ASPECTS OF NITROGEN AND PHOSPHORUS

IN THE ATHABASCA RIVER SYSTEM

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PREFACE

The information in this document was compiled by the EQMB from monitoring data on the Athabasca River and presented to the Alberta-Pacific Environmental Impact Assessment Review Board in two parts:

1. Phosphorus in the Athabasca River

Information was presented to the Board verbally on 7 December 1989, using overheads. A copy of the verbal transcript and of the overheads are enclosed.

2. Additional Information on Nitrogen and Phosphorus in the Athabasca River System and in Pulp Mill Effluents

As a result of questions on Part 1 above, EQMB undertook to supply additional information. Part 2 contains this information, which was presented to the Board on 15 January 1990, as part of a larger written submission entitled Alberta Environment's Response.

ACKNOWLEDGEMENTS

The verbal and written material was prepared by L. Noton. Data was taken from monitoring work of both Alberta Environment and Environment Canada, and from previous reports and sources as noted. Data was downloaded, compiled, and graphed by D. Asquin and typing done by L. Lockhart of EQMB.

PHOSPHORUS IN THE ATHABASCA RIVER SYSTEM

Prepared by:

Environmental Protection Services
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The last one deals with dioxin results obtained by Alberta Environment and released, I believe, in 1988, upstream and downstream of the two existing kraft mills in this province. Recognizing that this has only been just distributed, we would be prepared to answer questions on this document either now or later.

Thank you.

MR. STONE: Mr. Chairman, I would like to introduce Mr. Leigh Noton at this time for his presentation on nutrients.

ALTA. ENVIRONMENT PRESENTATION: NUTRIENTS:

MR. NOTON: Well, perhaps this subject will be a little less controversial. What I want to do today, in response to a number of questions that have come up during the hearings, is present some information to the Board regarding phosphorous in the Athabasca River system with respect to its concentrations, the possible mechanisms by which it cycles and functions in the system, and to describe some of the pertinent features of the river system as regards phosphorous and phosphorous dynamics there.

I'll do that using data that we have, Alberta Environment, for three main locations on the river system: in the Old Fort Delta, Lake

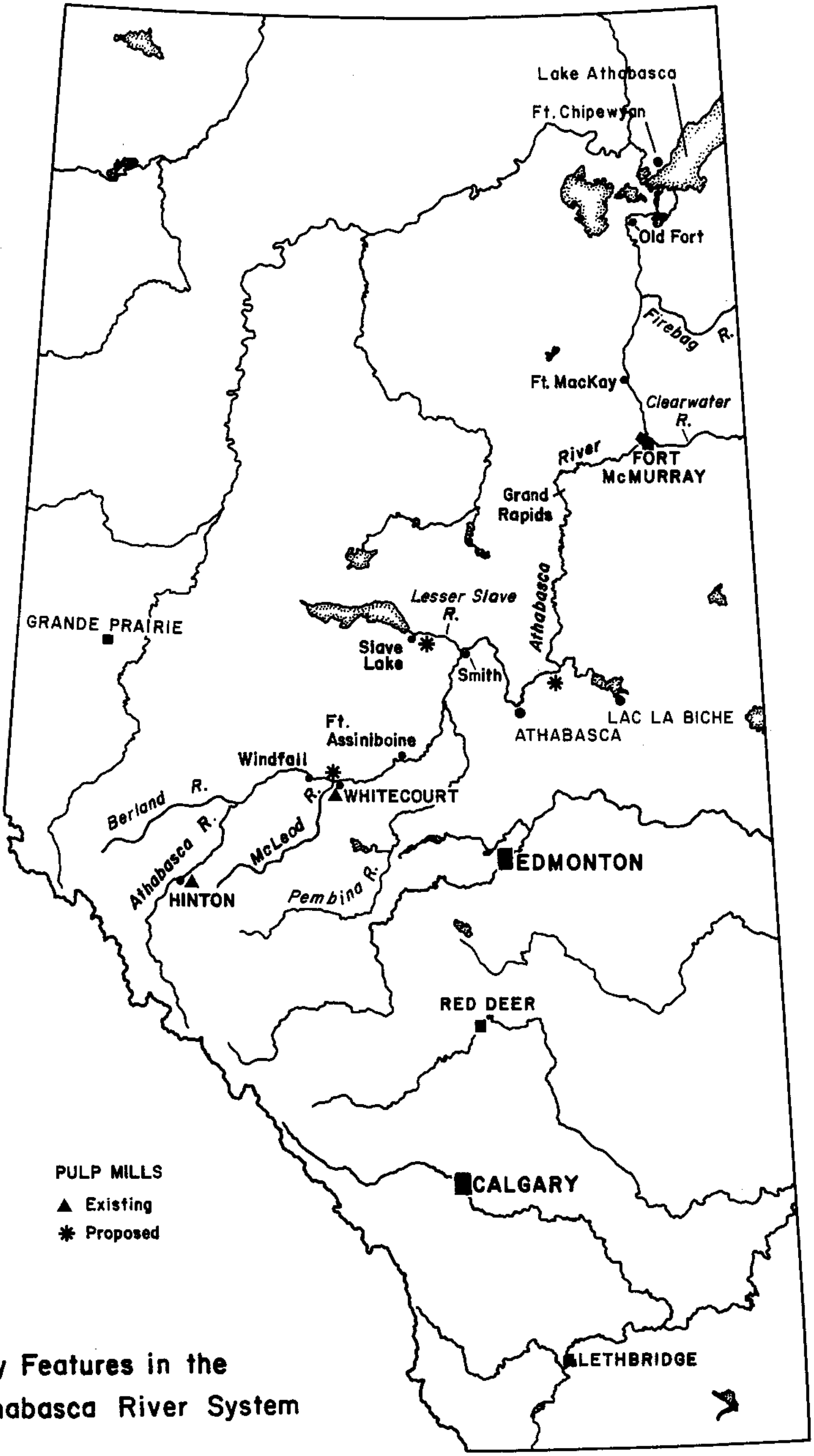
Athabasca area; near the Town of Athabasca; and in the Hinton area in the upper river system.

As a number of people have pointed out, and as we have pointed out before, phosphorous is of potential concern in the river system with respect to the pulp mills because it may contribute to the sediment oxygen demand in the river system.

Phosphorous may promote the organic decay or the decay of organic material in the river system thus enhancing or contributing to a sediment oxygen demand. Phosphorous may also promote growth of aquatic plants in the river system of benthic algae in the river which may, in the extreme cases, constitute nuisance growths, and which may also contribute to sediment oxygen demand during the winter season when they break down and decay.

Lastly, phosphorous is of concern because of potential, at least eutrophication, of downstream water bodies.

The Athabasca River is a fairly turbid river during the growing season. It is high in suspended solids, high in turbidity, poor in light penetration, and, therefore, you don't see large amounts of particularly higher aquatic plants



Key Features in the Athabasca River System in the river system.

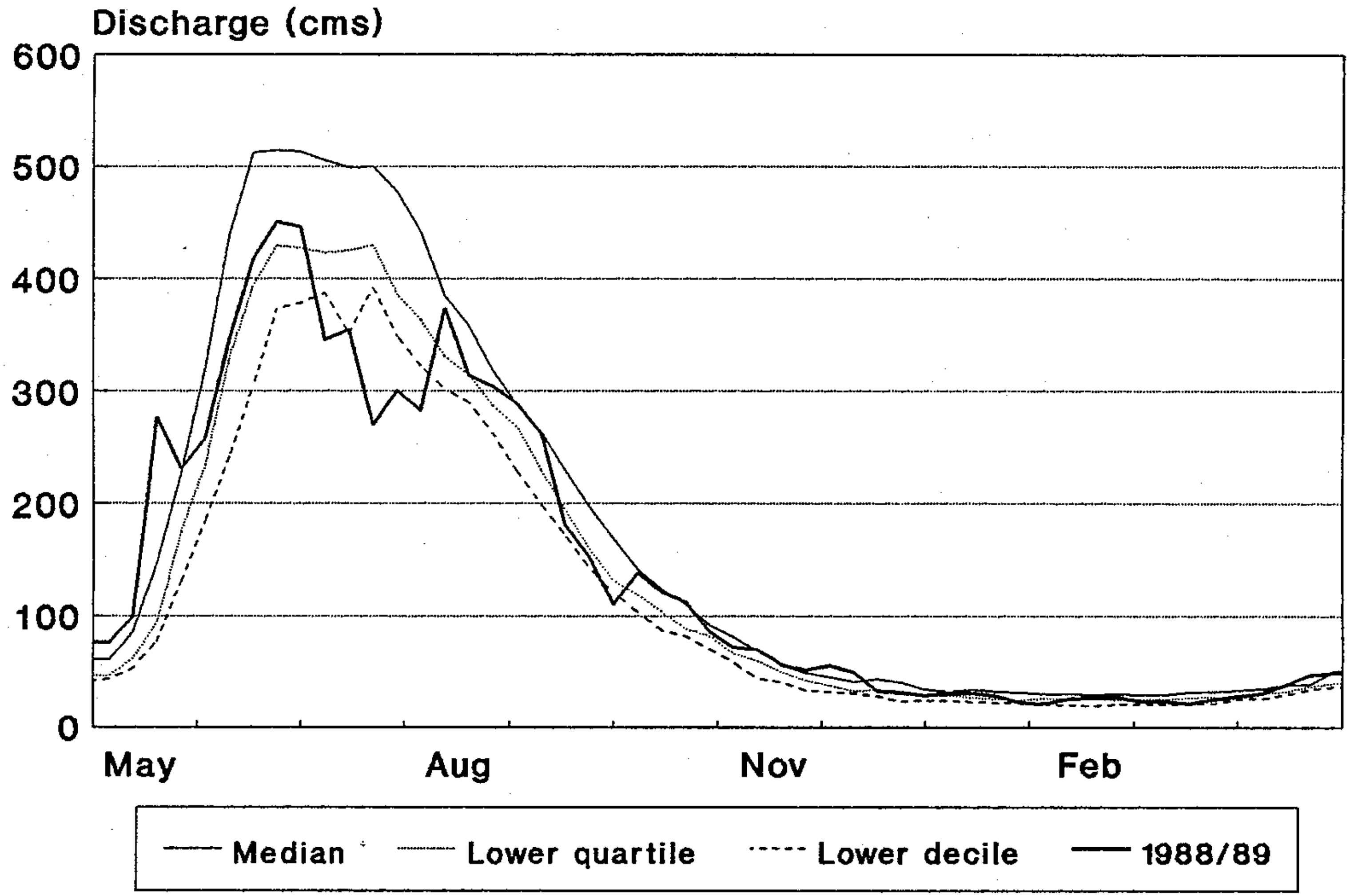
However, during the late summer and fall, flows decline in the system, and you can see that from these hydrographs for Hinton and for the Town of Athabasca and the situation applies generally down the river system. When the flows decline, turbulence declines, and the sediment suspended solids concentration in the river system declines as well.

This is illustrated in this graph of suspended solids for the river at the Town of Athabasca where you can see fairly low concentrations through the winter, very high and variable concentrations in the summer, but again, declining concentrations in the late summer/fall period.

When the suspended solids decline, turbidity declines, light can penetrate, and we get growth of benthic algae in the river system.

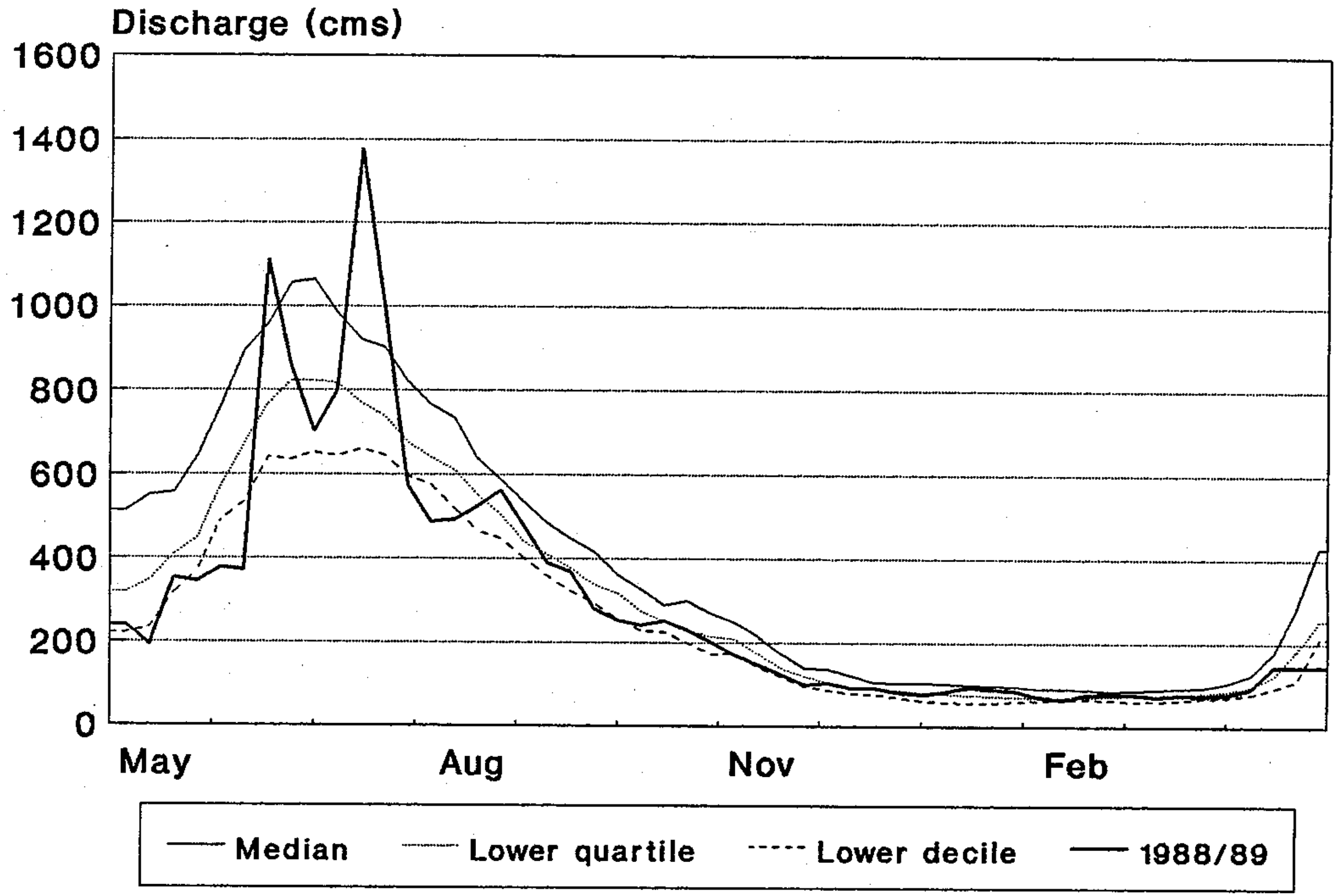
That is shown for some sampling we have done at and around Hinton where you can see the benthic algae as indicated by their chlorophyll content in samples from rocks, that is ~~epiphytic~~ epilithic sampling, you can see fairly low levels during the summer but increasing in the fall; in this case,

Athabasca River at Hinton
Seasonal Flow Variability



Hydrology Branch, Alberta Environment

Athabasca River at Athabasca
Seasonal Flow Variability



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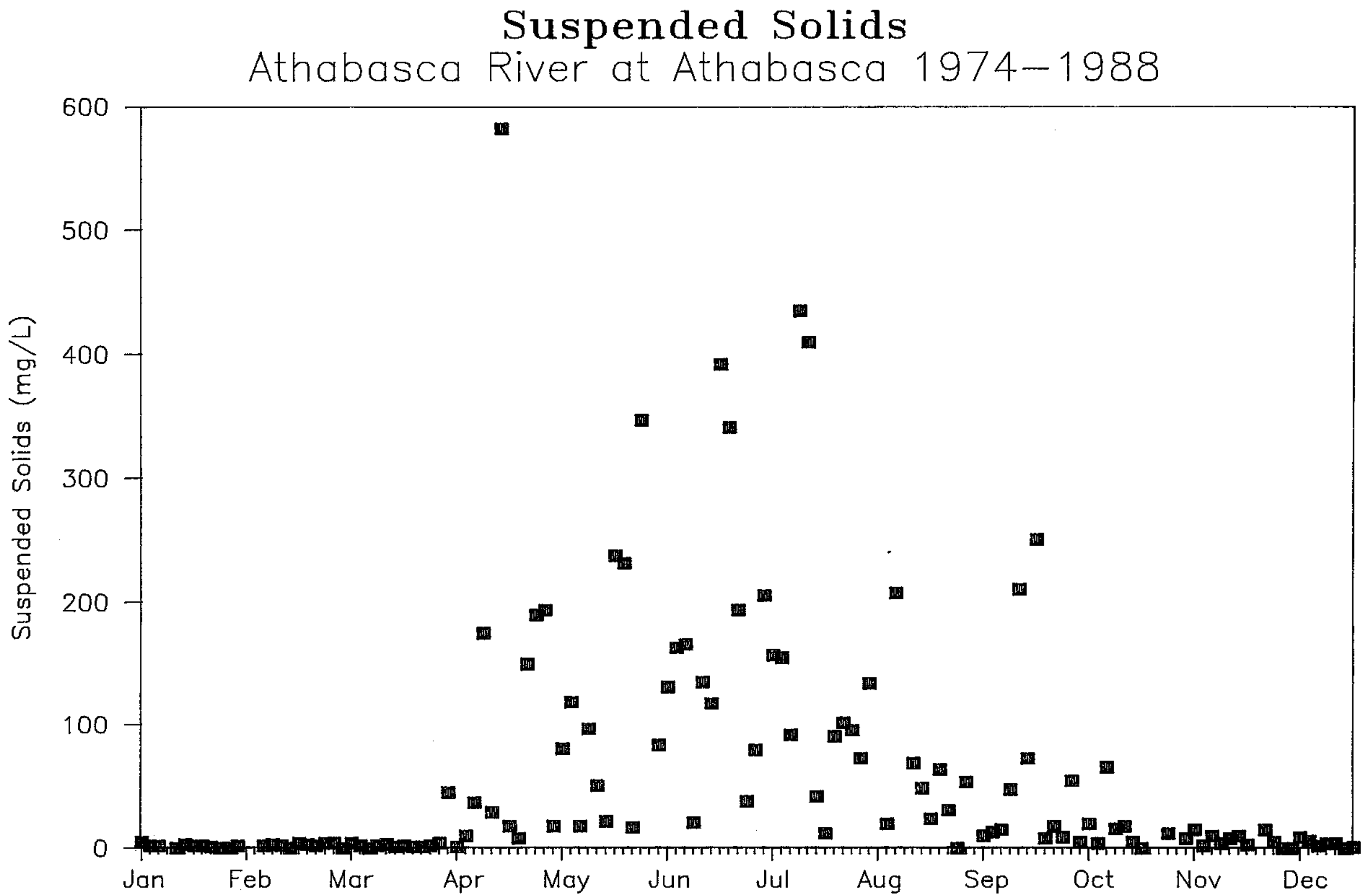

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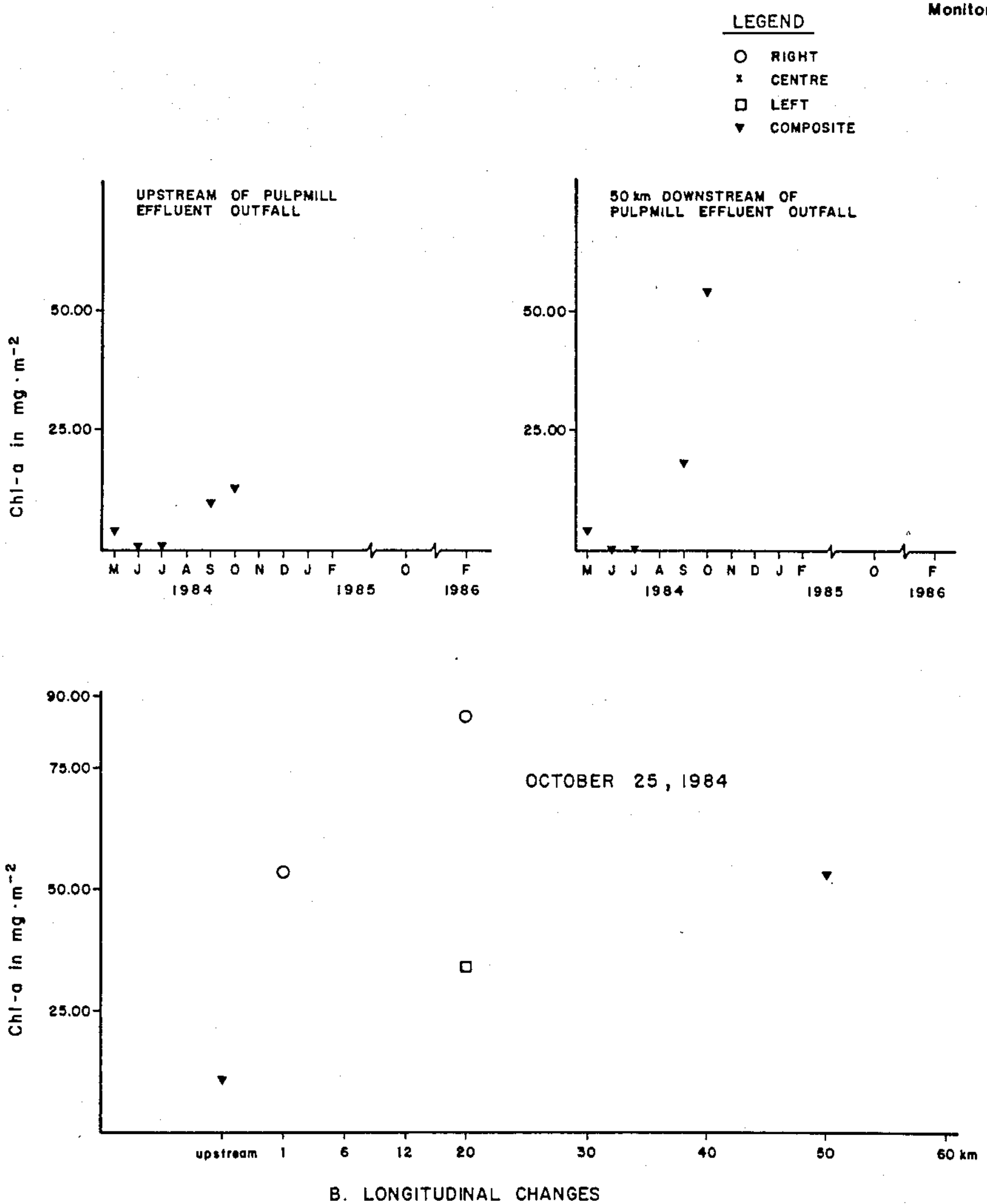


Athabasca River near Hinton: EPILITHIC CHLOROPHYLL-a CONCENTRATIONS.

Source: Anderson 1989

both upstream of the Hinton effluent and downstream of the Hinton effluent.

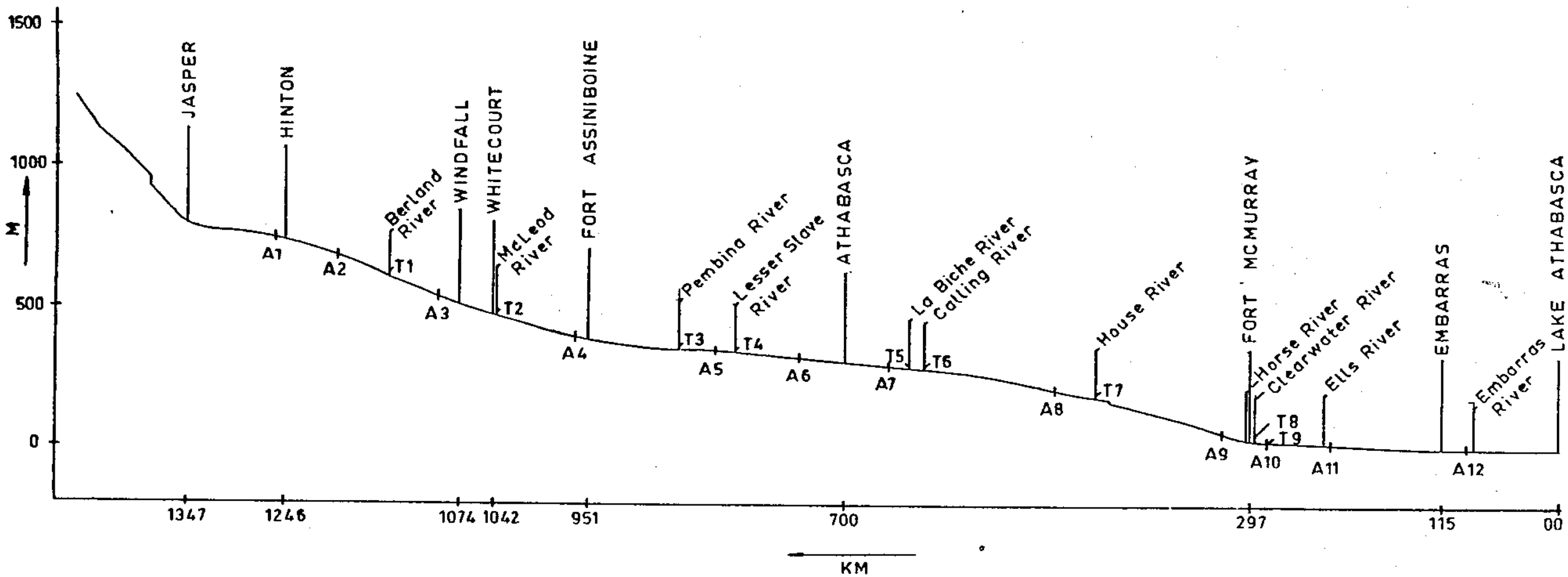
You can also in this case see the influence of the Hinton effluent itself in terms of fertilizing or adding nutrients to the system and increasing the amount of algae as measured by the chlorophyll concentrations at this downstream location compared to the upstream, and also in these locations plotted down the river system.

We have upstream samples here and samples downstream of the mill at those locations. In that particular case, we see effects at least as far downstream as 50 kilometres.

Now, the river system has a variable substrate. There are areas of silts, fine materials. There are areas of rubble, cobble and boulders and so forth, and you might expect that benthic algae would tend to grow best in areas of course substrate where it is more stable, less shifting. In fact, such locations occur particularly in the Hinton to Fort Assinaboine area where the gradient is steeper, the erosional power of the river is steeper, and they also tend to occur in the Calling River to Fort McMurray reach.

So although some areas may be unstable in terms of the substrate, there are also a

LONGITUDINAL PROFILE OF ATHABASCA RIVER



Source: Hamilton et al. 1985

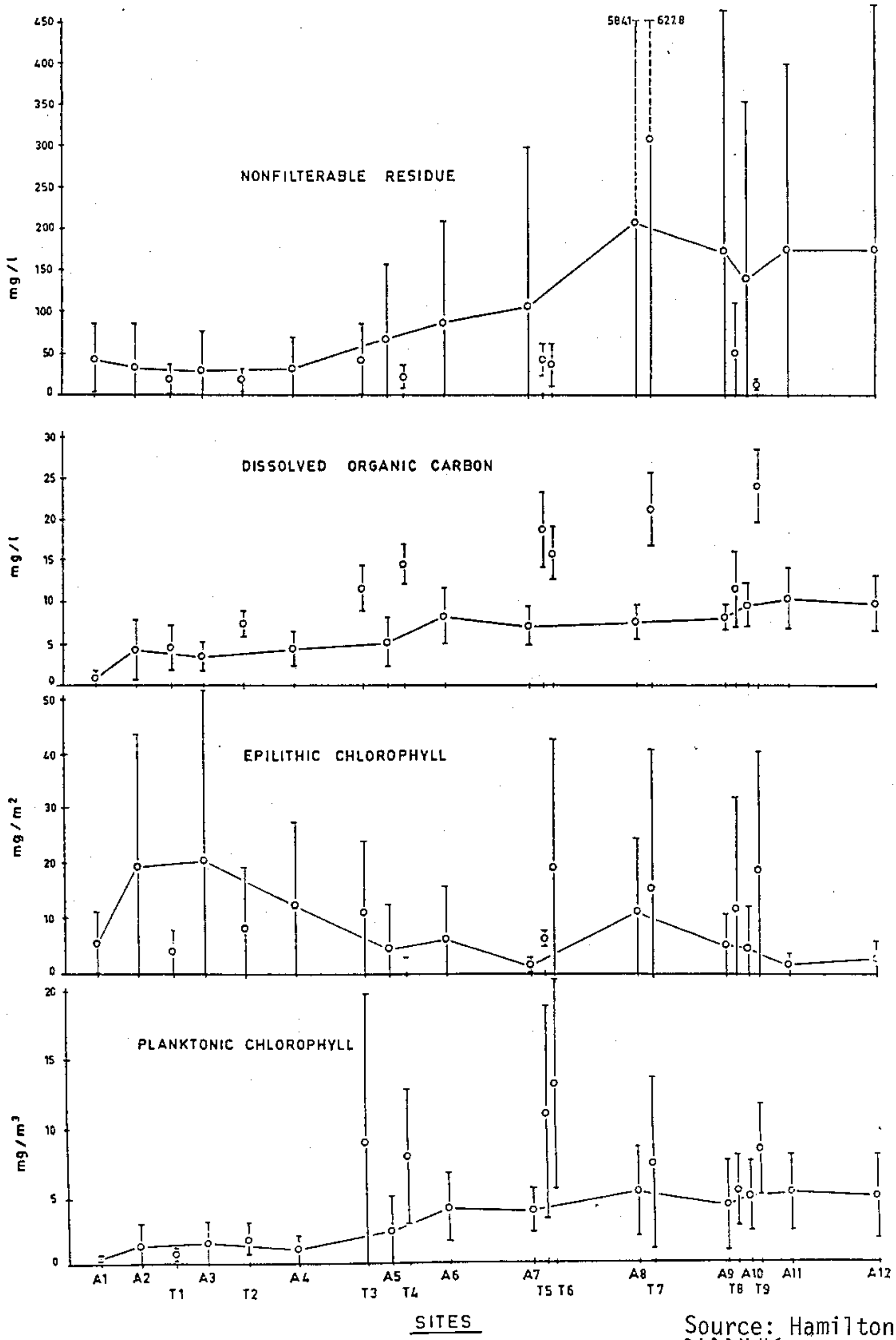
fair number of areas that are suitable for the growth of benthic algae. And this is also evident in this plot of ~~epiphytic~~ epilithic chlorophyll down the river system where, in fact, you see in this plot here plotted down the length of the river from Hinton to Lake Athabasca, you tend to see somewhat higher values between Hinton and Whitecourt, and also in the Calling River to Fort McMurray area.

Of course, stimulation of benthic algae, for example, may not necessarily be a bad effect. It may contribute to enhanced biological productivity in the river system, and the problem, of course, will be defining what is an acceptable level of stimulation versus what is a nuisance amount.

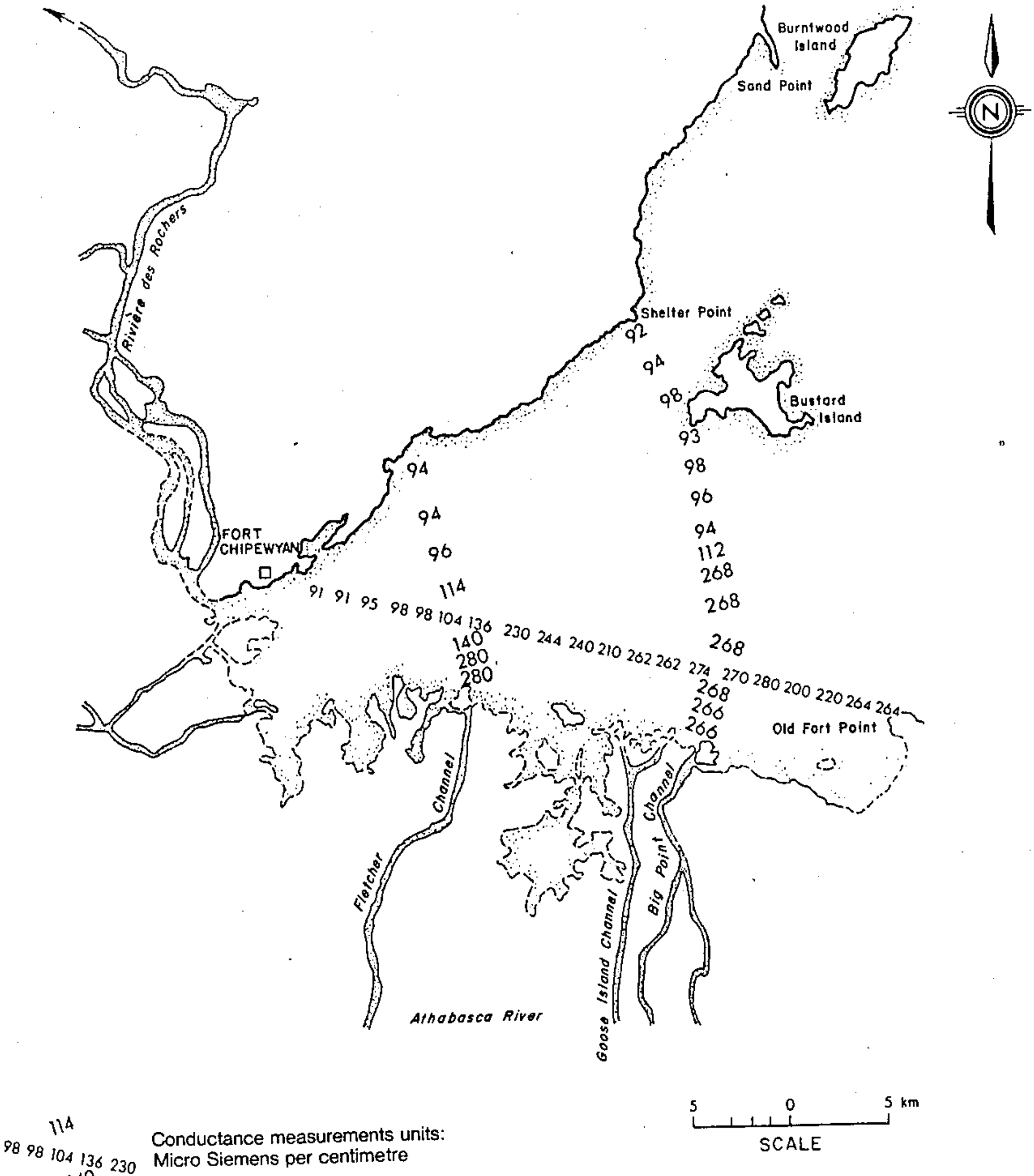
As far as downstream water bodies go, this is a map of the southwest end of Lake Athabasca. The point being that Lake Athabasca is not really a typical situation in terms of phosphorous input and eutrophication situation.

The river enters the southwest end of the lake, and plotted on here are conductance values from a survey done in that area about 10 years ago, which indicates the Athabasca River water having the higher values tend to be restricted to the southern side of the lake in that area; the lower values in the 90s representing the more

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.



Source: Hamilton et al. 1985



Spatial variance of specific conductance in Lake Athabasca on 25 October 1977.

From Seidner 1980

dilute waters from the east which tend to move in and flow out of the river system along the north shore.

The point being that the river flows into the lake, tends to take a left turn and short-circuit through the lake for much of the year. This area of the lake is also quite turbid during the growing season because of the in-flow of the Athabasca.

Consequently, we don't really see a classical-type response to nutrient input in that area. It's too turbid for a lot of plants to grow. Nonetheless, there is evidence that this area is fairly eutrophic. There is considerable growth of aquatic macrophytes in that area around the shore lines indicating there is a fair bit of nutrients already there.

The other end of the lake tends to be much more oligotrophic, and there is some but limited mixing of the Athabasca River down into this area of the lake.

So that's some of the background for possible concerns, at least, regarding phosphorous concentrations, phosphorous loads to the river system.

This is a plot of total

phosphorous in the river at the Town of Athabasca. It illustrates a number of things. One, are the fairly low concentrations that occur in the winter period; and secondly, of course, the very high and scattered concentrations that occur during the summer particularly in response to higher flows in the system in the summer.

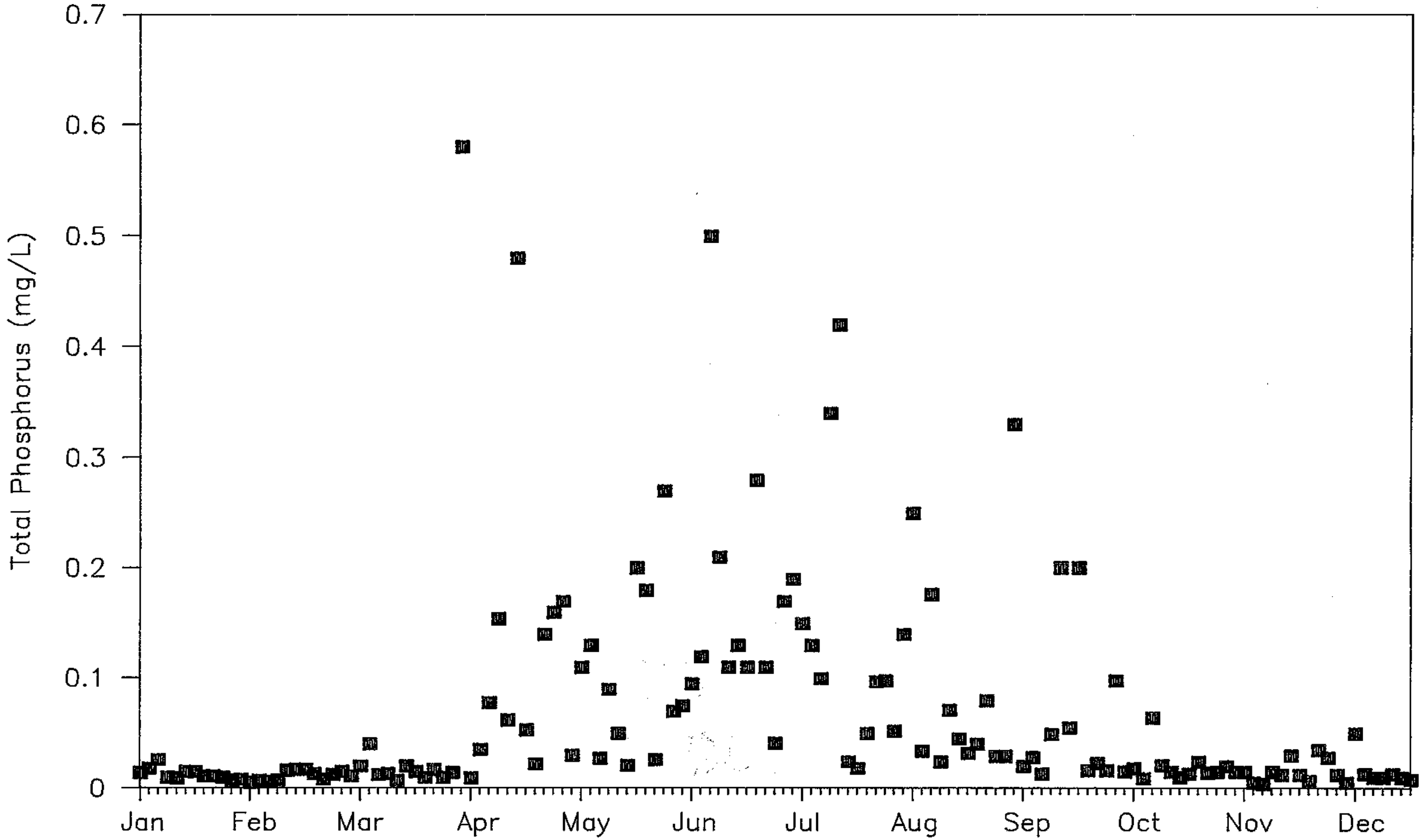
The data period that we have plotted up here, 1974 to 1988, predates the start-up of operation of the Millar Western mill, but would include the operation of the Hinton mill and sewage effluents and perhaps some other anthropogenic influences on phosphorous in the system.

You will notice that the Alberta surface water quality objective of .05 mg/L is routinely regularly violated or exceeded particularly during the summer as regards total phosphorous.

Farther down river at the head of the delta at the Old Fort location, there is a similar pattern of total phosphorous concentrations, relatively low in the winter, high and variable in the summertime. But a general tendency for the concentrations to be somewhat higher at that location.

Much of the total phosphorous in the river system is probably associated with

Total Phosphorus
Athabasca River at Athabasca 1974—1988



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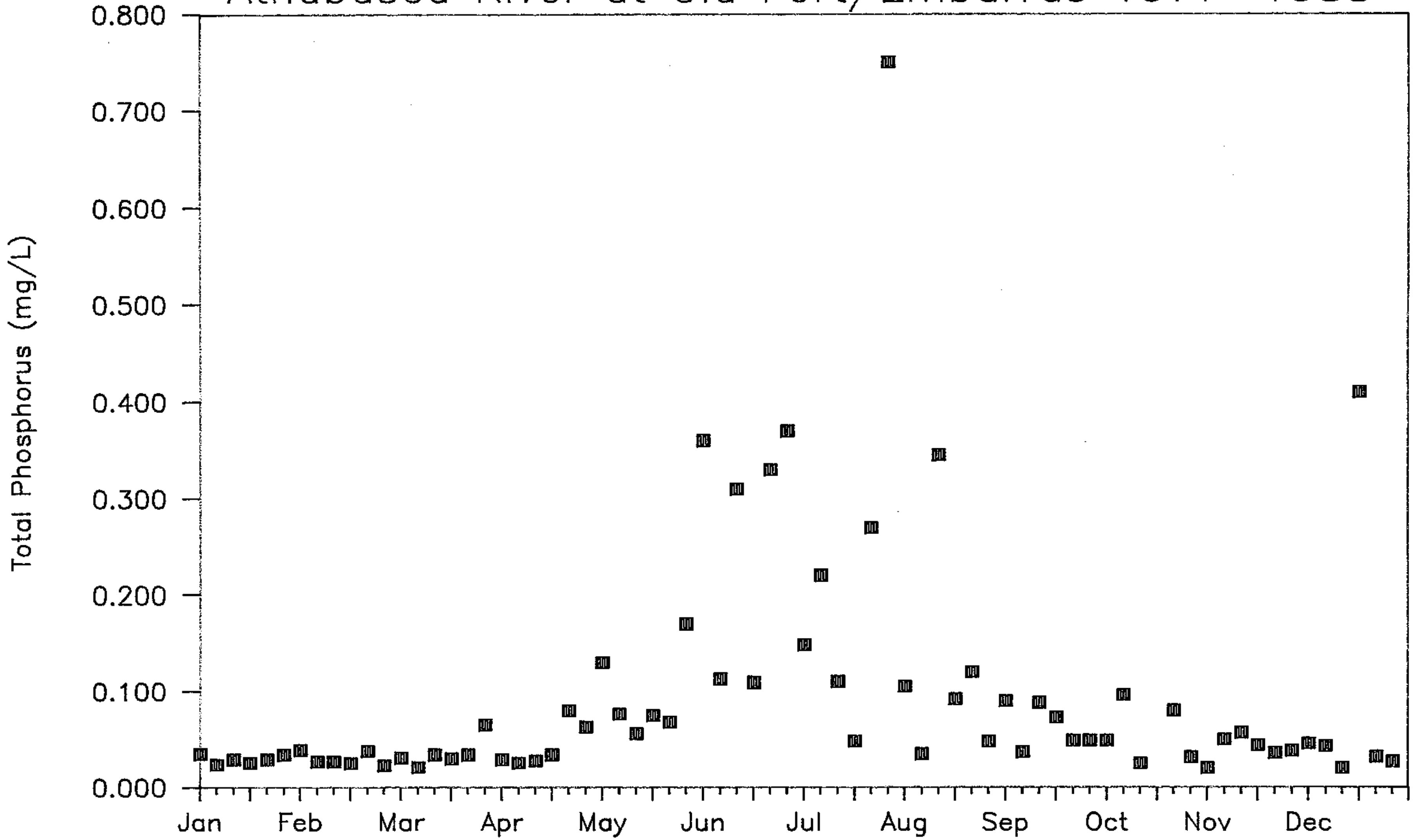
Total Phosphorus

Athabasca River at Old Fort/Embarras 1977–1988



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suspended solids and probably inorganic suspended solids and is probably not very available to biological organisms for uptake and growth, and this is illustrated by a plot of total phosphorous on this side in milligrams per litre versus suspended solids along here. There is a positive correlation between the two. That is to say, if you look at the total phosphorous in the river, a lot of it is attached to the silt that's flowing down the river, particularly in the summer situation.

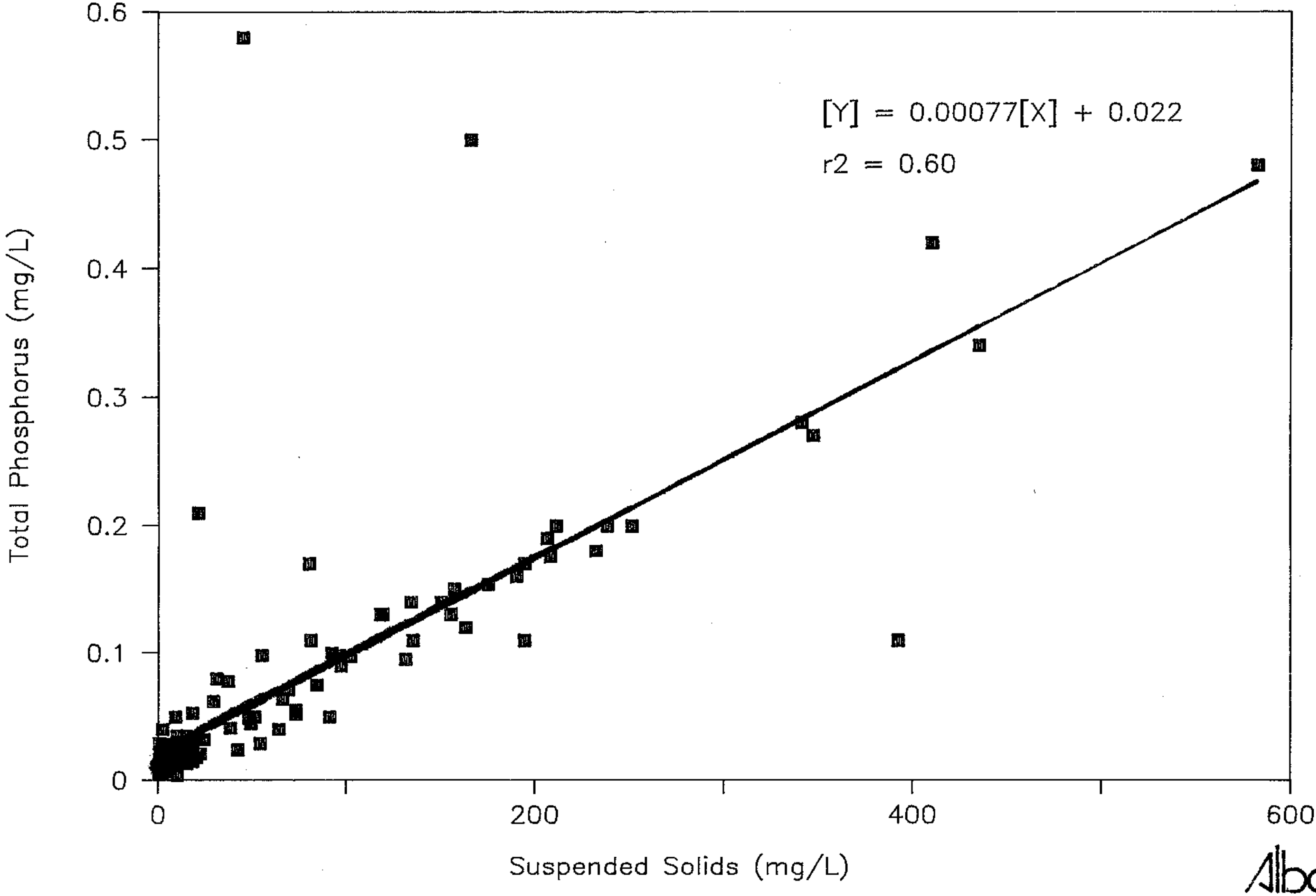
We have tabled up the actual concentrations at those two locations for dissolved and total phosphorous. If you just perhaps look at the mean values, you get some indication that there is a general increase down the river system in concentration in both dissolved and total phosphorous.

That trend down the river system is supported by a number of other samples. For example, the downriver synoptic surveys that were done in 1984, 1985, reported by Hal Hamilton and others, where you tend to see an increasing trend in concentration, both total and dissolved phosphorous down the river system.

We also see a similar trend in the winter. This particular graph is in the report

Total Phosphorus vs. Suspended Solids

Athabasca River at Athabasca 1974–1988



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PHOSPHORUS CONCENTRATIONS IN THE ATHABASCA RIVER

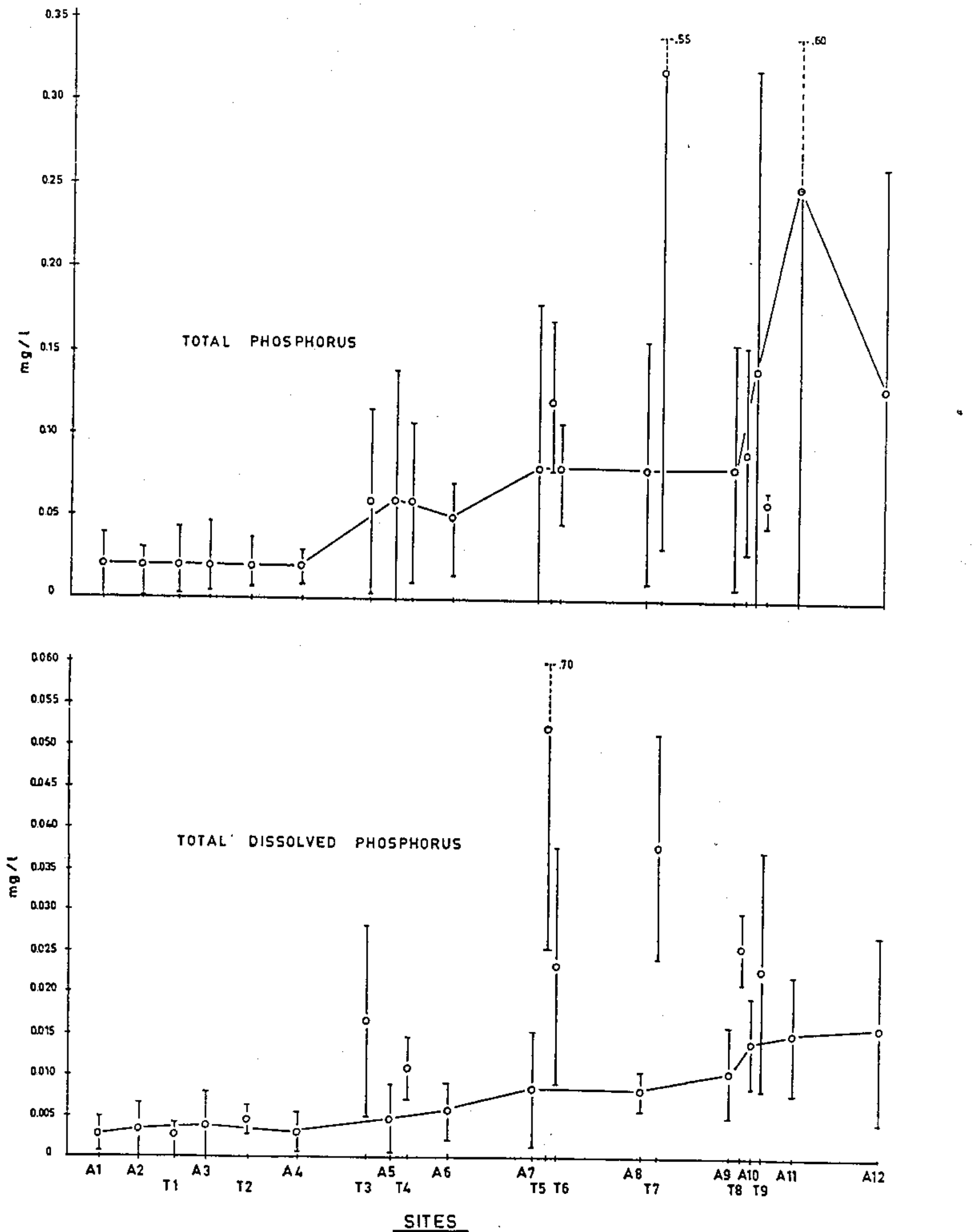
Statistic	mg/L at Athabasca 1974-88 Diss. P.	at Athabasca 1974-88 Total P	at Embarras/Old Fort 1977-88 *Diss. P	at Embarras/Old Fort 1977-88 Total P
n	121	139	18	73
Minimum	<0.003	0.004	0.006	0.020
Percentiles - 10th	0.003	0.009	0.007	0.025
- 25th	0.004	0.013	0.008	0.030
Median - 50th	0.006	0.024	0.010	0.048
- 75th	0.008	0.097	0.014	0.092
- 90th	0.013	0.190	0.015	0.270
Maximum	0.034	0.580	0.026	0.750
Mean	0.008	0.070	0.012	0.094
Std. Deviation	0.006	0.102	0.005	0.122

Note: Record includes the Hinton pulp mill but pre-dates the Whitecourt pulp mill.

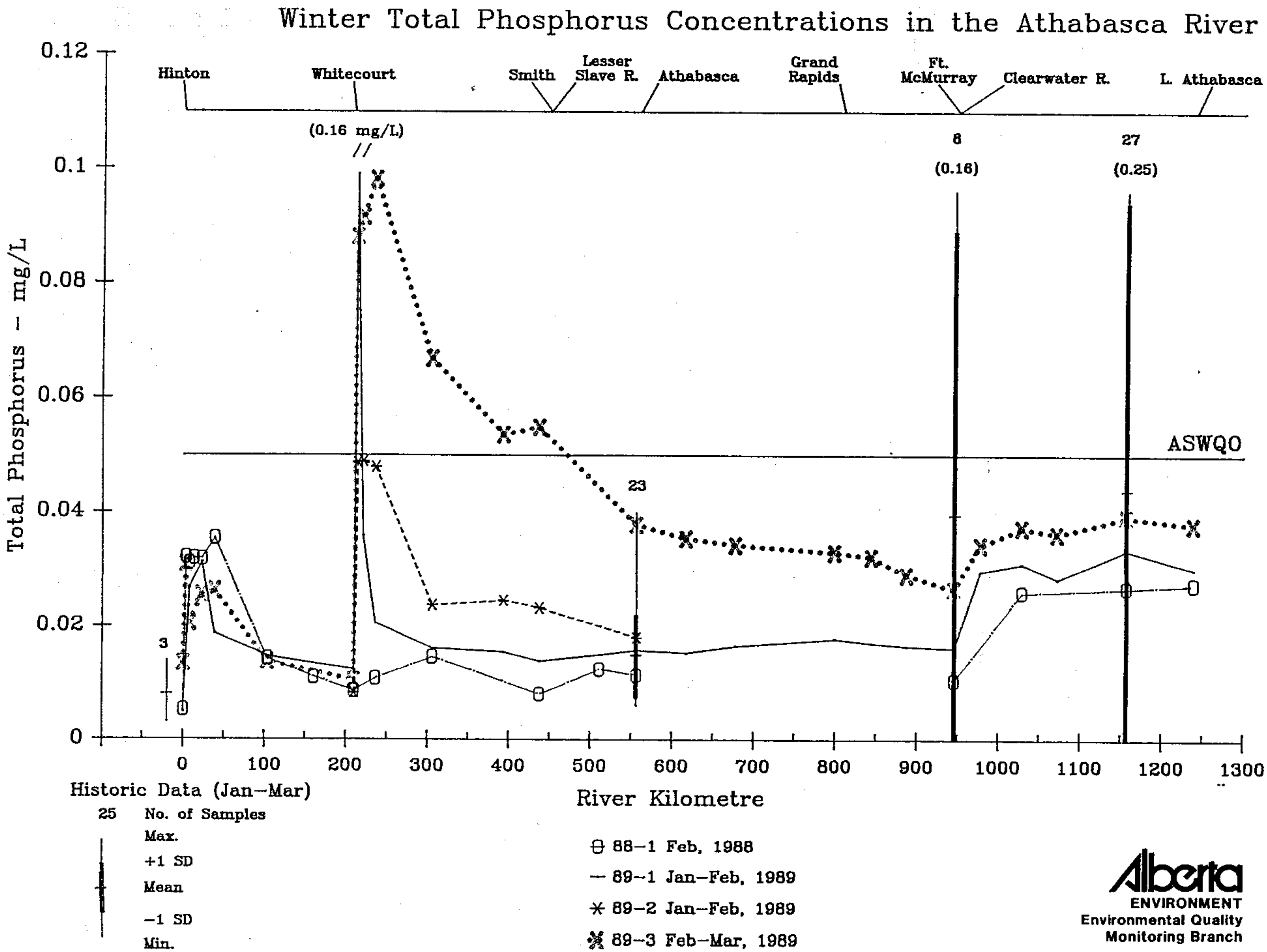
Values less than detection (0.003) assumed to be 1/2 detection limit.

* 1987-88 only.

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



Source: Hamilton et al. 1985



Winter Total Phosphorus Concentrations in the Athabasca River
Hinton
Whitecourt
Smith
Lesser Slave R.
Athabasca
Grand Rapids
Ft. McMurray
Clearwater R.
L. Athabasca
(0.16 mg/L)
//
8
(0.16)
27
(0.25)
23
3
ASWQO
Total Phosphorus - mg/L
0.12
0.1
0.08
0.06
0.04
0.02
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
River Kilometre
Historic Data (Jan-Mar)
25 No. of Samples
Max.
+1 SD
Mean
-1 SD
Min.
88-1 Feb, 1988
89-1 Jan-Feb, 1989
89-2 Jan-Feb, 1989
89-3 Feb-Mar, 1989
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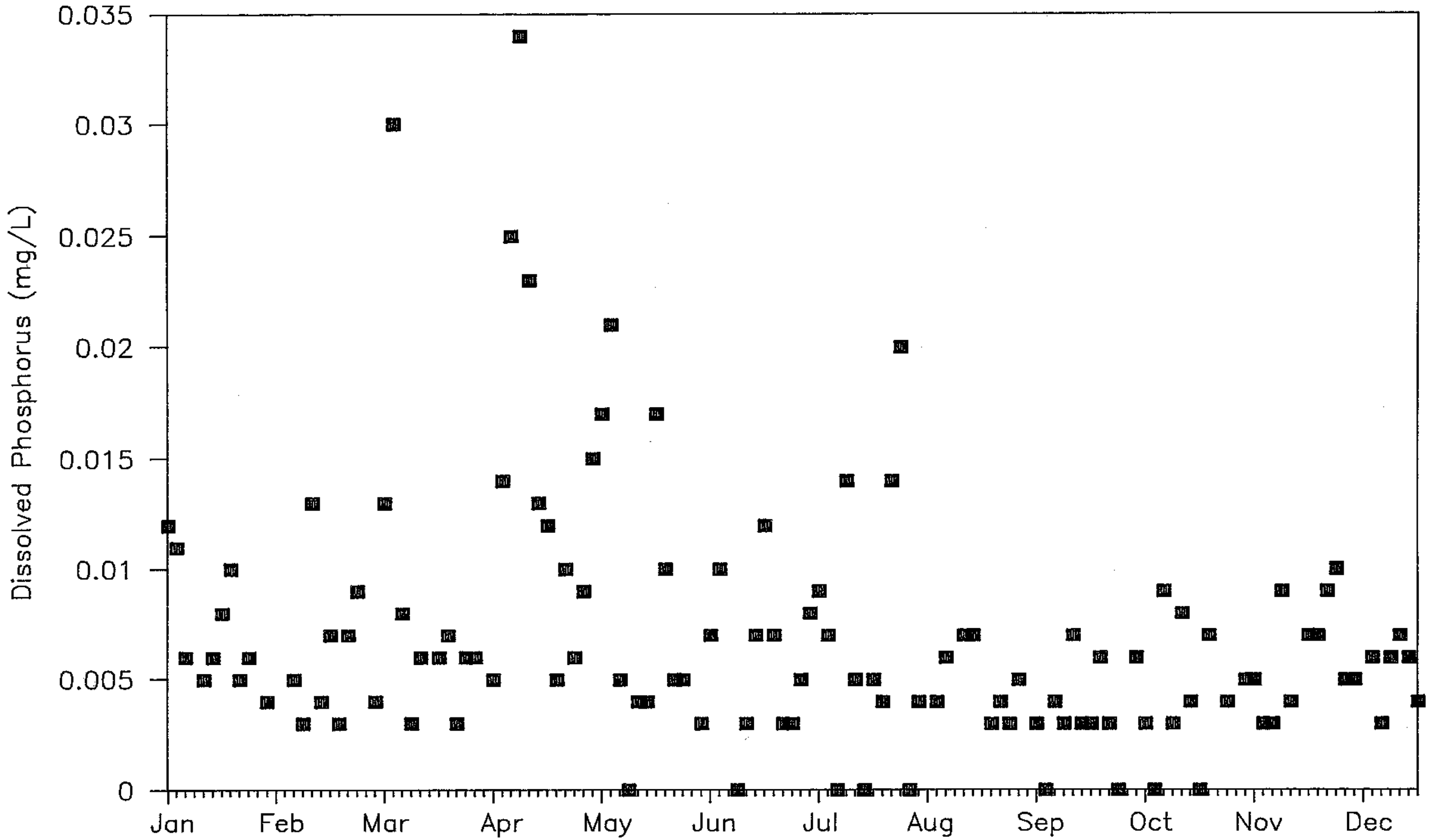
on winter water quality. As well as illustrating the effects of the two pulp mills in winter, if you sort of ignore the top example induced by Millar Western, you can see that concentrations at this level around Athabasca tend to be somewhat lower than concentrations in this level down closer to the lake and the delta. And the Clearwater River in this location and, secondarily, Fort McMurray sewage introduced a significant extra amount of phosphorous in that particular area.

Dissolved phosphorous, which is very likely much more available to aquatic organisms for growth, does not show really the same pattern as total phosphorous. It doesn't show nearly as pronounced a summer rise in concentrations.

At Athabasca, the average levels are about .008 milligrams per litre; near the delta they are somewhat higher. We have less data there, but they are somewhat higher at that location, but again do not show a clear or obvious seasonal pattern.

Again, we saw a downstream increase in total phosphorous in the system during winter, let's just say dissolved phosphorous in the winter. You can see influence of pulp mills at their locations. But leaving that aside, I think

Dissolved Phosphorus
Athabasca River at Athabasca 1974—1988



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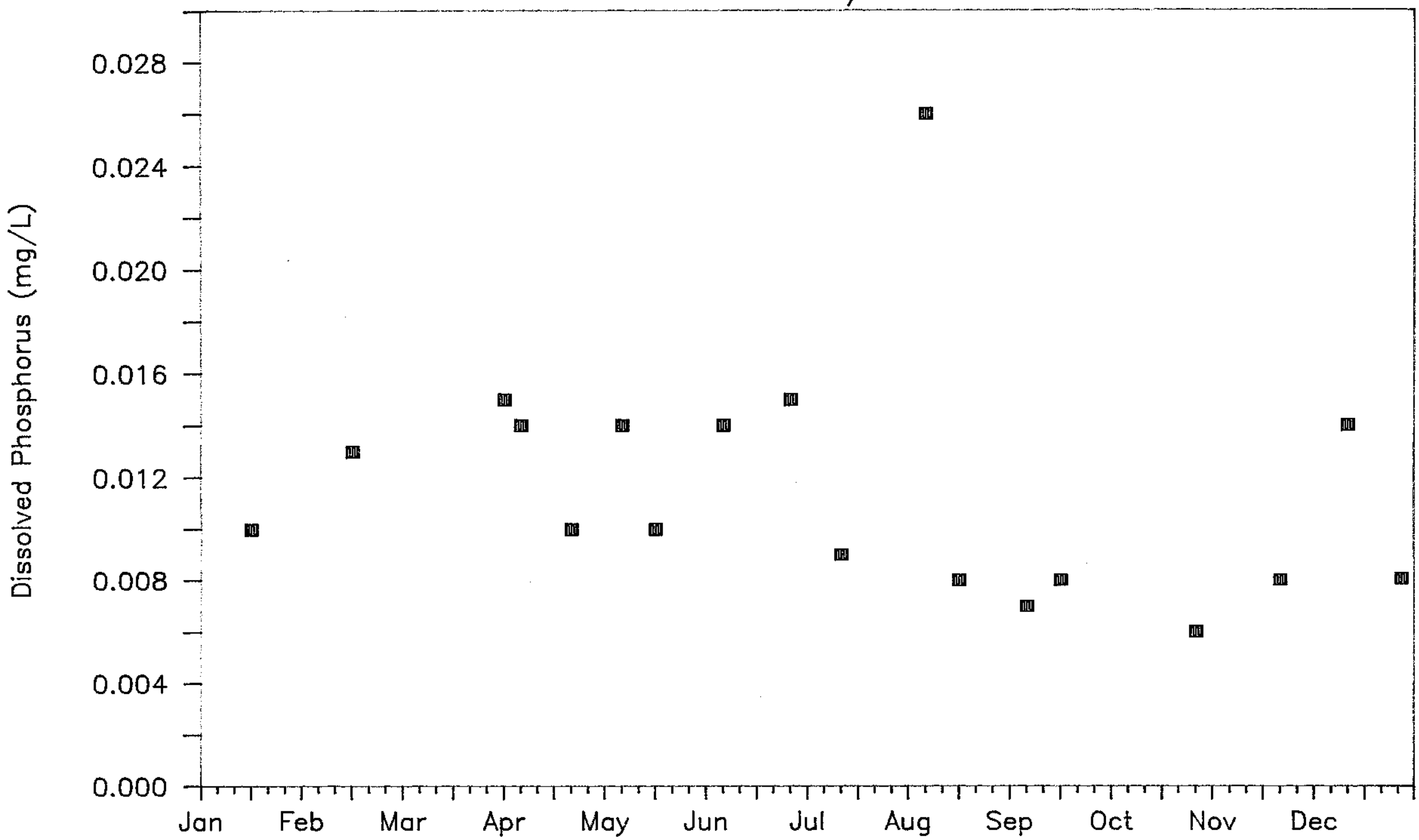
Dissolved Phosphorus

Athabasca River at Old Fort/Embarras 1977–1988



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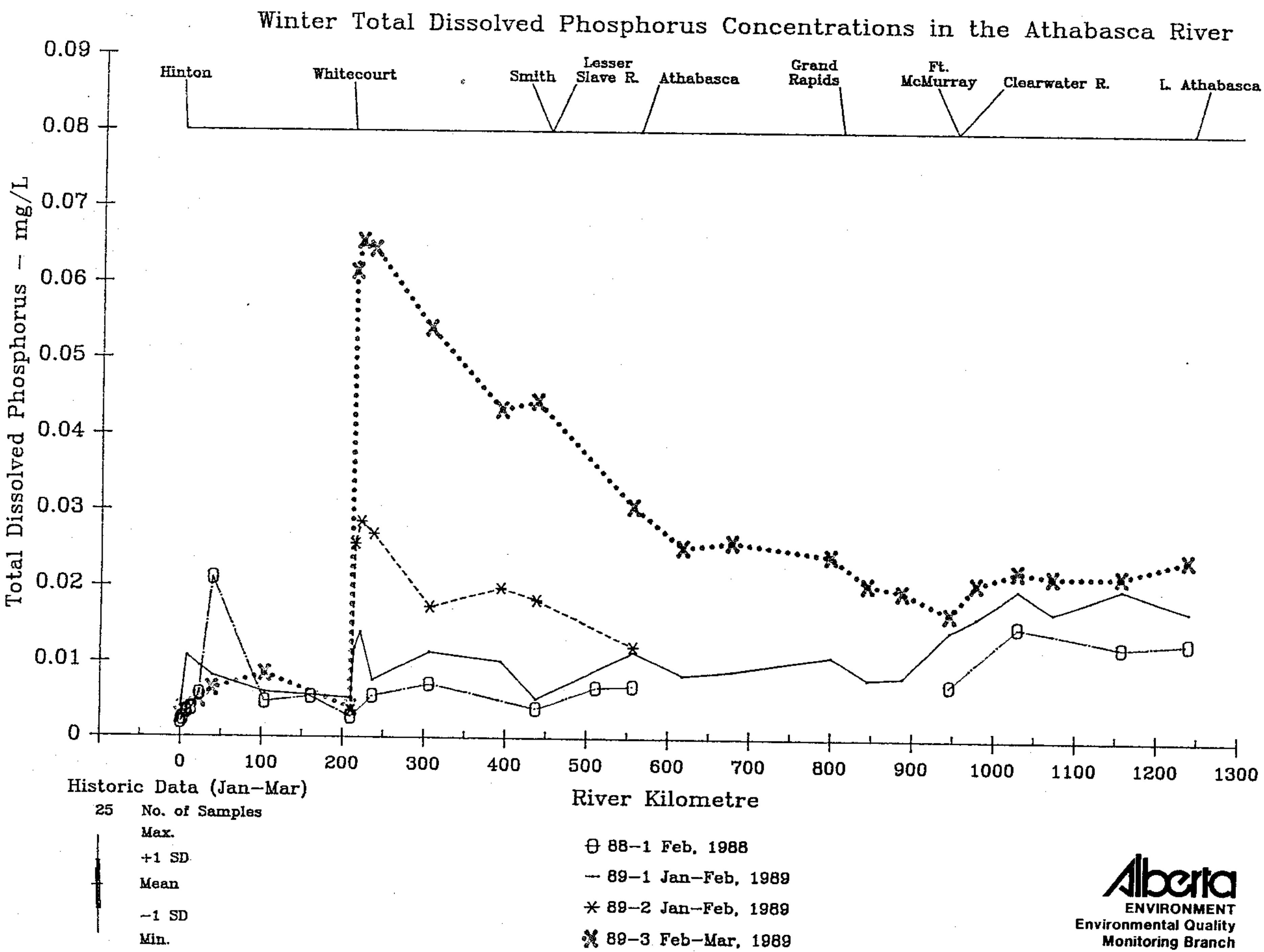

Winter Total Dissolved Phosphorus Concentrations in the Athabasca River
Hinton
Whitecourt
Smith
Lesser Slave R.
Athabasca
Grand Rapids
Ft. McMurray
Clearwater R.
L. Athabasca
Total Dissolved Phosphorus - mg/L
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
River Kilometre
Historic Data (Jan-Mar)
25 No. of Samples
Max.
+1 SD
Mean
-1 SD
Min.
88-1 Feb. 1988
89-1 Jan-Feb, 1989
89-2 Jan-Feb, 1989
89-3 Feb-Mar, 1989
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there is also the trend on here of lower concentrations at Athabasca, somewhat higher near the delta.

What we have also done is calculate some estimates of mass transport of phosphorous on an average monthly basis and on an annual average basis at Athabasca and at or near the delta. The mass transport or load expressed in kilograms per day is about twice as high at the delta as it is at the Town of Athabasca, both due to somewhat of an increase in concentration and, more importantly, due to an increase in flow at that location.

With regard to those estimated loads, we have compiled a table of estimated loads from the pulp mills and from the sewage treatment plants. The present load due to Weldwood and due to Millar Western is about 319, roughly, kilograms per day of total phosphorous.

This large amount from Millar Western reflects the troubles they are having at present with their waste-water treatment system where I believe they are probably adding arguably, are adding in excess amounts of phosphorous.

As one of the other speakers pointed out, pulp mills regularly have to add

ESTIMATED PHOSPHORUS MASS TRANSPORT
IN THE ATHABASCA RIVER

	Mean kg/d			
	at Athabasca 1974-88		at Embarras/Old Fort 1977-88	
	Diss. P.	Total P	*Diss. P.	Total P.
January	71	120	87	460
February	51	98	120	430
March	75	140	170	480
April	480	6300	340	2500
May	520	5600	800	7700
June	490	15000	1800	39000
July	680	17000	1500	39000
August	430	6300	500	15000
September	210	6800	360	3500
October	190	840	220	2800
November	110	310	260	4400
December	74	210	110	470
Annual Average	280	4900	520*	9600

Note: Record includes the Hinton pulp mill; pre-dates the Whitecourt pulp mill

* 1987-88 only

RELATIVE PHOSPHORUS LOADINGS TO THE ATHABASCA RIVER

TP SOURCE		PRESENT LOAD KG TP/D	EXPECTED LOAD KG TP/D
WELDWOOD		30	60
ANC			40
MILLAR WESTERN		289	60
AEC			32
ALPAC			24
	T O T A L	319	216
WHITECOURT STP		14	
ATHABASCA STP		7	
SLAVE LAKE STP		12	
FT MCMURRAY		37	
	T O T A L	70	

nutrients, including phosphorous, to their waste-water treatment system in order to promote the breakdown of the organic material in the treatment system. As a result, you do see phosphorous coming out of the final treated effluent.

It is expected that in the future, in fact, Millar Western will improve their performance and reduce their total load of phosphorous that's being discharged.

I should point out we made a calculation error here. I think the estimate for ALPAC is probably about 80 kilograms per day, and I think we have written that in on the hard copies that we have distributed, and this is revised upwards to about 270 kilograms per day. By comparison, the existing sewage treatment plants discharge roughly one-third of that amount.

One point to make, I think, is that the phosphorous discharged in either pulp mill or sewage effluents is probably much more biologically available than is the total phosphorous that occurs naturally or as background in the river.

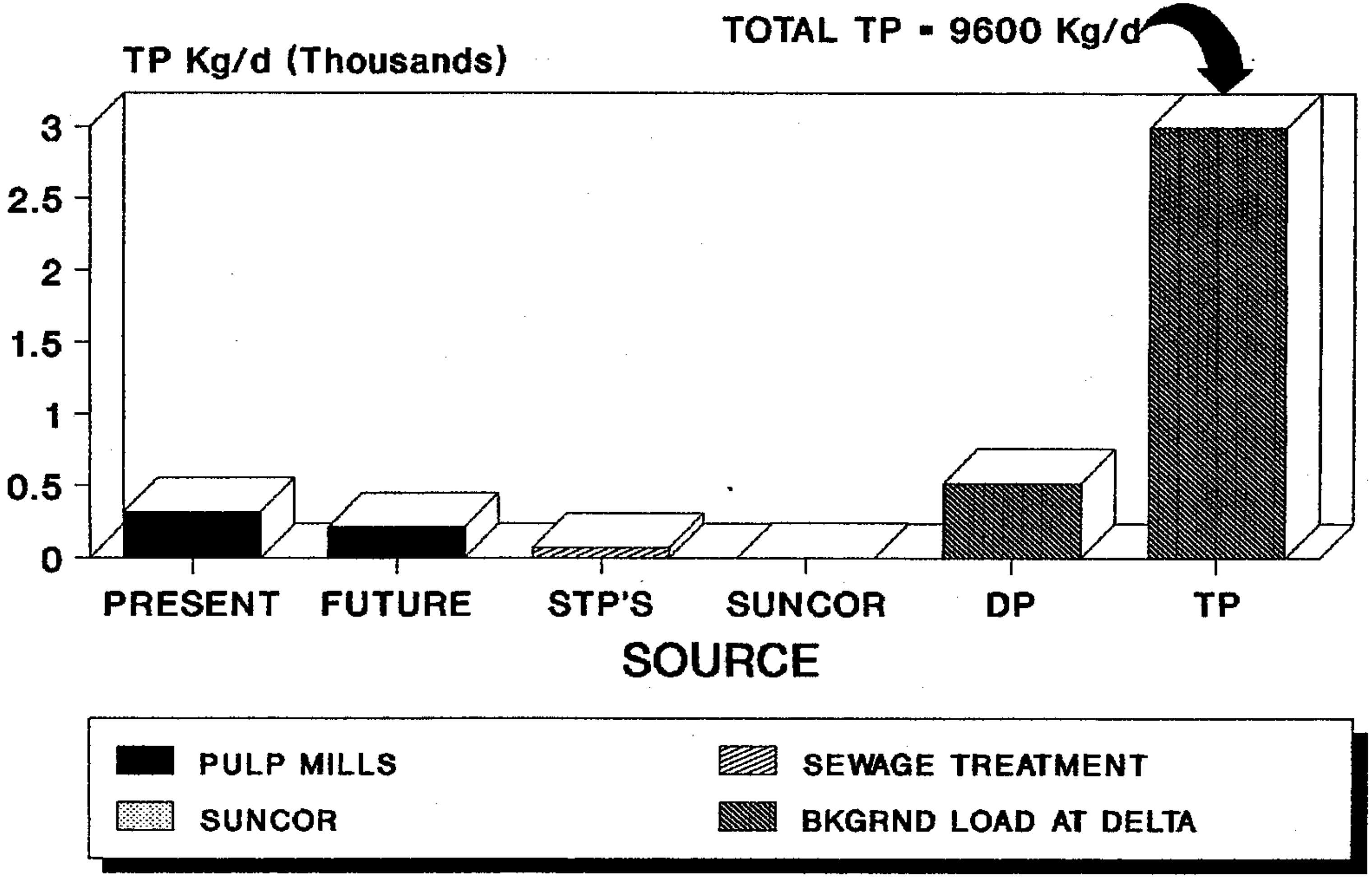
As I mentioned, a lot of the total phosphorous in the river, particularly in the summer, is associated with inorganic suspended solids and is probably not readily available to organisms for growth; whereas a lot of the phosphorous in effluents, although some of it may be associated with solids, it is more likely to be in an organic form and subject to breakdown and mobilization.

On that basis, we have just tabulated the various loads to the river or from the river. The background load at the delta are the figures that I showed you just now on the table. The estimated existing mass transport or load of phosphorous down the river and into the delta and the lake, in terms of dissolved phosphorous, at about, I think it was around 300 kilograms per day is more like 4 or 500 kilograms per day, and total phosphorous at about 9600 kilograms per day, which is actually off the chart.

The pulp mills at present, because of Millar Western's peculiar mode of operation, I guess, is fairly high. In fact, the total there is arguably somewhat greater than we might anticipate in the longer term, say, with all five mills discharging, and assuming they do not implement any particular form of tertiary treatment or phosphorous removal.

The future mills and the sewage treatment plants, as I say, form a fairly small fraction of the total phosphorous that is presently

RELATIVE PHOSPHORUS LOADINGS TO THE ATHABASCA RIVER



moving in the river, but, in fact, a more pertinent comparison may be made between these two amounts and the dissolved phosphorous that's moving in the river.

I think that's about all the information that I have to present today.

MR. STONE: Mr. Noton is available for questions, if you wish.

THE CHAIRMAN: I think we would like to have all of the presentations, and then we will have questions of the complete panel.

MR. STONE: Okay.

Mr. Hamilton will be presenting information now on the DOSTOC model.

ALBERTA ENVIRONMENT PRESENTATION: DOSTOC MODEL:

MR. HAMILTON: Mr. Chairman, members of the panel, this afternoon I have been asked by Alberta Environment to deal with four topics related to the oxygen modelling work our company has done on the Athabasca River.

First of all, I will give you a brief history of the development of the model that has occurred over a number of years now, overview with you the adjustments that were made to the model most recently in reflecting the extensive data collection that was carried out this past winter, chloroguaiacols, catechols, and there are acutely toxic in the range of 600 to 1,200 parts per billion.

They do exist in untreated effluents, but treatment of effluents do take away most of them, and most of them, except some resin acids, like dehydroabietic acid and some chlorophenols are present over a period of time. But they do degrade eventually. Thank you.

MR. STONE: Mr. Chairman, our panel is available for questions now.

THE CHAIRMAN: We will take a ten-minute break, and then have questions.

(Proceedings adjourned 3:45 p.m.)

(Proceedings resumed 4:00 p.m.)

REVIEW BOARD QUESTIONS ALBERTA ENVIRONMENT:

THE CHAIRMAN: Dr. Ross.

DR. ROSS: I have a general question for Mr. Noton. I guess I'm going to ask you to summarize your presentation in two lines, or maybe even one word.

Is there a phosphorous environmental problem that we should be watching for, that we should pay particular attention to, or is it manageable?

MR. NOTON: I can't give you a one word or one-line quick line answer to that. As I tried to point out, there is a potential for a problem.

At the moment, we see effects that are likely attributable to phosphorous, such as enhanced increased benthic algae downstream of the two existing mills. We see increased SOD downstream of the two existing mills, part of which may be attributable back to the phosphorous load, the larger part of which is simply due to the discharge of organic material.

I guess as far as downstream water body and possible eutrophication, we don't have a very good handle on that at present. So what I am saying, I guess, is there is some potential concern, and that at a minimum, we will be monitoring for possible effects with a view to what control measure we might have to take if we see effects that are unacceptable.

DR. ROSS: Fair enough, thank you.

Mr. Hamilton, I have two questions for you, the first one of which is the following: I guess one can, in assimilating the several mills on the river system, add up all of the BOD that gets deposited, but it's not simply additive in the sense that by the time BOD of mills upstream reach Athabasca, they will have been somewhat reduced.

THE CHAIRMAN: Dr. Schindler.

DR. SCHINDLER: I have a couple of questions for Leigh Noton.

Leigh, is phosphorous the nutrient we should be looking at? In other words, is there evidence that phosphorous is limiting all year-round on the Athabasca River?

MR. NOTON: I don't have good data to indicate one way or the other. Like, we haven't done any limiting nutrient studies or anything like that. It's just basically based on the general feeling that phosphorous is the most limiting nutrient in aquatic systems. And also, that on a ratio basis, I think in terms of the pulp mill effluents, it's a little more of concern in terms of how much is potentially coming out of these effluents than is nitrogen, for example.

DR. SCHINDLER: The lakes near the Athabasca system, at least in the Athabasca area, appear to be nitrogen limited, though. Is that not the case, at least from what you can draw from the published literature?

MR. NOTON: I may have to defer on that. My specialty isn't nutrient limitation in lakes. I really wasn't under that understanding. I assume that for a lot of the Alberta lakes, in fact, we had a similar classical sort of phosphorous/chlorophyll relationship.

DR. SCHINDLER: I wonder if we shouldn't be looking at some evidence of nitrogen loading, too, since it appears that that will also be increased as a result of these pulp mill activities.

My second question is, do you have any calculations for what the phosphorous loading is or will be to the western end of Lake Athabasca as a result?

MR. NOTON: The only calculations we've done is what we've presented today, which gives estimates for total and dissolved phosphorous as delivered through the Athabasca River, based on the last few years.

DR. SCHINDLER: But you haven't done any calculations that would take into account the hydraulic residence time of that?

MR. NOTON: No, we haven't done anything like a nutrient budget, say, for Lake Athabasca, no.

DR. SCHINDLER: Do you have any feel for whether we are even close to a problem there? Do you know what the chlorophyll levels are?

MR. NOTON: As I sort of alluded to when I was talking, the southwestern end of the lake where the river enters is a bit of a special case, I guess, in the fact that it's so turbid during the growing season.

We do have some data on chlorophyll levels in that area. I don't have the data right in front of me, but as I recall, they aren't particularly high. That's plankton chlorophyll, of course. In the eastern side of the lake, it's more oligotrophic, I would say, or the nutrients concentrations are indicative of that. And chlorophyll is quite low down there.

What I was trying to draw out is I think there probably is a fairly good nutrient supply already in that southwestern end of the lake, but because of the high turbidity, it's fairly light limited. You get a lot of growth of aquatic macrophytes around the shoreline that can grow up near the water surface and get adequate light. But phytoplankton growth is, I'm sure, definitely inhibited by the high turbidity in that area.

DR. SCHINDLER: Is the nitrogen to phosphorous ratio in the river such that this increase in P relative to N in loading is likely to cause a species shift in the direction of blue-greens?

MR. NOTON: I couldn't tell you right off. I'd have to go back and examine the data that we have. I haven't worked it over from that point of view.

DR. SCHINDLER: I see. Would it be fairly easy for you to do?

MR. NOTON: It wouldn't be too difficult. We could take a look at that.

DR. SCHINDLER: I wonder if you could do that for an undertaking.

MR. NOTON: Sure.

DR. SCHINDLER: I don't think we need it by the end of the hearing, but I'd certainly like to see it before our written deadline.

MR. NOTON: We can undertake to do that.

DR. SCHINDLER: Thank you. I have one question on the oxygen, and that concerns the difference between the assumed loading of 2 kilograms of BOD per air-dried tonne and what we see at Hinton now at 11.7.

Is there really confidence that Hinton can lower its BOD by six-fold and, if so, can they do that in the time that ALPAC would expect to be constructed and on line?

MR. KEMPER: I knew we were going to get to that. That's not in the undertakings that we tabled.

I guess the question is, could they do it; not are they going to do it.

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ADDITIONAL INFORMATION ON NITROGEN AND PHOSPHORUS
IN THE ATHABASCA RIVER SYSTEM
AND IN PULP MILL EFFLUENTS

Report as requested by Dr. D. Schindler at the

Alberta-Pacific Environmental Impact Assessment Review Board Hearing
held at Grassland on December 7, 1989

Presented to:
The Alberta-Pacific Environmental Impact Assessment Review Board
January 15, 1990

Prepared by:

Alberta Environment
Environmental Assessment Division

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1.0 INTRODUCTION

This document contains information on nitrogen and phosphorus in the Athabasca River system and in existing Alberta pulp mill effluents. It is provided in addition to the information entitled "Phosphorus in the Athabasca River System" which was presented to the Alberta-Pacific Environment Impact Assessment Review Board on December 7, 1989. Alberta Environment undertook to provide the enclosed information in response to Dr. Schindler's question "Is the nitrogen to phosphorus ratio in the river such that this increase in P relative to N in loading is likely to cause a species shift in the direction of blue-green [algae]?"

2.0 METHODS

As for the phosphorus data supplied earlier, nitrogen data from past sampling were assembled for station(s) at Athabasca and in the Old Fort/Embarras Airport region near the upstream end of the Athabasca Delta. Data for existing Alberta pulp mill final effluents were also compiled. All sampling was done by Alberta Environment or Environment Canada. Due to varying analytical methods and sampling programs over the years, the number of samples and period of record varies for different compounds and station.

3.0 FINDINGS

3.1 Athabasca River

Figures 1 and 2 show nitrate-nitrogen (analyzed as nitrate+nitrite) at Athabasca and at Old Fort/Embarras near the head of the Athabasca Delta. Mean nitrate-nitrogen (NO_3-N) has been 0.063 mg/L at Athabasca and 0.091 mg/L at Old Fort/Embarras (Table 1) with highest concentrations in winter-spring and lowest concentrations in September-October. Hamilton et al (1985) also noted that NO_3-N was lowest towards the end of the open-water season in the Athabasca River.

Ammonia-nitrogen (NH_3-N) has averaged 0.026 mg/L at Athabasca and 0.045 mg/L at the Delta (Table 1). The higher concentrations downstream have also been observed by Hamilton et al (1985). Ammonia-N had a similar seasonal pattern to NO_3-N but the low concentrations in fall have not been as pronounced (Figures 3 and 4).

Dissolved inorganic nitrogen (DIN), the sum of NO_2+NO_3+NH_3-N, has been compiled and plotted (Table 1 and Figures 5 and 6) since it is a measure of the forms of nitrogen most readily available for uptake and use by aquatic plants. Its seasonal fluctuations were a composite of NO_3-N and NH_3-N: NO_2-N is insignificant.

Total nitrogen (TN) was calculated as the sum of total kjeldahl nitrogen (TKN) + NO_2+NO_3-N, or in some instances, as the sum of particulate and dissolved nitrogen. Total N averaged 0.828 mg/L at the Delta, almost twice the concentration at Athabasca (Table 1). Hamilton et al. (1985) also observed increasing concentrations downstream. No distinct seasonal pattern in TN concentrations was apparent although the highest values occurred in the open water season (Figures 7 and 8).

Mass transport of nitrogen in the Athabasca River is estimated in Table 2. The mass is much greater at the Delta than at Athabasca, of course, due to greater discharge and secondarily higher concentrations, in the Delta. Transport of DIN has been approximately 10% of TN at both locations.

Nitrogen to phosphorus ratios are of interest in aquatic systems because they can indicate which of these two nutrients may be limiting general plant photosynthesis (Wetzel 1983). As a best approximation, aquatic plants require N and P in a weight ratio of 7:1, thus if N:P departs greatly from this in lake waters on an annual basis, it can indicate which nutrient limits lake trophic status. For the Athabasca River, the ratio of DIN:DP is estimated to be a bit higher than that for TN:TP (Table 3) but both indicate that river water is not greatly different from the theoretical ratio of 7 for plant requirements. The range of 4.3 to 10 in the ratios (Table 3) probably reflects short-term fluctuations and measurement error. However, the applicability of the TN:TP ratio is uncertain since the bio-availability of particulate N and P is unknown. Much of the TP transport occurs as particulate P in the high flow, open water season and that particulate P may be fairly strongly bound to the high concentrations of inorganic suspended solids.

3.2 Pulp Mill Effluents

Nitrogen and phosphorus concentrations in final, treated pulp mill effluent are compiled in Table 4 for Weldwood at Hinton, Millar Western at Whitecourt, and, for comparison, Procter and Gamble at Grande Prairie (on the Wapiti River). Note that Millar Western has been in a start-up mode of operation and the values in Table 4 may not be characteristic of their longer-term effluent.

Nitrate-N concentrations are not very different from those in the Athabasca River but NH_3-N and TKN are higher and during low river flows the mill effluents have caused increases in river concentrations of these variables (Anderson, 1989; Noton & Shaw, 1989). The load of TN and DIN discharged by the Hinton mill is equivalent to about 1% of the estimated mass transport of these variables at the Delta (Table 2), although the fate of effluent nitrogen between Hinton and the Delta is not known.

Of interest is the TN:TP ratio in the mill effluents: for both Weldwood and Procter and Gamble it is remarkably close to 7, the theoretical requirement for aquatic plants. The DIN:DP at Weldwood was 5.7, not greatly different than this. These ratios may partly reflect the nutrient supplementation practices in wastewater treatment at both mills. If no specific treatment to control nutrients is undertaken at the mills, it seems reasonable to assume this ratio will be similar in the future.

4.0 CONCLUSION

In the Athabasca River, N and P appear to be present in about the same ratio as that required by aquatic plants. However, the bio-availability of the particulate fractions of the N and P in the river water has not been investigated. Both nutrients are higher in concentration in pulp mill effluents than in the river, but in the effluents they are also present in a ratio of approximately 7. This implies that pulp mill effluent discharges may not alter the N:P ratios in the river.

In answer to the question posed for this undertaking (Section 1), it does not appear that total P will increase relative to total N as a result of pulp mill effluents. However, there might be changes in bio-available forms and ratios of these nutrients since it seems reasonable to assume that the TN and TP in pulp mill effluent is more bio-available than is the TN and TP in the river. This uncertainty will be addressed by future environmental monitoring.

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Table 1. Nitrogen Concentrations in the Athabasca River

Statistic	NO_2+NO_3 N mg/L	NH_3 N mg/L	Diss. Inorganic N (calc.) mg/L	Total N (calc.) mg/L
Athabasca R. at Athabasca	1974-88	1987-88	1987-88	1974-88
n	145	22	22	142
Min.	0.002	<0.01		
Percentiles - 10th	0.005	0.010		
- 25th	0.005	0.010		
Median - 50th	0.040	0.020	0.06	0.365
- 75th	0.100	0.030		
- 90th	0.140	0.060		
Max.	0.400	0.120		
Mean	0.063	0.026	0.089	0.451
Std. Deviation	0.071	0.027		
Athabasca R. at Old Fort/Embarras	1977-88	1977-88	1977-88	1977-88
n	69	68	68	52
Min.	0.002	0.001		
Percentiles - 10th	0.002	0.008		
- 25th	0.010	0.018		
Median - 50th	0.045	0.031	0.084	0.422
- 75th	0.160	0.064		
- 90th	0.240	0.100		
Max.	0.475	0.250		
Mean	0.091	0.045	0.137	0.828
Std. Deviation	0.102	0.042		

Record includes the Hinton pulp mill but pre-dates the Whitecourt pulp mill.
Values less than detection assumed to be 1/2 detection limit.

Table 2. Estimated Nitrogen Mass Transport in the Athabasca River (mean kg/d)

	at Athabasca		at Old Fort/Embarras	
	Diss. Inorganic N 1987-88	Total N 1974-88	Diss. Inorganic N 1977-88	Total N 1977-88
January	840	3,500	4,400	14,000
February	910	3,600	4,500	13,000
March	1,300	3,800	4,000	13,000
April	(11,000)	29,000	4,400	55,000
May	1,200	29,000	3,100	46,000
June	5,800	46,000	9,900	223,000
July	4,800	60,000	18,000	97,000
August	2,800	29,000	5,500	120,000
September	350	23,000	2,000	50,000
October	220	10,000	2,000	75,000
November	280	5,300	2,300	28,000
December	550	4,300	2,500	28,000
Annual Mean	2,500	21,000	5,200	63,000

Note: Record includes the Hinton pulp mill, pre-dates the Whitecourt pulp mill.
( ) - low sample size

Table 3. Nitrogen - Phosphorus Ratios, Athabasca River

	at Athabasca		at Old Fort/Embarras	
	DIN:DP	TN:TP	DIN:DP	TN:TP
April	(23)	4.6	13	22
May	2.3	5.2	3.9	6.0
June	12	3.1	5.5	5.7
July	7.1	3.5	12	2.5
August	6.5	4.6	11	8.0
September	1.7	3.4	5.6	14
October	1.2	12	9.1	27
Annual Mean	8.9	4.3	10	6.6

( ) - low sample size

Table 4. Nitrogen and Phosphorus in Alberta Pulp Mill Effluents

	NO_2+NO_3 N	NH_3 N	Total Kjeldahl N	Diss. Inorganic N (calc.)	Total N (calc.)	Diss. P	Total P
Weldwood of Canada							
Final Effluent Composite 1980–89							
n	36	34	33	34	33	9	35
Min.	<0.003	0.012	1.50			0.060	0.350
Max.	0.71	3.54	15.2			0.450	2.30
Mean	0.107	0.996	6.01	1.103	6.217	0.192	0.894
Std. Deviation	0.157	0.717	2.98			0.116	0.321
Ratios:	DIN:DP = 5.7		TN:TP = 7.0				
*Millar Western Pulp							
Final Effluent Composite 1988–89							
n	7	7	7	7	7	5	6
Min.	0.020	0.015	11.5			2.45	4.0
Max.	0.100	1.08	56.0			20.8	34.0
Mean	0.048	0.220	30.8	0.268	30.8	8.15	13.7
Std. Deviation	0.036	0.380	20.1			7.35	10.7
Procter and Gamble							
Final Effluent Composite 1988–89							
n	34	28	28	28	28	NA	28
Min.	<0.020	0.011	0.75				0.31
Max.	0.64	3.44	29.4				2.85
Mean	0.136	0.296	9.15	0.432	9.29		1.33
Std. Deviation	0.126	0.647	7.62				0.75
Ratios:	DIN:DP = NA		TN:TP = 7.0				

* Start-up mode of operation

Results as mg/L

Figure 1. Nitrogen - Nitrate + Nitrite
Athabasca River at Athabasca 1974-1988

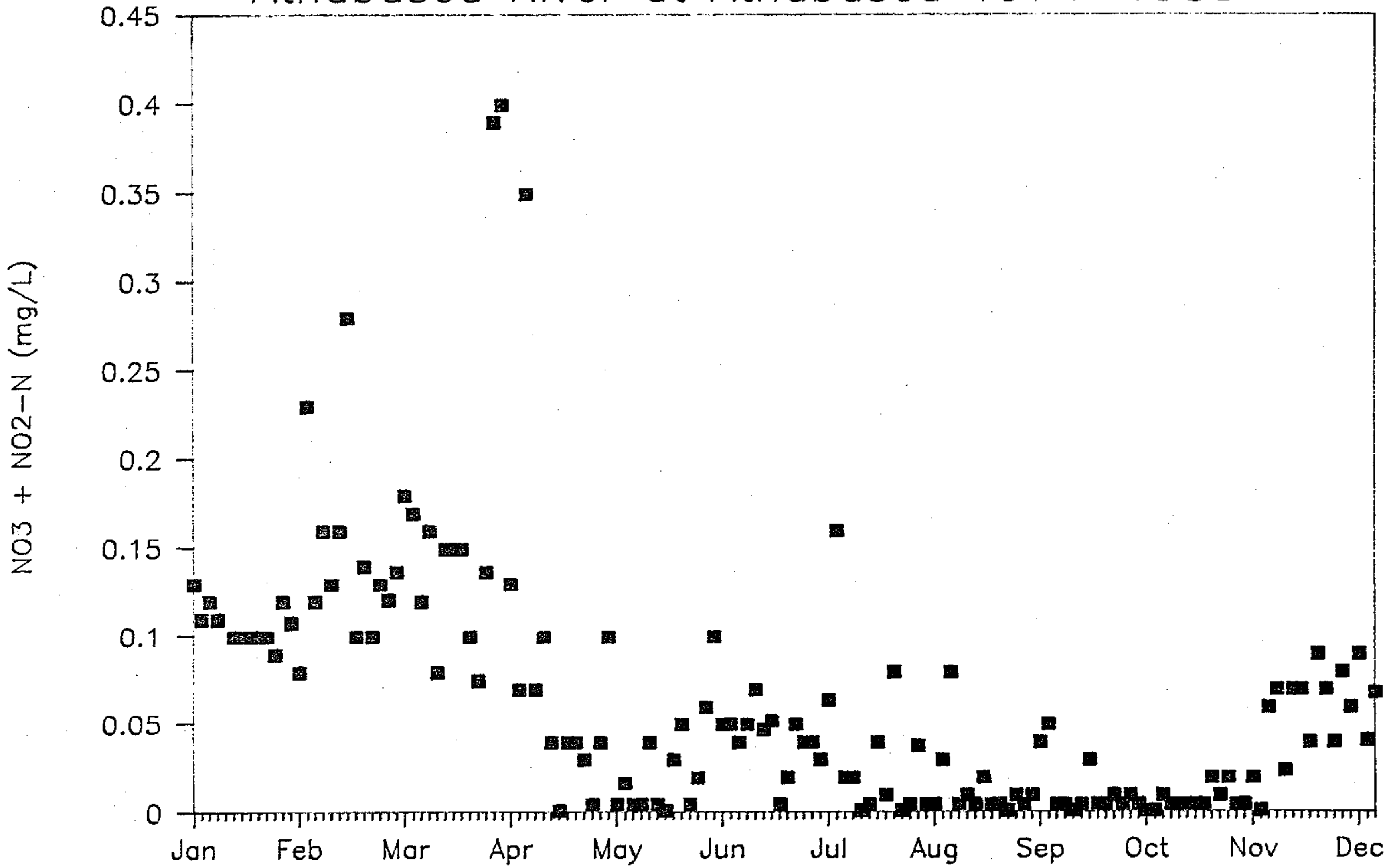

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Figure 2.

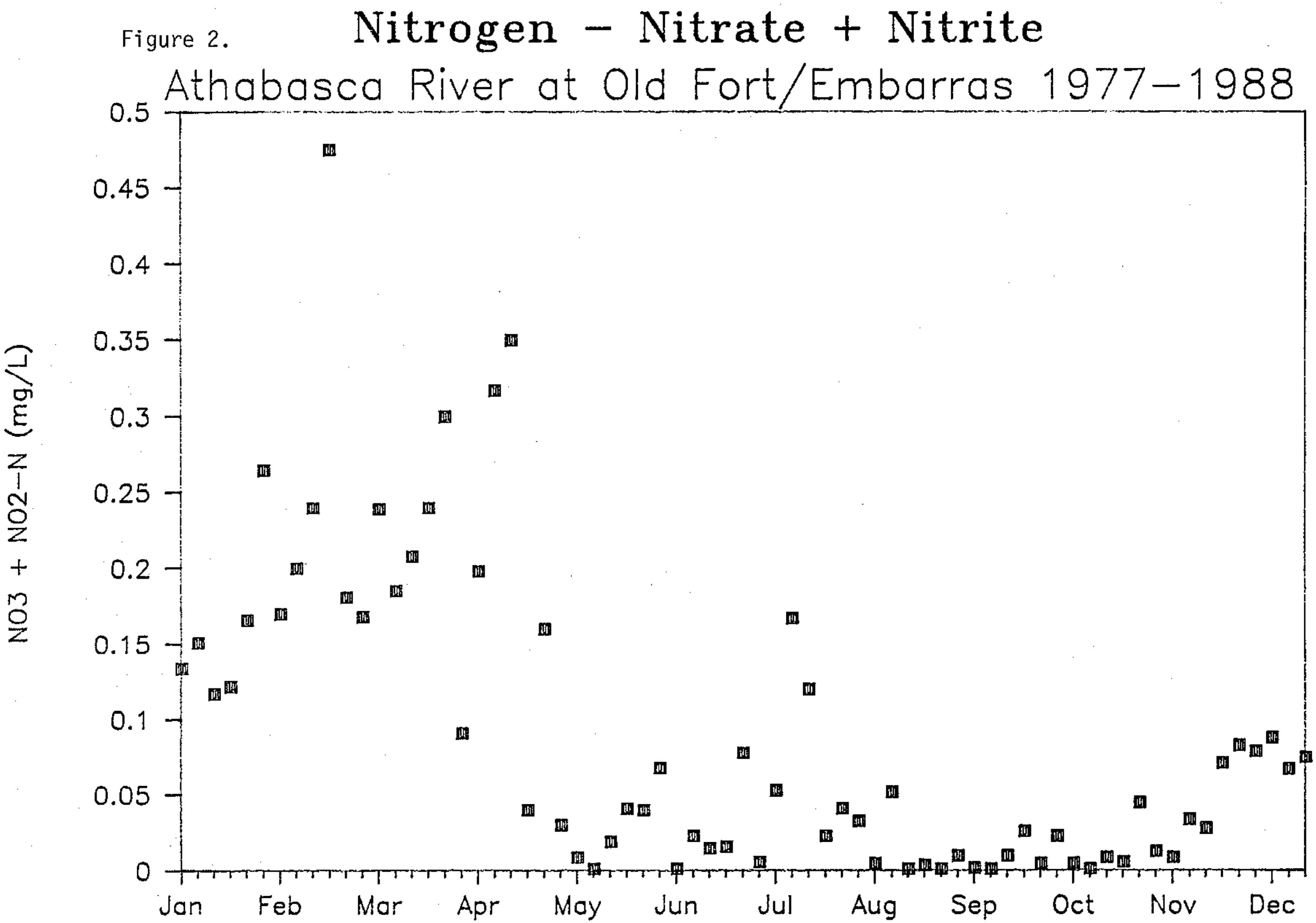

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Figure 3.

Nitrogen – Ammonia

Athabasca River at Athabasca 1987–1988

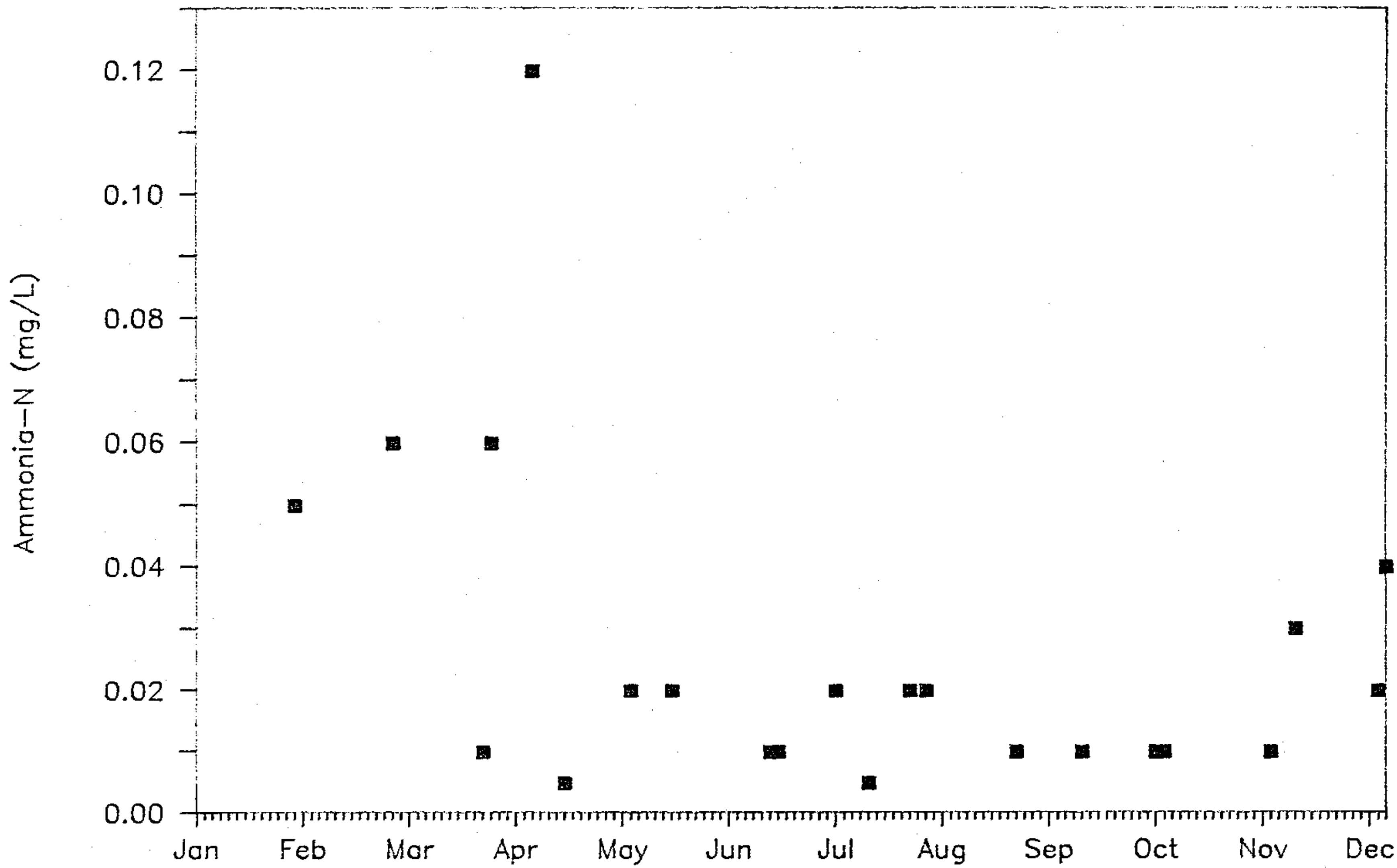

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Figure 4.

Nitrogen - Ammonia

Athabasca River at Old Fort/Embarras 1977-1988

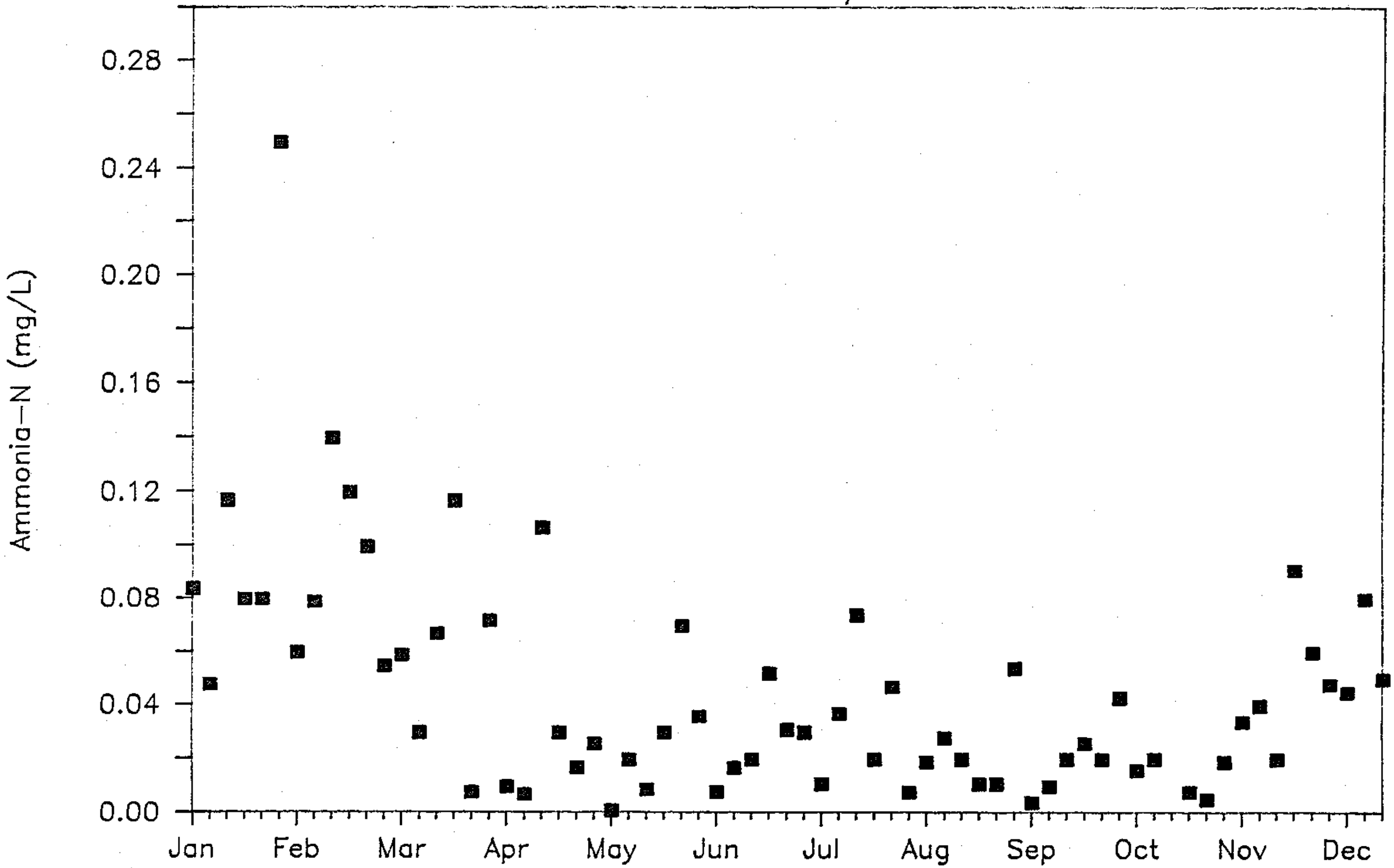

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Figure 5.

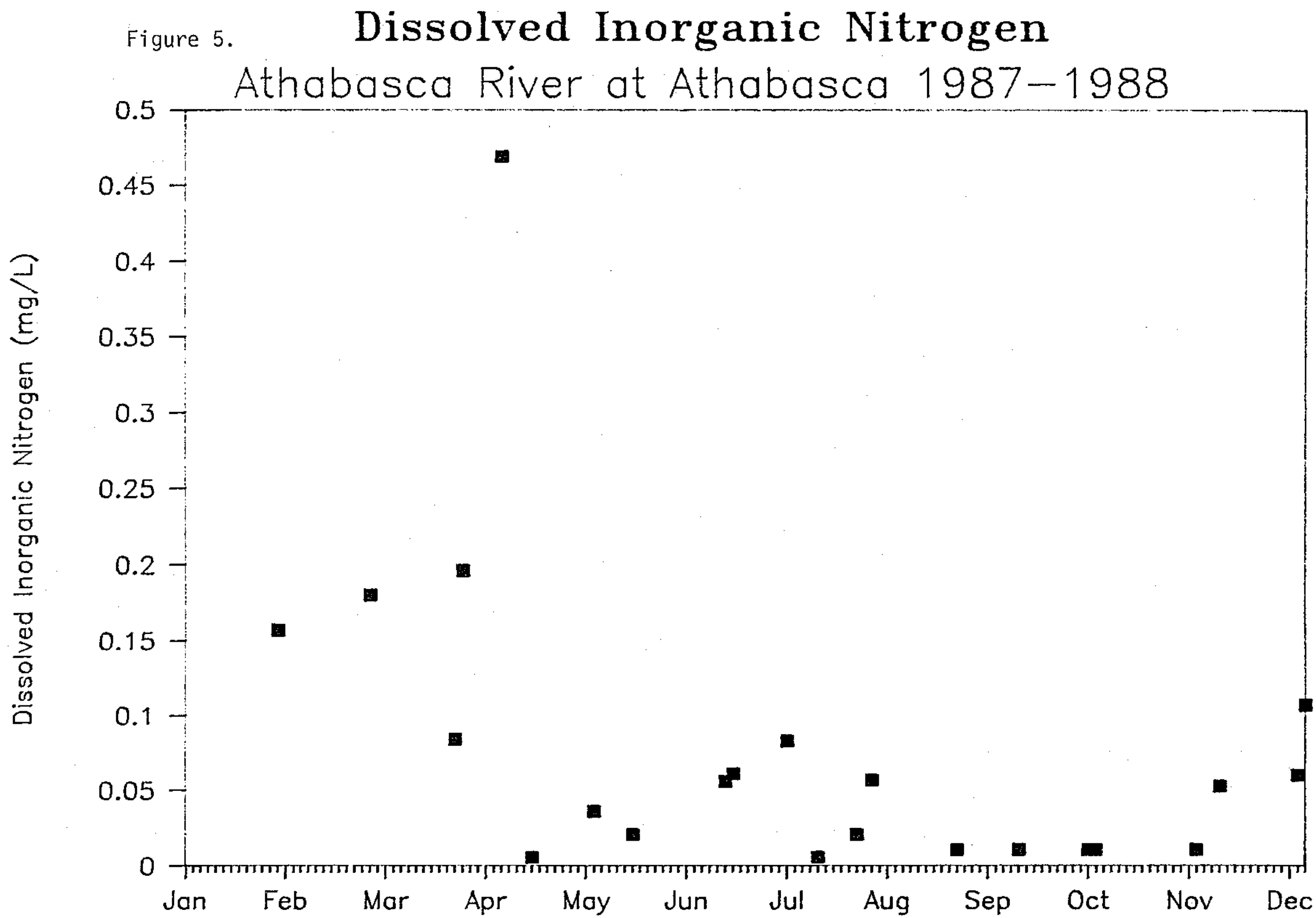

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Figure 6.

Dissolved Inorganic Nitrogen

Athabasca River at Old Fort/Embarras 1977–1988

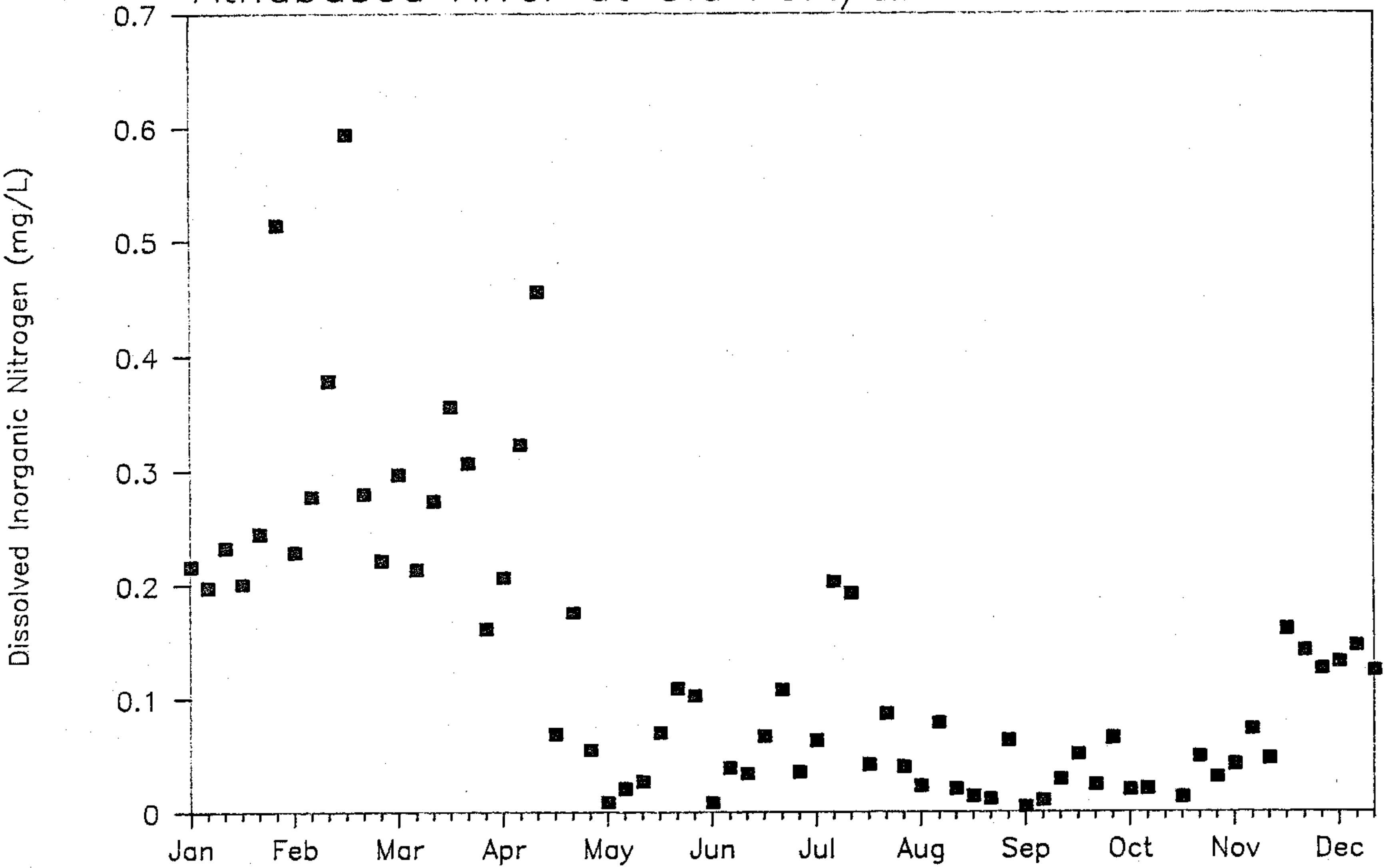

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Figure 7.

Total Nitrogen

Athabasca River at Athabasca 1974–1988

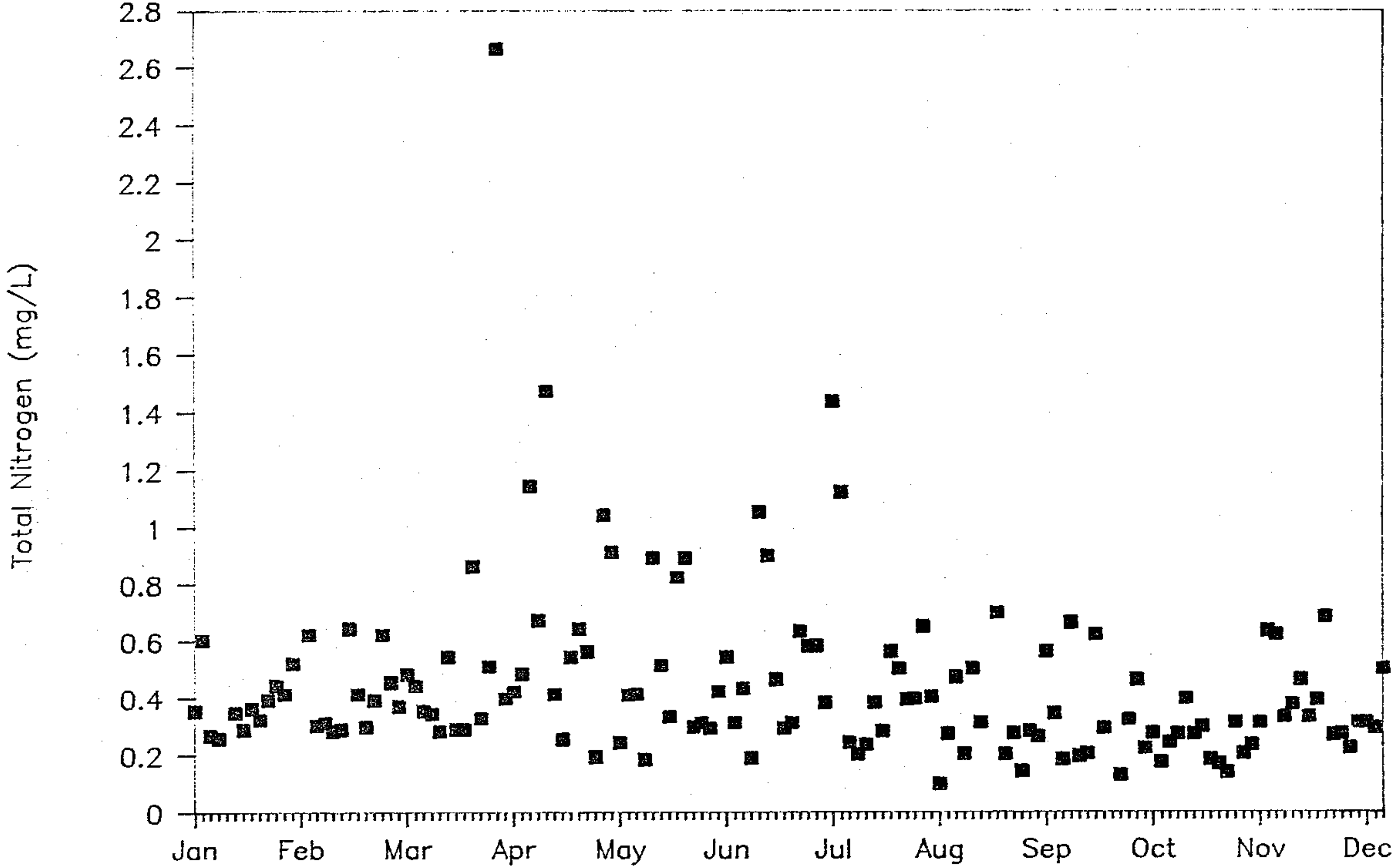

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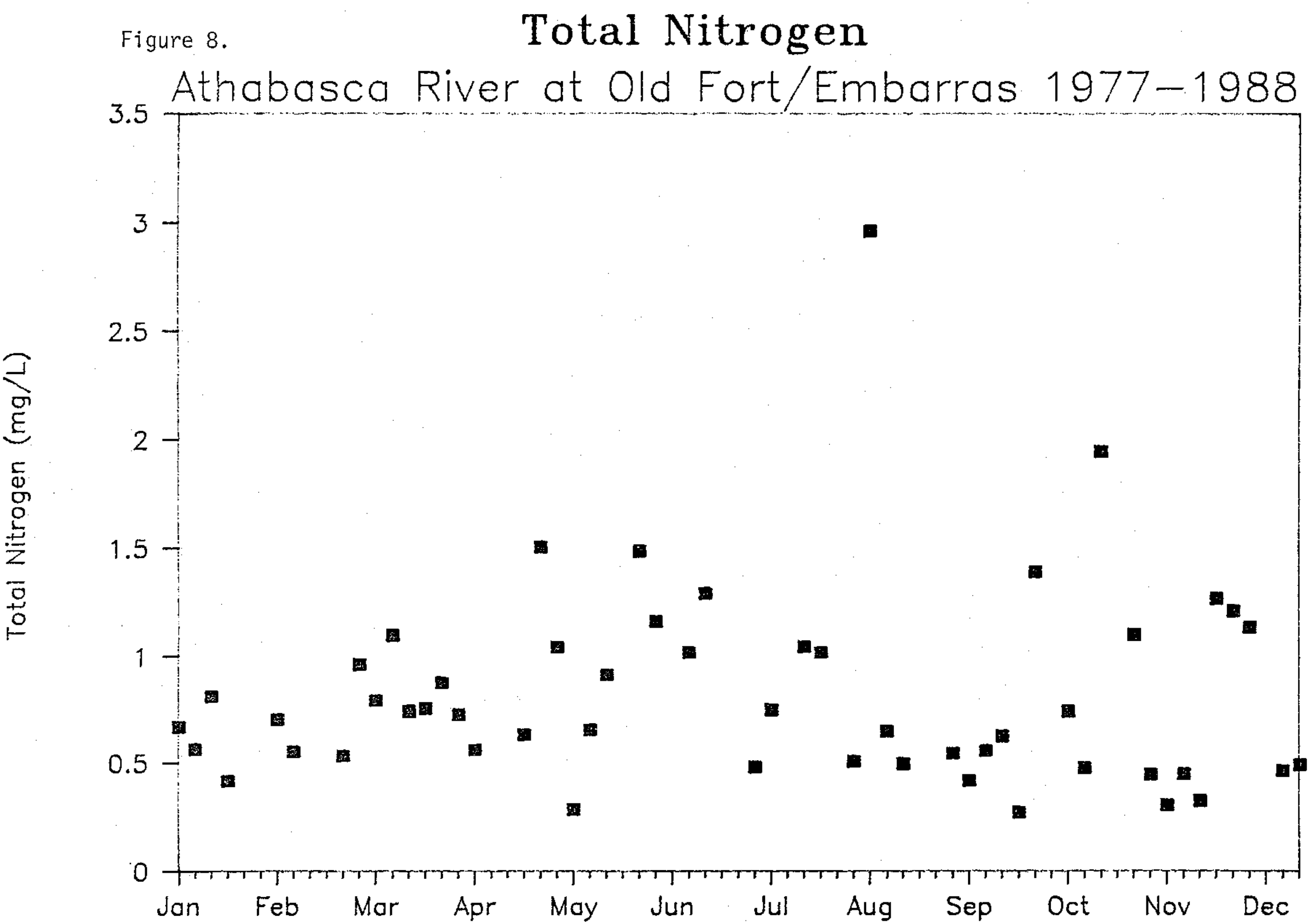
Figure 8.



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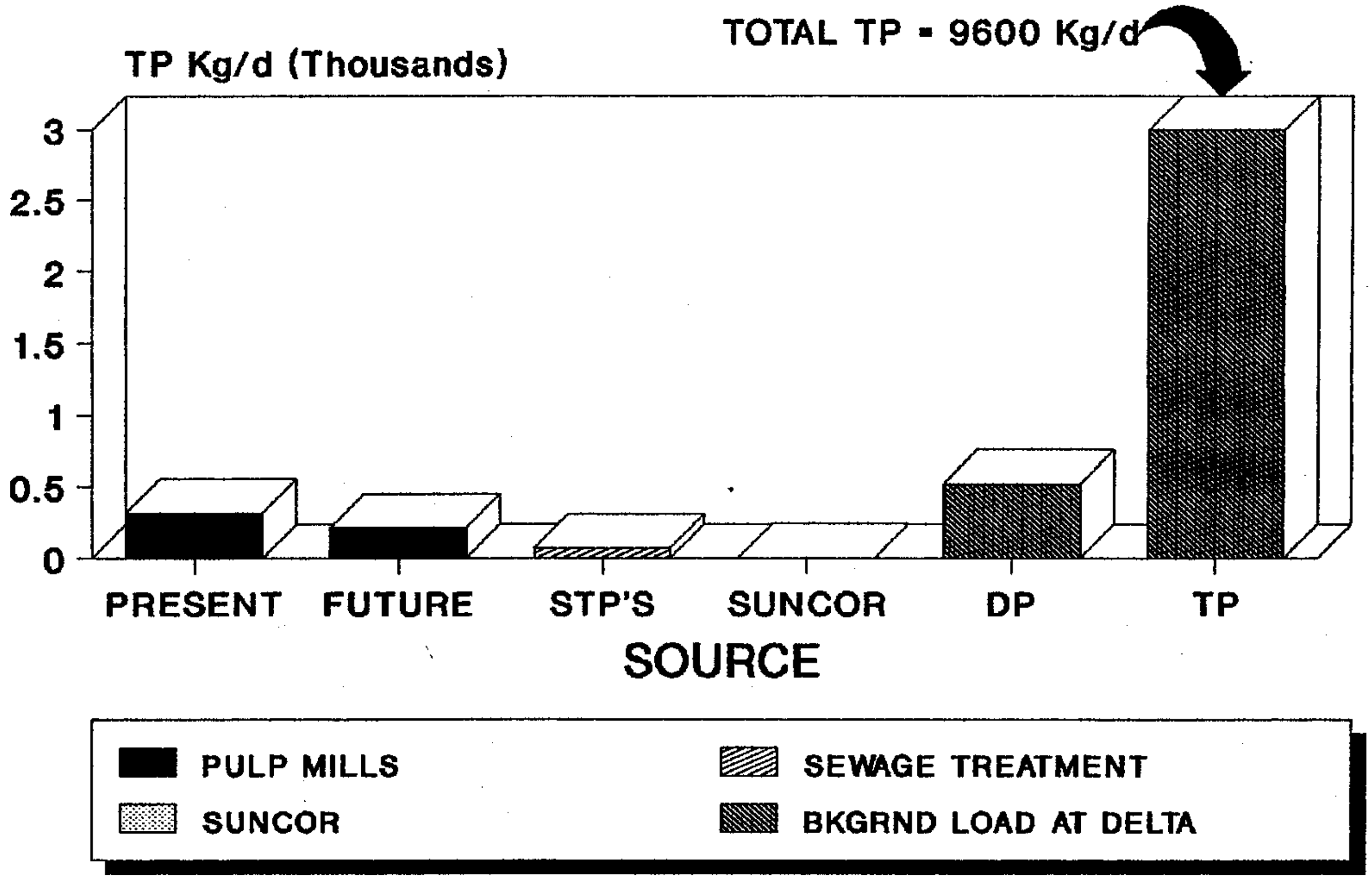
RELATIVE PHOSPHORUS LOADINGS TO THE ATHABASCA RIVER



RELATIVE PHOSPHORUS LOADINGS TO THE ATHABASCA RIVER