CHEMICAL AND BIOLOGICAL MONITORING OF MUSKEG DRAINAGE AT THE ALSANDS PROJECT SITE

Program Evaluation and Suggestions for Continued Monitoring

Prepared for

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SUMMARY OF SUGGESTIONS FOR AQUATIC MONITORING

The following suggestions for continued aquatic biomonitoring apply specifically to the Muskeg River drainage, but can serve as a guide for monitoring other rivers of a similar nature in the AOSERP area. There are few, if any, universally-accepted monitoring methods for aquatic biota, and those suggested below are those that were found useful in Alsands' 1980 Studies. Appropriate changes in the program should be made as experience is gained, and as new developments are added in the drainage basin. Any such modifications should, however, be made in a manner that maximizes comparability of the monitoring data from year to year. In monitoring rivers substantially different in character from the Muskeg River, at least one year of preliminary studies should be conducted to assess the suitability of alternative sampling methods and analytical approaches.

Station Selection and Sampling Design

1. Two comparable primary stations, one impact and one control, (eg Stations 4 and 5), should be selected, one above and one below any expected major discharge point.

2. Several comparable secondary control and impact stations should be selected at various distances above and below the expected major impact point (eg stations 1 to 3 and 6 to 8).

3. Any effluents entering natural watercourses should be sampled directly (eg Station 9 on the Alsands minesite drainage ditch).

4. The primary stations should be sampled most frequently (See Table 1 for an outline of the suggested frequency of routine sampling). Evidence of an impact in data from these stations would be a signal for more detailed study to be initiated to determine the extent and seriousness of the

impact. This would include, as necessary, immediate sampling of all stations, primary and secondary.

5. Regardless of the results of sampling at the primary stations, all stations should be sampled in detail once a year (Table 1) in an annual check-up.

<u>Water Quality and Physical Attributes</u>

1. The following water quality parameters should be measured: temperature, dissolved oxygen, chemical oxygen demand, biochemical oxygen demand (when heavy organic loading is expected), pH, conductivity, total and phenolphthalein alkalinity, suspended solids, total dissolved solids (gravimetric), turbidity, colour, ammonia-N, nitrate-N, nitrite-N, total Kjeldahl nitrogen, total phosphorus, total dissolved phosphorous, orthophosphate-P, total organic

carbon, silica, sulphate, chloride, calcium, magnesium, sodium, potassium, arsenic mercury, cadnium, hexavalent chromium, copper, iron, manganese, nickel, vanadium, lead, zinc, phenols, oil and grease.

2. The following physical attributes should be measured: current velocity, channel width, mean and maximum water depth across permanent transects. Silt accumulation in stony and pool areas should be measured by the substrate score method of Crouse et al (1981:283-284) and by direct measurement from a staff gauge, respectively.

3. Permanent photo stations should be established at each sampling site to monitor bank conditions.

Biological Attributes

1. At a minimum, some measure of benthic invertebrate community composition should be monitored. It is

suggested that principal components of species abundance data be used as measures of species composition if the necessary computing facilities and expertise are available. If not, some other measure (such as abundance by functional groups) could be substituted.

2. Monitoring of periphytic algae could provide a second measure of incipient biological effects, and would be particularly useful where nutrient enrichment is suspected. Measures of community composition (eg principal components of species abundance data), and total biomass (eg chlorophyll a) would be appropriate).

3. In routine sampling of primary stations for benthic invertebrates and periphyton, artificial substrates should be used to permit rapid sample analysis. Multiplate samplers for benthic invertebrates and glass slides for periphytic algae are suitable artificial substrates.

4. For the annual check-up, and for verifying findings based on artificial substrate sampling,

natural substrates should be sampled for benthic invertebrates and periphytic algae. An airlift sampler for fine sediments and a Neill-type cylinder sampler for stony substrates are suitable devices for benthic invertebrate sampling. A scraping method (eg Hickman et al 1979) is best for sampling periphytic algae.

5. Spring runs of fish should be monitored every three years using the methods of Bond and Machniak (1977, 1979) to detect longterm changes in fish use of the river, and to check for year-class weaknesses.

6. Trials should be conducted with drift or fyke nets to determine if this is a feasible method of monitoring annual fish spawning and rearing success.

Timing

1. A suggested sampling schedule is presented in Table 1 in the text. Results of routine sampling

at primary stations should be reported within one month. Results of the annual check-up should be reported within six months.

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1.0 INTRODUCTION

Volume I of this report reviewed the available data on the aquatic resources of the Muskeg River drainage as a background to further studies on the river system. Volume II presented the results of monitoring and fish studies conducted in 1980. The present volume evaluates the 1980 monitoring program, and makes suggestions for the conduct of future monitoring studies on the Muskeg River and elsewhere in the AOSERP area. More specifically, this volume is intended to meet the following requirements of Alberta Environment that have not been addressed in preceding volumes.

1. Assess the effectiveness of the ditch and outfall designs in limiting the suspended solids load contributed to the Muskeg River.

2. Discuss possible mitigative measures, based on the findings of the present monitoring program.

3. Evaluate the usefulness and suitability of the parameters chosen for monitoring in the current program.

In addition, Alberta Environment requested the following: Discuss general alternatives for future monitoring programs in the Alberta Tar Sands area. Consider:

a) timing, with respect to season and specific events (floods, washouts, droughts, etc);

b) integration of chemical, physical and biological approaches;

c) sampling station selection;

d) choice of chemical, physical and biological parameters for monitoring;

e) methodology; and

f) biological indicators.

These and many other related topics have recently been treated at some length for Alberta Oil Sands Environmental Research Program by Aquatic Environments Limited (McCart and Mayhood 1980). A copy of the report is appended. Most are also discussed at length here in connection with monitoring in the Muskeg River.

2.0 ASSESSMENT OF ALSANDS' 1980 MONITORING PROGRAM

2.1 Impacts

The results of the monitoring program demonstrated that the original ditch outfall design was inadequate to prevent severe siltation of the Muskeg River. The drainage water was simply directed, unchannelled, into the forest above the Muskeg River, with the intent to filter out suspended solids there. The water quality results suggest that, although this procedure was effective initially, the water had eroded one or two main channels for itself by 10 April 1980, and was in fact increasing its suspended solids load on that date as it passed through the forested area.

The most severe impact resulted from an accident that caused a flood which the outfall area could not control. The flood water initially eroded much of the ditch and outfall areas, then deposited the silt in the river and in the outfall area.

During the construction of the settling pond after the flood, the minesite drainage water was diverted into a low swampy area, which drained eventually to the Muskeg River perhaps 400 m below the original outfall. The drainage water was clear when it emerged from the swamp, but eroded a substantial portion of the bank at the outfall, and produced a silt delta in the river.

After the settling pond had been constructed, there was an improvement in the quality of the drainage water with respect to suspended solids. A diverse and moderately abundant benthic invertebrate community developed in the ditch below the pond, at the same time that the plantsite ditch (with no settling pond) had a depauperate fauna.

It is not possible to determine from the monitoring data if seeding of the ditch drainage areas reduced siltation of the ditch water. The procedure, which included a fertilizer treatment, did have the undesirable side effect of enriching the Muskeg River water, thereby increasing the algal biomass on artificial substrates. The effect was temporary, however, and it is possible that there was a net benefit in that the seeding may have substantially reduced erosion and siltation in the ditch.

2.2 Mitigation Measures

It would appear that the necessary mitigation measures to reduce impacts from siltation have already been taken. It is important that the ditch below the settling pond continue to be well-protected and maintained, particularly at the river bank, to prevent any further erosion and siltation. If additional fertilization of the drainage ditch areas is required to maintain plant growth there, applications should be as sparing and infrequent as possible. As a further precaution, drainage water after fertilization could be retained for as long as possible in the settling pond, to allow the nutrients the greatest possible time to sediment out.

2.3 Monitoring Parameters and Methods

2.3.1 Water Quality

The water quality parameters all provided useful information in the monitoring study, but many improvements could be made. Certain measurements would have been more valuable had they been measured in the field as well as in the laboratory. These parameters include pH and conductivity. Detection limits for certain parameters, especially sulphate, ammonia-N, nitrate-N and nitrite-N, should have been much lower. To aid accuracy checks, TDS should always have been measured gravimetrically, and silica should have been analyzed in all "long list" samples. Accuracy checks should have been run immediately after total analyses were completed, so that questionable analyses could have been redone. Finally, it would have been preferable to sample water for detailed analysis more frequently than bimonthly at at least certain key stations, eg 5, 4 and 9.

2.3.2 Biological Parameters

Biological parameters were monitored in the Alsands study as a complement to the chemical and physical parameters measured, not as a potential replacement for them. Whether or not there were physical or chemical changes in the river induced by Muskeg drainage, we wanted to know if there were measurable biological effects attributable to drainage activities. Benthic invertebrates and periphytic algae were selected for study because they have been found useful in many other monitoring studies (Hellawell 1977).

2.3.2.1 Benthic Invertebrates

Two gross measures of benthic invertebrates, total abundance and total biomass, were of little value in detecting impacts in this study. Catastrophic impacts could be expected to severely reduce both total numbers and total biomass of invertebrates, but less obvious impacts could cause uninterpretable changes or no measurable changes in these parameters, as was the case in this study. Community composition, as measured by the first few principal components of the species abundance data, did sometimes change measurably in response to the influence of muskeg drainage, and was therefore a more sensitive and useful parameter for monitoring purposes.

Sampling methods were a principal source of difficulty in the Alsands monitoring study. Ekman and cylinder samples usually provided highly variable data that made statistical analyses insensitive to differences among stations. Kick samples were less variable, but stations for kick sampling in the Alsands area were scarce and often not very comparable. Ekman, kick and cylinder samples all required a great deal of time to sort. Multiplate samples provided relatively precise data and required little sorting, but the samplers were vulnerable to losses from spates and beaver activity. In addition, multiplate samplers are artifical substrates. There is always a tendency on the part of some, often in spite of contrary evidence, to believe that artifical samples do not adequately reflect conditions in the natural environment.

2.3.2.2 Periphytic Algae

Total algal biomass (as cell volume) was found to be useful for detecting enrichment effects from fertilizer contamination, and other effects, possibly from siltation or scour. Chlorophyll *a* is a much more convenient measure of total algal biomass than cell volume and, despite the analytical problems in this study, should be used in future monitoring programs.

Community composition of periphytic algae, as measured by the first few principal components of the species abundance data, was not measurably altered by Muskeg drainage in this study. In many cases, however, community composition can be expected to be sensitive to a wide variety of impacts, and would be worth monitoring in other studies.

Natural substrates were difficult to sample adequately for periphytic algae. Closely comparable, stony sites were often not available for sampling of epilithic algae in control and impact zones.

The method used (Stockner sampler) contaminated the samples with phytoplankton, but a scraping method (eg Hickman et al 1979) could be substituted to overcome this problem. We know of no suitable method for quantitatively sampling the algae of fine sediments in the Muskeg River.

The artifical substrates used for sampling periphytic algae (glass slides) were selective, but were colonized by a substantial proportion of the periphytic algae found on natural substrates in the Muskeg River. The samplers were easy to handle in the field, but were prone to loss from high water and beaver activity.

2.4 Data Storage and Retrieval

A computerized storage and retrieval system is expensive to set up initially and requires a person with computing experience to maintain it and make changes as the need arises. Over the duration of the monitoring program, however, the annual cost of development and maintenance is likely to be low. The alternatives to a computerized system involve large volumes of paper copy, a greater chance of data loss, and a reduced degree of analytical sensitivity and sophistication in the long term. It is becoming almost a necessity to use a computer to analyze the biological data collected in even a small impact study (eg Green 1979).

A computerized data storage and retrieval system was initiated during this study to deal with a monitoring program that was expected to operate for the life of the Alsands project and perhaps for some time after shutdown. Ultimately, the system is to include:

1. Forms suitable for keypunching on which raw data are recorded;

2. Codes for non-numeric information (eg for taxonomic groups);

3. Data verification programs to check for unlikely or impossible values and to verify taxonomic codes;

4. File creation programs to rearrange the original keypunch data in a form suitable for further analysis;

5. Data summary programs to search data files for requested information to be printed out in tables or graphic formats, and

6. Components for standardized statistical analysis packages (eg BMDP, SAS, SPSS) suitable for the analysis of biomonitoring data.

To date, steps 3 and 5 have not been completed, and step 4 programs may require some modification to generalize them to deal with data collected in future.

2.5 Reporting

One of the principal objectives of a monitoring program is to provide an early warning of incipient environmental impact so that steps can be taken to prevent serious damage. The Alsands biological monitoring data were, however, not analyzed and reported until many months after the field collections had been completed. In future monitoring programs, it is important that results be reported within a short time--a month, for example.

2.6 Preliminary Studies

The main reason for the long delay in reporting was that the necessary preliminary work had not been done prior to development at the project site. It has been emphasized elsewhere (McCart and Mayhood 1980:79-80) that at least one year of preliminary studies would be necessary as a basis for operating a rationally-designed biomonitoring study in streams of the AOSERP area. The purpose of the preliminary studies is to test a variety of approaches, sampling methods and analytical techniques to arrive at a practical combination that would be sensitive to the impacts expected. Added advantages of preliminary studies are that pre-impact data are obtained, and operational difficulties are worked out prior to the time when rapid environmental changes may be occurring.

The 1980 Alsands program combined a preliminary study with operational monitoring. As a result, delay-causing difficulties that might have been eliminated by preliminary work retarded the monitoring data analysis and reporting.

Future biological monitoring work in other AOSERP-area streams will require that at least a year of preliminary evaluative work, as described above, be conducted if these streams (or the expected impacts) differ substantially from those in the present study.

3.0 SUGGESTIONS FOR CONTINUED MONITORING

The continuing monitoring at the Alsands project site must eliminate the long delays in reporting the biological. The following suggestions are made with this as one of the principal objectives. Many of the basic ideas have been elaborated upon elsewhere (eg Green 1979, McCart and Mayhood 1980).

3.1 Sampling Design

The most efficient sampling design would be one employing primary and secondary stations. The few primary stations would be sampled frequently (eg, monthly), and both primary and secondary stations would be sampled immediately whenever an impact was detected, to determine the extent and seriousness of any change.

At the Alsands site, stations 4 and 5 (Figure 1) could be the primary stations. These two sites could be sampled monthly in the open-water period and bimonthly in winter. If a comparison of the data from the two stations provided evidence of impact from development-related activities, all primary and secondary stations (1 to 9) would be immediately sampled to confirm the findings, if possible, and to determine the extent of any change.

It may prove necessary to make alterations in the approach and design as more experience is gained. For example, it may be unnecessary to resample if the impact detected is likely to be of negligible importance to the health of the stream.

It would be worthwhile to treat Station 9 as a primary station also. As a biological habitat, it is not directly comparable to stations 4 and 5, but samples from Station 9 would still provide essential information about the quality of muskeg drainage water entering the river.

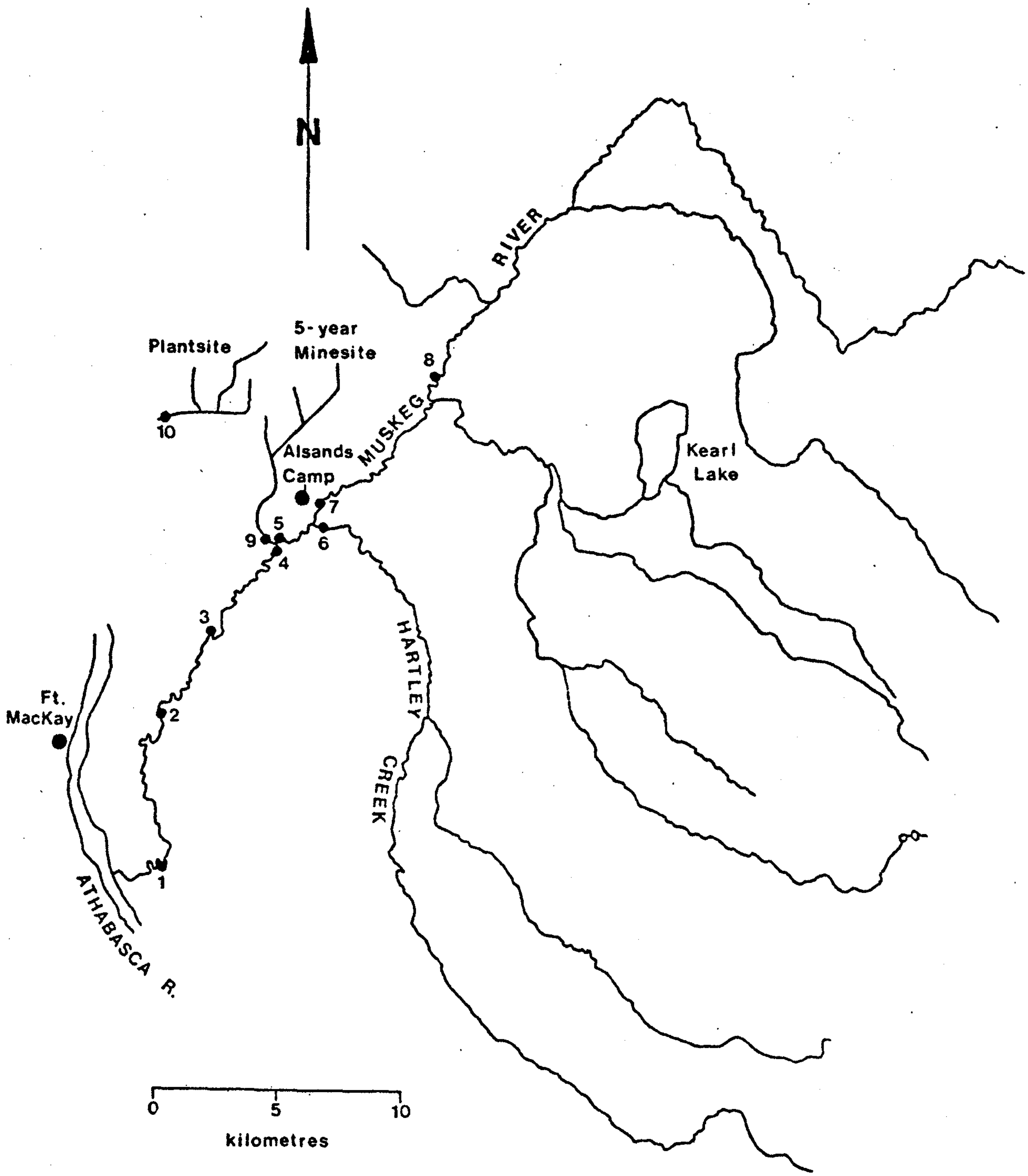

Figure 1. Sampling stations for monitoring the Muskeg River drainage.

If there is reason to suspect environmental impacts upstream of Station 5, additional stations will have to be sampled as primary stations. For example, if test pit water is to be discharged to the river, a new primary station should be added as a control a short distance above the discharge point (Station 8 is too far upstream to be useful for this purpose), and Station 7 should become a primary impact station.

In addition to the regular sampling of a few primary stations, there should be an annual "check-up" survey of all stations. The check-up survey would look for evidence of impact over a larger area, and would provide a measure of longterm, year-to-year change.

3.2 Monitoring Parameters

3.2.1 Water Quality

The same water quality parameters (long list) monitored in the 1980 study should be monitored in the continuing program. In addition, silica should be added and total dissolved solids should be measured gravimetrically so that various accuracy checks can be reliably made.

Seidner's (1980) data show that the conductivity of AOSERP-area surface waters could be used to predict the concentrations of the major ions. The possibility of monitoring the major ion concentrations by measuring conductivity alone should be investigated further with a view to eliminating direct analyses of major ions from the program if sufficiently accurate conductivity-concentration regressions can be determined. This would aid in reducing analysis time, reporting time, and costs.

In view of the relatively high suspended solids content sometimes present in muskeg drainage water, it would be valuable to monitor sediment accumulation, if any, in the river. This is a difficult technical problem, but a method satisfactory for monitoring purposes would be to install a staff gauge at selected stream stations above and below discharge sites. The gauges should be set in pool areas, where deposition would be expected to be heaviest. Sediment accumulation could then be determined on each sampling date by direct observation, or (in turbid water) by lowering a weight to the sediment surface at the gauge.

In addition, siltation of stony areas should be monitored because these sites are often important for fish spawning and benthic invertebrate production. Crouse et at (1981) described a simple field technique that compared favourably to a much more elaborate and time-consuming method involving sampling, seiving and sorting of the substrate materials.

Filterers, a trophic functional group (eg, Merritt and Cummins 1978) might be particularly sensitive to inorganic siltation, showing declines in abundance in response to relatively low loadings of inorganic suspended sediments. As another example, a habit functional group, crevice-dwellers (eg, capnid and leuctrid stoneflies), are also likely to be particularly sensitive to siltation. In streams in which they occur, their numbers could be monitored, and declines corresponding to increased siltation could be interpreted as an impact due to siltation.

The advantages of using a functional group approach are that there is usually an obvious hypothetical relationship between the evidence of impact and the impacting agent, and detailed identifications are seldom required. Disadvantages are that, in looking for a specific response other impacts may be overlooked, and by identifying only functional groups much of the information in the samples is ignored.

3.3 Biological Sampling Methods

To improve the sensitivity of biological monitoring and reduce reporting time, it is recommended that artificial substrate samplers be used as the collecting method for routine sampling at the primary stations. When the results of artificial substrate sampling provide evidence of ecological impact, follow-up sampling of natural substrates should then be conducted to determine if the truly natural communities of the river have been affected, and if so, to what extent. Likewise, natural substrates should be sampled during the annual check-up.

For benthic invertebrates, the multiplate sampler (Hester and Dendy 1962) is suggested as the most useful for routine work on the Muskeg River. It is an approximate mimic of the sunken wood substrate which is very common in the river, is inexpensive, lightweight, easy to clean and retrieve, and provides samples that require almost no sorting. The latter feature alone reduces the sample processing time by approximately 30 to 50%, a large saving in reporting time. Furthermore, sampling variance is remarkably low with multiplate samplers, which greatly improves the sensitivity of statistical comparisons between control and impact stations over that typical of natural substrate samples.

Because multiplate samplers are prone to loss from floods and beaver activity, it would be prudent to set out at least five at each of the primary sampling stations, even though three samples seemed to provide adequate results in the 1980 study. In contrast to the 1980 system, the samplers would best not be linked to a common rope--again to reduce losses.

For sampling natural, fine sediment substrates, a lightweight airlift sampler developed by Aquatic Environments Limited has shown considerable promise. Ekman samples had very high sampling variances in the 1980 program. Perhaps this problem will be reduced with the airlift sampler. Stony sites can be sampled with the cylinder or standardized kick techniques described in Volume II.

Rose Bengal, a vital stain (Lackey and May 1971) was used with some success to reduce sorting time in 1980, and work should continue to find ways of reducing still further the time required for this processing stage.

For sampling periphytic algae, the glass slide diatometer has the advantage of being a widely-used sampling device (eg Standard Methods 1975); however the plexiglass racks of glass slides used in 1980 worked satisfactorily. For sampling natural substrates for periphytic algae, a template-and-scraper method like that described by Hickman et al (1979) is preferable to the Stockner sampler used in 1980 (Stockner and Armstrong 1971). If a quantitative sampling method is found that could be used to collect algae from fine sediments in depositional areas of the Muskeg River, this should be used in place of the scraping method to obtain natural-substrate algal samples from this most characteristic substrate type.

3.4 Fish

Fish populations are not particularly useful as monitoring tools, as described elsewhere (McCart and Mayhood 1980). They are ecologically and economically significant, however, so it is important that they be monitored in the Muskeg River.

Preferably, young-of-the-year would be monitored annually at one or two standard locations at a standard time each year. This could provide information on spawning and rearing success each year. No satisfactory quantitative collecting method for young fish has yet been used on the Muskeg River, however. Small-mesh fike nets may prove useful for this purpose, and could be tried.

If annual monitoring of young-of-the-year cannot be done, the spring runs should be monitored at least every three years to detect any longterm changes in the fish populations. It will be particularly important to look for year-class failures or weaknesses. The methods used by Bond and Machniak (1977, 1979) should be adopted so that their work can serve as a precise baseline against which to compare later results.

3.5 Timing

Sampling for water quality and physical attributes should be conducted at least monthly at the primary stations when activities on the Alsands site are initiated. Artificial substrates for biological sampling should initially be set in place as soon as possible after ice-out or before freeze-up and permitted to colonize for at least one month before being sampled for the first time. Thereafter sampling could be conducted monthly in summer, and once each in fall, winter and spring.

July would seem to be the best time for the annual check-up. Low water levels and tolerable weather at that time should facilitate sampling, which can be difficult or impossible during high water on this river.

A suggested sampling schedule is presented in Table 1. With this scheme it should be possible to report results within one month, if there are only two or three primary stations. Results of the annual check-up, however, could not reasonably be expected before December.

3.6 Data Storage and Retrieval

If a standardized monitoring program using consistent sampling stations and techniques and having relatively consistent report requirements is going to be instituted, a computerized data storage and retrieval system will be worthwhile. Such a system, once in place, should greatly speed up data analysis and reporting. If large changes in the monitoring program through the life of the project are expected, such a system may not be worth developing.

Table 1. A suggested sampling schedule for monitoring the Muskeg River drainage for environmental impacts from the Alsands project. 1, primary stations only; 2, all stations; * standard station yet to be determined.

Parameter		Month											
		J	F	M	A	M	J	J	A	S	O	N	D
Water Quality		1	1	1	1	1	1	2	1	1	1	1	1
Physical Attributes		1	1	1	1	1	1	2	1	1	1	1	1
Benthos	-multiplates	1			1		1	1	1		1		
	-natural substrates							2					
Periphyton	-slides	1			1		1	1	1		1		
	-natural substrates							2					
Fish	-young-of-year						*						
	-spring run (near mouth)				———	———							

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