A LONGITUDINAL PHYSICO-CHEMICAL AND ALGAL SURVEY OF FIVE RIVERS FLOWING THROUGH THE AOSERP STUDY AREA

by

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for

ALBERTA OIL SANDS ENVIRONMENTAL RESEARCH PROGRAM

Project WS 1.3.4

September 1980

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ABSTRACT

Longitudinal surveys determining physico-chemical and algae parameters were conducted during 1979 upon the Muskeg, Steepbank, Hangingstone, Ells, and MacKay rivers. Results are presented for each site, and as an average for each river.

ACKNOWLEDGEMENTS

This research project, WS 1.3.4., was funded by the Alberta Oil Sands Environmental Research Programme, established to fund, direct, and co-ordinate environmental research in the Athabasca Oil Sands area of northeastern Alberta. The authors acknowledge with utmost appreciation Marianne Klemka for her laboratory work. Special thanks are extended to Michael Jeffery and Eva Romaniszyn, D. Hadler and crews of Liftair, particularly Jack Le Roux, for their assistance and support in field operations.

1. INTRODUCTION

Rivers can vary enormously along their lengths with respect to both their physical and chemical nature. These reflect changes in the local geography, geology, and climate, and include variations in substratum type (mud or rock) and chemistry (granite or limestone, inorganic or organic sediment), downstream channel slope, shape of valley, height of land above the river (i.e., fall from land to channel, porosity of surrounding land surface, vegetation, soil types, annual rainfall, water velocity, depth, and turbidity. All will interact exacting pressure and instigating changes in the biota, including species composition, diversity and abundance. The biota itself, in turn, will exact selective pressures upon many dissolved substances. Therefore, longitudinal variation will occur along that aquatic continuum (Stienmann 1907; Schelford 1911; Thienmann 1912; Carpenter 1928; Huet 1949, 1954; Müller 1951; Allen 1956; Illie 1964; Hynes 1970; Whitton 1975.

Surveys of the Muskeg, Steepbank, Hangingstone, Ells, and MacKay rivers were conducted during 1979. These rivers are mainly accessible only by helicopter. Thus, specific site selection was mitigated by the availability of a suitable area in which the helicopter could safely land. Also, the surveys had to be scheduled according to the availability of the helicopter. This necessitated spreading them over the summer such that surveys were conducted during June for the Ells River, July for the Muskeg River, and September for the Steepbank, MacKay, and Hangingstone rivers. The surveys included analyses of both physico-chemical and algal parameters. This report provides a descriptive account of the findings.

2. METHODS

At each site a visual examination was made first to determine which algal communities dominated and which could be sampled quantitatively. Major characteristices of each were noted. Physical factors (see Table 1) and some chemical factors (e.g., pH and total alkalinity) were determined in the field. Water samples collected just below the water surface were filtered through Whatman GF/C glass fibre filters to remove detritus and organisms (c.f. Happey 1970; Hickman et al. 1979), and placed in coolers for return to the laboratory.

Dissolved silica, phosphate-phosphorus, nitrate-nitrogen, and alkalinity were determined using methods outlined in MacKereth (1963), and chloride and sulphate according to an anonymous report (Anon. 1976). Phosphate-phosphorus extractions using n-hexanol and ammonium molybdate were performed, as soon as feasible after collection, in the Mildred Lake Research Facility. Similarly, the 100 mL samples utilized for nitrate-nitrogen determinations were evaporated to dryness in flat-bottomed conical flasks in the same laboratory. Subsequent analyses took place at the University of Alberta.

Sodium and potassium concentrations were determined using an IL Flame Photometer, Model 148, while those of magnesium, iron, calcium, and manganese were determined by atomic absorption spectrophotometry.

Conductance was measured with a YSI conductivity-temperature meter (Yellow Springs Instrument Co.) YSI Model 33, S-C-I meter; pH with a Radiometer pH meter, and water temperature with a mercury thermometer accurate to within ± 0.5°C.

The epilithic algae were collected quantitatively as described by Hickman et al. (1979). Multiple 4 cm^2 areas of rock were delineated by a template, the area within scraped with a sharp scalpel, and then brushed to remove the algae. These scrapings were placed in 20 mL vials together with 10 mL filtered river water and a few drops of Lugol's iodine solution as preservative. Further subsamples were filtered onto Whatman GF/C glass fibre filters,

Table 1. List of parameters determined at each site.

PHYSICAL	CHEMICAL	ALGAL
depth	conductance	species composition
width	pH	species abundance
colour	total alkalinity	standing crop
temperature	nitrate-nitrogen	(i) chlorophyll *a*
site description	phosphate-phosphorus	(ii) cell numbers
	dissolved silica	
	chloride	
	sulphate	
	magnesium	
	calcium	
	sodium	
	potassium	
	iron	
	manganese	

covered with anhydrous $MgCO_3$, carefully wrapped in aluminium foil, and stored on ice for subsequent chlorophyll *a* determinations. The spectrophotometric method and equations of Moss (1967b, 1967c), which correct for the amounts of pheophytin *a* present, were used to determine the chlorophyll *a* content.

Epipelic algal samples were collected using the area-based techniques described by Eaton and Moss (1966), Moss (1967a and 1969), Hickman (1969, 1971, 1974, 1976, 1978). The samples were prepared and the algae harvested for cell counts and chlorophyll *a* determinations using the tissue trapping technique of Eaton and Moss (1966).

Chlorophyll *a* determinations were also made on the river water itself. Here at least 1 L of water was filtered through Whatman GF/C filters in the field. These were treated as described earlier for the epilithon.

Benthic algal (epilithic and epipelic) species composition and numbers were determined using the inverted microscope (Wild M-40) and the sedimentation technique (Lund et al. 1958; Hickman et al. 1979). A minimum of 200, but frequently more, algae were counted. To enable diatoms to be identified, subsamples were treated with a mixture of concentrated sulphuric acid, potassium dichromate, and hydrogen peroxide to remove all traces of acid before slowly drying the cleared diatom frustules on cover glasses and mounting in Hyrax. Algae were identified according to Bourrelly (1966, 1968, 1970), Prescott (1961), Patrick and Reimer (1966, 1975), Cleve-Euler (1951-1955), Hustedt (1930), and Hindák et al.(1975.).

3. GENERAL DESCRIPTION OF THE RIVERS

The locations of the Alberta Oil Sands Environmental Research Program (AOSERP) study area and those of the five rivers in relation to the Athabasca River are presented in Figure 1.

3.1 MUSKEG RIVER

The Muskeg River is a brown water river originating in the Muskeg Mountains. It drains about 1455 km^2 and first meanders through the Clearwater Lowlands draining clay in the upper reaches, silty till, muskeg and outwash sands as it nears the Athabasca River. The slope varies from 0.003 to 0.004 in the upper and lower reaches, respectively. The river substratum commences as an organic mud but changes to small rocks.

3.2 STEEPBANK RIVER

The Steepbank River is a brown water river draining about 1425 km^2 of surficial deposits of outwash sands and gravels derived from glacial drift, and muskeg. About 15 km from the Athabasca River it flows through exposed bitumen deposits of either McMurray or Athabasca oil sands (Cretaceous sandstones). Below the juncture of the Steepbank and North Steepbank rivers it flows through a deep, steep-sided valley. The terrestrial vegetation ranges from *Picea mariana* and muskeg in the upper reaches to *Picea glauca* and *Populus banksiana* near the Athabasca River.

3.3 HANGINGSTONE RIVER

The Hangingstone River is a brown water river originating in the Stoney Mountains south of Fort McMurray and meanders north across the Algar Plain, Methy Portage Plain, and, finally, the Clearwater Lowland to the Athabasca and Fort McMurray. It drains clay and silty till as well as muskeg, and has a mean slope and drainage area of 0.003 and 914 km^2, respectively. The river bed material begins as organic mud but quickly changes to sands and gravels, and stones and boulders. *Populus banksiana* and *Picea mariana* are common in the upper

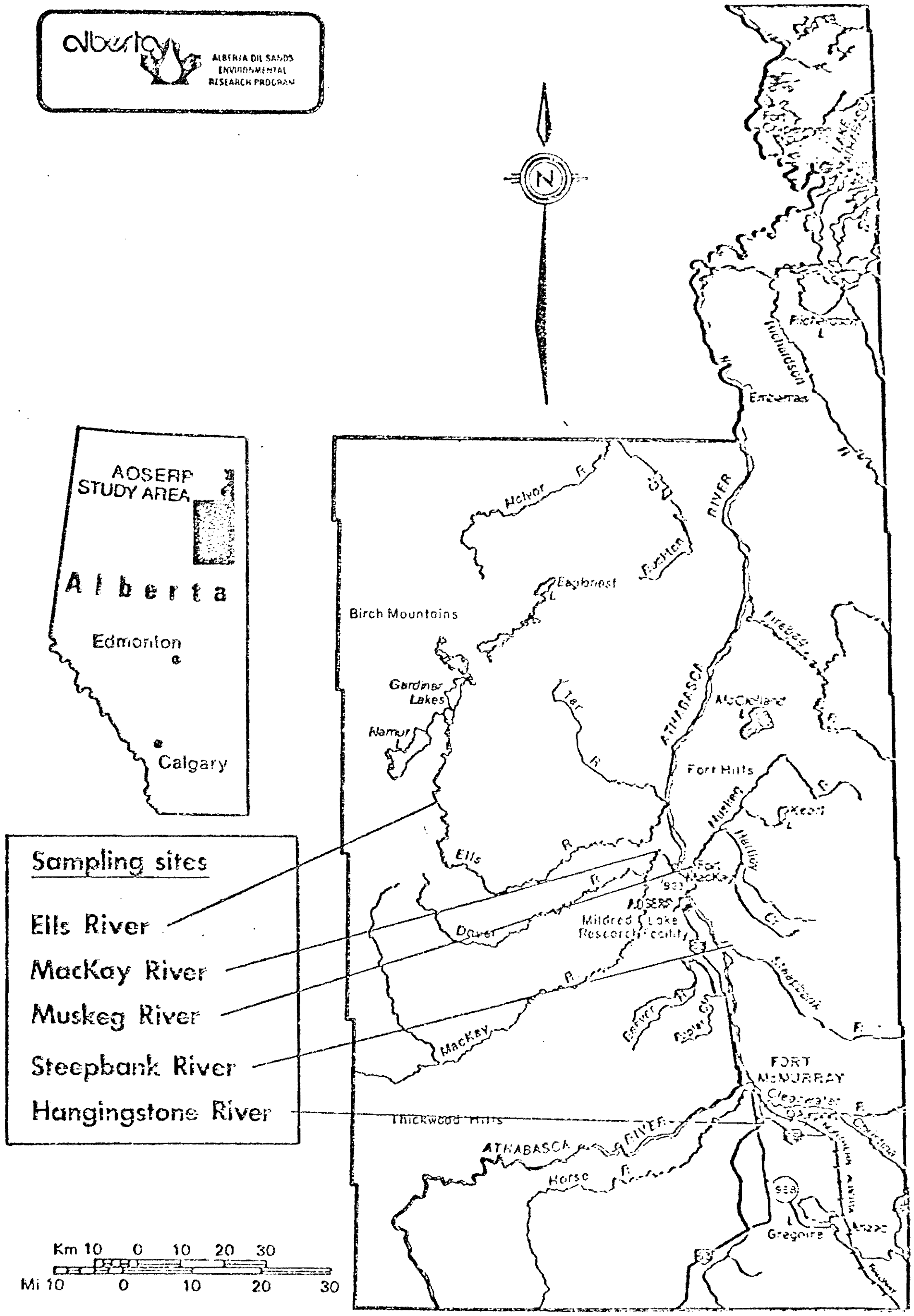

Figure 1. Map of the AOSERP study area.

reaches along with muskeg, and *Picea glauca* and *Picea mariana* are the predominant trees towards its confluence with the Athabasca River.

This river flows through the town of Fort McMurray and intermittently receives storm sewer effluent and raw sewage.

3.4. MACKAY RIVER

The MacKay River is a brown water river and is the longest surveyed draining an area of 5232 km^2 and possesses a mean slope of 0.002. It originates in the Birch Mountains in an area dominated by muskeg and *Picea mariana*. In the lower reaches it drains silty till and lacustrine deposits. The river bed material ranges from organic mud to gravels, oil sands, stones, and boulders. Also, as with the Steepbank River, this river flows through regions of exposed bitumen, particularly along its lower reaches.

3.5 ELLS RIVER

The Ells River is a brown water river flowing south from the Birch Mountains and then east across the Algar Plain and Clearwater Lowland, draining an area of 2700 km^2. It drains hummocky moraine till, sands, gravels, and muskeg, and clay, silty till (alluvial lacustrine materials), and muskeg in the upper and lower reaches, respectively. The mean slope is 0.002. This river originated from a lake and is much larger at its source than the four other rivers.

4. SAMPLING SITE DESCRIPTION

The locations of all sampling sites are shown on maps of the rivers (Figures 2 through 6) and their latitudes and longitudes are presented in Table 2. A brief description of each site is also presented in Table 3.

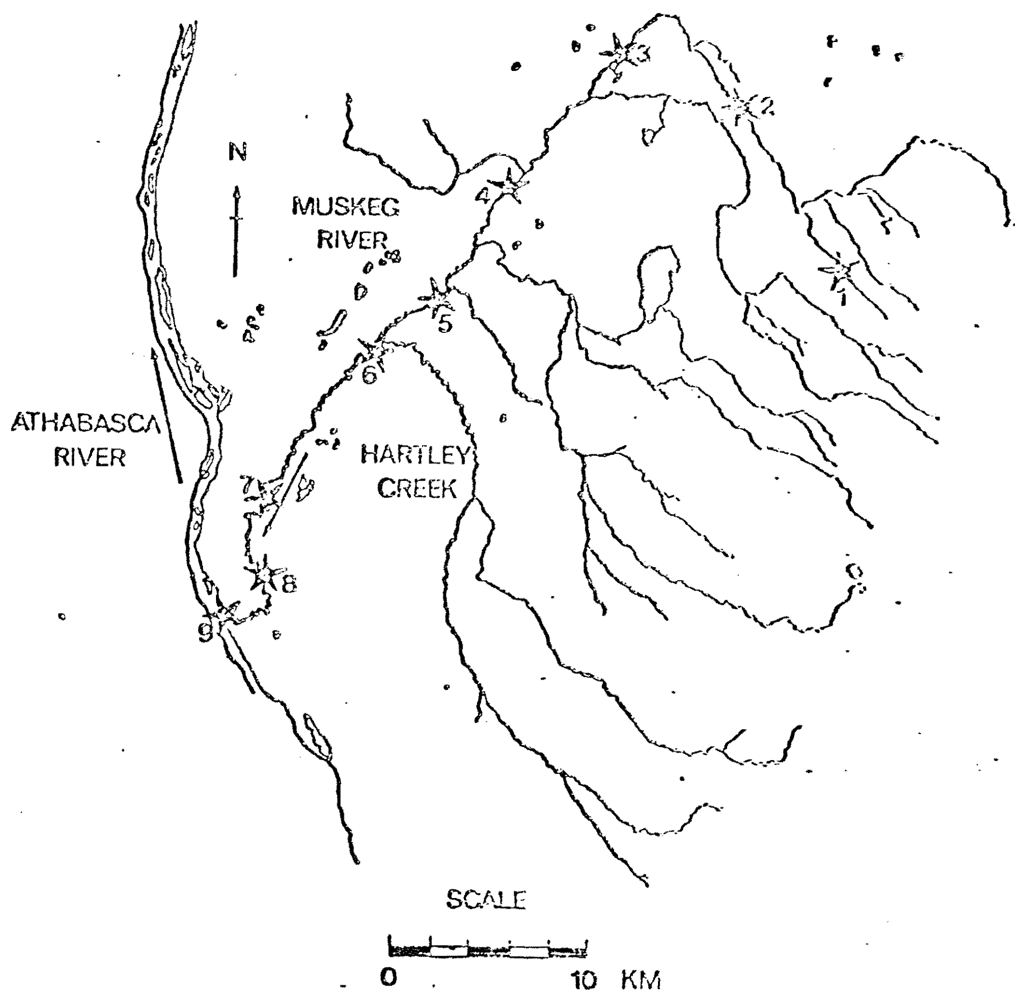

Figure 2. Map of the Muskeg River showing locations of the sampling sites.

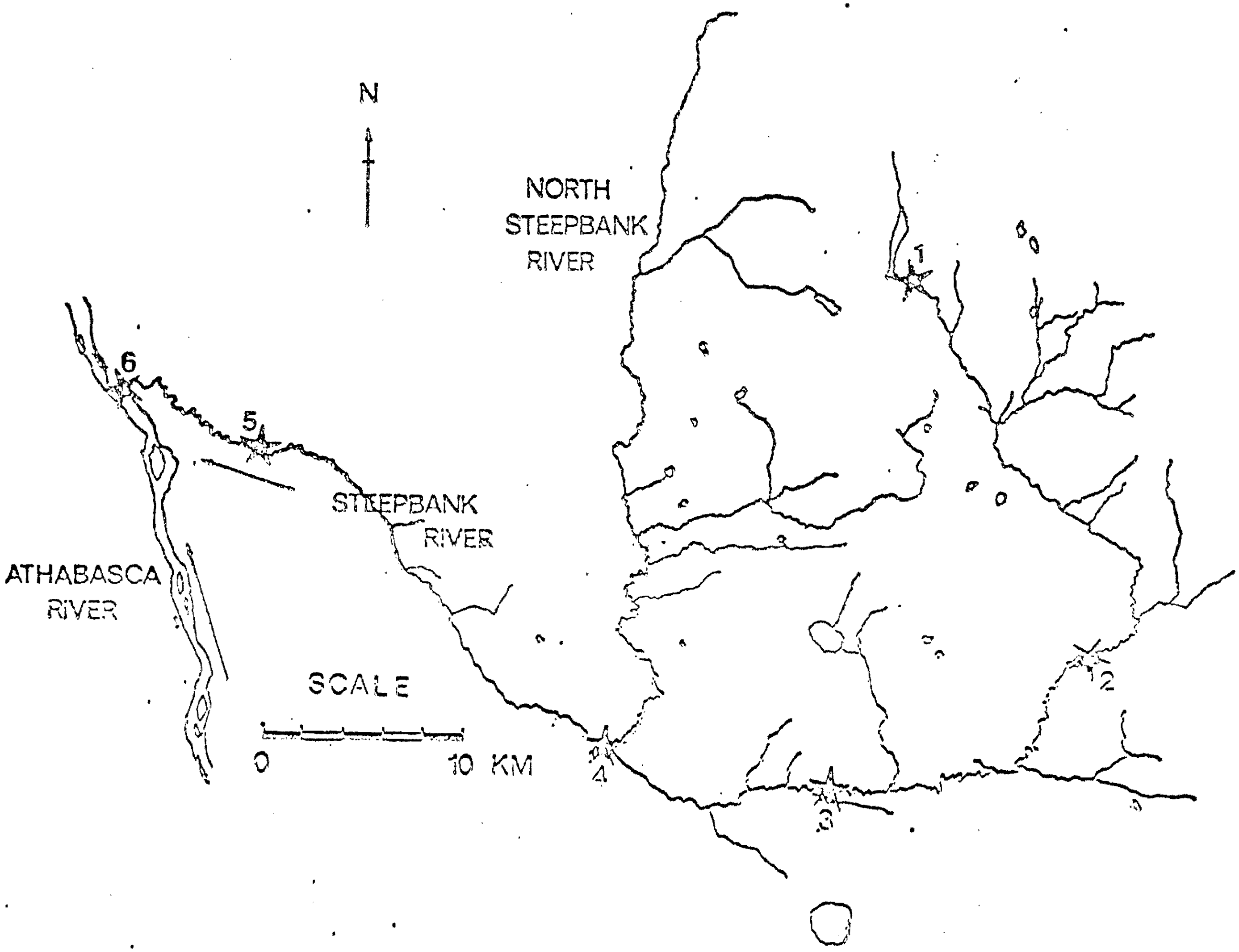

Figure 3. Map of the Steepbank River showing locations of the sampling sites.

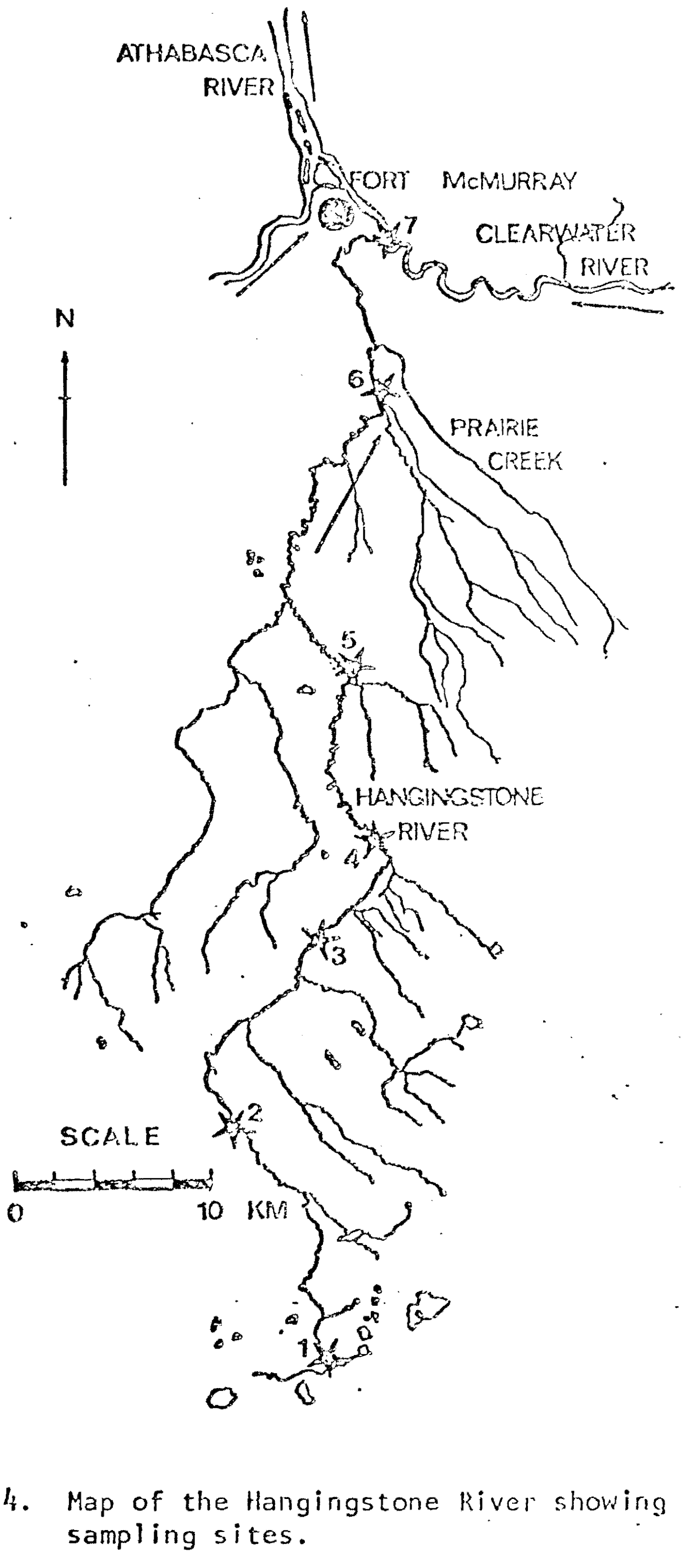

Figure 4. Map of the Hangingstone River showing locations of the sampling sites.

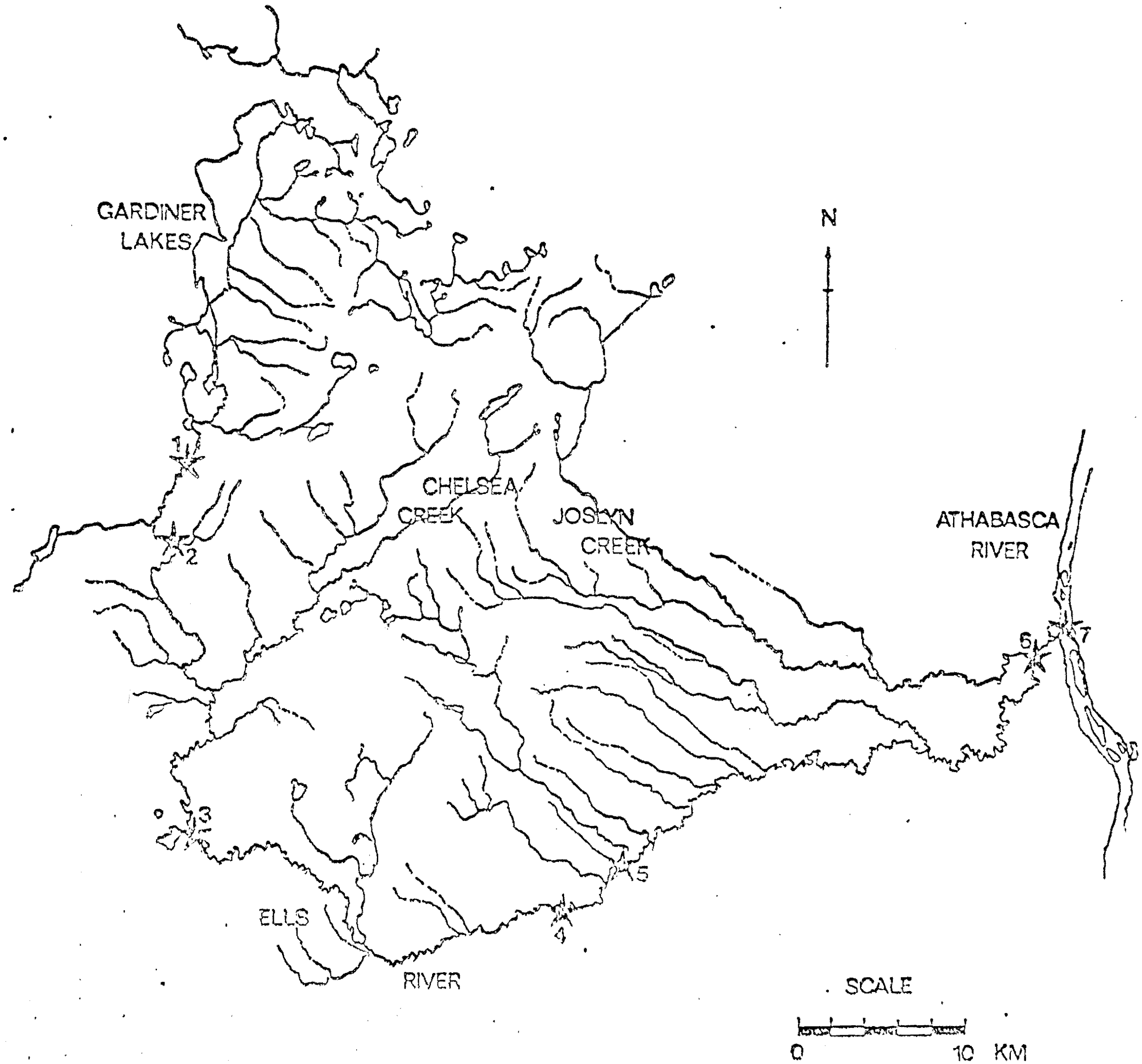

Figure 5. Map of the Ells River showing locations of the sampling sites.

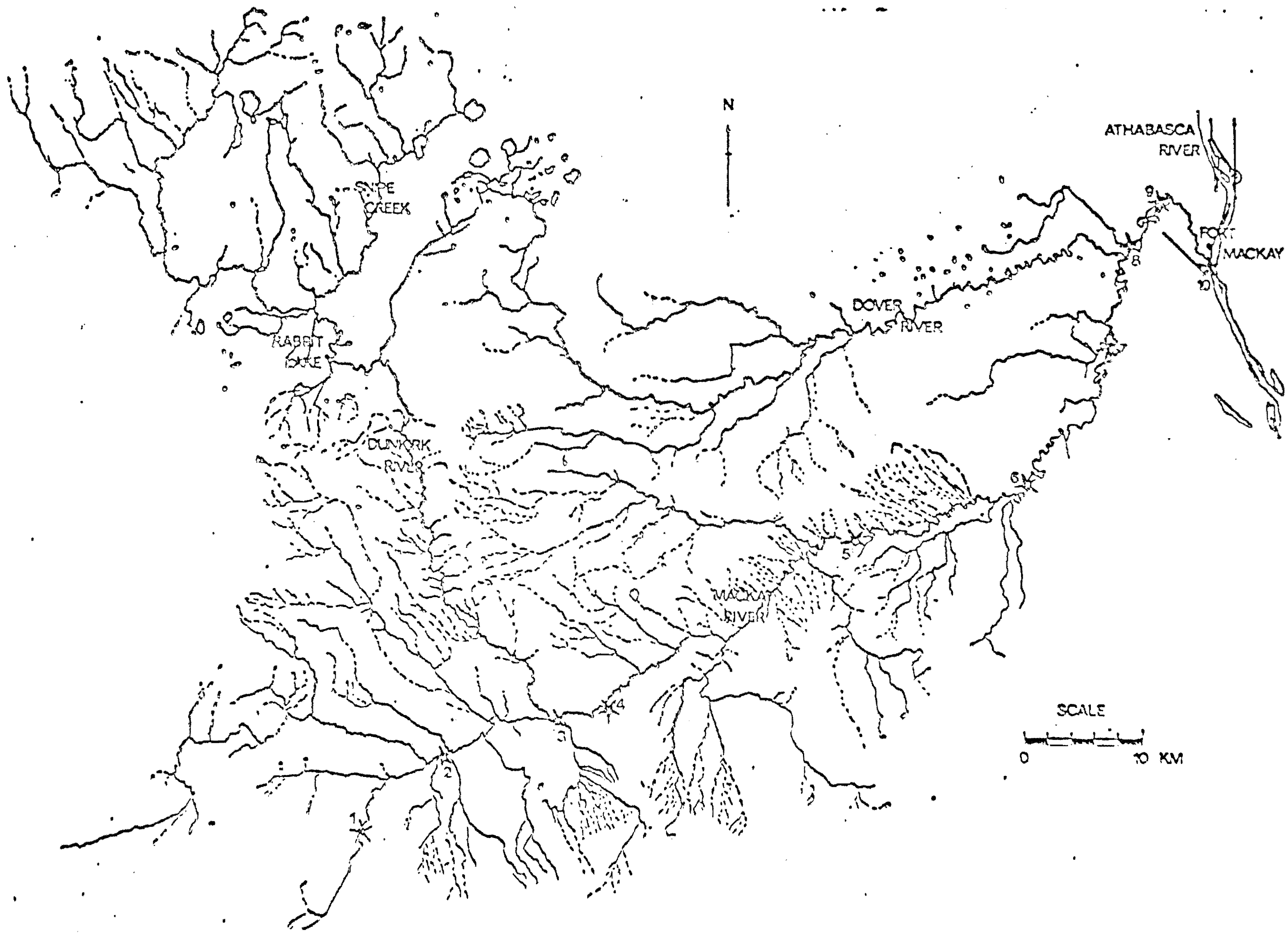

Figure 6. Map of the MacKay River showing locations of the sampling sites.

Table 2. The latitude and longitude of each sampling site.

River	Sampling Site	Latitude	Longitude
MUSKEG RIVER	1	57° 17 ' N	111° 04' W
	2	57° 21 ' N	111° 04' W
	3	57° 22 ' N	111° 14' W
	4	57° 16 ' N	111° 21' W
	5	57° 15 ' N	111° 25' W
	6	57° 09 ' N	111° 30' W
	7	57° 07 ' N	111° 33' W
	8	57° 08 ' N	111° 38' W
	9	57° 07.5' N	111° 36' W
STEEPBANK RIVER	1	57° 03 ' N	110° 50' W
	2	56° 53 ' N	110° 40' W
	3	56° 50 ' N	110° 54' W
	4	56° 51 ' N	111° 06' W
	5	56° 59 ' N	111° 21' W
	6	57° 01 ' N	111° 28' W
HANGINGSTONE RIVER	1	56° 15 ' N	111° 28' W
	2	56° 18 ' N	111° 31' W
	3	56° 23 ' N	111° 26' W
	4	56° 25 ' N	111° 23' W
	5	56° 30 ' N	111° 24' W
	6	56° 37 ' N	111° 22' W
	7	56° 42 ' N	111° 20' W
MACKAY RIVER	1	56° 40 ' N	112° 48' W
	2	56° 44 ' N	112° 41' W
	3	56° 46 ' N	112° 32' W
	4	56° 46 ' N	112° 28' W
	5	56° 56 ' N	112° 04' W
	6	56° 58 ' N	111° 53' W
	7	57° 06 ' N	111° 46' W
	8	57° 10 ' N	111° 46' W
	9	57° 10 ' N	111° 36' W
	10	57° 10 ' N	111° 38' W
ELLS RIVER	1	57° 24 ' N	112° 32' W
	2	57° 21 ' N	112° 33' W
	3	57° 11 ' N	112° 32' W
	4	57° 09 ' N	112° 10' W
	5	57° 11 ' N	112° 06' W
	6	57° 17 ' N	111° 42' W
	7	57° 18 ' N	111° 42' W

Table 3. A brief description of each sampling site.

River	Sampling Site	Brief Description
MUSKEG RIVER	1	Located on one of the numerous headwater streams meandering through muskeg; substratum-organic mud; submerged hydrophytes (*Myriophyllum exalbescens*, *Potamogeton* spp.) present.
	2	River wider (~4 m); substratum-organic mud; extensive mats of *Spirogyra* sp. along with submersed hydrophytes (*Potamogeton* spp. and *Utricularia vulgaris*). Again river flows through muskeg.
	3	Deeper than Sites 1 and 2 (1.5 to 2 m); substratum-organic mud; no substantial submersed hydrophyte populations; and surrounded by muskeg.
	4	Situated immediate upstream of the "Shell Canada Oil Sands pit". Shaded due to overhanging trees and possesses a cobble substratum (10 to 40 cm diameter); no submersed hydrophytes.
	5	Site used by several AOSERP researchers; comprises both pool and riffle areas; substratum ranges from sand to angular limestone stones.
	6	Riffle area; substratum predominately flat, limestone rocks (4 to 10 cm in size). Here the river flows through steep-sided valley.
	7	Similar to Site 6; rapid riffle areas dominated flowing over limestone rocks; shoreline vertical limestone cliffs.
	8	As above.
	9	Situated near the confluence of the Muskeg and Athabasca Rivers. Characterized by overhanging vegetation; substratum-silt; submersed hydrophytes lacking.
STEEPBANK RIVER	1	Situated in a small headwater stream flowing through muskeg, numerous slow flowing pools evident; substratum-organic mud.

continued ...

Table 3. Continued.

River	Sampling Site	Brief Description
	2	Also, situated in a similar situation to Site 1, but the river banks are much steeper being nearly vertical from 0.5 to 2 m high. Substratum varied from organic mud to sand.
	3	Riffle area; swiftly flowing water; substratum-cobble (5 to 80 cm in diameter); shaded by trees. High river banks (2 to 3 m) arising at an angle of 45°.
	4	Situated at confluence of Steepbank and North Steepbank rivers. Substratum-large cobbles and flat limestone rocks (5 to 40 cm); water much faster flowing due to confluence of the two rivers.
	5	Bounded by steep banks rich in oil sand; slow flowing and riffle areas; substratum-cobble, limestone, granite and oil sand. Extensive areas of "Pavement-like" oil sand occur along the shoreline.
	6	Situated at confluence of the Steepbank and Athabasca Rivers. Substratum-silty-mud rich in oil sand; no submersed hydrophytes. Water flowing slowly; deeper than Sites 3, 4, 5.
HANGINSTONE RIVER	1	Situated on a slow flowing, headwater stream meandering through muskeg; various submersed hydrophytes present (*Potomogeton* spp. dominant); substratum-organic mud.
	2	Water swiftly flowing over cobble (6 to 30 cm diameter); shaded by overhanging trees. *Cladophora glomerata* and *Marchantia* spp. were present.
	3	Banks of river nearly vertical approaching 15 m in height; substratum-cobble (6 to 40 cm diameter).
	4	Situated immediately downstream of Highway 63. Water flows swiftly over oil sand and cobble (5 to 35 cm diameter). No submersed hydrophytes.

continued ...

Table 3. Continued.

River	Sampling Site	Brief Description
	5	Swiftly flowing water; substratum-cobble (6 to 40 cm diameter).
	6	Situated immediately upstream of Fort McMurray. Riffle area; water swiftly flowing; substratum-cobbled plus flat sandstone rocks (6 to 50 cm diameter).
	7	Situated at the confluence of the Hangingstone and Clearwater rivers. Site that would be influenced by pollution from Fort McMurray. Substratum ranged from sand to cobble.
MACKAY RIVER	1	Situated in a slow flowing headwater stream meandering through muskeg. Substratum-organic mud. Many beaver dams result in slow flowing water and numerous pools.
	2	Very similar to Site 1 in all features.
	3	Here rock first appears. Riffle area, water swiftly flowing; substratum-cobble (10 to 50 cm diameter). Located immediately below the confluence of the MacKay and Dunkirk rivers. Aquatic mosses and macroalgae were visible.
	4	Comprised both pool and riffle areas; substratum-cobbled (very similar to Site 3).
	5	Nearly vertical banks (1 m high) lines the river; riffle area, substratum-cobble (5 to 30 cm diameter) otherwise similar to Sites 3 and 4.
	6	Banks sloped gently, rich in oil sand; shallow water; riffle area-substratum cobble (5 to 30 cm in diameter).
	7	Similar to Site 6 except vertical banks.
	8	Situated immediately downstream of the Dover River. Water swiftly flowing; riffle region (similar to Site 7).
	9	As above for Sites 7 and 8.

continued ...

Table 3. Concluded.

River	Sampling Site	Brief Description
	10	Situated at the mouth of the MacKay river as it enters the Athabasca River. Substratum variable with cobble dominaing but mud and sand were also present.
ELLS RIVER	1	Situated immediately downstream of the Gardiner Lakes District of the Birch Mountains. Water flow slow; substratum a mixture of sand, mud and cobble (12 cm diameter).
	2	Here the river is narrower than at Site 1. Water flow more rapid; riffle area; substratum-cobble.
	3	Similar to Site 2 except banks nearly vertical and up to 2 m high. Riffle area; water fast flowing; substratum cobble and boulders (14 to 40 cm diameter).
	4	Riffle area; water fast flowing; substratum-cobble (5 to 25 cm diameter) and gravel. River banks again steep rising to a height of 6 m above the stream bed.
	5	Similar to Site 4 with fast flowing water; substratum ranged from cobble, to boulder and flat rocks. Banks rose steeply to an estimated height of 40 m.
	6	As in Site 5.
	7	Situated at the confluence of Ells and Athabasca Rivers. Substratum mixed cobble and muddy sand rich in oil sand.

5. RESULTS

5.1 DEPTH

All rivers, except the Steepbank and MacKay, were shallow in their uppermost reaches (Figures 7 through 9). By Sites 2 and 3, the Muskeg River had deepened to 1.5 and 2.0 m, respectively, whereas afterwards, it became shallower. From Sites 4 to 8 it was about 0.6 m at each site. At Site 9 it was 2.0 m deep (Figure 7). The first two sites on the Steepbank river were about 1.0 m deep; Sites 3 to 5, 0.35 to 0.45 m deep, and Site 6, 1 m deep (Figure 7). Site depth varied little in both the Ells and Hangingstone rivers (Figure 8). In both, the deepest site was at the rivers' confluence with the Athabasca River. Sites, except the latter, varied between 0.4 and 0.6 m, and 0.3 and 0.6 m for the Ells and Hangingstone rivers, respectively. The first two sites in the MacKay River were 1.5 to 2.0 m deep but by Site 3 the water depth had decreased to 0.8 m, and from Site 4 to Site 6 it decreased further from 0.5 to 0.15 m. However, by Sites 7 and 8 it was 0.5 and 1.0 m deep, respectively. It remained about 1.0 m deep at Sites 9 and 10 (Figure 9).

5.2 WIDTH

River width, with some variability, generally increased downstream (Figures 7 through 9). The Ells River provided the most marked exception because it was 60 m wide at Site 1 which, at the time of the survey, represented the first area of the river that could be considered lotic.

5.3 COLOUR

All the rivers are brown water rivers with the Ells River being least coloured (Figure 8). Colour was most consistent in the Muskeg and Steepbank rivers (Figure 7). In contrast, values in the Hangingstone River were first high, then decreased to a minimum at Site 3 before gradually increasing again (Figure 8). Those in the MacKay River were first high (Sites 1 and 2) but afterwards were

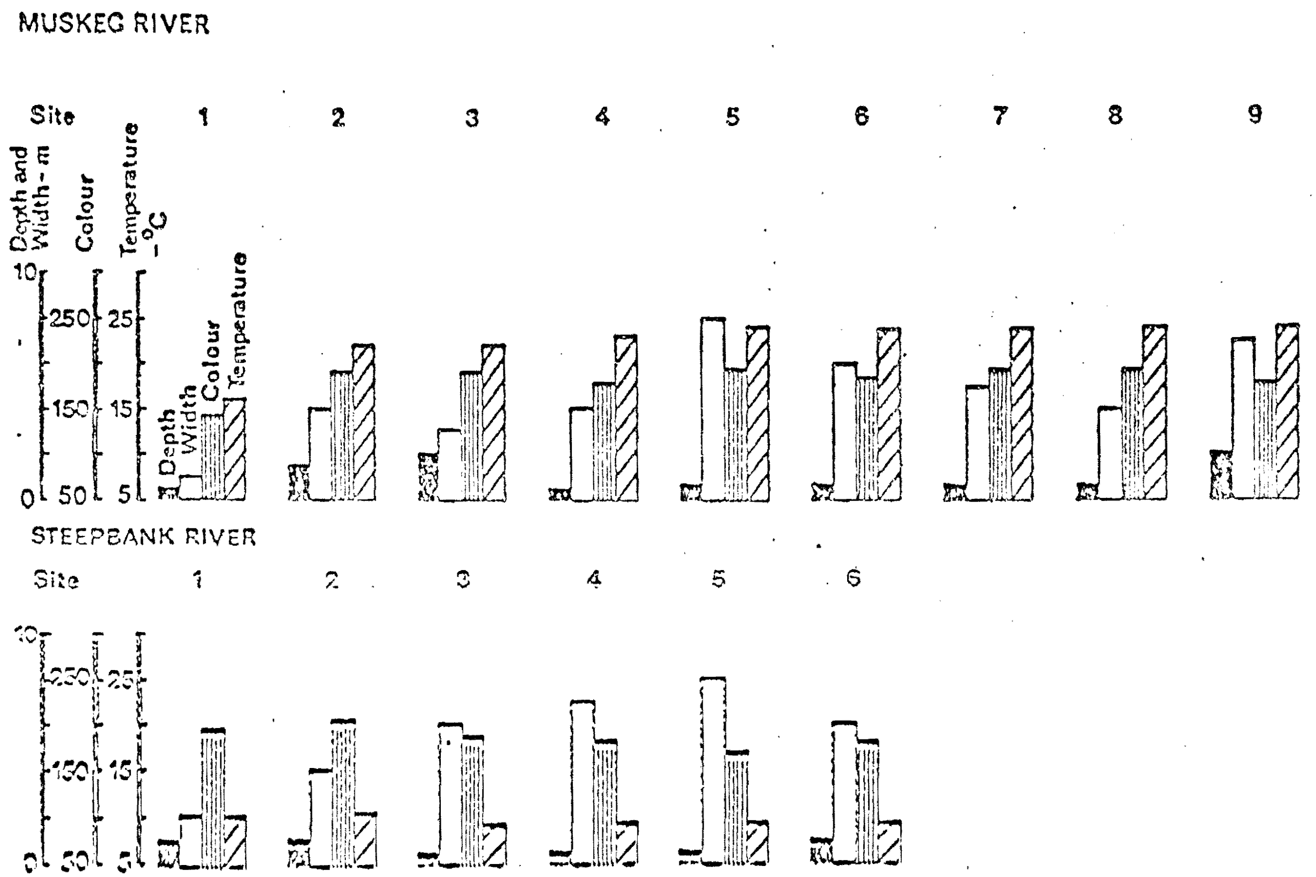

Figure 7. The depth, width, colour, and temperature at each site in the Muskeg and Steepbank rivers.

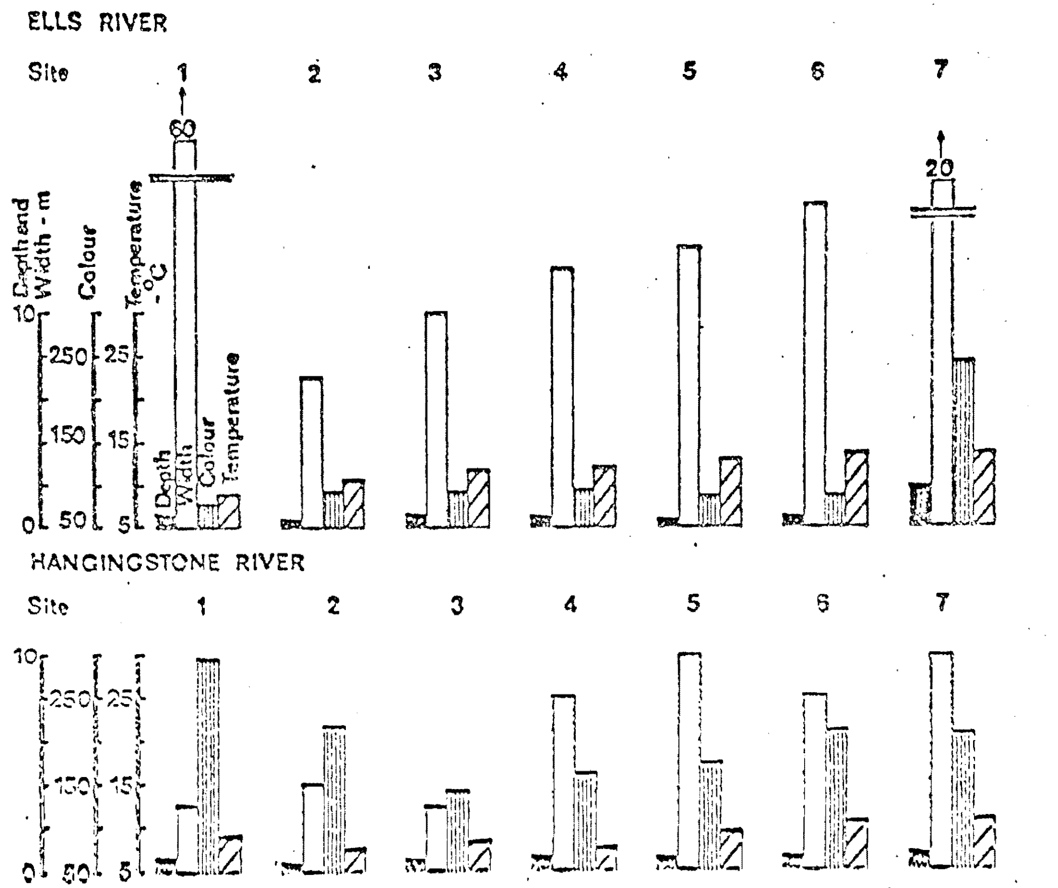

Figure 8. The depth, width, colour, and temperature at each site in the Ells and Hangingstone rivers.

MACKAY RIVER

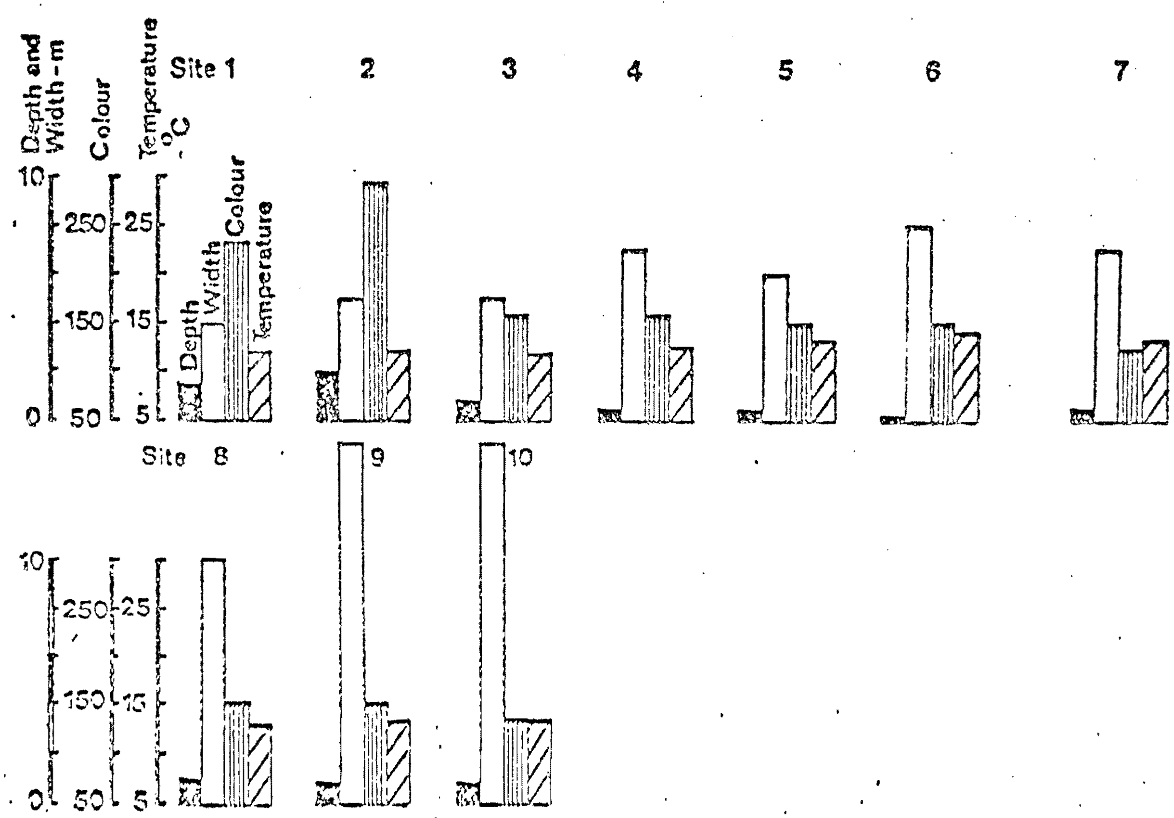

Figure 9. The depth, width, colour and temperature at each site in the MacKay River.

lower and fluctuated little (Figure 9). Consistent values were recorded in the Ells River with one exception, namely Site 7 which was 2.8 times greater on average than the others (Figure 8).

5.4 TEMPERATURE

Temperatures were generally cooler in the headwater regions increased slightly, and then remained fairly constant throughout the remaining sites in all rivers (Figures 7 through 9).

5.5 pH

In the Muskeg River, pH rose from 7.0 at Site 1 and

slightly through Sites 2, 3, and 4, where it was 7.5. Further increases occurred at Sites 5, 6, and 7 (7.8, 7.9, and 8.1, respectively) and at Sites 8 and 9 it stabilized at 8.0 (Figure 10). A slightly different pattern occurred in the Steepbank River (Figure 10). First, the pH range found in the river was small (7.0 to 7.4) and, second, it was 7.3 at Site 1 but had decreased to 7.0 by Site 2. The remaining sites varied between 7.1 and 7.4. A more regular pattern occurred in the Ells and Hangingstone rivers where pH increased from Site 1 downstream (Figure 11). In the former river, pH at Site 1 was 6.6. By Sites 2, 3, and 4, it had risen to 6.8, 7.0, and 7.2, respectively. A further increase had occurred by Site 5 to 7.4 and pH remained at this value at Sites 6 and 7. At Site 1, in the latter river, pH was even lower (6.1) (Figure 11). It had risen to 6.9 by Site 2 and 7.2 by Site 3. At Sites 4, 5, and 6, it remained at 7.4, increasing again at Site 7 to 7.8. pH in the MacKay River followed a pattern similar to that found in the Ells and Hangingstone rivers, commencing at 6.8 at Site 1 and increasing steadily through Sites 2 to 8 (6.9, 7.2, 7.7, 7.9, 8.1, 8.2, 8.4, respectively). At Sites 9 and 10 it was 8.4 and 8.3, respectively (Figure 12).

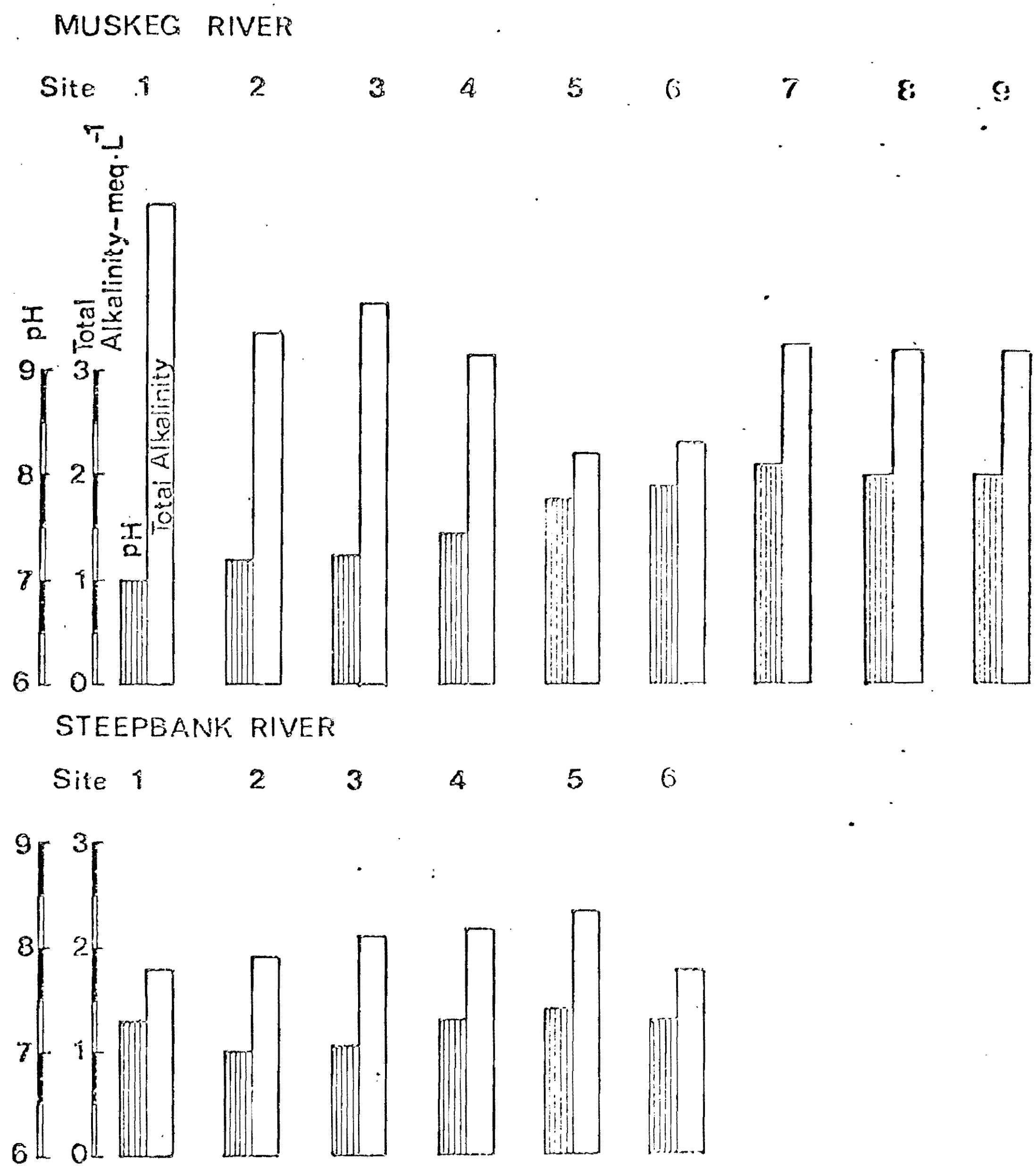

Figure 10. The pH and total alkalinity (meq·L^{-1}) at each site in the Muskeg and Steepbank rivers.

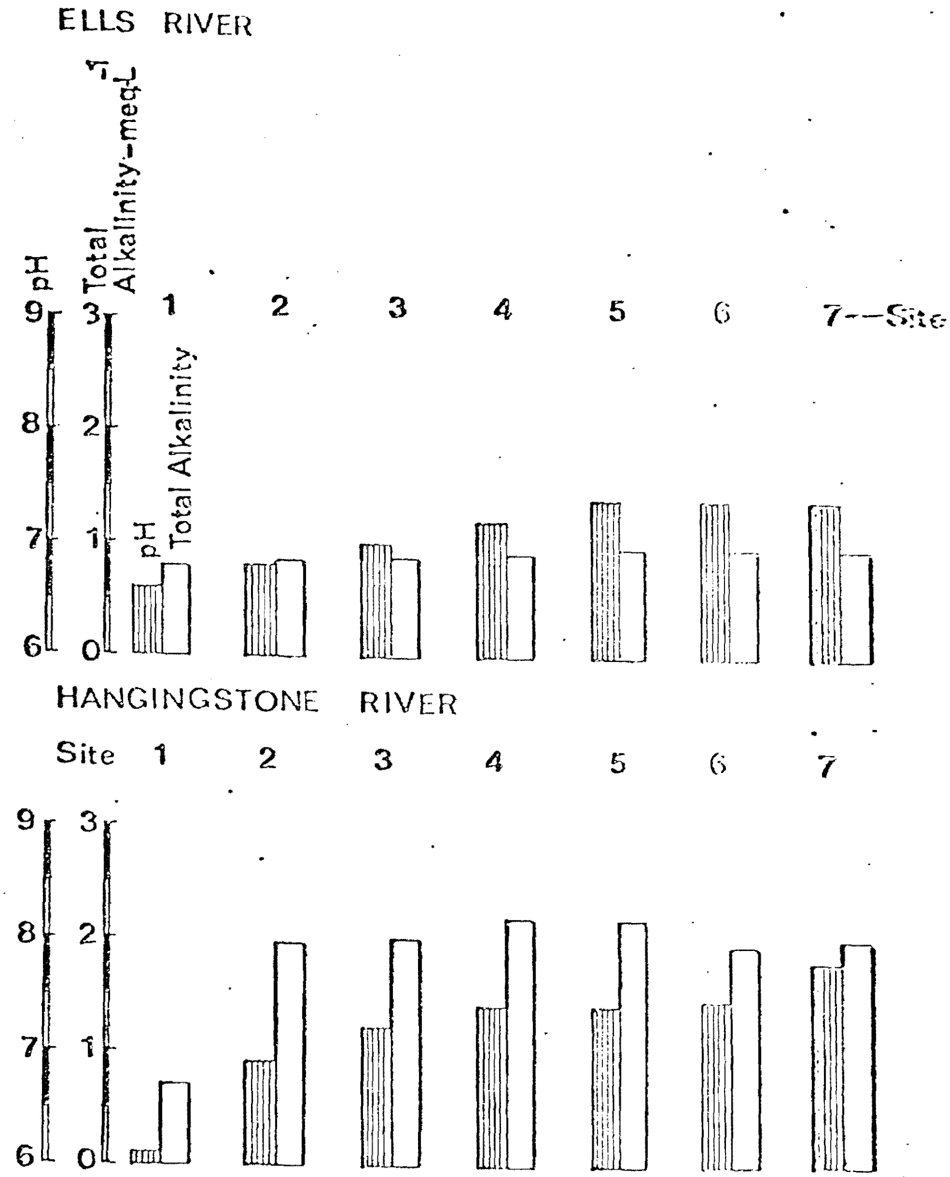

Figure 11. The pH and total alkalinity (meq·L^{-1}) at each site in the Ells and Hangingstone rivers.

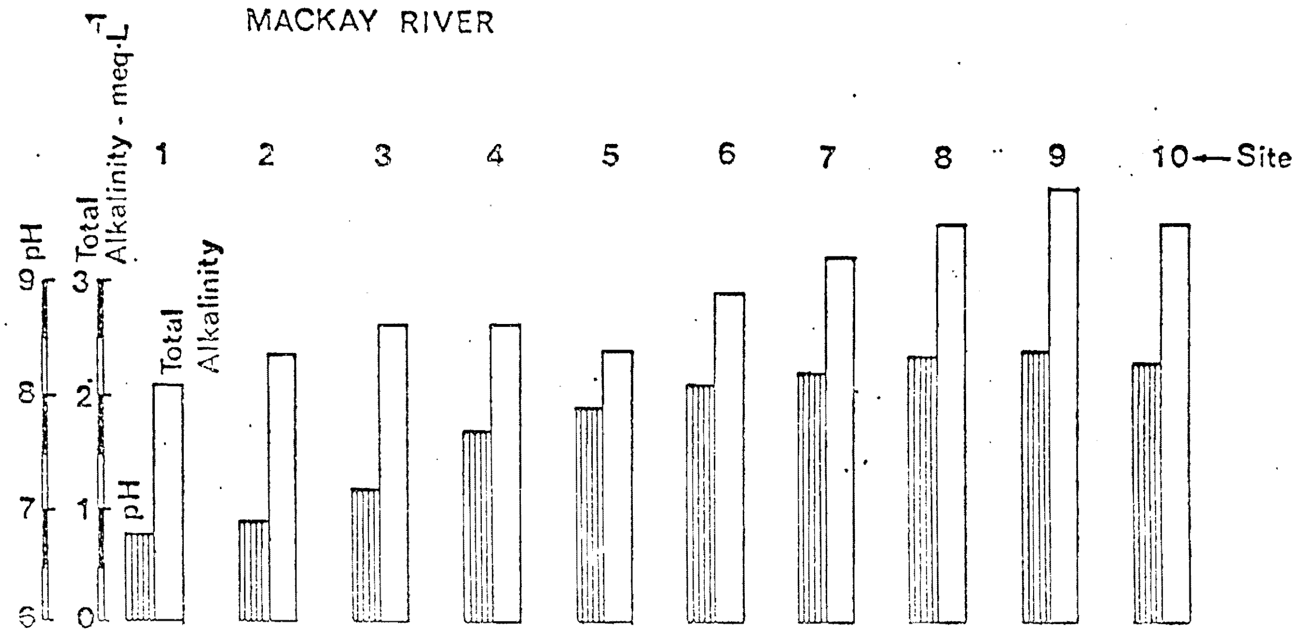

Figure 12. The pH and total alkalinity (meq·L^{-1}) at each site in the MacKay River.

5.6 TOTAL ALKALINITY

In the Muskeg River, total alkalinity was greatest at Site 1 (4.62 $meq \cdot L^{-1}$), dropping quickly to 3.35 $meq \cdot L^{-1}$ by Site 2 (Figure 10). After a rise at Site 3, it decreased, reaching a minimum at Sites 5 and 6 (2.22 and 2.32 $meq \cdot L^{-1}$, respectively). Values at Sites 7, 8, and 9 were comparable to those found at Site 4 (3.2 $meq \cdot L^{-1}$). In the other four rivers, total alkalinity generally increased downstream from Site 1. Least variability was found in the Ells and Steepbank rivers (0.79 to 0.98 and 1.78 to 2.35 $meq \cdot L^{-1}$, respectively). Similarly, except for Site 1, values in the Hangingstone River were fairly constant (Site 1, 0.70 $meq \cdot L^{-1}$; range for Sites 2 to 7, 1.95 to 2.6 $meq \cdot L^{-1}$) (Figure 11). The total alkalinity of the MacKay River displayed a greater variability from source downstream ranging from 2.10 to a maximum of 3.78 $meq \cdot L^{-1}$ at Sites 1 and 9, respectively (Figure 12).

5.7 CONDUCTANCE

Conductance in the Muskeg, Steepbank, Ells, and Hangingstone (except Site 1) river varied little from site to site in each river (Figures 13 and 14). the ranges found were 296 to 380, 140 to 205, 108 to 145, and (except Site 1 which was 50) (165 to 240 $\mu mhos \cdot cm^{-1}$ for each of the above rivers. In the MacKay River, the conductance steadily increased from 220 at Site 1 to a maximum of 435 $\mu mhos \cdot cm^{-1}$ at Sites 8 and 9 (Figure 15). The largest increases occurred between Sites 5 and 6, and 6 and 7.

5.8 MAGNESIUM

Magnesium concentrations were most constant in the Steepbank, Ells and, except for Site 1, the Hangingstone rivers ranging from 2.25 to 4.23, 5.20 to 9.17, and 7.15 to 8.76 $mg \cdot L^{-1}$, respectively (Site 1, Hangingstone River, 1.79 $mg \cdot L^{-1}$) (Figures 13 and 14). In the Muskeg River, concentrations at the first three sites were greater than the others (22.1, 17.0, 18.3 $mg \cdot L^{-1}$ for Sites 1, 2, and 3, respectively). Values at Sites 4 to 9 were quite constant ranging

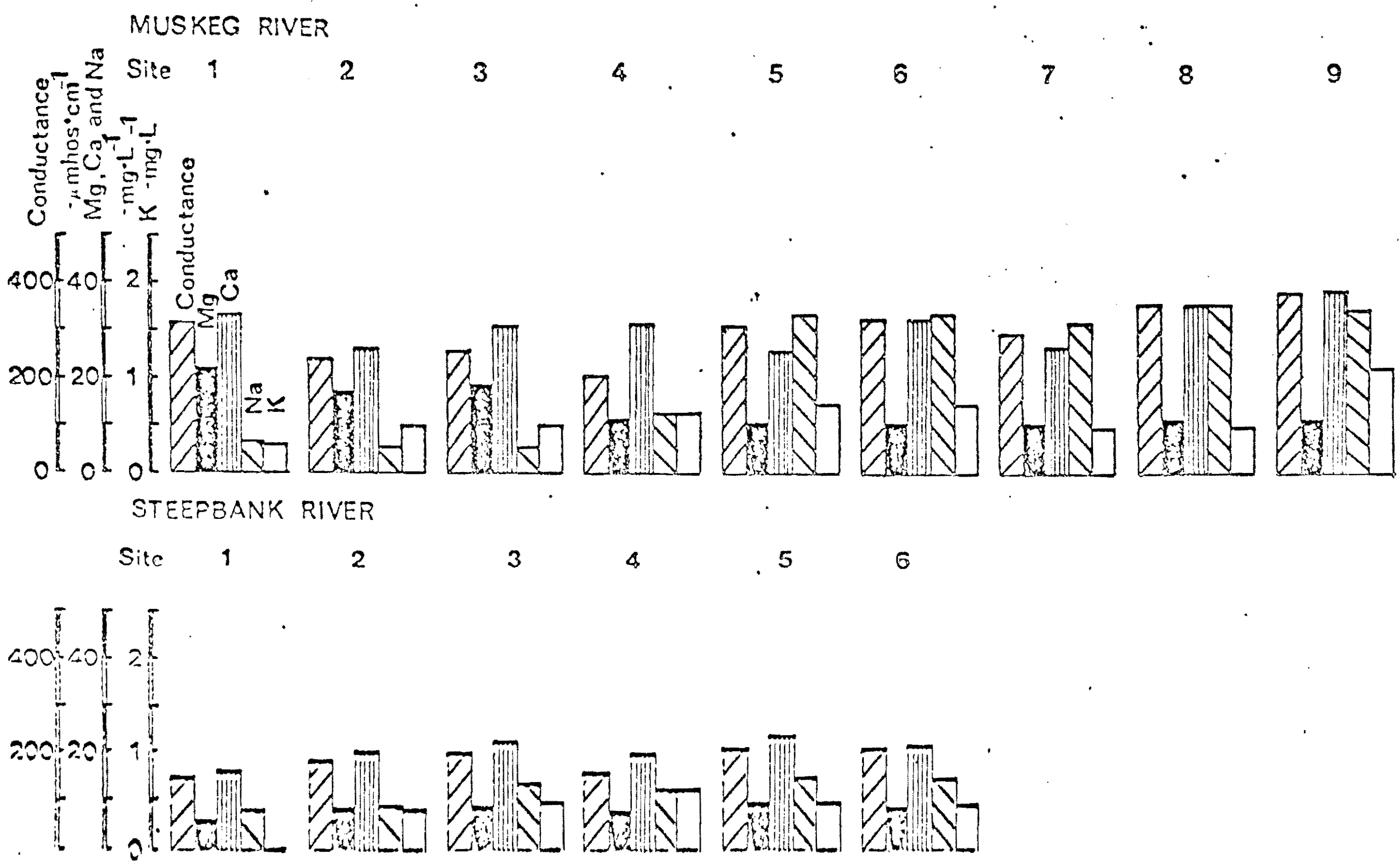

Figure 13. Conductance (μmhos · cm^{-1}), magnesium, calcium, sodium, and potassium (mg · L^{-1}) concentrations at each site in the Muskeg and Steepbank rivers.

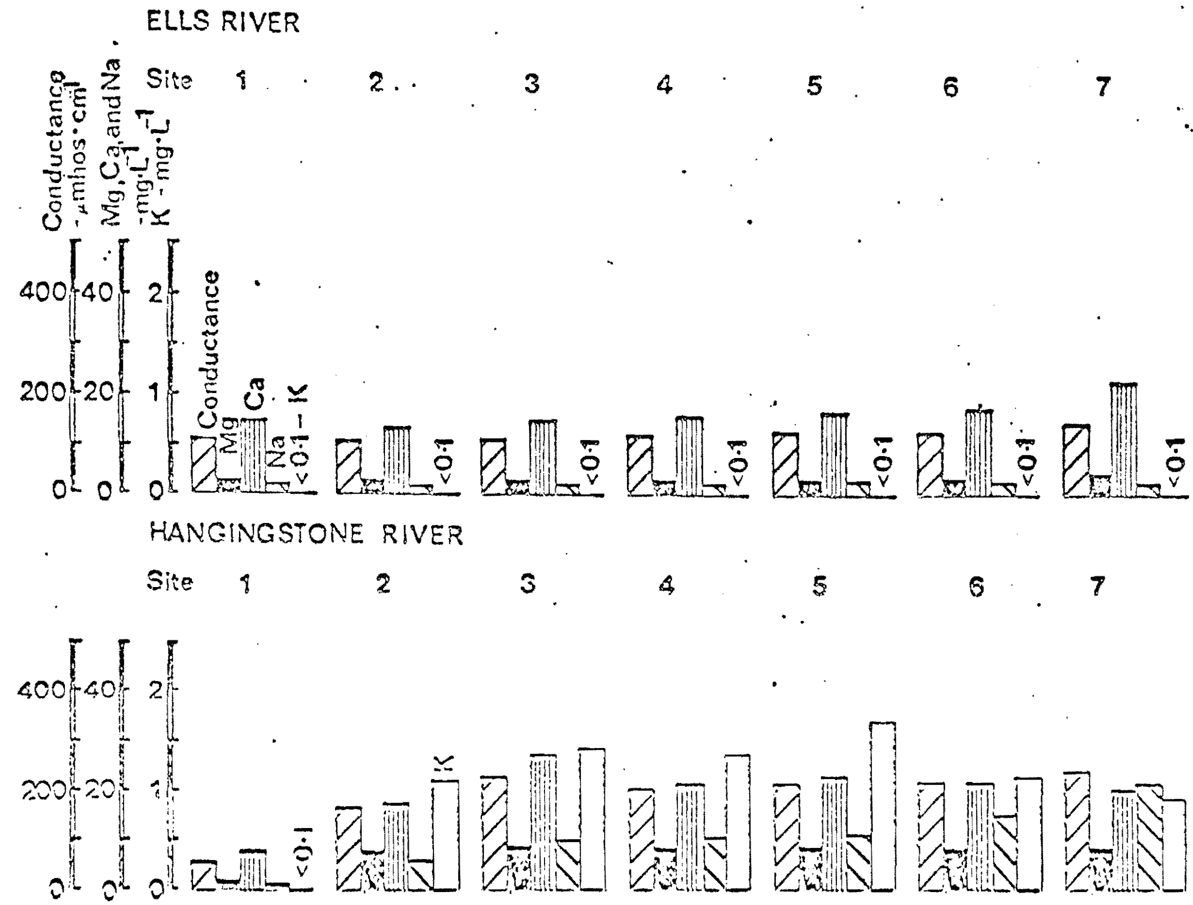

Figure 14. Conductance (µmhos·cm^{-1}), magnesium, calcium, sodium, and potassium (mg·L^{-1}) concentrations at each site in the Ells and Hangingstone rivers.

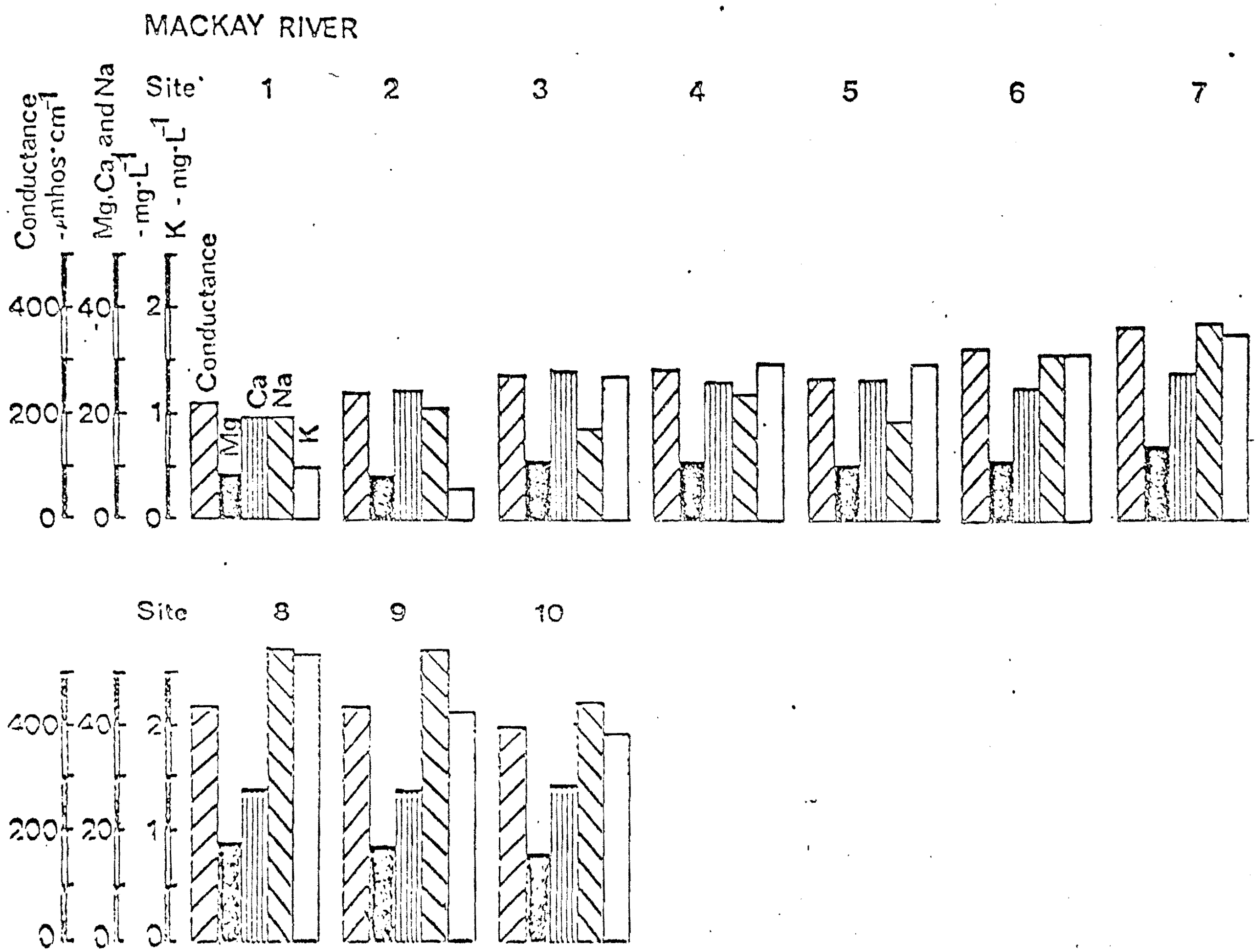

Figure 15. Conductance (μmhos · cm^{-1}), magnesium, calcium, sodium, and potassium (mg · L^{-1}) concentrations at each site in the MacKay River.

between 10.3 and 11.9 mg·L^{-1} (Figure 13). In contrast, magnesium concentrations increased little from Site 1 to 6 in the MacKay river (8.4 to 11.9 mg·L^{-1}) but by Site 7 it had risen to 14.9 mg·L^{-1} and Sites 8 and 9, 17.9 and 17.0 mg·L^{-1}, respectively (Figure 15).

5.9 CALCIUM

In all rivers, calcium concentrations from the headwaters downstream varied little (Figures 13 through 15). An exception was Site 1 in the Hangingstone River where a value of 7.2 mg·L^{-1} was, found while between Sites 2 and 7 values ranged between 18.0 and 23.0 mg·L^{-1}. In the Ells River, a steady but small increase occurred from Site 1 to 7 (14.2 to 22.9 mg·L^{-1}) (Figure 14).

5.10 SODIUM

Initially, sodium concentrations were low in the Muskeg River with values of 6.5, 5.2, and 5.6 mg·L^{-1} being found at Sites 1, 2, and 3, respectively. By Site 4 concentrations had increased to 12.4 mg·L^{-1} and by Sites 5 to 33.5 mg·L^{-1} (Figure 13). They then fluctuated little from Site 6 to 9. Values fluctuated less in the Steepbank River and generally increased downstream from 7.5 mg·L^{-1} at Site 1 to 14.5 mg·L^{-1} at Site 6, with the largest increase 4.4 mg·L^{-1} occurring between Sites 2 and 3 (Figure 13). A similar trend was found in the Ells River, but values were much smaller ranging from 1.54 to 2.73 mg·L^{-1} (Figure 14), and in the Hangingstone and MacKay rivers (Figures 14 and 15). In the former, sodium concentrations were very low at Site 1 (0.6 mg·L^{-1}) but increased to 5.5. and 10.0 mg·L^{-1} at Sites 2 and 3, respectively. A slight increase occurred at Site 5, and a larger one at Sites 6 and 7 where values of 15.2 and 21.3 mg·L^{-1} were found (Figure 14). Greater variability occurred in the latter river (Figure 15). Irregular fluctuations in sodium values occurred among Sites 1 to 5 over a range 19.0 to 24.0 mg·L^{-1}, which were followed by a quick increase from 19.0 mg·L^{-1} at Site 5 to 31.6 mg·L^{-1} at Site 6. A further rapid increase occurred between Sites 6 and 7 (34.4 to 54.4 $mg \cdot L^{-1}$) while after Site 9 values fell from 54.5 to 44.9 $mg \cdot L^{-1}$ at Site 10.

5.11 POTASSIUM

Potassium concentrations generally increased in a downstream direction except in the Ells River where they were always <0.1 $mg \cdot L^{-1}$, and the Steepbank River where, after an increase from 0 to 0.4 $mg \cdot L^{-1}$ between Sites 1 and 2, they remained very constant (Figures 13 through 15). In the Muskeg River, potassium concentrations increased slowly between Sites 1 to 6 (0.3 to 0.74 $mg \cdot L^{-1}$); decreased but peaked again at Site 9 (1.14 $mg \cdot L^{-1}$) (Figure 13). A low value was found at Site 1 in the Hangingstone River (<0.1 $mg \cdot L^{-1}$) but at Site 2 values had risen to 1.10 $mg \cdot L^{-1}$ (Figure 14). They continued to rise to a maximum at Site 5 (1.70 $mg \cdot L^{-1}$) before they fell again. In the MacKay River, values rose from 0.5 $mg \cdot L^{-1}$ at Site 1 to a maximum of 2.10 $mg \cdot L^{-1}$ at Site 8. The largest increase (1.2 $mg \cdot L^{-1}$) occurred between Sites 7 and 8 (Figure 15).

5.12 NITRATE-NITROGEN

Nitrate-nitrogen concentrations were initially low at Site 1 (0.08 $mg \cdot L^{-1}$) in the Muskeg River but increased to 0.14 $mg \cdot L^{-1}$ at Site 2, and then varied irregularly from Sites 3 to 9 over a range of 0.13 to 0.15 $mg \cdot L^{-1}$ (Figure 16). Values were quite consistent in the Steepbank River (0.25 to 0.21 $mg \cdot L^{-1}$) with the peak value occurring at Site 1 (Figure 16). Similarly, values were constant in the Ells River except for Site 7 (Figure 17). From Sites 1 to 6, values ranged from 0.10 to 0.12 $mg \cdot L^{-1}$, and at Site 7 it was 0.27 $mg \cdot L^{-1}$. Nitrate-nitrogen concentrations in the Hangingstone River were not only higher but displayed more of a trend in that, at Site 1, a maximum of 0.35 $mg \cdot L^{-1}$ was found (Figure 17). Afterwards, concentrations decreased until Site 5, where a minimum occurred (0.16 $mg \cdot L^{-1}$), and then increased again (0.22 and 0.26 $mg \cdot L^{-1}$ at Sites 6 and 7, respectively). In the MacKay River, values at Sites 1

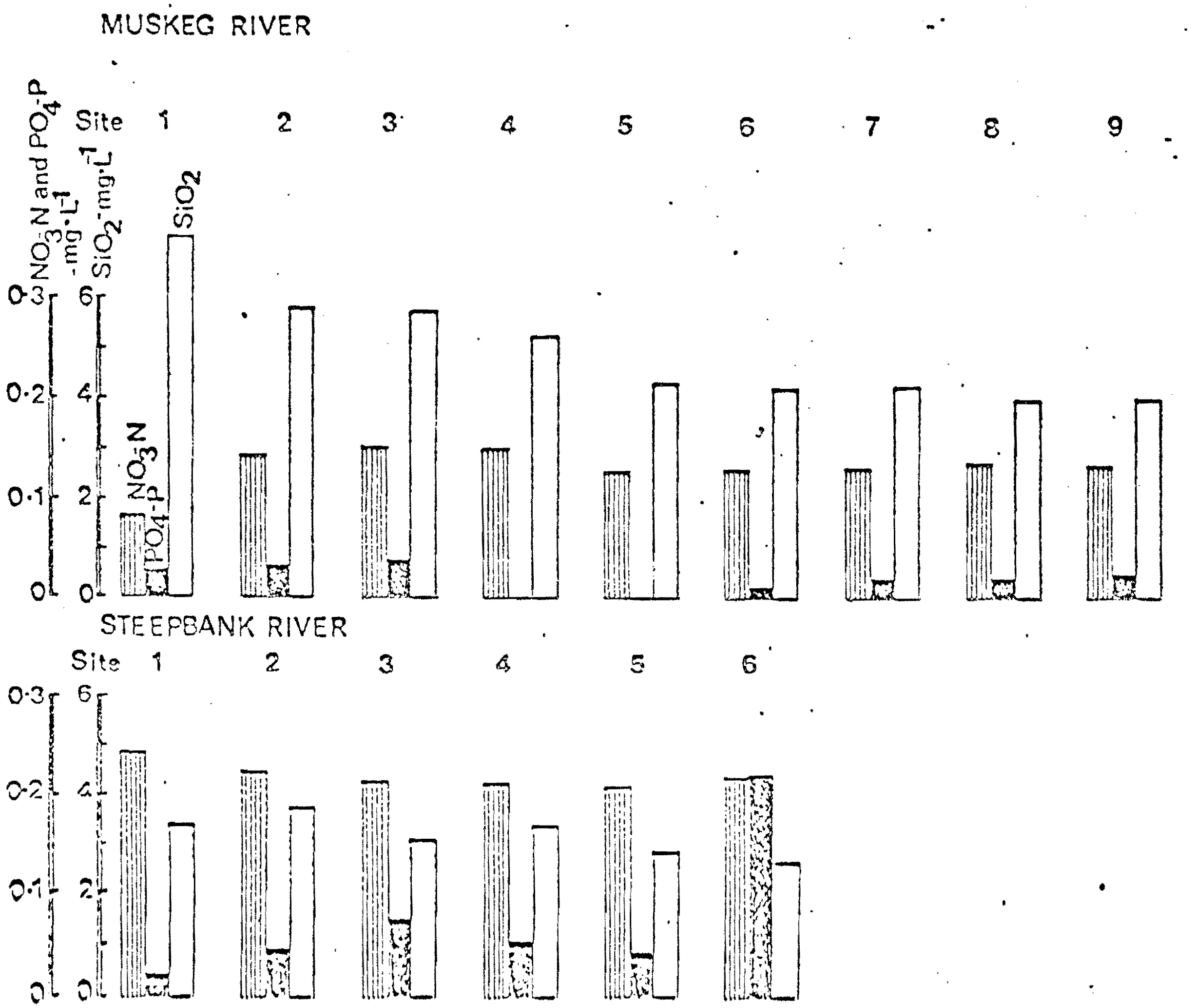

Figure 16: Nitrate-nitrogen, phosphate-phosphorus, and silica (mg · L^{-1}) concentrations at each site in the Muskeg and Steepbank rivers.

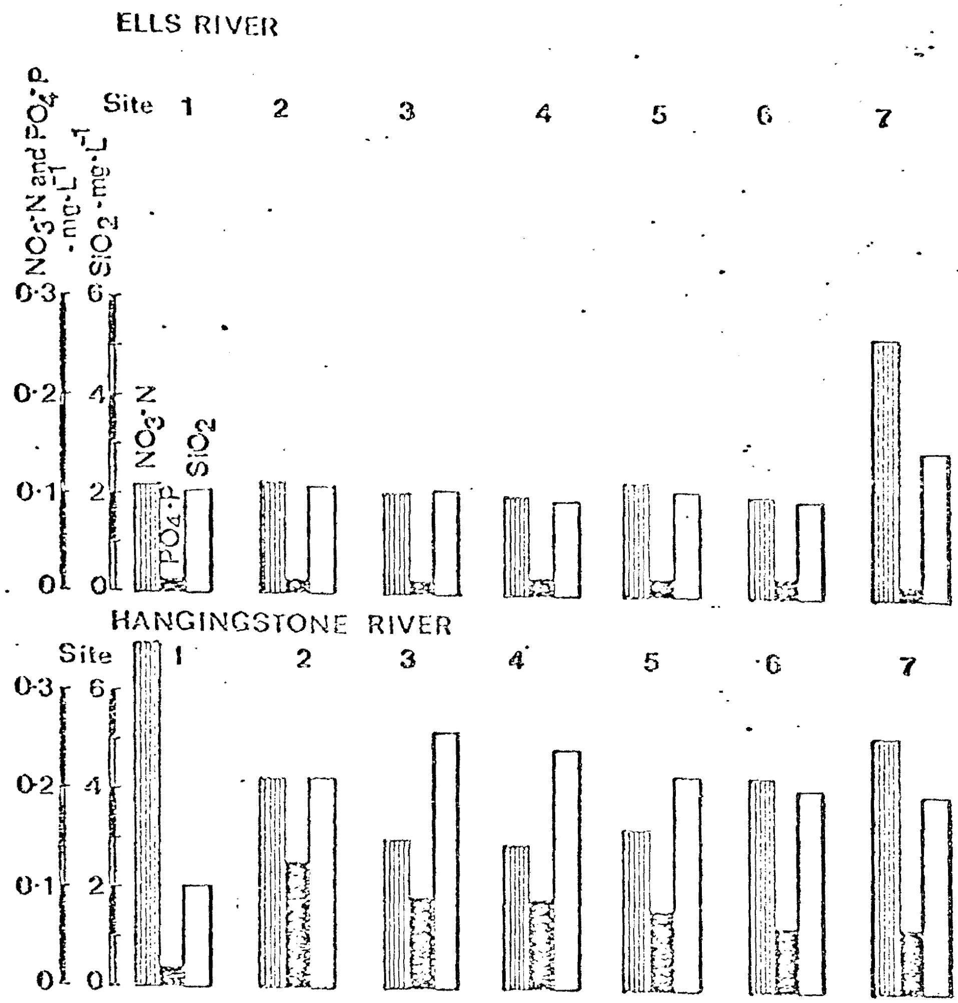

Figure 17. Nitrate-nitrogen, phosphate-phosphorus, and silica ($mg \cdot L^{-1}$) concentrations at each site in the Ells and Hangingstone rivers.

MACKAY RIVER

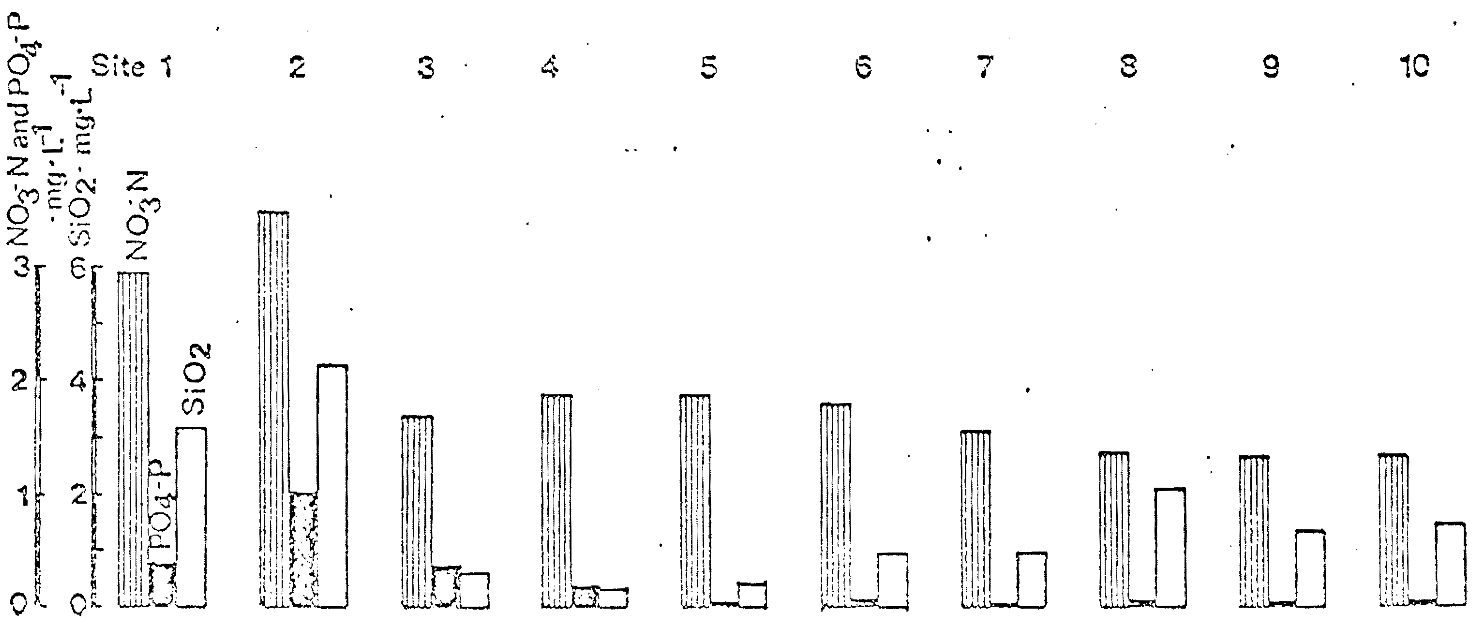

Figure 18. Nitrate-nitrogen, phosphate-phosphorus, and silica (mg·L^{-1}) concentrations at each site in the MacKay River.

and 2 were again high (0.29 and 0.35 mg·L^{-1}, respectively) and quickly decreased to 0.17 mg·L^{-1} by Site 3. A small increase then occurred peaking at Site 5 (0.19 mg·L^{-1}) before a slow decrease occurred throughout the remaining sites (Figure 18).

5.13 PHOSPHATE-PHOSPHORUS

Phosphate-phosphorus concentrations in the Muskeg River began high at Site 1 (0.028 mg·L^{-1}) and had increased to 0.039 mg·L^{-1} by Site 3. In contrast at the next two sites it was undetectable but reappeared at Site 6 (0.011 mg·L^{-1}). From here it gradually increased to a peak at Site 9 (0.024 mg·L^{-1}) (Figure 16). A greater range of values occurred in the Steepbank River (0.021 to 0.220 mg·L^{-1} at Sites 1 and 6, respectively) (Figure 16). From Site 1 to Site 3 values increased (0.071 mg·L^{-1} at Site 3), then fell at both Sites 4 and 5 (0.053 and 0.043 mg·L^{-1}, respectively). The maximum value of 0.220 mg·L^{-1} occurred at Site 6. In contrast, values were more consistent in the Ells River (range 0.011 to 0.020 mg·L^{-1}) (Figure 17), and increased slowly from Site 1 (0.011 mg·L^{-1}) to a peak at Site 6 (0.020 mg·L^{-1}). Phosphate-phosphorus concentrations in the Hangingstone River began low at Site 1 (0.02 mg·L^{-1}) and peaked at Site 2 (0.128 mg·L^{-1}) (Figure 17). Further downstream values fell from Site 3 (0.093 mg·L^{-1}) to 0.065 mg·L^{-1} at Site 6. A different pattern occurred in the MacKay River (Figure 18). Values were greatest at Sites 1 to 4. Initial values were 0.037 mg·L^{-1}, peaking to 0.106 mg·L^{-1} at Site 2. By Site 3 values had fallen to 0.034 mg·L^{-1}, and by Site 4 to 0.019 mg·L^{-1}. From here phosphate-phosphorus concentration remained consistently low.

5.14 SILICA

Silica concentrations were highest at Site 1 (7.20 mg·L^{-1}) in the Muskeg River (Figure 16). They fell to 5.80 mg·L^{-1} at Site 2 and remained around this level at Sites 3 and 4 (5.70 and 5.25 mg·L^{-1}, respectively). From Site 5 values were lower but more stable ranging from 4.30 to 4.0 mg·L^{-1} at Sites 5 and 9, respectively. Less variation from site to site occurred in the Steepbank River (range 3.40 to 2.60 $mg \cdot L^{-1}$ at Sites 1 and 6, respectively) but no definite pattern emerged (Figure 16). Similarly, little variation occurred in the Ells River (range 1.95 to 2.10 $mg \cdot L^{-1}$) except at Site 7 where a value of 3.0 $mg \cdot L^{-1}$ was found (Figure 17). In contrast, values found at sites in the Hangingstone River began low (2.05 $mg \cdot L^{-1}$) at Site 1, then increased quickly to 4.25 $mg \cdot L^{-1}$ at Site 2 (Figure 17). A peak value occurred at Site 3 (5.20 $mg \cdot L^{-1}$) which was followed by a gradual decrease to 4.00 $mg \cdot L^{-1}$ at Site 7. A similar pattern was apparent in the MacKay River (Figure 18). Highest values occurred at Sites 1 and 2 (3.15 and 4.25 $mg \cdot L^{-1}$, respectively). At Sites 3, 4, 5, 6, and 7, values were much lower (0.55, 0.30, 0.40, 0.90, and 0.90 $mg \cdot L^{-1}$, respectively). They increased again at Site 8 (2.10 $mg \cdot L^{-1}$) and were 1.50 and 1.30 $mg \cdot L^{-1}$) at Sites 9 and 10, respectively.

5.15 CHLORIDE

Chloride concentrations were undetectable at some sites in all rivers (Figure 19). After Site 1 in the Muskeg River, where it was found in a concentration of 0.5 $mg \cdot L^{-1}$, it became undetectable at Sites 2 to 4, inclusive. This was followed by a marked increase to 21.5 $mg \cdot L^{-1}$ at Site 5 and remained high at all the succeeding sites. In contrast, in the Steepbank River, chloride was detectable only at Site 6 and then only at a concentration of 0.5 $mg \cdot L^{-1}$ (Figure 19). Similarly, it was detectable only at one site in the Ells River, namely Site 4 (1.0 $mg \cdot L^{-1}$) (Figure 19), while a more variable pattern was found in the Hangingstone River with chloride undetectable at Sites 1, 2, 4, and 5 and values of 3.5, 2.5, and 15.0 $mg \cdot L^{-1}$ at Sites 3, 6, and 7 (Figure 19). Again chloride was undetectable in the MacKay River until Site 5 (0.50 $mg \cdot L^{-1}$) (Figure 19). From here it increased irregularly peaking at Site 9 (19.0 $mg \cdot L^{-1}$).

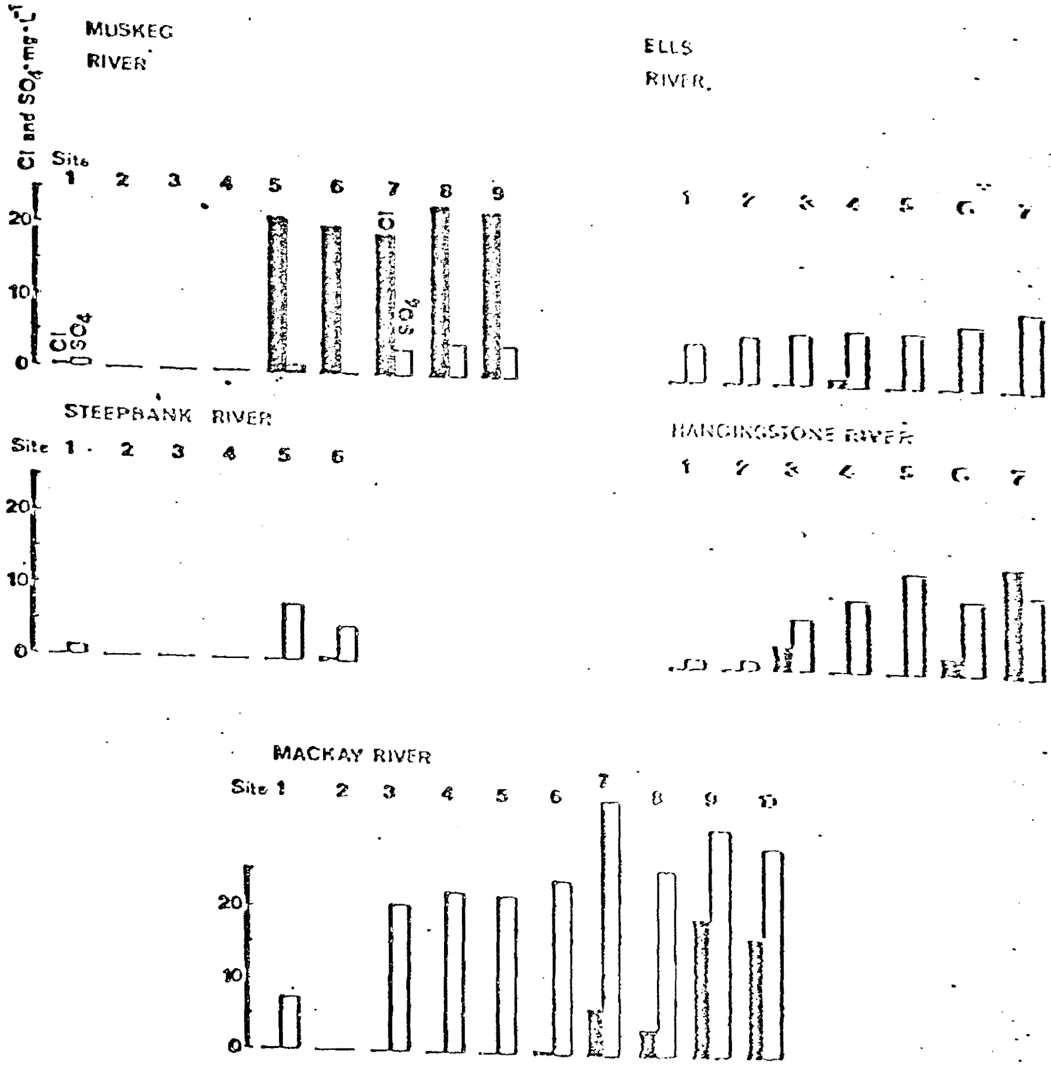

Figure 19. Chloride and sulphate ($mg \cdot L^{-1}$) concentrations at each site in the Muskeg, Steepbank, Ells, Hangingstone, and MacKay rivers.

5.16 SULPHATE

Sulphate also was not found at every site except in the Ells River (Figure 19). Here concentrations steadily rose in a downstream direction from 5.25 $mg \cdot L^{-1}$ at Site 1 to 11.0 $mg \cdot L^{-1}$ at Site 7. They also increased in the Hangingstone River in a similar manner but more rapidly (1.25 $mg \cdot L^{-1}$ at Sites 1 and 2, 7.20 $mg \cdot L^{-1}$ at Site 3) reaching a maximum at Site 5 (14.0 $mg \cdot L^{-1}$) (Figure 19). In contrast, values were much lower in both the Muskeg and Steepbank rivers (Figure 19). In the former it was found at Sites 1 and 5 (1.0 $mg \cdot L^{-1}$) but not 2, 3, 4 and 6. Then at Sites 7, 8, and 9, values of 3.5, 4.5, and 4.4 $mg \cdot L^{-1}$, respectively, were found (Figure 19). Similarly, in the latter river, a concentration of 1.5 $mg \cdot L^{-1}$ occurred at Site 1 but nothing at 2, 3, and 4, whereas a peak of 7.5 $mg \cdot L^{-1}$ occurred at Site 5 and a value of 4.75 $mg \cdot L^{-1}$ at Site 6. Highest sulphate values were found in the MacKay River (Figure 19). Here again in the upper reaches they were low or undetectable (7.2 and 0 $mg \cdot L^{-1}$ at Sites 1 and 2, respectively). Afterwards sulphate levels were much higher ranging between 20.4 and 35.3 $mg \cdot L^{-1}$ at Sites 3 and 7.

5.17 IRON

Iron concentrations in the Muskeg River rose from 0.028 $mg \cdot L^{-1}$ at Site 1 to a peak of 0.179 $mg \cdot L^{-1}$ at Site 4; decreased to (0.119 $mg \cdot L^{-1}$) by Site 7 only to increase again slightly (Figure 20). In the Steepbank River, levels were more uniform (0.141 to 0.123 $mg \cdot L^{-1}$) except for the peak at Site 2 (0.298 $mg \cdot L^{-1}$) (Figure 20). In both the Ells and Hangingstone rivers, iron concentrations were far more variable with large peaks occurring at Sites 1, 5, and 7 (0.698, 0.750, and 16.75 $mg \cdot L^{-1}$, respectively) in the Ells River and at Sites 1 and 6 (0.355 and 0.518 $mg \cdot L^{-1}$, respectively) in the Hangingstone River (Figure 21). In contrast, those in the MacKay River were initially high (0.179, 0.417, 0.191 $mg \cdot L^{-1}$ at

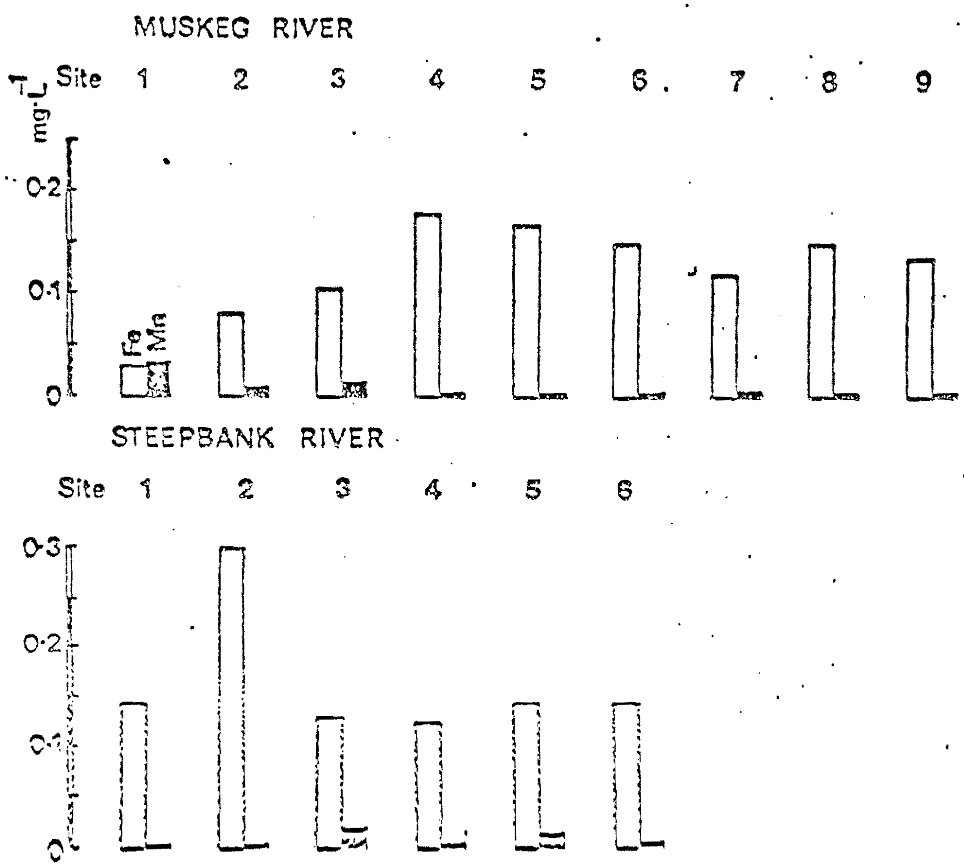

Figure 20. Iron and manganese (mg · L^{-1}) concentrations at each site in the Muskeg and Steepbank rivers.

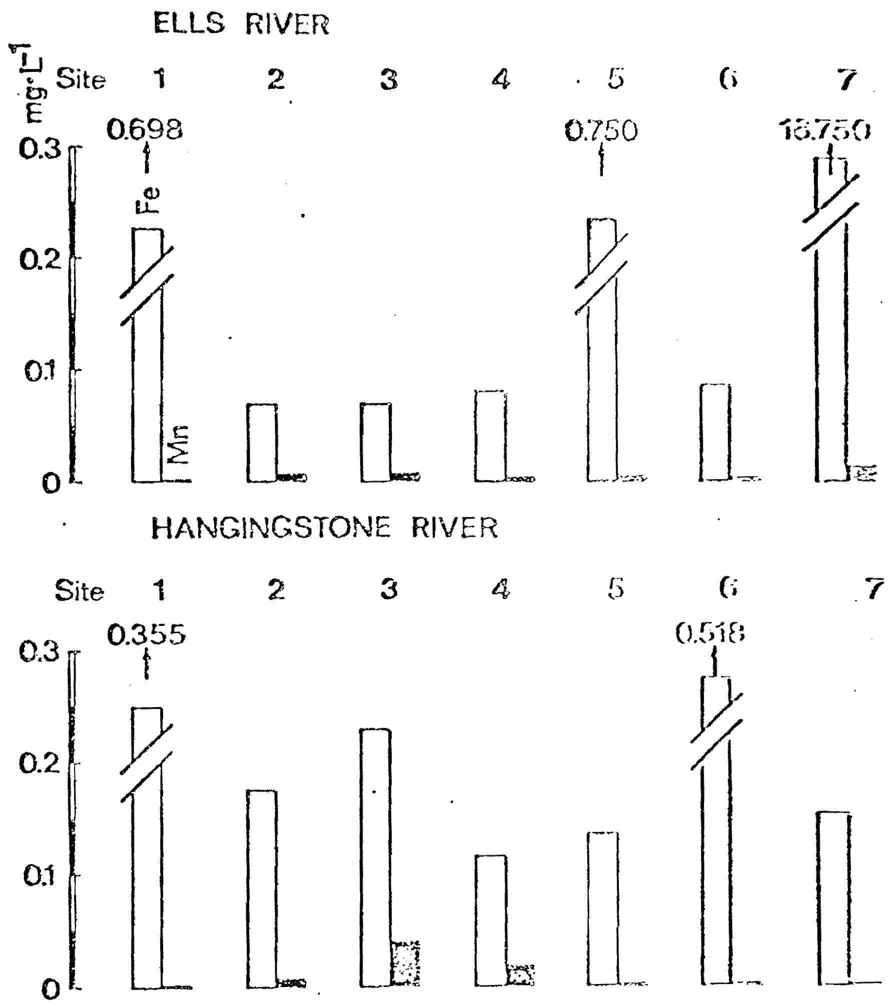

Figure 21. Iron and manganese ($mg \cdot L^{-1}$) concentrations at each site in the Ells and Hangingstone rivers.

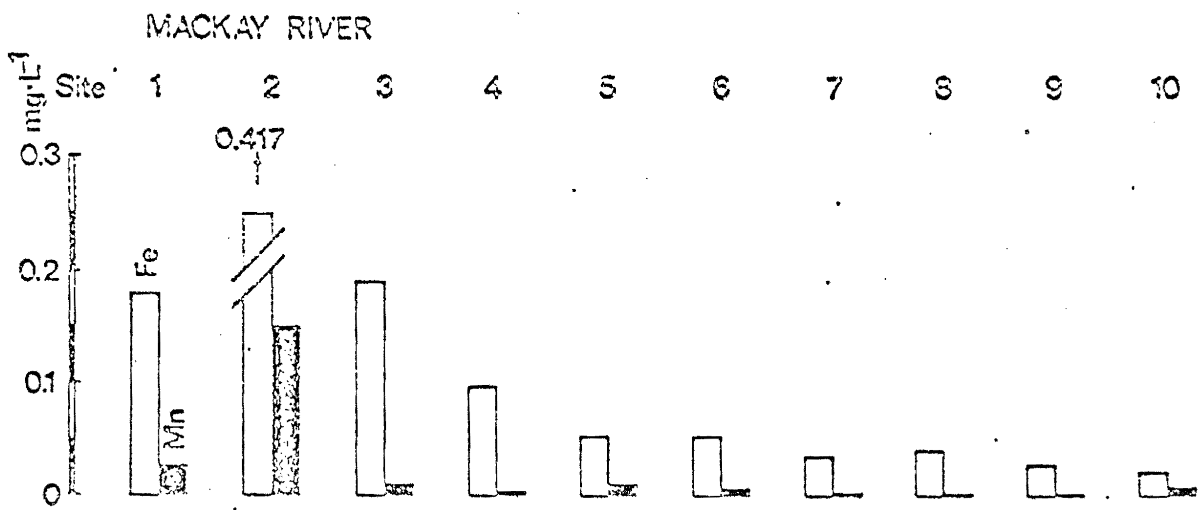

Figure 22. Iron and manganese (mg • L^{-1}) concentrations in the MacKay River.

Sites 1, 2, and 3, respectively), then decreased to 0.097 $mg \cdot L^{-1}$ at Site 4, and further to 0.054 $mg \cdot L^{-1}$ by Site 5 (Figure 22). Afterwards, they irregularly and slowly decreased to a minimum at Site 10 (0.02 $mg \cdot L^{-1}$).

5.18 MANGANESE

Manganese concentrations were low in all rivers and displayed no particular trend (Figures 20 through 22). Only in the MacKay River did values increase markedly particularly at Site 2 (0.149 $mg \cdot L^{-1}$).

5.19 STANDING CROP (AS MEASURED BY CHLOROPHYLL *a* CONTENT)

5.19.1 PHYTOPLANKTON

In the Muskeg River, phytoplankton standing crops (expressed as $mg \cdot m^{-2}$ chlorophyll *a*) increased from Site 1 to a peak at Site 3 (2.5 and 12.5 $mg \cdot m^{-2}$, respectively); then from Sites 4 to 7 values were lower but fairly constant (range 4.0 to 6.0 $mg \cdot m^{-2}$) (Figure 23). In the Steepbank and MacKay rivers, standing crops were initially high (5.5 and 9.5 $mg \cdot m^{-2}$ at Sites 1 in both rivers, respectively) but decreased quickly downstream remaining low at all other sites (Figures 23 and 25). A similar trend occurred in the Ells River (Figure 24). However, here standing crops decreased more slowly downstream. In the Hangingstone River, other than at Sites 1 and 3, phytoplankton standing crops were very tiny (<0.5 $mg \cdot m^{-2}$) (Figure 24) and no downstream pattern was evident.

5.19.2 EPIPELON

The epipelon, alone, constituted the major benthic algal community in the upper reaches of each river where the substratum was mud. In the Muskeg River, this community was important at the first three sites with maximum standing crops being recorded by Site 2 (10.7 $mg \cdot m^{-2}$ chlorophyll *a*), while at Sites 1 and 3, standing crop was 0.64 and 5.86 $mg \cdot m^{-2}$, respectively (Figure 23). In the

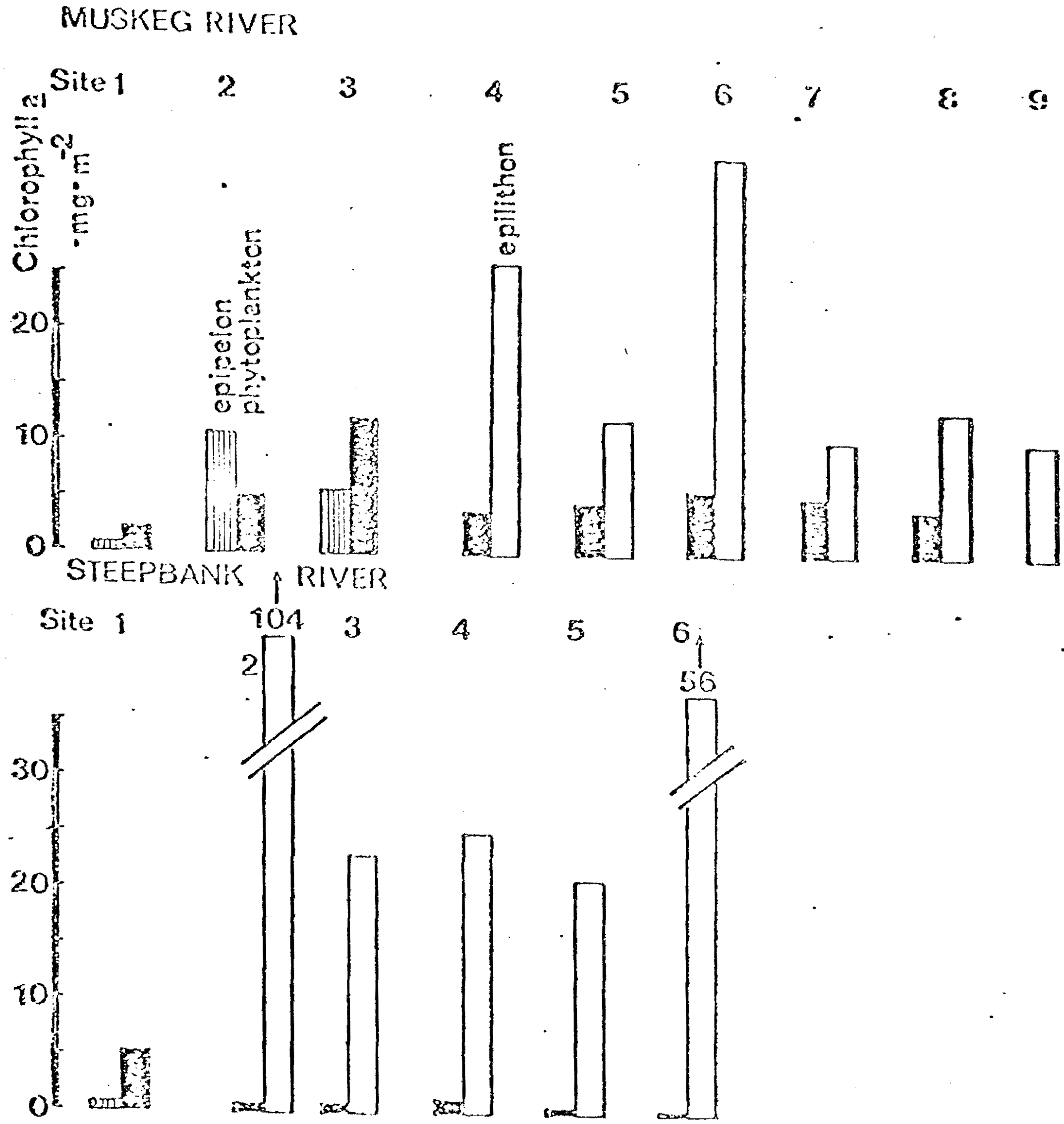

Figure 23. The standing crop (mg · m^{-2} chlorophyll *a*) of the benthic algal communities (epipelon and epilithon) and phytoplankton at each site in the Muskeg and Steepbank rivers.

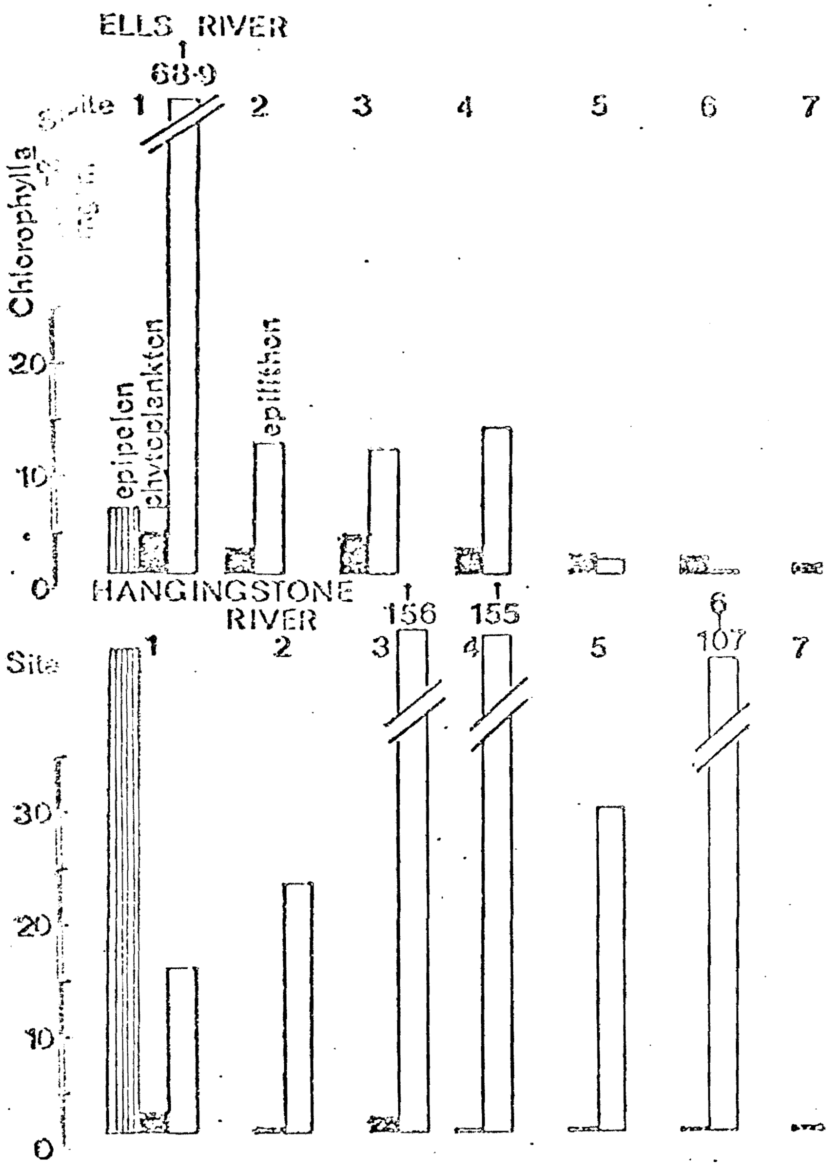

Figure 24. The standing crop ($mg \cdot m^{-2}$ chlorophyll a) of the benthic algal communities (epipelon and epilithon) and phytoplankton at each site in the Ells and Hangingstone rivers.

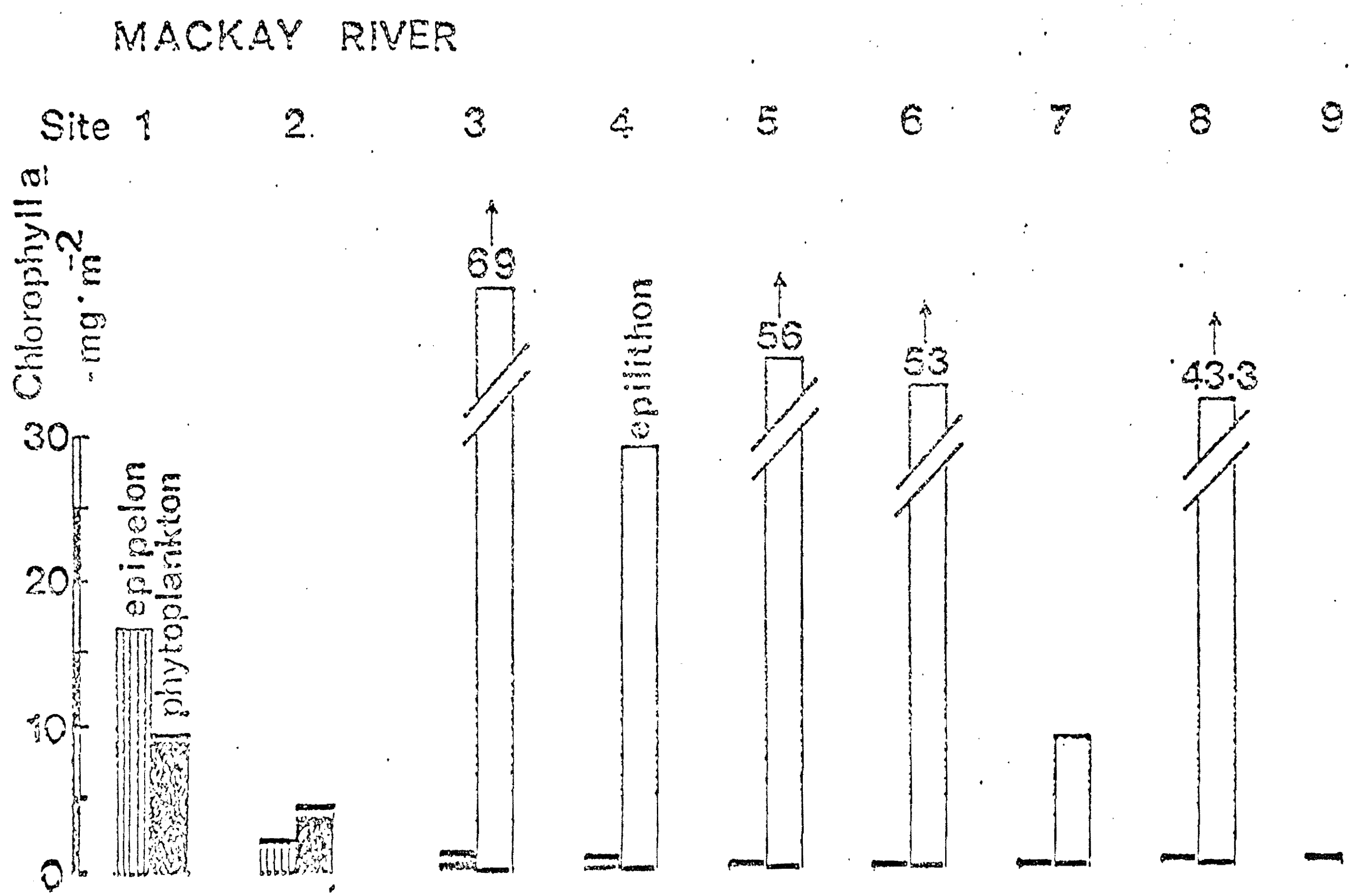

Figure 25. The standing crop (mg • m^{-2} chlorophyll *a*) of the benthic algal communities (epipelon and epilithon) and phytoplankton at each site in the MacKay River.

Steepbank, Ells, and Hangingstone rivers, only at Site 1 in each was the epipelon important (Figures 23 and 24). Standing crops were 0.6, 5.75, and 43.1 mg·m^{-2} chlorophyll *a*, respectively. It was important at the first two sites in the MacKay River (Figure 25) and the standing crops were 16.7 and 2.0 mg·m^{-2} chlorophyll *a* at Sites 1 and 2, respectively.

5.19.3 EPILITHON

The epilithic algal community was the major algal community of all rivers. Site 4 was the first to possess a major epilithic algal community in the Muskeg River (Figure 23). Here the standing crop was 26.2 mg·m^{-2} chlorophyll *a*. It was smaller at Site 5 (12.0 mg·m^{-2}) whereas the largest occurred at Site 6 (36.0 mg·m^{-2}). Standing crops at Sites 7, 8, and 9 were similar and of the same magnitude as Site 5. It was at Site 2 in the Steepbank River that the epilithon became dominant. The standing crop was 104 mg·m^{-2} (Figure 23). It was lower at Sites 3, 4, and 5 but peaked again at Site 6 (56.9 mg·m^{-2}). A similar pattern occurred in the Ells River but here the largest epilithic/algal standing crop was at Site 1 (68.9 mg·m^{-2}) (Figure 24). At Site 2 it had decreased to 11.7 mg·m^{-2} and was similar at the next two sites (10.5 and 12.6 mg·m^{-2}, respectively). Afterwards, standing crops were extremely tiny. Great variability among sites was evident in the Hangingstone River but standing crops were much larger than in any of the other rivers (Figure 24). Peaks of 156, 155, and 107 mg·m^{-2} chlorophyll *a* occurred at Sites 3, 4, and 6, respectively. Standing crops in the MacKay River were again high (69.0, 56.0, 53.0, and 43.3 mg·m^{-2} at Sites 3, 5, 6, and 8, respectively; Figure 25).

5.20 BENTHIC ALGAL NUMBERS

Data are presented as $\log_{10}$ cell number (Figures 26, 28, and 30) and, also, as a percentage (both on an algal division basis) (Figures 27, 29, and 31). Total cells·m^{-2} for each site are presented in Table 4.

The epipelic algal community in the Muskeg River peaked at Site 2 (94.5 X 10^7 cells·m^{-2}). Here cyanophycean algae dominated followed by diatoms (46.4 and 39.6 X 10^7 cells·m^{-2}) (Figures 26 and 27). Also, at this and Site 3, euglenophycean species were present along with chrysophycean and cryptophycean algae at Site 3.

The epilithic algal community of the Muskeg River was dominated by cyanophycean algae at each site (maximum populations at Site 5, 825.64$10^7$ cells·m^{-2}). From Site 5 cyanophycean numbers gradually decreased. Chlorophycean algae and diatoms were the other two algal groups encountered (Figures 26 and 27) but constituted a minor percentage of the community, except at Site 4 when chlorophycean algae comprised 41.1% of the community. Total cell numbers ranged from 38.4 to 834.7 X 10^7 cells·m^{-2} (Table 4).

The epipelon at Site 1 in the Steepbank River was almost solely cyanophycean algae (343.8 X 10^9 cells·m^{-2} constituting 99.0%; Figures 26 and 27) along with a small number of chlorophycean algae (36.24 10^8 cells·m^{-2}). In this river, the epilithic algal community was again dominated by cyanophycean algae except at Site 5, where diatoms were most numerous (62.2 X 10^7 cells·m^{-2} and 84.6% of the total population). Rhodophycean algae were found only at Site 2 (197.9 X 10^7 cells·m^{-2} and 38.8% of the total population; Figures 26 and 27). Chlorophycean algae, consistently present at each site, developed best at Site 3 (193.3 X 10^7 cells·m^{-2} and 28.5% of the total population). The largest epilithic cyanophycean population was found at Site 4 (925.2 X 10^7 cells·m^{-2}) and the smallest at Site 5 (5.7 X 10^7 cells·m^{-2}). Total cell numbers ranged from 73.5 to 972.6 X 10^7 cells·m^{-2} (Table 4) and, as in the Muskeg River, numbers were quite variable from site to site.

The epipelon at Site 1 in the Ells River was dominated by diatoms followed by chlorophycean algae (23.8 and 14.1 X 10^7 cells·m^{-2}) (Figures 28 and 29). In contrast, and like the epilithic algal community in the other rivers, cyanophycean algae dominated but only at Sites 1, 2, and 4 (169.7, 1662.6, and 1187.6 X 10^7 cells·m^{-2}, respectively). None were found at the other three sites (Figures 28

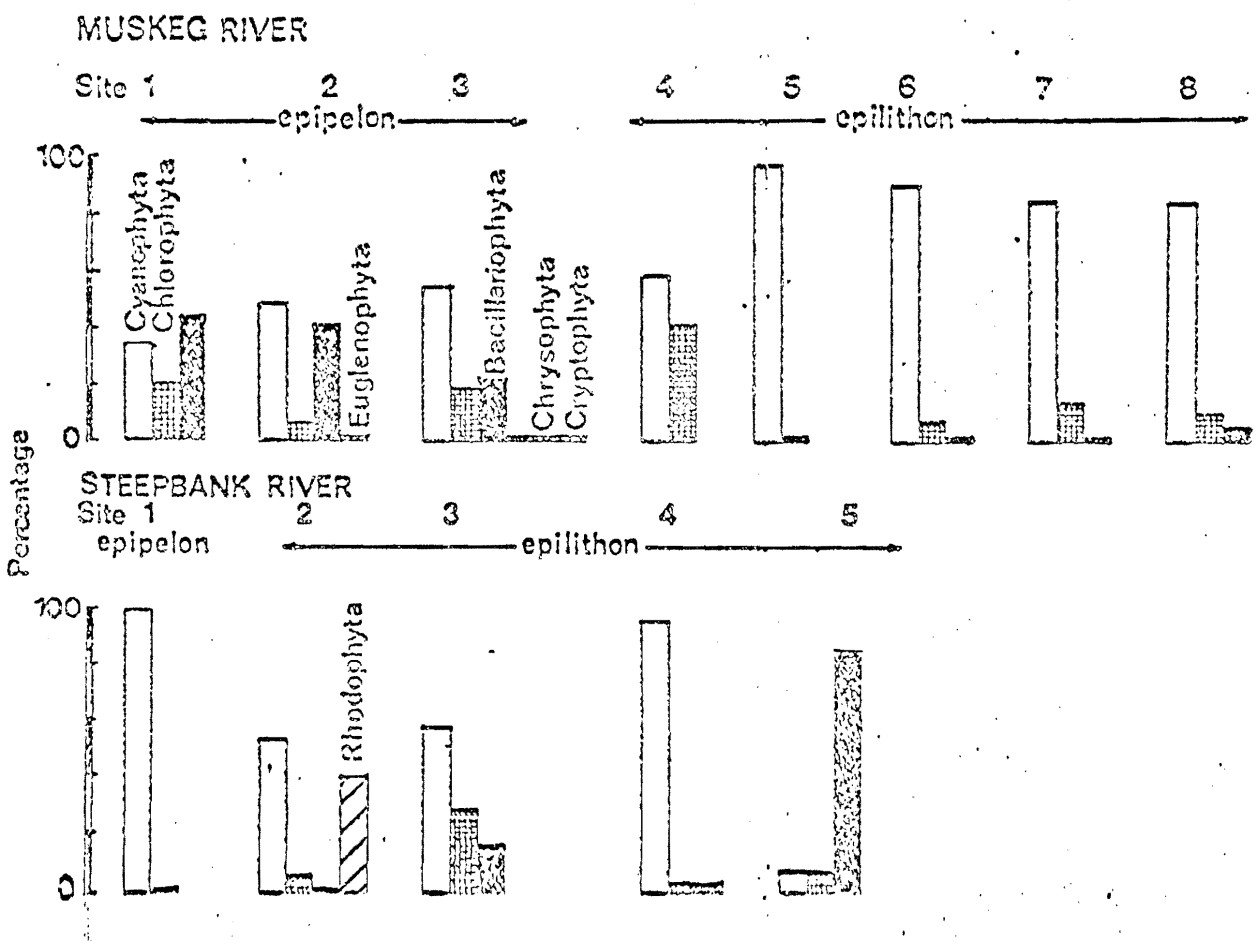

Figure 27. Percentage algal composition at each site in the Muskeg and Steepbank rivers.

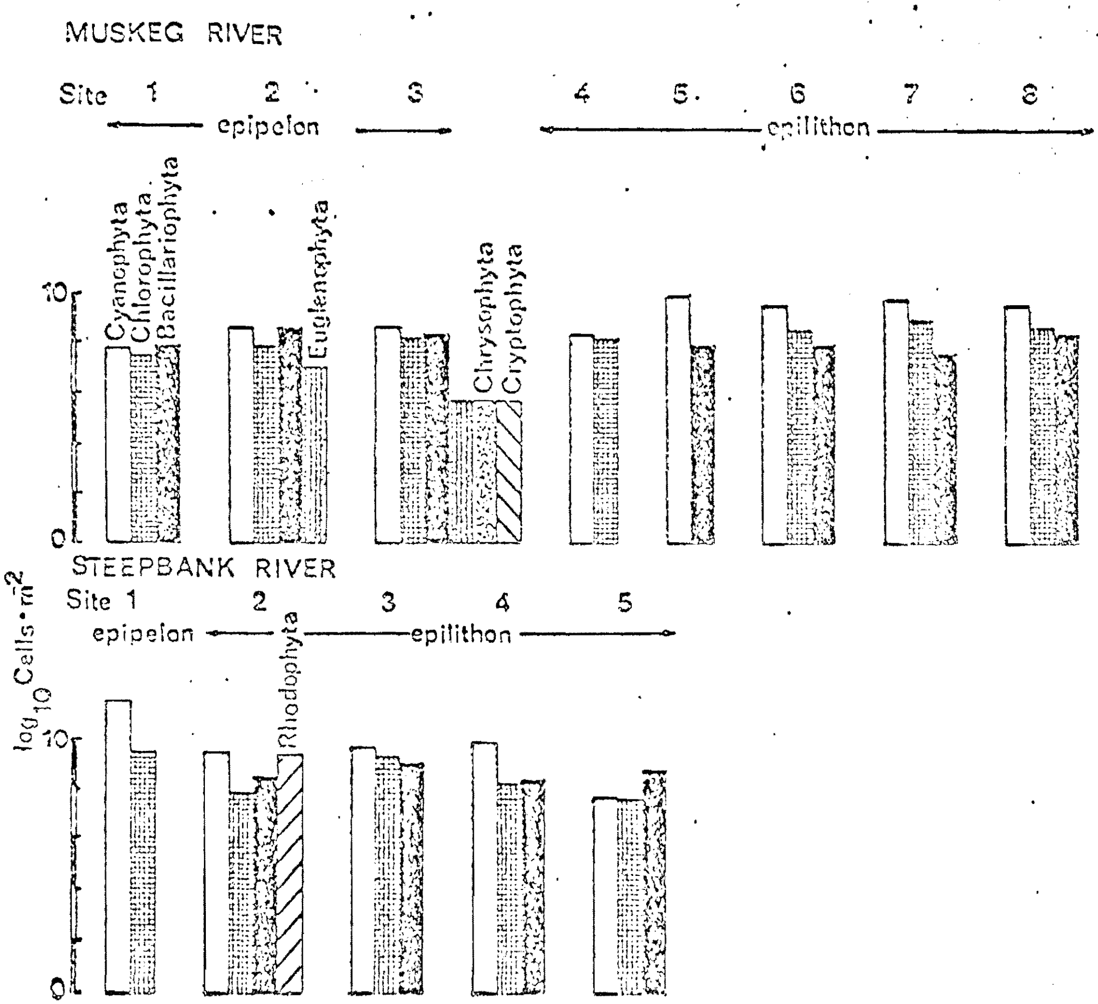

Figure 26. Cell numbers ($\log_{10} \cdot m^{-2}$) of the algal divisions found at each site in the Muskeg and Steepbank rivers.

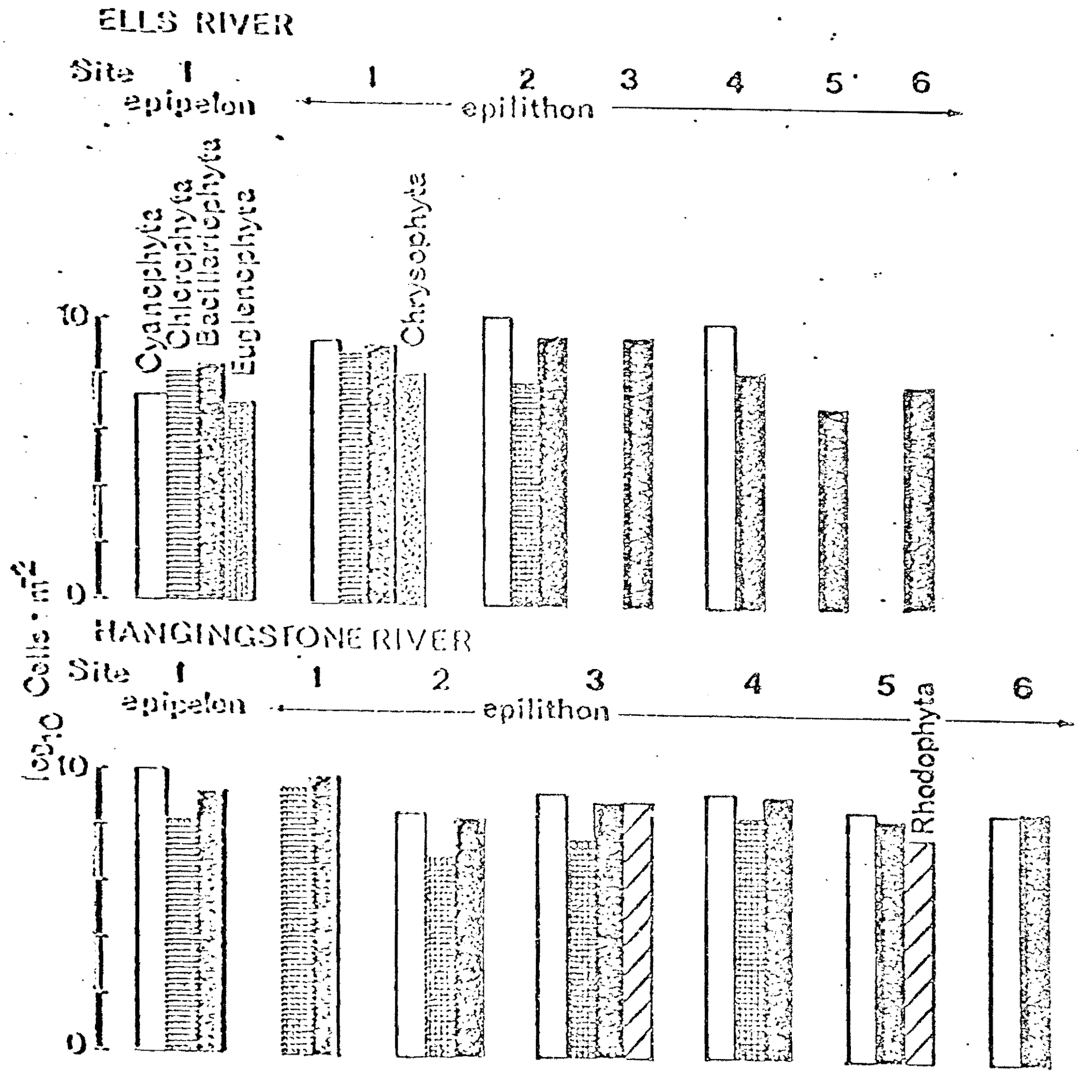

Figure 28. Cell numbers ($log_{10} \cdot m^{-2}$) of the algal divisions found at each site in the Ells and Hangingstone rivers.

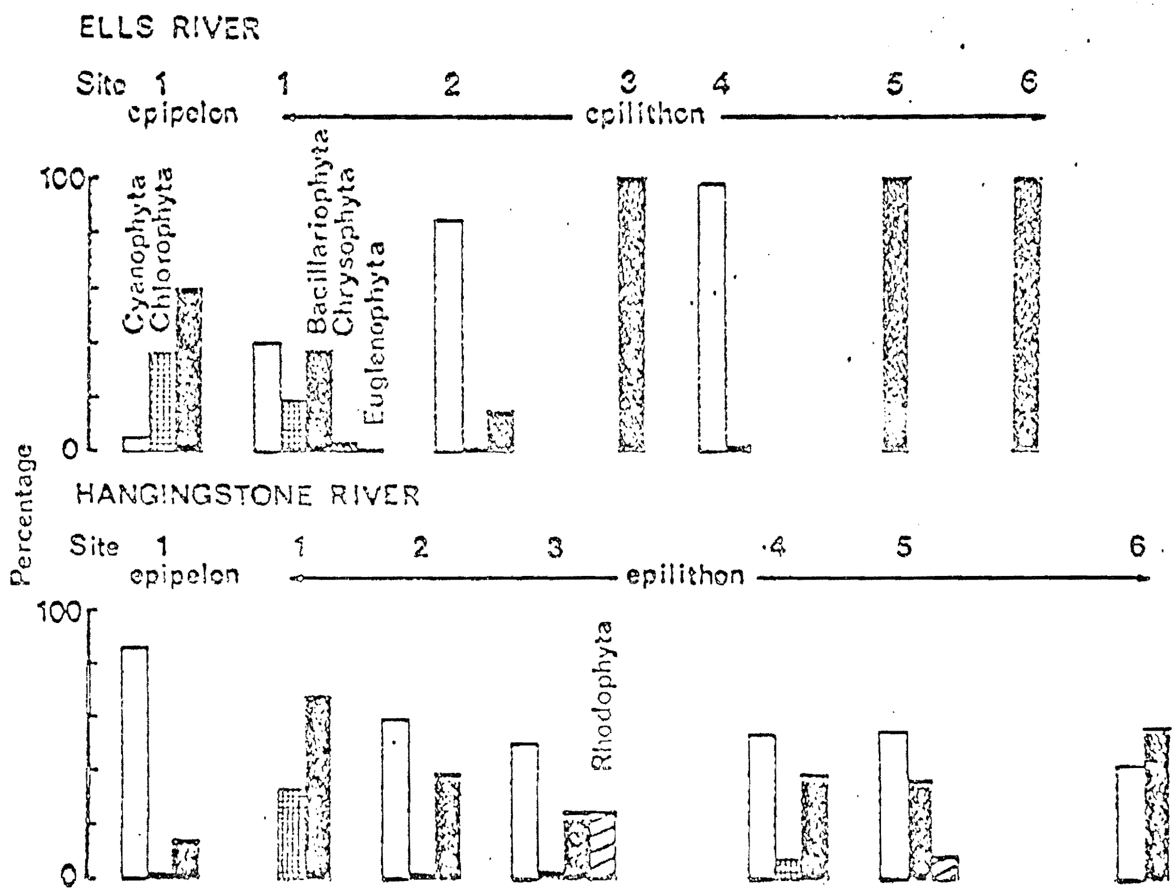

Figure 29. Percentage algal composition at each site in the Ells and Hangingstone rivers.

and 29). Diatoms, important at all sites, replaced the cyanophycean algae at these sites while chlorophycean algae were found only at Sites 1 and 2. Total cell numbers were very variable (Table 4) ranging from 1.1 to 1975.9 X 10^7 cells·m^{-2}.

The epipelon at Site 1 in the Hangingstone River, like that in the Steepbank River was dominated by cyanophycean algae (1074.5 X 10^7 cells·m^{-2}) (Figures 28 and 29). In contrast, none were found in the epilithon; instead, diatoms and chlorophycean algae dominated (724.0 and 362.0 X 10^7 cells·m^{-2}, and 66.7% and 33.3% of the total populations, respectively) (Figures 28 and 29). However, at all other sites, cyanophycean algae were present as the dominant group except at Site 6 where diatoms, which comprised the secondmost important group, replaced them. Rhodophycean algae were found at Sites 3 and 5 (109.7 and 7.9 X 10^7 cells·m^{-2}, and 23.4% and 7.6% of the total populations, respectively). Total cell numbers were greatest and smallest at Sites 1 and 2, respectively, while similar sized populations produced site pairs of 3 and 4, and 5 and 6 (Table 4).

Cyanophycean and chlorophycean algae dominated the epipelon at Sites 1 and 2, respectively, in the MacKay River (79.2 X 10^7 and 760.2 X 10^8 cells·m^{-2}, respectively). Diatoms were also prominent at Site 1 (67.9 X 10^7 cells·m^{-2}) but not at Site 2 where greater diversity existed since members of the Chrysophyta, Cryptophyta, Pyrrophyta, and Euglenophyta were found. At Sites 3 and 4, the epilithon was dominated by cyanophycean algae (594.9 and 169.7 X 10^7 cells·m^{-2}, and 70.6% and 68.8% of the total populations, respectively). However, this group declined in importance downstream (Figures 30 and 31) while chlorophycean algae and, to a lesser extent, diatoms became more important. Rhodophycean algae were found only at Site 6 but constituted the dominant algal group (282.8 X 10^7 cells·m^{-2} and 37.8% of the total population). Total cell numbers alternately rose and fell from site to site along the length of the MacKay River (Table 4).

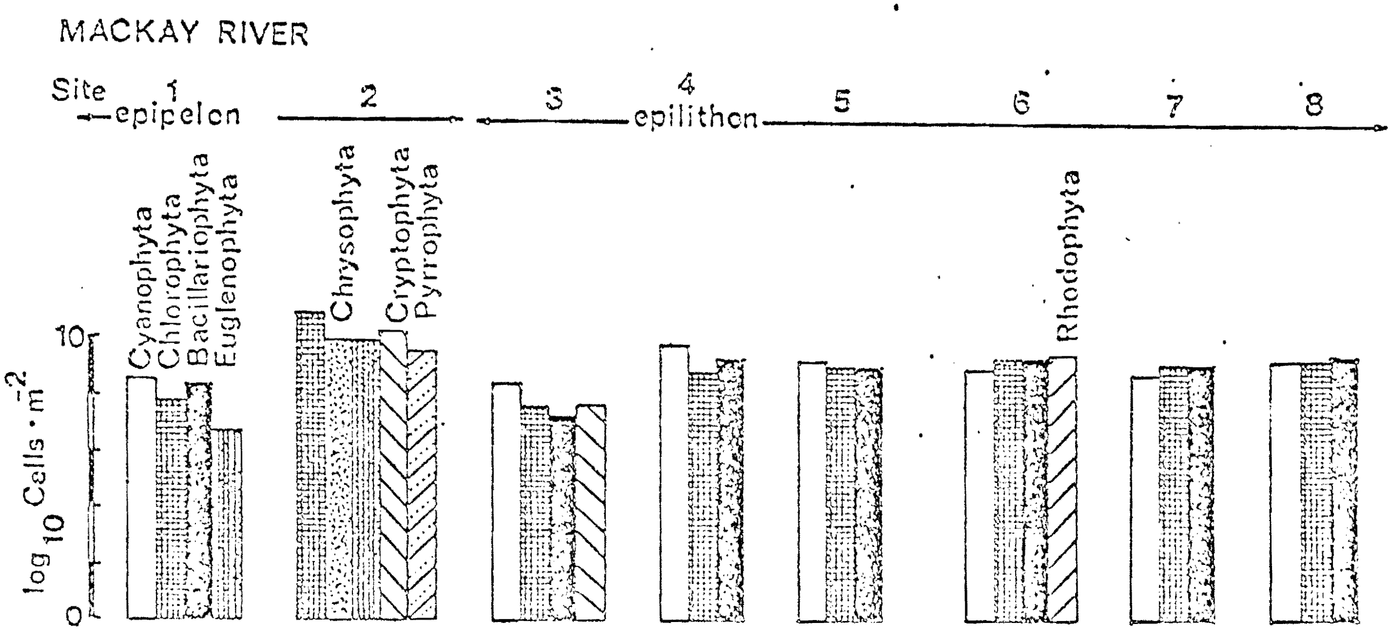

Figure 30. Cell number ($\log_{10} \cdot m^{-2}$) of the algal divisions found at each site in the MacKay River.

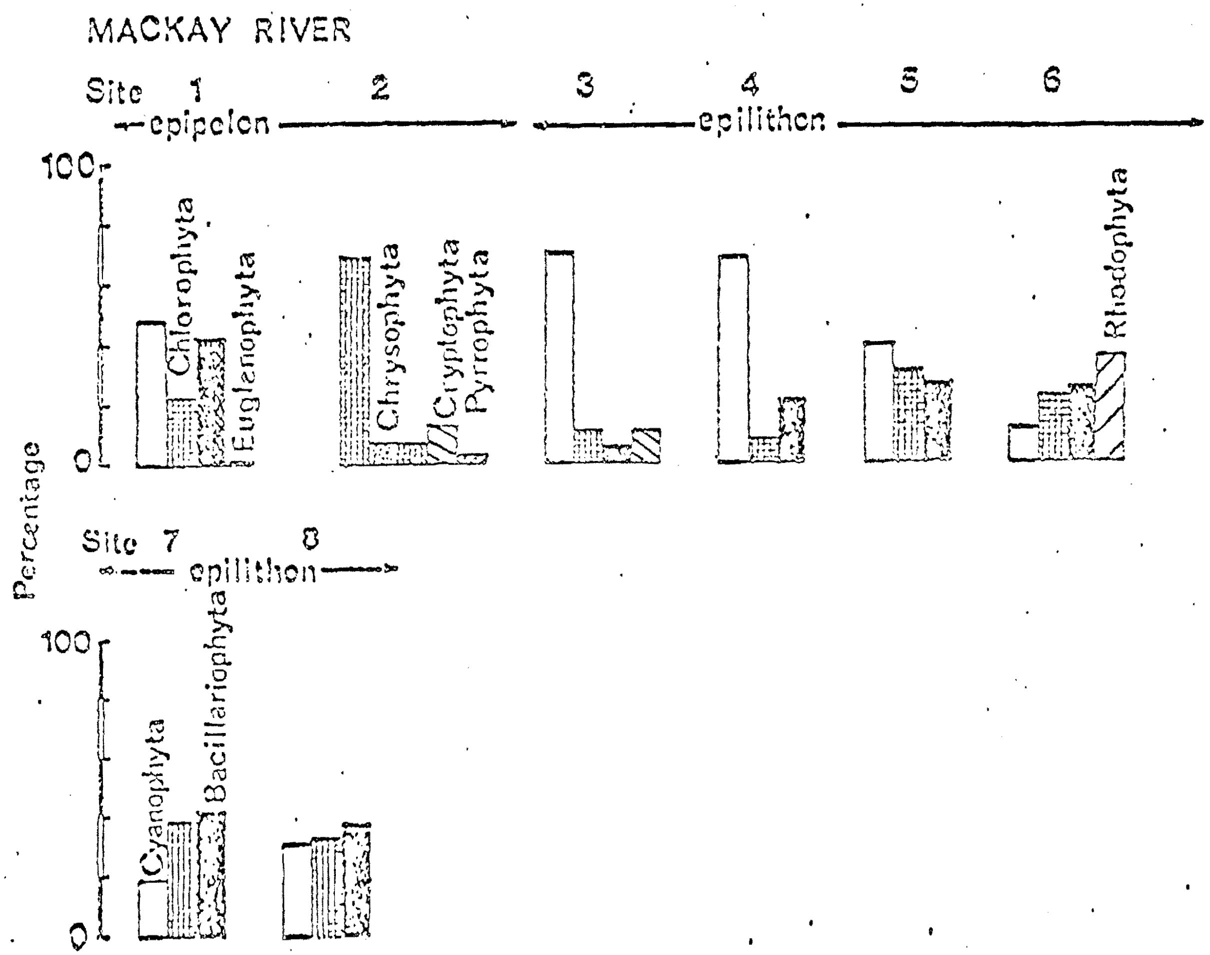

Figure 31. Percentage algal composition at each site in the MacKay River.

Table 4. Total Cell numbers found at each site in the five rivers.

Site	Epipelon	Epilithon
	Cells x 10^7 m^{-2}	
MUSKEG RIVER		
1	16.5	-
2	94.5	-
3	79.8	-
4	-	38.4
5	-	834.7
6	-	398.2
7	-	661.6
8	-	437.7
STEEPBANK RIVER		
1	34 743.0	-
2	-	510.0
3	-	804.8
4	-	972.6
5	-	73.5
ELLS RIVER		
1	40.7	423.2
2	-	1 975.9
3	-	350.6
4	-	1 209.1
5	-	1.1
6	-	7.9

continued ...

Table 4. Concluded.

Site	Epipelon	Epilithon
	Cells x 10^7 m ^{2}	
HANGINSTONE RIVER		
1	1 260.0	1 086.0
2	-	61.0
3	-	468.3
4	-	468.3
5	-	103.0
6	-	107.4
MACKAY RIVER		
1	159.6	-
2	10 860.0	38.4
3	-	864.1
4	-	423.2
5	-	747.7
6	-	275.8
7	-	516.8

5.21 BENTHIC ALGAL SPECIES COMPOSITION

A complete listing of all the algae found during the surveys in each river is presented in Table 5. This does not represent the total algal flora of the river because the data were obtained from one date and not from seasonal studies. Therefore, this list is not as extensive as reported by Hickman et al. (1979).

A number of algae was cosmopolitan in that they were found in all rivers (e.g., *Lyngbya* sp., *Chlamydomonas* sp., *Chlorella vulgaris*, *Achnanthes lanceolata*, *Cocconeis pediculus*, *Cocconeis placentula*, *Cyclotella meneghiniana*, *Cymbella ventricosa*, *Epithemia argus*, *Fragilaria capucina*, *Gomphonema lanceolatum*, *Gomphonema olivaceum*, *Navicula cryptocephala*, *Nitzschia palea*, and *Synedra ulna*).

Another group of algae was found in all but one river [e.g., river in brackets where the particular species was not found) *Anabaena affinis* (Ells R.), *Calothrix braunii* (MacKay R.), *Nostoc* spp. (Hangingstone R.), *Oscillatoria* sp. (Ells R.), *Cladophora glomerata* (Hangingstone R.), *Cryptomonas ovata* (Steepbank R.), *Chromulina* spp. (Hangingstone R.), *Euglena* sp. (Ells R.), *Batrachospermum vagum* (Ells R.), *Cymbella prostrata* (Steepbank R.), *Epithemia sorex* (MacKay R.), *Fragilaria pinnata* (Hangingstone R.), *Fragilaria vaucheriae* (Steepbank R.), *Gomphonema parvulum* (Ells R.), *Navicula graciloides* (MacKay R.), *Navicula radiosa* (Hangingstone R.), *Nitzschia dissipata* (Steepbank R.), *Nitzschia recta* (Steepbank R.), and *Surirella angustata* (Hangingstone R.)].

The above groupings represent the most common species. In contrast, some species had very restricted distributions, being found in only one river. For example, *Gomphosphaeria aponina*, *Gomphosphaeria lacustris* v. *compacta*, *Crucigenia quadrata*, *Cryptomonas erosa*, *Achnanthes* sp., *Cymbella turgida*, *Eunotia lunaris*, *Fragilaria leptostauron*, *Gomphonema acuminatum* v. *coronata*, *Gomphonema ventricosum*, *Navicula gracilis*, *Pinnularia mesolepta*, and *Tabellaria fenestrata* were found only in the Muskeg River; *Hyalotheca* spp., *Pediastrum biradiatum*, *Gomphonema gracile*, and *Nitzschia hantzschiana* were confined to the Steepbank River; *Microspora pachyderma*,

Table 5. A complete list of algae found in the five rivers during the survey.

Division	River[a]				
	M	SB	E	HS	MK
CYANOPHYTA					
Anabaena affinis Lemm.	+	+	-	+	+
Calothrix braunii Bornet & Flahault	+	+	+	+	-
Chroococcus limneticus Lemm.	-	-	-	-	+
Gomphosphaeria aponina Kütz.	-	-	-	-	+
G. lacustris v. *compacta* Lemm.	+	-	-	-	-
Lyngbya sp.	+	+	+	+	+
Merismopedia glauca (Ehr.) Naegeli	+	-	-	-	+
Nostoc spp.	+	+	+	-	+
Oscillatoria amphibia C.A. Agardh.	-	-	-	-	+
Oscillatoria sp.	+	+	-	+	+
CHLOROPHYTA					
Ankistrodesmus falcatus (Corda) Ralfs.	+	+	-	-	+
Chlamydomonas globosa Snow	-	-	-	-	+
Chlamydomonas spp.	+	+	+	+	+
Chlorella ellipsoidea Gerneck	-	-	-	-	+
C. vulgaris Beyer	+	+	+	+	+
Cladophora glomerata (L) Kütz.	+	+	+	-	+
Closterium sp.	+	-	-	+	+
Coelastrum scabrum Reinsch.	+	-	-	-	+
Cosmarium spp.	-	+	+	-	+
Crucigenia quadrata Morren	+	-	-	-	-
Gloeocystis gigas (Kütz.) Lager	-	-	-	-	+
Hyalotheca spp.	-	+	-	-	-
Microspora loefgrenii (Norst.) Lager	-	+	-	-	+

continued ...

Table 5. Continued.

Division	River M	SB	E	HS	MK
M. pachyderma (Wille) Lager.	-	-	+	-	-
Microspora sp.	-	+	+	-	-
Odeogonium sp.	-	-	-	-	+
Pediastrum biradiatum Meyer	-	+	-	-	-
P. biradiatum v. *emarginatum* f. *convexum*	-	-	-	-	+
P. Boryanum (Turp.) Meneghini	-	-	-	+	-
Pleurotaenium spp.	-	-	-	+	-
Scenedesmus acutiformis Schroeder	-	-	-	-	+
S. bijuga (Turp.) Lager	+	-	-	-	+
S. quadricauda (Turp.) de Bréb.	-	-	-	-	+
Sphaerocystis schroeteri Chodat	-	-	-	-	+
Sphaeroplea annulina (Roth.) C.A. Agardh	-	-	-	-	+
Spirogyra sp.	+	-	-	+	-
Stigeoclonium sp.	+	-	+	-	+
Ulothrix sp.	-	-	-	-	+
CRYPTOPHYTA					
Cryptomonas erosa Ehr.	+	-	-	-	-
C. ovata Ehr.	+	-	+	+	+
Rhodomonas minutum Skuja	+	-	-	+	+
PYRROPHYTA	+	+	-	-	+
CHRYSOPHYTA					
Chromulina spp.	+	+	+	-	+
Dinobryon sertularia Ehr.	-	-	-	-	+
Mallomonas sp.	-	-	-	-	+

continued ...

Table 5. Continued.

Division	River				
	M	SB	E	HS	MK
EUGLENOPHYTA					
Euglena sp.	+	+	-	+	+
Phacas sp.	+	-	+	-	+
Trachelomonas sp.	+	-	+	-	+
RHODOPHYTA					
Batrachospermum vagum (Roth.) C.A. Agardh.	+	+	-	+	+
BACILLARIOPHYTA					
Achnanthes sp.	+	-	-	-	-
A. lanceolata Bréb.	+	+	+	+	+
A. lanceolata v. *rostrata* Hust.	+	-	-	-	-
A. minutissima Kütz.	+	+	+	-	-
Amphipleura lindheimeri Grun.	-	-	+	-	+
A. pellucida Kütz.	+	-	-	+	+
Asterionella formosa Hass.	-	-	+	-	-
Cocconeis pediculus Ehr.	+	+	+	+	+
C. placentula Ehr.	+	+	+	+	+
Cyclotella comta (Ehr.) Kütz.	-	-	+	-	-
C. kützingiana Thwaites	-	-	+	-	-
C. meneghiniana Kütz.	+	+	+	+	+
Cymatopleura solea (Bréb.) W. Sm.	+	-	+	+	-
Cymbella cistula (Hemp.) Grun	-	+	-	-	+
C. lanceolata (Ehr.) V.H.	-	-	-	-	+
C. prostrata (Berk.) Cl.	+	-	+	+	+
C. sinuata Greg.	+	-	+	+	-
C. turgida (Greg.) Cl.	+	-	-	-	-

continued ...

Table 5. Continued.

Division	River				
	M	SB	E	HS	MK
C. ventricosa Kütz.	+	+	+	+	+
Diatoma elongatum Agardh.	-	-	+	-	-
D. vulgare Bory	-	+	+	+	-
D. vulgare v. *grandis* (Sm.) Grun.	-	+	+	-	-
D. vulgare v. *ovalis* (Fricke) Hust.	-	-	+	-	-
Epithemia argus Kütz.	+	+	+	+	+
E. sorex Kütz.	+	+	+	+	-
E. turgida (Ehr.) Kütz.	-	+	-	+	+
Eunotia lunaris (Ehr.) Grun.	+	-	-	-	-
E. pectinalis v. *minor* (Kütz.) Rabh.	-	-	-	-	+
E. valida Hust.	-	-	-	-	+
Fragilaria capucina Desm.	+	+	+	+	+
F. construens (Ehr.) Grun.	-	-	+	-	-
F. construens v. *binodis* (Ehr.) Grun.	-	-	+	-	-
F. crotonensis Kitton	+	-	+	-	-
F. leptostauron (Ehr.) Hust.	+	-	-	-	-
F. pinnata Ehr.	+	+	+	-	+
F. vaucheriae (Kütz.) Peters	+	-	+	+	+
Frustulia rhomboides v. *amphipleuroides* Grun.	-	+	+	-	-
Gomphonema abbreviatum (Agardh.) Kütz.	+	-	+	+	-
G. acuminatum Ehr.	+	+	-	-	-
G. acuminatum v. *coronata* (Ehr.) W. Sm.	+	-	-	-	-
G. gracile Ehr.	-	+	-	-	-
G. lanceolatum Ehr.	+	+	+	+	+
G. olivaceum (Lyngb.) Kütz.	+	+	+	+	+
G. ventricosum Greg.	+	-	-	-	-

continued ...

Table 5. Continued.

Division	River				
	M	SB	E	HS	MK
Gyrosigma acuminatum (Kütz.) Rabh.	-	-	+	+	+
Hantzschia amphioxys (Ehr.) Grun.	-	-	-	-	+
Melosira islandica O. Müll.	+	-	-	+	-
M. varians C. A. Ag.	+	+	+	+	-
Meridion circulare Agardh.	+	-	-	-	+
Navicula cryptocephala Kütz.	+	+	+	+	+
N. cuspidata Kütz.	+	-	-	-	+
N. gracilis Ehr.	+	-	-	-	-
N. graciloides A. Mayer	+	+	+	+	-
N. minima v. *atomoides* (Grun.) Cl.	-	-	+	-	-
N. pupula Kütz.	-	-	-	-	+
N. radiosa Kütz.	+	+	+	-	+
Neidium affine (Ehr.) Cl.	-	-	-	-	+
N. affine v. *amphirhynchus* (Ehr.) Cl.	-	-	-	-	+
Nitzschia acuta Hantzsch.	-	-	-	+	+
N. dissipata (Kütz.) Grun.	+	-	+	+	+
N. fonticola Grun.	+	-	+	-	+
N. gracilis Hantzsch.	+	+	-	-	-
N. hantzschiana Rabh.	-	+	-	-	-
N. palea (Kütz.) W. Sm.	+	+	+	+	+
N. recta Hantzsch.	+	-	+	+	+
N. sublinearis Hust.	+	-	-	-	+
Pinnularia gibba Ehr.	+	-	-	+	+
P. mesolepta (Ehr.) W. Sm.	+	-	-	-	-
P. molaris Grun.	+	-	+	-	+
P. viridis v. *sudetica* (Hilse) Hust.	-	-	-	-	+
Rhoicosphenia curvata (Kütz.) Grun.	+	+	+	-	-
Rhopalodia gibba (Ehr.) O. Müll.	-	+	-	+	+

continued ...

Table 5. Concluded.

Division	River				
	M	SB	E	HS	MK
R. gibberula (Ehr.) O. Müll.	-	-	+	+	-
Stauroneis anceps Ehr.	-	-	-	-	+
S. phoenicentron Ehr.	+	-	-	-	+
Stephanodiscus astraea (Ehr.) Grun.	-	-	+	-	-
Surirella angustata Kütz.	+	+	+	-	+
S. ovalis Bréb.	-	-	-	-	+
Synedra ulna (Nitzsch.) Ehr.	+	+	+	+	+
Tabellaria fenestrata (Lyngb.) Kütz.	+	-	-	-	-
T. flocculosa (Roth.) Kütz.	-	+	-	-	+

a

M = Muskeg River

SB = Steepbank River

E = Ells River

HS = Hangingstone River

MK = MacKay River

\+ = present

\- = absent

Table 6. The algae found at each site in the Muskeg River.

Algae	Site[a] 1	2	3	4	5	6	7	8
CYANOPHYTA								
Anabaena affinis	-	+	+	-	-	+	-	-
Calothrix braunii	-	-	-	+	+	+	+	+
Gomphonema lacustris v. *compacta*	-	+	-	-	-	-	-	-
Lyngbya sp.	+	+	+	+	+	+	+	+
Merismopedia glauca	-	+	-	-	-	-	-	-
Nostoc spp.	-	-	-	-	-	+	+	+
Oscillatoria sp.	-	+	+	+	-	-	-	-
CHLOROPHYTA								
Ankistrodesmus falcatus	-	+	-	-	+	+	+	+
Chlamydomonas sp.	+	+	+	-	-	-	-	-
Cladophora glomerata	-	-	-	+	+	+	+	+
Closterium sp.	-	+	-	-	-	-	-	-
Coelastrum scabrum	-	+	-	-	-	-	-	-
Crucigenia quadrata	-	-	-	-	-	-	-	+
Scenedesmus bijuga	-	-	-	-	-	-	-	+
Spirogyra sp.	-	+	-	-	-	-	-	-
Stigeoclonium sp.	-	-	-	-	+	-	-	+
CRYPTOPHYTA								
Cryptomonas erosa	+	+	-	-	-	-	-	+
C. ovata	-	-	+	-	-	-	-	-
Rhodomonas minutum	-	-	+	-	-	-	-	-
PYRROPHYTA	-	+	+	-	-	-	-	-

continued ...

Table 6. Continued.

Algae	Site							
	1	2	3	4	5	6	7	8
CHRYSOPHYTA								
Chromulina spp.	-	-	+	-	-	-	-	-
EUGLENOPHYTA								
Euglena sp.	-	+	+	-	-	-	-	-
Phacus sp.	-	+	+	-	-	-	-	-
Trachelomonas sp.	-	+	+	-	-	-	-	-
RHODOPHYTA								
Batrachospermum vagum	-	-	-	-	+	+	-	-
BACILLARIOPHYTA								
Achnanthes sp.	+	-	-	+	-	-	-	+
A. lanceolata	-	+	+	+	+	+	-	+
A. minutissima	-	-	-	+	-	-	-	-
Amphipleura pellucida	-	-	+	-	-	+	-	+
Cocconeis pediculus	+	-	-	-	-	-	-	-
C. placentula	-	+	-	+	+	+	+	+
Cyclotella meneghiniana	-	-	-	-	-	-	-	+
Cymatopleura solea	-	+	+	-	-	-	-	-
Cymbella prostrata	-	+	-	-	-	-	-	-
C. sinuata	-	-	-	-	+	-	-	-
C. ventricosa	-	+	+	+	+	+	+	-
Epithemia argus	+	-	-	-	-	+	-	-
E. sorex	+	+	-	-	+	-	+	+
Eunotia lunaris	+	+	+	-	-	-	-	-

continued ...

Table 6. Continued.

Algae	Site 1	2	3	4	5	6	7	8
Fragilaria capucina	-	+	-	-	-	+	+	-
F. crotonensis	-	+	-	-	-	-	-	-
F. pinnata	-	+	-	-	-	-	-	-
F. vaucheriae	-	+	+	+	+	-	-	+
Gomphonema abbreviatum	-	-	-	-	+	-	-	+
G. acuminatum	-	+	+	-	-	-	-	-
G. acuminatum v. *coronata*	+	-	-	-	-	-	-	-
G. lanceolatum	+	-	-	-	-	-	-	+
G. olivaceum		+	-	-	+	+	+	-
G. parvulum	-	-	-	+	-	-	-	-
Melosira islandica	-	-	+	-	-	-	-	-
Meridion circulare	-	-	-	-	-	+	-	-
Navicula cryptocephala	+	+	+	+	-	+	-	-
N. cuspidata	-	+	+	-	-	-	-	-
N. gracilis	+	+	+	-	-	-	-	+
N. graciloides	-	+	+	+	-	+	+	-
N. Radios	-	+	+	-	-	-	-	+
Nitzschia acuta	-	-	-	-	+	-	-	-
N. dissipata	+	-	-	+	-	-	-	+
N. fonticola	-	+	-	-	-	-	-	-
N. gracilis	-	+	-	-	-	-	-	-
N. palea	+	-	-	+	-	+	+	+
N. recta	-	+	-	+	-	-	-	-
N. sublinearis	-	+	-	-	-	-	-	-
Pinnularia gibba	-	+	+	-	-	-	-	-
P. molaris	-	+	+	-	-	-	-	-

continued ...

Table 6. Concluded.

Algae	Site 1	2	3	4	5	6	7	8
Rhoicosphenia curvata	-	-	-	+	-	-	-	-
Stauroneis phoenicenteron	-	-	+	-	-	-	-	-
Surirella angustata	-	-	-	-	-	+	-	-
Synedra ulna	+	+	+	+	+	+	-	-
Tabellaria fenestrata	+	+	-	-	-	-	-	-

a

+ = present

- = absent

Table 7. The dominant algal species found at each site in the Muskeg River.

Site	Species	Percentage of Total Population (%)
1	*Lyngbya* sp.	34.5
	Chlamydomonas	20.6
	Tabellaria fenestrata	6.9
	Eunotia lunaris	5.2
2	*Gomphosphaeria lacustris* v. *compacta*	19.2
	Lyngbya sp.	18.0
	Fragilaria capucina	12.5
	Merismopedia glauca	12.0
	Fragilaria vaucheriae	9.6
3	*Oscillatoria* sp.	42.5
	Chlamydomonas spp.	14.2
	Lyngbya sp.	7.1
	Anabaena affinis	5.6
	Navicula cryptocephala	4.3
4	*Lyngbya* sp.	58.9
	Cladophora glomerata	41.1
5	*Lyngbya* sp.	96.2
	Calothrix braunii	2.7
6	*Lyngbya* sp.	82.4
	Anabaena affinis	5.1
	Cladophora glomerata	4.3
	Calothrix braunii	3.4

continued ...

Table 7. Concluded.

Site	Species	Percentage of Total Population (%)
7	*Lyngbya* sp.	85.5
	Cladophora glomerata	12.1
8	*Lyngbya* sp.	59.4
	Calothrix braunii	24.6
	Stigeoclonium sp.	5.9
	Cocconeis placentula	3.3

Asterionella formosa, Cyclotella comta, Cyclotella kützingianum, Diatoma elongatum, Diatoma vulgare v. *ovalis, Fragilaria construens, Fragilaria construens* v. *binodis, Navicula minima* v. *atomoides,* and *Stephanodiscus astraea* were confined to the Ells River; *Pediastrum boryanum* and *Pleurotaenium* spp. were confined to the Hangingstone River; and to the MacKay River were confined *Chroococcus limneticus, Gomphosphaeria aponina, Oscillatoria amphibia, Chlorella ellipsoidea, Gloeocystis gigas, Oedogonium* sp., *Pediastrum biradiatum* v. *emarginatum* f. *convexum, Scenedesmus acutiformis, Scenedesmus quadricauda, Sphaerocystis schroeteri, Sphaeroplea annulina, Ulothrix* sp., *Dinobryon sertularia, Mallomonas* sp., *Cymbella lanceolata, Eunotia pectinalis* v. *minor, Eunotia valida, Hantzschia amphioxys, Neidium affine, Neidium affine* v. *amphirhynchus, Stauroneis anceps,* and *Surirella ovalis.*

The benthic algae found at each site in each river are presented in Tables 6, 8, 10, 12, and 14. Only *Lyngbya* sp. was found at each site in the Muskeg River (Table 6). However, it was most abundant at all but Sites 2 and 3, ranging between 34.5 and 96.2% of the total populationsSites 1 and 5, respectively) (Table 7). *Calothrix braunii* and *Cladophora glomerata* were confined to Sites 4 to 8, inclusive with *Calothrix braunii* forming significant populations at Sites 5, 6, and 8; and *Cladophora glomerata* doing so at Sites 4, 6, and 7 (Table 7). *Chlamydomonas* spp. and *Eunotia lunaris* were confined to Sites 1, 2, and 3; *Chlamydomonas* spp. accounted for 20.7 and 14.2% at Sites 1 and 3; *Eunotia lunaris* 5.2% of the total population at Site 1. Of the other algae forming significant populations, *Merismopedia glauca* and *Gomphosphaeria lacustris* v. *compacta* were confined to Site 2; *Tabellaria fenestrata* to Sites 1 and 2; *Stigeoclonium* sp. to Sites 5 and 8; *Fragilaria capucina* to Sites 2, 6, and 7; and *Anabaena affinis* to Sites 2, 3, and 6. In contrast, *Navicula cryptocephala, Fragilaria vaucheriae,* and *Cocconeis placentula* were all more widely distributed along the river's length (Table 6). Other less important algae showed more limited, and sometimes, variable occurrences.

Table 8. The algae found at each site in the Steepbank River

Algae	Site 1	2	3	4	5
CYANOPHYTA					
Anabaena affinis	+	-	+	+	-
Calothrix braunii	-	-	+	+	-
Lyngbya sp.	-	+	+	+	+
Nostoc spp.	+	+	+	+	-
Oscillatoria sp.	-	+	-	+	-
CHLOROPHYTA					
Ankistorodesmus falcatus	+	-	-	+	+
Chlamydomonas sp.	+	-	+	+	-
Chorella vulgaris	-	-	+	+	+
Cladophora glomerata	-	+	+	+	-
Cosmarium spp.	-	+	-	+	+
Hyalotheca spp.	-	-	+	-	-
Microspora loefgrenii	-	+	+	-	-
Microspora sp.	-	-	-	-	+
Pediastrum biradiatum	-	-	-	-	+
PYRROPHYTA	+	-	-	-	-
CHRYSOPHYTA					
Chromulina spp.	+	-	-	-	-
EUGLENOPHYTA					
Euglena sp.	+	-	-	-	-

continued ...

Table 8. Continued.

Algae	Site 1	2	3	4	5
RHODOPHYTA					
Batrachsopermum vagum	-	+	-	-	-
BACILLARIOPHYTA					
Achnanthes sp.	-	-	-	-	+
A. lanceolata	-	-	+	+	+
A. minutissima	-	+	-	-	-
Cocconeis pediculus	-	+	+	+	+
C. placentula	-	+	+	+	+
Cyclotella meneghiniana	-	+	+	+	+
Cymbella cistula	-	-	-	-	+
C. ventricosa	-	-	+	+	+
Diatoma vulgare	-	+	-	-	+
D. vulgare v. *grandis*	-	+	+	-	-
Epithemia argus	-	+	+	-	+
E. sorex	-	-	+	+	+
E. turgida	-	+	-	-	+
Fragilaria capucina	-	-	+	+	-
F. pinnata	-	-	+	-	-
Frustulia rhomboides v. *amphileuroides*	-	-	+	-	-
Gomphonema acuminatum	-	+	-	-	-
G. gracile	-	+	-	-	-
Melosira varians	-	+	-	-	-
Navicula cryptocephala	-	+	+	+	+
N. gracilis	-	-	+	-	-
N. graciloides	-	-	-	+	+
N. radiosa	-	-	-	-	+

continued ...

Table 8. Concluded.

Algae	Site				
	1	2	3	4	5
Nitzschia gracilis	-	+	-	-	+
N. hantzschiana	-	-	+	-	-
N. palea	-	+	+	-	+
Rhoicosphenia curvata	-	-	+	-	-
Rhopalodia gibba	-	+	+	+	+
Surirella angustata	-	-	+	-	-
Synedra ulna	-	+	+	+	+
Tabellaria flocculosa	+	+	+	-	-

+ = present

- = absent

Table 9. The dominant algal species found at each site in the Steepbank River.

Site	Species	Percentage of Total Population (%)
1	*Anabaena affinis*	67.7
	Nostoc spp.	31.2
2	*Lyngbya* sp.	53.2
	Batrachospermum vagum	38.8
3	*Lyngbya* sp.	53.4
	Cladophora glomerata	16.4
	Cocconeis placentula	11.5
	Microspora loefgrenii	5.6
	Anabaena affinis	4.5
4	*Calothrix braunii*	48.6
	Anabaena affinis	34.9
	Lyngbya sp.	11.6
5	*Cocconeis placentula*	37.0
	Epithemia sorex	17.6
	Lyngbya sp.	7.8
	Synedra ulna	7.0

Table 10. The algae found at each site in the Ells River.

Algae	Site 1	2	3	4	5	6
CYANOPHYTA						
Calothrix braunii	+	-	-	-	-	-
Lyngbya sp.	+	+	-	+	-	-
Nostoc spp.	+	-	-	-	-	-
CHLOROPHYTA						
Chlamydomonas sp.	+	+	-	-	-	+
Chlorella vulgaris	+	+	-	-	-	-
Cladophora glomerata	+	+	-	-	-	-
Cosmarium spp.	+	-	-	-	-	-
Microspora pachyderma	+	-	-	-	-	-
Microspora sp.	+	-	-	-	-	-
Stigeoclonium sp.	+	-	-	-	-	-
CRYPTOPHYTA						
Cryptomonas ovata	-	+	+	-	-	-
CHRYSOPHYTA						
Chromulina spp.	+	-	-	-	-	-
EUGLENOPHYTA						
Phacus sp.	+	-	-	-	-	-
Trachelomonas sp.	+	-	-	-	-	-
BACILLARIOPHYTA						
Achnanthes lanceolata	+	-	-	-	+	-
A. minutissima	-	-	-	-	-	-
Amphipleura lindheimeri	-	-	-	+	-	-

continued ...

Table 10. Continued.

Algae	Site 1	2	3	4	5	6
Asterionella formosa	+	-	-	-	-	-
Cocconeis pediculus	+	-	+	+	-	-
C. placentula	+	+	+	-	+	+
Cyclotella comta	+	+	+	+	-	-
C. kützingiana	-	-	+	-	-	-
C. meneghiniana	+	+	+	-	-	+
Cymatopleura solea	+	-	-	-	-	-
Cymbella prostrata	+	-	-	+	-	-
C. sinuata	+	-	-	-	+	-
C. ventricosa	+	+	+	+	+	-
Diatoma elongatum	-	+	-	+	+	-
D. vularge	+	-	-	-	-	-
D. vulgare v. *grandis*	+	+	+	+	+	+
D. vulgare v. *ovalis*	-	-	+	-	-	-
Epithemia argus	+	-	-	-	-	-
E. sorex	+	-	-	+	-	-
Fragilaria capucina	-	+	-	-	-	-
F. construens	+	+	-	+	-	-
F. construens v. *binodis*	+	-	-	-	-	-
F. crotonensis	-	-	-	+	-	-
F. pinnata	-	+	+	+	+	-
F. vaucheriae	+	-	+	-	-	+
Frustulia rhomboides v. *amphilpleuroides*	+	-	-	-	-	-
Gomphonema abbreviatum	+	-	-	-	-	-
C. lanceolatum	+	+	+	+	-	-
G. olivaceum	+	+	+	+	-	+
Gryrosigma acuminatum	-	-	+	-	-	-
Melosira varians	-	-	-	+	-	-

continued ...

Table 10. Concluded.

Algae	Site 1	2	3	4	5	6
Navicula cryptocephala	-	+	+	+	+	+
N. graciloides	-	-	-	+	+	+
N. minima v. *atomoides*	-	-	-	-	+	-
Nitzschia dissipata	+	+	+	+	+	+
N. fonticola	+	+	+	-	-	-
N. palea	-	+	+	+	-	+
N. recta	+	-	+	-	+	-
Pinnularia molaris	-	-	+	-	-	-
Rhoicosphemia curvata	-	-	-	+	-	-
Rhopalodia gibrula	-	-	-	-	+	-
Stephanodiscus astraea	-	+	-	-	-	-
Surirella angustata	-	-	-	-	+	-
Synedra ulna	-	+	-	+	+	-

+ = present

- = absent

No species was found at all sites in the Steepbank River (Table 8). *Lyngbya* sp., *Nostoc* spp., *Cocconeis pediculus, Cocconeis placentula, Cyclotella meneghiniana, Navicula cryptocephala, Rhopalodia gibba,* and *Synedra ulna* were found at all but one of the sites. Of these, *Nostoc* spp., *Lyngbya* sp., and *Cocconeis placentula* were present in significant numbers at Site 1 (*Nostoc* spp. -- 53.2%, 11.6%, and 7.8%, respectively); and Sites 3 and 5 (*Cocconeis placentula* -- 11.5%, and 37.0% of the total population, respectively) (Table 9). Of the other dominant algae, *Batrachospermum vagum* was only found at Site 2; *Anabaena affinis* was dominant at Sites 1 (67.7%) and 3 (4.5%) and occurred also at Site 5; *Cladophora glomerata* was dominant at Site 3 (16.4% and occurred also at Sites 2 and 4; *Microspora loefgrenii* was dominant at Site 3 (5.6%) and was also found at Site 2; *Calothrix braunii* was dominant at Site 4 (48.6%) and was only present elsewhere at Site 2; and *Epithemia sorex*, first encountered at Site 2, did not become dominant until Site 5 (17.6%). Similarly, *Synedra ulna* was consistently present from Site 2 but not dominant until Site 5 (7.0%). Other species encountered had more variable distributions (Table 8).

In the Ells River, only *Diatoma vulgaris* v. *grandis* and *Nitzschia dissipata* were found at all sites (Table 10). Both were found in significant numbers; *Diatoma vulgare* v. *grandis* at Sites 2 (2.0%) and 3 (10.5%) and *Nitzschia dissipata* at Sites 5 (17.3%), and 6 (9.0%). Three other dominant algae were widely distributed and found at all but one site: *Cocconeis placentula,* present at all but Site 4 and dominant at Sites 3 and 6; *Cymbella ventricosa,* absent from just Site 6 and dominant at Sites 1 and 5; and *Navicula cryptocephala,* absent from only Site 1 and dominant at Site 6.

Algae such as *Lyngbya* sp., *Chlorella vulgaris, Achnanthes lanceolata, Cyclotella kützingianum, Cymbella sinuata, Navicula minima* v. *atomoides,* and *Diatoma vulgare* had a more limited distribution but were present in significant numbers at at least one site (Table 11). *Lyngbya* sp., in particular, was numerically the most important (e.g., at Sites 1, 2, and 4 accounting for 40.1%,

Table 11. The dominant algal species found at each site in the Ells River.

Site	Species	Percentage of Total Population (%)
1	*Lyngbya* sp.	40.1
	Cymbella ventricosa	15.6
	Chlorella vulgaris	15.6
	Achnanthes lanceolata	3.9
2	*Lyngbya* sp.	84.1
	Gomphonema olivaceum	9.6
	Diatoma vulgare v. *grandis*	2.0
3	*Gomphonema olivaceum*	31.6
	Diatoma vulgaris v. *grandis*	10.5
	Nitzschia recta	10.5
	Cocconeis placentula	7.9
	Nitzschia palea	7.9
	Fragilaria pinnata	5.3
	Cyclotella kützingianum	5.3
4	*Lyngbya* sp.	98.2
5	*Achnanthes lanceolata*	17.3
	Nitzschia dissipata	17.3
	Cymbella sinuata	11.8
	Cymbella ventricosa	11.8
	Navicula minima v. *atomoides*	11.8

continued...

Table 11. Concluded.

Site	Species	Percentage of Total Population (%)
6	*Navicula cryptocephala*	36.3
	Cocconeis placentula	9.0
	Cyclotella meneghiniana	9.0
	Diatoma vulgare	9.0
	Fragilaria pinnata	9.0
	Gomphonema olivaceum	9.0
	Nitzschia dissipata	9.0
	Nitzschia palea	9.0

Table 12. The algae found at each site in the MacKay River.

Algae	Site 1	2	3	4	5	6	7	8
CYANOPHYTA								
Anabaena affinis	+	+	+	+	-	+	+	+
Chroococcus limneticus	-	-	-	-	+	-	-	-
Gomphosphaeria aponina	-	-	-	-	+	+	+	-
Lyngbya sp.	+	-	+	+	+	+	+	+
Merismopedia glauca	-	-	+	-	-	+	+	+
Nostoc spp.	-	-	-	+	-	-	-	-
Oscillatoria amphibia	+	-	-	-	-	-	-	-
Oscillatoria sp.	+	-	-	+	-	-	-	-
CHLOROPHYTA								
Ankistrodesmus falcatus	-	-	+	+	+	+	+	-
Chlamydomonas globosa	+	+	-	-	-	-	-	-
Chlamydomonas sp.	+	+	+	+	-	+	+	+
Chlorella ellipsoidea	+	-	-	-	-	-	-	-
C. vulgaris	+	+	-	+	+	-	+	+
Cladophora glomerata	+	-	+	+	+	+	+	+
Closterium sp.	-	-	+	+	+	+	+	-
Coelastrum scabrum	-	-	-	+	-	-	-	-
Cosmarium spp.	-	-	+	+	+	+	+	-
Gloeocystis gigas	-	-	-	+	+	-	-	-
Microspora loefgrenii	-	-	+	-	-	-	-	-
Oedogonium sp.	-	-	+	+	+	-	+	-
Pediastrum biradiatum v. *emarginatum* f. *convexum*	-	-	-	-	+	-	-	+
Scenedesmus acutiformis	-	-	-	-	+	+	+	+
S. bijuga	-	-	+	-	+	+	+	+

continued ...

Table 12. Continued

Algae	Site							
	1	2	3	4	5	6	7	8
S. quadricauda	-	-	-	-	+	-	-	+
Spaerocystis schroeter	-	-	-	-	-	+	-	-
Sphaeroplea annulina	-	-	-	-	+	-	-	-
Stigeoclonium sp.	-	-	+	-	+	+	+	-
Ulothrix sp.	-	-	-	-	+	-	-	-
CRYPTOPHYTA								
Cryptomonas ovata	-	+	+	-	-	-	-	-
Rhodomonas minutum	+	+	-	-	-	-	-	-
PYRROPHYTA	+	-	-	-	-	-	-	-
CHRYSOPHYTA								
Chromulina spp.	-	-	-	+	-	-	-	-
Dinobryon sestularia	+	-	-	-	-	-	-	-
Mallomonas spp.	+	-	-	-	-	-	-	-
EUGLENOPHYTA								
Euglena sp.	+	+	-	+	+	-	-	-
Phacus sp.	+	-	-	-	+	-	-	-
Trachelomonas sp.	+	+	-	-	-	-	-	-
RHODOPHYTA								
Batrachospermum vagum	-	-	-	-	-	+	-	-
BACILLARIOPHYTA								
Achnanthes lanceolata	+	-	+	-	+	-	+	+
Amphipleura lindheimeri	-	-	+	+	-	-	-	-

continued ...

Table 12. Continued.

Algae	Site 1	2	3	4	5	6	7	8
A. pellucida	-	-	+	+	+	+	-	-
Cocconeis pediculus	-	+	+	+	+	+	+	+
C. placentula	+	+	+	+	+	+	+	+
Cyclotella meneghiniana	+	-	-	-	-	-	+	-
Cymbella cistula	-	-	-	-	+	-	-	-
C. lanceolata	+	-	-	-	-	-	-	-
C. prostrata	-	-	-	-	-	+	-	-
C. ventricosa	+	-	+	-	+	+	+	+
Epithemia argus	-	-	-	-	+	+	+	+
E. sorex	-	-	-	-	+	+	+	+
E. turgida	-	-	-	-	-	+	-	-
Eunotia pecinalis v. *minor*	-	-	+	-	-	-	+	+
E. valida	-	-	-	-	-	-	+	+
Fragilaria capucina	-	-	+	-	-	-	+	+
F. pinnata	+	-	-	-	-	-	+	+
F. vaucheriae	-	-	-	+	+	+	-	-
Gomphonema lanceolatum	-	-	+	+	-	+	+	+
G. olivaceum	-	-	-	-	+	+	-	-
G. parvulum	-	-	+	-	-	-	-	-
Gyrosigma acuminatum	-	-	-	-	+	-	+	+
Hantzschia amphioxys	-	-	-	-	-	-	+	+
Meridion circulare	-	-	-	+	-	-	-	-
Navicula cryptocephala	+	-	+	+	+	+	+	+
N. cuspidata	-	-	-	-	-	+	-	-
N. pupula	+	-	-	-	-	-	-	-
N. radiosa	+	-	+	+	+	+	+	+
Neidium affine	-	-	+	-	-	-	-	-
N. affine v. *amphirhynchus*	+	-	-	-	-	-	-	-

continued ...

Table 12. Concluded.

Algae	Site 1	2	3	4	5	6	7	8
Nitzschia acuta	-	-	+	-	-	-	-	-
N. dissipata	-	-	+	-	-	-	-	-
N. fonticola	+	-	-	-	-	-	-	-
N. palea	+	-	+	-	+	+	+	+
N. recta	+	-	+	+	-	-	+	-
N. sublinearis	-	-	+	-	-	-	-	-
Pinnularia gibba	+	-	-	-	-	-	+	-
P. molaris	+	-	-	-	-	-	+	-
P. viridis v. *sudetica*	-	-	-	-	+	-	-	-
Rhopalodia gibba	+	-	+	-	-	+	+	+
Stauroneis anceps	+	-	-	-	-	-	-	-
S. phoenicentron	+	-	-	-	+	-	-	-
Surirella angustata	+	-	+	+	+	+	-	-
S. ovalis	-	-	-	-	+	-	-	-
Synedra ulna	-	-	+	+	-	+	+	+
Tabellaria flocculosa	+	-	-	-	-	-	-	-

+ = present

- = absent

Table 13. The dominant algae found at each site in the Mackay River.

Site	Species	Percentage of Total Population (%)
1	*Lyngbya* sp.	24.8
	Oscillatoria sp.	17.7
	Navicula cryptocephala	14.5
	Pinnularia gibba	7.5
	Anabaena affinis	7.1
	Chlorella vulgaris	7.1
	Navicula pupula	5.6
2	*Chlamydomonas* spp.	50.0
	Chlorella vulgaris	16.7
	Rhodomonas minutum	13.3
	Trachelomonas	6.7
3	*Anabaena affinis*	70.6
	Chlamydomonas spp.	11.7
	Cryptomonas ovata	8.9
	Cocconeis pediculus	3.0
	Cocconeis placentula	3.0
4	*Lyngbya* sp.	65.4
	Amphipleura lindheimeri	7.8
	Oedogonium sp.	4.6
	Navicula cryptocephala	4.4
	Gomphonema lanceolatum	2.4
	Nitzschia recta	2.4

continued...

Table 13. Continued.

Site	Species	Percentage of Total Population (%)
5	*Lyngbya* sp.	40.1
	Chlorella vulgaris	19.0
	Fragilaria vaucheriae	9.6
	Oedogonium sp.	8.3
	Epithemia sorex	6.4
	Cocconeis pediculus	5.0
6	*Batrachospermum vagum*	37.8
	Cladophora glomerata	15.4
	Cocconeis pediculus	11.0
	Gomphosphaeria aponina	7.3
	Lyngbya sp.	4.5
	Epithemia sorex	4.4
7	*Lyngbya* sp.	12.3
	Scendesmus acutiformis	11.5
	Scenedesmus bijuga	8.2
	Gomphosphaeria aponina	6.6
	Stigeoclonium sp.	4.9
	Navicula cryptocephala	4.8
	Cocconeis placentula	4.3
	Ankistrodesmus falcatus	4.1
	Cladophora glomerata	4.1

continued...

Table 13. Concluded.

Site	Species	Percentage of Total Population (%)
8	*Anabaena affinis*	22.4
	Chlorella vulgaris	10.9
	Cladophora sp.	9.2
	Lyngbya sp.	5.9
	Pediastrum biradiatum v. *emarginatum* f. *convexum*	5.3
	Cocconeis placentula	4.2
	Achnanthes lanceolata	4.2

Table 14. The algae found at each site in the Hangingstone River.

Algae	Site					
	1	2	3	4	5	6
CYANOPHYTA						
Anabaena affinis	+	+	-	+	-	-
Calothrix braunii	-	-	+	-	-	+
Lyngbya sp.	+	+	+	+	-	+
Oscillatoria sp.	-	-	+	+	+	-
CHLOROPHYTA						
Chlamydomonas sp.	+	+	-	-	-	-
Chlorella vulgaris	+	-	+	-	-	-
Closterium sp.	-	-	-	+	+	+
Pediastrum boryanum	-	-	-	+	-	-
Pleurotaenium spp.	-	-	-	-	-	-
Spirogyra sp.	-	-	-	-	-	+
CRYPTOPHYTA						
Cryptomonas ovata	+	-	-	-	-	-
Rhodomonas minutum	-	+	-	-	-	-
EUGLENOPHYTA						
Euglena sp.	+	+	-	-	-	-
RHODOPHYTA						
Batrachospermum vagum	-	-	-	-	+	+

continued...

Table 14. Continued.

Algae	Site					
	1	2	3	4	5	6
BACILLARIOPHYTA						
Achnanthes lanceolata	[a]	+	+	+	+	+
Amphipleura pellucida		-	-	-	-	+
Cocconeis pediculus		-	-	-	+	-
C. placentula		-	+	-	+	+
Cyclotella meneghiniana		+	+	+	-	-
Cymatopleura solea		-	-	+	+	-
Cymbella prostrata		-	+	+	+	-
C. sinuata		-	-	-	+	-
C. ventricosa		+	+	+	+	-
Diatoma vulgare		-	-	-	-	+
Epithemia argus		-	-	-	+	-
E. sorex		-	-	+	+	+
E. turgida		-	-	-	+	+
Fragilaria capucina		-	+	-	-	+
F. vaucheriae		+	+	+	+	+
Gomphonema abbreviatum		+	+	-	-	-
G. lanceolatum		-	-	-	-	+
G. olivaceum		-	-	+	-	-
G. parvulum		+	-	-	-	+
Gyrosigma acuminatum		-	-	+	-	-
Melosira islandica		-	-	+	-	-
M. varians		-	-	+	+	-
Navicula cryptocephala		+	-	-	+	+
N. graciloides		+	+	+	+	+
Nitzschia acuta		-	+	-	-	-
N. dissipata		-	+	-	+	+
N. palea		+	+	+	-	-

continued...

Table 14. Concluded.

Algae	Site 1	2	3	4	5	6
N. recta	a	+	-	-	+	-
Pinnularia gibba		-	-	+	-	-
Rhopalodia gibba		-	-	+	+	-
R. gibberula		-	-	+	-	+
Synedra ulna		+	+	+	+	+

[a]Diatom sample lost in transit.

\+ = present

\- = absent

Table 15. The dominant algae found at each site in the Hangingstone River.

Site	Species	Percentage of Total Population (%)
1	*Anabaena affinis*	85.0
	Diatoms[a]	13.2
2	*Lyngbya* sp.	37.0
	Anabaena affinis	22.3
	Navicula graciloides	14.9
	Navicula cryptocephala	7.1
	Achnanthes lanceolata	5.0
3	*Oscillatoria* sp.	26.6
	Batrachospermum	23.4
	Lyngbya sp.	21.7
	Navicula graciloides	12.3
4	*Lyngbya* sp.	26.6
	Navicula graciloides	25.3
	Anabaena affinis	14.5
	Oscillatoria sp.	12.1
	Pediastrum boryanum	7.7
5	*Oscillatoria* sp.	55.0
	Epithemia sorex	12.1
	Batrachospermum vagum	7.7
6	*Lyngbya* sp.	42.1
	Epithemia sorex	28.3
	Cocconeis placentula	8.8
	Synedra ulna	4.7

[a]Sample for species identifications lost.

and 98.2% of the total population, respectively). Another feature of this river was the larger number of species contributing to the overall population (e.g., Sites 3 and 6). In complete contrast, *Lyngbya* sp. (98.2%) made up almost the entire population at Site 4.

Only *Cocconeis placentula* occurred at all sites in the MacKay River, contributing significantly at Sites 3, 7, and 8 (3.0%, 4.3%, and 4.2% of the total population, respectively) (Table 12). Seven other algae were found at all but one site, *Anabaena affinis*, *Lyngbya* sp., *Chlamydomonas* spp., *Cladophora glomerata*, *Cocconeis pediculus*, *Navicula cryptocephala*, and *Navicula radiosa*. Only *Navicula radiosa* never contributed significantly at any site. *Lyngbya* sp. was dominant at most sites ranging between 4.5 and 65.4% of the total population (Table 13). Peak development occurred at Sites 4 and 5 where it accounted for 65.4% and 40.1% of the total population. *Cladophora glomerata* and *Navicula cryptocephala* were both absent from Site 2 (Table 12). The former did not assume importance until Site 6 but remained so at Sites 7 and 8 while the latter was important at Sites 1, 4, and 7 with peak contribution at Site 1 (14.5%) (Table 13). *Anabaena affinis* and *Chlamydomonas* spp. were both absent from Site 5 (Table 12). *Anabaena affinis* occurred at three sites spread out the entire length of the river, accounting for 7.1%, 70.6[illegible] and 22.4% of the total population at Sites 1, 3, and 8, respective[illegible] *Chlamydomonas* spp. contributed most at Sites 2 and 3 (50.0% and 1[illegible]7% of the total population, respectively) (Table 13). The last of the group, *Cocconeis placentula*, was only absent from Site 1, contributing significantly at Sites 3, 5, and 6 (3.0%, 5.0%, and 11.0% of the total population, respectively).

Chlorella vulgaris was the next most widely distributed algae contributing significantly at Sites 1, 2, and 5 (7.1%, 16.7%, and 19.0% of the total populations, respectively) (Table 13). Three algae contributing significantly at at least one site were found at a total of five sites, *Achnanthes lanceolata*, *Ankistrodesmus falcatus*, and *Gomphonema lanceolatum*. The former two were most prominent at Sites 8 and 7, respectively (4.1% and 4.2% of the total population,

Table 16. The distribution of dominant algae among the five rivers.

Species	River				
	M	SB	E	HS	MK
Anabaena affinis	+	D	-	D	D
Calothrix braunii	D	D	+	-	+
Gomphosphaeria aponina	-	-	-	-	D
G. lacustris v. *compacta*	D	-	-	-	-
Lyngbya sp.	D	D	D	D	D
Merismopedia glauca	D	-	-	-	+
Nostoc spp.	+	D	+	-	+
Oscillatoria sp.	D	+	-	+	+
Ankistrodesmus falcatus	+	+	-	-	D
Chlamydomonas spp.	D	+	+	+	D
Chlorella vulgaris	+	+	D	+	D
Cladophora glomerata	D	D	+	-	D
Microspora loefgrenii	D	+	-	-	+
Oedogonium sp.	-	-	-	-	D
Pediastrum biradiatum v. *emarginatum* f. *convexum*	-	-	-	-	D
P. boryanum	-	-	-	D	-
Scenedesmus acutiformis	-	-	-	-	D
S. bijuga	+	-	-	-	D
Stigeoclonium sp.	D	-	+	-	D
Cryptomonas ovata	+	-	+	+	D
Rhodomonas minutum	+	-	-	+	D
Trachelomonas sp.	+	-	+	-	D
Batrachospermum vagum	-	D	-	D	D
Achnanthes lanceolata	+	+	D	D	D
Amphipleura lindheimeri	-	-	+	-	D
Cocconeis pedicul[illegible]	+	+	+	+	D
C. placentula	D	D	D	D	D

continued ...

Table 16. Concluded.

Species	River M	SB	E	HS	MK
Cyclotella kützingianum	-	-	D	-	-
C. meneghinianum	+	+	D	+	+
Cymbella sinuata	+	-	D	+	-
C. ventricosa	+	+	D	+	+
Diatoma vulgare	-	+	D	+	-
D. vulgare v. *grandis*	-	+	D	-	-
Epithemia sorex	+	D	+	D	D
Eunotia lunaris	D	-	D	-	-
Fragilaria capucina	D	+	+	+	+
F. pinnata	+	+	D	-	+
F. vaucheriae	D	-	+	+	D
Gomphonema lanceolatum	+	+	+	+	D
G. olivaceum	+	+	D	+	+
Navicula cryptocephala	D	+	+	D	D
N. graciloides	+	+	+	D	-
N. minima v. *atomoides*	-	-	D	-	-
N. pupula	-	-	-	-	D
Nitzschia dissipata	+	-	D	+	+
N. palea	+	+	D	+	+
N. recta	+	-	D	+	D
Pinnularia gibba	+	-	-	+	D
Synedra ulna	+	D	+	+	+
Tabellaria fenestrata	D	-	-	-	-

M = Muskeg River
SB = Steepbank River
E = Ells River
HS = Hangingstone River
MK - MacKay River

D = dominant population at at least one site
+ = present

respectively), while *Gomphonema lanceolatum* peaked at Site 4 (2.4% of the total population). A large number of algae were found at four sites contributing significantly to at least one site. This group included *Scenedesmus acutiformis*, *Scenedesmus bijuga*, and *Stigeoclonium* sp., all of which were prominent at Site 7 (11.5%, 8.2%, and 4.9% of the total population, respectively); *Oedogonium* sp. and *Nitzschia recta*, both important st Site 4 (4.6% and 2.4% of the total population respectively); and *Epithemia sorex*, prominent at both Sites 5 and 6 (6.4%, and 4.4% of the total population, respectively) (Table 13). Three aglae occurred at just three sites but contributed at one significantly. *Pinnularia gibba* accounted for 7.5% of the total population at Site 1 and was not encountered again until Sites 7 and 8. *Fragilaria vaucheriae* and *Gomphosphaeria aponina* were confined to Sites 4, 5, and 6, and 5, 6, and 7, respectively, contributing significantly at Sites 5 and 6, respectively (9.6% and 7.3% of the total population). A further six algae contributed significantly but had an even more limited distribution, being found at only two sites, namely, *Oscillatoria* sp., *Rhodomonas minutum*, *Trachelomonas* sp., *Amphipleura lindheimeri*, *Cryptomonas ovata*, and *Pediastrum biradiatum* v. *emarginatum* f. *convexum*. They produced dominant populations at Sites 1, 2, 2, 4, 3, and 8, respectively (Table 13). Two algae were found at only one site, namely, *Batrachospermum vagum* at Site 6 (37.8% of the total population) and *Navicula pupula* at Site 1 (5.6% if the total population).

The diatom identification sample from Site 1 in the Hangingstone River was lost. Therefore, of the non-diatomaceous algae, none were found at every site (Table 14). *Anabaena affinis* occurred at three sites and was important at all, particularly Site 1 where it accounted for 85% of the total population (Table 15). Similarly, *Lyngbya* sp. was important everywhere it was present, constituting not less than 21.7% of the total population, except at Site 1. Both *Navicula graciloides* and *Achnanthes lanceolata* were at Sites 2 to 6, inclusive. *Navicula graciloides* made major contributions at Sites 2, 3, and 4 (14.9%, 12.3%, and 25.3% of the total population, respectively) and *Achnanthes lanceolata* did so only at Site 2 (5.0% of the total population). Another important contributor at Site 2 was *Navicula cryptocephala* (14.9% of the total population). It was not found again until Sites 5 and 6 (Table 15). *Synedra ulna* was also found consistently at Sites 2 to 6, inclusive, but made no significant contribution until Site 6 (4.7% of the total population). Both *Batrachospermum vagum* and *Cocconeis placentula* occurred at Sites 3, 5, and 6. The former was dominant at Sites 3 and 5 (23.4% and 7.7% of the total population), and the latter at only Site 6 (8.8% of the total population). *Oscillatoria* sp. was most dominant at Site 3 (26.6% of the total population) but did still occur at the next two sites. Similarly, *Epithemia sorex* was found at three consecutive sites, 4, 5, and 6, and was important at the latter two (12.1% and 28.3% of the total population). Lastly, *Pediastrum boryanum* was encountered once at Site 4 where it accounted for 7.7% of the total population.

All the algae, previously designated as cosmopolitan because they were found in every river, formed a dominant population, except *Epithemia argus*, at at least one site in each river. Only *Lyngbya* sp. and *Cocconeis placentula* formed dominant populations in all rivers (Table 16). The majority did so only in one river (e.g., *Cocconeis pediculus, Cyclotella meneghiniana, Cymbella ventricosa, Fragilaria capucina, Gomphonema lanceolatum, Gomphonema olivaceum, Nitzschia palea,* and *Synedra ulna*).

Of the next grouping (present in all but one river) only *Euglena* sp., *Chromulina* sp., *Gomphonema parvulum,* and *Surirella angustata* never formed dominant populations (at the time of the surveys). Four species (*Anabaena affinis, Cladophora glomerata, Batrachospermum vagum,* and *Epithemia sorex*) were dominant in three rivers, three species were in two rivers (*Calothrix braunii, Fragilaria vaucheriae*, and *Nitzschia recta*), and five species were in one river (*Nostoc* spp., *Oscillatoria* sp., *Cryptomonas ovata, Fragilaria pinnata,* and *Navicula graciloides*).

In contrast, a number of species possessing the most limited distribution (present in only one river) also were found in significant numbers. These included *Gomphosphaeria aponina*, *Gomphosphaeria lacustris* v. *compacta*, *Eunotia lunaris*, *Tabellaria fenestrata*, *Cyclotella kützingianum*, *Navicula minima* v. *atomoides*, *Pediastrum boryanum*, *Oedogonium* sp., *Scenedesmus acutiformis*, *Scenedesmus bijuga*, *Pediastrum biradiatum* v. *emarginatum* f. *convexum*, and *Navicula pupula*.

5.22 SUMMARY DISCUSSION

Data obtained at each site in the individual river have been averaged and mean values are presented.

Mean water depth varied little among the five rivers (Figure 32). In contrast, widths were different since the Ells River was considerably wider, particularly in the upper reaches, compared to the other rivers. All but this river possessed highly coloured water due to the muskeg they drain. The Ells River, emerging from a lake situation and flowing through less muskeg, would be expected to be the least coloured. Mean water temperatures are not directly comparable because of the different survey dates (e.g., Ells and Muskeg rivers). Highest mean pH and alkalinity were found in the Muskeg and MacKay rivers (Figure 33). pH was similar in the other three but alkalinity varied between 3.22 and 0.90 $meq \cdot L^{-1}$ (Steepbank and Ells rivers, respectively). Conductance was greatest in the MacKay and Muskeg rivers (324.5 and 303.1 $\mu mhos \cdot cm^{-1}$, respectively) and lowest in the Steepbank and Hangingstone rivers (170.3 and 189.3 $\mu mhos \cdot cm^{-1}$) (Figure 34). Calcium was the major cation in all but the MacKay River (expressing the results as $mg \cdot L^{-1}$) where it was replaced by sodium (Table 17). Magnesium also replaced sodium as the second major cation in the Ells River. These patterns changed when the results were expressed as $meq \cdot L^{-1}$ (Table 17). Calcium was always the major cation and magnesium the second, except in the MacKay River where sodium replaced magnesium. These concentrations are in accordance with the more concentrated waters of open river

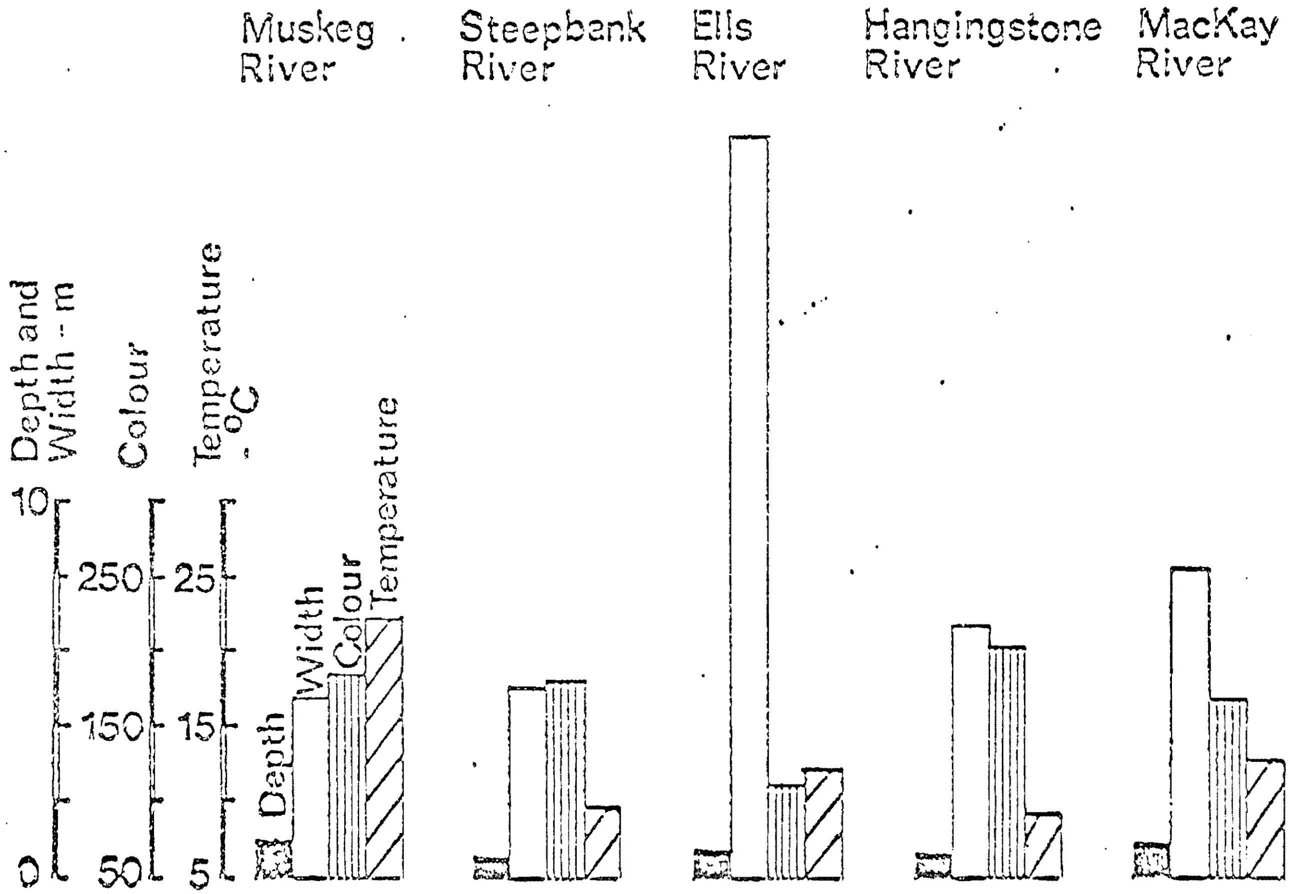

Figure 32. Mean water depth, width, colour, and temperature for the five rivers.

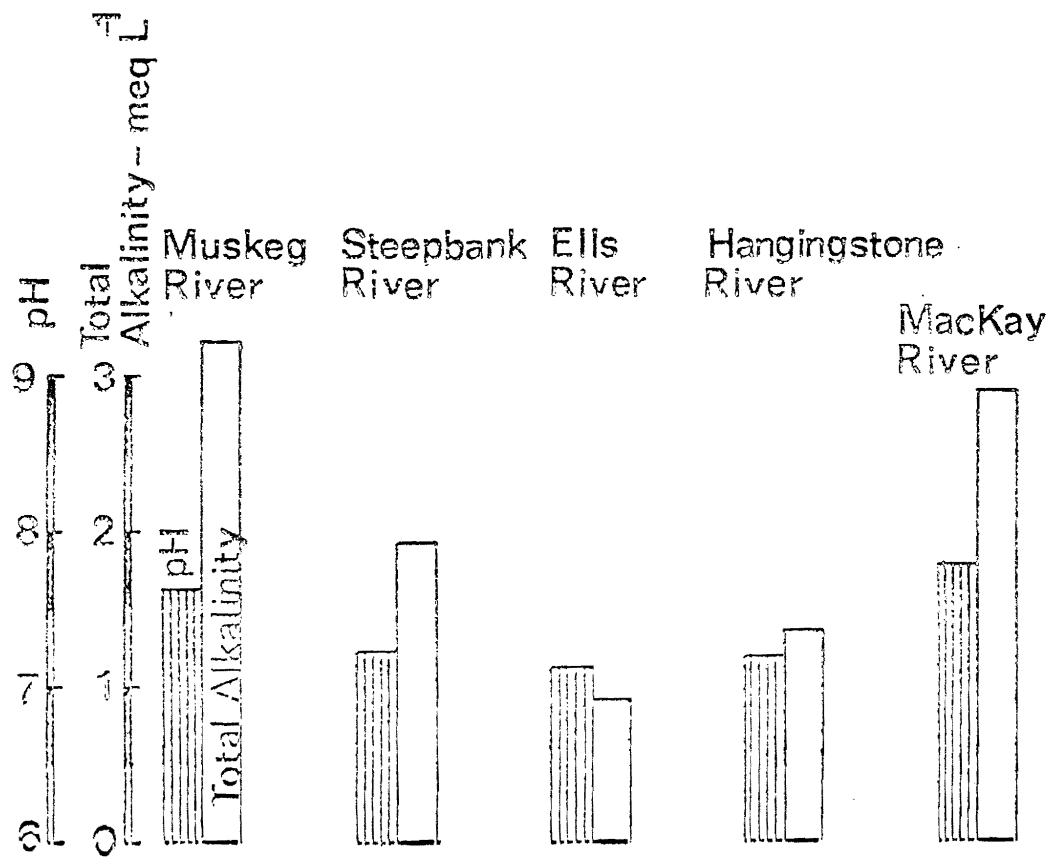

Figure 33. Mean pH and total alkalinity for the five rivers.

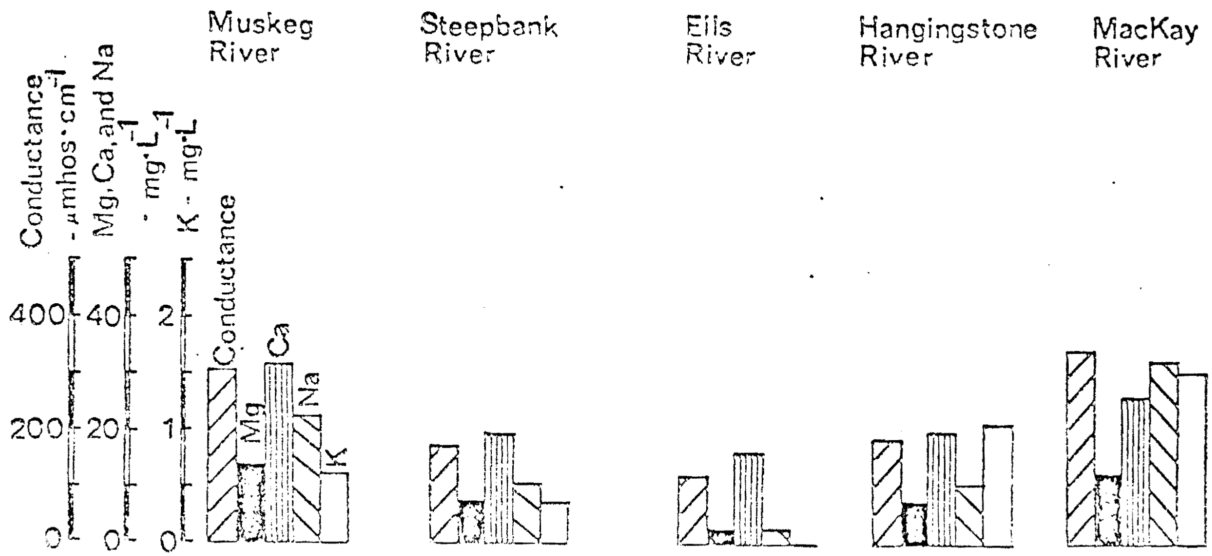

Figure 34. Mean conductance, magnesium, calcium, sodium, and potassium for the five rivers.

Table 17. The order of importance of major cations.

River	Major Cations
	$mg \cdot L^{-1}$
Muskeg	Ca > Na > Mg > K
Steepbank	Ca > Na > Mg > K
Ells	Ca > Mg > Na > K
Hangingstone	Ca > Na > Mg > K
MacKay	Na > Ca > Mg > K
	$meq \cdot L^{-1}$
Muskeg	Ca > Mg > Na > K
Steepbank	Ca > Mg > Na > K
Ells	Ca > Mg > Na > K
Hangingstone	Ca > Mg > Na > K
MacKay	Ca > Na > Mg > K

systems (Hutchinson 1957). Highest calcium values occurred in the Muskeg and MacKay rivers and the lowest in the Ells River (Figure 34). Magnesium showed a similar pattern, and again the Muskeg and MacKay rivers formed one similar pair, and the Steepbank and Hangingstone rivers another. The latter two also had almost identical sodium levels (Figure 34) while the MacKay river possessed the highest mean value and again the Ells the least. The MacKay and Hangingstone rivers had the highest potassium levels (1.53 and 1.09 $mg \cdot L^{-1}$, respectively) and again the Ells River had the lowest (<0.1 $mg \cdot L^{-1}$) (Figure 34).

A consistent pattern with respect to major anions emerged whether results were expressed as mg or $meq \cdot L^{-1}$ with $HCO_3 > SO_4^= > Cl^-$ in all but the Muskeg River (Table 18). Chloride replaced sulphate here mainly due to the high concentrations originating from the catchment area sediments or ground water at Site 5. The general patterning is typical of bicarbonate water (Hutchinson 1957). Highest sulphate levels occurred in the MacKay River (21.7 $mg \cdot L^{-1}$) while the Ells and Hangingstone rivers formed a pair with lower but similar levels (7.7 and 7.9 $mg \cdot L^{-1}$, respectively). Similarly, the Muskeg and Steepbank rivers formed another pair with the lowest levels (1.6 and 1.9 $mg \cdot L^{-1}$, respectively) (Figure 35). In contrast, the highest chloride level (12.1 $mg \cdot L^{-1}$) occurred in the Muskeg River. The MacKay and Hangingstone rivers had similar values (4.61 and 3.0 $mg \cdot L^{-1}$) and the smallest values were found in the Steepbank and Ells rivers (1.0 and <0.1 $mg \cdot L^{-1}$, respectively) (Figure 35).

Of the major nutrients, silica was most plentiful ranging on average from 4.97 to 1.54 $mg \cdot L^{-1}$ in the Muskeg and MacKay rivers, respectively (Figure 36). The value for the Hangingstone River was similar to the Muskeg River; and those of the Steepbank and Ells rivers were lower but quite similar (2.74 and 2.17 $mg \cdot L^{-1}$, respectively). Mean nitrate-nitrogen values were always greater than those of phosphate-phosphorus (Figure 36). Identical nitrate-nitrogen mean values occurred in the Steepbank and Hangingstone rivers (0.213 $mg.L^{-1}$); lower but identical values occurred in the Muskeg and Ells rivers (0.130 $mg \cdot L^{-1}$). Values for the MacKay River lay in between but closer

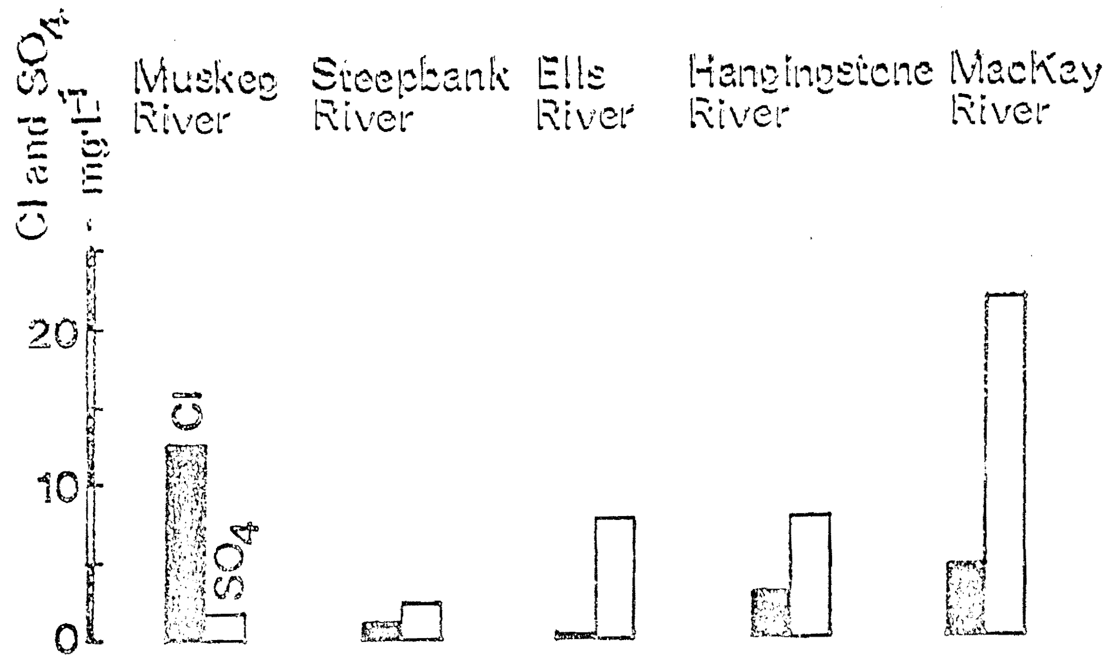

Figure 35. Mean chloride and sulphate for the five rivers.

Table 18. The order of importance of major anions.

River	Major Anions ($mg \cdot L^{-1}$ and $meq \cdot L^{-1}$)
Muskeg	HCO_3^- > CL^- > $SO_4^=$
Steepbank	HCO_3^- > $SO_4^=$ > CL^-
Ells	HCO_3^- > $SO_4^=$ > CL^-
Hangingstone	HCO_3^- > $SO_4^=$ > CL^-
MacKay	HCO_3^- > $SO_4^=$ > CL^-

to the upper levels (0.192 $mg \cdot L^{-1}$). The Steepbank and Hangingstone rivers all possessed the highest mean phosphate-phosphorus values (0.067 and 0.078 $mg \cdot L^{-1}$, respectively) (Figure 36). The Muskeg and MacKay rivers formed a similar pair (0.01⁻ and 0.022 $mg \cdot L^{-1}$, respectively) and the lowest level was found in the Ells River (0.015 $mg \cdot L^{-1}$).

Algae, particularly planktonic algae, have generally been assumed to require nitrogen and phosphorus in a ratio of 7.2:1 (Redfield 1934; Richards and Vaccaro 1956; Vollenweider 1968). If this ratio is less, it is logical to suspect that future increases in available nitrogen might be accompanied by future increases in algal standing crop size, along with possible changes in species composition. In all five rivers, this ratio was always less than 7.2:1 = N:P. Also, in general, but excepting the MacKay River, cyanophycean (nitrogen fixing) algae were the dominant algal group (Figure 40), perhaps reflecting the low N:P ratios. However, at the same time, they undoubtedly are fixing considerable quantities of nitrogen which will become available to the ecosystem. Interestingly, particularly considering the time differences among the surveys, the mean benthic algal standing crop of each river was positively correlated with both PO_4-P and NO_3-N concentrations ($r = 0.864$ and 0.825, $p = 0.10$). Thus, the higher the PO_4-P or NO_3-N concentrations, the larger was the benthic algal standing crop.

Iron values were highest in the Ells River (2.644 $mg \cdot L^{-1}$) (Figure 37), being over four times greater than the other rivers. The Muskeg, Steepbank, and MacKay rivers had very similar levels while those in Hangingstone River were twice these levels. Manganese concentrations were always low with the largest mean value found in the MacKay River (Figure 37).

As mentioned previously, benthic algal standing crops were closely related to PO_4-P and NO_3-N concentrations, with the largest mean value found in the Hangingstone River (75.4 $mg \cdot m^{-2}$ chlorophyll *a*) (Figure 38). Those of the Steepbank and MacKay rivers were similar (38.6 and 35.0 $mg \cdot m^{-2}$ chlorophyll *a*) and the Muskeg and Ells rivers

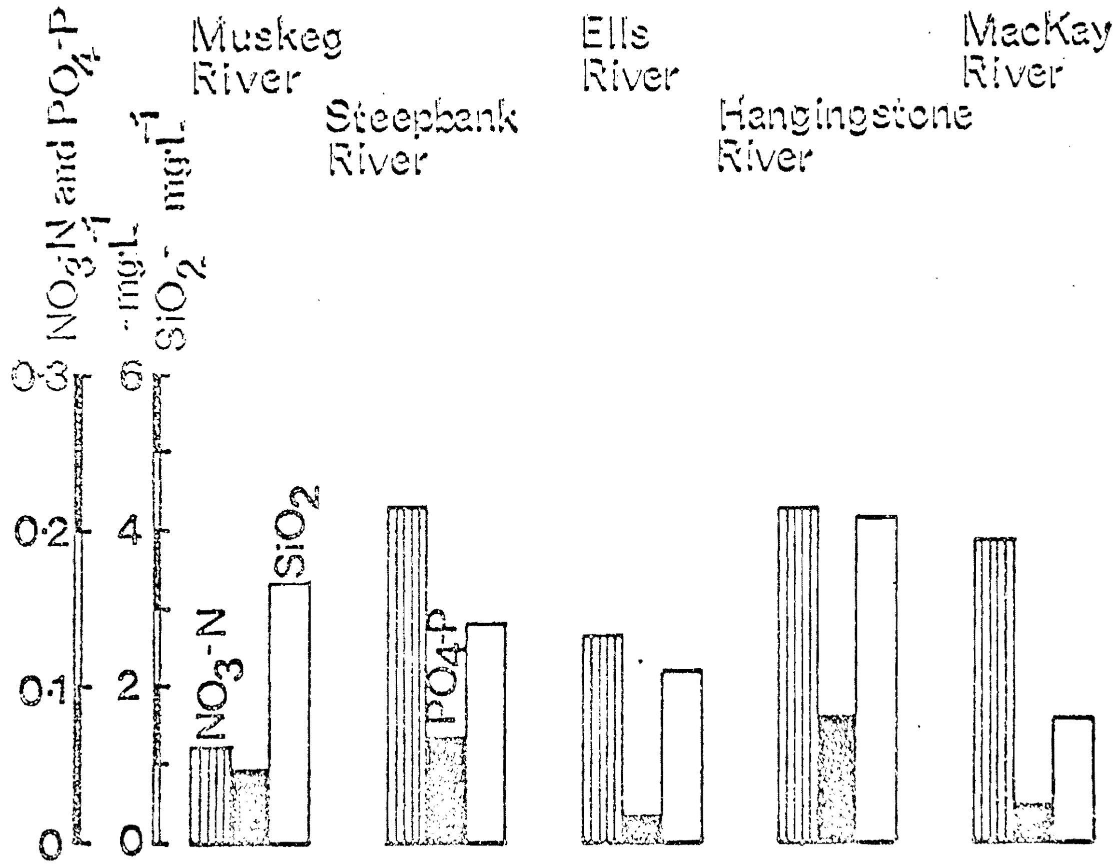

Figure 36. Mean nitrate-nitrogen, phosphate-phosphorus, and silica in the five rivers.

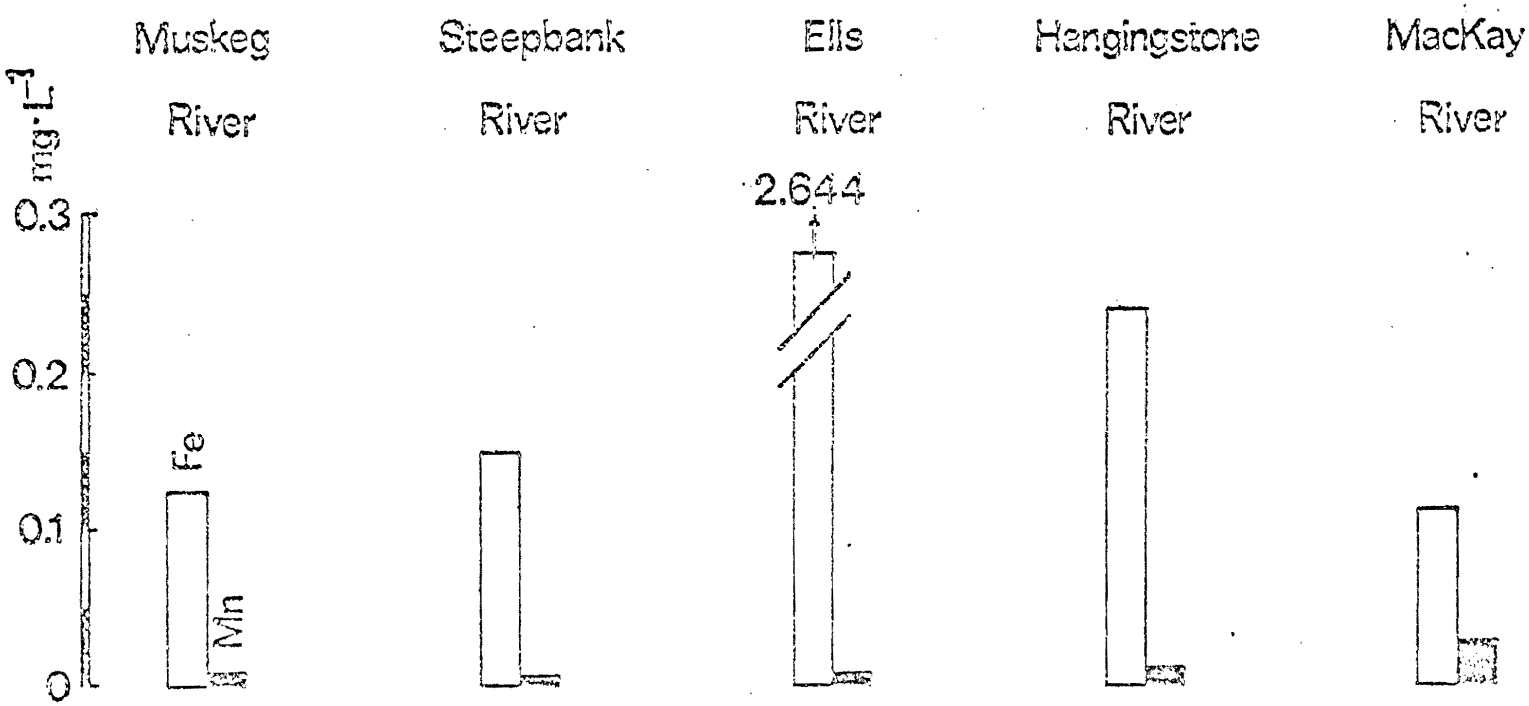

Figure 37. Mean iron and manganese in the five rivers.

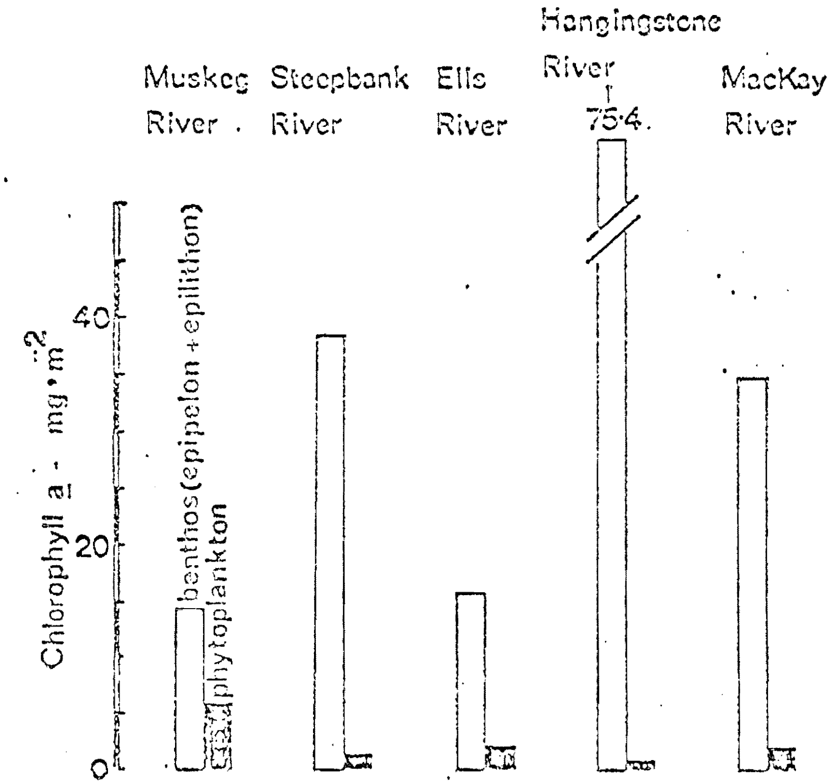

Figure 38. Mean benthic and planktonic standing crop in the five rivers.

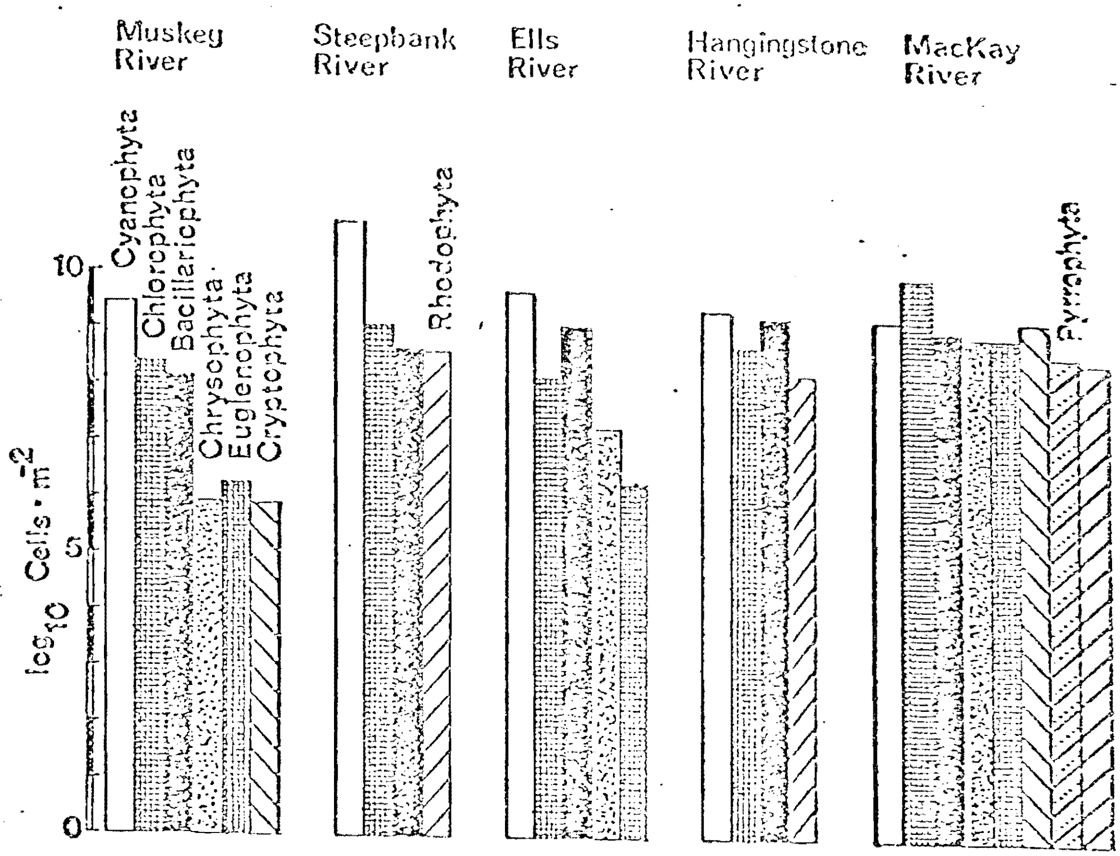

Figure 39. Mean cell numbers for the algal divisions in the five rivers.

formed another pair (14.5 and 16.0 $mg \cdot m^{-2}$ chlorophyll *a*). Again, it should be emphasized that the surveys were conducted on widely separate dates.

Cyanophycean algae dominated the standing crop in all but the MacKay River (Figures 39 and 49). This group accounted for 97.3% in the Steepbank River. *Anabaena affinis*, *Lyngbya* sp., *Calothrix braunii*, and *Nostoc* spp. were the dominant cyanophycean algae. This algal group accounted for 87.4% in the Muskeg River (Figures 39 and 40). *Lyngbya* sp. was the most important but *Anabaena affinis* and *Calothrix braunii* were both present. Other cyanophycean algae were *Gomphosphaeria lacustris* v. *compacta*, *Merismopedia glauca*, and *Oscillatoria* sp. On average, chlorophycean algae only accounted for 8.1%, although at some sites some accounted for as much as 41.1% (e.g., Site 4 -- *Cladophora glomerata*) (Table 7). Diatoms accounted for only 4.3%. A further decrease in the overall importance of cyanophycean algae occurred in the Ells River (75.4%). Here diatoms were important (21.7%). *Lyngbya* sp. was the most important cyanophycean alga while a variety of diatoms were important, depending upon the site. They included *Achnanthes lanceolata*, *Cymbella sinuata*, *Cymbella ventricosa*, *Diatoma vulgaris* v. *grandis*, *Gomphonema olivaceum*, *Cocconeis placentula*, *Cyclotella kützingianum*, *Fragilaria pinnata*, *Nitzschia palea*, *Nitzschia recta*, *Navicula minima* v. *atomoides*, *Diatoma vulgare*, and *Cyclotella meneghiniana*. In the Hangingstone River, diatoms were even more important compared to cyanophycean algae (37.0% and 47.8%, respectively) (Figures 39 and 40). *Lyngbya* sp., *Anabaena affinis*, and *Oscillatoria* sp. were the important cyanophycean algae while *Navicula cryptocephala*, *Navicula graciloides*, *Achnanthes lanceolata*, *Epithemia sorex*, *Cocconeis placentula*, and *Synedra ulna* comprised the important diatoms. Overall, chlorophycean and rhodophycean algae were minor components (11.9% and 3.3%, respectively) even though, for example, *Batrachospermum vagum* accounted for 23.4% at Site 3.

The MacKay River was the most diverse and on average all algae groups contributed at least 2.0% (Figures 39 and 40).

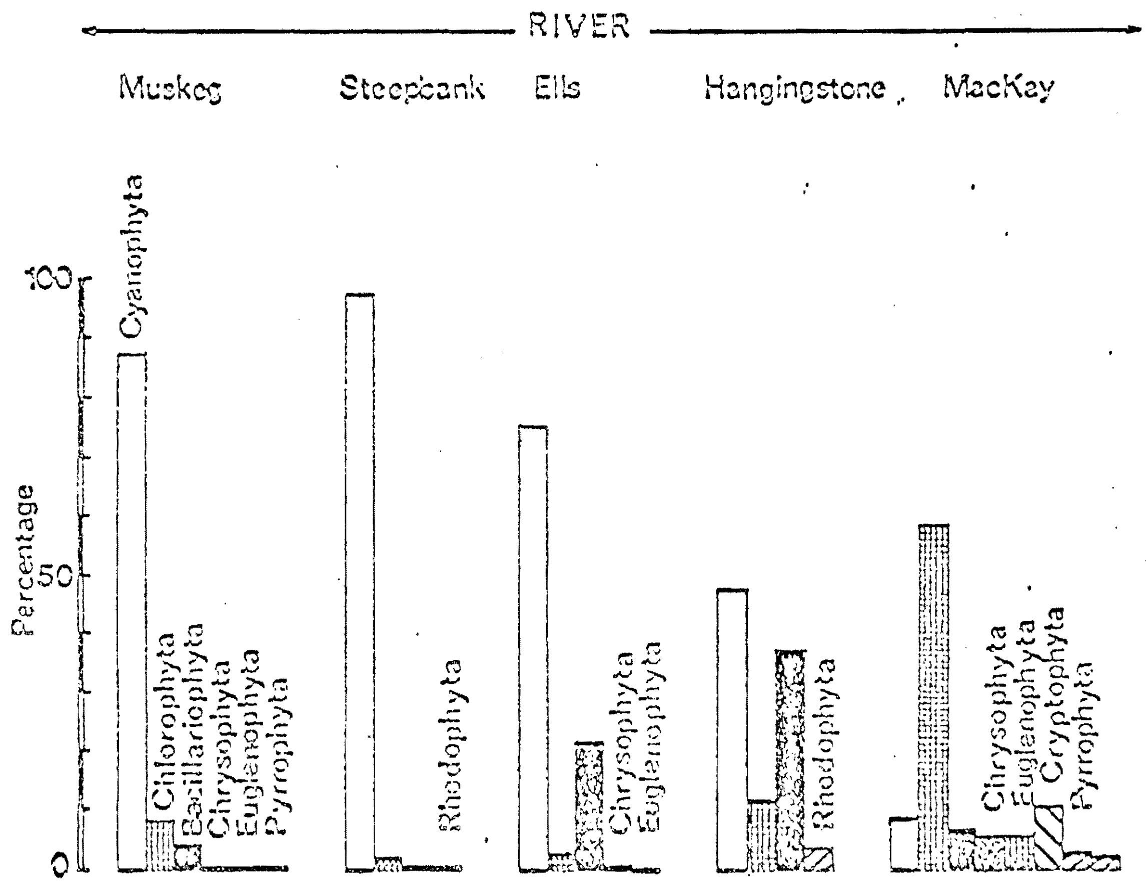

Figure 40. Mean percentage algal composition in the five rivers.

Chlorophycean algae were the most important (58.1%). Several species contributed with none being absolutely dominant (e.g., *Chlorella vulgaris, Chlamydomonas* spp., *Oedogonium* sp., *Cladophora glomerata, Stigeoclonium* sp., *Scenedesmus* spp.). Cryptophycean algae (*Cryptomonas ovata* and *Rhodomonas minutum*) comprised 10.2%; cyanophycean algae (mainly *Lyngbya* sp., *Oscillatoria* sp., and *Anabaena affinis*), 8.3%; diatoms (*Pinnularia gibba, Navicula cryptocephala, Fragilaria vaucheriae, Cocconeis pediculus, Epithemia sorex*) 6.3%; Chrysophyta and Euglenophyta both 5.1%; and Pyrrophyta and Rhodophyta 2.5% and 2.0%, respectively.

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