Taber	1	EAP
	7	Mouth	1	EAP
Bow	1	Below Bearspaw Dam	4	WAP
	2	Upstream 85th St. Bridge	4	WAP
	3	Near Inglewood Golf Course	4	WAP
	4	Below Bonnybrook Sewage Outfall	3	WAP
	5	Acadia Trailer Park	3	WAP
	6	Bonnybrook Study Site M4 km8	3	WAP
	7	Below Carseland Dam	3	WAP
	8	Bonnybrook Study Site M5 km12	3	WAP
	9	Fish Creek Location 11	3	WAP
	10	Bonnybrook Study Site M7 km17.5	3	WAP
	11	Stiers Ranch	3	WAP
	12	Bonnybrook Study Site M9 km30	3	WAP
	13	Bonnybrook Study Site M10 km37	3	WAP
	14	Below Confluence Highwood R.	3	WAP
	15	Bonnybrook Study Site M11 km45	3	WAP
	16	Bonnybrook Study Site M12 km52	3	WAP
	17	Upstream Hwy24	3	WAP
	18	Bonnybrook Study Site M13 km74	2	WAP
	19	Cluny	2	WAP
	20	Below Bassano Dam	2	WAP
	21	Bow City Bridge	1	WAP
	22	Ronalane Bridge	1	WAP
	23	Before Oldman R.	1	EAP
Highwood	1	Below Pekisko Creek	3	PH
	2	Above High River	3	PH
	3	Below High River	3	PH
	4	Downstream Hwy547 Bridge	3	PH
	5	At Hwy522	3	PH
Sheep	1	Downstream of Hwy22	4	RMF
South Sask	1	Hwy879	1	EAP
	2	Above Medicine Hat	1	EAP
	3	Below Medicine Hat	1	EAP
	4	Hwy41 Bridge	1	EAP

RIVER	SITE	LOCATION	ECOREGION NUMBER	PHYSIOGRAPHIC ZONE
Red Deer	1	Dam Impact Site 1	9	WAP
	2	Dam Impact Site 3	4	WAP
	3	Dam Impact Site 4	4	WAP
	4	Dam Impact Site 5	4	WAP
	5	10k above Blindman R.	4	WAP
	6	Dam Impact Site 6	4	EAP
	7	Nevis Bridge	4	EAP
	8	Hwy585 Bridge	4	EAP
	9	Above Drumheller	2	EAP
	10	Below Drumheller	2	EAP
	11	Finnegan above Hwy36	1	EAP
	12	Hwy884 near Jenner	1	EAP
	13	Near Border	1	EAP
North Sask	1	Whirlpool Point		
	2	Below Bighorn Reservoir	10	RMF
	3	At Ancona	10	RMF
	4	3k above Rocky Mountain House	9	WAP
	5	1k above Baptiste R.	9	WAP
	6	1k above Brazeau R.	9	WAP
	7	Drayton Valley Bridge	9	EAP
	8	Genesee Bridge	8	EAP
	9	Upstream Devon Bridge	4	EAP
	10	Upstream 50th St. bridge, Left	4	EAP
	11	Upstream 50th St. bridge, Right	4	EAP
	12	Beverly Rail Trestle, Left	4	EAP
	13	Beverly Rail Trestle, Right	4	EAP
	14	Ft. Sask. Rail Trestle, Left	4	EAP
	15	Ft. Sask. Rail Trestle, Right	4	EAP
	16	Vinca Trailer, Right	4	EAP
	17	Vinca Trailer, Left	4	EAP
	18	Dnstr. Confl. Beaverhills Cr., Left	4	EAP
	19	Dnstr. Confl. Beaverhills Cr., Right	4	EAP
	20	Waskatenau Bridge	4	EAP
	21	90m Upstr. Pakan Bridge, Left	4	EAP
	22	90m Upstr. Pakan Bridge, Right	4	EAP
	23	Pakan Bridge	4	EAP
	24	Duvernay	4	EAP
	25	Elk Point	4	EAP
	26	Lea Park	4	EAP
	27	Lloydminster Ferry	4	EAP
Pembina	1	Above Centre Cr.	10	RMF
	2	Adjacent Hwy40	10	RMF
	3	Hwy40 bridge	10	RMF
	4	10km dnstr Hwy40 bridge	10	RMF
	5	Before confl Athabasca R., Right	8	LSL
Lovett	1	Above confl Coal Cr.	10	RMF
	2	Lovettville	10	RMF
	3	Dnstr Lovettville	10	RMF

APPENDIX 2. Table of median epilithic chlorophyll a, nutrient and nonfilterable residue values for sampling sites on each river.

RIVER	SITE	EPI CHL A (mg/m2) n	EPI CHL A (mg/m2) MEDIAN	TP (mg/l) n	TP (mg/l) MEDIAN	TDP (mg/l) n	TDP (mg/l) MEDIAN	NN (mg/l) n	NN (mg/l) MEDIAN	TKN (mg/l) n	TKN (mg/l) MEDIAN	DA (mg/l) n	DA (mg/l) MEDIAN	NFR (mg/l) n	NFR (mg/l) MEDIAN
Milk	1	6	18.626			12	0.005							12	4.000
	2	9	6.103			24	0.005							24	15.100
	3	5	176.500			24	0.007							24	33.600
North Milk	1	3	14.100			13	0.004							13	5.300
Crowsnest	1	13	245.670	29	0.030	34	0.014	28	0.070	6	0.285	30	0.030	59	9.000
Castle	1	11	94.117	6	0.008	33	0.003	6	0.040	6	0.075	6	0.003	36	2.400
Oldman	1	26	22.858	6	0.008	33	0.005	6	0.000	6	0.120	6	0.004	35	2.800
	2	26	29.262	6	0.013	36	0.004	6	0.010	6	0.105	6	0.003	40	4.000
	3	24	30.740	6	0.020	33	0.004	6	0.000	6	0.150	6	0.006	35	6.600
	4	15	89.520	5	0.044	39	0.006	6	0.010	6	0.200	6	0.007	100	8.700
	5	14	163.285	7	0.166	38	0.160	6	0.070	5	0.300	48	0.200	120	10.000
	6	15	143.840	6	0.133	15	0.128	7	0.000	6	0.290	50	0.200	35	23.000
	7	22	75.490	6	0.104	51	0.044	6	0.010	6	0.330	6	0.010	116	6.000
Bow	1	18	23.510			19	0.003							67	2.000
	2	40	39.350			60	0.003							65	2.000
	3	5	111.940			20	0.003								
	4	10	254.390			25	0.020								
	5	10	70.384			38	0.019								
	6	10	104.870			39	0.020								
	7	6	218.885												
	8	9	117.560			20	0.021								
	9	9	98.363			38	0.031	3	0.100					2	45.500
	10	9	252.200			30	0.063								
	11	52	204.950			84	0.027	16	0.550			43	0.650	109	8.400
	12	9	393.980			30	0.056								
	13	10	122.875			18	0.010								
	14	9	340.880			14	0.013							6	3.000
	15	35	218.760			23	0.120							5	2.000
	16	9	296.130			17	0.015								
	17	32	261.710			60	0.031							107	6.000
	18	21	157.240			10	0.035								
	19	22	187.365			34	0.016	15	0.700			39	0.400	45	10.000
	20	17	172.090			38	0.053							96	7.000
	21	34	57.070			70	0.013							105	7.000
	22	31	89.400			61	0.013	9	0.080					118	12.000
	23	7	23.908			14	0.010							17	8.000

RIVER	SITE	EPI CHL A (mg/m2)		TP (mg/l)		TDP (mg/l)		NN (mg/l)		TKN (mg/l)		DA (mg/l)		NFR (mg/l)	
		n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN
Highwood	1	22	47.626			6	0.005							28	2.000
	2	24	36.831			6	0.005							31	1.600
	3	13	158.260			7	0.028							31	2.000
	4	21	176.270			9	0.002					7	0.200	37	3.200
	5	14	132.520			6	0.015							30	2.400
Sheep	1	5	82.752	23	0.050			21	0.050			60	0.200	29	10.000
South Sask	1	6	6.984			30	0.055							92	11.000
	2	6	1.892			31	0.031	21	0.600			32	0.300	110	12.500
	3	7	41.840			17	0.022							55	23.000
	4	7	18.688			33	0.030	9	0.040			32	0.300	110	21.000
Red Deer	1	30	19.585	18	0.013	62	0.004	19	0.050	19	0.120	15	0.100	77	9.600
	2	32	134.920	18	0.018	65	0.005	19	0.050	19	0.180	19	0.017	68	4.000
	3	37	54.800	18	0.016	65	0.006	19	0.020	19	0.260	33	0.016	74	6.200
	4	18	106.645	17	0.018	55	0.006	32	0.020	18	0.245	18	0.009	67	4.400
	5	4	217.100			6	0.067							5	8.000
	6	31	224.930	17	0.040	63	0.032	19	0.010	18	0.380	87	0.300	85	7.300
	7	13	48.700	13	0.034	16	0.021	14	0.000	15	0.320	43	0.200	22	8.000
	8	11	45.000	11	0.026	16	0.014	12	0.000	13	0.300	12	0.010	17	9.000
	9	12	44.300	14	0.038	27	0.016	28	0.010	15	0.320	74	0.215	52	22.000
	10	11	23.800	15	0.046	15	0.016	14	0.000	15	0.440	14	0.012	16	32.000
	11	11	36.000	14	0.045	13	0.014	12	0.000	14	0.360	15	0.012	15	26.000
	12	12	11.450	14	0.081	15	0.016	13	0.010	14	0.470	15	0.014	16	70.500
	13	10	23.800	14	0.089	14	0.013	14	0.000	14	0.480	15	0.012	16	66.000

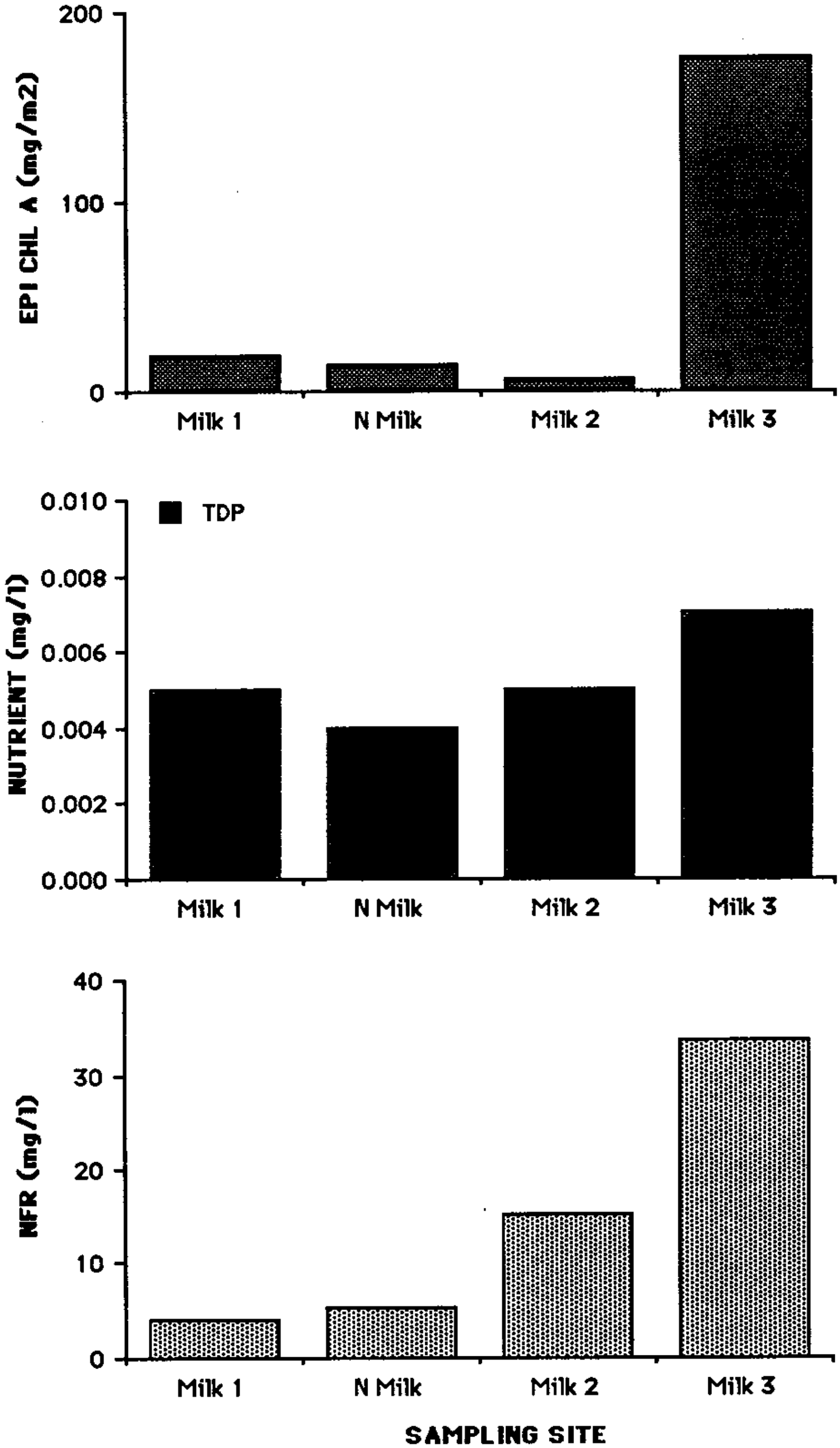
RIVER	SITE	EPI CHL A (mg/m2) n	EPI CHL A (mg/m2) MEDIAN	TP (mg/l) n	TP (mg/l) MEDIAN	TDP (mg/l) n	TDP (mg/l) MEDIAN	NN (mg/l) n	NN (mg/l) MEDIAN	TKN (mg/l) n	TKN (mg/l) MEDIAN	DA (mg/l) n	DA (mg/l) MEDIAN	NFR (mg/l) n	NFR (mg/l) MEDIAN
North Sask	1	7	2.575	6	0.016	8	0.002	8	0.090	8	0.050	8	0.004	8	7.500
	2	7	0.280	6	0.006	8	0.002	8	0.070	8	0.050	32	0.200	12	10.000
	3	7	6.157	6	0.006	8	0.002	8	0.070	8	0.050	8	0.005	8	5.800
	4	7	1.888	6	0.012	8	0.002	8	0.050	8	0.060	8	0.002	8	13.600
	.5	7	11.517	6	0.015	8	0.002	8	0.030	8	0.080	8	0.006	8	21.200
	6	7	12.918	6	0.008	8	0.002	8	0.010	8	0.110	8	0.004	8	17.600
	7	6	0.185	12	0.008	8	0.002	8	0.010	14	0.130	63	0.100	20	15.000
	8	6	8.555	12	0.027	8	0.003	15	0.010	8	0.140	10	0.009	31	10.800
	9	6	7.176												
	10	9	20.571	12	0.019			24	0.050	12	0.210	12	0.010	17	15.600
	11	9	8.500	12	0.024			24	0.050	12	0.190	12	0.010	17	17.000
	12	10	21.347	12	0.019			24	0.050	12	0.190	12	0.019	17	12.000
	13	9	72.632	17	0.250			24	0.150	17	1.000	17	0.672	17	11.000
	14	9	53.700	18	0.084	9	0.040	9	0.160	20	0.450	20	0.139	24	15.300
	15	9	41.358	18	0.160	9	0.124	9	0.310	20	0.660	20	0.333	23	20.600
	16	7	28.023												
	17	7	77.235												
	18	9	50.401	11	0.116			23	0.100	11	0.440	11	0.140	16	9.000
	19	9	107.060	11	0.104			23	0.270	11	0.720	11	0.240	16	13.500
	20	6	140.135	5	0.104	7	0.036	32	0.270	7	0.480	115	1.100	44	35.100
	21	9	85.135	12	0.121			23	0.200	12	0.670	12	1.260	17	12.000
	22	9	78.754	12	0.108			23	0.300	12	0.655	12	0.185	17	14.000
	23	4	179.360	3	0.096	5	0.052	17	0.220	5	0.560	5	0.103	22	11.900
	24	6	116.674	7	0.107	9	0.040	13	0.320	9	0.580	137	1.300	61	18.000
	25	7	146.000	7	0.078	9	0.033	9	0.210	9	0.460	9	0.038	9	17.200
	26	6	30.692	7	0.111	9	0.031	9	0.190	9	0.480	9	0.009	9	15.000
	27	2	36.500	7	0.111	9	0.026	20	0.200	9	0.440	133	1.200	60	13.500
Pembina	1	3	23.570	16	0.013			16	0.010	16	0.190	16	0.004	16	6.900
	2	3	70.400	3	0.008			3	0.090	3	0.250	3	0.008	3	6.900
	3	2	38.530	16	0.010			16	0.130	16	0.240	16	0.007	16	9.500
	4	3	44.550	3	0.008			3	0.060	3	0.200	3	0.006	3	4.800
	5	3	4.853												
Lovett	1	9	8.330	17	0.012			16	0.010	17	0.180	17	0.006	143	6.000
	2	6	47.375	12	0.020			12	0.430	12	0.270	12	0.014	12	13.200
	3	9	63.270	17	0.018			16	0.570	17	0.240	17	0.022	168	26.000

RIVER	SITE	EPI CHL A (mg/m2) n	MEDIAN	TP (mg/l) n	MEDIAN	TDP (mg/l) n	MEDIAN	NN (mg/l) n	MEDIAN	TKN (mg/l) n	MEDIAN	DA (mg/l) n	MEDIAN	NFR (mg/l) n	MEDIAN
McLeod	1	6	33.915	9	0.006			9	0.050	9	0.080	9	0.006	8	3.700
	2	3	24.250	4	0.006			4	0.050	4	0.075	4	0.004	3	3.600
	3	3	4.070	5	0.006			5	0.240	5	0.090	5	0.007	4	4.200
	4	3	12.940	5	0.006			5	0.190	5	0.070	5	0.005	4	5.000
	5	3	22.040	4	0.006			4	0.100	4	0.085	4	0.007	3	4.000
	6	6	26.365	9	0.006			9	0.140	9	0.140	9	0.008	8	5.200
	7	6	31.360	8	0.006			8	0.090	8	0.135	8	0.007	8	5.100
	8	6	29.020	7	0.006			7	0.160	7	0.140	7	0.006	7	5.200
	9	6	23.995	14	0.007			14	0.070	14	0.150	14	0.006	14	5.100
	10	6	42.805	21	0.008			21	0.100	21	0.140	21	0.005	21	6.000
	11	10	27.500	21	0.012	14	0.003	21	0.070	21	0.180	20	0.007	21	8.600
	12	5	14.420	21	0.012			21	0.030	21	0.200	20	0.007	21	8.800
	13	2	11.845	2	0.006										
	14	2	20.825	2	0.008										
	15	2	108.440	3	0.024			3	0.080	3	0.340	3	0.005	3	6.200
	16	2	201.680	2	0.014										
	17	2	180.465	2	0.009										
	18	2	167.895	2	0.011										
	19	2	137.335	3	0.010			4	0.010	4	0.230	4	0.010	4	2.600
	20	5	45.940	6	0.014			6	0.010	6	0.240	6	0.005	6	10.700
	21	2	81.755	2	0.011										
	22	2	76.060	2	0.011										
	23	2	76.495	2	0.012										
	24	5	50.400	7	0.015			7	0.010	7	0.240	7	0.009	7	7.400
	25	5	6.990	7	0.018			7	0.020	7	0.270	7	0.007	7	9.000
	26	3	9.480	2	0.014	4	0.003	5	0.010	5	0.220	5	0.005	4	4.500
	27	4	4.896	8	0.012	7	0.005	9	0.000	8	0.340	30	0.200	11	10.800
Gregg	1	3	4.290	10	0.006			6	0.180	9	0.060	10	0.005	9	2.000
	2	3	110.360	5	0.007			5	1.390	5	0.190	5	0.036	117	9.000
	3	2	11.800	21	0.006			20	0.760	20	0.115	21	0.008	20	4.700
	4	2	12.885	3	0.006			3	0.340	3	0.180	3	0.008	3	4.000
	5	9	10.440	18	0.006			18	0.190	18	0.145	18	0.006	18	5.200

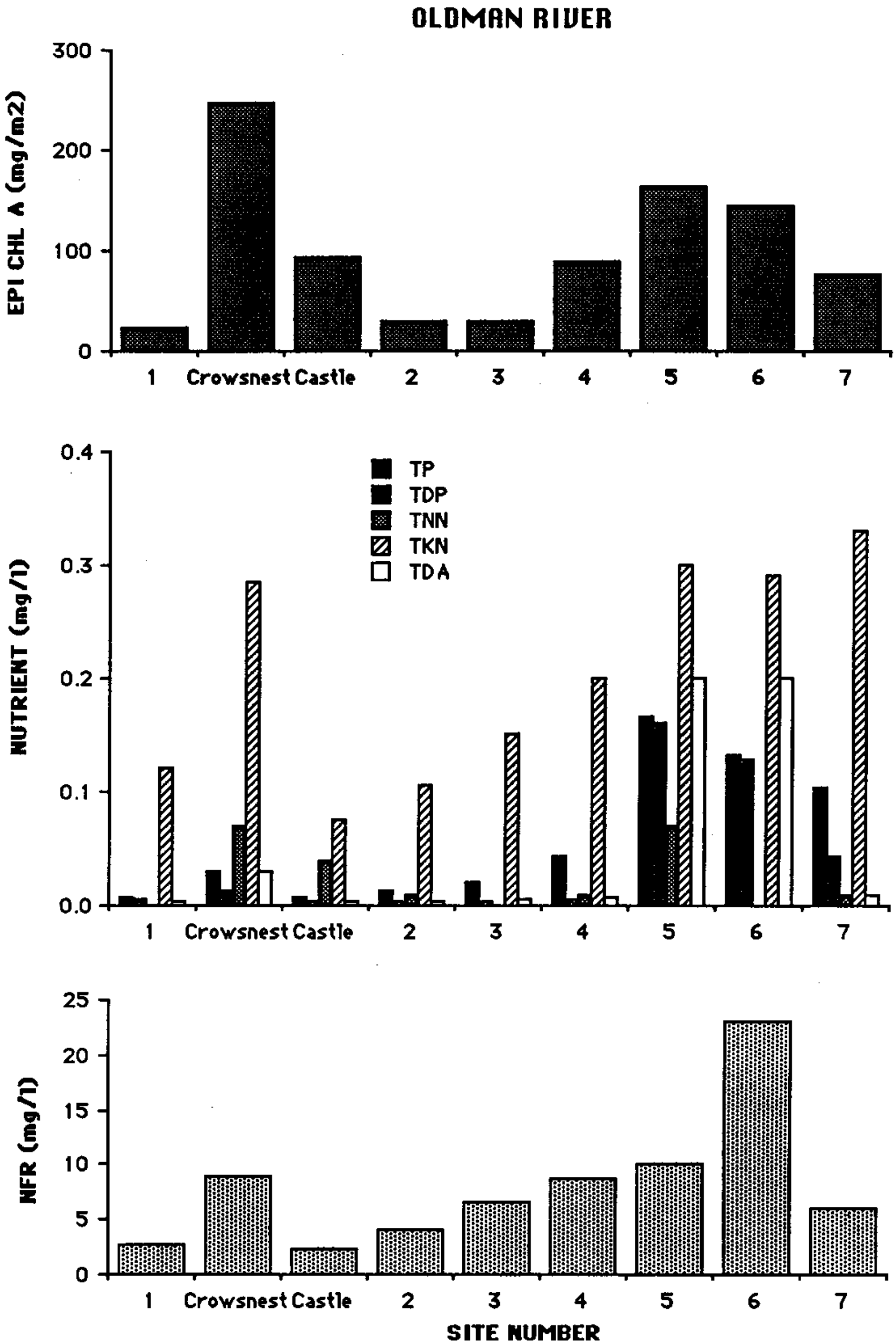
RIVER	SITE	EPI CHL A (mg/m2)		TP (mg/l)		TDP (mg/l)		NN (mg/l)		TKN (mg/l)		DA (mg/l)		NFR (mg/l)	
		n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN	n	MEDIAN
Berland	1	5	3.422	7	0.006	8	0.002	7	0.000	7	0.180	7	0.002	7	8.200
Embarras	1	5	21.690	14	0.013	14	0.005	14	0.000	14	0.265	13	0.006	14	7.300
La Biche	1	4	5.986	8	0.119	8	0.041	8	0.040	8	0.990	8	0.026	8	38.000
Calling	1	3	7.559	8	0.074	8	0.017	8	0.010	8	0.840	8	0.013	8	28.200
House	1	5	4.063	5	0.167	4	0.038	5	0.040	5	0.800	5	0.023	5	105.400
Clearwater	1	5	4.750	15	0.044	15	0.023	15	0.010	15	0.379	16	0.014	15	9.000
Poplar Cr.	1	5	11.268	5	0.060	5	0.021	5	0.010	5	1.020	5	0.046	70	9.100
Athabasca	1	5	4.744	6	0.011	6	0.002	6	0.050	6	0.070	6	0.009	6	38.300
	2	3	8.200	2	0.015	4	0.002	4	0.040	4	0.054	4	0.007	3	27.000
	3	4	3.048	8	0.022	8	0.006	8	0.060	8	0.150	8	0.009	8	20.900
	4	5	0.737	8	0.030	8	0.002	8	0.060	8	0.220	8	0.014	8	27.000
	5	5	4.777	6	0.029	6	0.003	6	0.060	6	0.250	6	0.023	6	26.800
	6	5	10.632	6	0.025	6	0.003	6	0.060	6	0.230	6	0.016	6	30.300
	7	5	5.470	8	0.009	8	0.002	9	0.050	8	0.160	12	0.024	10	10.900
	8	4	6.064	6	0.011	6	0.002	6	0.040	6	0.150	6	0.006	6	12.200
	9	3	12.700	4	0.030	4	0.002	7	0.020	6	0.123	33	0.200	9	14.000
	10	4	6.902	6	0.019	6	0.002	6	0.030	6	0.210	6	0.010	6	20.600
	11	3	5.040	2	0.012	4	0.002	4	0.030	4	0.141	4	0.025	3	10.000
	12	3	10.280	2	0.015	4	0.004	4	0.010	4	0.138	4	0.006	3	7.000
	13	4	0.643	5	0.056	5	0.002	6	0.030	5	0.180	32	0.200	10	37.000
	14	4	0.714	6	0.047	7	0.007	6	0.030	6	0.360	6	0.009	6	46.200
	15	3	4.050	4	0.020	4	0.003	6	0.000	5	0.300	6	0.007	3	10.000
	16	5	0.831	8	0.063	8	0.011	8	0.030	8	0.370	8	0.026	8	50.800
	17	5	2.070	6	0.052	6	0.008	6	0.020	6	0.420	6	0.024	6	47.500
	18	5	3.633	6	0.043	6	0.009	14	0.030	6	0.360	6	0.009	81	40.400
	19	5	0.200	6	0.056	6	0.014	6	0.020	6	0.450	6	0.025	6	32.700
	20	4	1.119	6	0.063	6	0.013	6	0.030	6	0.470	6	0.018	6	51.900
	21	3	1.412	6	0.053	5	0.012	6	0.020	6	0.430	6	0.014	55	28.000

APPENDIX 3. River course variation in median epilithic chlorophyll a, nutrient and nonfilterable residue values.

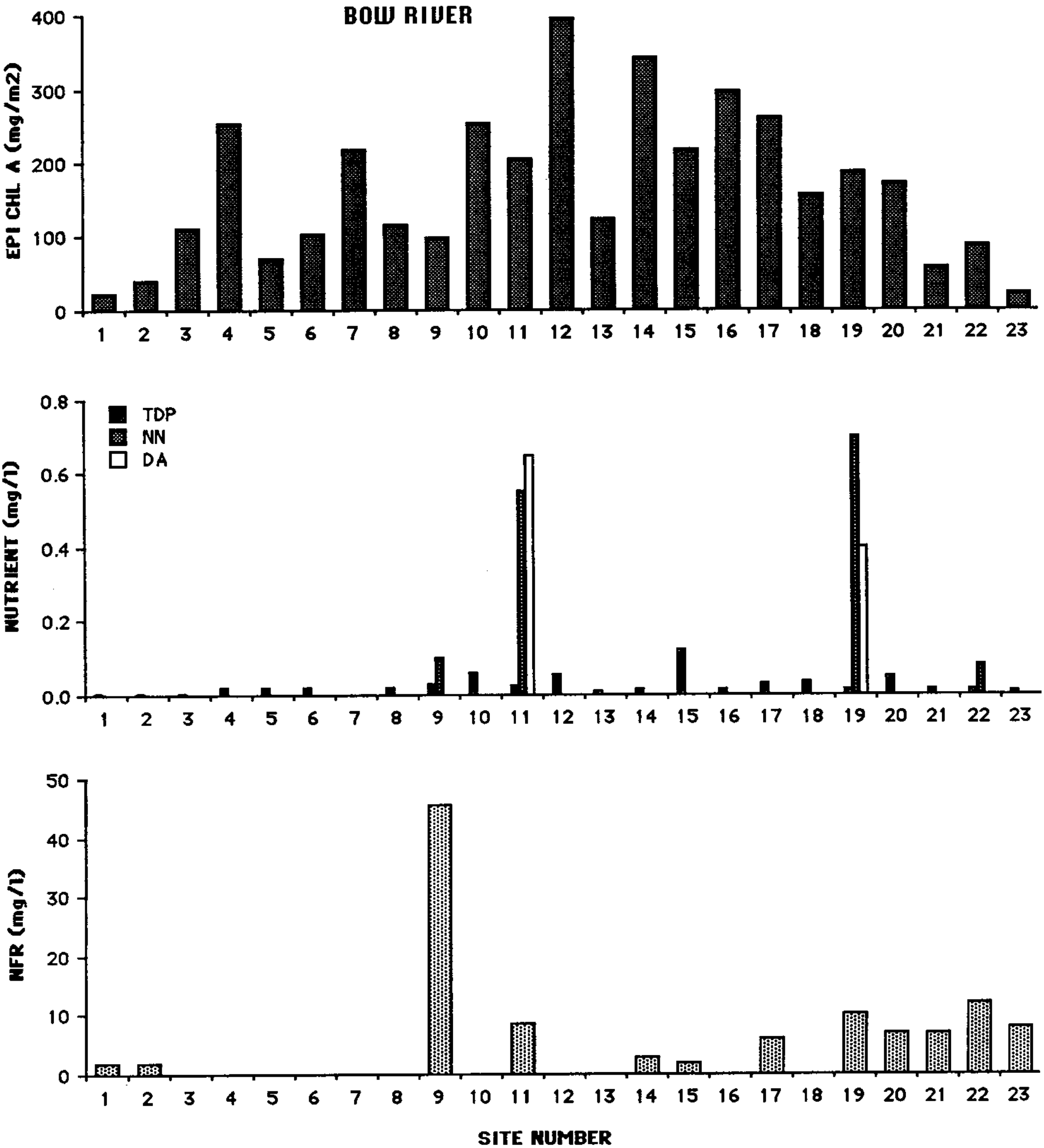
MILK RIVER



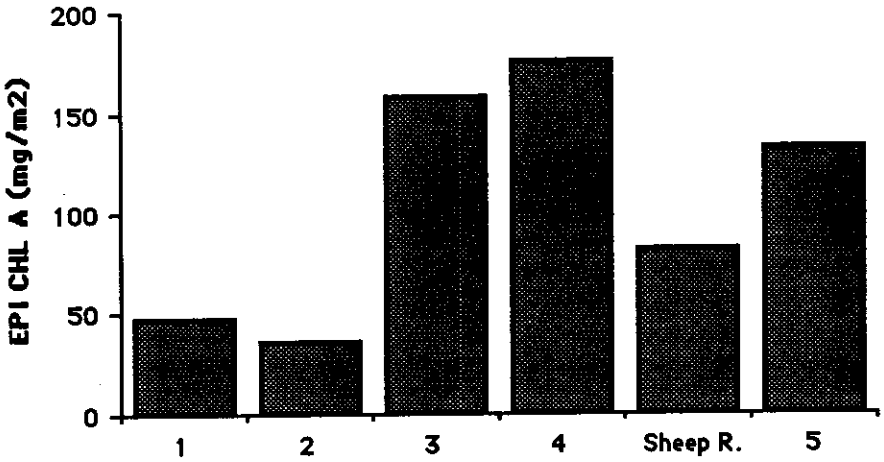
200
100
0
EPI CHL A (mg/m2)
Milk 1
N Milk
Milk 2
Milk 3
0.010
0.008
0.006
0.004
0.002
0.000
NUTRIENT (mg/l)
TDP
Milk 1
N Milk
Milk 2
Milk 3
40
30
20
10
0
NFR (mg/l)
Milk 1
N Milk
Milk 2
Milk 3
SAMPLING SITE

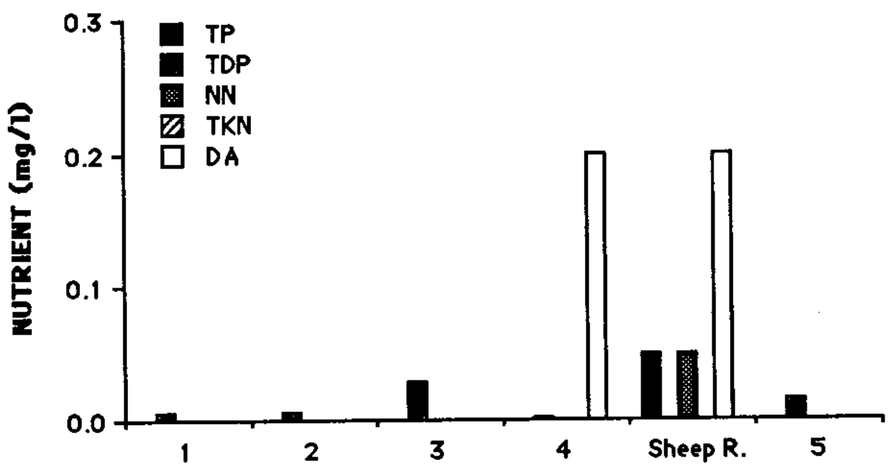


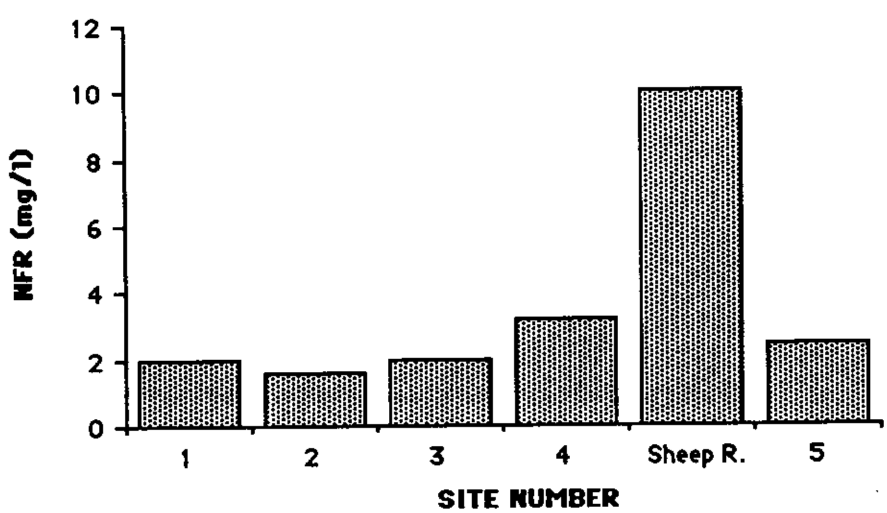
OLDMAN RIVER
EPI CHL A (mg/m2)
300
200
100
0
1
Crowsnest
Castle
2
3
4
5
6
7
TP
TDP
TNN
TKN
TDA
NUTRIENT (mg/l)
0.4
0.3
0.2
0.1
0.0
NFR (mg/l)
25
20
15
10
5
0
SITE NUMBER


BOW RIVER
EPI CHL A (mg/m2)
0
100
200
300
400
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
NUTRIENT (mg/l)
0.0
0.2
0.4
0.6
0.8
TDP
NN
DA
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
NFR (mg/l)
0
10
20
30
40
50
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23
SITE NUMBER

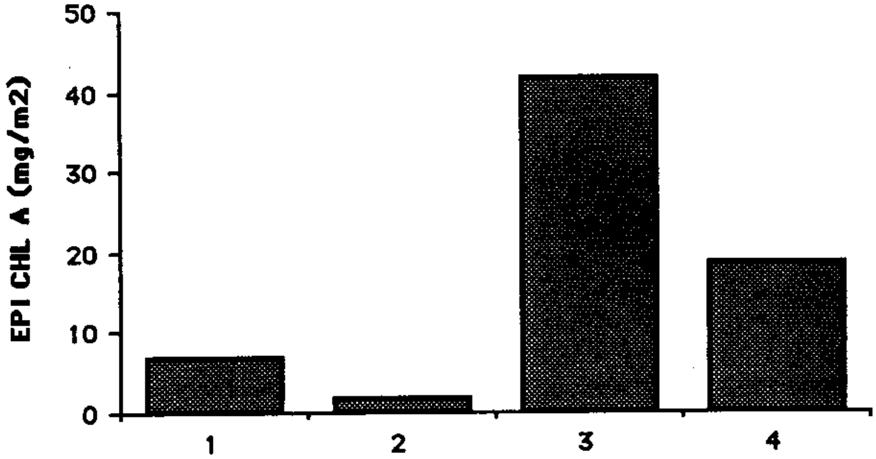
HIGHWOOD RIVER

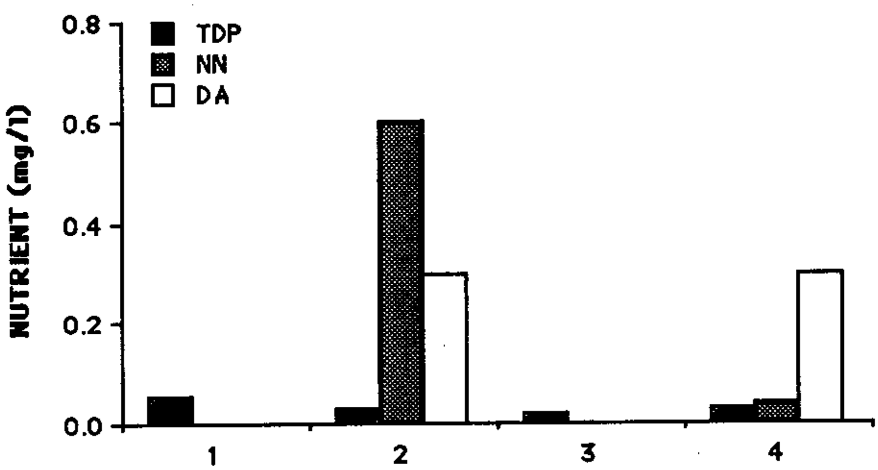


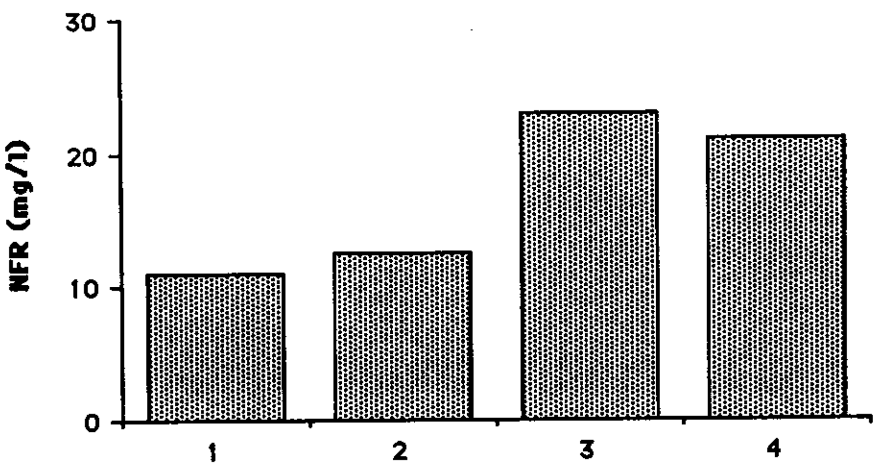


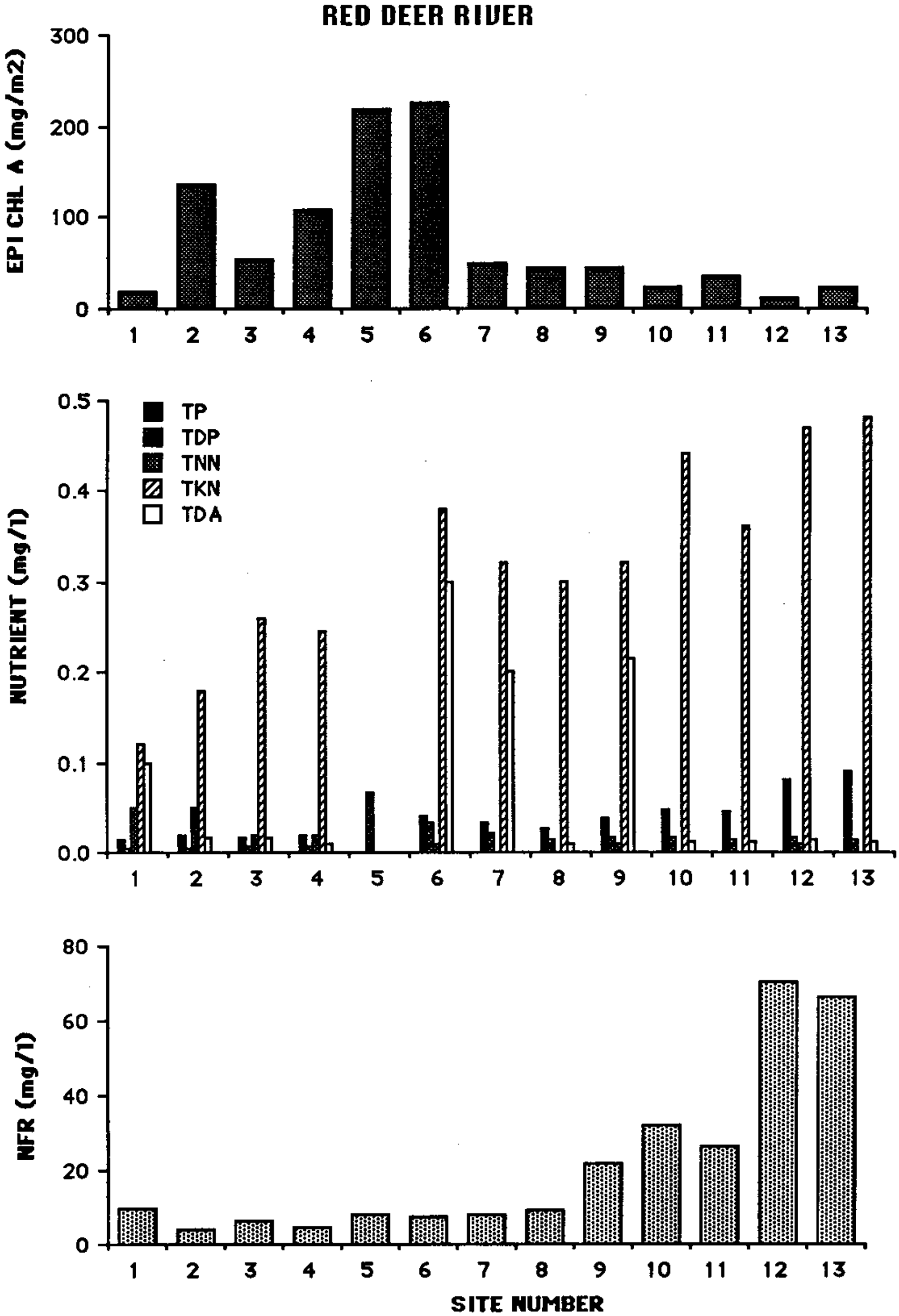


SOUTH SASKATCHEWAN RIVER

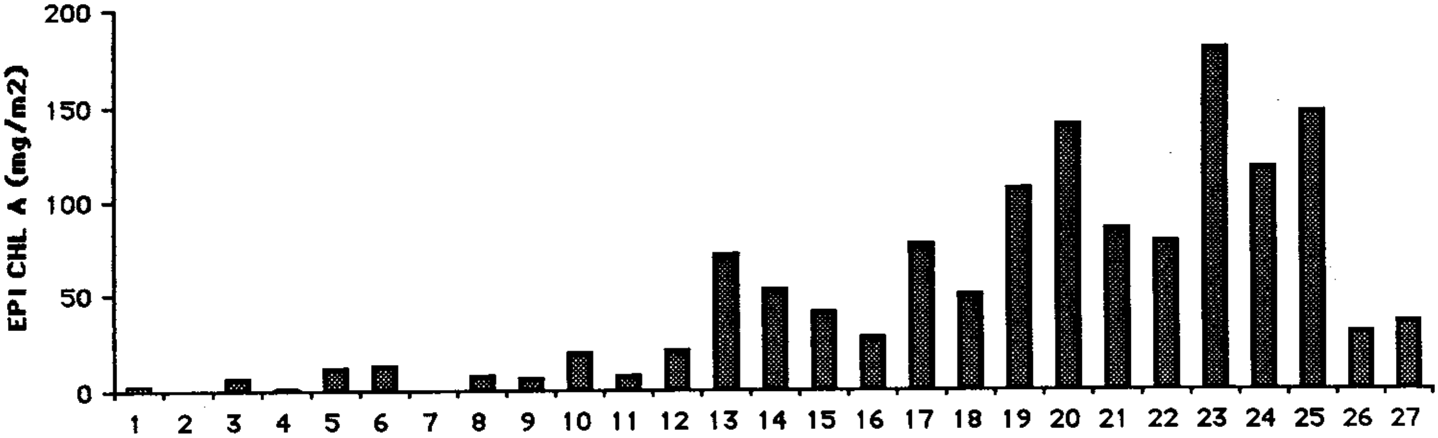


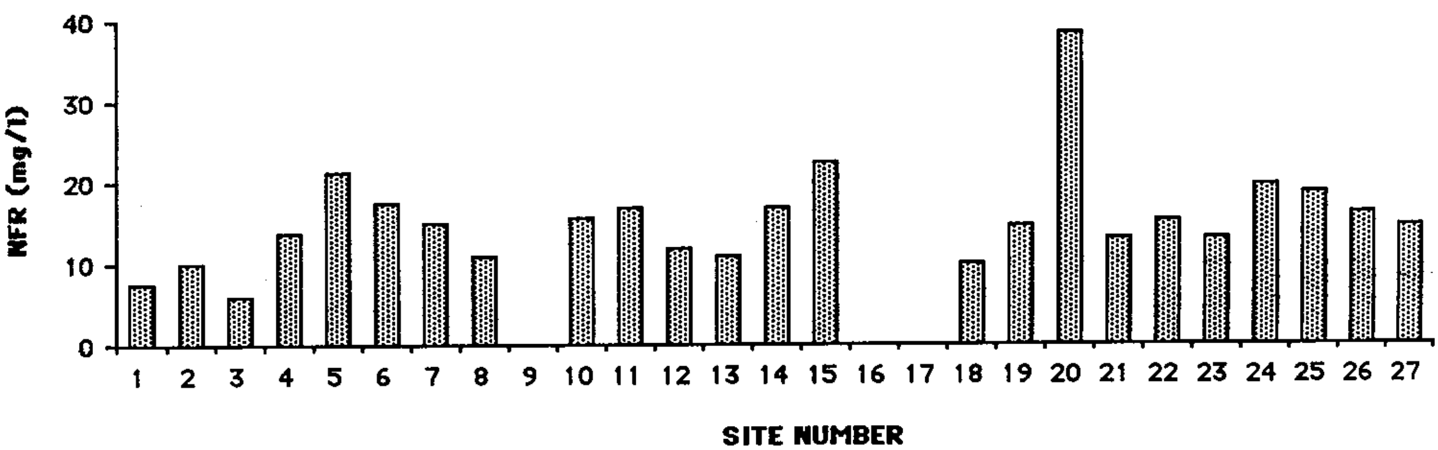


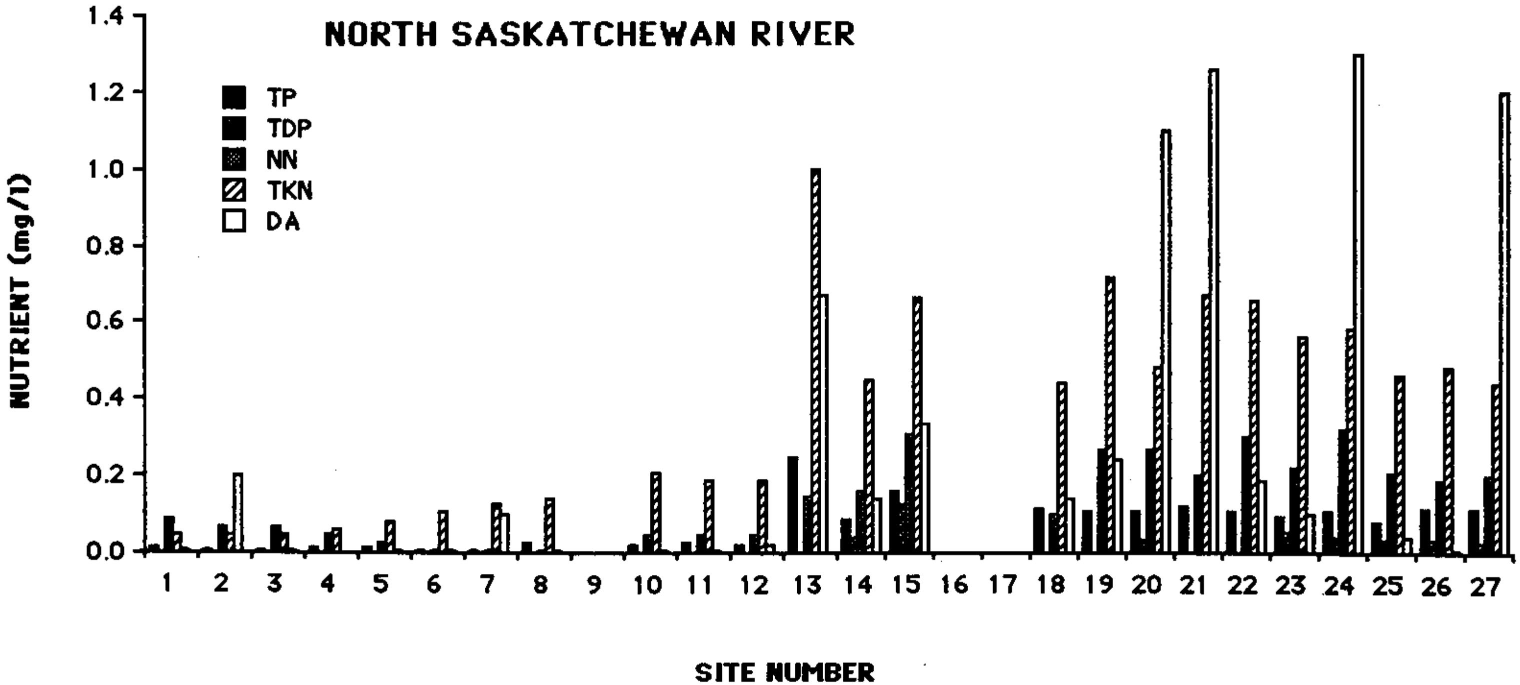



RED DEER RIVER
EPI CHL A (mg/m2)
300
200
100
0
1 2 3 4 5 6 7 8 9 10 11 12 13
NUTRIENT (mg/l)
0.5
0.4
0.3
0.2
0.1
0.0
TP
TDP
TNN
TKN
TDA
1 2 3 4 5 6 7 8 9 10 11 12 13
NFR (mg/l)
80
60
40
20
0
1 2 3 4 5 6 7 8 9 10 11 12 13
SITE NUMBER

NORTH SASKATCHEWAN RIVER

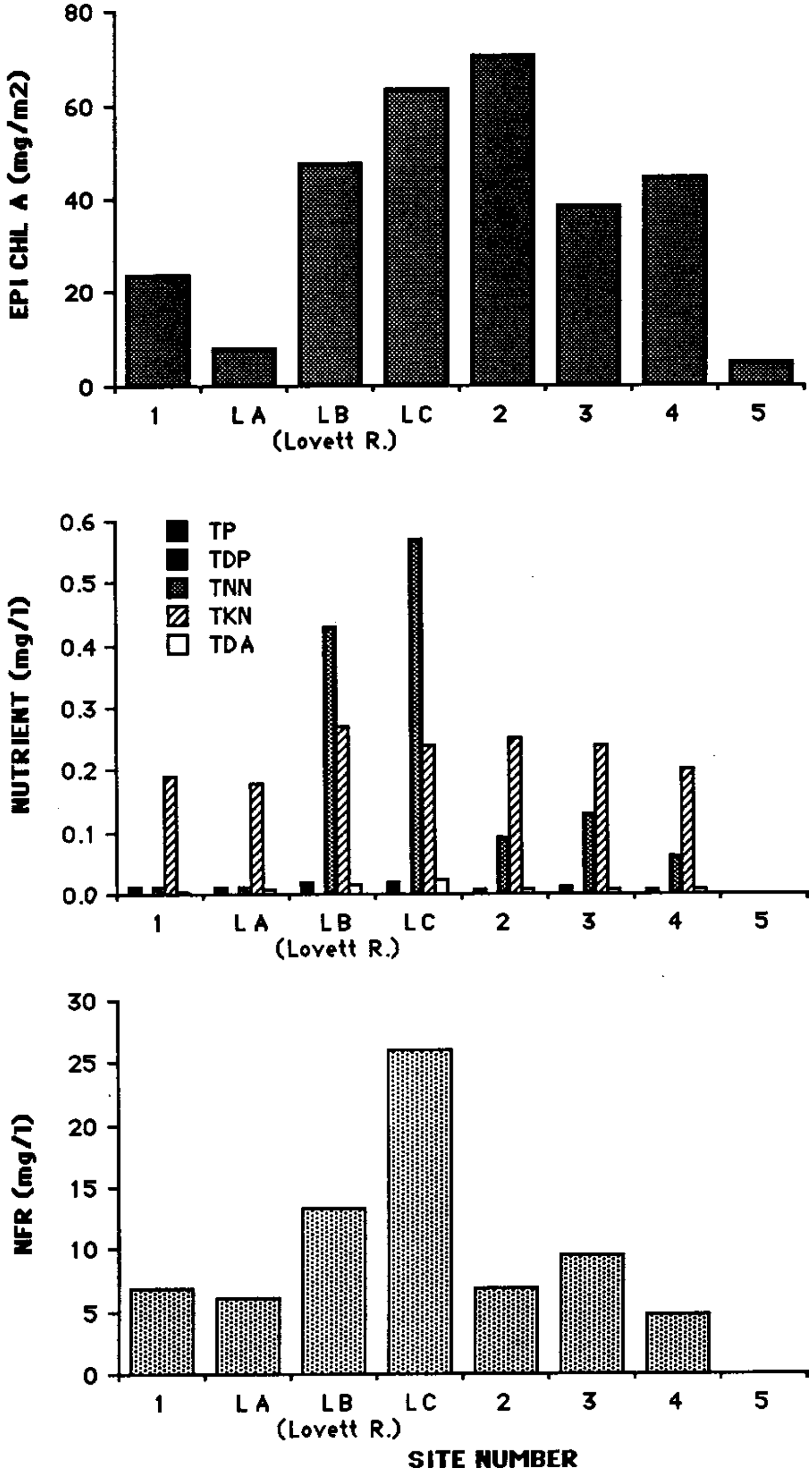


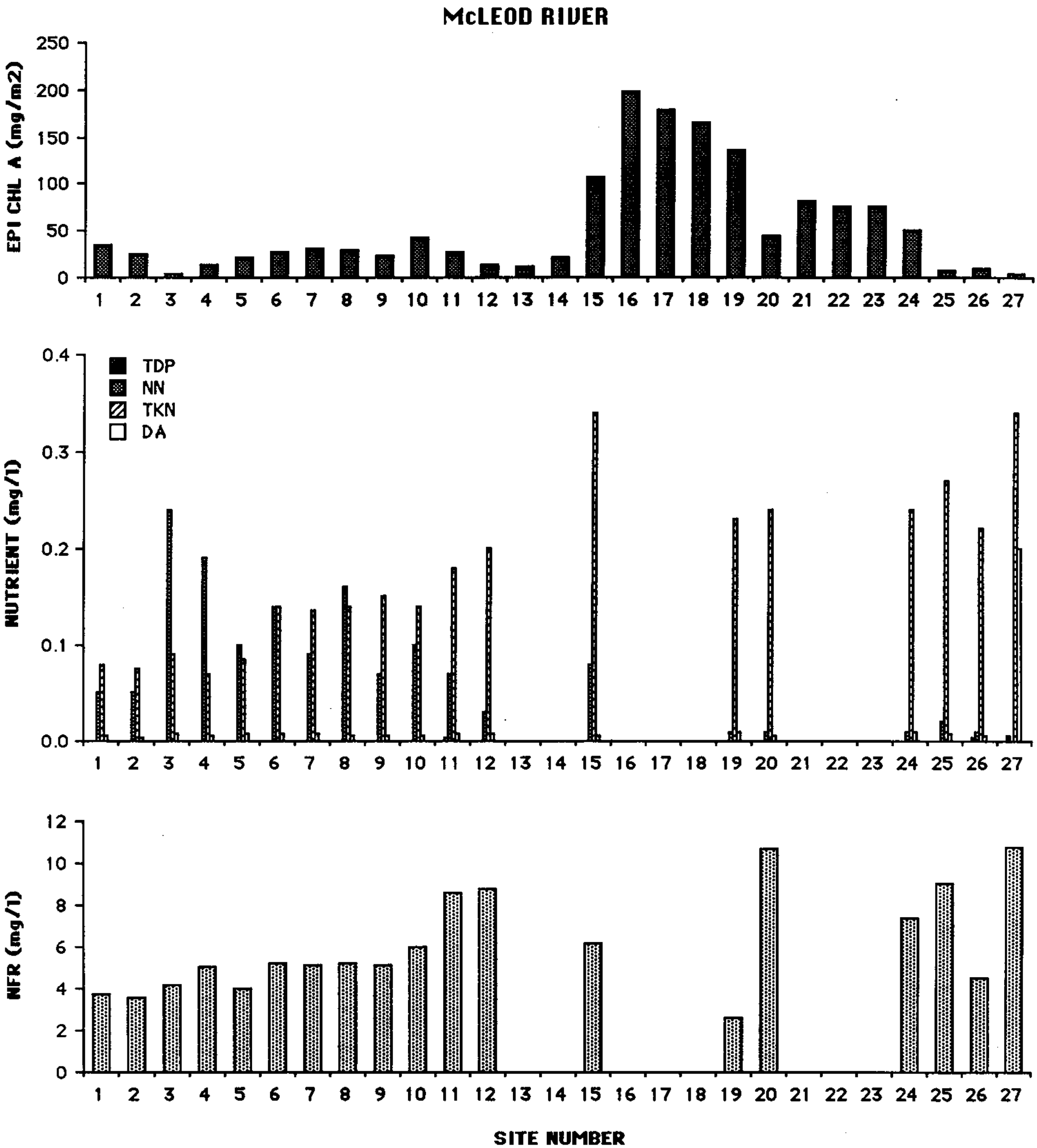




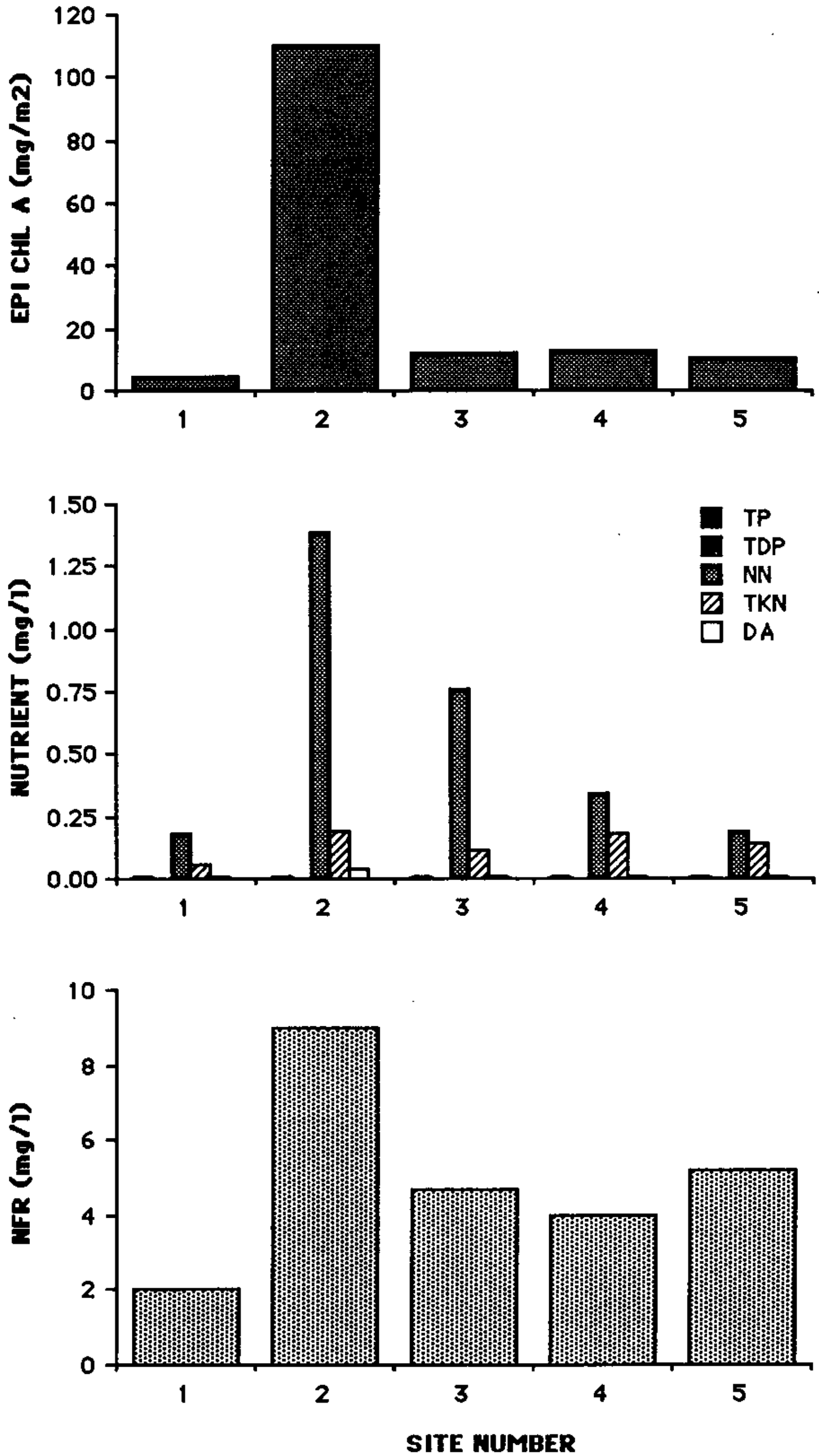
NORTH SASKATCHEWAN RIVER
TP
TDP
NN
TKN
DA
NUTRIENT (mg/l)
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
SITE NUMBER

PEMBINA RIVER

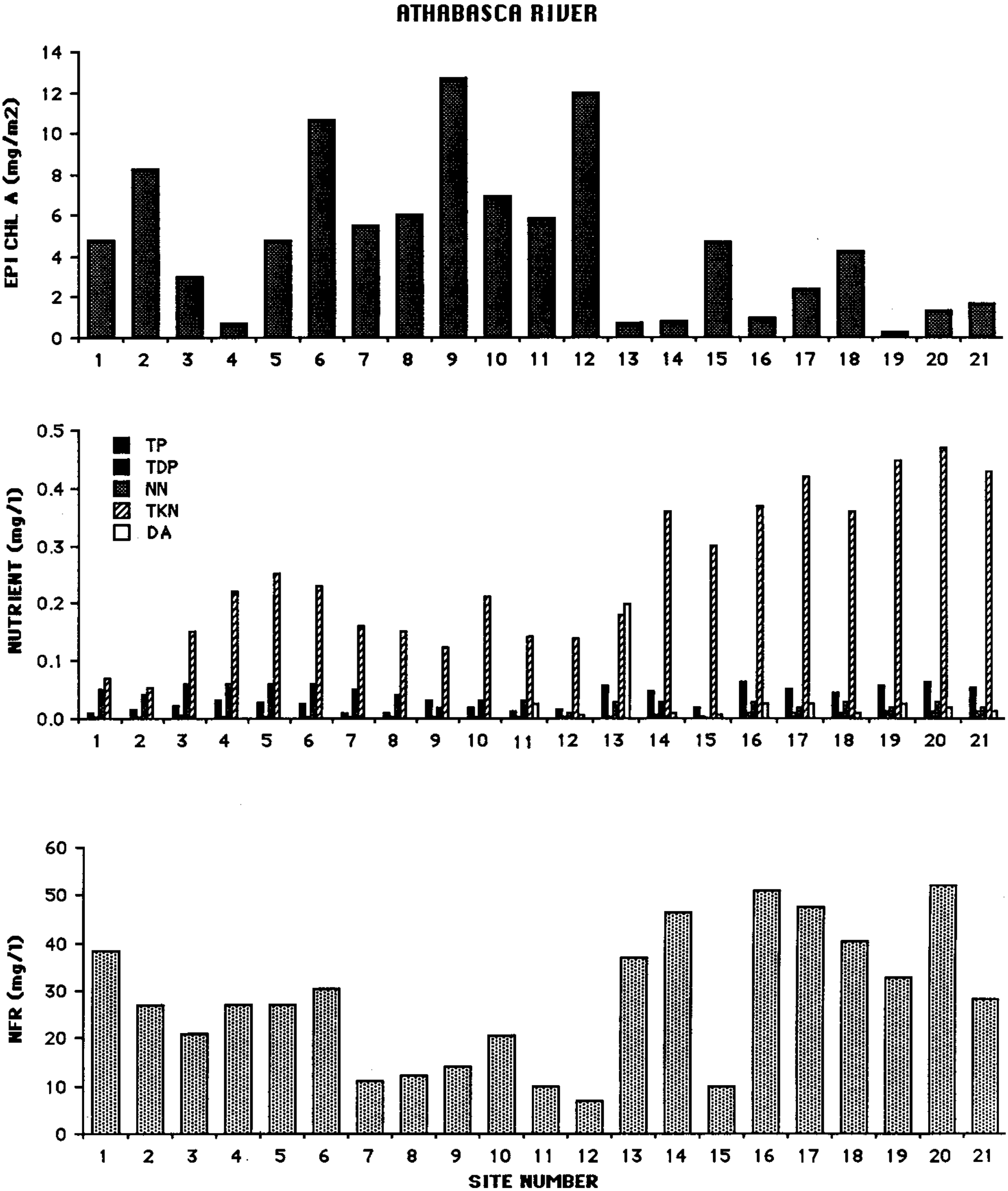


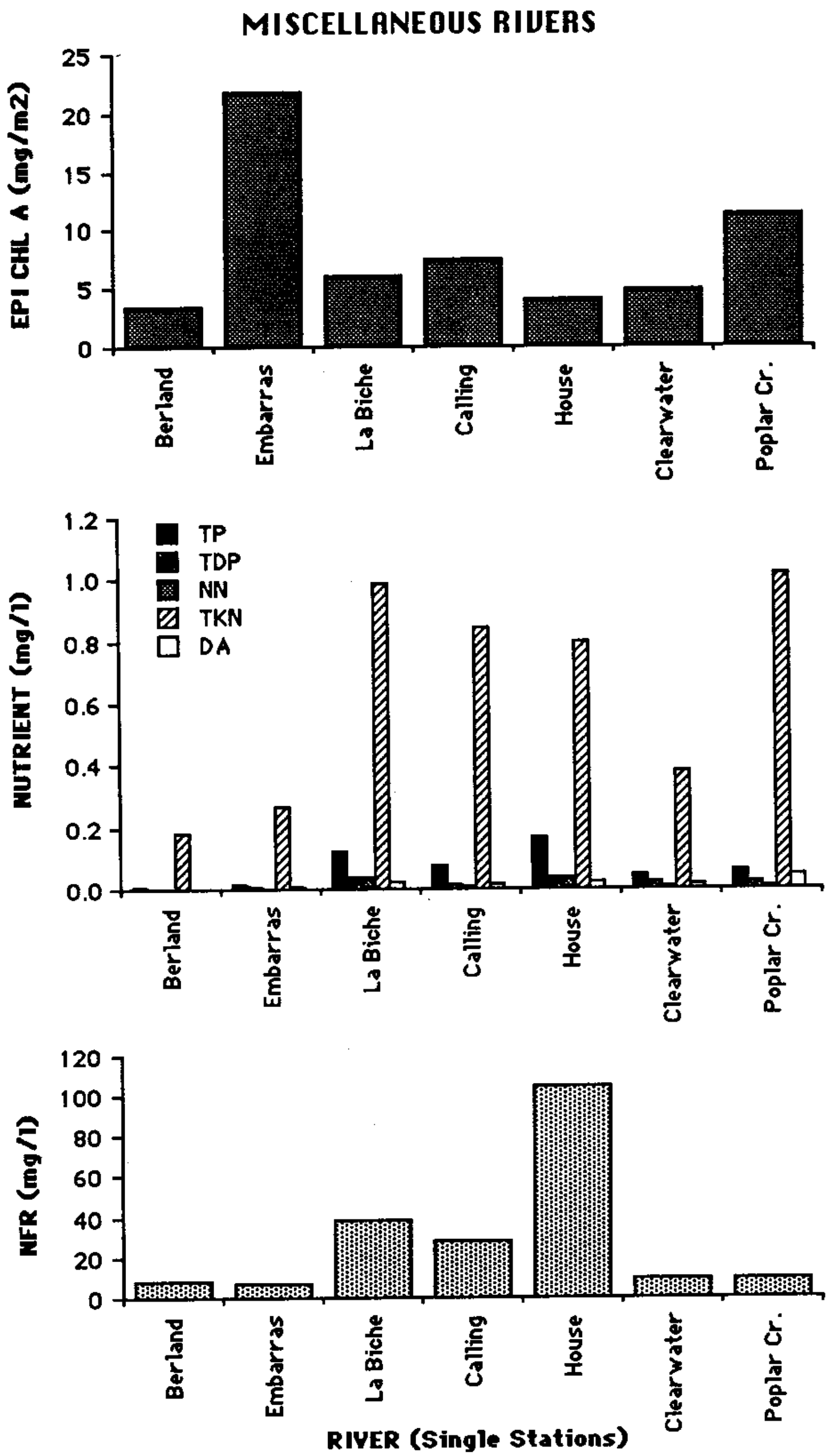

McLEOD RIVER
EPI CHL A (mg/m2)
250
200
150
100
50
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
NUTRIENT (mg/l)
0.4
0.3
0.2
0.1
0.0
TDP
NN
TKN
DA
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
NFR (mg/l)
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27
SITE NUMBER

GREGG RIVER



120
100
80
60
40
20
0
EPI CHL A (mg/m2)
1
2
3
4
5
1.50
1.25
1.00
0.75
0.50
0.25
0.00
NUTRIENT (mg/l)
TP
TDP
NN
TKN
DA
1
2
3
4
5
10
8
6
4
2
0
NFR (mg/l)
1
2
3
4
5
SITE NUMBER


ATHABASCA RIVER
EPI CHL A (mg/m2)
NUTRIENT (mg/l)
TP
TDP
NN
TKN
DA
NFR (mg/l)
SITE NUMBER


MISCELLANEOUS RIVERS
EPI CHL A (mg/m2)
25
20
15
10
5
0
Berland
Embarras
La Biche
Calling
House
Clearwater
Poplar Cr.
NUTRIENT (mg/l)
1.2
1.0
0.8
0.6
0.4
0.2
0.0
TP
TDP
NN
TKN
DA
Berland
Embarras
La Biche
Calling
House
Clearwater
Poplar Cr.
NFR (mg/l)
120
100
80
60
40
20
0
Berland
Embarras
La Biche
Calling
House
Clearwater
Poplar Cr.
RIVER (Single Stations)

APPENDIX 4. Ecoregions of Alberta