

**AQUATIC MACROPHYTES AND SELECTED PHYSICAL PROPERTIES OF SHINGOBEE
AND WILLIAMS LAKES, MINNESOTA, 1991-92**

by Virginia Carter, P.T. Gammon, D.O. Rosenberry, and Michael Turtora

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CONVERSION FACTORS

<u>Multiply</u>	<u>by</u>	<u>To obtain</u>
meter (m)	3.281	foot
square meter (m ²)	10.764	square foot
gram (g)	.03527	ounces

Temperature in degrees Celsius (°C) can be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = 9/5 (^{\circ}\text{C}) + 32$$

Sea level: In this report "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)-a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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ABSTRACT

This report summarizes data collected on the species composition and biomass of aquatic macrophytes in the floating-leafed and submersed aquatic zones of Shingobee and Williams Lakes in Minnesota. Plant species were identified and sampled on transects in each lake in August of 1991, and dry weights were determined for all samples. Nutrient contents were analysed for selected species. Data also were collected on the composition of species in the emergent zone of both lakes in June and August 1992. Light penetration was measured with an underwater spectroradiometer in August 1991. Hypsographic data were obtained and depth-volume calculations were made for both lakes.

INTRODUCTION

Williams and Shingobee Lakes, small lakes in north-central Minnesota, are two of several natural lakes selected by the U. S. Geological Survey and its cooperators for intensive field research on the interactions of the hydrologic cycle and nutrient balances of lakes (Siegal and Winter, 1980; LaBaugh and others, 1981). One of the objectives of the ongoing investigations at these lakes is to interrelate the physical and chemical characteristics of the water and biological production. To evaluate the species composition and biomass of aquatic macrophytes in these lakes, surveys were conducted in August 1991, and June and August 1992. This report presents the findings of these surveys and related information on Shingobee and Williams Lakes.

ACKNOWLEDGMENTS

We appreciate the assistance of Robert G. Striegl, Jr., U.S. Geological Survey, whose diving skills were required to sample the aquatic macrophytes, and Sharon Locke, University of Minnesota, who participated in the sample collection and handling.

DESCRIPTION OF STUDY AREA

Williams and Shingobee Lakes are in Hubbard County, Minnesota, about 150 miles north-northeast of Minneapolis-St. Paul and about 40 miles south-southeast of Bemidji (fig. 1). The surficial geologic materials in the Williams Lake drainage basin are mostly sand and gravel. Although the Minnesota Soil Atlas (Arneman and others, 1969) shows Williams Lake on a small northern projection of the Park Rapids-Staples glacial outwash plain, the local physiography is characteristic of

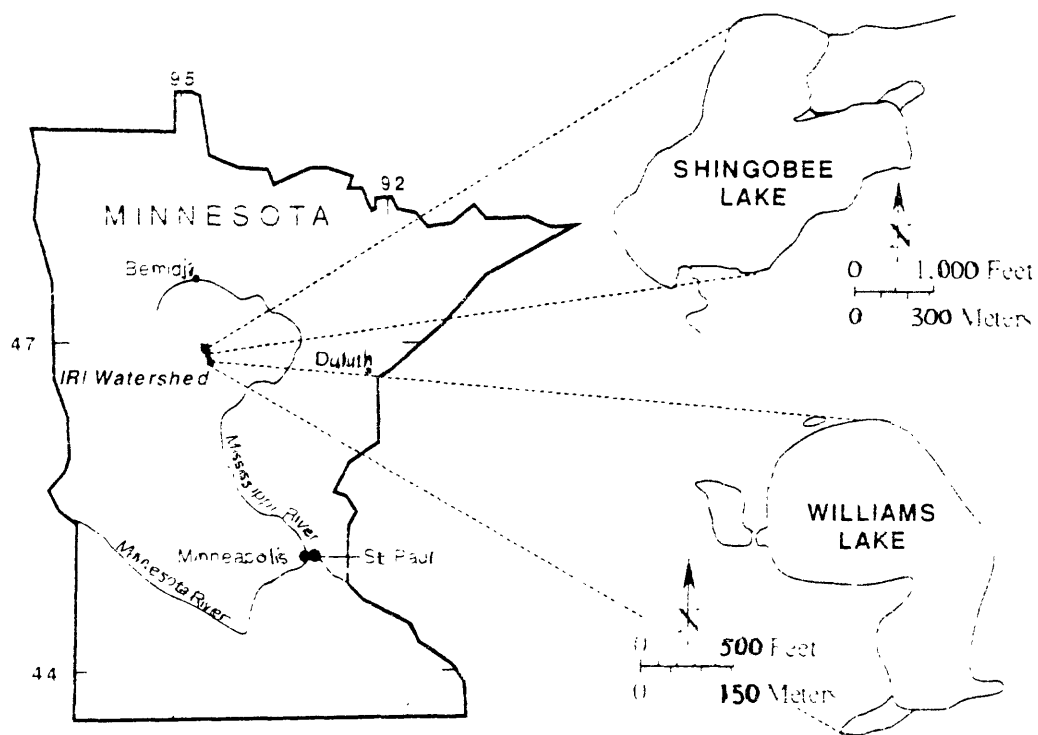


Figure 1. Map of the study area and lakes.

ice-contact deposits (Siegel and Winter, 1980). Shingobee Lake is located at the southern edge of the Itasca Moraine; it lies north of, and at a lower elevation than Williams Lake.

No streams flow in or out of Williams Lake. Annual precipitation approximately balances evaporation (Kohler and others, 1959; Siegel and Winter, 1980), and ground water fluxes largely determine the annual hydrological balance. Shingobee Lake, on the other hand, has both an inlet and an outlet stream. Water-residence time in Williams Lake is about 3.7 years whereas water-residence time is about seven months in Shingobee Lake. Ground water in the region is approximately saturated with respect to calcite because of dissolution of soil carbonates by soil carbon dioxide (Groschen, 1981). Calcium and bicarbonate are the dominant ions in the lakes and in ground water. A survey of the aquatic macrophyte distribution in Williams Lake conducted in 1982 showed that 55 percent of the total lake area was covered by macrophytes (Taylor and others, 1985). Surveys of Shingobee Lake conducted by the Minnesota Department of Natural Resources in 1976 and 1989 noted species composition and abundance for submersed and emergent macrophytes (Minnesota Department of Natural Resources, written commun., 1992).

COLLECTION AND ANALYSIS OF AQUATIC MACROPHYTE AND PHYSICAL PROPERTY DATA

A survey was conducted to analyze species composition and determine biomass of submersed aquatic vegetation in Williams and Shingobee Lakes in August, 1991. Six transects were sampled in each lake (figs 2 and 3). Transects were perpendicular to the shore across the floating-leafed zone to the depth at which no appreciable amount of vegetation was present. Samples were collected at depths of 0.5, 1, 2, 3, 4, and 5 meters in Shingobee Lake and at depths of 0.5, 1, 2, 3, 4, 5, 6, and 7 meters in Williams Lake. At each depth, three 0.305-m square (1-ft square) quadrats were randomly placed on the bottom and all vegetation within the quadrat was collected by divers. In the deeper sections where vegetation became sparse, quadrats were not placed randomly but an attempt was made to sample available plant material.

Each sample was sorted by species and each species placed in individual plastic mesh bags. Species were identified according to Fassett (1969) and Fernald (1970). (Appendix 1, table 1). Because of the heavy incrustation of calcium carbonate (CaCO_3) on the submersed plants, the samples were soaked in 100 *mM* (millimolar) acetic acid for 12 to 16 hours to dissolve the carbonate. The floating-leafed and emergent species which had only small amounts of CaCO_3 on the undersurfaces of the leaves, were not soaked. Samples were air dried for approximately 12 hours, after which they were dried in a 110°C (degrees Celsius) oven for 12 to 24 hours to determine dry weight in grams (g). Appendix 1, tables 2 and 3, list sampled biomass by species for each depth in Shingobee and Williams Lakes. Appendix 1, table 4, lists total biomass for each species by lake. Appendix 1, tables 5 and 6, list total biomass by species for each sampled depth in Shingobee and Williams Lakes. The hypsographic data in Appendix 4, tables 17 and 18, were used to calculate the area between metric contours. Appendix 1, table 9, lists estimates of total biomass for each lake based on these areas and sample data.

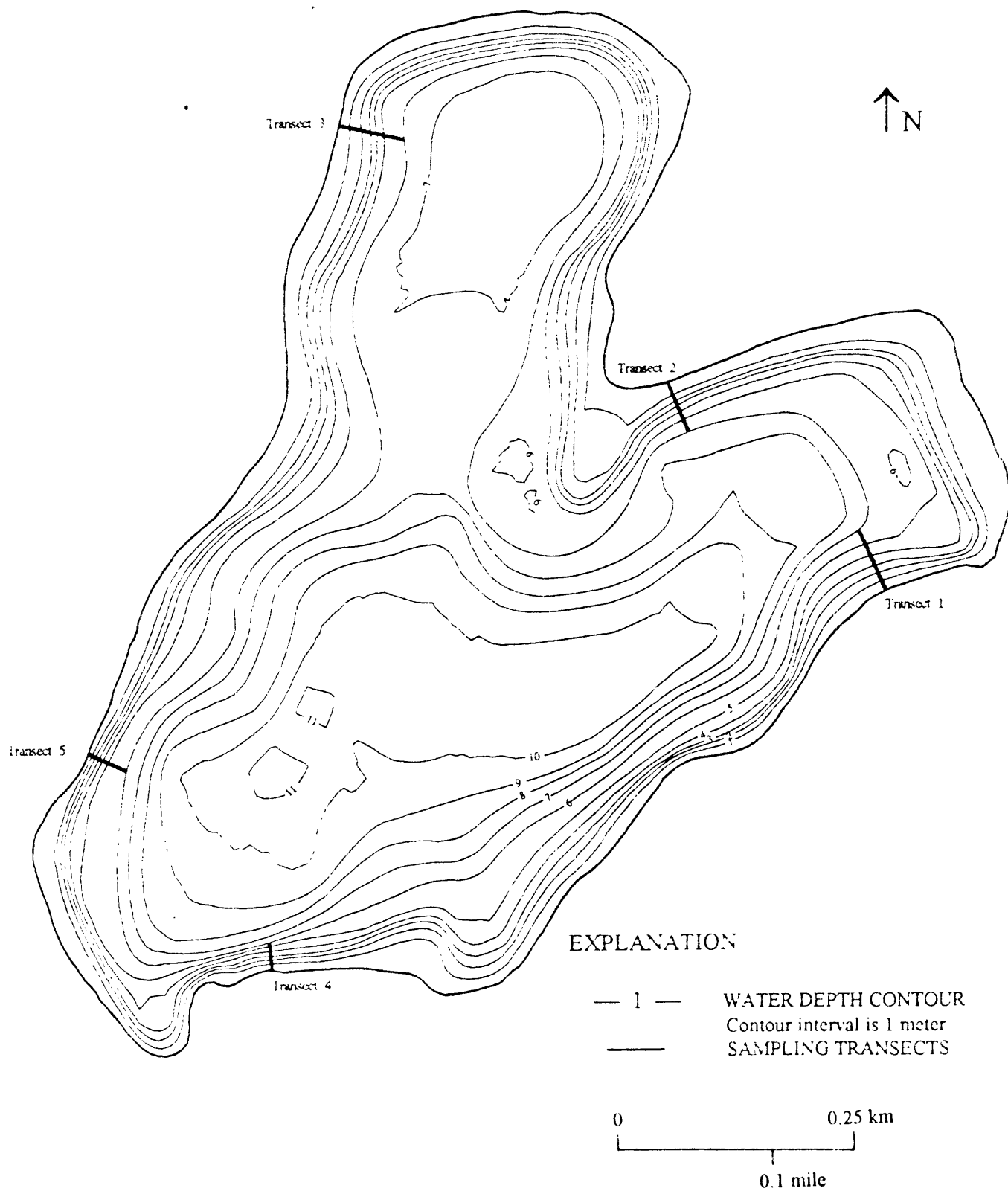


Figure 2 Bathymetric map of Shingobee Lake showing location of transects

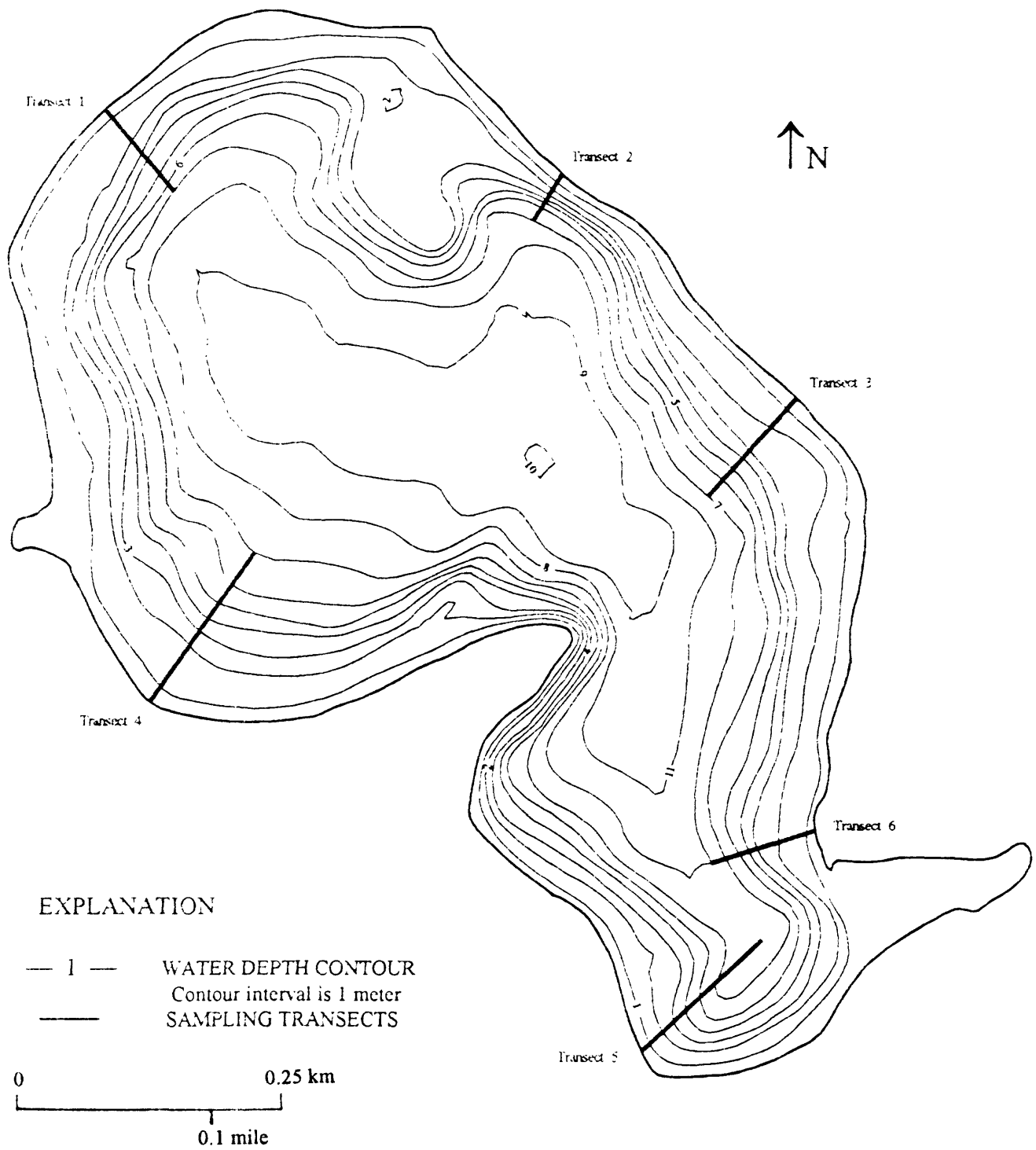


Figure 3. Bathymetric map of Williams Lake showing location of transects.

Selected samples of plant material were sent to the University of Maryland Cooperative Extension Service for analysis of elemental nutrients. Percent by weight of carbon, hydrogen and nitrogen was determined using a Leco¹ CHN-600 analyzer. Infrared absorption was used to determine carbon and hydrogen, and thermal conductivity was used to determine nitrogen. Percent by weight of phosphorus, potassium, calcium and magnesium was determined by digesting a 0.33 gram sample with nitric and perchloric acids; analysis was done on a Technicon AutoAnalyzer. Phosphorus and magnesium were determined using a colorimeter and potassium and calcium were determined using a flame photometer (Buriel, 1991, written commun.) (Appendix 2, tables 8 through 14).

In June and August 1992, a survey was made of the species composition of the emergent zone of both lakes (Appendix 3, tables 15 and 16). Species identification follows Fernald (1970), Voss (1972), and Britton and Brown (1970).

Hypsographic data for Williams Lake were obtained from a 0.616-m (2-ft)-interval bathymetric map of the lake (Minnesota Department of Natural Resources). Areas encircled by each 0.616-m (2-ft) contour were determined by planimetry, and depth-area data were interpolated to yield areas for each 1-m stratum of the lake. The area of the lake was assumed to be zero at the 9.8-meter depth; lake surface elevation is 421.38 m above sea level. For Shingobee Lake, bathymetric data were available on a 1.524-m (5-ft) interval (Minnesota Department of Natural Resources), and identical procedures were used to obtain hypsographic data for each 1-m stratum. The area of the lake was assumed to be zero at 11.9-m depth, and the elevation at the lake surface is 405.10 m above sea level.

Volumes for each stratum were calculated using the equation for a truncated cone:

$$V = 1/3(A_T + A_B + (A_TA_B)^{0.5})(B-T) \quad (1)$$

where

A_T = area at the top of each stratum,

A_B = area at the bottom of each stratum, and

$B-T$ = difference between the depths at the bottom and top of each stratum.

Hypsographic and depth-volume data are presented in Appendix 4, tables 17 and 18, and depth-volume curves are shown in figure 4.

Incident and underwater irradiance were measured with a portable submersible scanning spectroradiometer. The radiometer is equipped with a hemispherical silicon detector, a holographic grating monochromator and filter wheel to select narrow bandwidths, and an internal computer that handles all data collection and storage. Light energy, in watts per square meter ($W\ m^{-2}$), was

¹Brand names used in this report are for identification only and do not constitute endorsement by the U.S. Geological Survey.

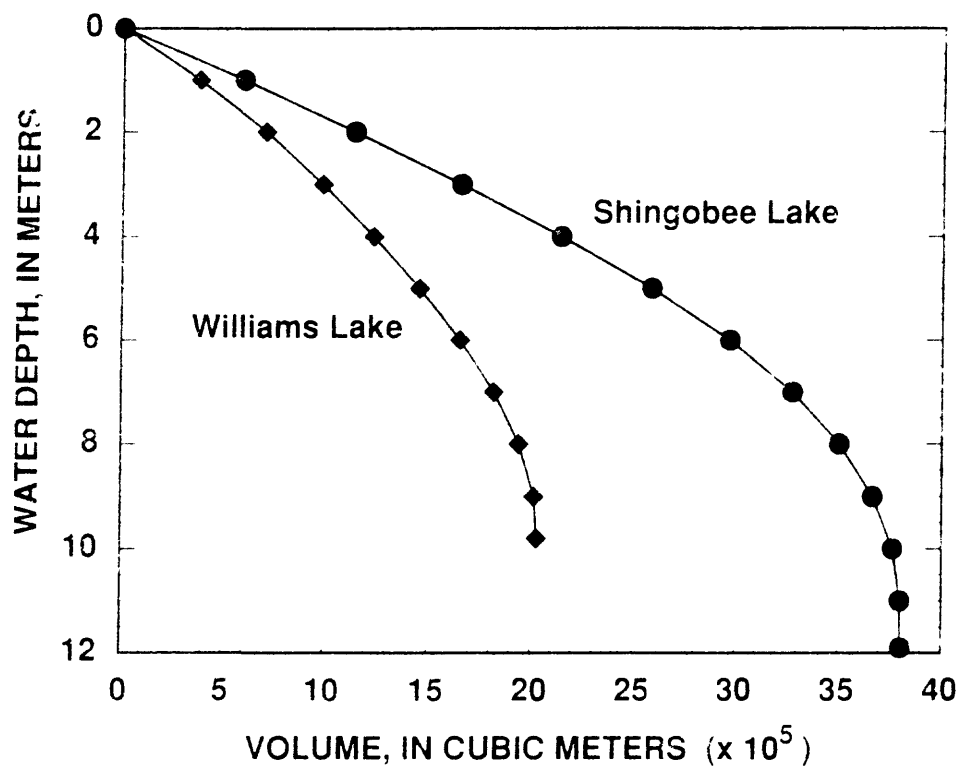


Figure 4. Depth-volume curves for Williams and Shingobee Lakes.

measured at 5-nm (nanometer) light intervals from 400 to 800 nm; each measurement represents the average of 5 complete scans. Measurements were made about 1 m from the boat in the center of the lake between 10:00 am and 2:00 pm. Attenuation coefficients (K_λ) were calculated for all individual wavelengths measured and for total photosynthetically active radiation (K_{PAR} , 400-700 nm) using Beer's Law:

$$I_z = I_0 e^{-Kz},$$

where

I_z = average irradiance at depth z , in $W\ m^{-2}$,

I_0 = average light intensity just below the water surface, and

K = vertical attenuation coefficient (m^{-1}).

Appendix 5, table 19 lists attenuation coefficients (K_{PAR}) for both lakes for selected depths.

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Appendix 1. Aquatic Macrophyte Species and Biomass Data

Table 1. Plant species collected in floating-leaved and submersed-macrophyte zones during survey of Shingobee and Williams Lakes

[Taxonomy follows Fernald (1970) and Fassett (1969)]

Lake	Species	Common name
Shingobee	<i>Ceratophyllum demersum</i> L.	hornwort
	<i>Chara</i> sp.	muskgrass
	<i>Elodea canadensis</i> Michx.	waterweed
	<i>Lemna trisulca</i> L.	star duckweed
	<i>Myriophyllum exalbescens</i> Fern.	water-milfoil
	<i>Najas flexilis</i> (Willd.) Rostk. & Schmidt	naiad
	<i>Nuphar variegatum</i> Engelm.	bullhead lily
	<i>Nymphaea odorata</i> Ait.	fragrant water-lily
	<i>Potamogeton amplifolius</i> Tuckerm.	large-leaf pondweed
	<i>Potamogeton natans</i> L.	pondweed
	<i>Potamogeton pectinatus</i> L.	sago pondweed
	<i>Potamogeton pulcher</i> Tuckerm.	pondweed
	<i>Potamogeton Richardsonii</i> (Ar. Benn.) Rydb.	red-head pondweed
	<i>Potamogeton zosteriformis</i> Fern.	flat-stem pondweed
	<i>Scirpus validus</i> Vahl	soft-stem bulrush
	<i>Sparganium eurycarpum</i>	bur-reed
	<i>Utricularia vulgaris</i> L.	bladderwort
	<i>Zizania aquatica</i> L.	wild rice
Williams	<i>Ceratophyllum demersum</i> L.	hornwort
	<i>Chara</i> sp.	muskgrass
	<i>Heteranthera dubia</i> (Jacq.) MacM.	water-stargrass
	<i>Megalodonta beckii</i> (Torr.) Greene	water marigold
	<i>Myriophyllum exalbescens</i> Fern.	water-milfoil
	<i>Najas flexilis</i> (Willd.) Rostk. & Schmidt	naiad
	<i>Nitella</i> sp.	muskgrass
	<i>Nuphar variegatum</i> Engelm.	bullhead lily
	<i>Nymphaea odorata</i> Ait.	fragrant water-lily
	<i>Potamogeton amplifolius</i> Tuckerm.	large-leaf pondweed
	<i>Potamogeton gramineus</i> v. <i>graminifolius</i> Fries.	variable pondweed
	<i>Potamogeton lucens</i> L.	pondweed
	<i>Potamogeton natans</i> L.	pondweed
	<i>Potamogeton pulcher</i> Tuckerm.	pondweed
	<i>Potamogeton Richardsonii</i> (Ar. Benn.) Rydb.	red-head pondweed
	<i>Potamogeton</i> sp. L.	pondweed
	<i>Potamogeton zosteriformis</i> Fern.	flat-stem pondweed
	<i>Sagittaria graminea</i> Michx.	arrowhead
	<i>Scirpus validus</i> Vahl	soft-stem bulrush

Table 2. Sampled biomass by species for each depth on Shingobee Lake transects

[depth in meters; biomass in grams; t = less than 0.05 gram]

Transect number	Depth	Species	Sampled biomass
1	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	2.0
1	0.5	<i>Sparganium eurycarpum</i>	13.3
1	0.5	<i>Zizania aquatica</i>	5.1
1	0.5	<i>Scirpus validus</i>	t
1	0.5	<i>Ceratophyllum demersum</i>	25.3
1	0.5	<i>Utricularia vulgaris</i>	0.6
1	0.5	<i>Elodea canadensis</i>	t
1	0.5	<i>Myriophyllum exalbescens</i>	0.2
1	0.5	<i>Lemna trisulca</i>	t
1	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	36.1
1	1	<i>Sparganium eurycarpum</i>	1.3
1	1	<i>Ceratophyllum demersum</i>	18.7
1	1	<i>Potamogeton zosteriformis</i>	1.8
1	1	<i>Utricularia vulgaris</i>	0.4
1	1	<i>Potamogeton Richardsonii</i>	t
1	2	<i>Ceratophyllum demersum</i>	20.3
1	2	<i>Potamogeton zosteriformis</i>	3.8
1	2	<i>Utricularia vulgaris</i>	0.2
1	2	<i>Elodea canadensis</i>	0.1
1	4	<i>Ceratophyllum demersum</i>	21.4
1	4	<i>Potamogeton zosteriformis</i>	4.6
1	4	<i>Potamogeton amplifolius</i>	1.4
1	5	<i>Ceratophyllum demersum</i>	0.1
2	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	0.3
2	0.5	<i>Sparganium eurycarpum</i>	2.7
2	0.5	<i>Scirpus validus</i>	20.1
2	0.5	<i>Ceratophyllum demersum</i>	3.0
2	0.5	<i>Myriophyllum exalbescens</i>	0.3
2	0.5	<i>Najas flexilis</i>	0.1
2	0.5	<i>Lemna trisulca</i>	t
2	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	39.6
2	1	<i>Scirpus validus</i>	12.1
2	1	<i>Ceratophyllum demersum</i>	14.2
2	1	<i>Potamogeton zosteriformis</i>	0.3
2	1	<i>Utricularia vulgaris</i>	0.9
2	1	<i>Myriophyllum exalbescens</i>	t
2	2	<i>Ceratophyllum demersum</i>	72.3
2	2	<i>Potamogeton zosteriformis</i>	0.7
2	2	<i>Utricularia vulgaris</i>	4.4

Table 2. Sampled biomass by species for each depth on Shingobee Lake transects -continued

[depth in meters; biomass in grams; t = less than 0.05 gram]

Transect number	Depth	Species	Sampled biomass
2	2	<i>Myriophyllum exalbescens</i>	0.1
2	4	<i>Ceratophyllum demersum</i>	26.5
2	4	<i>Potamogeton zosteriformis</i>	2.6
2	5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	t
2	5	<i>Ceratophyllum demersum</i>	10.1
2	5	<i>Potamogeton zosteriformis</i>	0.7
3	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	7.3
3	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	7.3
3	0.5	<i>Sparganium eurycarpum</i>	8.9
3	0.5	<i>Scirpus validus</i>	t
3	0.5	<i>Ceratophyllum demersum</i>	t
3	0.5	<i>Myriophyllum exalbescens</i>	t
3	0.5	<i>Chara</i> sp.	42.6
3	0.5	<i>Potamogeton Richardsonii</i>	t
3	0.5	<i>Lemna trisulca</i>	t
3	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	31.3
3	1	<i>Ceratophyllum demersum</i>	1.2
3	1	<i>Myriophyllum exalbescens</i>	t
3	1	<i>Potamogeton amplifolius</i>	1.0
3	1	<i>Chara</i> sp.	0.6
3	1	<i>Potamogeton pectinatus</i>	0.8
3	2	<i>Ceratophyllum demersum</i>	14.6
3	2	<i>Potamogeton zosteriformis</i>	t
3	2	<i>Utricularia vulgaris</i>	2.1
3	3	<i>Ceratophyllum demersum</i>	47.4
3	3	<i>Potamogeton zosteriformis</i>	t
3	3	<i>Chara</i> sp.	t
3	3	<i>Potamogeton pectinatus</i>	t
3	4	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	t
3	4	<i>Ceratophyllum demersum</i>	5.0
3	4	<i>Potamogeton zosteriformis</i>	0.6
3	5	<i>Ceratophyllum demersum</i>	0.1
4	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	28.5
4	0.5	<i>Sparganium eurycarpum</i>	14.1
4	0.5	<i>Scirpus validus</i>	17.8
4	0.5	<i>Ceratophyllum demersum</i>	9.0
4	0.5	<i>Potamogeton zosteriformis</i>	t

Table 2. Sampled biomass by species for each depth on Shingobee Lake transects -continued
[depth in meters; biomass in grams; t = less than 0.05 gram]

Transect number	Depth	Species	Sampled biomass
4	0.5	<i>Utricularia vulgaris</i>	0.3
4	0.5	<i>Elodea canadensis</i>	t
4	0.5	<i>Chara</i> sp.	10.3
4	0.5	<i>Potamogeton natans</i>	1.7
4	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	49.6
4	1	<i>Ceratophyllum demersum</i>	5.9
4	1	<i>Potamogeton zosteriformis</i>	t
4	1	<i>Utricularia vulgaris</i>	0.6
4	1	<i>Myriophyllum exalbescens</i>	0.1
4	1	<i>Chara</i> sp.	0.4
4	1	<i>Potamogeton pectinatus</i>	t
4	2	<i>Ceratophyllum demersum</i>	14.5
4	2	<i>Potamogeton zosteriformis</i>	t
4	2	<i>Utricularia vulgaris</i>	2.3
4	2	<i>Potamogeton amplifolius</i>	0.4
4	2	<i>Chara</i> sp.	0.4
4	3	<i>Potamogeton zosteriformis</i>	t
4	3	<i>Utricularia vulgaris</i>	1.2
4	4	<i>Ceratophyllum demersum</i>	19.0
4	4	<i>Utricularia vulgaris</i>	3.3
4	4	<i>Chara</i> sp.	0.6
4	4	<i>Lemna trisulca</i>	t
4	5	<i>Ceratophyllum demersum</i>	0.6
5	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	17.0
5	0.5	<i>Sparganium eurycarpum</i>	4.6
5	0.5	<i>Scirpus validus</i>	10.9
5	0.5	<i>Ceratophyllum demersum</i>	11.2
5	0.5	<i>Elodea canadensis</i>	t
5	0.5	<i>Myriophyllum exalbescens</i>	0.1
5	0.5	<i>Potamogeton pectinatus</i>	0.1
5	0.5	<i>Potamogeton natans</i>	0.3
5	0.5	<i>Lemna trisulca</i>	t
5	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	1.0
5	1	<i>Scirpus validus</i>	14.9
5	1	<i>Ceratophyllum demersum</i>	11.4
5	1	<i>Potamogeton zosteriformis</i>	t
5	1	<i>Myriophyllum exalbescens</i>	t
5	1	<i>Potamogeton natans</i>	0.4

Table 2. Sampled biomass by species for each depth on Shingobee Lake transects -continued

[depth in meters; biomass in grams; t = less than 0.05 gram]

Transect number	Depth	Species	Sampled biomass
5	2	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	1.2
5	2	<i>Ceratophyllum demersum</i>	28.5
5	2	<i>Potamogeton zosteriformis</i>	t
5	2	<i>Potamogeton Richardsonii</i>	0.5
5	3	<i>Ceratophyllum demersum</i>	22.5
5	3	<i>Utricularia vulgaris</i>	0.7
5	4	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	1.2
5	4	<i>Ceratophyllum demersum</i>	18.4
5	4	<i>Potamogeton zosteriformis</i>	1.9
5	5	<i>Ceratophyllum demersum</i>	0.6
6	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	2.0
6	0.5	<i>Scirpus validus</i>	30.3
6	0.5	<i>Ceratophyllum demersum</i>	2.5
6	0.5	<i>Utricularia vulgaris</i>	0.1
6	0.5	<i>Chara</i> sp.	62.3
6	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	18.3
6	1	<i>Scirpus validus</i>	0.6
6	1	<i>Ceratophyllum demersum</i>	9.2
6	1	<i>Potamogeton zosteriformis</i>	t
6	1	<i>Utricularia vulgaris</i>	0.3
6	1	<i>Myriophyllum exalbescens</i>	0.3
6	1	<i>Potamogeton pulcher</i>	0.2
6	2	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	2.5
6	2	<i>Ceratophyllum demersum</i>	10.5
6	2	<i>Potamogeton zosteriformis</i>	t
6	2	<i>Utricularia vulgaris</i>	2.9
6	2	<i>Potamogeton pulcher</i>	0.8
6	3	<i>Ceratophyllum demersum</i>	15.3
6	3	<i>Potamogeton zosteriformis</i>	0.6
6	3	<i>Potamogeton Richardsonii</i>	0.8
6	4	<i>Ceratophyllum demersum</i>	7.6
6	4	<i>Utricularia vulgaris</i>	t
6	5	<i>Ceratophyllum demersum</i>	1.4

Table 3. Sampled biomass by species for each depth on Williams Lake transects

[depth in meters; biomass in grams; t = less than 0.05 gram]

Transect number	Depth	Species	Sampled biomass
1	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	9.9
1	0.5	<i>Potamogeton zosteriformis</i>	4.2
1	0.5	<i>Myriophyllum exalbescens</i>	1.3
1	0.5	<i>Potamogeton pectinatus</i>	0.1
1	0.5	<i>Potamogeton natans</i>	1.5
1	0.5	<i>Najas flexilis</i>	2.7
1	0.5	<i>Heteranthera dubia</i>	1.0
1	0.5	<i>Megalodonta beckii</i>	0.2
1	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	15.0
1	1	<i>Ceratophyllum demersum</i>	t
1	1	<i>Potamogeton zosteriformis</i>	0.3
1	1	<i>Myriophyllum exalbescens</i>	8.8
1	1	<i>Potamogeton amplifolius</i>	1.4
1	1	<i>Potamogeton natans</i>	0.1
1	1	<i>Najas flexilis</i>	t
1	1	<i>Heteranthera dubia</i>	19.6
1	1	<i>Megalodonta beckii</i>	0.2
1	2	<i>Ceratophyllum demersum</i>	0.4
1	2	<i>Potamogeton zosteriformis</i>	17.3
1	2	<i>Myriophyllum exalbescens</i>	0.8
1	2	<i>Potamogeton amplifolius</i>	1.5
1	2	<i>Potamogeton pectinatus</i>	4.9
1	2	<i>Heteranthera dubia</i>	26.7
1	2	<i>Megalodonta beckii</i>	28.7
1	3	<i>Ceratophyllum demersum</i>	0.3
1	3	<i>Potamogeton zosteriformis</i>	8.4
1	3	<i>Myriophyllum exalbescens</i>	4.2
1	3	<i>Potamogeton amplifolius</i>	2.7
1	3	<i>Megalodonta beckii</i>	12.3
1	4	<i>Potamogeton zosteriformis</i>	0.4
1	4	<i>Potamogeton amplifolius</i>	5.2
1	4	<i>Chara</i> sp.	10.8
1	4	<i>Heteranthera dubia</i>	t
1	4	<i>Megalodonta beckii</i>	6.5
1	5	<i>Potamogeton zosteriformis</i>	t
1	5	<i>Potamogeton amplifolius</i>	4.0
1	5	<i>Megalodonta beckii</i>	0.3
1	6	<i>Ceratophyllum demersum</i>	50.6

Table 3. Sampled biomass by species for each depth on Williams Lake transects -continued

[depth in meters; biomass in grams; t = less than 0.05 g]

Transect number	Depth	Species	Sampled biomass
2	0.5	<i>Sagittaria graminea</i>	0.7
2	0.5	<i>Ceratophyllum demersum</i>	t
2	0.5	<i>Potamogeton amplifolius</i>	4.2
2	0.5	<i>Potamogeton pectinatus</i>	0.2
2	0.5	<i>Najas flexilis</i>	0.8
2	0.5	<i>Heteranthera dubia</i>	1.0
2	1	<i>Potamogeton zosteriformis</i>	6.6
2	1	<i>Myriophyllum exalbescens</i>	0.2
2	1	<i>Potamogeton amplifolius</i>	2.7
2	1	<i>Potamogeton pectinatus</i>	0.8
2	1	<i>Najas flexilis</i>	t
2	1	<i>Heteranthera dubia</i>	0.2
2	1	<i>Megalodonta beckii</i>	1.0
2	2	<i>Potamogeton zosteriformis</i>	2.4
2	2	<i>Potamogeton pectinatus</i>	7.7
2	2	<i>Megalodonta beckii</i>	22.5
2	3	<i>Ceratophyllum demersum</i>	0.1
2	3	<i>Myriophyllum exalbescens</i>	2.6
2	3	<i>Potamogeton amplifolius</i>	2.8
2	3	<i>Potamogeton pectinatus</i>	3.0
2	3	<i>Heteranthera dubia</i>	3.0
2	3	<i>Megalodonta beckii</i>	3.0
2	4	<i>Ceratophyllum demersum</i>	t
2	4	<i>Myriophyllum exalbescens</i>	1.8
2	4	<i>Potamogeton amplifolius</i>	12.3
2	4	<i>Heteranthera dubia</i>	6.2
2	5	<i>Myriophyllum exalbescens</i>	0.8
2	5	<i>Potamogeton amplifolius</i>	1.1
2	6	<i>Potamogeton zosteriformis</i>	0.2
2	6	<i>Myriophyllum exalbescens</i>	0.2
2	6	<i>Potamogeton amplifolius</i>	t
3	0.5	<i>Chara</i> sp.	8.9
3	0.5	<i>Najas flexilis</i>	0.1
3	0.5	<i>Potamogeton gramineus</i> var <i>graminifolius</i>	t
3	1	<i>Sagittaria graminea</i>	2.0
3	1	<i>Potamogeton zosteriformis</i>	0.3
3	1	<i>Myriophyllum exalbescens</i>	0.8
3	1	<i>Potamogeton amplifolius</i>	1.8

Table 3. Sampled biomass by species for each depth on Williams Lake transects -continued
[depth in meters; biomass in grams; t = less than 0.05 g]

Transect number	Depth	Species	Sampled biomass
3	1	<i>Chara</i> sp.	4.0
3	1	<i>Najas flexilis</i>	0.6
3	1	<i>Megalodonta beckii</i>	0.2
3	1	<i>Potamogeton gramineus</i> var <i>graminifolius</i>	0.5
3	1	<i>Potamogeton lucens</i>	0.8
3	2	<i>Myriophyllum exalbescens</i>	0.5
3	2	<i>Chara</i> sp.	47.5
3	2	<i>Potamogeton lucens</i>	1.8
3	3	<i>Potamogeton zosteriformis</i>	24.5
3	3	<i>Myriophyllum exalbescens</i>	1.6
3	3	<i>Potamogeton amplifolius</i>	13.2
3	3	<i>Chara</i> sp.	t
3	3	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	13.8
3	4	<i>Potamogeton zosteriformis</i>	t
3	4	<i>Myriophyllum exalbescens</i>	1.4
3	4	<i>Potamogeton amplifolius</i>	4.2
3	4	<i>Chara</i> sp.	40.0
3	5	<i>Myriophyllum exalbescens</i>	0.4
3	5	<i>Potamogeton amplifolius</i>	t
3	5	<i>Potamogeton pectinatus</i>	0.1
3	5	<i>Heteranthera dubia</i>	0.1
3	6	<i>Ceratophyllum demersum</i>	0.1
3	6	<i>Myriophyllum exalbescens</i>	0.2
3	6	<i>Potamogeton</i> sp.	t
4	0.5	<i>Sagittaria graminea</i>	0.1
4	0.5	<i>Potamogeton zosteriformis</i>	1.0
4	0.5	<i>Myriophyllum exalbescens</i>	1.9
4	0.5	<i>Chara</i> sp.	6.2
4	0.5	<i>Najas flexilis</i>	0.9
4	0.5	<i>Megalodonta beckii</i>	0.2
4	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	5.0
4	1	<i>Sagittaria graminea</i>	t
4	1	<i>Myriophyllum exalbescens</i>	3.9
4	1	<i>Chara</i> sp.	4.9
4	1	<i>Potamogeton pectinatus</i>	6.1
4	1	<i>Potamogeton pulcher</i>	0.9
4	1	<i>Potamogeton natans</i>	1.1
4	1	<i>Najas flexilis</i>	7.4

Table 3. Sampled biomass by species for each depth on Williams Lake transects -continued

[depth in meters; biomass in grams; t = less than 0.05 g]

Transect number	Depth	Species	Sampled biomass
4	1	<i>Potamogeton</i> sp.	8.7
4	1	<i>Potamogeton lucens</i>	1.4
4	2	<i>Potamogeton zosteriformis</i>	0.8
4	2	<i>Myriophyllum exalbescens</i>	1.3
4	2	<i>Potamogeton amplifolius</i>	4.8
4	2	<i>Potamogeton natans</i>	18.9
4	2	<i>Heteranthera dubia</i>	5.3
4	2	<i>Megalodonta beckii</i>	13.5
4	3	<i>Potamogeton zosteriformis</i>	1.1
4	3	<i>Myriophyllum exalbescens</i>	11.8
4	3	<i>Potamogeton amplifolius</i>	4.5
4	3	<i>Megalodonta beckii</i>	33.6
4	4	<i>Ceratophyllum demersum</i>	2.0
4	4	<i>Potamogeton zosteriformis</i>	0.1
4	4	<i>Myriophyllum exalbescens</i>	0.3
4	4	<i>Potamogeton amplifolius</i>	2.5
4	4	<i>Chara</i> sp.	0.3
4	5	<i>Myriophyllum exalbescens</i>	0.4
4	5	<i>Potamogeton amplifolius</i>	2.9
4	5	<i>Megalodonta beckii</i>	0.1
4	6	<i>Potamogeton zosteriformis</i>	0.4
4	6	<i>Myriophyllum exalbescens</i>	0.2
4	6	<i>Potamogeton amplifolius</i>	0.2
4	6	<i>Potamogeton gramineus</i> var <i>graminifolius</i>	0.2
5	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	10.6
5	0.5	<i>Sagittaria graminea</i>	2.2
5	0.5	<i>Myriophyllum exalbescens</i>	0.1
5	0.5	<i>Chara</i> sp.	t
5	0.5	<i>Potamogeton natans</i>	3.5
5	0.5	<i>Najas flexilis</i>	4.2
5	0.5	<i>Heteranthera dubia</i>	t
5	0.5	<i>Potamogeton gramineus</i> var <i>graminifolius</i>	0.7
5	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	17.3
5	1	<i>Myriophyllum exalbescens</i>	3.0
5	1	<i>Potamogeton amplifolius</i>	5.9
5	1	<i>Potamogeton natans</i>	15.6
5	1	<i>Najas flexilis</i>	t
5	1	<i>Heteranthera dubia</i>	1.1

Table 3. Sampled biomass by species for each depth on Williams Lake transects -continued

[depth in meters; biomass in grams; t = less than 0.05 g]

Transect number	Depth	Species	Sampled biomass
5	1	<i>Megalodonta beckii</i>	0.7
5	3	<i>Potamogeton zosteriformis</i>	0.7
5	3	<i>Myriophyllum exalbescens</i>	1.0
5	3	<i>Potamogeton amplifolius</i>	6.2
5	3	<i>Megalodonta beckii</i>	7.2
5	4	<i>Myriophyllum exalbescens</i>	0.3
5	5	<i>Ceratophyllum demersum</i>	t
5	5	<i>Potamogeton zosteriformis</i>	t
5	5	<i>Myriophyllum exalbescens</i>	t
5	5	<i>Potamogeton</i> sp.	t
5	6	<i>Ceratophyllum demersum</i>	t
5	6	<i>Potamogeton zosteriformis</i>	t
5	6	<i>Myriophyllum exalbescens</i>	t
5	6	<i>Potamogeton</i> sp.	t
6	0.5	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	11.9
6	0.5	<i>Scirpus validus</i>	1.2
6	0.5	<i>Sagittaria graminea</i>	1.8
6	0.5	<i>Ceratophyllum demersum</i>	t
6	0.5	<i>Potamogeton zosteriformis</i>	0.1
6	0.5	<i>Myriophyllum exalbescens</i>	0.4
6	0.5	<i>Potamogeton amplifolius</i>	0.4
6	0.5	<i>Potamogeton natans</i>	7.9
6	0.5	<i>Najas flexilis</i>	3.5
6	0.5	<i>Potamogeton</i> sp.	t
6	1	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	30.0
6	1	<i>Potamogeton zosteriformis</i>	t
6	1	<i>Myriophyllum exalbescens</i>	0.8
6	1	<i>Potamogeton amplifolius</i>	3.9
6	1	<i>Chara</i> sp.	t
6	1	<i>Potamogeton natans</i>	20.2
6	1	<i>Najas flexilis</i>	0.4
6	1	<i>Heteranthera dubia</i>	1.9
6	1	<i>Megalodonta beckii</i>	0.3
6	2	<i>Potamogeton zosteriformis</i>	5.1
6	2	<i>Myriophyllum exalbescens</i>	3.1
6	2	<i>Potamogeton amplifolius</i>	4.1
6	2	<i>Potamogeton pectinatus</i>	0.6
6	2	<i>Potamogeton natans</i>	4.0

Table 3. Sampled biomass by species for each depth on Williams Lake transects -continued

[depth in meters; biomass in grams; t = less than 0.05 g]

Transect number	Depth	Species	Sampled biomass
6	2	<i>Najas flexilis</i>	0.1
6	2	<i>Heteranthera dubia</i>	13.0
6	2	<i>Megalodonta beckii</i>	4.9
6	3	<i>Potamogeton zosteriformis</i>	3.3
6	3	<i>Myriophyllum exalbescens</i>	1.0
6	3	<i>Potamogeton amplifolius</i>	19.5
6	3	<i>Heteranthera dubia</i>	10.7
6	3	<i>Megalodonta beckii</i>	1.2
6	4	<i>Potamogeton zosteriformis</i>	1.5
6	4	<i>Myriophyllum exalbescens</i>	2.4
6	4	<i>Potamogeton amplifolius</i>	5.6
6	4	<i>Chara</i> sp.	t
6	4	<i>Heteranthera dubia</i>	0.3
6	4	<i>Megalodonta beckii</i>	1.8
6	5	<i>Potamogeton zosteriformis</i>	0.4
6	5	<i>Myriophyllum exalbescens</i>	1.5
6	5	<i>Potamogeton</i> sp.	0.3
6	5	<i>Nitella</i> sp.	2.5
6	6	<i>Potamogeton zosteriformis</i>	0.1
6	6	<i>Myriophyllum exalbescens</i>	0.7
6	6	<i>Potamogeton</i> sp.	0.1
6	7	<i>Nitella</i> sp.	0.5

Table 4. Total biomass collected during survey for each species found in Shingobee and Williams Lakes

[leaders (-----) indicate species not found; biomass in grams]

Species	Shingobee Lake Biomass	Williams Lake Biomass
<i>Ceratophyllum demersum</i>	491.5	53.5
<i>Chara</i> sp.	117.2	122.7
<i>Elodea canadensis</i>	0.2	-----
<i>Heteranthera dubia</i>	-----	90.4
<i>Lemna trisulca</i>	0.1	-----
<i>Megalodonta beckii</i>	-----	138.2
Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	-----	13.8
<i>Myriophyllum exalbescens</i>	1.1	59.5
<i>Najas flexilis</i>	0.1	20.7
<i>Nitella</i> sp.	-----	3.0
<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	238.1	99.7
<i>Potamogeton Richardsonii</i>	1.4	-----
<i>Potamogeton amplifolius</i>	2.7	117.3
<i>Potamogeton gramineus</i> v. <i>graminifolius</i>	-----	1.4
<i>Potamogeton lucens</i>	-----	4.1
<i>Potamogeton natans</i>	2.4	72.8
<i>Potamogeton pectinatus</i>	1.0	23.5
<i>Potamogeton pulcher</i>	0.9	0.9
<i>Potamogeton</i> sp.	-----	9.2
<i>Potamogeton zosteriformis</i>	18.0	79.3
<i>Sagittaria graminea</i>	-----	6.7
<i>Scirpus validus</i>	106.8	1.2
<i>Sparganium eurycarpum</i>	44.8	-----
<i>Utricularia vulgaris</i>	20.2	-----
<i>Zizania aquatica</i>	5.1	-----
Total biomass	1051.7	918.0

Table 5. Biomass collected during survey for each species at each sampled depth in Shingobee Lake

[biomass in grams; t = less than 0.05; leader (-----) indicates species not found; *Nym.* = *Nymphaea*; *Nuph.* = *Nuphar*]

Species	Depth in meters					
	0.5	1	2	3	4	5
<i>Ceratophyllum demersum</i>	51.0	60.5	160.6	108.6	98.0	12.8
<i>Chara</i> sp.	115.2	0.9	0.4	t	0.6	-----
<i>Elodea canadensis</i>	0.1	-----	0.1	-----	-----	-----
<i>Lemna trisulca</i>	0.1	-----	-----	-----	t	-----
<i>Myriophyllum exalbescens</i>	0.6	0.4	0.1	-----	-----	-----
<i>Najas flexilis</i>	0.1	-----	-----	-----	-----	-----
<i>Nym. odorata</i> , <i>Nuph. variegatum</i>	57.2	176.0	3.7	-----	1.2	t
<i>Potamogeton Richardsonii</i>	t	t	0.5	0.8	-----	-----
<i>Potamogeton amplifolius</i>	-----	1.0	0.4	-----	1.4	-----
<i>Potamogeton natans</i>	2.0	0.4	-----	-----	-----	-----
<i>Potamogeton pectinatus</i>	0.1	0.9	-----	t	-----	-----
<i>Potamogeton pulcher</i>	-----	0.2	0.8	-----	-----	-----
<i>Potamogeton zosteriformis</i>	t	2.2	4.7	0.7	9.8	0.7
<i>Scirpus validus</i>	79.2	27.7	-----	-----	-----	-----
<i>Sparganium eurycarpum</i>	43.4	1.3	-----	-----	-----	-----
<i>Utricularia vulgaris</i>	0.9	2.1	11.9	2.0	3.3	-----
<i>Zizania aquatica</i>	5.1	-----	-----	-----	-----	-----
Total biomass	355.0	273.6	183.1	112.1	114.3	13.5

Table 6. Biomass collected during survey for each species at each sampled depth in Williams Lake

[biomass in grams; t = less than 0.05; leader (----) indicates species not found; *Nym.* = *Nymphaea*; *Nup.* = *Nuphar*]

Species	Depth in meters							
	0.5	1	2	3	4	5	6	7
<i>Megalodonta beckii</i>	0.4	2.3	69.6	57.3	8.3	0.3	----	----
<i>Ceratophyllum demersum</i>	t	t	0.4	0.3	2.0	t	50.7	----
<i>Chara</i> sp.	15.1	8.9	47.5	t	51.2	----	----	----
<i>Heteranthera dubia</i>	2.1	22.9	44.9	13.7	6.6	0.1	----	----
Mixed <i>P. zosteriformis</i> / <i>Chara</i> sp.	----	----	----	13.8	----	----	----	----
<i>Myriophyllum exalbescens</i>	3.6	17.4	5.7	22.1	6.2	3.2	1.3	----
<i>Najas flexilis</i>	12.1	8.5	0.1	----	----	----	----	----
<i>Nitella</i> sp.	----	----	----	----	----	2.5	----	0.5
<i>Nym. odorata</i> , <i>Nup. variegatum</i>	32.4	67.3	----	----	----	----	----	----
<i>Potamogeton amplifolius</i>	4.6	15.7	10.4	48.8	29.7	8.0	0.2	----
<i>P. gramineus</i> v. <i>graminifolius</i>	0.7	0.5	----	----	----	----	0.2	----
<i>Potamogeton lucens</i>	----	2.3	1.8	----	----	----	----	----
<i>Potamogeton natans</i>	12.9	37.0	22.9	----	----	----	----	----
<i>Potamogeton pectinatus</i>	0.3	6.8	13.2	3.0	----	0.1	----	----
<i>Potamogeton pulcher</i>	----	0.9	----	----	----	----	----	----
<i>Potamogeton</i> sp.	----	8.7	----	----	----	0.3	0.1	----
<i>Potamogeton zosteriformis</i>	5.2	7.1	25.6	38.1	2.1	0.4	0.8	----
<i>Sagittaria graminea</i>	4.7	2.0	----	----	----	----	----	----
<i>Scirpus validus</i>	1.2	----	----	----	----	----	----	----
Total biomass	95.3	208.3	242.2	197.2	106.1	15.0	53.4	0.5

Table 7. Total biomass of aquatic macrophytes for Williams and Shingobee Lakes calculated from sample data.

[m² = square meters; g ft⁻¹ = grams per square foot; g m⁻² = grams per square meter]

Lake	Depth	Area (m ² x 10 ⁵)	Mean biomass (g ft ⁻¹)	Mean biomass (g m ⁻²)	Total biomass (g x 10 ⁵)
Shingobee	0-1	0.575	59.17	636.91	366.22
	1-2	0.419	38.06	409.68	171.66
	2-3	0.246	29.53	317.86	78.19
	3-4	0.302	22.65	243.80	73.63
	4-5	0.492	11.62	125.08	61.54
	5-6	0.742	2.70	29.06	21.56
				Total	772.80

Total biomass in metric tons = 77.28

Williams					
	0-1	0.375	15.89	171.04	64.14
	1-2	0.537	40.95	440.79	236.70
	2-3	0.432	39.94	429.91	185.72
	3-4	0.256	26.00	279.86	71.65
	4-5	0.260	10.38	111.73	29.05
	5-6	0.245	5.69	61.25	15.01
	6-7	0.395	7.70	82.88	32.74
				Total	635.00

Total biomass in metric tons = 63.50

Appendix 2. Plant Nutrient Composition

Table 8. Percent of carbon (C) in selected species collected during survey of Shingobee and Williams Lakes

[If more than one sample, the percent of C is calculated as the mean; No. = number; % = percent; Std = standard deviation]

Lake	Species	Plant part	No. of samples	C %	Std.
Shingobee	<i>Ceratophyllum demersum</i>	stems & leaves	3	37.1	0.14
	<i>Chara</i> sp.	stems & leaves	3	35.3	1.09
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	42.6	0.20
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	stems & leaves	3	38.2	0.23
	<i>Potamogeton Richardsonii</i>	stems & leaves	2	39.7	0.32
	<i>Potamogeton amplifolius</i>	stems & leaves	2	40.0	0.83
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	39.9	0.31
	<i>Scirpus validus</i>	stems & leaves	2	42.1	0.24
	<i>Scirpus validus</i>	roots	1	43.0	-----
	<i>Sparganium eurycarpum</i>	leaves	3	37.6	0.81
	<i>Utricularia vulgaris</i>	stems & leaves	3	37.0	0.41
	<i>Zizania aquatica</i>	stems	2	39.5	0.73
	<i>Zizania aquatica</i>	leaves	3	38.9	1.10
Williams	<i>Ceratophyllum demersum</i>	stems & leaves	3	39.4	1.16
	<i>Chara</i> sp.	stems & leaves	3	32.5	1.54
	<i>Heteranthera dubia</i>	leaves	3	38.7	0.11
	<i>Megalodonta beckii</i>	stems & leaves	3	43.9	0.20
	<i>Megalodonta beckii</i>	leaves	3	39.0	1.40
	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	stems & leaves	3	40.5	0.18
	<i>Myriophyllum exalbescens</i>	stems & leaves	3	41.4	0.61
	<i>Najas flexilis</i>	stems & leaves	3	41.1	0.07
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	46.0	0.22
	<i>Potamogeton amplifolius</i>	stems & leaves	1	41.6	-----
	<i>Potamogeton amplifolius</i>	leaves	3	42.8	0.57
	<i>Potamogeton natans</i>	leaves	3	44.5	0.49
	<i>Potamogeton natans</i>	stems	3	40.6	0.13
	<i>Potamogeton pectinatus</i>	stems & leaves	3	40.2	2.87
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	45.3	2.82
	<i>Sagittaria graminea</i>	leaves	3	40.0	0.61

Table 9. Percent of nitrogen (N) in selected species collected during survey of Shingobee and Williams Lakes

[If more than one sample, the percent of N is calculated as the mean; No. = number; % = percent; Std = standard deviation]

Lake	species	plant part	No. of samples	N %	Std
Shingobee	<i>Ceratophyllum demersum</i>	stems & leaves	3	2.0	0.04
	<i>Chara</i> sp.	stems & leaves	3	2.3	0.29
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	2.9	0.41
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	stems & leaves	3	1.4	0.30
	<i>Potamogeton Richardsonii</i>	stems & leaves	2	2.4	0.06
	<i>Potamogeton amplifolius</i>	stems & leaves	2	2.2	0.57
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	2.0	0.17
	<i>Scirpus validus</i>	stems & leaves	2	0.7	0.14
	<i>Scirpus validus</i>	roots	1	0.5	-----
	<i>Sparganium eurycarpum</i>	leaves	3	1.4	0.37
	<i>Utricularia vulgaris</i>	stems & leaves	3	2.0	0.04
	<i>Zizania aquatica</i>	stems	2	1.1	0.07
	<i>Zizania aquatica</i>	leaves	3	2.4	0.10
Williams	<i>Ceratophyllum demersum</i>	stems & leaves	3	2.2	0.12
	<i>Chara</i> sp.	stems & leaves	3	2.1	0.11
	<i>Heteranthera dubia</i>	leaves	3	1.7	0.10
	<i>Megalodonta beckii</i>	stems & leaves	3	1.8	0.11
	<i>Megalodonta beckii</i>	leaves	3	2.6	0.31
	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	stems & leaves	3	1.7	0.04
	<i>Myriophyllum exalbescens</i>	stems & leaves	3	2.1	0.13
	<i>Najas flexilis</i>	stems & leaves	3	1.8	0.11
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	2.9	0.17
	<i>Potamogeton amplifolius</i>	stems & leaves	1	1.4	-----
	<i>Potamogeton amplifolius</i>	leaves	3	1.9	0.23
	<i>Potamogeton natans</i>	leaves	3	2.8	0.23
	<i>Potamogeton natans</i>	stems	3	1.3	0.02
	<i>Potamogeton pectinatus</i>	stems & leaves	3	1.7	0.30
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	2.4	0.09
	<i>Sagittaria graminea</i>	leaves	3	2.2	0.01

Table 10. Percent of hydrogen (H) in selected species collected during survey of Shingobee and Williams Lakes

[If more than one sample, the percent of H is calculated as the mean; No. = number; % = percent; Std = standard deviation]

Lake	species	plant part	No. of samples	H %	Std
Shingobee	<i>Ceratophyllum demersum</i>	stems & leaves	3	5.7	0.06
	<i>Chara</i> sp.	stems & leaves	3	5.8	0.26
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	5.8	0.16
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	stems & leaves	3	5.6	0.06
	<i>Potamogeton Richardsonii</i>	stems & leaves	2	6.1	0.11
	<i>Potamogeton amplifolius</i>	stems & leaves	2	6.1	0.23
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	6.2	0.06
	<i>Scirpus validus</i>	stems & leaves	2	6.0	0.06
	<i>Scirpus validus</i>	roots	1	6.1	-----
	<i>Sparganium eurycarpum</i>	leaves	3	5.5	0.13
	<i>Utricularia vulgaris</i>	stems & leaves	3	5.7	0.01
	<i>Zizania aquatica</i>	stems	2	5.6	0.09
	<i>Zizania aquatica</i>	leaves	3	5.6	0.16
Williams	<i>Ceratophyllum demersum</i>	stems & leaves	3	6.1	0.08
	<i>Chara</i> sp.	stems & leaves	3	4.7	0.29
	<i>Heteranthera dubia</i>	leaves	3	5.6	0.04
	<i>Megalodonta beckii</i>	stems & leaves	3	6.3	0.11
	<i>Megalodonta beckii</i>	leaves	3	5.6	0.25
	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	stems & leaves	3	5.8	0.01
	<i>Myriophyllum exalbescens</i>	stems & leaves	3	6.1	0.08
	<i>Najas flexilis</i>	stems & leaves	3	6.4	0.17
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	6.2	0.02
	<i>Potamogeton amplifolius</i>	stems & leaves	1	6.5	-----
	<i>Potamogeton amplifolius</i>	leaves	3	6.2	0.06
	<i>Potamogeton natans</i>	leaves	3	6.3	0.03
	<i>Potamogeton natans</i>	stems	3	6.1	0.09
	<i>Potamogeton pectinatus</i>	stems & leaves	3	5.9	0.32
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	7.0	0.43
	<i>Sagittaria graminea</i>	leaves	3	6.1	0.10

Table 11. Percent of phosphorus (P) in selected species collected during survey of Shingobee and Williams Lakes

[If more than one sample, the percent of P is calculated as the mean; No. = number; % = percent; Std = standard deviation]

Lake	species	plant part	No. of samples	P %	Std
Shingobee	<i>Ceratophyllum demersum</i>	stems & leaves	3	0.2	0.01
	<i>Chara</i> sp.	stems & leaves	3	0.1	0.02
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	0.2	0.05
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	stems & leaves	3	0.2	0.06
	<i>Potamogeton Richardsonii</i>	stems & leaves	2	0.2	0.01
	<i>Potamogeton amplifolius</i>	stems & leaves	2	0.2	0.04
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	0.1	0.03
	<i>Scirpus validus</i>	stems & leaves	2	0.1	0.01
	<i>Scirpus validus</i>	roots	1	0.1	-----
	<i>Sparganium eurycarpum</i>	leaves	3	0.2	0.06
	<i>Utricularia vulgaris</i>	stems & leaves	3	0.1	0.02
	<i>Zizania aquatica</i>	stems	2	0.2	0.02
	<i>Zizania aquatica</i>	leaves	3	0.1	0.08
Williams	<i>Ceratophyllum demersum</i>	stems & leaves	3	0.1	0.01
	<i>Chara</i> sp.	stems & leaves	3	0.1	0.00
	<i>Heteranthera dubia</i>	leaves	3	0.1	0.01
	<i>Megalodonta beckii</i>	stems & leaves	3	0.1	0.00
	<i>Megalodonta beckii</i>	leaves	3	0.1	0.01
	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	stems & leaves	3	0.1	0.00
	<i>Myriophyllum exalbescens</i>	stems & leaves	3	0.1	0.01
	<i>Najas flexilis</i>	stems & leaves	3	0.1	0.02
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	0.1	0.02
	<i>Potamogeton amplifolius</i>	stems & leaves	1	0.1	-----
	<i>Potamogeton amplifolius</i>	leaves	3	0.1	0.02
	<i>Potamogeton natans</i>	leaves	3	0.1	0.00
	<i>Potamogeton natans</i>	stems	3	0.1	0.01
	<i>Potamogeton pectinatus</i>	stems & leaves	3	0.1	0.01
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	0.1	0.00
	<i>Sagittaria graminea</i>	leaves	3	0.1	0.01

Table 12. Percent of potassium (K) in selected species collected during survey of Shingobee and Williams Lakes

[If more than one sample, the percent of K is calculated as the mean; No. = number; % = percent; Std = standard deviation]

Lake	species	plant part	No. of samples	K %	Std
Shingobee	<i>Ceratophyllum demersum</i>	stems & leaves	3	0.1	0.00
	<i>Chara</i> sp.	stems & leaves	3	0.1	0.05
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	1.2	0.29
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	stems & leaves	3	2.3	0.11
	<i>Potamogeton Richardsonii</i>	stems & leaves	2	0.3	0.01
	<i>Potamogeton amplifolius</i>	stems & leaves	2	0.2	0.00
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	0.1	0.05
	<i>Scirpus validus</i>	stems & leaves	2	0.8	0.04
	<i>Scirpus validus</i>	roots	1	0.8	-----
	<i>Sparganium eurycarpum</i>	leaves	3	3.1	0.61
	<i>Utricularia vulgaris</i>	stems & leaves	3	0.2	0.04
	<i>Zizania aquatica</i>	stems	2	0.9	0.05
	<i>Zizania aquatica</i>	leaves	3	0.4	0.50
Williams	<i>Ceratophyllum demersum</i>	stems & leaves	3	0.1	0.00
	<i>Chara</i> sp.	stems & leaves	3	0.1	0.01
	<i>Heteranthera dubia</i>	leaves	3	0.1	0.03
	<i>Megalodonta beckii</i>	stems & leaves	3	0.1	0.01
	<i>Megalodonta beckii</i>	leaves	3	0.2	0.12
	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	stems & leaves	3	0.9	0.03
	<i>Myriophyllum exalbescens</i>	stems & leaves	3	0.1	0.00
	<i>Najas flexilis</i>	stems & leaves	3	0.1	0.00
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	0.2	0.02
	<i>Potamogeton amplifolius</i>	stems & leaves	1	0.4	-----
	<i>Potamogeton amplifolius</i>	leaves	3	0.3	0.10
	<i>Potamogeton natans</i>	leaves	3	0.0	0.01
	<i>Potamogeton natans</i>	stems	3	0.1	0.02
	<i>Potamogeton pectinatus</i>	stems & leaves	3	0.2	0.04
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	0.1	0.00
	<i>Sagittaria graminea</i>	leaves	3	0.4	0.05

Table 13. Percent of calcium (Ca) in selected species collected during survey of Shingobee and Williams Lakes

[If more than one sample, the percent of Ca is calculated as the mean; No. = number; % = percent; Std = standard deviation]

Lake	species	plant part	No. of samples	Ca %	Std
Shingobee	<i>Ceratophyllum demersum</i>	stems & leaves	3	2.4	0.01
	<i>Chara</i> sp.	stems & leaves	3	3.3	1.13
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	2.0	1.04
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	stems & leaves	3	1.4	0.25
	<i>Potamogeton Richardsonii</i>	stems & leaves	2	1.6	0.10
	<i>Potamogeton amplifolius</i>	stems & leaves	2	1.9	0.34
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	1.5	0.32
	<i>Scirpus validus</i>	stems & leaves	2	0.2	0.00
	<i>Scirpus validus</i>	roots	1	0.2	-----
	<i>Sparganium eurycarpum</i>	leaves	3	2.4	0.60
	<i>Utricularia vulgaris</i>	stems & leaves	3	2.3	0.21
	<i>Zizania aquatica</i>	stems	2	0.4	0.04
	<i>Zizania aquatica</i>	leaves	3	0.6	0.82
Williams	<i>Ceratophyllum demersum</i>	stems & leaves	3	4.1	0.68
	<i>Chara</i> sp.	stems & leaves	3	11.4	1.03
	<i>Heteranthera dubia</i>	leaves	3	3.2	0.10
	<i>Megalodonta beckii</i>	stems & leaves	3	1.7	0.07
	<i>Megalodonta beckii</i>	leaves	3	4.4	1.71
	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	stems & leaves	3	2.1	0.17
	<i>Myriophyllum exalbescens</i>	stems & leaves	3	2.2	0.51
	<i>Najas flexilis</i>	stems & leaves	3	2.3	0.30
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	1.5	0.02
	<i>Potamogeton amplifolius</i>	stems & leaves	1	2.0	-----
	<i>Potamogeton amplifolius</i>	leaves	3	2.3	0.06
	<i>Potamogeton natans</i>	leaves	3	1.7	0.17
	<i>Potamogeton natans</i>	stems	3	2.5	0.08
	<i>Potamogeton pectinatus</i>	stems & leaves	3	3.0	1.08
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	1.8	0.18
	<i>Sagittaria graminea</i>	leaves	3	2.2	0.38

Table 14. Percent of magnesium (Mg) in selected species collected during survey of Shingobee and Williams Lakes

[If more than one sample, the percent of Mg is calculated as the mean; No. = number; % = percent; Std = standard deviation]

Lake	species	plant part	No. of samples	Mg %	Std
Shingobee	<i>Ceratophyllum demersum</i>	stems & leaves	3	0.4	0.06
	<i>Chara</i> sp.	stems & leaves	3	0.1	0.03
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	0.3	0.06
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	stems & leaves	3	0.3	0.04
	<i>Potamogeton Richardsonii</i>	stems & leaves	2	0.2	0.00
	<i>Potamogeton amplifolius</i>	stems & leaves	2	0.2	0.01
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	0.2	0.02
	<i>Scirpus validus</i>	stems & leaves	2	0.1	0.01
	<i>Scirpus validus</i>	roots	1	0.1	-----
	<i>Sparganium eurycarpum</i>	leaves	3	0.6	0.06
	<i>Utricularia vulgaris</i>	stems & leaves	3	0.8	0.00
	<i>Zizania aquatica</i>	stems	2	0.2	0.00
	<i>Zizania aquatica</i>	leaves	3	0.1	0.16
Williams	<i>Ceratophyllum demersum</i>	stems & leaves	3	0.2	0.02
	<i>Chara</i> sp.	stems & leaves	3	0.4	0.06
	<i>Heteranthera dubia</i>	leaves	3	0.2	0.00
	<i>Megalodonta beckii</i>	stems & leaves	3	0.1	0.01
	<i>Megalodonta beckii</i>	leaves	3	0.2	0.05
	Mixed <i>P. zosteriformis</i> and <i>Chara</i> sp.	stems & leaves	3	0.2	0.00
	<i>Myriophyllum exalbescens</i>	stems & leaves	3	0.1	0.01
	<i>Najas flexilis</i>	stems & leaves	3	0.2	0.02
	<i>Nymphaea odorata</i> , <i>Nuphar variegatum</i>	leaves	3	0.2	0.01
	<i>Potamogeton amplifolius</i>	stems & leaves	1	0.2	-----
	<i>Potamogeton amplifolius</i>	leaves	3	0.2	0.02
	<i>Potamogeton natans</i>	leaves	3	0.1	0.01
	<i>Potamogeton natans</i>	stems	3	0.1	0.01
	<i>Potamogeton pectinatus</i>	stems & leaves	3	0.1	0.02
	<i>Potamogeton zosteriformis</i>	stems & leaves	3	0.1	0.01
	<i>Sagittaria graminea</i>	leaves	3	0.3	0.03

Appendix 3. Plant Species in the Emergent Zones of Shingobee and Williams Lakes

Table 15. Plant species identified in the emergent zone of Shingobee Lake.

[The emergent zone was widest along the south and east shores, and narrow along the north and west shores. Soils were primarily organic. The emergent zone was dominated by *Carex* sp. and *Phalaris arundinacea* with *Phragmites communis* and *Typha latifolia* dominant in some locales. In this table, the emergent zone does not include the floating-leafed zone.]

Species	Common name
<i>Acer rubrum</i> L.	red maple
<i>Agrostis gigantea</i> Roth	black bent
<i>Aster</i> sp.	aster
<i>Bidens cernua</i> L.	stick-tight
<i>Bromus ciliatus</i> L.	brome grass
<i>Calamagrostis canadensis</i> (Michx.) Nutt.	blue-joint
<i>Caltha palustris</i> L.	cowslip
<i>Campanula aparinoides</i> Pursh.	marsh bellflower
<i>Carex pseudo-cyperus</i> L.	cyperus-like sedge
<i>Carex lanuginosa</i> Michx.	wooly sedge
<i>Carex rostrata</i> Stokes	beaked sedge
<i>Carex stricta</i> Lam.	tussock sedge
<i>Carex trichocarpa</i> Muhl.	sedge
<i>Cicuta bulbifera</i> L.	bulb-bearing water-hemlock
<i>Cornus stolonifera</i> Michx.	red osier
<i>Epilobium leptophyllum</i> Raf.	narrow-leafed willowherb
<i>Equisetum</i> sp.	horsetail, scouring-rush
<i>Eupatorium</i> sp.	
<i>Galium</i> sp.	bedstraw
<i>Hippuris vulgaris</i> L.	mare's-tail
<i>Impatiens capensis</i> Meerb.	jewelweed
<i>Iris virginica</i>	iris
<i>Muhlenbergia glomerata</i> (Willd.) Trin.	satin-grass, dropseed
<i>Phalaris arundinacea</i> L.	reed canary-grass
<i>Phragmites communis</i> Trin.	common reed-grass
<i>Picea mariana</i> (Mill.) BSP	black spruce
<i>Polygonum lapathifolium</i> L.	smartweed
<i>Rumex</i> sp.	dock
<i>Sagittaria latifolia</i> Willd.	duck-potato
<i>Salix</i> sp.	willow
<i>Scirpus validus</i> Vahl.	soft-stem bulrush
<i>Sparganium androcladum</i> (Engelm.) Morong	branching bur-reed
<i>Sparganium eurycarpum</i> Engelm.	broad-fruited bur-reed
<i>Typha latifolia</i> L.	common cattail
<i>Alnus</i> sp.	alder
<i>Zizania aquatica</i> L.	wild rice

Table 16. Plant species identified in the emergent zone of Williams Lake.

[The emergent zone of Williams Lake is narrow and has soils ranging from sands and gravels to organic. The species composition listed below reflects the heterogeneity of the shore line; different species were dominant in different locales. In this table, the emergent zone does not include the floating-leafed zone.]

Species	Common name
<i>Agrostis hyemalis</i> (Walt.) BSP	ticklegrass, hairgrass
<i>Bidens cernua</i> L.	stick-tight
<i>Calamagrostis canadensis</i> (Michaux) Nutt.	blue joint
<i>Calamagrostis neglecta</i> (Ehrh.) Gaertn., Mey. & Scherb.	reed bentgrass
<i>Campanula aparinoides</i> Pursh	marsh bellflower
<i>Carex atherodes</i> Spreng.	awned sedge
<i>Carex Bebbii</i> Olney	Bebb's sedge
<i>Carex hirta</i> L.	hairy sedge
<i>Carex hyalinolepis</i> Steud.	sedge
<i>Carex hystrix</i> Muhl.	porcupine sedge
<i>Carex lasiocarpa</i> Ehrh.	slender sedge
<i>Carex rostrata</i> Stokes	beaked sedge
<i>Carex viridula</i> Michx.	sedge
<i>Carex vulpinoidea</i> Michx.	sedge
<i>Cicuta bulbifera</i> L.	bulb-bearing water hemlock
<i>Echinochloa muricata</i> (Beauv.) Fern.	grass
<i>Eleocharis acicularis</i> (L.) R. & S.	needle spike-rush
<i>Eleocharis Smallii</i> Britt.	Small's spike-rush
<i>Epilobium glandulosum</i> Lehm.	willow-herb
<i>Epilobium leptophyllum</i> Raf.	narrow-leaved willow-herb
<i>Equisetum</i> sp.	horsetail
<i>Fraxinus pennsylvanica</i> Marsh.	red ash
<i>Glyceria borealis</i> (Nash) Batchelder	float-grass
<i>Glyceria grandis</i> S. Wats.	reed-meadow grass
<i>Glyceria striata</i> (Lam.) Hitchc.	fowl-meadow grass
<i>Glyceria striata</i> var. <i>stricta</i> (Scribn.) Fern.	fowl-meadow grass
<i>Hypericum punctatum</i> Lam.	spotted St. John's-wort
<i>Impatiens capensis</i> Meers.	jewelweed
<i>Juncus brevicaudatus</i> (Engelm.) Fern.	narrow-panicked rush
<i>Juncus Dudleyi</i> Wieg.	Dudley's rush
<i>Juncus nodosus</i> L.	knotted rush
<i>Linaria canadensis</i> (L.) Dumont	old-field-toadflax
<i>Lobelia siphilicita</i> L.	blue cardinal flower
<i>Lycopus americanus</i> Muhl.	water-horehound
<i>Muhlenbergia mexicana</i> (L.) Trin.	satin-grass
<i>Phalaris arundinacea</i> L.	reed-canary-grass

Table 16. Plant species identified in the emergent zone of Williams Lake -continued

[The emergent zone of Williams Lake is narrow and has soils ranging from sands and gravels to organic. The species composition listed below reflects the heterogeneity of the shore line; different species were dominant in different locales. In this table, the emergent zone does not include the floating-leafed zone.]

Species	Common name
<i>Poa compressa</i> L.	Canada bluegrass, wiregrass
<i>Poa palustris</i> L.	fowl-meadowgrass
<i>Polygonum lapathifolium</i> L.	smartweed
<i>Sagittaria graminea</i> Michx.	grass-leafed arrowhead
<i>Sagittaria latifolia</i> f. <i>gracilis</i> (Pursh) Robins.	arrowhead
<i>Sagittaria latifolia</i> Willd.	duck-potato
<i>Salix interior</i> Rowlee	sandbar-willow
<i>Salix</i> sp.	willow
<i>Scirpus atrovirens</i> Willd.	dark-green bulrush
<i>Scirpus cyperinus</i> (L.) Kunth	wool-grass
<i>Scirpus Smithii</i> Gray	bulrush
<i>Scirpus validus</i> Vahl.	soft-stem bulrush
<i>Setaria glauca</i> (L.) Beauv.	foxtail, pigeon-grass
<i>Typha latifolia</i> L.	common cattail
<i>Utricularia subulata</i> L.	bladderwort

Appendix 4. Lake Hypsographic Data

Table 17. Hypsographic and depth-volume data for Williams Lake

[m = meters]

Depth (m)	Area m ² x 10 ⁵	Stratum (m)	Volume m ³ x 10 ⁵	Percent of total volume
0	3.946	0-1	3.757	18.5
1	3.571	1-2	3.299	16.3
2	3.034	2-3	2.816	13.9
3	2.602	3-4	2.473	12.2
4	2.346	4-5	2.215	10.9
5	2.086	5-6	1.962	9.7
6	1.841	6-7	1.640	8.1
7	1.446	7-8	1.229	6.1
8	1.024	8-9	0.752	3.7
9	0.510	9-9.8	0.136	0.7
Total =			20.278	100.0

Table 18. Hypsographic and depth-volume data for Shingobee Lake

[m = meters]

Depth (m)	Area m ² x 10 ⁵	Stratum (m)	Volume m ³ x 10 ⁵	Percent of total volume
0	6.244	0-1	5.954	15.6
1	5.669	1-2	5.458	14.3
2	5.250	2-3	5.126	13.5
3	5.004	3-4	4.852	12.8
4	4.702	4-5	4.453	11.7
5	4.210	5-6	3.833	10.1
6	3.468	6-7	3.054	8.0
7	2.658	7-8	2.284	6.0
8	1.930	8-9	1.629	4.3
9	1.346	9-10	0.986	2.6
10	0.665	10-11	0.373	1.0
11	0.145	11-11.9	0.043	0.1
Total =			38.046	100.0

Appendix 4. Light Attenuation Data

Table 19. Attenuation coefficients (K_{PAR}) calculated from radiometer data collected in Williams and Shingobee Lakes in 1991 and Secchi depth readings made in 1990

[m = meters]

Lake	Attenuation coefficients		Secchi depth readings
	Below surface to 2 meters	Below surface to 4 meters	
Shingobee	0.52 m ⁻¹	0.57 m ⁻¹	4 meters
Williams	0.51 m ⁻¹	0.48 m ⁻¹	5 meters