WUSKWATIM GENERATION PROJECT

ENVIRONMENTAL IMPACT STATEMENT

Manitoba Hydro
and
Nisichawayasihk Cree Nation

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Volume 5
Aquatic Environment

Available in accessible formats upon request.

PREFACE

Volume 5 (Aquatic Environment) is one of a series of supporting technical volumes for Manitoba Hydro's and Nisichawayasihk Cree Nation's (NCN) application for environmental licensing of the Wuskwatim Generation Project (the Project), which is entitled Wuskwatim Generation Project Environmental Impact Statement, Volume 1 (April 2003). Volume 5 has been prepared by independent discipline specialists who are members of the environmental study team retained to assist in the environmental assessment of the proposed project and provides an Aquatic Environment Impact Assessment prepared in accordance with Final Guidelines issued by provincial and federal regulators for the Project. The supporting volumes have contributed to the preparation of the summary Environmental Impact Statement (Volume 1) and also provide additional technical and professional supporting information to assist in the technical review of the EIS. The supporting documents have been reviewed by Manitoba Hydro and NCN and are technically consistent with the EIS. They have not been edited for consistency in format, style, or wording with either the Volume 1 or other supporting volumes.

The Wuskwatim Generation Project EIS is comprised of the following:

Volume 1 – Wuskwatim Generation Project – Environmental Impact Statement
Volume 2 – Public Consultation and Involvement
Volume 3 – Project Description and Evaluation of Alternatives
Volume 4 – Physical Environment
Volume 5 – Aquatic Environment
Volume 6 – Terrestrial Environment
Volume 7 – Resource Use
Volume 8 – Socio-Economic Environment
Volume 9 – Heritage Resources
Volume 10 – Cumulative Effects Assessment (Framework Approach)

Volume 5 was prepared by North/South Consultants Inc.

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1.0 INTRODUCTION

This section describes the existing **aquatic** environment and assesses the anticipated impacts of the construction and operation of the Wuskwatim Generation Project (the Project) on the aquatic environment. The Nisichawayasihk Cree Nation (NCN) identified water quality (upon which all life depends) and certain fish species important to the domestic and commercial fisheries (specifically lake whitefish, walleye, northern pike, and lake cisco) as key components of interest. The assessment also focused on fish habitat due to its importance to fish and to address requirements under the federal *Fisheries Act*. Fish habitat is defined in the *Fisheries Act* as "spawning grounds and nursery, rearing, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes." These studies also addressed requirements pertaining to the Manitoba Fishery Regulations and the Manitoba *Endangered Species Act*.

The assessment included a range of components of the aquatic ecosystem to ensure that major potential linkages between project-induced effects and their ultimate impacts on fish were addressed. This approach is consistent with NCN's holistic view of the environment, that all parts are interconnected and important.

The existing aquatic environment is a regulated system in which water flows are managed for the purposes of providing water to several large hydroelectric facilities downstream on the lower Nelson River (Volume 3); therefore, the existing water regime does not follow a natural seasonal pattern. Diversion of the Churchill River in the mid-1970s increased flows through the study area approximately 8-fold and raised the level of Wuskwatim Lake an estimated 3 m (Volume 4), disrupting the existing aquatic environment and riparian areas, and flooding **terrestrial** areas.

The baseline for the assessment of the Project is this regulated environment and, therefore, includes categories such as "flooded terrestrial vegetation", which are not common in natural systems. Information collected from pre-diversion studies and in the decade following diversion is of limited value to describe current conditions, as over time new shorelines have formed and fish populations have become established in the altered environment. For the purposes of this EIS, it was assumed that the existing aquatic environment represents a relatively stable state. This assumption was based on studies from other regulated systems where the post-development fish community was no longer experiencing significant annual changes in terms of abundance and species composition 20-25 years after development (e.g., Long Spruce Forebay), as well as the stability observed over the last decade or more in non-biological parameters in the **CRD** (e.g., erosion rates, described in Volume 4, and water quality in Section 5.0 of this volume). However, it should be noted that the aquatic system may still be undergoing some changes as a result of CRD; these changes may be masked by other activities (e.g., annual variation in commercial fish harvests), which would introduce a larger amount of variation into the system.

Water levels and flows are described in Volume 4. The following components of the aquatic environment are described in this volume.

Water quality is important to both humans and aquatic biota. In response to concerns raised by NCN and other communities regarding the effects of hydroelectric development on water quality, and in consideration of the importance of water quality to the local communities and aquatic biota, water quality has been designated a VEC. Information on current water quality was collected and effects on water quality have been considered in terms of its use as a drinking water source and for other human uses, and its suitability for aquatic biota and wildlife.

Aquatic habitat is defined as the environment in which fish and other aquatic **organisms** live, including the interacting physical, chemical, and biological constituents that form a particular environment. The aquatic habitat section provides a quantitative description of the physical habitat [i.e., water depth and velocity, substratum type, and the presence or absence of **cover** (e.g., aquatic vegetation, terrestrial debris, and riparian vegetation)] and forms the basis upon which effects to the biological components of the aquatic environment are assessed.

Lower trophic levels include all organisms apart from fish that occupy the aquatic environment, including **algae**, rooted plants, **zooplankton**, and **benthic invertebrates**. Changes in the abundance and distribution of these groups as a result of physical changes in habitat are an important linkage to effects to fish. Although **bacteria** and other **microscopic** forms (e.g., **meiofauna**) are included in the lower trophic levels, these forms were not considered directly in this assessment.

Fish community includes all groups of fish. Although NCN members indicated that all fish species are considered important, for the purposes of decision-making related to the Project it was necessary to distinguish those species that are of specific interest to resource users. Key domestic and commercial fish species, including walleye, lake whitefish, lake cisco, and northern pike, were identified as VECs and were the focus for assessing the significance of any Project-related effects on the fish community.

Fish quality studies focused on parameters that affect the suitability of fish for consumption by humans, specifically levels of mercury, other heavy metals, and parasites (cysts in whitefish), and taste/texture.

Section 2 of this volume discusses the aquatic ecosystem, valued ecosystem components (VECs), and assessment approach. An overview of the study area is provided in Section 3. The linkages between Project construction and operation and the aquatic ecosystem are described in Section 4. Sections 5, 6, 7, 8, and 9 present the descriptions and impact assessments for water quality, aquatic habitat, lower trophic levels, fish community and fish movements, and fish quality, respectively. Each of these sections includes background information, descriptions of methods employed, summaries of information and data, topic descriptions, as well as identified impacts, and possible mitigation. Section 10 lists the residual effects and Section 11 discusses cumulative effects. Section 12 completes the volume with an outline of proposed follow-up and monitoring programs.

Aquatic resources support commercial and recreational fisheries in the region and are an important domestic food item for NCN members. These and other resource utilization activities are documented in Volume 7.

2.0 OVERVIEW OF THE AQUATIC ECOSYSTEM, VALUED ECOSYSTEM COMPONENTS, AND ASSESSMENT APPROACH

The assessment considers the effects of the construction and operation of the Project, including any ancillary facilities required to construct or operate the Project. The Project has been designed for a 100-year life and decommissioning plans have not been developed. If at any time in the future Manitoba Hydro or the Wuskwatim Power Partnership conclude that the Wuskwatim Generating Station is no longer required, then Manitoba Hydro is legally obligated under the Maintenance of the Water Regime Section of 1996 Nelson House NFA Implementation Agreement to maintain the overall water regime range established as a result of the Wuskwatim Generating Station (Volume 1).

Upon completion of construction and final commissioning of the generating station, most construction camp and work site buildings, and temporary structures including the lagoon will be removed and the site will be cleaned-up and rehabilitated. The excavated material placement area(s) and the borrow sites will also be rehabilitated to the extent possible.

Project effects during construction and operation are predicted by comparing (a) what is expected to happen with the Project, and (b) what would be expected without the Project. The assessment approach recognizes that Wuskwatim Lake and adjoining waters, as well as the entire Churchill River Diversion (CRD) route, is a disrupted environment, as a result of both the initial diversion of water from the Churchill River in the 1970s and on-going regulation, as approved under *The Water Power Act*. For the purpose of assessing the effects of the proposed Project, this regulated environment is considered the baseline.

2.1 THE AQUATIC ECOSYSTEM AND VALUED ECOSYSTEM COMPONENTS

The aquatic environment is an interlinked ecosystem. Energy, primarily from the sun, is received and organisms within the system process this energy. The solar energy is captured by the producers (i.e., plants and algae) and is converted into organic carbon. These organisms require nutrients, such as nitrogen and phosphorus, for growth. Producers such as plants grow in shallow water along the shoreline, while algae grow on rocks and plants. Some microscopic algae live and grow in the water column (e.g., phytoplankton). Other organisms, known as consumers, acquire energy through the consumption of organic carbon. Plants and algae are eaten by herbivores (e.g., crayfish, snails, clams, zooplankton and some fish), which in turn are consumed by carnivores (e.g., walleye and northern pike).

Many plants and algae are not eaten but die and settle to the bottom where they are decomposed by fungi, bacteria, and other microorganisms. The decomposers break down dead organic matter, returning it to the environment, before they themselves are consumed by other organisms. Together, the producer, consumer, and decomposer organisms within an ecosystem form one or more food webs.

Besides energy, the ecosystem cycles other materials required for life, such as water, oxygen, nitrogen, phosphorous, and minerals. The ecosystem also incorporates parts of the physical and biological environment that support organisms' life history requirements. These include areas suitable for the hatching and nurturing of young (e.g., spawning and nursery areas); sites for feeding, resting, and sheltering from predators; and places to survive adverse conditions (e.g., overwintering areas) during various times of the year. These different areas required for organisms to complete their life are known as habitats. For many species, these habitats occur in spatially discrete areas and migration between these areas is an important life history requirement. Water levels, flows (volumes and speed), and water quality (temperature, transparency, and chemistry) are all important components of habitat for aquatic organisms.

Valued Ecosystem Components

It is not possible to investigate and describe all aquatic components of the ecosystem in all places at all times or to predict and assess the possible effects of the Project on each component. Therefore, certain valued ecosystem components (VECs) were selected as the focus of this **environmental impact assessment**. The VECs were selected because they met one or more of the following criteria: i) of particular importance (economic, traditional use, food source) for humans; ii) representative of a group of species; iii) good indicators of effects on producers and consumers within their food web; iv) rare or endangered; or v) of special ecological significance.

The VECs were selected through consultation between Project Team biologists, NCN resource users, and resource managers. Four fish species were selected as VECs: lake whitefish, lake cisco (tullibee), northern pike (jackfish), and walleye (pickerel). These species meet the criteria listed above, and are present throughout the study area and can be sampled with proven technology providing opportunity for long-term monitoring. The main attributes of the four VEC fish species are:

- lake whitefish: mid-level in food web, harvested in domestic and commercial fisheries;
- lake cisco: mid-level in food web, harvested in commercial fishery;
- northern pike: top level predator, harvested in domestic, recreational, and commercial fisheries; and
- walleye: top level predator, harvested in domestic, recreational, and commercial fisheries.

Water quality was also identified as a VEC. In scoping meetings held to develop a work plan to conduct the environmental studies for the Project, NCN identified water as a critical component of the aquatic environment on which all life depends.

Other components of the aquatic ecosystem were also studied to provide information required to assess potential effects of the Project on the VECs. For example, information was collected on lower trophic levels, including aquatic plants, algae, zooplankton, and benthic invertebrates as these are an important part of the food web that ultimately supports the VEC fish species.

The potential effects of the Project on the aquatic ecosystem were assessed both as direct impacts to VECs and other individual components, and as indirect impacts occurring within the ecosystem. Pathways of effect are indicated by the ecosystem linkages shown in Figure 2-1. For example, if changes in water level as a result of the Project increase erosion, which temporarily degrades water quality at a site by increased suspended sediment levels, the local macrophyte community may be less productive, providing inferior habitat for algae and zooplankton, which are the food source for forage fish that support a nearby walleye population. Conversely, a reduction in water level fluctuations, may improve growing conditions for aquatic plants and benthic invertebrates, which will in turn increase the amount of forage fish and, ultimately, predators such as walleye and northern pike.

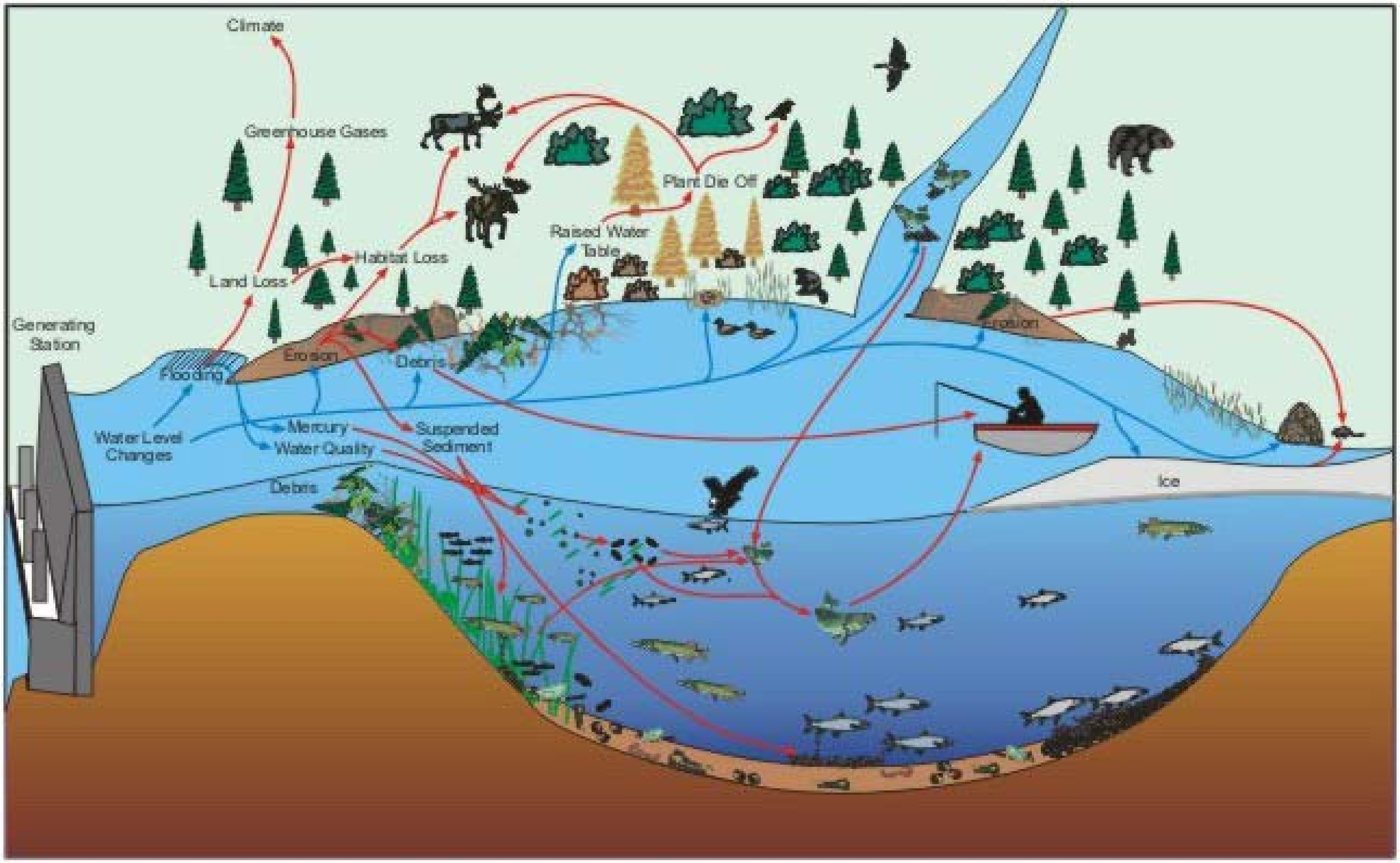


Figure 2-1. Pathways by which the Project can affect the environment.

2.2 ASSESSMENT APPROACH

Although a broad range of environmental components are considered in the environmental impact assessment, the determination of whether or not impacts are "significant" focuses on the VECs. The significance of potential impacts to VECs were evaluated on the basis of the following criteria:

- nature of the effect (positive, neutral, or negative);
- magnitude of the effect (size of effect – see below);
- duration of the effect (how long the effect would last – see below);
- frequency of the effect (how often and when the effect would occur);
- spatial boundaries or geographical extent of the effect (would the effect occur in a small or a large area – see below);
- reversibility of the effect/ resilience of the VEC (could the VEC readily recover from the impact); and
- ecological context (is the VEC particularly sensitive to disturbance).

With respect to the assessment of significance for impacts to VECs, the three key assessment components were:

- *duration*: short-term (effects that last no more than one generation span of the species affected or five years for other Valued Ecosystem Components (VECs) such as water quality); long-term (more than one generation of the species affected or greater than five years for other VECs).
- *magnitude*: small (impact does not have a measurable effect on the VEC population under consideration); moderate (effect could be measured with a well designed monitoring program); and large (impact would be large enough to be readily noticed without a monitoring program).
- *geographic extent*: site (impact confined to a small area and not transportable to other areas); local (the area physically impacted by the GS including areas affected by changes in water levels and flows); and regional (the area impacted could extend well beyond the area physically impacted by the Project e.g., effects on migratory species).

A matrix that generally illustrates the differences between insignificant and significant impacts based on duration, magnitude, and geographic extent is provided in Figure 2-2; it should be noted while this matrix guides the assessment of significance, the assessment also considers other components such as "frequency" (does the effect occur more than once), "confidence" (how confident are we in the degree of impact), and VEC-specific characteristics such as "resilience" and "ecological context". For example, if the VEC in question is known to be highly resilient (i.e., adaptable and recovers well from disturbance), effects that would otherwise be considered significant could be classed as insignificant, despite the magnitude and/or duration of the impact. Conversely, impacts that might not generally be considered significant (e.g., ones that affect a small proportion of the population for a short period) might be significant for a highly vulnerable VEC where the loss of even a few individuals may affect the long-term status of the population.

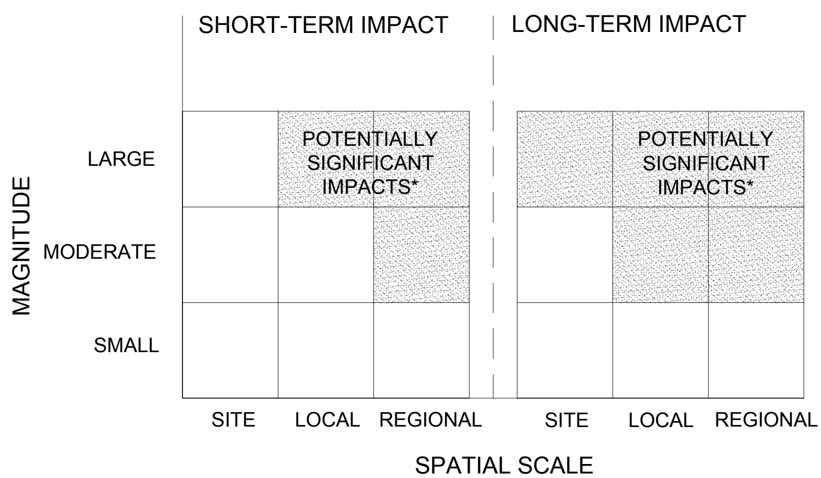


Figure 2-2. Matrix illustrating the definition of "significant" effects to VECs (*In addition to the above, effects are assessed in terms of their "frequency of occurrence", "confidence in the assessment", "resilience", and "ecological content".)

3.0 STUDY AREA

The aquatic environment studies focused on waterbodies that would be directly affected by changes in water levels and flows as a result of the Project, i.e., the Burntwood River downstream from Early Morning Rapids to, and including, Opegano Lake (Figure 3-1). Downstream of Opegano Lake, the expected effects of the Project on water regimes are minimal, i.e., less than current wind and wave effects. As described below, the study area for water quality extended further downstream, as water quality effects can extend beyond the zone of direct effects to water flows. Aquatic environment studies were also conducted on the streams crossed by the proposed access road.

The degree of physical change (e.g., change in water levels and flows) differs substantially from one portion of the study area to another. To facilitate descriptions and discussions, the affected portion of the Burntwood River was divided into four distinct reaches (Figure 3-1). A fifth area was selected to include the sections of the streams crossed by the access road. These reaches are delineated as follows:

Reach 1 - Wuskwatim: The 22 km reach from Early Morning Rapids to the crest of Wuskwatim Falls, including an 8 km reach of the Burntwood River, and Wuskwatim Lake and adjacent waterbodies (Cranberry Lakes, Sesep Lake, and Wuskwatim Brook). This reach will comprise the reservoir for the proposed GS. The full-supply level will be 234 m ASL;

Reach 2 - Falls: The 1 km reach between the crest of Wuskwatim Falls and the tail-water of Taskinigup Falls. This reach corresponds to the immediate forebay of the proposed GS; it will have an increased water level up to the 234 m ASL (reservoir operating elevation);

Reach 3 - Burntwood: The 14 km reach, including the Burntwood River mainstem and several small backwater inlets, between the tail-water of Taskinigup Falls and Opegano Lake. This reach will be subjected to daily water level and discharge fluctuations from operation of the GS superimposed on the existing fluctuations due to CRD operation and seasonal events;

Reach 4 - Opegano: The 8 km reach from the inlet of Opegano Lake to the crest of Jackpine Falls, immediately downstream of Opegano Lake. This reach will be subjected to detectable daily water level fluctuations, although the magnitude of the fluctuations will be much less than those experienced in the upstream river reach; and

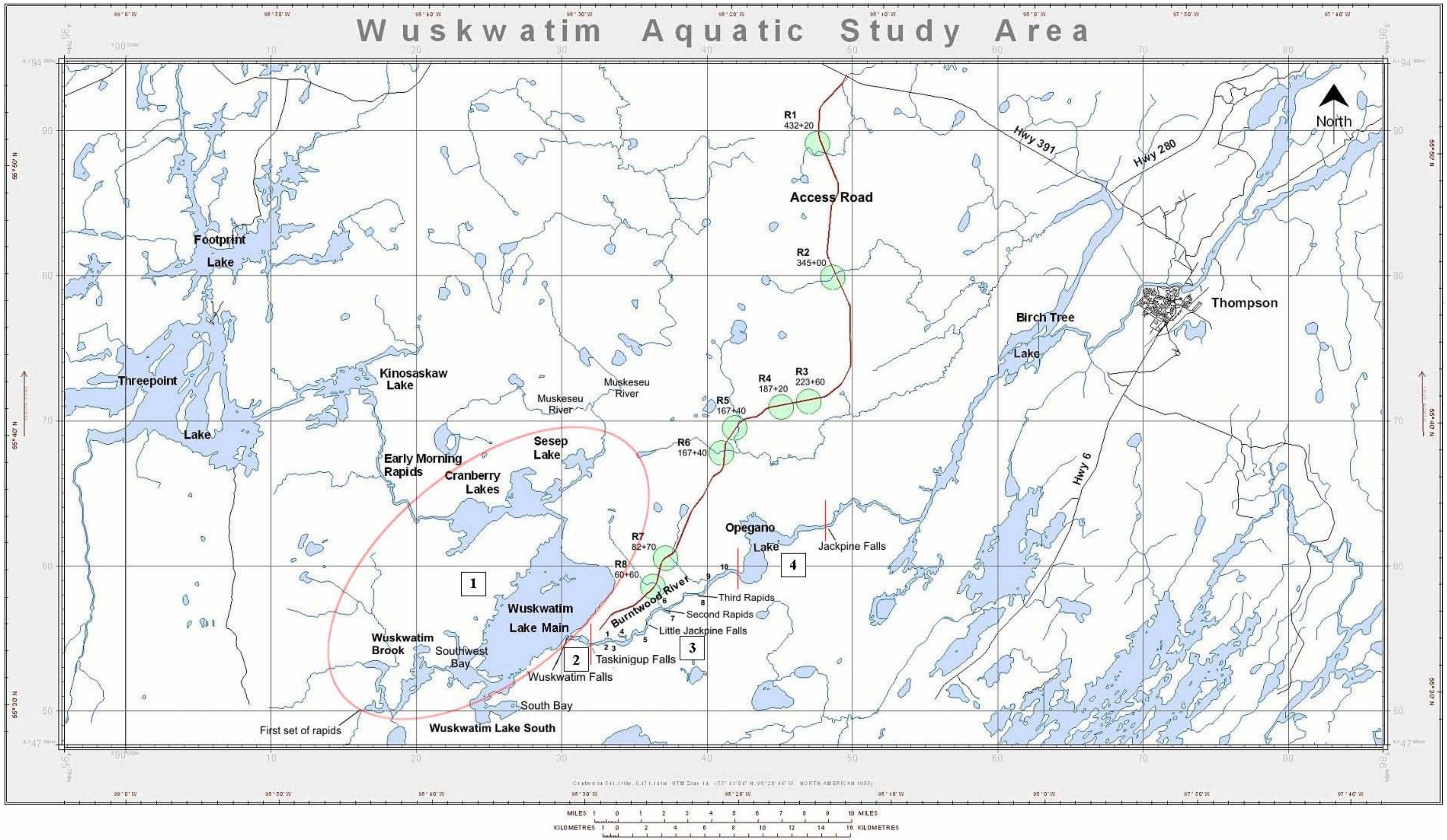


Figure 3-1. Wuskwatim Generation Project aquatic study area.

Stream Crossings: Reaches of streams crossed by the access road linking the proposed GS site to Provincial Road #391 (Access Road).

In addition to the reaches discussed above, water quality studies were carried out on downstream reaches of the Burntwood River (Figure 3-2) because: (i) impacts to water quality can be carried downstream beyond the extent of the direct physical changes caused by the Project (e.g., sediments suspended in the water); and (ii) downstream communities raised concerns pertaining to potential impacts to local water quality. Water samples were also taken at one site at the outlet of Kinosakaw Lake, 8.5 km upstream of any potential physical effects of the Project. The additional reaches were designated as follows:

Reach 5 - Downstream of Opegano: The reach of the Burntwood River from Jackpine Falls, through Birch Tree Lake, to the City of Thompson; and

Reach 6 - Downstream of Thompson: The approximately 100 km reach of the Burntwood River downstream from the City of Thompson to the Burntwood River mouth at Split Lake.

Most of the sites in Reach 6 were sampled for the first time in 2002 and, as the data are being collected to establish a pre-Project baseline, results of this sampling program were presented in a stand-alone monitoring report (Cooley and Shipley 2003).

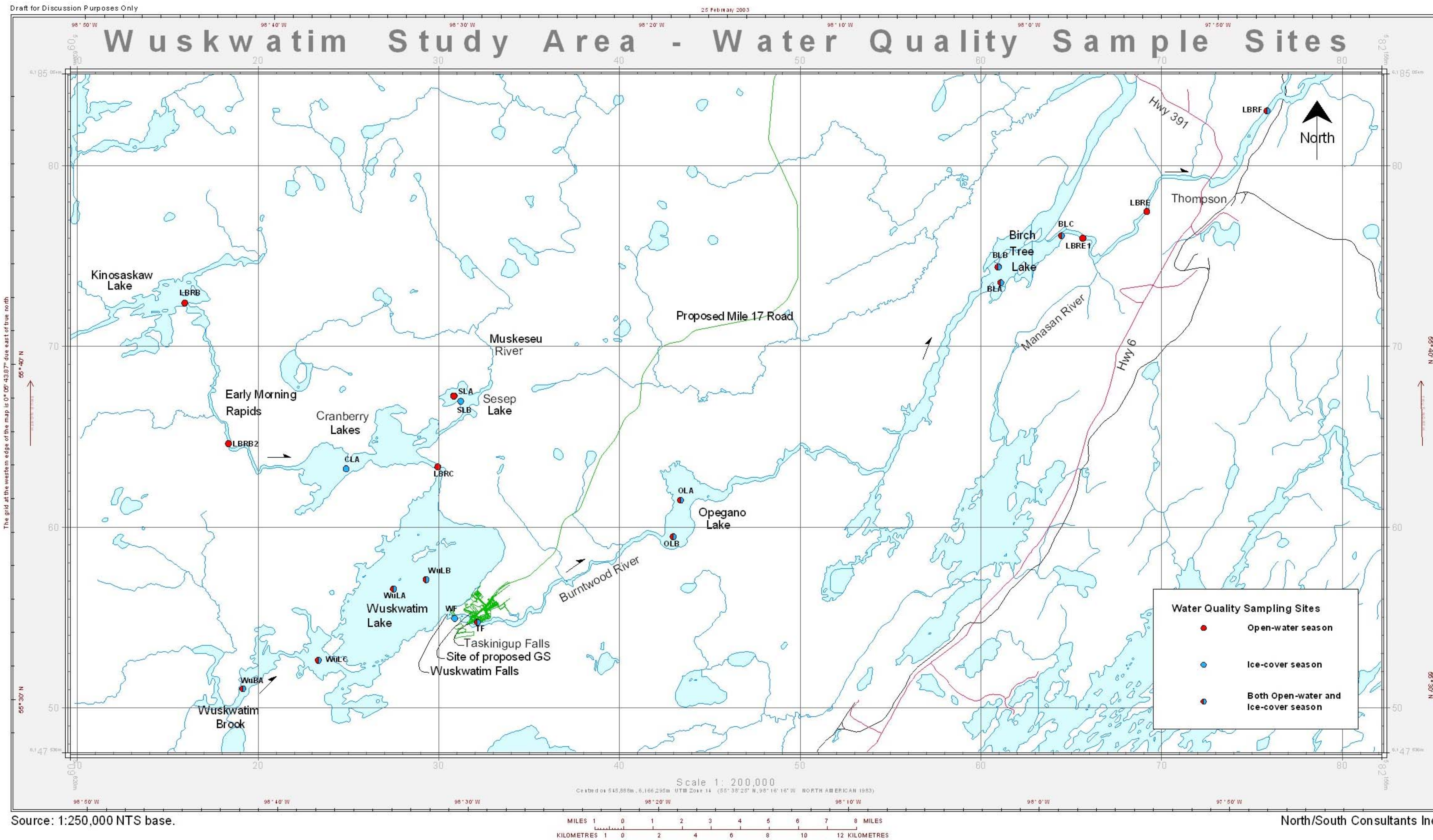


Figure 3-2. Water quality sampling sites in the study area.

4.0 LINKAGES

This section provides an overview of the major impacts from the construction and operation of the Project that were considered in the assessment of effects to the aquatic environment. Information on the planned construction and operation of the Project, as well as measures to be implemented to reduce potential adverse environmental effects, was obtained from volumes 3 (Project Description) and 4 (Physical Environment). Measures identified in volumes 3 and 4, as well as additional measures identified in this volume, will be described in an Environmental Protection Plan (EnvPP), which is being prepared by Manitoba Hydro and NCN specifically for this Project.

4.1 CONSTRUCTION-RELATED IMPACTS

The majority of impacts to the aquatic ecosystem during construction will be related to releases of substances affecting water quality and, indirectly, aquatic biota. As described in Volume 3, measures employed during construction will reduce impacts and subsequent effects to aquatic biota. Activities affecting water quality include clearing and grubbing of terrestrial areas, run-off from work sites, instream work (cofferdam construction and removal), discharges from settling ponds, treated effluent from the sewage lagoon, and increased riverbed and riverbank erosion during some stages of river management. It is noted that the potential for significant contamination of the aquatic environment as a result of a spill is considered negligible due to the proposed handling procedures for hydrocarbons and hazardous materials and the proposed emergency response measures (Volume 3).

Blasting of bedrock near and in the aquatic environment is another potential source of impact. As described in Volume 4, the majority of the blasting will be conducted in the dry and will be carried out in compliance with the guidelines developed by the Department of Fisheries and Oceans (Wright and Hopkey 1998). However, removal of the final rock plugs for completion of the spillway and channel excavation at Wuskwatim Falls is not expected to meet guidelines (it should be noted that these rock plug removals will each involve a relatively small, single blast).

The presence of a large, on-site workforce, as well as the road access to Wuskwatim Lake, have the potential to affect the local fisheries. NCN and Manitoba Hydro, in consultation with the Nelson House Resource Management Board, are developing an Access Management Plan (Volume 3). The effectiveness of measures taken to control access through the Access Management Plan, and of measures taken by Manitoba

Conservation (the agency responsible for managing the fishery), will determine the magnitude and duration of the impact to the Wuskwatim fishery.

Project-related water regime changes and flooding begin during construction, but are discussed as impacts of operation.

4.2 OPERATION-RELATED IMPACTS

The primary impacts to the aquatic ecosystem during the operating phase of the Project are linked to changes in the water regime (which initiate changes in processes such as erosion and sedimentation), the presence of the generating station structures, and the provision of road access.

Water Regime

The water regimes discussed in the following paragraphs were derived from information presented in Volumes 3 and 4 of this EIS. In assessing the potential effects of the post-Project water regimes on the aquatic environment, two different stream-flow records for the Burntwood River at Wuskwatim Lake were used: a record based on flows that occurred since 1977 (post-CRD flows) and a long-term simulated record (86 years). The average flow for the long-term record is wetter than the post-CRD flow record, but both records have similar minimum and maximum values. The "existing environment" conditions were based on the post-CRD record, while the "post-Project environment" conditions were based on the long-term simulated record. Therefore, the predicted differences between the two conditions reflect the combined effects of the Project and the differences in the water records. For the purposes of this assessment, no attempt was made to differentiate between the relative contribution of these two sources of change.

Reach 1: Wuskwatim

Regulation of the CRD results in month-to-month and inter-annual changes in water levels that do not follow a consistent seasonal pattern (Volume 4). Water levels range from 232.88 m (5th percentile) to 234.09 m ASL (95th percentile), resulting in a relatively large area that is intermittently exposed during normal operations. Project operation will generally stabilize water levels near 234 m ASL, though levels will vary somewhat (the 2.5th percentile elevation is expected to be 233.75 m). For the purposes of the assessment, the post-Project intermittently exposed area was defined as the area between the elevations of 233.75 and 234.0 m ASL. Post-Project, the median lake level will increase by approximately 0.3 m, and the range of water level fluctuations will be reduced. Operation of the station will cause small stage variations within the day (median 0.06 m, up to 0.13 m in the immediate forebay).

During periods of low flow, conditions could arise when water levels in the reservoir would be drawn below 233.75 m ASL (Volume 3). Models show these low flows generally occurring during the open-water period, and usually for several years in succession. During these times, several cycles of gradual drawdown and reponding could occur within a single season, although drawdown to the minimum reservoir level of 233 m ASL is expected to occur rarely. It is expected that use of the reservoir storage below 233.75 m ASL will occur for 2.5% of the time.

The effects of abnormal operation depend to a large extent on the frequency, magnitude, and duration of drawdown. The nearshore and intermittently exposed environment will tend to shift towards conditions seen during low flow conditions in the pre-Project environment (the 5th percentile water elevation of 232.88 m ASL is marginally lower than the projected post-Project minimum). The greatest relative change would occur when a prolonged period of normal operation was followed by an extended period of abnormal operation. In this case, benthic invertebrate abundance and the biomass of aquatic plants in the nearshore and intermittently exposed environments would be reduced, and the die-off of plants could result in localized effects to water quality. Changes in lower trophic levels could also influence the fish community; the relative effect on the fish community depends on the magnitude and duration of the change in the lower trophic levels. Certain fish species could also be directly affected (e.g., access to spawning areas, exposure of spawn) depending on the timing of the water level changes.

Periods of abnormal operation would be followed by a period of recovery as the aquatic community returns to the condition typical of the normal operating regime. As these abnormal events are infrequent (of similar frequency to natural low flow events), they will not affect the overall lake environment in the long-term and were not considered further in the assessment.

Reach 2: Falls

Water levels in this reach (the immediate forebay) will be raised approximately 7 m, flooding about 37 ha of terrestrial area. Water levels in the immediate forebay will tend to be slightly lower than in Reach 1, and water level changes within the day will be greater. Water velocity in the reach will be reduced: immediately upstream of the GS maximum velocity will be approximately 0.6 m/s, while the inundation of Wuskwatim

Falls will reduce velocities at the outlet of Wuskwatim Lake into the range of 0.5 – 0.7 m/s.

Changes in the spatial extent of aquatic habitat due to flooding and the presence of the GS itself were assessed based on maps provided in Volume 4.

Reaches 3 and 4: Burntwood and Opegano

Operation of the station would involve cycling between the 3 units, each of which would generally be operated at maximum efficiency or "best gate" discharge (Volume 3). The variation in the number of units operating during various periods within the day will superimpose water level changes within the day on the month-to-month changes that presently occur downstream of the GS site. The magnitude of these fluctuations varies with discharge and location along the river. The largest fluctuations within the day occur in the tailrace (median 0.4 m to a maximum of 1.5 m) and decrease down river until, at Opegano Lake, the median fluctuation is 0.1 m with a maximum of 0.4 m. (As discussed in Volume 3, under extremely unusual conditions, these changes could be greater). These water level changes within the day will increase the frequency of water level fluctuations within the zone that is currently dewatered infrequently. For example, daily changes are minimal under existing conditions at Opegano Lake, but daily changes greater than 0.1 m will be experienced about 60% of the time post-Project.

Minimum water levels in this reach will decrease, as the discharge of 1 unit (328 m^3/s) is considerably lower than the post-CRD minimum of 440m^3/s and the 5th percentile flow (600 m^3/s). Several hours of minimum water levels may occur each day when GS discharge is less than approximately 660 m^3/s (7th percentile flow), and operation consists of cycling between 1 and 2 units within the day (Volume 3). Median and greater flows are higher in the post-Project period, and areas that are currently considered terrestrial (above the current 95th percentile water regime) will become the upper portion of the aquatic zone in the post-Project environment.

Daily fluctuations in discharge will cause shifts in water velocity within the river. The assessment of these effects is based on the results of 2-D flow modeling (Volume 4).

Ice Conditions

Ice conditions are not expected to change significantly as a result of the Project, although ice cover may form on portions of the immediate forebay between Wuskwatim Falls and Taskinigup Falls; this reach is not ice covered under current conditions (Volume 4).

Erosion and Sedimentation

Approximately 30% of the shoreline in Reach 1 is currently eroding, mostly in Cranberry Lakes and Wuskwatim Lake (75% of the shoreline of Wuskwatim Lake main is eroding) (Volume 4). The altered water regime will increase the rate of erosion on these shorelines, resulting in an estimated 2.5-fold increase in the amount of eroded material during the first five years of the Project (Volume 4). It is expected that approximately 50% of this material would settle in the nearshore environment and an additional 25% would settle in deeper waters, with the remainder staying in suspension and moving downstream (Volume 4).

Erosion downstream of the GS is not expected to change within the majority of the river channel (Volume 4).

Debris

The increased rate of erosion will result in additional debris; however, the majority of this debris is expected to be trapped within existing debris fields (Volume 4) and therefore, would not affect the aquatic environment to an extent greater than that presently experienced.

Presence of the GS

Fish passing downstream in the post-Project environment would generally pass through the turbines of the GS. Information on turbines is provided in Volume 3. The presence of the GS, dam, and spillway will preclude upstream movement of fish, however, the height of the natural falls and the velocity of the water passing over the falls currently prohibits upstream fish movement at this site (Section 8.0).

Increased Fishery

The availability of road access is expected to increase the domestic, commercial, and recreational fisheries on Wuskwatim Lake (Volume 7). As described for construction, NCN and Manitoba Hydro, in consultation with the Nelson House Resource Management Board, will develop an Access Management Plan prior to construction (Volume 3).

5.0 WATER AND SEDIMENT QUALITY

5.1 INTRODUCTION

Water quality is an important component of the **aquatic environment** from the perspective of both humans and aquatic life and wildlife that rely upon it. Water quality affects various human usages of water, including its use for purposes of recreation, irrigation, and drinking water and is also significant from an **aesthetics** perspective. Water quality also forms a significant facet of the environment for aquatic life and wildlife. The quality of sediments is also of significance to the health of aquatic **biota** that live in, on, or either directly or indirectly associate with the sediments and/or **benthic** communities.

Questions about the potential effects of hydroelectric generation facilities on water quality have been raised by many communities, including NCN members, over the years. In response to these concerns and in consideration of the importance of water quality to the local communities, water quality has been designated a VEC for the purposes of conducting this impact assessment. Effects on water quality have been considered in terms of its use as drinking water, for recreation, its significance from an aesthetics perspective, and its importance to the health of aquatic biota and wildlife as set out for various parameters in the Manitoba Water Quality Standards, Objectives, and Guidelines (**MWQSOG**s). Existing conditions with respect to water quality in the study area have been evaluated in order to provide necessary information for the impact assessment for the Wuskwatim Generation Project.

5.1.1 Water and Sediment Quality Study Area

5.1.1.1 Water and Sediment Quality Study Area for Wuskwatim

Potential impacts of the proposed Wuskwatim Project on water quality are being considered over a reach, extending from the Burntwood River at the outlet of Kinosaskaw Lake (downstream of Threepoint Lake and upstream of Early Morning Rapids) to the lower Burntwood River at the inlet to Split Lake (Figure 5-1). The upper boundary of the study area incorporates one site upstream of all potential impacts of the project, at the outlet of Kinosaskaw Lake; this site would serve as an upstream reference site for post-project monitoring.

Intensive sampling was first initiated in Wuskwatim Lake and adjacent waters and the Burntwood River downstream to Opegano Lake, where measurable impacts to water quality are most likely to occur. In 2001, the study area was expanded to incorporate sites up to, and just downstream of, the City of Thompson (Figure 5-2). In 2002, sampling for the pre-Project baseline monitoring program was extended to sites between Thompson and the inlet of the Burntwood River to Split Lake, in response to concerns raised by downstream users. These data are presented in Cooley and Shipley 2003.

The study area includes Wuskwatim, Cranberry, Sesep, Opegano, and Birch Tree lakes and a number of tributaries to the Burntwood River, such as Wuskwatim Brook (which flows into Wuskwatim Lake), tributaries entering the Burntwood between Taskinigup Falls and Opegano Lake, and tributaries at crossings of the access road. To facilitate assessment of potential impacts associated with the Project, the study area has been divided into the following reaches:

- Wuskwatim - Reach 1: upstream end of the study area including Wuskwatim Lake and the Burntwood River from the outlet of Kinosaskaw Lake to the outlet at Wuskwatim Lake. This reach also includes Sesep Lake and the area of Wuskwatim Brook impacted by elevated water levels resulting from CRD;
- Falls - Reach 2: The lower Burntwood River between Wuskwatim Falls and Taskinigup Falls;
- Burntwood - Reach 3: The Burntwood River from Taskinigup Falls to Opegano Lake. This reach includes 10 tributary streams (Streams 1 – 10);
- Opegano – Reach 4; Opegano Lake;
- Downstream of Opegano – Reach 5: The Burntwood River downstream of Opegano Lake, including Birch Tree Lake, to the City of Thompson;
- Downstream of Thompson – Reach 6: The Burntwood River downstream of the City of Thompson to the inlet at Split Lake; and,
- Stream Crossings: streams crossed by the access road.

Note that Reach 2 and 3 are discussed collectively in the results presented below, because only one sample was obtained from Reach 2 due to problems associated with access. Locations of stream crossing sampling sites for the access road and tributary streams are indicated in Figures 5-3 and 5-4, respectively.

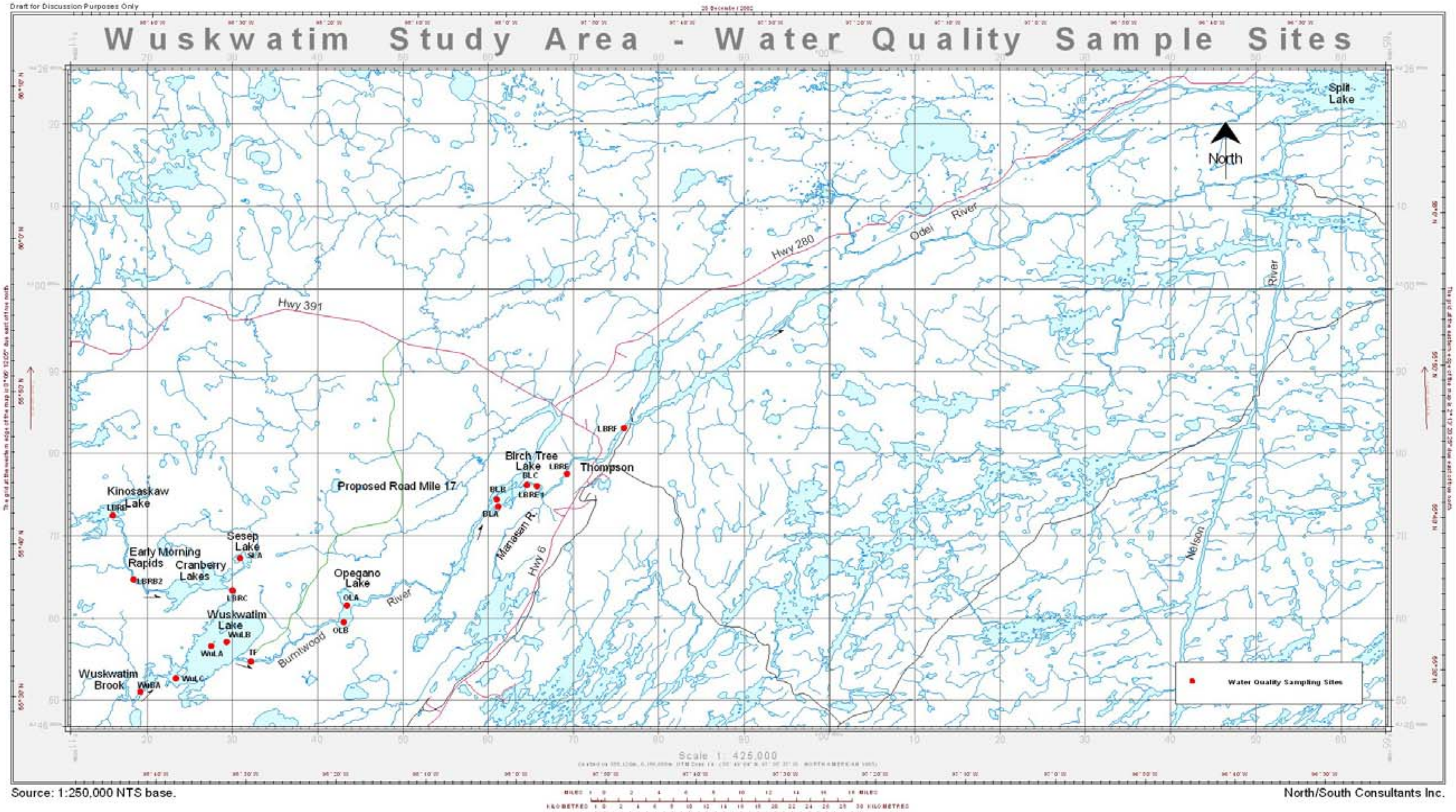


Figure 5-1. The water quality study area for the Wuskwatim Generation Project.

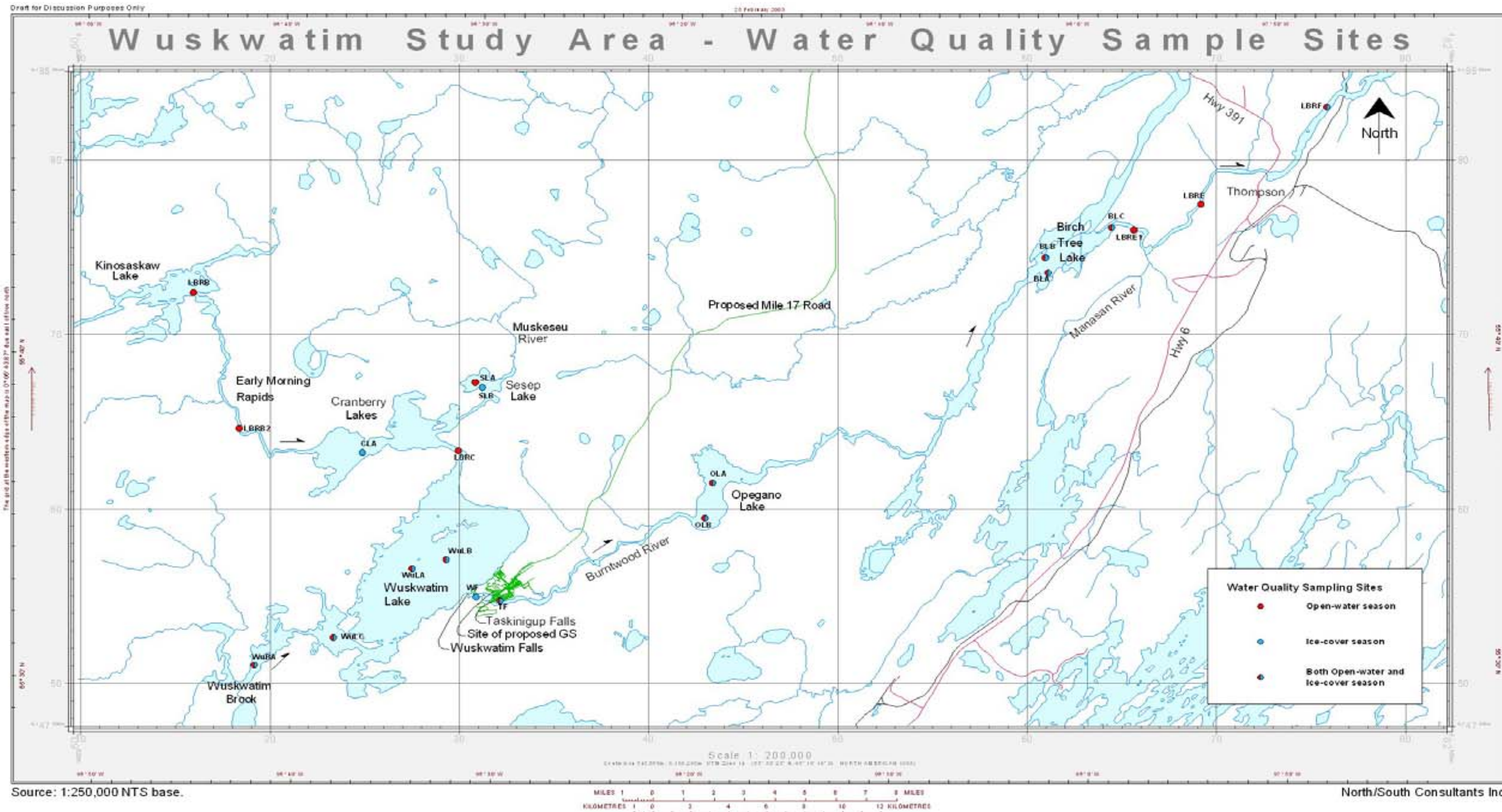


Figure 5-2. Water quality sampling locations in the study area, 1999 – 2002.

5.1.1.2 Developments in the Study Area Affecting Water Quality

There are numerous developments within the water and sediment quality study area that affect or may affect water quality. In the vicinity of the City of Thompson, there are numerous industrial and municipal wastewater outfalls that discharge directly or indirectly to the lower Burntwood River, the presence and locations of which are pertinent to the interpretation of water quality data collected in the area. Brief descriptions, as provided by Manitoba Conservation (2002), of these effluent sources follow.

INCO Thompson Facilities

The INCO Ltd., Thompson Division, operation is an integrated nickel mining, milling, smelting and refinery complex located at Thompson, MB. There are two active mines operated by INCO near Thompson: the Birchtree Mine; and, the Thompson Mine.

The Birch Tree mine discharges cooling water and treated mine water effluent at the confluence of the Manasan and Burntwood rivers, which is approximately 11 km upstream of the City of Thompson. In addition, the Birchtree Mine Lagoon and INCO Slag water are discharged to the lower Burntwood River approximately 1.5 km downstream of the PTH 6 bridge in Thompson. The Thompson INCO Mill, Refinery, and Tailings effluent and the T-3 Mine Lagoon effluent are discharged to the Burntwood River approximately 9 km downstream of the PTH 6 bridge. Principal constituents of concern, with respect to water quality, are **pH**, **total suspended solids** (TSS), and metals and metalloids (primarily nickel, copper, zinc, and arsenic).

Thompson Municipal Wastewaters and Sewer System

Treated municipal wastewaters from the City of Thompson are discharged to the Burntwood River from the Primary Sewage Treatment Plant and the aerated lagoon for the City of Thompson, located approximately 700 m and 1.5 km downstream of the PTH 6 bridge, respectively. Wastewaters are treated through a primary system, which removes solids and which aerates and chlorinates the water prior to discharge to the river.

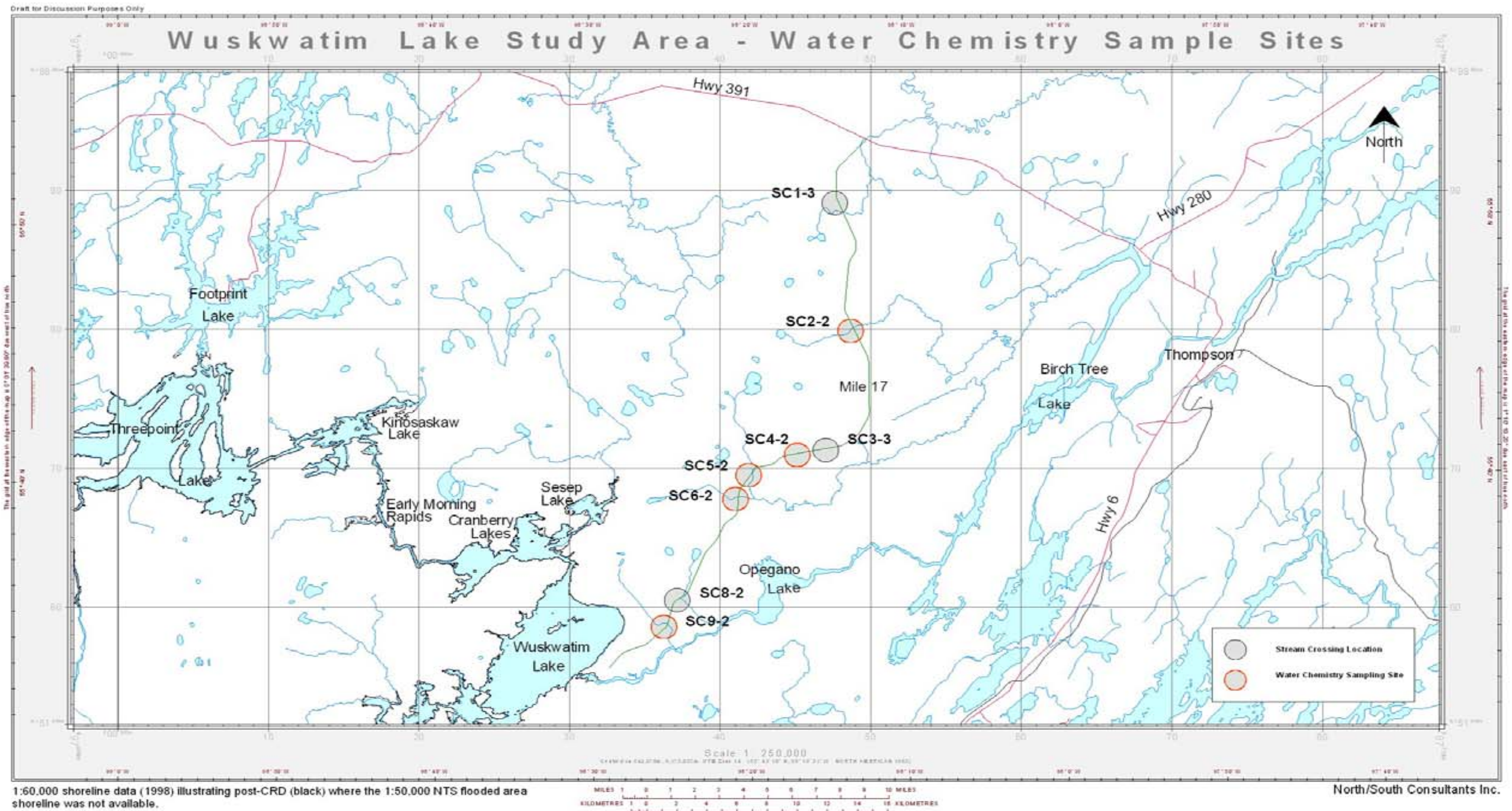


Figure 5-3. Stream crossings along the access road and tributary streams sampled in Reaches 2 and 3. Water chemistry sampling sites are indicated by the red circles.

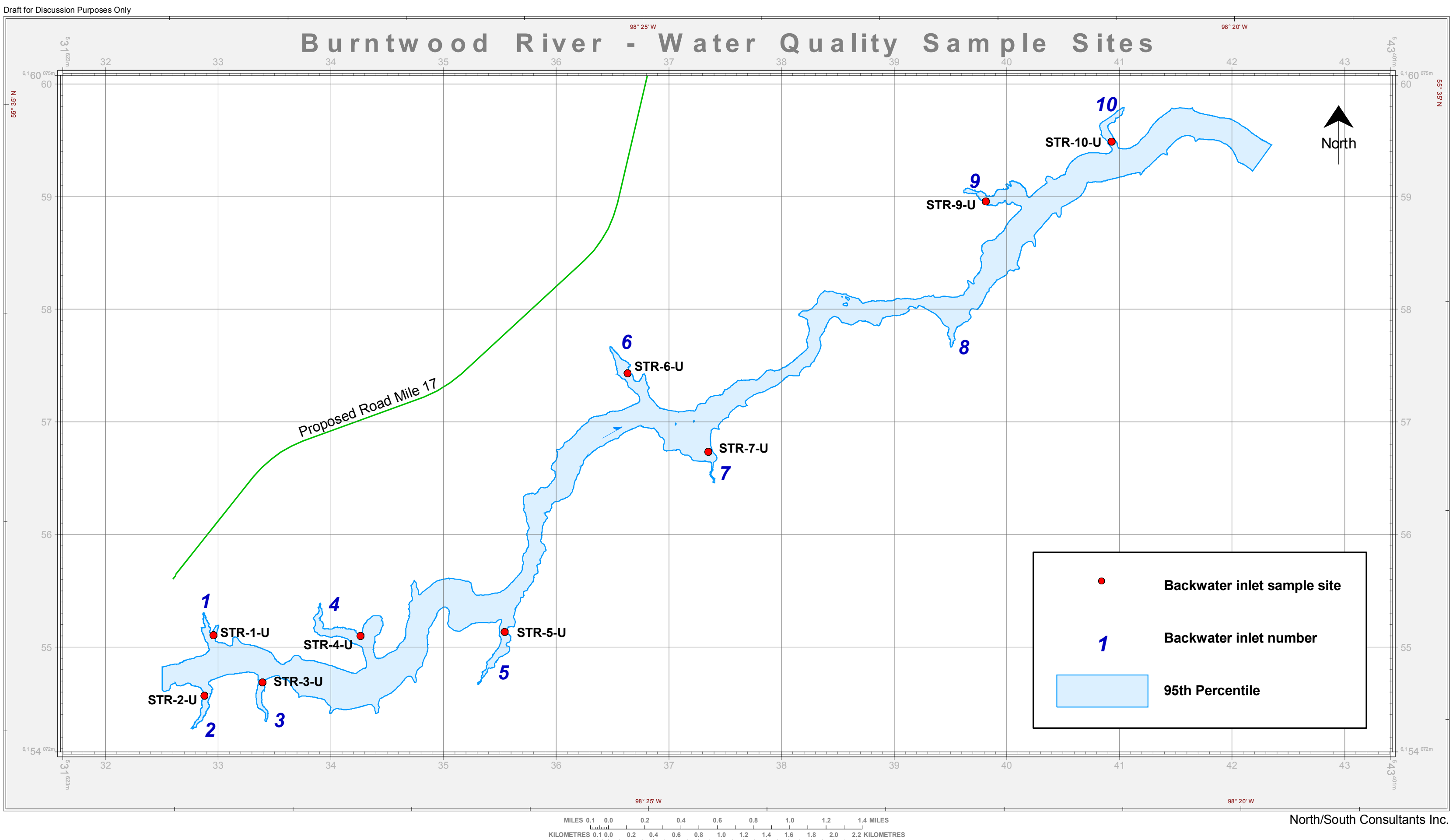


Figure 5-4. Water quality sampling sites in the backwater inlets of tributary streams in Reach 3: September 2002. Sites sampled upstream of the backwater inlets are not shown in the figure.

There are also a total of seven storm sewers that discharge to the Burntwood River, five range from 1 to 5 km upstream of the PTH 6 bridge and two are located approximately 500 m downstream of the PTH 6 bridge. Storm sewers receive precipitation and drainage from weeping tile systems and are distinct from the sanitary system. An emergency sanitary by-pass (i.e., the Riverside Lift Station) is located 1 km upstream of the PTH 6 bridge. Discharge from the emergency sanitary by-pass occurred once (July 12, 1999) during the conduct of the baseline studies for the Wuskwatim (Manitoba Conservation 2002); but at the time of that discharge (i.e., the open-water season of 1999), the water and sediment quality study area did not extend as far downstream as Thompson.

Other

There is also an unregulated discharge from the Thompson Horse Owners Association (i.e., stables) 3 km upstream of the PTH 6 bridge in Thompson, however manure handling issues were corrected in 1997 (Manitoba Conservation 2002). Some degree of run-off is reportedly still a possibility (Manitoba Conservation 2002).

5.2 APPROACH AND METHODS

5.2.1 Traditional Knowledge

NCN members have been consulted through scoping workshops and in Traditional Knowledge (TK) interviews to document and incorporate local knowledge pertaining to current water quality conditions in the study.

5.2.2 Historical Scientific Data

Several data sources, presented in Appendix 1, were consulted and incorporated into the description of the existing environment including: Manitoba Conservation water quality monitoring data at station WQ0093.00 on the Burntwood River at Thompson; MB Conservation reports (Williamson 1980); and, the Federal Ecological Monitoring Program (**FEMP**) results (Ramsey 1991).

Manitoba Conservation has maintained a water quality monitoring station on the Burntwood River (WQ0093.00) at the upstream side of the PTH 6 bridge in Thompson, since July 1975 (MB Conservation 2001). Data provided by MB Conservation (2001), for the period from 1980 up to that most recently available at the time of data analysis (up to December 2000) were plotted to evaluate water quality parameters over a longer period of record than that afforded in the baseline studies for the Wuskwatim EIS. This analysis was conducted to: (i) provide an estimate of between year variation in water quality based on a larger sample size; and (ii) identify any major (i.e., large magnitude) trends in water quality. Data collected during the ice-cover and open-water seasons were evaluated separately to account for possible seasonal differences in water quality. Data were plotted as both concentrations and loads (calculated based on discharge data for the Burntwood River at Thompson for the same day that samples were collected). Analysis for trends over time consisted of visual inspection of plots, as the objective was to identify only gross changes in water quality that may be occurring.

For statistical purposes, all values reported as 'greater than' were assigned the value indicated (e.g., TSS > 30 mg/L was assigned a **concentration** of 30 mg/L). All values reported as below analytical detection limits (DLs) were assigned a value of one half of the associated detection limit (e.g., TSS < 30 was assigned a value of 15 mg/L).

Data were also compared to Manitoba Water Quality Standards, Obejctives, and Guideline (MWQSOGs) to evaluate the occurrence and frequency of exceedences of water quality criteria over that 20-year period to provide a context for data obtained at sites evaluated in the baseline studies for the Project.

Sediment chemistry data collected from the Burntwood River at Thompson in August 1979 (Williamson 1980), were also incorporated for relative comparison to sediment quality data derived during the collection of **baseline information** for the Wuskwatim project.

Statistically summarized FEMP water chemistry data, which covered the period of September 1986 to October 1989, were extracted from Ramsey (1991) to assist in defining existing water quality conditions in the study area.

5.2.3 EIS Studies

5.2.3.1 Water Quality Parameters and Rationale

A range of water quality parameters was measured in the study area to address potential effects of the Project on the aquatic environment. The rationale for the inclusion of the various parameters is indicated below.

Total suspended solids (TSS) and turbidity

Water clarity can be described using measures of **total suspended solids** (**TSS**) or **turbidity**, which are indicators of the scattering of light by suspended particles in water. At very high concentrations, TSS can reduce fish growth rates, modify fish movements, affect fish egg and larval development, impair foraging and predation behaviour of fish, reduce abundance of fish diet items, affect reproduction of aquatic biota, reduce **immunocompetency** of aquatic biota, and harm benthic habitats. At lower concentrations, suspended sediment can influence aquatic ecosystems by reducing light penetration into the water column, thereby limiting the growth of plants and algae, and may affect behaviour of aquatic life (e.g., predation success of fish). Turbidity and total suspended solids are also relevant to the suitability of water used for drinking and recreation, and affect the aesthetic quality of aquatic ecosystems. In **riverine** systems, suspended solids concentrations generally vary with river discharge, because settling of suspended solids out of the water column increases when water velocity decreases.

Colour

Colour, measured as **true colour** in this study, is the result of backscattering of light upward from a water body after it is selectively absorbed at various depths. True colour is used as an indicator of dissolved and suspended materials in water. Colour of light (i.e., wavelength) along with turbidity of water determines the depth to which light penetrates in a water body. It is important in terms of aesthetics, drinking water quality (aesthetics), the toxicity of certain contaminants (e.g., mercury toxicity increases with increasing water colour, Haines et al. 1995), and affects the behaviour and presence of aquatic flora and fauna (e.g., algal species composition) (reviewed in **CCME** 2001a).

Dissolved oxygen (DO)

Dissolved oxygen is essential for the survival of most aquatic biota. It is consumed by aquatic organisms including, animals, plants, algae, and bacteria in the water column and sediments. Sources of dissolved oxygen to aquatic systems are aeration (i.e., input of oxygen from the atmosphere) and **photosynthesis** by plants and algae.

Water temperature

Water temperature is important because it affects the rates and occurrence of biological processes and influences water chemistry (e.g., the amount of dissolved oxygen that water can hold is determined by its temperature). Changes to water temperature may affect water chemistry, growth and biological processes, and **productivity** of aquatic organisms.

Nutrients

Dissolved and suspended forms of nitrogen, phosphorus, and **organic carbon**, are the major nutrients in surface waters that support the growth of aquatic plants, benthic algae (i.e., **periphyton**), and algae in the water column (**phytoplankton**). Sources of nutrients in surface waters include the breakdown of **organic** matter, excretion by organisms, wastewater discharges, erosion and run-off from nutrient-rich soils, and atmospheric deposition. Nutrients are not toxic at the concentrations normally found in surface waters. However, nutrient enrichment (i.e., **eutrophication**) can stimulate excessive growth of plants and algae, which can subsequently lead to the degradation of aquatic habitat through physical changes (e.g., excessive plant or algal growth over gravel **substrate**), and through changes to water quality (reduced dissolved oxygen at night, reduced water clarity due to phytoplankton, and possible production of toxins by some forms of phytoplankton). Stimulation of plant or algal growth by nutrient enrichment in individual water bodies also depends on several other factors that potentially limit plant or algal growth, such as water clarity, temperature, flushing rates, and turbulence.

pH

pH is a measure of the acidity of water. Fairly wide ranges of pH in surface waters are suitable for aquatic life and wildlife. However, pH can affect the toxicity of substances such as ammonia and metals to aquatic biota. pH may directly affect aquatic biota (i.e., highly **acidic** or **alkaline** conditions can threaten aquatic life) or may be indirectly harmful to aquatic life (e.g., increase **bioavailability** of metals). Reductions of pH may mobilize metals bound in sediments (i.e., release metals to water) and may alter the **physico-chemical** form of metals in aquatic systems. Additionally, accumulation of **methylmercury** in fish is greater in low pH lakes (Spry and Wiener 1991). pH may be altered by flooding of soils, decomposition of organic matter, and photosynthesis.

Hardness

Hardness, a measure of the concentration of calcium carbonate in water, affects the accumulation and toxicity of numerous metals to aquatic biota (i.e., metals are less toxic to aquatic life in hard water). Hardness is a reflection of the type of soil minerals and bedrock in the local environment, as well as the hydrological characteristics of the area (e.g., length of time water is in contact with bedrock). In general, soft water occurs in watersheds characterized by igneous rock, whereas hard water occurs in systems draining through carbonate rock (Williamson and Ralley 1993).

Alkalinity

Alkalinity is a measure of the water's acid neutralizing capability, which is largely dependent upon the concentration of hydroxides, bicarbonates, and carbonates in the water. It is generally a reflection of the local geology and bicarbonates being leached from the soil. Production and bioaccumulation of methylmercury in aquatic food webs is greater in low alkalinity/low pH lakes (Spry and Wiener 1991). Furthermore, lakes with low-buffering capacity may be more susceptible to acidification due to flooding or acidic precipitation. High alkalinity may indicate high levels of **primary production** and nutrient inputs. The sensitivity of lakes to acidification is often categorized on the basis of total alkalinity. A common categorization is: lakes with a total alkalinity between 0 and 10 mg/L as $CaCO_3$ are deemed highly sensitive to acidification; lakes with a total alkalinity of 11 to 20 mg/L as $CaCO_3$ are deemed moderately sensitive to acidification; lakes with a total alkalinity between 21 and 40 mg/L as $CaCO_3$ are deemed to have low sensitivity to acidification; and, lakes with a total alkalinity in excess of 40 mg/L as $CaCO_3$ are deemed to have very low sensitivity to acidification (Palmer and Trew 1987).

Total dissolved solids (TDS) and conductivity

Total dissolved solids (**TDS**) and **conductivity** are measures of the amount of minerals and organic matter dissolved in water, reflecting both natural conditions such as local geology, and **anthropogenic** activities that increase these substances in water (e.g., mining effluents). TDS may affect quality of water for human use (i.e., taste, scaling, corrosion, and laxative effects).

Bacteria and parasites

Pathogenic bacteria (**fecal coliform bacteria**) and the protozoan parasites ***Cryptosporidium*** sp. and ***Giardia*** sp. can be spread through the release of untreated human and livestock wastes into surface waters. These organisms may have human or animal (i.e., wildlife) origin. *Giardia* causes giardiasis, known colloquially as ‘beaver fever’, and *Cryptosporidium* causes cryptosporidiosis in humans, both of which are intestinal disorders. Their presence affects the quality of water used for drinking and for recreation.

Major ions and trace elements

Major ions, **metals**, and **metalloids** are typically present in surface waters and sediments. They are introduced to surface waters through erosion and weathering of soils and rock and atmospheric deposition. Whereas high levels of metals occur naturally in some waterbodies, they may become elevated due to various anthropogenic activities including, acidification (e.g., acid rain), agricultural activities, mining and smelting, combustion of fossil fuels, or the release of municipal and industrial effluents. At sufficient concentrations, metals (such as nickel, cadmium, and mercury) can be harmful to fish, wildlife, and humans. In aquatic ecosystems, metals may **bioaccumulate** in aquatic biota via both exposure to metals in water and via ingestion of food containing metals.

Hydrocarbons

The **aromatic hydrocarbons benzene**, **xylene**, and **toluene**, may be introduced to aquatic ecosystems through combustion or release of fossil fuels, forest fires, or the release of municipal and industrial effluents. Sources of **polycyclic aromatic hydrocarbons (PAHs)**, such as **naphthalene** and **benz(a)pyrene**, in surface waters can include accidental spills, leaching from contaminated soils, atmospheric deposition, municipal and industrial effluents, forest fires, runoff from roads, and combustion of fossil fuels (e.g., exhaust gases from boat motors and cars).

Radioactivity

Naturally-occurring radioactive elements (**radionuclides**) occur in several types of rocks and **surficial** deposits, as they are **ubiquitous** in the environment. Naturally occurring radionuclides (e.g., uranium and thorium decay chain radionuclides) may be introduced to surface waters through weathering of minerals and rocks containing these substances. During construction, these substances could be introduced to the aquatic environment through fossil fuel combustion (directly through aerial deposition to surface waters and indirectly by deposition in the terrestrial environment followed by precipitation events and runoff), as uranium is also often concentrated in petroleum (Bradford et al. 1990). Levels of radionuclides have been measured through analysis of **gross α and β radioactivity**, to facilitate comparison to guidelines.

5.2.3.2 Sediment Quality Parameters and Rationale

Sediment chemistry was evaluated in the Wuskwatim study area for a number of reasons. Metals introduced into the aquatic environment accumulate in sediments (sediments typically contain the highest concentrations and of metals in aquatic systems), where they may pose a risk to resident biota. Metals in sediments may enter the aquatic food web, by accumulating in **benthos** and via direct ingestion of sediments by benthic feeding fish.

5.2.3.3 Sampling Periods

Data presented in this document include describe water quality in samples collected during the open-water seasons in 1999, 2000, and 2001, and once in the winters of 2001 and 2002 in the main study area[1]. As water chemistry in surface waters can vary during the growing season due to changes in physical conditions and succession of algal

[1] Sampling was also conducted in the open-water season of 2002 in the main study area. Data are provided in Cooley and Shipley 2003 and are not discussed in this document.

communities, water sampling was conducted several times during each of the open-water seasons. A summary of the sampling periods is as follows:

- 1999: late May / early June (28 May – 02 June); late June (20– 26 June); August (19– 23 August); September (23 – 29 September).
- 2000: June (04 – 14 June); July / August (17 – 25 July, August 15 – 20); September (14 – 24 September).
- 2001: March (28 March); late May (29 – 31 May); July (15 – 17 July); August (22 – 27 August); late September/early October (26 September – 01 October).
- 2002: March (25 March – April 02).

Not all water chemistry parameters or sites were sampled during each period; sites and parameters were added as the study progressed in accordance with results of the on-going analysis of data and identification of new information requirements. Sediments were sampled for chemical analysis in July 2001 and August 2002. Water quality was measured at stream crossing sites for the access road in June, 2002. Water quality was also measured at tributary streams located between Wuskwatim and Opegano lakes in September 2002. More comprehensive dissolved oxygen measurements were collected at a number of sites within the study area in late March/early April 2002, to more accurately define concentrations under ice-cover in the main stem and environs.

5.2.3.4 Sampling Sites and Site Selection

Water

Water samples were collected from a total of 20 sites (excluding tributary stream and stream crossing sites), as illustrated in Figure 5-2 and summarized below (not all sites were sampled during each sampling episode):

Reach 1: Wuskwatim Lake Area

- LBRB (on Kinosaskaw Lake at the outlet to the Burntwood River);
- LBRB2 (on the Burntwood River at the base of Early Morning Rapids);
- CLA (in the west basin of Cranberry Lakes);

- SLA (on the west basin of Sesep Lake);
- SLB (on the west basin of Sesep Lake – ice-cover season only);
- LBRC (on the Burntwood River above the mouth at Wuskwatim Lake);
- WuBA (on Wuskwatim Brook, within the area impacted by water level changes resulting from CRD);
- WuLA, WuLB, and WuLC (on Wuskwatim Lake);

Reach 2 and 3: Wuskwatim Falls to Opegano Lake

- WF (on the Burntwood River upstream of Wuskwatim Falls – ice-cover season only);
- TF (below the base of Taskinigup Falls);

Reach 4: Opegano Lake

- OLA and OLB (on Opegano Lake);

Reach 5: Downstream of Opegano Lake

- BLA and BLB (near the upstream end of Birch Tree Lake);
- BLC (Birch Tree Lake at the outlet to the Burntwood River);
- LBRE1 (on the Burntwood River just upstream of Manasan Falls); and,
- LBRE (on the Burntwood River between Manasan Falls and Thompson).

Reach 6: Downstream of Thompson

- LBRF (on the Burntwood River approximately 5.5 km downstream of the PR 391 Bridge).

Note that sampling site LBRE was accessed only once in the open-water season of 2001 and was not sampled again due to safety and accessibility considerations.

Due to the small size and rapid flushing rates of the lakes in the study area, water chemistry in the lakes is similar to that of the Burntwood River. However, some "off-current" portions of the larger lakes, such as secluded bays with tributaries, may remain somewhat isolated from the flow in the main "on-current" portions of the lakes, and at times may differ in water quality. Sampling sites on the larger lakes were selected to include areas with differing amounts of current from the Burntwood River, as follows:

- Wuskwatim Lake: WuLC primarily off-current; WuLA and WuLB primarily on-current; and,
- Birch Tree Lake: BLA primarily off-current; BLB and BLC primarily on-current.

Sites on the lower Burntwood River and lake sites that are typically on-current are referred to hereafter as 'mainstem sites'.

Stream Crossings

Eight major stream crossing sites, indicated in Table 5-1 and Figure 5-3, along the access road have been identified. Water chemistry was evaluated at the following sites: SC2-2; SC4-2; SC5-2; SC6-2; and SC9-2 (Figure 5-3) in June 2002. Under ice dissolved oxygen data were collected in March 2002 at SC2-2, SC5-2, and SC6-2.

Table 5-1. Major stream crossings for the access road.

Stream	Stream ID	Station	Northing	Easting
Stream 1	SC1-3	432+20	6189249.6	547810.3
Stream 2	SC2-2	345+00	6180039.7	548861.2
Stream 3	SC3-3	243+00	6171479.3	547210.6
Stream 4	SC4-2	223+60	6171109.3	545306.2
Stream 5	SC5-2	187+20	6169660.4	542099.9
Stream 6	SC6-2	167+40	6167936.1	541203.7
Stream 8	SC8-2	82+70	6160674.1	537342.4
Stream 9	SC9-2	60+60	6158739.9	536474.8

Reach 2 and 3: Tributary Streams

Sampling also occurred at 10 tributary streams between Wuskwatim and Opegano lakes in September 2002 (Figure 5-4). With one exception, two sites were sampled at each stream, one site at the backwater inlets of each stream was sampled (STR-1-D to STR-10 – D) and one site upstream (approximately 500 – 1000 m upstream) of the backwater inlets at a point upstream of visible influence of the lower Burntwood River was sampled

(STR-1-U to STR-10-U). Only one site was sampled at Stream 8 (STR-8-U), due to problems associated with access.

Sediments

Sediment samples were collected at Wuskwatim Lake (WuLB) and Opegano Lake (OLB) in July 2001 and at Wuskwatim Lake (WuLB), Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in August 2002 for the analysis of sediment quality (inorganic elements and **hydrocarbon**s). To provide information regarding the spatial variability of measured parameters, three samples, spaced 50-200 m apart, were collected from the area surrounding each site.

5.2.3.5 Sample Collection and Field Measurements

Water

At each location, dissolved oxygen, pH, temperature, conductivity, and turbidity were measured *in situ* approximately 10 cm below the water surface. Dissolved oxygen, temperature, and conductivity were also measured at the bottom and along depth profiles at sites where vertical **stratification** of the water column was detected or suspected; depth profiles for turbidity and pH were also obtained in the open-water season 2001. **Secchi disc depth** was measured at each lake site and occasionally at river sites.

During the open-water seasons, water samples were collected from approximately 10 cm below the water surface for laboratory analysis. In winter, water samples were collected with a Kemmerer sampler from just below the bottom of the ice. Samples were delivered to Enviro-Test Laboratories in Winnipeg for analysis.

Sediments

Sediment samples were collected in triplicate using a Wildco Hand Corer or an Ekman dredge depending on water depth. The top approximately 5 cm were collected for analysis at EnviroTest Laboratories.

5.2.3.6 Chemical Analyses

Water

The following parameters were analyzed by Enviro-Test Laboratories using standard methodologies:

- pH;

- Calcium carbonate, bicarbonate, carbonate, and hydroxide alkalinity;
- Hardness (as $CaCO_3$);
- Total suspended solids and total dissolved solids;
- Fluoride, chloride, and sulphate;
- Dissolved nitrate / nitrite and **ammonia nitrogen**;
- **Total Kjeldahl nitrogen** (**TKN**);
- Total phosphorus (**TP**) and dissolved phosphorus;
- Total organic carbon and dissolved organic carbon (**DOC**);
- True colour;
- Fecal coliform bacteria;
- *Cryptosporidium* sp. and *Giardia* sp.;
- Total and dissolved **metals**;
- Polycyclic aromatic hydrocarbons (PAH);
- Total extractable hydrocarbons (**TEH**);
- Benzene, toluene, ethylbenzene, and xylenes (BTEX) and Total Volatile Hydrocarbons (TVH);
- Pentachlorophenol (PCP); and,
- Gross α and β radioactivity.

Sediments

Total metals, PAH, TEH, BTEX, TVH, PCP, particle size, and organic matter were analyzed by Enviro-Test Laboratories using standard methodologies.

5.2.3.7 Data Analysis and Presentation

Detailed results and statistical summaries of water chemistry analyses are presented in appendices 2 and 3, respectively. Analytical results for fecal coliform bacteria and parasites and sediment chemistry are presented in appendices 4 and 5, respectively.

MWQSOGs for Water Chemistry Parameters

Manitoba Water and Sediment Quality Criteria

Guidelines and objectives have been generated for many water and sediment quality parameters, for the purposes of protecting aquatic biota and wildlife, as well as various human usages, including recreation, drinking, irrigation, and livestock; a summary of relevant criteria are presented in Appendix 6. In Manitoba, revisions to existing water quality criteria (Williamson 1988) are currently undergoing the final phase of review (Williamson 2002); proposed revisions (and additions), are largely in accordance with national guidelines (CCME 1999). These proposed revisions include addition of sediment quality guidelines for a number of inorganic and organic substances, established to provide protection to aquatic life.

Data collected during baseline studies (describing water and sediment quality) were compared to the proposed MWQSOGs (Williamson 2002), where available, and criteria applied by other jurisdictions, where criteria were not available for Manitoba.

Drinking Water Quality Objectives

Proposed Manitoba water quality objectives and guidelines for drinking water (Williamson 2002) are adopted directly from the federal Health Canada objectives, summarized in CCME (1999); relevant objectives for the Wuskwatim Project are presented in Appendix 6. Drinking water quality objectives and guidelines are intended to be applied to treated or finished water as it emerges from the tap and "are not intended to be applied directly to source waters" (CCME 1999). However, comparison of water quality in the study area to drinking water quality objectives is included to provide context; it is clearly indicated in the proposed MWQSOGs (Williamson 2002): "All surface waters…are susceptible to uncontrolled microbiological contamination. It is therefore assumed that all raw surface water supplies will be disinfected as the minimum level of treatment prior to consumption." Furthermore, it is indicated that Manitoba Water Quality Guidelines "apply to finished drinking water, but can be extrapolated to provide protection to raw drinking water sources."

Comparison to MWQSOGs

In general, water quality criteria are more stringent for the protection of aquatic life and wildlife, relative to criteria established to protect various human usages, including drinking water objectives. Furthermore, some water quality criteria apply only to the protection of aquatic life and wildlife (e.g., dissolved oxygen). Throughout this document, observed water quality conditions in the study area are compared to the MWQSOGs; in most instances, the criteria discussed refer to the MWQSOGs for the protection of aquatic life, because water quality conditions generally fall below the objectives established for drinking water protection. Where exceptions to this generality occur, they are indicated in the discussion.

Data Analysis and Interpretation

Summary statistics, including means± **Standard Error** (SE) of water and sediment chemistry parameters were calculated for each water quality sampling site for ease in comparison (Appendices 3 and 5). For the purposes of calculating mean±SE values, measurements reported below analytical detection limits were assigned a value of one half the **DL**.

Data were compared to proposed MWQSOGs for the protection of aquatic life, where available (Williamson 2002), as summarized in Appendix 6. Site-specific objectives were calculated for ammonia based on the range of pH and water temperature observed in the study area. Site-specific objectives were also calculated for cadmium, copper, chromium, lead, nickel, and zinc, based on **water hardness** measured in the same water sample. With one exception (arsenic), for all substances for which there are MWQSOGs for the protection of aquatic life, guidelines and objectives are more stringent for the protection of aquatic life than for protection of human health as drinking water (Williamson 2002). Therefore, no discussion is included of compliance with drinking water quality objectives if measurements were below MWQSOGs for the protection of aquatic life. Where the MWQSOGs for the protection of aquatic life are exceeded, consideration of compliance with drinking water quality guidelines is included.

Manitoba and Ontario sediment quality criteria for inorganic substances, nutrients, and hydrocarbons, and 'background' concentrations of select metals in lake and stream sediments in Canada are summarized in Appendix 6. Ontario sediment quality criteria were considered where criteria do no exist for Manitoba (see Appendix 6 for details).

Light Extinction and Euphotic Zone Estimates

Light extinction coefficients (K_e) and the depth of the **euphotic zone** (z_1) (defined as depth at which 1% of surface radiation still remains) were estimated from Secchi Disc depths (z_{sd}) using the following relationships for **turbid** (i.e., turbidity > 5 **NTU**) systems:

$K_e = 1.3/ z_{sd}$; and,

$Z_1 = z_{sd} \times 3.3$ (Kalff 2002).

Nutrient Ratios

Nitrogen to phosphorus molar ratios were calculated for the purposes of evaluating the potential limiting nutrient. Ratios less than 10 were considered indicative of nitrogen limiting conditions and values greater than 16 were considered indicative of phosphorus limitation. Ratios between 10 and 16 were considered to indicate co-limitation (Kalff 2002).

Carbon to nitrogen molar ratios were calculated to evaluate the potential significance of **autochthonous** (i.e., derived from decomposition of plankton in the lake) and **allochthonous** (i.e., derived from decomposition of peat and/or organic matter that falls into streams) carbon. Ratios of 12:1 generally indicate that organic matter is authochthonous whereas ratios of 45-50:1 indicate that organic matter is derived from allochthonous sources, such as peaty material (Hutchinson 1957).

5.3 EXISTING ENVIRONMENT

5.3.1 Traditional Knowledge

Since CRD, access to the area by NCN members has been limited due to dangerous travel conditions on the waterways. Therefore, most TK was related to water quality changes along the CRD route as a whole. At scoping workshops and in TK interviews, NCN members have stated that CRD caused water quality to decline and, in particular, that water is “muddy” and of “poor quality” due to flooding of terrestrial vegetation. NCN members have also indicated a direct link between poor water quality and effects to aquatic life (i.e., fish).

5.3.2 Historical Scientific Information

5.3.2.1 Water Quality

Statistical summaries of water quality data collected at MB Conservation Water Quality Monitoring Station 0093.00 on the lower Burntwood River at PTH 6 in Thompson, in the open-water and ice-cover seasons (January 1980 – December 2000) are provided in Appendix 1. Scatter plots of selected water quality parameters measured from 1980 to 2000 are also presented in Appendix 1.

Statistical summaries of data collected at the Burntwood River at Thompson and at the inlet to Split Lake during FEMP (January 1987 – October 1989), presented in Ramsey (1991), are also provided in Appendix 1.

<u>Compliance With MWQSOGs: WQ0093.00 at Thompson</u>

Water chemistry data for the ice-cover and open-water seasons measured at the MB Conservation water quality monitoring station 0093.00 on the lower Burntwood River at the PTH 6 Bridge in Thompson were compared to MWQSOGs to evaluate the occurrence of exceedences of water quality criteria over the 20-year period that was examined. A detailed summary of the frequency of exceedences for various water chemistry parameters are presented in Appendix 1. The following is a brief synopsis of the occurrence of exceedences in this data set.

Measurements of the following parameters were consistently in compliance with MWQSOGs for the protection of aquatic life and drinking water quality in the open-water and ice-cover seasons, 1980 - 2000: pH (laboratory); dissolved oxygen; ammonia (total, dissolved, and soluble); nitrate/nitrite (dissolved and soluble); antimony; barium; boron; chromium; molybdenum; thallium; uranium; zinc; chloride; and, sulphate.

Compliance could not be assessed for all measurements reported for all parameters because analytical detection limits sometimes exceeded the MWQSOGs. All measurements of silver and mercury and some measurements for true colour, copper, lead, selenium, and cadmium, could not be assessed for compliance, for this reason.

Parameters for which at least one exceedence occurred in the period of record examined include: pH (*in situ*); TSS; true colour; phosphorus (total); aluminum (extractable, dissolved, and total); arsenic (extractable); cadmium (extractable); copper (extractable and total); iron (extractable, dissolved, and total); lead (extractable and total); nickel (extractable); and, selenium (total).

In general, parameters that were most consistently in non-compliance with MWQSOGs were true colour, aluminum, and iron. Virtually all (90% and 100% of measurements in the open-water and ice-cover seasons, respectively) were above the aesthetic drinking water quality objective for true colour. All measurements of aluminum (in extractable, dissolved, and total forms) taken in the open-water and ice-cover seasons were above the guideline for the protection of aquatic life (there is no guideline for drinking water). With one exception (a single measurement of dissolved iron), all measurements of iron (in extractable, dissolved and total forms) were above water quality guidelines for the protection of aquatic life and above the aesthetic drinking water quality guideline. Exceedences of the water quality guideline for phosphorus for streams was also reasonably frequent (55% in the open-water season and 23% in the ice-cover season).

One measurement of pH (*in situ*), equal to approximately 2% of measurements, taken in the open-water season was slightly above the aesthetic drinking water quality guideline but within guidelines for the protection of aquatic life. TSS exceeded the previous water quality objective of 25 mg/L (Williamson 1988) in 15% and 10% of samples analysed for the open-water and ice-cover seasons, respectively.

Other than aluminum and iron, which are discussed above, the metals that most frequently exceeded MWQSOGs were copper, cadmium, and lead. In the open-water season, 20% and 43% of measurements of extractable and total forms of copper, respectively, exceeded the chronic water quality objectives for the protection of aquatic life. In the ice-cover season 34% of extractable copper measurements exceeded this objective. Small fractions (approximately 2%) of measurements of lead and cadmium in the open-water and ice-cover seasons exceeded the maximum acceptable concentrations for drinking water. As MWQSOGs for the protection of aquatic life are more stringent for lead and cadmium than are drinking water quality guidelines, greater frequencies of exceedences for lead and cadmium were observed with respect to chronic water quality objectives for the protection of aquatic life.

Evaluation of Trends

Visual examination of scatter plots of concentrations and loads constructed for a number of water quality parameters did not provide evidence of a strong upward or downward trend over the time period evaluated (i.e., increase or decrease over time) (Appendix 1).

Water Quality Index

Water quality index values were derived for a number of monitoring sites in northern Manitoba for the years 1991 through 1994, using the B.C. Water Quality Index (MB

Conservation 1997). Water quality indices (WQIs) provide broad overviews of environmental performance, by considering the scope, frequency, and occurrence of non-compliance of water quality data against water quality criteria. Water quality parameters considered in the **WQI** include dissolved oxygen, pH, TSS, ammonia, trace elements, fecal coliform bacteria, nutrients, and conductivity. Ultimately, WQI values are generated and assigned a rank according to specified criteria (for further discussion of WQIs see Section 5.3.6).

Using the B.C. WQI and ranking scheme, water quality in the Burntwood River at Thompson was ranked as 'fair' for the period of 1991-1994. Furthermore, the WQI remained relatively uniform, ranging between the boundaries of "fair" and "good", over this five-year interval for water flowing from Southern Indian Lake to Split Lake, indicating that water quality was not changing substantively in space or time (MB Conservation 1997).

5.3.2.2 Sediment Quality

Concentrations of copper, zinc, cadmium, nickel, lead, and mercury measured in a surficial (1-3 cm) sediment sample collected from the lower Burntwood River at the float plane base in Thompson in August 1979 are presented in Table 5-2 (Williamson 1980). Cadmium and nickel were elevated above Manitoba sediment quality guidelines (SQGs) but below the **PEL**; all other metals were below sediment quality criteria (Williamson 2002).

Table 5-2. Concentrations of metals in surficial sediments collected from the lower Burntwood River in Thompson, August 1979 (Williamson 1980) and Manitoba Sediment Quality Criteria (Williamson 2002). SQG = sediment quality guideline; and, PEL = probable effect level.

Location	Concentration (µg/g dry weight)						
	Cadmium	Copper	Lead	Nickel	Zinc	Mercury	Mercury (wet weight)
Burntwood River at Thompson	1.0	10.0	10.0	36.0	33.0	0.02	0.02
Manitoba SQGs	0.6	35.7	35	16	123	0.17	-
Manitoba Sediment Quality PEL	3.5	197	91.3	75	315	0.486	-

5.3.3 EIS Studies: Overview of Water and Sediment Quality

This section provides an overview of the results of the water and sediment studies. Detailed results are provided in Section 5.3.4.

5.3.3.1 Water Chemistry

Wuskwatim, Opegano, and Birch Tree lakes can be broadly described as meso-eutrophic to **eutrophic**, highly oxygenated (in ice-free and ice-cover seasons), soft-water, slightly alkaline lakes with low transparency. The lower Burntwood River in the study area, can be described in similar terms: highly turbid, soft, slightly alkaline and highly oxygenated. Concentrations of nitrogen and phosphorus are considerably high in the study area and the area is characterized by moderate levels of organic carbon. Most measurements of total phosphorus in the lakes and at locations on the lower Burntwood River at the point of entry to the lakes exceeded the Manitoba Water Quality Standards, Objectives, and Guidelines for total phosphorus of 0.025 mg/L for the prevention of nuisance plant growth. Conditions, in general, appeared to indicate that of the two major plant nutrients (N and P), conditions were generally nitrogen limiting. However, due to the hydraulic conditions (i.e., high turbulence, high velocities, high flushing rates and low river travel times) and the low water transparency at most sites along the mainstem of the study area, phytoplankton growth is likely limited (or co-limited) by light and/or physical characteristics of the aquatic environment.

Water chemistry at sites not lying along the main stem of the study area including Sesep Lake, Wuskwatim Brook, and Wuskwatim Lake south (WuLC), differs somewhat from conditions along the main stem of the study area. Sesep Lake and Wuskwatim Brook contain higher levels of TKN, organic carbon, and **chlorophyll** *a*, lower concentrations of total phosphorus and TSS, and are more clear (less turbid and higher **secchi depth**s) and acidic than Wuskwatim, Opegano, or Birch Tree lakes. Conductivity in Sesep Lake is also higher than other sites evaluated on the mainstem of the study area. Water chemistry in Wuskwatim Lake south (WuLC), which is influenced by Wuskwatim Brook water, is similar to conditions encountered in Wuskwatim Brook; generally, levels of nitrogen, organic carbon, and chlorophyll *a* are higher, pH is lower, and water clarity (lower turbidity and higher secchi depths) is greater at this site, relative to Wuskwatim Lake main and the remainder of the study area on the main stem. In addition, off-current areas in Wuskwatim Lake south and in waterbodies adjacent to Wuskwatim Lake (Wuskwatim Brook, Sesep Lake, Muskeseu River) experience lower dissolved oxygen concentrations under ice cover. At some sites in these areas, **DO** occurred at levels below acute and chronic MWQSOGs for the protection of aquatic life; near **hypoxic** conditions were observed in the Muskeseu River and Wuskwatim Brook in March 2002.

Relative to the main stem of the study area, tributary streams in Reach 3 were, in general, more nutrient-rich (ammonia, nitrate/nitrite, **organic nitrogen** [ON], TKN, total nitrogen (**TN**), dissolved phosphorus, total phosphorus), had higher concentrations of organic carbon, total dissolved solids, and TSS, and higher levels of water hardness, true colour. Streams were also less oxygenated, although DO was higher than water quality objectives, and more acidic than the main stem Burntwood River. As these streams drain bogs and support a number of beaver dams, these observations are as expected.

Some seasonal differences in certain water chemistry parameters were observed throughout the study area. In general, concentrations of inorganic forms of nitrogen and phosphorus are higher, while total concentrations of nitrogen and phosphorus are lower in winter. Furthermore, water clarity is greater and pH is lower (due to reduced photosynthetic activity and entrapment of carbon dioxide by ice cover) under ice cover conditions.

Concentrations of some metals are elevated in the study area as a whole, most notably aluminum and iron; levels of both these metals are typically at least an order of magnitude above MWQSOGs for the protection of aquatic life, although both have been elevated in this system for decades (Ramsey 1991, Appendix 1). Iron also exceeds the aesthetic objective for drinking water quality throughout the study area. Several other metals/metalloids were, at times, elevated above MWQSOGs for the protection of aquatic life in the study area including copper (three measurements at Birch Tree Lake, one measurement at Wuskwatim Lake, and one measurement at Opegano Lake), lead (two measurements at Birch Tree Lake, one measurement in the lower Burntwood River downstream of Birch Tree Lake, and one upstream of Wuskwatim Lake), nickel (one measurement in Birch Tree Lake), and selenium (one measurement at Wuskwatim Lake and one at Taskinigup Falls). The most exceedences of criteria for metals and metalloids occurred in Birch Tree Lake. One value of gross alpha radiation (Taskinigup Falls) occurred at the CCME guideline (0.1 Bq/L) for drinking water (CCME 2001b). The occurrence of high levels of iron and aluminum, and occasionally high concentrations of other metals, in the study area has been described as 'natural' (Ramsey 1991) and exceedences have been observed for many metals and metalloids from 1980 to 2000 in the lower Burntwood River at Thompson at the MB Conservation monitoring site **WQ** 0093.00 (Appendix 1).

Inorganic elements were measured at two tributary streams in Reach 3. Results were similar to the main stem; aluminum, iron, zinc, and lead exceeded MWQSOGs for the protection of aquatic life and iron exceeded the aesthetic objective for drinking water.

Concentrations of aluminum and iron measured in Stream 4 were the highest measurements recorded for the entire Wuskwatim study area.

PAHs were infrequently detected in water samples collected in the study area and there is no indication of significant hydrocarbon pollution. Occasional measurements above analytical detection limits for certain PAHs are believed to reflect localized releases of hydrocarbons (e.g., boat motor fuel) and/or atmospheric deposition of PAHs released from distant locations and are not perceived as evidence of chronic pollution/contamination. PAHs are ubiquitous in the aquatic environment and it is not unusual to detect trace amounts of these compounds in aquatic ecosystems.

A number of PAHs were detected in the lower Burntwood River, downstream of Thompson in 2001. Most were in compliance with MWQSOGs. However, one measurement of benzo(a)pyrene collected downstream of Thompson exceeded the drinking water quality guideline and the guideline for the protection of aquatic life and the same sample contained benz(a)anthracene at a concentration above the MWQSOG for the protection of aquatic life. The presence of PAHs at this location is not unusual given that the lower Burntwood River at Thompson receives industrial and municipal effluents and would receive atmospheric deposition of PAHs released during combustion of fossil fuels in the area.

Benz(a)anthracene, benzo(b)fluoranthene, benzo(g)perylene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene were also detected in the water sample collected from Tributary Stream 4 in Reach 3. All PAHs were below MWQSOGs for the protection of aquatic life and drinking water quality, for those parameters for which criteria exist. Although the precise reason for the presence of these substances is not known, they may indicate effects from upstream site evaluations (i.e., stream crossing investigations) or reflect other local or distant sources of PAHs.

The Canadian Water Quality Index (**CWQI**) (CCME 2001c) was applied to water quality data collected in the study area during the open-water season 2001 for Birch Tree Lake (BLB), Wuskwatim Lake (WuLB), the lower Burntwood River downstream of Taskinigup Falls (TF), and the lower Burntwood River downstream of Early Morning Rapids (LBRB2). The water quality index (WQI) value for Birch Tree Lake, ranked as 'marginal', reflects water quality conditions that are consistently in non-compliance with objectives for iron, phosphorus, and aluminum, and two values for lead that were above the water quality objectives. Aluminum concentrations were in the range of 10 – 25 times the water quality objective.

The WQI value for Wuskatim Lake, ranked as 'fair', is slightly higher than that for Birch Tree Lake. All concentrations of iron and aluminum and three of the four measurements of phosphorus obtained for this site were in non-compliance with objectives.

Values for the water quality index for both sites on the lower Burntwood River for the year 2001 are ranked as 'fair'. These values are a reflection of consistent non-compliance with objectives for iron and aluminum. One measurement of lead in water collected at the lower Burntwood River downstream of early morning rapids (LBRB2) was also above the corresponding water quality objective. As observed at the two lake sites, all but one measurement (Lower Burntwood River Site B2) of aluminum fell in the range of 10 – 25 times the objective.

Although not directly comparable, water quality index values were derived for a number of monitoring sites in northern Manitoba for the years 1991 through 1994, using the B.C. Water Quality Index (MB Conservation 1997). Using the B.C. WQI and ranking scheme, the Burntwood River at Thompson was ranked as 'fair' for 1991-1994.

5.3.3.2 Sediment Chemistry

Sediment chemistry was evaluated at Wuskwatim Lake (2001 and 2002), Opegano Lake (2001 and 2002), Taskinigup Falls (2002), and Birch Tree Lake (2002). Of the substances for which either provincial or other sediment quality criteria are available, cadmium, lead, mercury, selenium, and zinc were consistently below the existing criteria at all sites (Williamson 2002). In addition, concentrations of cobalt were below the Ontario Open Water Disposal Guidelines (Persaud et al. 1993).

Substances for which at least one sub-sample (i.e., one of three samples collected in each lake) measurement exceeded a guideline include arsenic, chromium, copper, iron, manganese, and nickel. Compliance with Ontario Open Water Disposal Guidelines (Persaud et al. 1993) for silver could not be assessed because analytical detection limits (< 1 μg/g) were higher than the guideline (0.5 μg/g).

Site mean concentrations of chromium were consistently above **MSQG**s at all sites examined and site mean concentrations of arsenic were above the MSQG at Opegano Lake in 2002 and above the probable effect level (PEL) at Taskinigup Falls in 2002. Although all site means for copper were below the Manitoba Sediment Quality Guidelines, a single measurement obtained from a sediment sub-sample from Opegano Lake in 2001 exceeded the MSQG.

All but one site mean (Birch Tree Lake) exceeded the Ontario Lowest Effect Level (**LOEL**) for iron, indicating high 'natural' concentrations of iron in the study area; this observation is consistent with high concentrations of iron in surface water that is observed across the study area.

Concentrations of manganese in sediments were high, as compared to Ontario LOEL and Severe Effect Level (**SEL**), at all sites except Taskinigup Falls, indicating that the study area is also generally rich in manganese. All site mean concentrations of nickel in sediments were in excess of the Ontario LOEL, indicating a high 'natural' occurrence and reasonably consistent spatial distribution of this element in the study area. Naturally high levels of this metal in the aquatic environment would not be unexpected, as the study area is located in a nickel belt. The results presented herein are in agreement with the results presented in Williamson (1980), where it was reported that concentrations of nickel measured in surficial sediments collected from the lower Burntwood River in Thompson in 1979 exceeded the **OMOE** LOEL for sediment quality (Persaud et al. 1993).

Individual hydrocarbons and PCP were not detected in Wuskatim or Opegano Lake sediments, which is consistent with results of water chemistry analyses that indicate there is no evidence of chronic contamination in the study area.

5.3.4 EIS Studies: Detailed Results of Water Sampling Program

Raw data for water chemistry analyses are presented in Appendix 2 and statistical summaries are presented in Appendix 3. Results of microbiological analyses are presented in Appendix 5. Water and sediment quality objectives referred to in the following discussion are presented and summarized in Appendix 6.

Dissolved oxygen concentrations measured across the study area under ice in March/April 2002 are presented in Figures 5-5 to 5-7. Site means of pH, conductivity, TSS, turbidity, ammonia, total nitrogen, dissolved **inorganic nitrogen** (**DIN**), total phosphorus, dissolved phosphorus (**DP**), total organic carbon (**TOC**), TOC:ON ratios, and DIN:DP ratios for the open-water season of 2001 are presented in Figures 5-8 to 5-21.

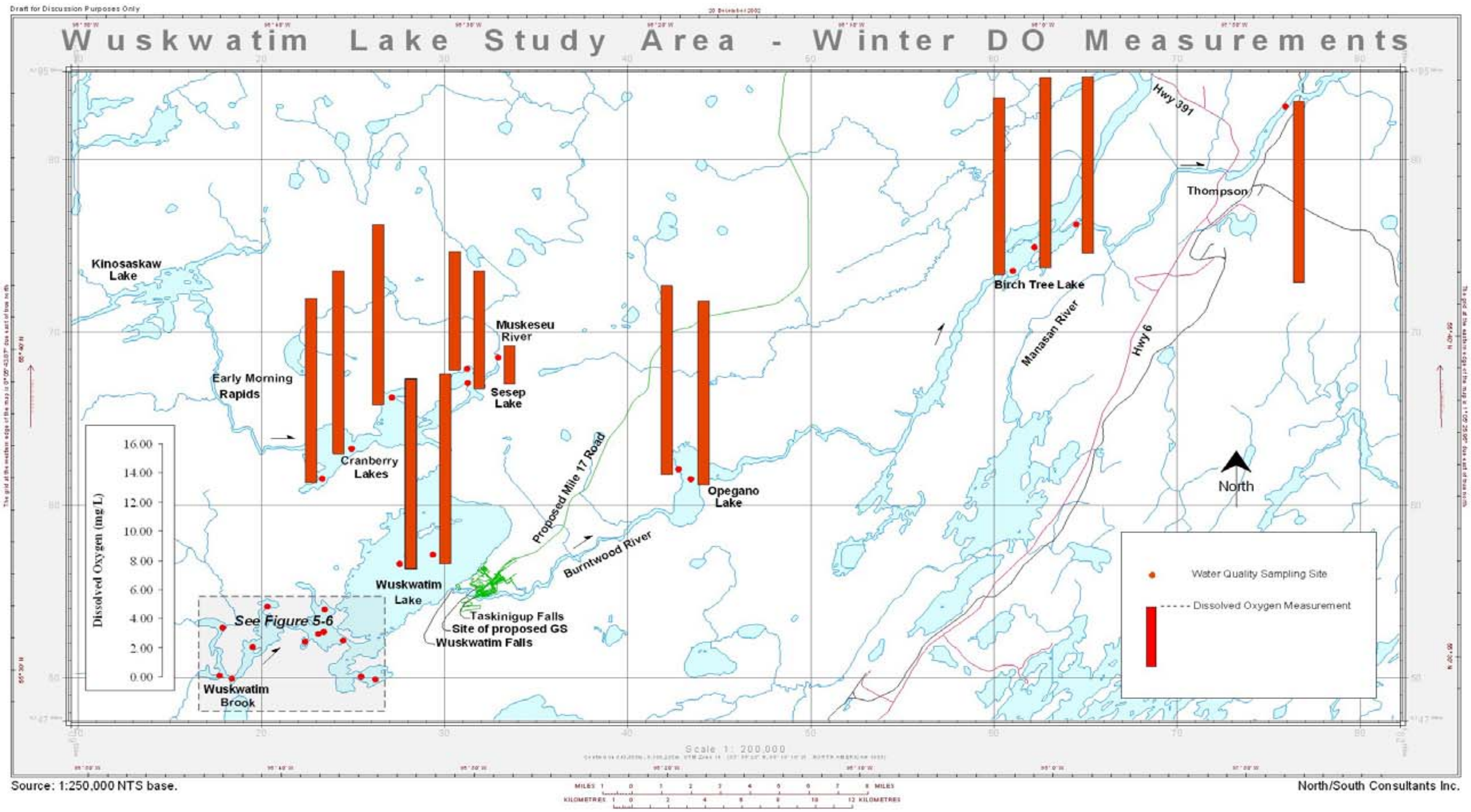


Figure 5-5. Dissolved oxygen concentrations measured under ice in the extended study area, March 25 - April 02, 2002.

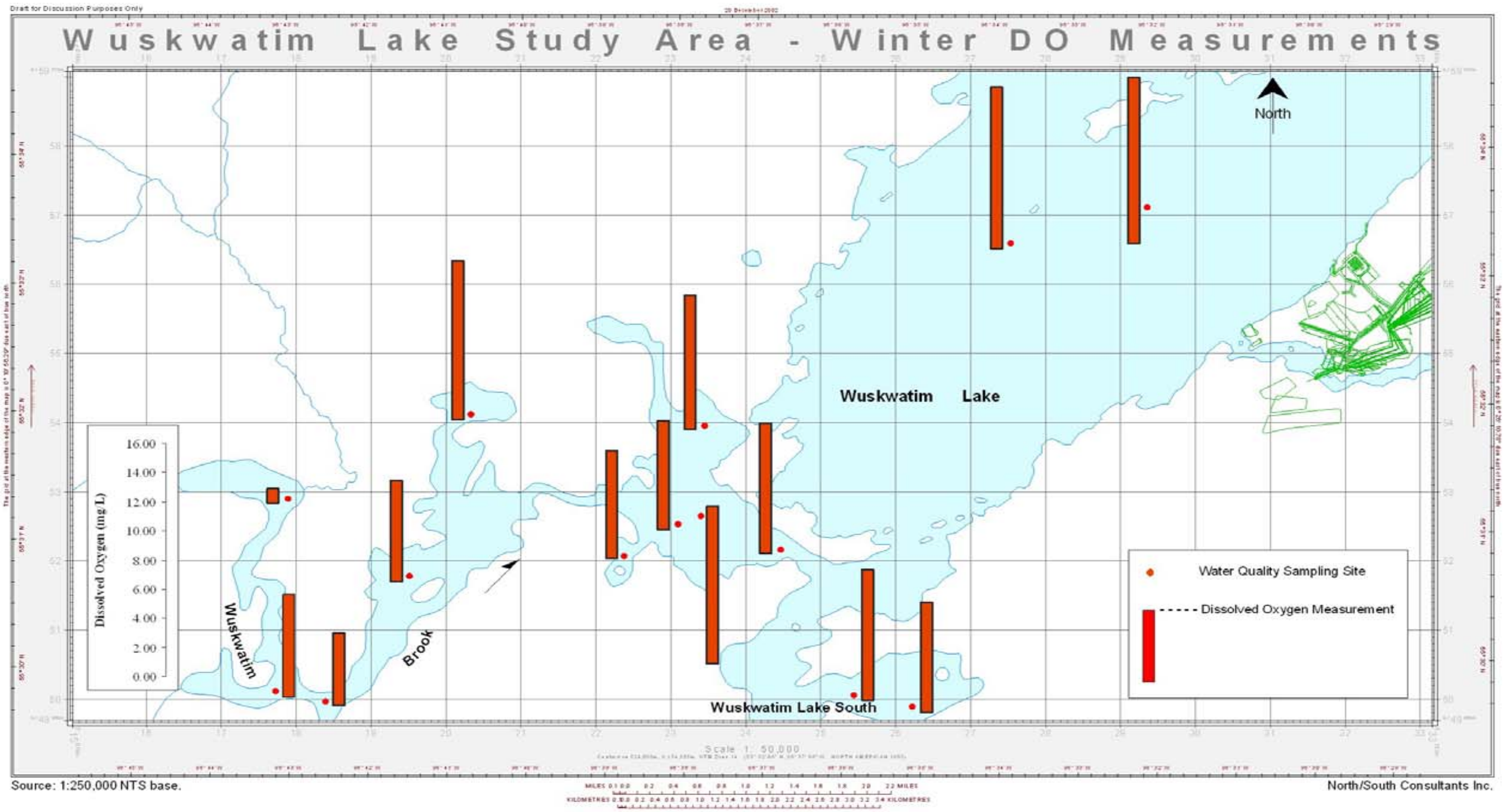


Figure 5-6. Dissolved oxygen concentrations measured under ice in Wuskwatim Lake and Wuskwatim Brook, March 25 - April 01, 2002.

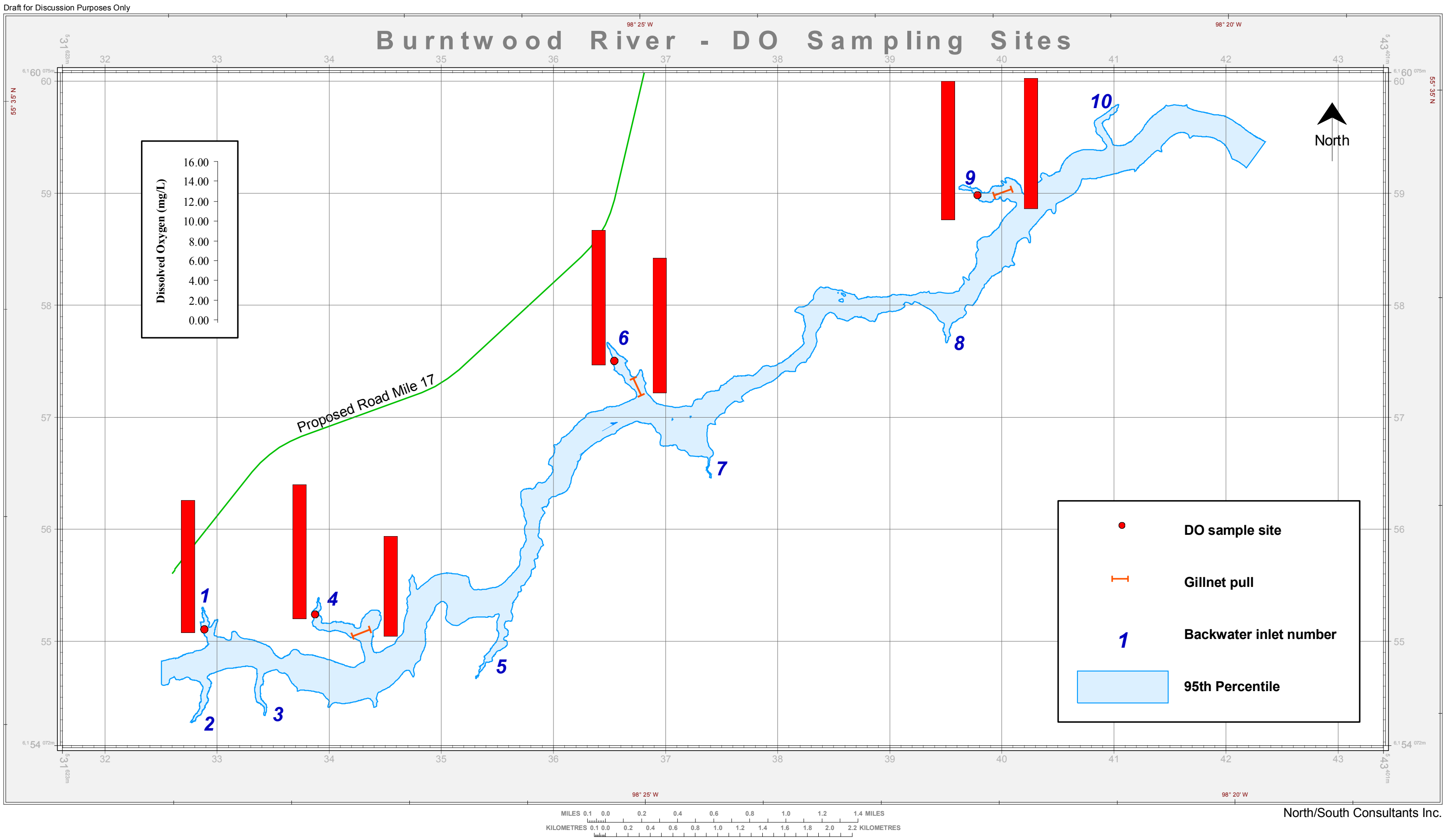


Figure 5-7. Dissolved oxygen concentrations measured under ice in the backwater inlets of tributary streams in Reach 3, March 25 - April 01, 2002.

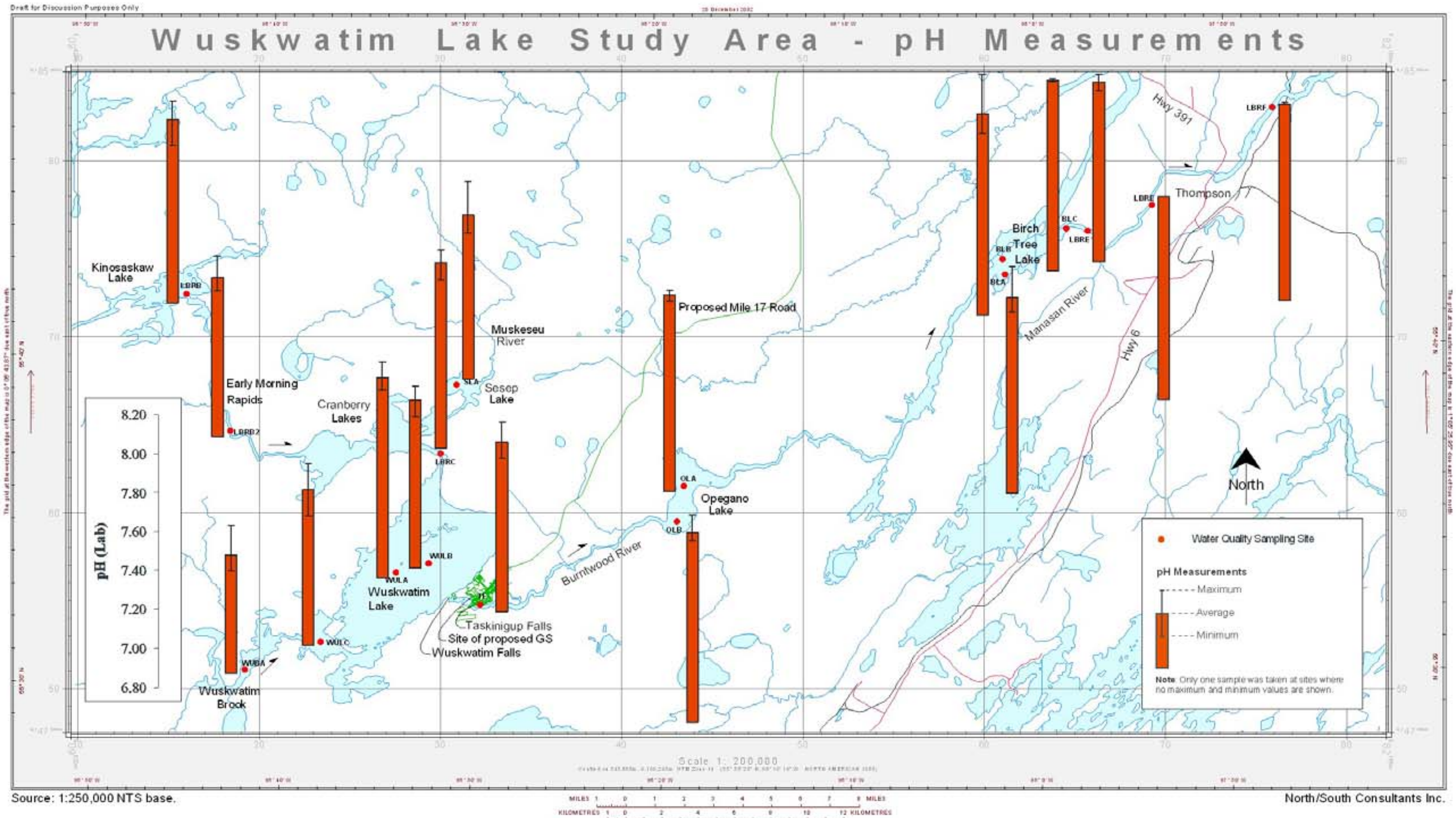


Figure 5-8. Mean surface pH (lab) measured in the study area in the open-water season, 2001.

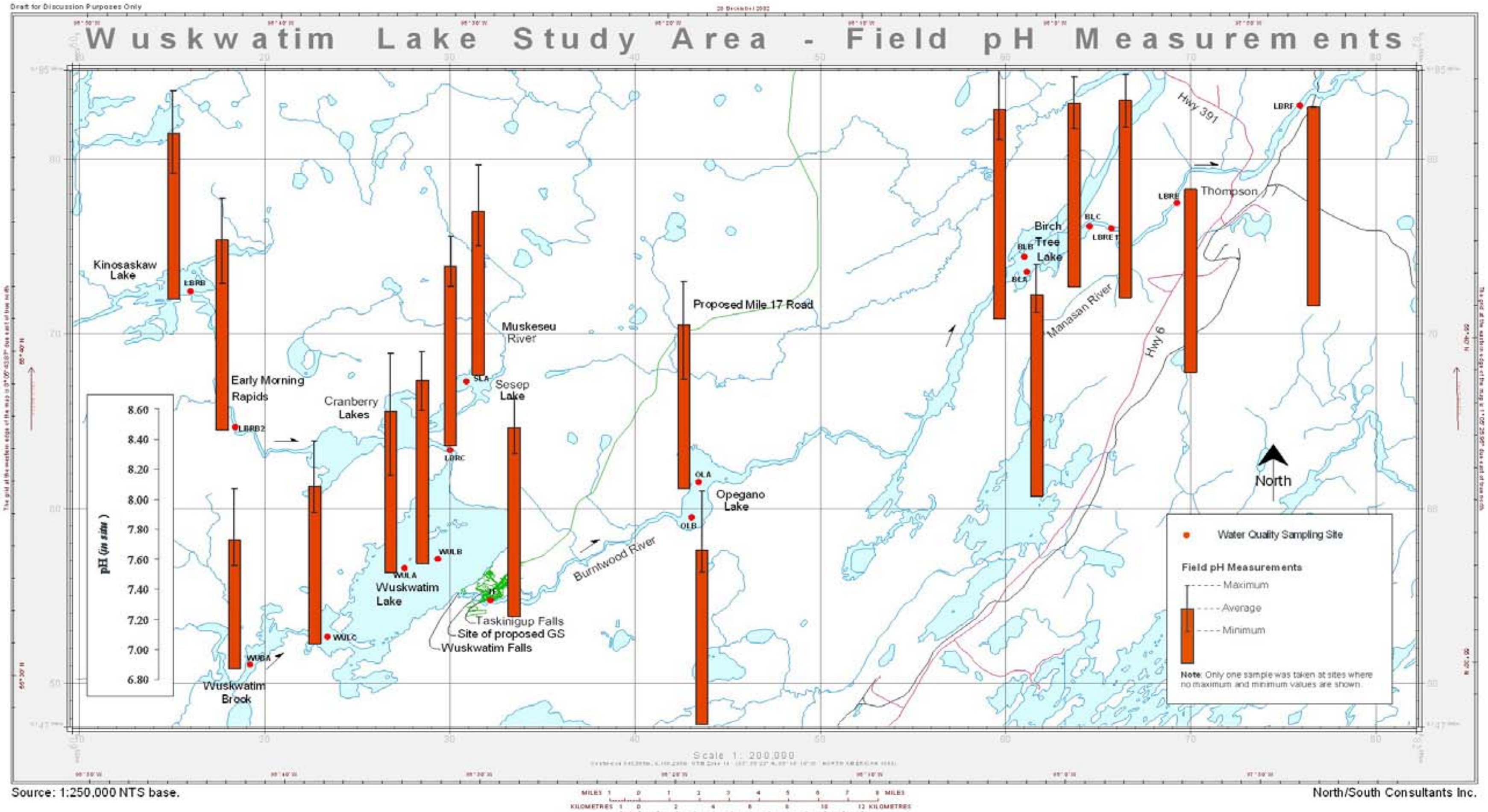


Figure 5-9. Mean surface *in situ* pH measured at the water surface in the study area in the open-water season, 2001.

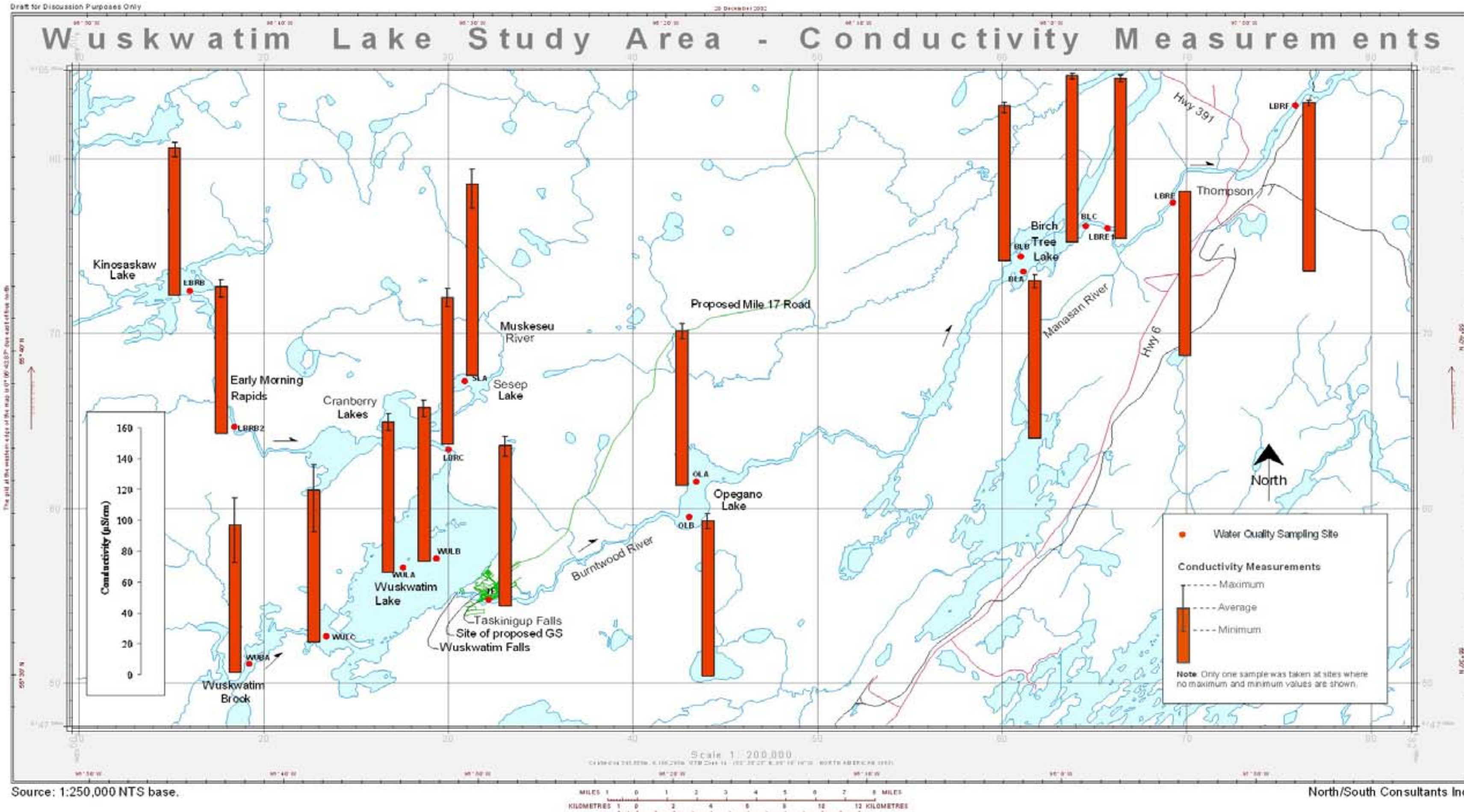


Figure 5-10. Mean surface *in situ* conductivities measured in the study area in the open-water season, 2001.

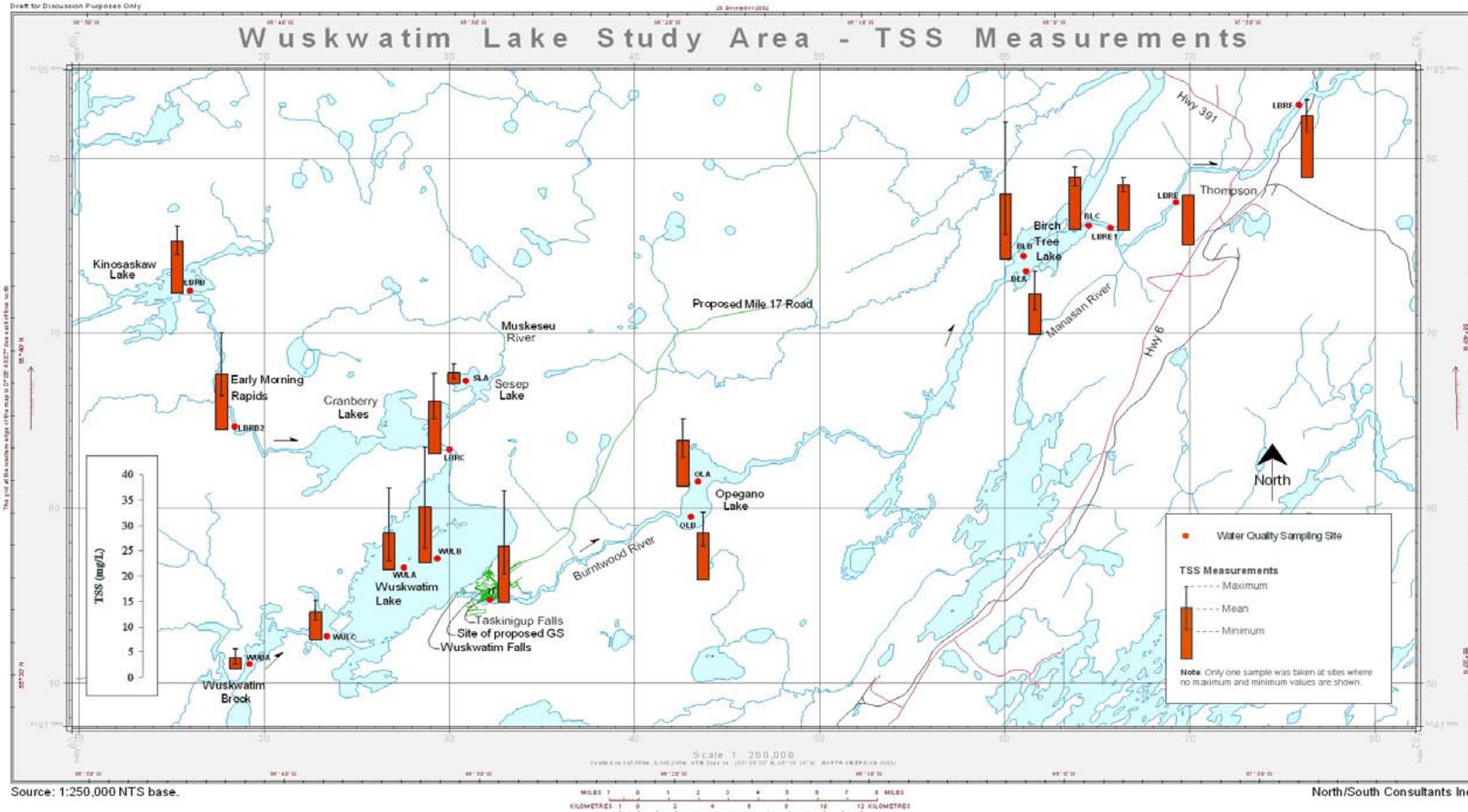


Figure 5-11. Mean surface total suspended solids (TSS) concentrations measured in the study area in the open-water season, 2001.

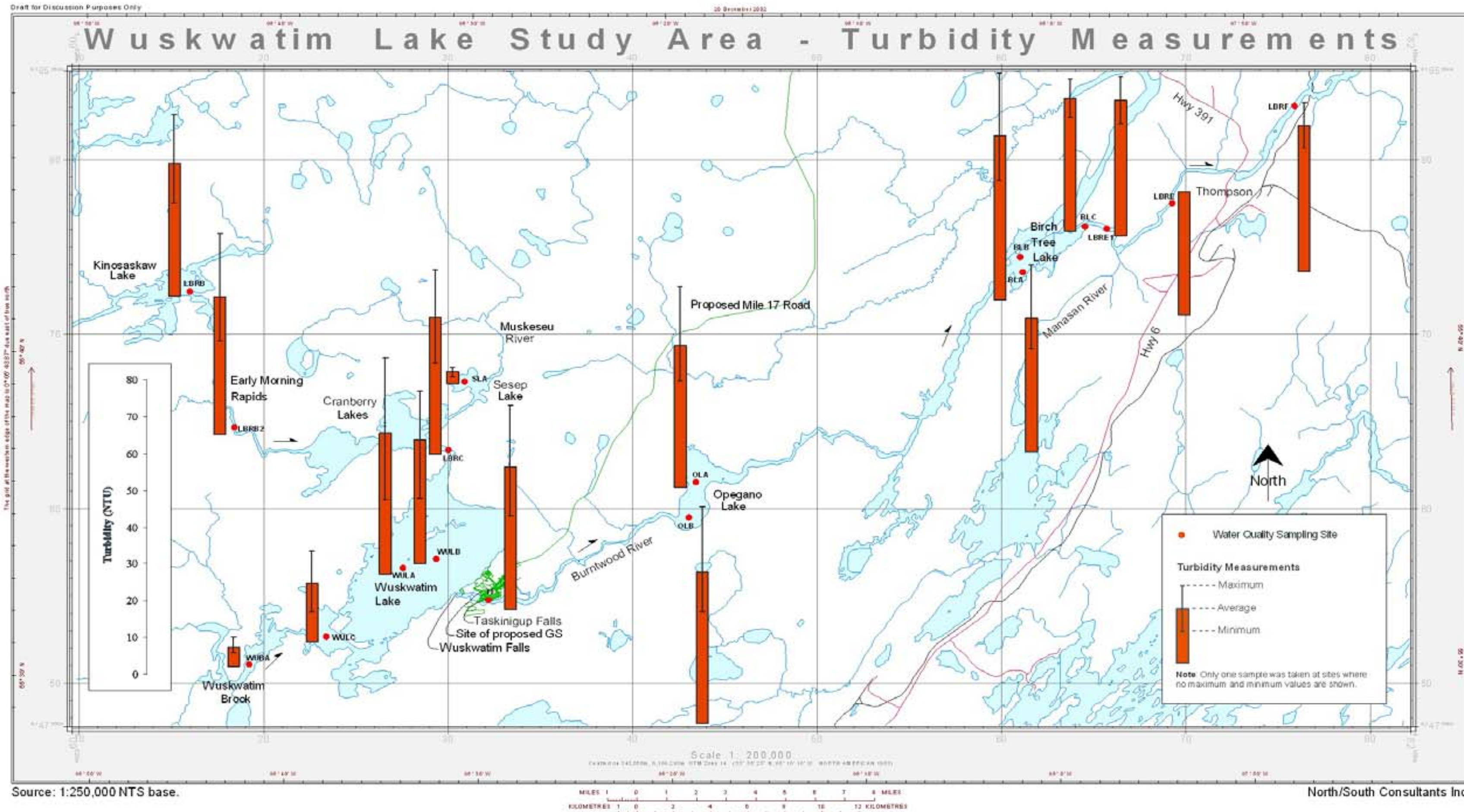


Figure 5-12. Mean surface *in situ* turbidity measured in the study area in the open-water season, 2001.

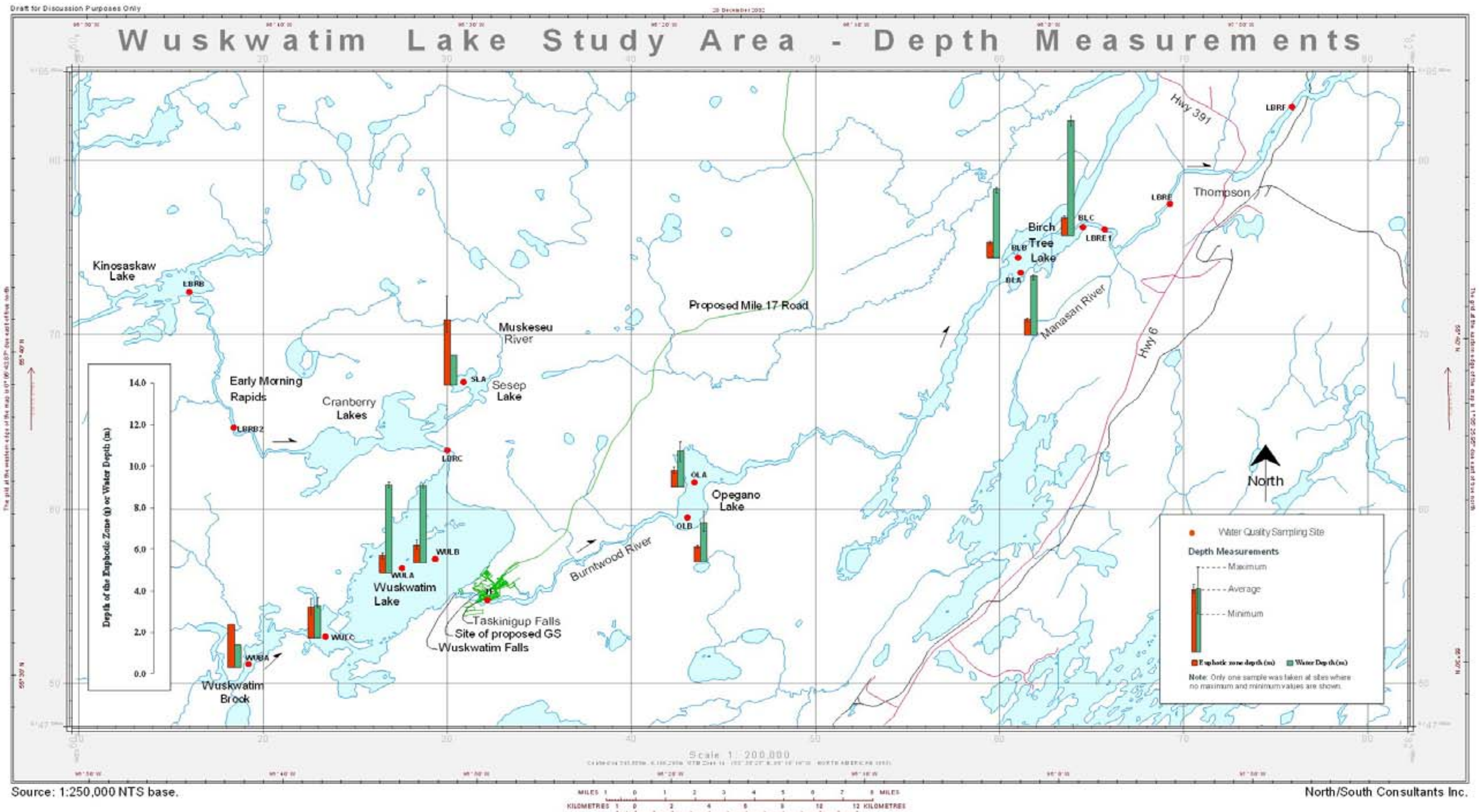


Figure 5-13. Mean water depths and depths of the euphotic zone (z_1) measured in the study area in the open-water season, 2001.

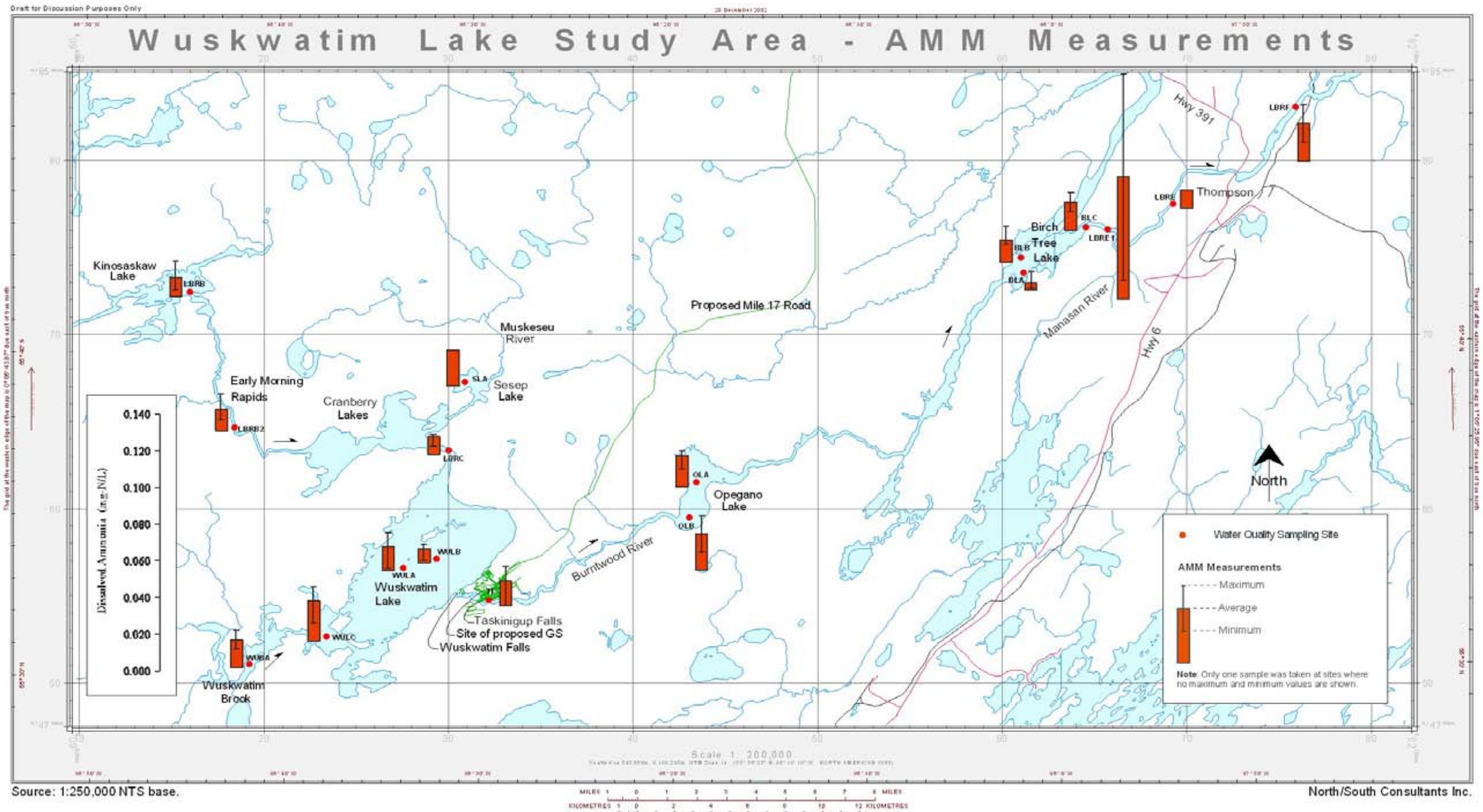


Figure 5-14. Mean surface dissolved ammonia concentrations measured in the study area in the open-water season, 2001.

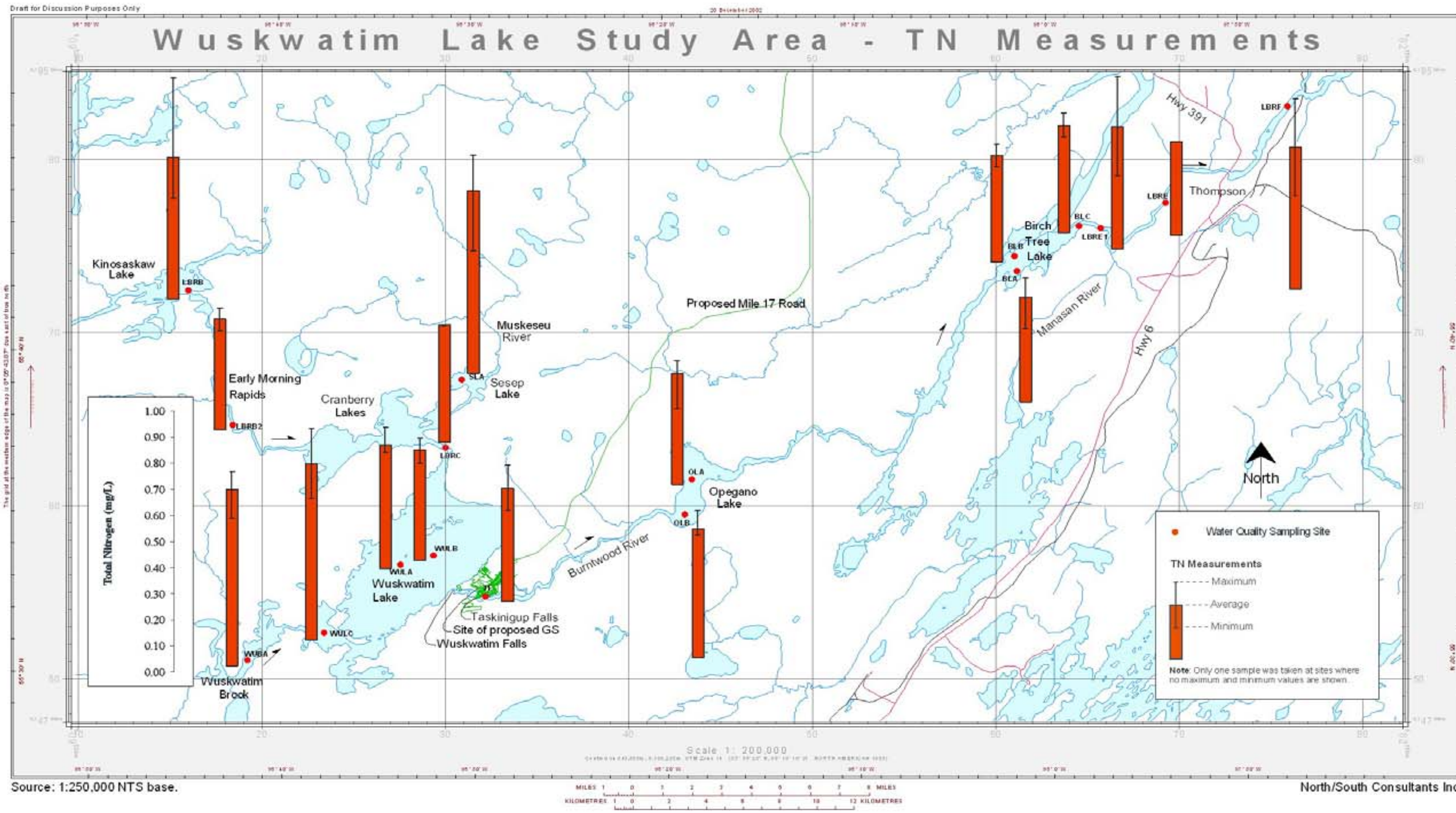


Figure 5-15. Mean surface total nitrogen concentrations measured in the study area in the open-water season, 2001.

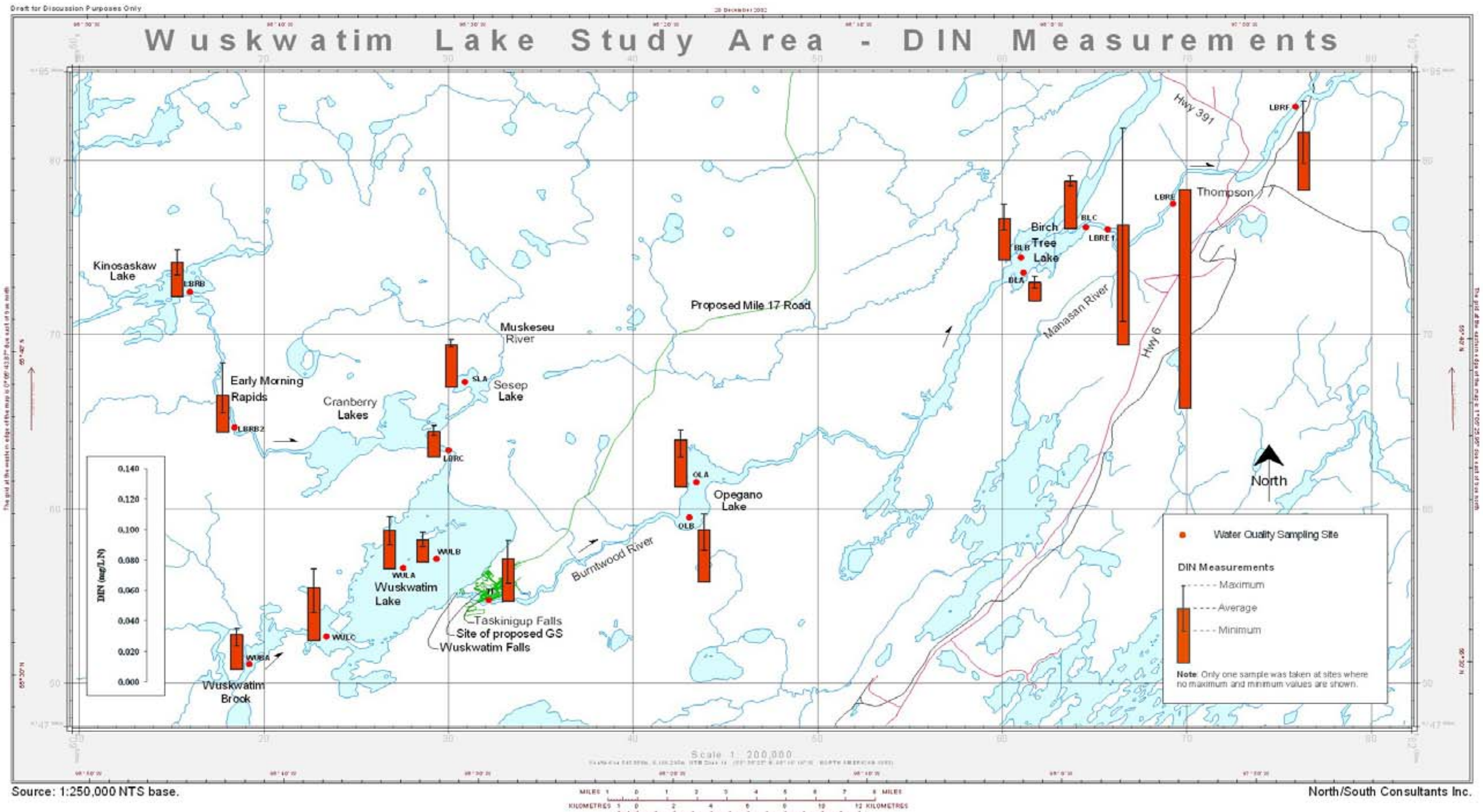


Figure 5-16. Mean surface dissolved inorganic nitrogen (DIN) concentrations measured in the study area in the open-water season, 2001.

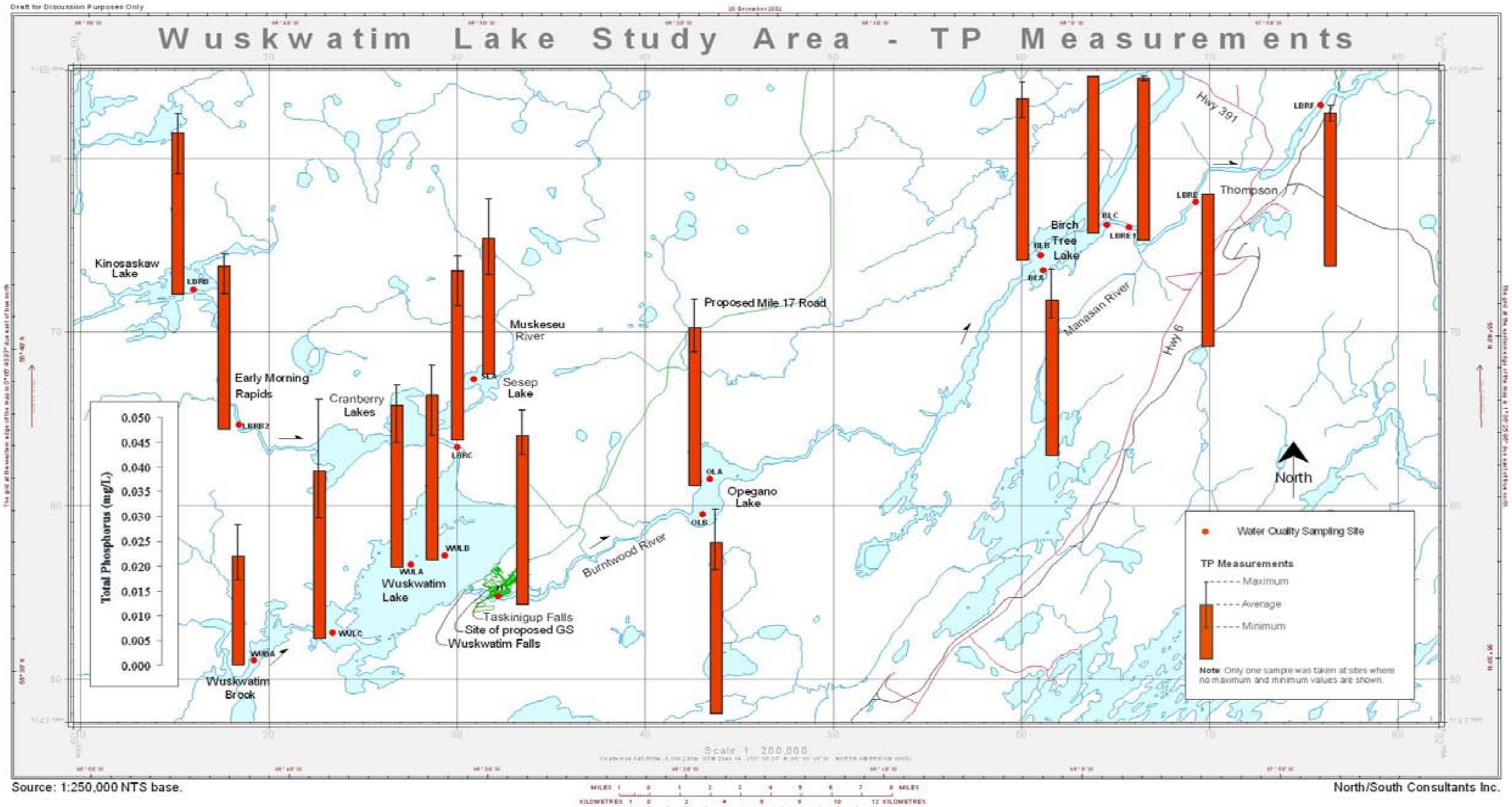


Figure 5-17. Mean surface total phosphorus concentrations measured in the study area in the open-water season, 2001.

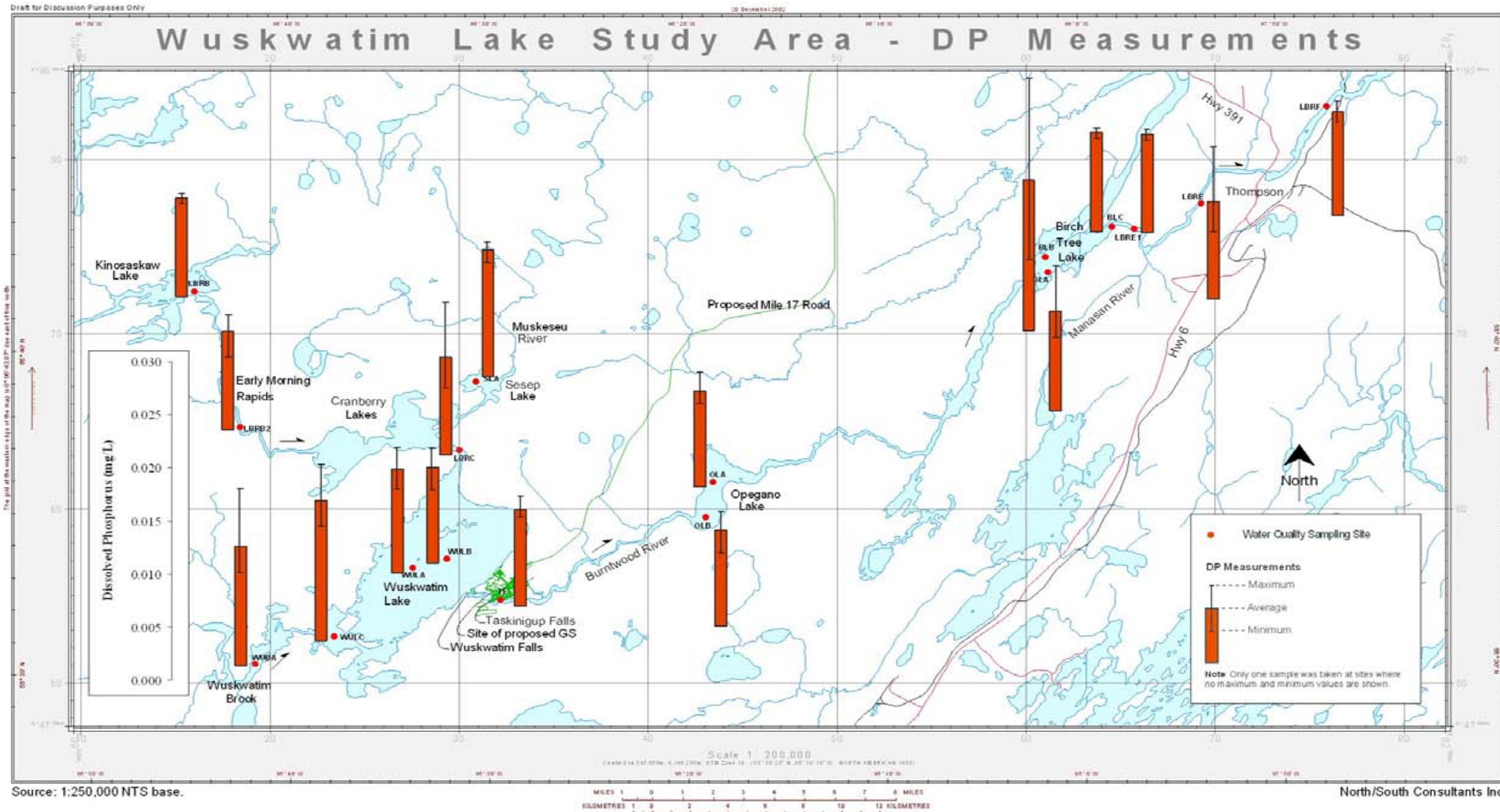


Figure 5-18. Mean surface dissolved phosphorus concentrations measured in the study area in the open-water season, 2001.

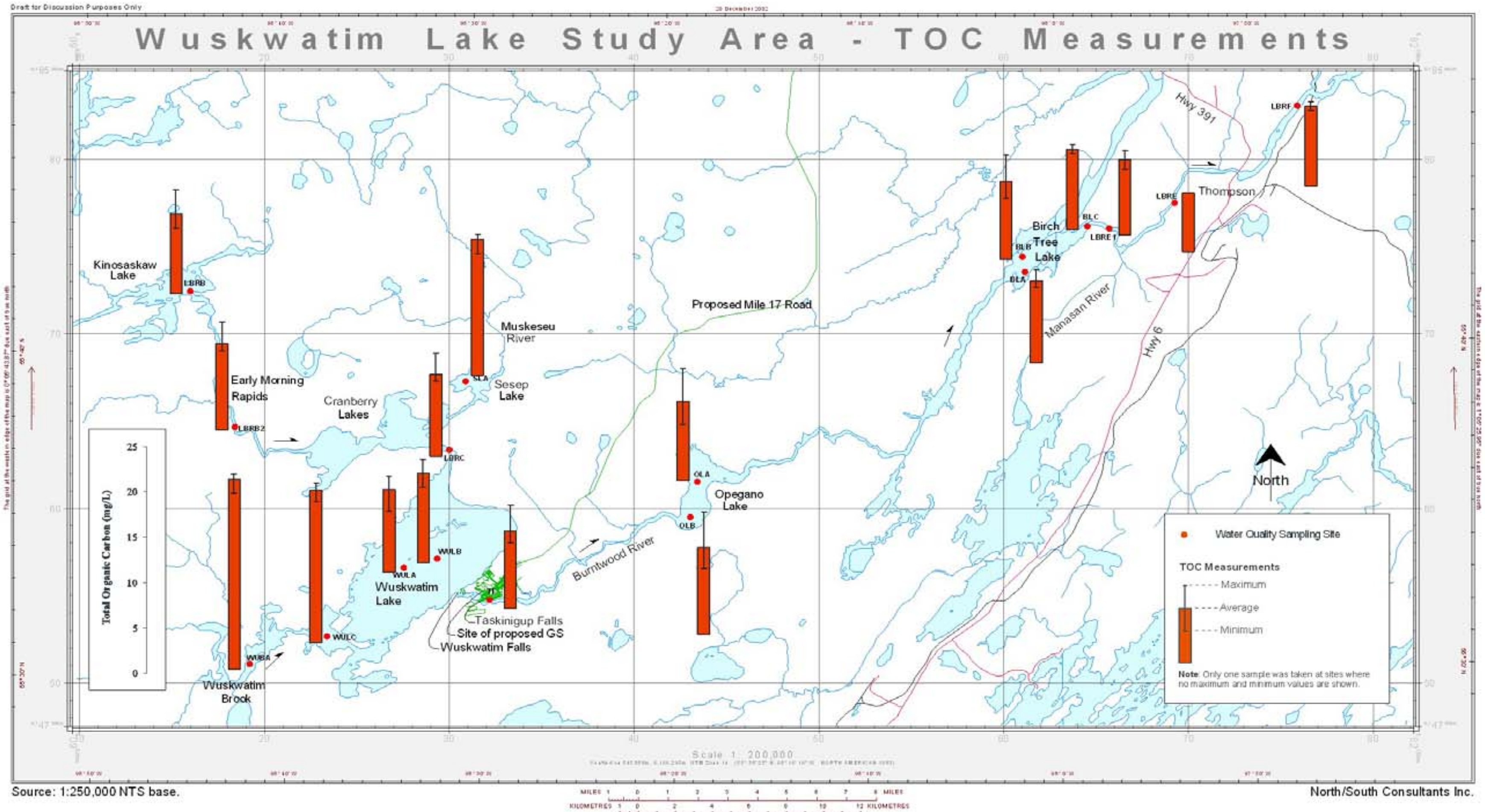


Figure 5-19. Mean surface total organic carbon concentrations measured in the study area in the open-water season, 2001.

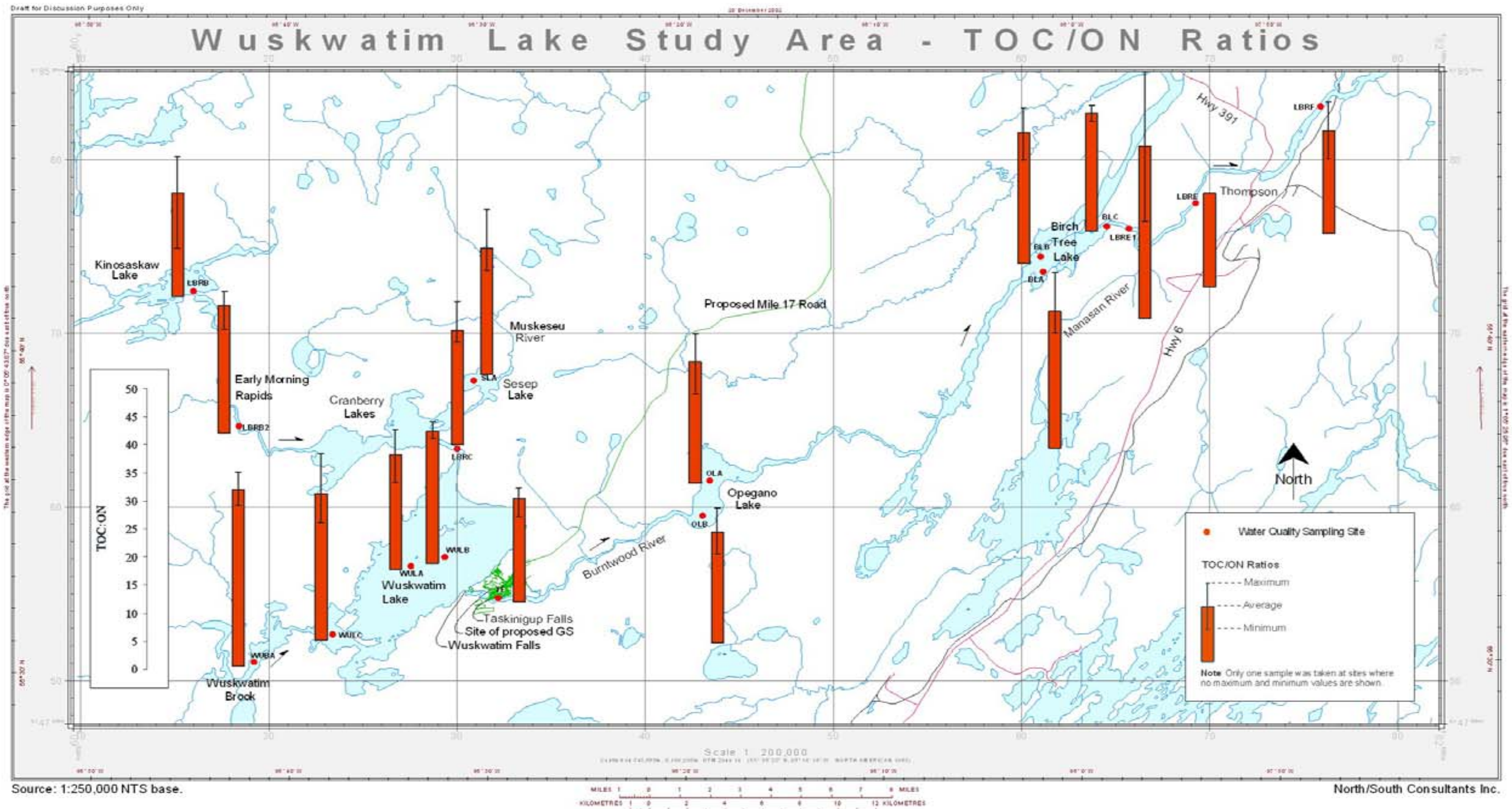


Figure 5-20. Mean surface total organic carbon (TOC) to organic nitrogen (ON) ratios calculated for the study area in the open-water season, 2001. ON was estimated as the difference between total Kjeldahl nitrogen and dissolved ammonia.

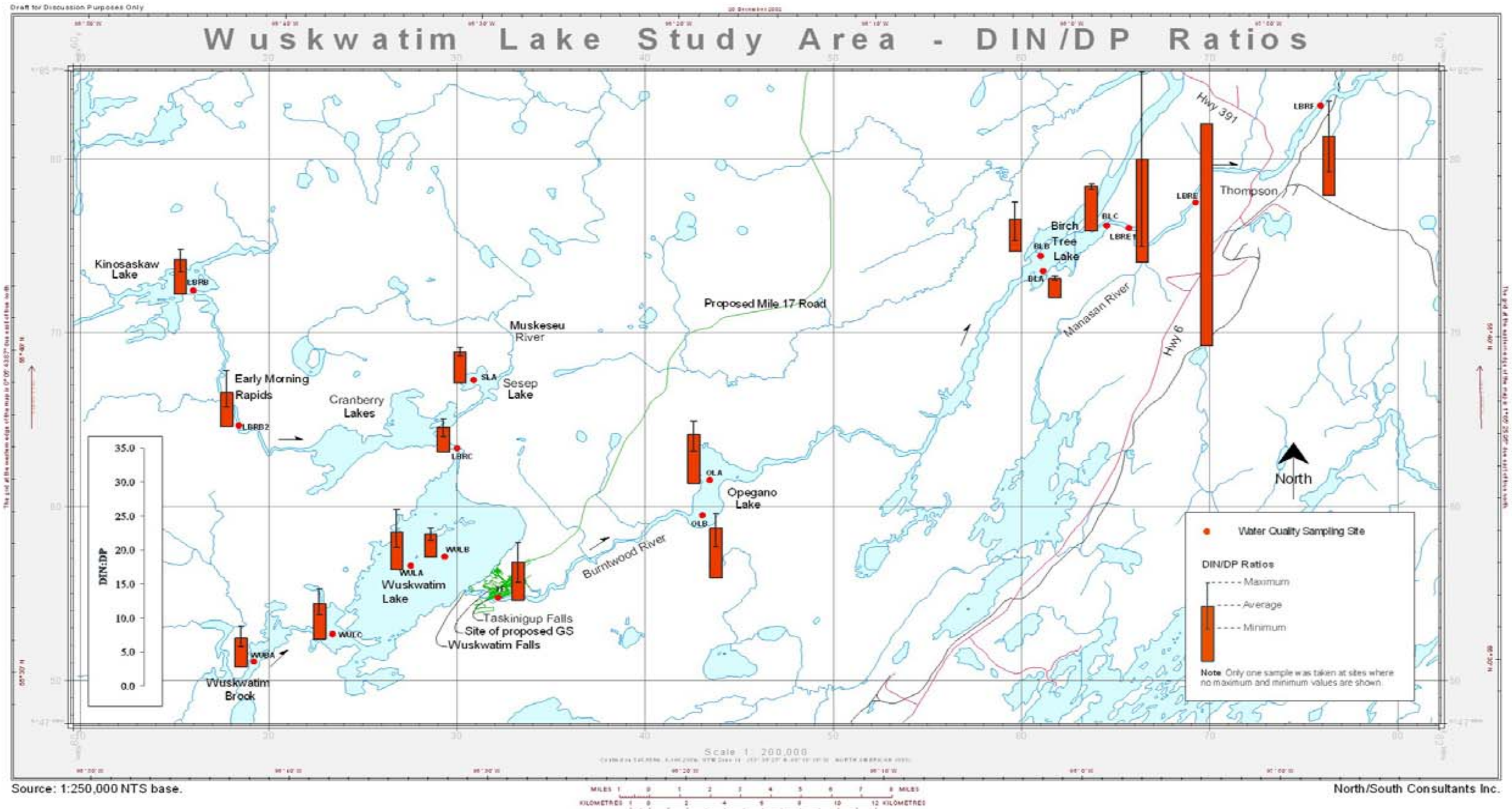


Figure 5-21. Mean surface dissolved inorganic nitrogen (DIN) to dissolved phosphorus (DP) ratios calculated for the study area in the open-water season, 2001. DIN was estimated from the sum of dissolved ammonia and nitrate/nitrite nitrogen.

5.3.4.1 Water Levels

A range of water levels occurred over the conduct of the baseline studies for water and sediment quality in the Wuskwatim study area. In general, 2000 was a high water year and 1999 and 2001 were low water years (Figure 5-22). Specifically, in 1999 levels were below average year-round. In 2001, water levels were below average in the open-water season and above average in the ice-cover season. In 2000, levels were generally above average all year.

5.3.4.2 Wuskwatim Lake: Reach 1

Water Clarity

Measurements of TSS collected from within the Burntwood River and main basin of Wuskwatim Lake during the open-water seasons ranged from 3 – 17 mg/L in 1999 (a year with lower-than average flow in the Burntwood River), 6 – 21 mg/L in 2000 (a year with higher-than average flows), and 2 – 24 mg/L in 2001 (flows were slightly below average in most of the open-water season, Figure 5-11). These measurements were similar to those measured in 1986 - 1989 (Ramsey 1991). TSS was notably higher in Reach 1 in spring of 2001, relative to summer and fall, possibly reflecting spring freshet. This spring peak observed in 2001 was not observed in 2000 possibly related to the flow pattern in 2000 when flows were actually lowest in spring and notably higher than average for the rest of the open-water season.

Although some seasonal variation occurs, the Burntwood River and main basin of Wuskwatim Lake can be characterized as a turbid system year-round. In 2001, turbidity ranged from 20 - 64 NTU along the mainstem of the lower Burntwood River and in Wuskwatim Lake (WuLA and WuLB). At these sites, like other sites along the main stem of the system, turbidity was highest in May 2001, relative to later sampling periods. Turbidity levels of $\leq$ 25 NTU are generally considered acceptable for lakes and reservoirs, whereas higher levels may be deemed acceptable for streams. Previous water quality objectives in Manitoba applied a threshold of 25 NTU (Williamson 1988). On this basis, the Wuskwatim Lake area, like most of the study area, is characterized as turbid. It is noteworthy, that high turbidity (i.e., in excess of water quality guidelines) is characteristic of many river systems in northern Manitoba, including the upper Burntwood River upstream of Threepoint Lake, and is a condition described as ‘natural’ (Ramsey 1991).

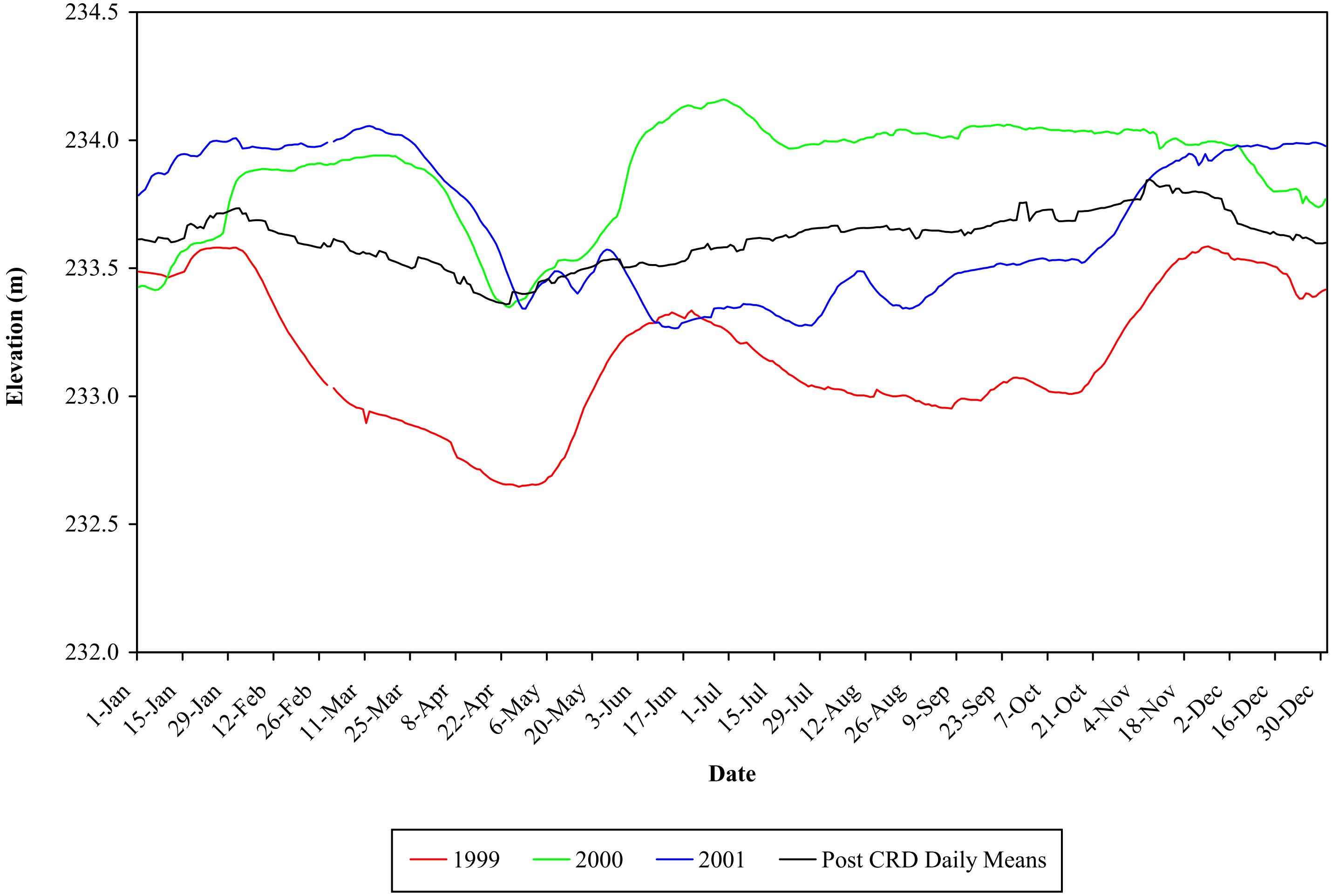


Figure 5-22. Water level elevation at Wuskwatim Lake, 1999 - 2001, and mean daily elevations in Wuskwatim Lake, post Churchill River Diversion (CRD). Data provided by Manitoba Hydro.

Waterbodies adjacent to Wuskwatim Lake and Wuskwatim Lake south are clearer than the main stem sites on the Burntwood River and in Wuskwatim Lake (Figures 5-11, 5-12 and 5-13). TSS concentrations in Sesep Lake during the open-water season in 2001 ranged from <2 – 4 mg/L (turbidity 2 – 5 NTU) and in Wuskwatim Brook ranged from <2 – 4 mg/L (turbidity 4 – 9 NTU). Wuskwatim Lake south (Site WuLC) which is influenced by Wuskwatim Brook water exhibited TSS and turbidity levels between values for the main part of the lake and Wuskwatim Brook. Turbidity did not change markedly with depth in Wuskwatim Lake, Sesep Lake, the lower Burntwood River, or Wuskwatim Brook (Appendix 2).

Turbidity and TSS are lower in Wuskwatim Lake in winter. As turbidity and TSS are already low in Sesep Lake and Wuskwatim Brook in the open-water season, seasonal differences are negligible at these locations.

There is limited light penetration in the main basin of Wuskwatim Lake (WuLA and WuLB) and greater transparency in Wuskwatim Lake south (WuLC), as estimated from Secchi disc depths. The depth of the euphotic zone ranged between just under 1 m to just over 2 m in the open-water seasons of 1999, 2000, and 2001 in the main basin (WuLA and WuLB), whereas the depth of the euphotic zone ranged from approximately 2 - 4 m in Wuskwatim Lake south (WuLC) in the open-water season 2001 (Figure 5-13). As the depth at this site (WuLC) was only 3 - 4 m, the euphotic zone extended between 50% and 100% of the total water depth. Consistent with lower levels of turbidity and TSS, water clarity as estimated from Secchi disc depths was also higher in winter in Wuskwatim Lake.

The depth of the euphotic zone in the lower Burntwood River, measured in 1999 and on one occasion in 2000, was similar to Wuskwatim Lake, ranging from approximately 1 - 2 m.

Water transparency was highest at Sesep Lake than any location in the study area that was evaluated. In the open-water season of 2001, the depth of the euphotic zone ranged from approximately 5 - 9 m. As the depth at the sampling location was only 3 m at the time of sampling, the euphotic zone extended the full depth of the water column at all four sampling times. Similarly, relatively high transparency (z_1 4.3 m) was also measured at Wuskwatim Brook in August 2001 (single measurement taken at this site).

Dissolved Oxygen and Water Temperature

Water temperature in Wuskwatim Lake and upstream in the Burntwood River varies seasonally, from 0 °C in winter to a mid-summer maximum of approximately 20 °C. Water temperature in the shallower tributaries and isolated bays (such as Sesep Lake, Wuskwatim Brook, and the south end of the lake at Site WuLC) warmed to temperatures of approximately 23 °C in summer 2001.

Higher surface temperatures were observed under ice cover in Wuskwatim Brook (WuBA) (0.5 °C) and Sesep Lake (SLA) (0.9 °C) in March 2002, relative to other sites accessed at this time where water temperature was 0.1 °C. Temperature was also higher near the bottom (0.9 °C) at Wuskwatim Brook, relative to the surface (0.5 °C).

With the exceptions of three measurements of approximately 70% saturation collected in the lower Burntwood River, upstream of Wuskwatim Lake (LBRB), and near the bottom of Wuskwatim Lake in August 1999, DO concentration at all depths in Reach 1 exceeded approximately 80% saturation during the open-water seasons in 1999, 2000, and 2001. In the open-water season, MWQSOGs indicate DO should not be less than 6.5 mg/L, 5.0 mg/L, and 4.0 mg/L over a 30-day averaging period, as a 7-day minimum, and as an instantaneous minimum, respectively, for the protection of cold water species (Williamson 2002). All measurements of dissolved oxygen collected at all depths in the Wuskwatim Lake area from 1999 to 2001 in the open-water seasons were above these objectives.

In the ice-cover season, early life stages of cold-water fish species are present in the study area (e.g., lake whitefish). Relevant water quality objectives are a 7-day average concentration of 9.5 mg/L and an instantaneous minimum of 8.0 mg/L (Williamson 2002). Dissolved oxygen measurements taken under ice in March 2002 (Figures 5-5 and 5-6) revealed that levels of DO were low at some locations in winter, most notably the off-current sites and waterbodies adjacent to Wuskatim Lake. Concentrations of DO were typically below the chronic objective (i.e., 9.5 mg/L) for the protection of early life stages of cold-water species, such as lake whitefish, and in some cases were below the instantaneous minimum for early life stages of cold-water species (i.e., 8.0 mg/L) in Wuskwatim Brook, Sesep Lake, and the Muskeseu River. Hypoxic conditions occurred at a shallow site in Wuskwatim Brook (1.15 mg/L, effective depth 0.5 m) and in the Muskeseu River (2.63 mg/L, effective depth 0.3 m). DO concentrations were high at water chemistry sampling stations in Wuskwatim Lake (WuLA, WuLB, and WuLC all above 13 mg/L) and lower in nearshore, off-current sites in the lake (around 9 mg/L). Similarly, DO was high (> 13 mg/L) in Cranberry Lakes.

Collectively, these results indicate that DO may be depleted under ice in tributaries to, and in shallow, off-current, isolated areas of Wuskwatim Lake and adjacent waterbodies. These conditions likely occur due to stagnation of water and decomposition of plant materials in the littoral zones, coupled with a lack or reduction of atmospheric aeration due to ice cover. Relatively high DO concentrations would be expected in the lower Burntwood River upstream of Wuskwatim Lake and in the lake itself in winter due to the typical lack of ice cover from Gods Rapids to Early Morning Rapids which facilitates atmospheric re-aeration and due to high water volumes and low **residence times** along the main stem.

Distinct vertical stratification was not detected in the Burntwood River, Wuskwatim Lake, or in Sesep Lake in 1999, 2000, or 2001 (Appendix 2). However, in Wuskwatim Lake in mid-summer, slight differences in temperature, conductivity, and/or dissolved oxygen concentration were observed at depths greater than approximately 5 – 7 m (within 1 – 2 m of bottom at sites WuLA and/or WuLB). Therefore, some reduced vertical mixing can occur near the lake bottom under appropriate conditions. In all cases, dissolved oxygen saturation at the lake bottom was within approximately 10% of that in the upper portion of the water column, indicating that significant dissolved oxygen depletion did not occur near the lake bottom.

Nitrogen

Concentrations of ammonia measured in surface water samples collected from within the Burntwood River and main basin of Wuskwatim Lake during the open-water seasons were similar between years, ranging from 0.002 – 0.02 mg/L in 1999, to < 0.01 – 0.02 mg/L in 2000 and from < 0.002 – 0.03 mg/L in 2001. All values were considerably below water quality objectives (Appendix 6).

Mean ammonia was higher in the Wuskwatim Lake south in 2001 (0.02 mg/L), relative to the other two Wuskwatim Lake locations (WuLA 0.01 mg/L; WuLB 0.01 mg/L). Concentrations of ammonia in Wuskwatim Brook and Sesep Lake measured in 2001 were similar to values reported for Wuskwatim Lake and the lower Burntwood River; concentrations measured in Sesep Lake in 2001 were consistently at 0.02 mg/L (Figure 5-14).

Dissolved nitrate/nitrite was similar between the open water seasons of 1999 (range < 0.01 – 0.02 mg/L), 2000 (range < 0.01 – 0.02 mg/L), and 2001 (range < 0.005 – 0.019 mg/L in the lower Burntwood River and Wuskwatim Lake. Concentrations measured in

Wuskwatim Brook and Sesep Lake were similar and were mostly below analytical detection limits (< 0.005 mg/L) in 2001.

Concentrations of TKN ranged from < 0.2 – 0.6 mg/L in the open-water season 1999, from 0.3 - 0.6 in the open-water season of 2000, and from 0.4 - 0.9 mg/L in the open-water season of 2001 in the Wuskwatim Lake area, including Sesep Lake and Wuskwatim Brook. The mean TKN concentration for the open-water season 2001 was higher in Sesep Lake (0.8 mg/L), Wuskwatim Brook (0.7 mg/L), and the Wuskwatim Lake south (WuLC 0.8 mg/L) than other sites in the Wuskwatim Lake area (i.e., WuLA and WuLB) and the study area as a whole.

Total nitrogen (TN), estimated from the sum of dissolved nitrate/nitrite-N and TKN, was in all cases only slightly higher than TKN (nitrate/nitrite-N concentrations were low). Although there is no water quality guideline for nitrogen in Manitoba, all estimates of TN were below water quality objectives that have been established in other provincial jurisdictions (e.g., Alberta 1.0 mg/L, reviewed in Chambers et al. 2001). In general, site mean concentrations of total nitrogen were higher in Sesep Lake, the Wuskwatim Lake south, and Wuskwatim Brook, relative to the Burntwood River or the main basin of Wuskwatim Lake (Figure 5-15).

Phosphorus

Phosphorus was measured in dissolved and total forms in surface water samples. In general, total phosphorus concentrations were high. In the lower Burntwood River and Wuskwatim Lake total phosphorus concentrations were similar between years and ranged from 0.018 - 0.040 mg/L in 1999, from 0.024 - 0.045 mg/L in 2000, and from 0.024 mg/L - 0.048 mg/L in 2001. Total phosphorus was similar in Sesep Lake to the Burntwood River and Wuskwatim Lake but was generally lower (mean 0.027 mg/L). Of all sites evaluated in the study area in 2001, the lowest site mean total phosphorus concentration occurred in Wuskwatim Brook (mean 0.022 mg/L) (Figure 5-17).

Dissolved phosphorus concentrations ranged from 0.004 - 0.024 mg/L in 1999, from 0.004 - 0.014 mg/L in 2000, and from 0.007 - 0.017 mg/L in 2001 in the lower Burntwood River and Wuskwatim Lake. Concentrations measured in Wuskwatim Brook and Sesep Lake in 2001 fell within the latter range. The fraction of total phosphorus that was in dissolved form in this area is substantive, generally ranging from greater than 20% to in excess of 50% in the lower Burntwood River and Wuskwatim Lake. In general, a relatively greater fraction of total phosphorus was in dissolved form in Sesep Lake (37-

60%) and Wuskwatim Brook (42-61%) in 2001, than the lower Burntwood River (24-46%) or Wuskwatim Lake (25-54%).

The majority of total phosphorus measurements collected in Wuskwatim Lake and the lower Burntwood River at the inlet to Wuskwatim Lake (LBRC) exceeded the proposed Manitoba water quality guideline of 0.025 mg/L for tributaries at the point of entry to a lake and lakes/reservoirs (Williamson 2002). For example, all measurements of total phosphorus taken at the inlet to Wuskwatim Lake and all but two of the 12 measurements taken in Wuskwatim Lake in 2001 were in excess of 0.025 mg/L. Half the measurements of total phosphorus collected from Sesep Lake and one of four collected from Wuskwatim Brook in 2001 exceeded the 0.025 mg/L guideline.

Concentrations in winter did not vary markedly from levels measured in the open-water season, with the possible exception of Wuskwatim Brook where a substantively higher concentration of total phosphorus was measured in March 2002 (0.035 mg/L) than in the open-water season (0.017 – 0.028 mg/L) of 2001. The ratio of total phosphorus to dissolved phosphorus was generally lower in the winter, relative to the open-water season, which indicates uptake of the dissolved forms by primary **producer**s during the open-water season at these sites.

Organic Carbon

Ranges of total organic carbon (TOC) in 1999 were 6 - 8 mg/L, in 2000 were 6 - 10 mg/L, and in 2001 were 7-17 mg/L in the lower Burntwood River and Wuskwatim Lake. These concentrations are indicative of meso-eutrophic to eutrophic lakes (Table 5-3). In 2001, notably higher levels of TOC occurred in the Wuskwatim Lake south (mean 16 mg/L), relative to other sites on the lake and on the lower Burntwood River, possibly due to a substantive influence of Wuskwatim Brook water at this time; Wuskwatim Brook contained the highest (approximately two to three times higher) TOC concentrations of all sites evaluated in the study area in 2001 (range 18-20 mg/L, mean 20 mg/L) (Figure 5-19). Sesep Lake contained concentrations of TOC similar to the south basin of Wuskatim Lake (WuLC) (mean 15 mg/L). There is some indication that TOC concentrations may be reduced in winter in Wuskwatim Lake. Most organic carbon measured in the Wuskwatim Lake area was in dissolved form; therefore values of DOC were similar to TOC.

Carbon to nitrogen molar ratios, which are indicative of the major source (i.e., allochthonous or autochthonous) of carbon in an aquatic ecosystem, were quite variable at a given site in the Wuskwatim Lake area over the course of the open-water sampling season. Ratios generally ranged from the mid-teens to values in the low fifties in the Wuskwatim Lake area, which indicates that at most sites and times sampled, a large portion of organic matter is derived from allochthonous sources (i.e., terrestrial and/or wetland sources) (Hutchinson 1957). Organic carbon to organic nitrogen molar ratios were highest at Wuskwatim Brook of all sites evaluated in 2001, indicating a relatively greater input of allochthonous carbon at this site, relative to other locations (Figure 5-20).

Nutrient Status

Concentrations of nitrogen and phosphorus are high in the Wuskwatim Lake area. Based on concentrations of total phosphorus and, to a lesser extent, nitrogen (as well as chlorophyll *a* and organic carbon), Wuskwatim and Sesep lakes would be considered meso-eutrophic to eutrophic (Table 5-3). Low nitrogen to phosphorus ratios (expressed as molar ratios of dissolved inorganic nitrogen (DIN): dissolved phosphorus (DP)), which may be used to indicate the limiting nutrient(s) in aquatic environments, in conjunction with high measurements of phosphorus indicate that of the two nutrients, nitrogen is limiting at most times.

DIN:DP ratios were consistently less than 10, generally considered to indicate nitrogen-limiting conditions (Kalff 2002), in Wuskwatim Lake, Wuskwatim Brook, and Sesep Lake in the open-water season of 2001 (Figure 5-21). Ratios ranged from less than 10 to 19 in the open-water season 2000 and from 3 to 5 in the open-water season 1999. Nitrogen limiting conditions are more common in streams than previously believed; nitrogen limitation occurs in watersheds with a naturally high geological source of phosphorus, in systems dominated by agriculture (Scrimgeour and Chambers 2001), and/or in environments receiving effluent with low nitrogen to phosphorus ratios (Kalff 2002).

Although these aquatic systems are generally not phosphorus limited, phytoplankton growth is likely significantly light-limited at most sites and times in the Wuskwatim Lake area, as it is downstream (with the exception of Sesep Lake and Wuskwatim Brook) (Section 7.0). Low transparency is evident from low Secchi disc depths and estimates of the depth of the euphotic zone in Wuskwatim Lake and the lower Burntwood River. Conversely, phytoplankton growth at Sesep Lake and Wuskwatim Brook may be less light-limited, as indicated by higher water transparencies, and less limited by rapid flushing (as residence times are greater in these off-current areas) and therefore more influenced by nutrient concentrations.

pH, Alkalinity, and Hardness

pH

In general, sites evaluated in the Wuskwatim Lake area can be characterized as near-neutral to slightly alkaline. In general, *in situ* pH varied from 7.04 to 8.39 in the lower Burntwood River and Wuskwatim Lake in the open-water seasons of 1999, 2000, and 2001. Therefore, pH was within the proposed MWQSOG ranges for pH of 6.5-9.0 for the protection of aquatic life and the aesthetic objective for drinking water of 6.5-8.5 (Williamson 2002). On the basis of pH, Wuskwatim and Sesep lakes would be characterized as lakes with low to very low sensitivity to acidification (Palmer and Trew 1987). pH generally declined by approximately 0.5 pH units from the water surface to the lowest depth evaluated at the sites in the Wuskwatim Lake area.

Mean pH (lab) of Sesep Lake (7.67) was similar to that measured at the Wuskwatim Lake south (WuLC), both of which were somewhat lower than sites on the main stem of the study area (Figure 5-8). Wuskwatim Brook had a notably lower pH than other sites (mean pH (lab) in 2001 was 7.45).

Not unexpectedly, pH was lower at all locations accessed in winter, relative to the open-water season. pH typically declines in aquatic environments under ice cover, because ice prevents the release of carbon dioxide, produced from decomposition and respiration processes, to the atmosphere and because photosynthetic activity, which removes carbon dioxide, is greatly reduced in winter. The magnitude of the decline of pH in winter in aquatic systems is related to buffering capacity; in the Wuskwatim Lake area, pH declined on the order of approximately 0.5 pH units between the open-water season of 2001 and the sampling period in March 2002. This level of seasonal change is indicative of an environment with a moderate buffering capacity. A more marked seasonal decline (approximately 0.5 – 0.9 pH units) was observed in Sesep Lake, indicating these waters may have a lower buffering capacity and/or may be a reflection of greater productivity.

Table 5-3. Classification schemes for lake trophic status.

Variable	Units	Lake Trophic Status							Reference
		Ultra-oligotrophic	Oligotrophic	Oligo-mesotrophic	Mesotrophic	Meso-eutrophic	Eutrophic	Hypereutrophic	
Total P	(µg/L)	-	< 10	-	10 – 20	-	> 20	-	(Thomann and Mueller 1987)
	(µg/L)	-	< 5	-	10 – 30	-	-	> 100	(Chambers et al. 2001)
Chlorophyll *a*	(µg/L)	-	< 4	-	4 – 10	-	> 10	-	(Thomann and Mueller 1987)
Secchi Depth	(m)	-	> 4	-	2 – 4	-	< 2	-	(Thomann and Mueller 1987)
Hypolimnetic oxygen saturation	(% saturation)	-	> 80	-	10 – 80	-	< 10	-	(Thomann and Mueller 1987)
Inorganic N	(µg/L)	< 200	-	200-400	-	300-650	500-1,500	> 1,500	(Wetzel 1983)
Organic N	(µg/L)	< 200	-	200-400	-	400-700	700-1,200	> 1,200	(Wetzel 1983)
Total N	(µg/L)	< 1-250	-	250-600	-	500-1,100	-	500-> 15,000	(Wetzel 1983)
Total P	(µg/L)	< 5	-	5-10	-	10-30	30-100	> 100	(Wetzel 1983)
Dissolved Organic Carbon	(mg C/L)	-	2	-	3	-	10	-	(Kalff 2002)
Chlorophyll *a*	(µg/L)	0.01-0.5	0.3-3	-	2-15	-	10-500	-	Wetzel (1983)

Alkalinity

Alkalinity, an indicator of the buffering capacity of water, reflects the surficial geology of a drainage basin. Low values of alkalinity are indicative of surface waters that are vulnerable to acidification, via such occurrences as flooding of forest soil (SEBJ 1982a: in Hydro-Québec 1993). Calcium carbonate and bicarbonate alkalinity in the open water season of 2001 ranged from 50-54 mg/L and 61-66 mg/L in the lower Burntwood River (LBRB2), respectively. Alkalinity was similar at Wuskwatim Lake, ranging from 63-69 mg/L as bicarbonate and 52-57 mg/L as calcium carbonate alkalinity. These concentrations generally represent relatively high levels of alkalinity and buffering capacity and are generally considered to indicate a very low sensitivity to acidification (Palmer and Trew 1987). In addition, moderately high buffering capacity of the Wuskwatim Lake area can be inferred from the relatively high true colour measurements, which reflect the presence of organic acids. There was no indication that alkalinity varies substantively between the open-water and ice-cover seasons.

Hardness

The lower Burntwood River and Wuskwatim Lake are characterized as relatively soft aquatic systems. Water hardness, expressed as $CaCO_3$, in the lower Burntwood River upstream of Wuskatim Lake (LBRB2), and in Wuskwatim Lake (WuLB) ranged from approximately 56 - 59 mg/L in the open-water season of 2001; hardness was lower in March 2002 (approximately 49 – 50 mg/L). These values fall on the border between what is typically classified as soft (30 – 60 mg/L) and moderately soft (hard) (61 – 120 mg/L) waters (CCME 1987). Because toxicity of some metals is inversely proportional to water hardness (e.g., cadmium, copper, chromium, lead, nickel, zinc), aquatic life may be more vulnerable to metal contamination in this system than in more hard water environments.

Colour, Total Dissolved Solids, and Conductivity

In general, high TC values may indicate a substantive fraction of allochthonous organic matter (Hutchinson 1957). The lower Burntwood River upstream of Wuskwatim Lake and Wuskwatim Lake itself are coloured; true colour averaged 31 **TCU** in the lower Burntwood River near Early Morning Rapids (LBRB2) and in the main basin of Wuskwatim Lake (WuLB) in the open-water season of 2001. TC was similar in winter in Wuskwatim Lake (25 TCU). The highest levels of true colour observed at these sites occurred in May and TC declined at both locations over the open-water period. Relatively high true colour was also measured at Taskinigup Falls in May.

There are no guidelines for true colour for the protection of aquatic life. However, most values measured in the Wuskwatim Lake area were above the aesthetic objective for drinking water of 15 TCU (Williamson 2002). Evaluation of water quality data for the lower Burntwood River at Thompson (MB Conservation 2001) indicated that virtually all samples analysed from 1980 to 2000 exceeded this water quality guideline (see Section 5.3.3.1).

Conductivity and TDS are moderately high in the Wuskwatim Lake area, indicating that surface waters in the study area contain a substantive quantity of minerals. Levels are similar to, but somewhat lower than, those typical of rivers in north central Canada where conductivity is approximately 140 µS/cm (Kalff 2002). Conductivity ranged from 92 to 120 µS/cm in the lower Burntwood River upstream of Wuskwatim Lake and in Wuskwatim Lake. TDS averaged 94 mg/L in the lower Burntwood River near Early Morning Rapids and 88 mg/L at a site in the main basin of Wuskwatim Lake (WuLB) in the open-water season 2001. In general, conductivity is notably higher in Sesep Lake (113 – 139 µS/cm in the open-water season of 2001), relative to other sites in the Wuskwatim Lake area (Figure 5-10). All values are well below the aesthetic objective for drinking water quality of 500 mg/L (Williamson 2002).

It is also noteworthy that a strong vertical gradient in conductivity was observed in Sesep Lake (SLA) in March 2002; surface, middle, and bottom measurements were 98.8 µS/cm, 114.2 µS/cm, and 280.0 µS/cm, respectively, at a site with a total depth of 2.3 m.

Bacteria and Parasites

Fecal coliform bacteria and the protozoan parasites *Cryptosporidium* and *Giardia* were below analytical detection limits at sites evaluated in Reach 1. However, an amorphous oocyst of *Cryptosporidium* and a nonviable (i.e., empty) *Giardia* cyst were identified in a sample of water collected from the Burntwood River upstream of Wuskwatim Lake in May 2001.

Inorganic Elements

Inorganic elements (metals and metalloids and major minerals) were measured at three sites in the Wuskwatim Lake area in the open-water season in 2000 and 2001, including: the lower Burntwood River (LBRB2) upstream of Wuskwatim Lake (2001); and, two sites in Wuskwatim Lake (WuLA in 2000 and WuLB in 2001). In addition, surface water samples collected in Cranberry Lakes (CLA) and the main basin of Wuskwatim Lake (WuLB) in March 2002 were analyzed for inorganic constituents.

Most substances were below analytical detection limits and/or were below water quality guidelines for the protection of aquatic life and drinking water quality objectives at all times (Appendix 2). Site means of arsenic, cadmium, chromium, molybdenium, nickel, thallium, and zinc for 2000, 2001, and 2002 (winter only) were below MWQSOGs for the protection of aquatic life (Appendix 3). Compliance with MWQSOGs for the protection of aquatic life could not be adequately assessed for silver, mercury, and selenium in the open-water seasons of 2000 and 2001 because the analytical detection limits were higher than the MWQSOGs for these substances (a lower level analysis method was developed by the analytical laboratory and instituted in 2002). However, the site mean of selenium in Wuskwatim Lake (WuLA) in the open water season 2000 (2±1 µg/L), exceeded the MWQSOG for the protection of aquatic life (1.0 µg/L). In winter 2002, the analytical detection limits were decreased to below the MWQSOGs for these substances (i.e., silver, mercury, and selenium); none were detected in water samples collected at this time.

The mean lead concentration (2.2 µg/L) for the open-water season of 2001 in the Burntwood River near Early Morning Rapids (LBRB2), upstream of Wuskwatim Lake, also exceeded the calculated mean site-specific MWQSOG of 1.5 ug/L. The sample of water collected in Wuskwatim Lake (WuLB) in March 2002 contained copper at a concentration above the MWQSOG for the protection of aquatic life. Similarly, some exceedences of drinking water quality objectives for lead and guidelines (chronic) for the protection of aquatic life for lead and copper have been measured at the MB Conservation water quality monitoring station (WQ 0093.00) in the lower Burntwood River at Thompson from 1980 through 2000 (see Section 5.3.3.1).

Aluminum and iron consistently exceeded MWQSOGs for the protection of aquatic life at all four sites examined in the Wuskwatim Lake area (Table 5-4). Both were an order of magnitude higher than MWQSOGs in the open-water season; concentrations of both metals were lower in winter at Wuskwatim Lake although still considerably above water quality criteria. Iron was also above the aesthetic guideline for drinking water. Similar trends were observed for water quality data collected on the lower Burntwood River at Manitoba Conservation water quality monitoring station WQ 0093.00 from 1980 through 2000 (Section 5.3.3.1). All measurements of aluminum and iron exceeded water quality objectives for aquatic life and drinking water in this period of record.

Elevated concentrations of aluminum and iron in surface waters are not uncommon (aluminum is the third and iron is the fourth most abundant element in the earth's crust) and do occur in 'pristine' environments as a consequence of local geology. Manitoba Conservation monitoring data indicate that concentrations of iron in the Burntwood River at Thompson have been elevated above water quality objectives as far back as data records extend (1972) (Williamson and Ralley 1993). Furthermore, Ramsey (1991) concluded that high levels of aluminum, iron, and copper (and occasional high levels of lead and zinc) in the Burntwood (above Threepoint Lake), Footprint (above Footprint Lake), and Aiken rivers (all 'natural, unregulated rivers') were 'natural'. Concentrations or iron reported for surface waters in central Canada range from 0.001 – 7.55 mg/L, as measured from 1980 – 1985 at 1,315 sites (CCME 1987).

With the exception of iron, where the aesthetic objective for drinking water (≤ 300 µg/L) was consistently exceeded in the Wuskwatim Lake area, all inorganic constituents (i.e., metals and metalloids) in water were below drinking water quality guidelines.
Gross alpha and beta activity were below the CCME drinking water quality guidelines for the protection of human health (CCME 2001b); there are no guidelines for radiation for the protection of aquatic life.

Table 5-4. Mean± SE concentrations of aluminum (Al) and iron (Fe) in surface water samples collected in the Wuskwatim Lake area, 2000 to 2002.

Site	Averaging Period	Al (mg/L)	Fe (mg/L)
MWQSOG for aquatic life	-	0.10	0.30
MWQSOG for drinking water	-	-[1]	0.300 [2]
Lower Burntwood River (LBRB2)	Open-water season 2001	1.35 ± 0.29	1.13 ± 0.22
Wuskwatim Lake (WuLA)	Open-water season 2000	1.80 ±0.17	1.34 ±0.17
Wuskwatim Lake (WuLB)	Open-water season 2001	1.42 ±0.24	1.31 ±0.21
Wuskwatim Lake (WuLB)	Ice-cover season 2002 [3]	0.89	0.66
Cranberry Lakes (CLA)	Ice-cover season 2002 [3]	0.84	0.61

1 "A health based guideline for aluminum in drinking water has not been established…Operational guidance values of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended." (CCME 2001b)
2 Aesthetic guideline; no guideline for protection of human health.
3 Single measurement.

Hydrocarbons

Hydrocarbons were rarely detected in surface water samples collected in the Wuskwatim Lake area in the open-water season of 2001. Exceptions include a single measurement of extractable hydrocarbons (C11-C30) in Wuskwatim Lake (WuLB) in August, 2001 and measurements of total xylene (0.7 µg/L) and meta/para xylene (0.7 µg/L) in July, 2001 that were just above the analytical DL (Appendix 2); total xylene did not exceed the proposed MWQSOG aesthetic guideline of 300 µg/L (Williamson 2002). Hydrocarbons, including xylene, may have been introduced during sampling from boat motor fuel. Xylene may have also entered the local environment through leaching from paint (i.e., xylene is used as a solvent).

All organic constituents that were analyzed in water samples collected in March 2002 were below analytical detection limits (Appendix 2).

5.3.4.3 Wuskwatim Falls to Opegano Lake: Reaches 2 and 3

The following description is broken down into the main stem (to describe conditions on the Burntwood River) and tributaries (to describe water quality conditions in the 10 major tributary streams within Reach 3).

Water Clarity

Main Stem

In general, TSS and turbidity were similar in the lower Burntwood River downstream of Taskinigup Falls to sites upstream in Wuskwatim Lake and downstream in Opegano Lake (Figures 5-11 and 5-12). TSS ranged from 6 to 24 mg/L in the open-water season 2001 at Taskinigup Falls. Values obtained under ice-cover were in the lower range (5 and 8 mg/L upstream and downstream of Taskinigup Falls); greater water clarity in winter is consistent with observations made regarding the main stem in the Wuskwatim study area.

Tributary Streams

There was a fair bit of variability observed in the measurements of water clarity taken at tributary streams. TSS ranged from 3 mg/L (stream 1) to 120 mg/L (Stream 3) at upstream locations on tributary streams and laboratory turbidity generally paralleled TSS measurements. On a relative scale, streams 1 and 7 are characterized by high clarity (i.e., TSS ≤ 5 mg/L), streams 5, 6, 8, 9, and 10 can be considered to have moderate water clarity (i.e., TSS 10 – 20 mg/L), streams 2 and 4 have moderately high TSS (i.e., 25-30 mg/L), and stream 3 has very low water clarity (i.e., TSS > 100 mg/L).

Conversely, TSS and turbidity measurements were fairy similar at the downstream sites, within the backwater inlets, of the 9 streams assessed (Stream 8 could not be accessed at the inlet), with TSS ranging from 11 to 21 mg/L; this consistency is a reflection of the influence of Burntwood River water and it indicates similar conditions with respect to TSS at backwater inlets, relative to the main stem.

Dissolved Oxygen and Water Temperature

Main Stem

All measurements of DO in the open-water and ice-cover seasons were above MWQSOGs for the protection of aquatic life.

DO measured immediately downstream of Taskinigup Falls throughout the open-water season in 2001 was near or slightly above saturation. DO levels were also near saturation in the open-water season of 2001 upstream (i.e., Reach 1) and downstream of Reach 3 in Opegano Lake, indicating that DO remains near saturation in the lower Burntwood River between Wuskwatim Lake and Opegano Lake. The presence of rapids and changes in elevation (i.e., falls) is expected to augment atmospheric aeration of the river.

All measurements of DO obtained in the ice-cover season indicated that DO likely remains high in the lower Burntwood River between Wuskwatim and Opegano lakes year-round. The single measurement obtained in Reach 2 indicated that the water below Wuskwatim Falls was fully oxygenated in late winter 2001. DO levels were also high downstream in Opegano Lake in March 2002, further indicating that this stretch of the river likely maintains high DO concentrations throughout the ice-cover season (Figure 5-5). Maintenance of open-water through Wuskwatim and Taskinigup Falls, as well as intermittent ice cover downstream of the falls, facilitates atmospheric aeration of the river between Wuskwatim and Opegano lakes in the ice-cover season. Dissolved oxygen concentrations in the backwater inlets of tributary streams in Reach 3 (see below), which are heavily influenced by Burntwood River water, were also high in the ice-cover season, further indicating that highly oxygenated conditions are maintained along the length of Reaches 2 and 3 under ice.

Water temperature was consistent with conditions observed upstream in the Wuskwatim Lake area; temperature ranged from 11.0 ^{o}C (September) to 18.8 ^{o}C (July) during the open-water season of 2001 and measured 0.2 ^{o}C in the winter of 2001.

Tributary Streams

Dissolved oxygen concentrations measured in September 2002 were high in tributary streams, both in backwater inlets and upstream of the influence of the Burntwood River, indicating the occurrence of well-oxygenated conditions in all streams. Typically DO concentrations were higher at upstream locations, than at the backwater inlet areas; however, because water temperature was consistently lower at upstream sites, relative to downstream sites, dissolved oxygen expressed as a percent saturation were more similar between upstream and downstream sites than when expressed as concentrations. Temperature differentials ranged from 0.2 ^{o}C (Stream 9) to 5.3 ^{o}C (Stream 1) between upstream and downstream sampling locations. Higher water temperatures at the backwater inlets reflect the influence of warmer Burntwood River water.

Tributaries appear to remain highly oxygenated year-round; with one exception (DO of 10.73 mg/L at the backwater inlet site of Stream 4) dissolved oxygen concentrations were in excess of 13 mg/L in March/April 2002 in the four tributaries to the lower Burntwood River evaluated (Figure 5-21). All measurements of DO in the open-water and ice-cover seasons were above MWQSOGs for the protection of aquatic life.

Nitrogen

Main Stem

Concentrations of ammonia measured in surface water samples collected at Taskinigup Falls during the open-water season of 2001 ranged from 0.003 to 0.02 mg/L (mean 0.013 mg/L) and were similar to measurements obtained at other sites along the main stem (Figure 5-14); ammonia measured 0.01 mg/L upstream (WF) and downstream (TF) of Taskinigup Falls in March 2001. All values were considerably below water quality objectives.

Dissolved nitrate/nitrite ranged from 0.007 to 0.013 mg/L (mean 0.010 mg/L) at Taskinigup Falls in the open-water season of 2001. Concentrations of TKN were similar to values measured at other sites in the study area, ranging from 0.4 - 0.6 mg/L (mean 0.5 mg/L) in the open-water season 2001.

Concentrations of nitrate/nitrite (0.08 mg/L) were higher in this stretch of the lower Burntwood River in winter than in the open-water season. This is consistent with observations made regarding seasonal differences at other locations in the study area and may be explained by the substantively lower rates of phytoplankton growth in winter.

Tributary Streams

In most streams, dissolved inorganic nitrogen concentrations were lower and ammonia concentrations were higher at upstream, relative to downstream, sampling locations. Ammonia and nitrate/nitrite ranged from 0.006 to 0.012 mg/L and < 0.005 to 0.015 mg/L, respectively, at upstream locations; similar ranges were observed at backwater inlet sites. Overall, concentrations were similar to those measured at Taskinigup Falls in 2001, indicating no major differences between the main stem and tributary streams.

Streams 1 to 4, and 7 had higher total nitrogen concentrations at upstream sites, relative to the downstream backwater inlet sites, indicating a more nutrient rich environment. Conversely, nitrogen concentrations were similar upstream and downstream in stream 9 and lower at upstream locations of streams 5, 6, and 10.

Phosphorus

Main Stem

In general, total phosphorus concentrations are relatively high in the lower Burntwood River (TF and WF) between Wuskwatim and Opegano lakes, as they are in the study area as a whole (Figure 5-17). Concentrations of total phosphorus ranged from 0.030 to 0.039 mg/L (mean 0.034 mg/L) in the open-water season 2001, with the dissolved fraction comprising from 26 to 35% of the total fraction (concentrations ranged between 0.009 and 0.011 mg/L).

While total phosphorus concentrations were similar in winter upstream (0.030 mg/L) and downstream (0.028 mg/L) of Taskinigup Falls relative to the open-water season, a higher fraction (50 to 54% of the total fraction) of the total phosphorus pool was dissolved at this time (0.015 mg/L at both sites). These values of dissolved phosphorus are near the upper end of the range measured throughout the study area in the ice-free season. Higher concentrations of the bioavailable dissolved fraction of phosphorus are not unexpected in winter because less is accumulated by algae and plants in winter due to the reduced primary production under low temperatures and reduced light.

At all times evaluated, total phosphorus concentrations did not exceed the proposed guideline for phosphorus in streams (0.05 mg/L) (Williamson 2002).

Tributary Streams

Total phosphorus concentrations ranged from 0.016 mg/L (stream 1) to 0.072 mg/L (stream 3) in tributary streams at sites upstream of the influence of the Burntwood River in September 2002. Ranges downstream at backwater inlet areas were 0.022 mg/L to 0.057 mg/L. Some streams had higher total phosphorus at upstream sites, relative to downstream (streams 3, 5, and 10), whereas others were similar (streams 4 and 9), and the remainder had lower concentrations (streams 1, 2, 6, and 7). Overall, exceedences of the MWQSOG for total phosphorus for streams occurred at streams 2 and 6 at backwater inlet sites and at upstream sites in streams 3 and 10.

Organic Carbon

Main Stem

TOC, which ranged from 7 to 11 mg/L (mean 8 mg/L) in the open-water season 2001, was similar in this stretch of the lower Burntwood River to sites upstream and downstream in Wuskwatim and Opegano lakes (Figure 5-19). DOC was virtually identical to TOC (i.e., most organic carbon was in the dissolved form). No seasonal difference was apparent in this area; TOC and DOC measured 9 mg/L at both sites evaluated in March 2001 in this area.

Carbon to nitrogen molar ratios ranged from 16 to 22 in the open-water season; two values derived for the ice-cover season were both 27. Collectively, these ratios indicate a substantive portion of organic matter is derived from allochthonous sources (i.e., terrestrial and/or wetland sources) (Hutchinson 1957).

Tributary Streams

With the exception of stream 5 which had a total organic carbon value of 7 mg/L, upstream sites on tributary streams were characterized by a relatively high organic carbon content (ranging from 21 to 31 mg/L), as expected in drainages from bogs, wetlands and highly organic terrain.

Carbon to nitrogen molar ratios were relatively high at both upstream (20.7 – 52.5) and downstream sites (15.7 – 43.3) evaluated at the 10 major tributary streams in September 2002, indicating significant contribution of allochthonous carbon sources to these streams. In general, ratios were higher than those observed in the main stem of the lower Burntwood River in the open-water season of 2001.

Nutrient Status

Main Stem

Phosphorus concentrations are comparable to those measured in Wuskwatim and Opegano lakes, but within the proposed MWQSOG for streams of 0.05 mg/L (the water quality guideline is less stringent for streams). In general, concentrations of phosphorus are relatively high in this stretch of the lower Burntwood River, as they are upstream and downstream, and conditions appear to be more nitrogen- than phosphorus-limiting (i.e., DIN:DP ratios < 10 in the open-water season). Nitrogen limitation is common in eutrophic systems, but under eutrophic conditions, phytoplankton growth is often more light limited than nutrient limited (Kalff 2002).

Tributary Streams

Overall, exceedences of the MWQSOG for total phosphorus for streams occurred at streams 2 and 6 at backwater inlet sites and at upstream sites in streams 3 and 10, indicating high natural concentrations of phosphorus in these environments as expected. Values were in general, similar to or higher than those measured in previous years on the Burntwood River. Similar to observations made of the main stem of the study area, DIN:DP ratios (all below 5) indicate nitrogen-limiting conditions in the 10 streams evaluated.

pH, Alkalinity, and Hardness

Main Stem

pH

All measurements of pH were within water quality criteria for the protection of aquatic life and the aesthetic objective for drinking water. pH downstream of Taskinigup Falls is slightly alkaline averaging 7.78 in the lab and 8.15 *in situ* in the open-water season 2001 (a pH > 7.4 is generally considered alkaline); values are similar to other locations in the study area, including sites accessed upstream in Wuskwatim Lake and downstream in Opegano Lake (Figures 5-8 and 5-9). Therefore, pH does not appear to change appreciably in the stretch of river between Wuskwatim and Opegano lakes. Values are representative of systems with a low to very low sensitivity to acidification (Palmer and Trew 1987).

pH appears to be typically lower in the study area as a whole (on the main system), including the lower Burntwood River between Wuskwatim and Opegano lakes, in the ice-cover season, relative to the ice-free season; pH (lab) measured 7.42 and 7.54 upstream (WF) and downstream (TF) of Taskinigup Falls in March 2001, respectively. This is consistent with reduced photosynthetic activities in winter and accumulation of carbon dioxide under ice. This level of seasonal change indicates a moderate buffering capacity.

Alkalinity

Conditions, with respect to alkalinity, were consistent with those observed upstream on the lower Burntwood River and in Wuskwatim Lake as well as downstream in Opegano and Birch Tree lakes and the lower Burntwood River. Alkalinity as bicarbonate and calcium carbonate averaged 67 mg/L and 55 mg/L, respectively in the open-water season, 2001; alkalinity as carbonate and hydroxide was not detectable. These levels, in conjunction with measurements of true colour, indicate a moderately high buffering capacity; levels below 24 mg/L (as $CaCO_3$) are considered low and surface waters with these levels of alkalinity are considered vulnerable to changes in pH (CCME 1987). The Burntwood River between Wuskwatim and Opegano lakes can be considered to exhibit very low sensitivity to acidification, on the basis of alkalinity (Palmer and Trew 1987).

Hardness

Hardness (as $CaCO_3$) averaged 55 and 59 mg/L in the open-water seasons of 2000 and 2001, in agreement with values obtained at other locations on the lower Burntwood River system, and the generally soft to moderately soft water conditions in the study area.

Tributary Streams

pH

pH is near neutral to slightly alkaline at upstream and downstream sites in tributary streams. *In situ* measurements ranged from 7.23 to 8.20 at upstream locations and 8.14 to 8.33 at backwater inlet sites. With the exception of Stream 6, where pH was similar at the upstream and downstream site, pH was lower at upstream locations of tributary streams, relative to backwater inlets in September 2002. Overall, pH was similar to that observed at main stem sites in Reaches 2 and 3. The lowest pH (7.23) was observed at the upstream location at Stream 1.

Alkalinity

Alkalinity was measured at streams 1 and 4. Alkalinity as $CaCO_3$ was very similar in stream 1 at the upstream site (55 mg/L) and at the backwater inlet site (50 mg/L) and was consistent with measurements obtained at Taskinigup Falls and other sites in the study area. Conversely, alkalinity was considerably higher at the upstream location in stream 4 (91 mg/L as $CaCO_3$), relative to the backwater inlet site influenced by Burntwood River water, indicating this stream has a greater **acid neutralizing capacity** than the main stem of the study area and is highly insensitive to acidification (Palmer and Trew 1987).

Hardness

Upstream locations at streams 1 and 4 can be characterized as moderately soft waters (CCME 1987), but harder than the backwater inlet sites and the main stem of the Burntwood River.

Colour, Total Dissolved Solids, and Conductivity

Main Stem

In general, true colour values were similar at Taskinigup Falls to values observed at other sites on the main stem of the study area, averaging 30 TCU in the open-water season 2001. All values were either at or above the aesthetic objective for drinking water quality (15 TCU) (Williamson 2002). These high colour values reflect the coloured state of the water and relatively high contributions of allochthonous organic matter. Virtually all measurements of true colour collected from the MB Conservation monitoring station on the lower Burntwood River at Thompson from 1980 – 2000 (see Section 5.3.3.1) exceeded the aesthetic drinking water quality objective, indicating this is a typical occurrence in the study area.

TDS concentrations were also similar to those measured upstream on the Burntwood River and in Wuskwatim Lake in the open-water season 2001, averaging 89 mg/L. Conductivity at Taskinigup Falls was consistent with values measured at other sites along the main stem of the study area (Figure 5-10).

Tributary Streams

Colour and total dissolved solids were measured at streams 1 and 4. Both streams exhibited high colour at upstream locations (140 and 120 mg/L in streams 1 and 4, respectively) and both exhibited higher total dissolved solids concentrations (140 and 160 mg/L in streams 1 and 4, respectively) than observed at the backwater inlet sites and measurements obtained in the main stem of the Burntwood River. This is typical of environments associated with bogs and wetlands and it reflects the presence of tannins, lignins, and various organic acids (Williamson and Ralley 1993).

Similarly, in general, conductivity measurements were high at all upstream sites and reasonably high at backwater inlet sites for all streams evaluated. Overall, conductivity exceeded 100 µS/cm at all locations and was higher than that recorded at Taskinigup Falls in 2001, as well as other locations in the study area.

Bacteria and Parasites

Main Stem

Fecal coliform bacteria and the protozoan parasites *Cryptosporidium* and *Giardia* were below analytical detection limits in surface water samples collected at Taskinigup Falls in the open-water season of 2001. However, one viable *Giardia* cyst was identified in the water sample collected below the falls in May 2001.

Tributary Streams

Low concentrations of fecal coliform bacteria were detected at the upstream site on Stream 1 (20 **CFU**/100 mL) and the downstream site at Stream 4 (10 CFU/100 mL), which is not unusual given the preponderance of beaver dams. *Cryptosporidium* and *Giardia* were not detected at any tributary stream locations evaluated in September 2002.

Inorganic Elements

Main Stem

Only one site, Taskinigup Falls, was sampled in the Burntwood River between Wuskwatim and Opegano lakes for analysis of trace elements and radiation. Samples were collected three and four times during the open-water season in 2000 and 2001, respectively.

Overall, results of trace element analysis were similar for the upstream Wuskatim Lake area and downstream in Opegano and Birch Tree lakes and the Burntwood River (Appendix 2). Many substances were near or below detection limits and/or below MWQSOGs for the protection of aquatic life, including: antimony; arsenic; beryllium; boron; cadmium; chromium; copper; mercury; lead; nickel; silver; thallium; and, zinc.

Compliance with MWQSOGs for aquatic life could not be adequately assessed for mercury, selenium, and silver because analytical detection limits exceeded the guidelines (note, this has since been corrected and samples collected in 2002 were analysed using lower detection limits). However, one measurement of selenium (September 2000) was at the analytical DL of 2 µg/L and thus exceeded the MWQSOG of 1 µg/L for the protection of aquatic life.

As observed in the Wuskwatim Lake area, and in the study area in general, all measurements of aluminum and iron exceeded MWQSOGs for the protection of aquatic life and wildlife in the lower Burntwood River, just downstream of Taskinigup Falls (Table 5-5). All measurements of iron were approximately three to in excess of six times the aesthetic drinking water quality objective, which is the same as the objective for the protection of aquatic life (0.3 mg/L). As indicated in the Section 5.4.3.2, these conditions are not unusual and are believed to be a reflection of the local geology (Ramsey 1991).

Table 5-5. Mean± SE concentrations of aluminum (Al) and iron (Fe) in surface water samples collected downstream of Taskinigup Falls, 2000 and 2001.

Site	Averaging Period	Al (mg/L)	Fe (mg/L)
MWQSOG for aquatic life	-	0.10	0.30
MWQSOG for drinking water	-	-[1]	0.300 [2]
TF	Open-water season 2001	1.56 ± 0.22	1.26 ± 0.19
TF	Open-water season 2000	2.06 ±0.36	1.54 ±0.24

[1] "A health based guideline for aluminum in drinking water has not been established…Operational guidance values of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended." (CCME 2001b)

[2] Aesthetic guideline; no guideline for protection of human health.

In general, gross alpha and beta activity were below the CCME drinking water quality guidelines for the protection of human health (2001b); one value of gross alpha radiation (0.10 Bq/L) obtained in July, 2001 at Taskinigup Falls was at the CCME drinking water quality objective for the protection of human health (0.1 Bq/L) (CCME 2001b). There are no guidelines for radiation for the protection of aquatic life.

Tributary Streams

Inorganic elements were measured at upstream and downstream (i.e., backwater inlets) locations at streams 1 and 4 in September 2002. Exceedences of MWQSOGs for the protection of aquatic life were observed for aluminum, iron (also exceeded aesthetic drinking water quality guideline), lead, and zinc in at least one of the two samples in Stream 1. Both aluminum and iron were considerably lower upstream of the backwater inlets in Stream 1, indicating these substances occur at lower levels in the stream proper than in the lower Burntwood River.

In Stream 4, exceedences of MWQSOGs for the protection of aquatic life were observed for aluminum, iron (also exceeded aesthetic drinking water quality guideline), and silver in at least one of the two samples in Stream 1. In contrast to Stream 1, aluminum and iron concentrations were considerably higher at the upstream location relative to the backwater inlet in Stream 4, indicating higher background conditions in this stream for these two elements. In fact the concentrations of aluminum (3.06 mg/L) and iron (2.6 mg/L) measured at the upstream site for Stream 4 were the highest measurements recorded for the entire Wuskwatim study area.

Hydrocarbons

Main Stem

In general, hydrocarbons were not detected in surface water samples collected from Taskinigup Falls in the open water seasons of 2000 and 2001. However, extractable hydrocarbons were detected in May 2000 (140 µg/L) and August 2001 (250 µg/L) at this site.

Tributary Streams

Hydrocarbons were not detected in water samples collected from Stream 1. Conversely, a number of hydrocarbons were detected at low levels (at or just exceeding analytical detection limits) at the upstream location assessed in Stream 4. Benz(a)anthracene, benzo(b)fluoranthene, benzo(g)perylene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceeded analytical detection limits at this site, but were not detected downstream. All PAHs were below MWQSOGs for the protection of aquatic life and drinking water quality, for those parameters for which criteria exist. Although the precise reason for the presence of these substances is not known, they may reflect local or distant sources of PAHs. These same PAHs were also detected in a water sample collected in the lower Burntwood River, downstream of Thompson in 2001.

5.3.4.4 Opegano Lake: Reach 4

Water Clarity

Measurements of turbidity and TSS at Opegano Lake in the open-water seasons of 2000 and 2001 ranged from 33 – 64 NTU and < 5 – 15 mg/L, respectively. TSS measured 8 and 9 mg/L in the winter of 2001 and 2002, respectively, falling within the range observed in the open-water season. However, the single turbidity measurement obtained in Opegano Lake (OLB) in March 2002 (18 NTU) was notably lower than measurements obtained in the ice-free period.

Water clarity was always similar at the two sites on Opegano Lake. No trend of increased or decreased clarity was observed between the sites further upstream (Taskinigup Falls and Wuskwatim Lake) and Opegano Lake.

Transparency of Opegano Lake was similar to Wuskwatim and Birch Tree lakes; the depth of the euphotic zone ranged from approximately 1 - 2 m in the open-water season of 2001 (Figure 5-13). Lower light penetration occurred at the times evaluated in the open-water season of 2000 (a year with higher than average flows on the Burntwood River), when the depth of the euphotic zone ranged from approximately 0.7 - 1.3 m.

Dissolved Oxygen and Water Temperature

DO was near saturation or slightly supersaturated in all measurements collected during the open-water seasons in 2000 and 2001, and in the winter of 2001 and 2002 in Opegano Lake; all concentrations were above the most stringent DO criteria for the protection of cold-water or cool-water fish species in either season.

Water temperature was similar to that measured elsewhere in the study area, peaking in July. There was no evidence of vertical stratification with regards to temperature or dissolved oxygen in Opegano Lake in either the ice-free or ice-cover seasons.

Nitrogen

Like other sampling locations in the study area, concentrations of ammonia in Opegano Lake were low in the open-water seasons of 2000 and 2001 and under ice (winter 2001 and 2002). Ranges for all sampling periods were similar: 0.004 - 0.01 mg/L in the open-water season of 2000; 0.01 - 0.03 mg/L in the open-water season of 2001; and, 0.01 mg/L in March 2001 and 2002. In 2001, mean concentrations of ammonia were higher in Opegano Lake, notably OLB (mean 0.020 mg/L), than most other sites along the main stem of the study area (Figure 5-14). However, all concentrations were well below MWQSOGs for ammonia for the protection of aquatic life (Table A5-6.1).

Concentrations of nitrate/nitrite were low in Opegano Lake and similar to those observed elsewhere in the study area. Ranges recorded for the open-water seasons of 2000 and 2001 were 0.02 to 0.04 mg/L and 0.007 to 0.012 mg/L, respectively. Also consistent with observations along the main stem of the study area in general, concentrations are higher in Opegano Lake in winter; single measurements obtained under ice cover in 2001 (0.09 mg/L) and 2002 (0.078 mg/L) were notably higher than concentrations observed in the open-water seasons. Also as indicated earlier, higher values of nitrate in winter are not unexpected because under low levels of irradiance and temperature, primary production is limited and less nitrate/nitrite is accumulated by plants and algae.

TKN in Opegano Lake was similar to other lakes and river locations evaluated in the study area. In 2000, TKN was consistently 0.4 mg/L and in 2001 TKN ranged from 0.3 to 0.6 in the open-water seasons. There was no indication of seasonal differences as values obtained in the winter of 2001 and 2002 (both 0.5 mg/L) fell within the range observed in the ice-free periods.

Phosphorus

As observed across the study area, total phosphorus concentrations are generally quite high in Opegano Lake, ranging from 0.037 to 0.046 mg/L in the open-water season of 2000 and from 0.028 to 0.041 mg/L in the open-water season of 2001. Also consistent with measurements obtained upstream of Opegano Lake, concentrations of total phosphorus are similar between ice-cover (0.027 mg/L in March 2001 and 0.034 mg/L in March 2002) and ice-free periods but dissolved phosphorus appears to comprise a greater fraction of total phosphorus in winter.

Organic Carbon

Virtually all organic carbon present in surface water samples collected in Opegano Lake in the open-water seasons of 2000 and 2001 and under ice in 2001 and 2002 was in dissolved form. TOC ranged from 7 - 8 mg/L in 2000 and from 6 - 13 in 2001. Values of TOC were similar in March 2001 and March 2002 (9 mg/L) to the open-water period. Concentrations of DOC in Opegano Lake indicate mesotrophic to eutrophic conditions (Kalff 2002).

Carbon to nitrogen ratios ranged from the high teens to high twenties in both years at the time of water collection indicating a substantive input of allochthonous carbon to the lake.

Nutrient Status

Levels of nitrogen and most notably phosphorus are relatively high in Opegano Lake, as they are in the study area as a whole. Opegano Lake would be classified as meso-eutrophic to eutrophic on the basis of total phosphorus and DOC concentrations (Table 5-3). All concentrations of TP recorded during the baseline study in Opegano Lake exceeded the proposed Manitoba Water Quality Objective for phosphorus in lakes and reservoirs of 0.025 mg/L (Williamson 2002). Furthermore, DIN:DP ratios calculated based on nutrient measurements collected in the open-water seasons of 2000 and 2001 were indicative of nitrogen limiting conditions (i.e., DIN:DP < 10) during the growing season. However, as indicated previously, primary production is likely limited to some extent by light in these turbid waters (Section 7).

pH, Alkalinity, and Hardness

pH

pH was consistent with measurements obtained upstream and downstream of this stretch of the Burntwood River, indicating slightly alkaline conditions. pH was typically similar between the two sampling locations in Opegano Lake at any given sampling time, averaging 7.88 (lab) and 7.85 (lab) at sites OLA and OLB, respectively, in the open-water season of 2001 (Figure 5-8). pH was typically lower at depth than on the surface in the open-water season 2001 but was not stratified. As observed in the Wuskwatim Lake area, pH was lower under ice-cover conditions; pH measured 7.56 (OLB) and 7.47 (OLA) in Opegano Lake in March 2001 and 2002, respectively.

Alkalinity

Alkalinity, measured in March 2001 in Opegano Lake (OLB), was very similar to values obtained throughout the study area. Expressed as bicarbonate and calcium carbonate, alkalinity measured 66 mg/L and 54 mg/L, respectively. These values are indicative of environments with moderate acid neutralizing capacities and, subsequently, low sensitivity to acidification (Palmer and Trew 1987).

Hardness

The single reading for hardness (55.0 mg/L as calcium carbonate), obtained in March 2001, is indicative of relatively soft water conditions and is consistent with values obtained for the rest of the study area.

Colour, Total Dissolved Solids, and Conductivity

True colour and TDS were 20 TCU and 160 mg/L (the highest value recorded during this study), respectively in Opegano Lake (OLB) in winter 2001. Conductivity in Opegano Lake was also consistent with values obtained throughout the study area, ranging from 99 to 113 µS/cm in the open-water season of 2000 and 2001 (Figure 5-10).

Bacteria and Parasites

Fecal coliform bacteria and the protozoan parasites *Cryptosporidium* and *Giardia* were not detected in the single water sample analyzed for these parameters from Opegano Lake (OLB) in March 2001.

Inorganic Elements

Opegano Lake was sampled for analysis of inorganic constituents on one occasion in March, 2001 (Appendix 2). Many substances were below or slightly above analytical detection limits and most met MWQSOGs for the protection of aquatic life, and therefore also met drinking water quality guidelines which are less stringent. Exceptions include copper (11 µg/L), iron (0.86 mg/L), and aluminum (0.88 mg/L). For context, the range of copper concentrations in surface waters in central Canada is 1 to 68 µg/L (CCME 1987).

With the exception of iron, where the aesthetic objective was exceeded, all measurements were below drinking water quality objectives. As with the other sites evaluated, compliance with MWQSOGs could not be adequately assessed for mercury, selenium, and silver because analytical detection limits were higher than water quality criteria.

Gross alpha and beta activity were below the CCME drinking water quality guidelines for the protection of human health (CCME 2001b) in the single sample analyzed.

Hydrocarbons

Hydrocarbons were generally not detected in the surface water sample collected from Opegano Lake (OLB) in March 2001. The two exceptions were naphthalene (0.11 µg/L) and 2-methylnaphthalene (0.06 µg/L); however, naphthalene was below the proposed

Manitoba Water Quality Guideline for the protection of aquatic life of 1.1 µg/L (there is no guideline for 2-methylnaphthalene) (Williamson 2002). Naphthalene may have been introduced to the local surface waters from motor fuel, as it is a natural component of fossil fuels.

5.3.4.5 Downstream of Opegano Lake: Reaches 5 and 6

Measurements were collected in Birch Tree Lake during the open-water seasons in 2000 and 2001 and during the winters of 2001 and 2002, and from the Burntwood River extending downstream approximately 5 km east of Thompson in the open-water season of 2001 and the winter of 2002.

Water Clarity

Measurements collected during the open-water seasons in 2000 and 2001 indicated similar concentrations of TSS and turbidity in Birch Tree Lake and the lower Burntwood River downstream to values measured elsewhere in the study area. In the open-water season of 2001, TSS ranged from 5 to 33 mg/L in Birch Tree Lake and from 8 to 17 mg/L in the lower Burntwood River. In the lake, the highest concentrations occurred in spring (the river was not sampled at that time). Measurements collected in winter 2002 indicate TSS may decline in the lake in winter but no evidence of reduction was evident in the Burntwood River downstream of Thompson, possibly due to discharge of effluents in the area.

As observed for Opegano and Wuskwatim lakes, transparency, as indicated by Secchi depth, was greater in 2000, relative to 2001, likely a reflection of higher flows in 2001.

Turbidity measurements collected in August and September 2001 indicated that water clarity in the Burntwood River did not change substantially between Birch Tree Lake and the most downstream site (LBRF, approximately 5 km downstream of Thompson). However, TSS (17 mg/L) was higher in the lower Burntwood River downstream of Thompson (LBRF) in September 2001 than at Birch Tree Lake (13 mg/L).

Dissolved Oxygen and Water Temperature

Birch Tree Lake and the lower Burntwood River downstream of Birch Tree Lake are well oxygenated in the open-water and ice-cover seasons. All measurements of DO were above 80% saturation, and differences in DO were not observed between sites. The lake is well oxygenated in winter, as DO concentrations were above 12 mg/L under ice in March 2002 (Figure 5-5); DO was also in excess of 12 mg/L in the lower Burntwood River, downstream of Thompson, at this time (Figure 5-5). DO concentrations were consistently above the most stringent water quality objectives for cold- and cool-water aquatic life at all times evaluated.

Temperature was slightly higher (by approximately 1 ^{o}C) at the only off-current site within the reach (BLA), than at the on-current sites during early summer (May-July) 2001.

Vertical stratification of the water column, in terms of temperature or dissolved oxygen, was not observed in the Burntwood River or in Birch Tree Lake.

Nitrogen

As observed at other locations in the study area, in general, ammonia concentrations were low downstream of Opegano Lake. With one exception, ammonia concentrations fell within the range of < 0.002 to 0.04 mg/L at the times evaluated; a single elevated measurement (0.12 mg/L) was collected on the lower Burntwood River upstream of the confluence with the Manasan River (LBRE1), in August 2001. This elevation was not evident upstream in Birch Tree Lake or immediately downstream and the reason for the elevation is not known. However, that ammonia was not elevated downstream of this site may reflect dilution by the Manasan River. Concentrations were also low under ice-cover conditions (0.005 – 0.006 mg/L). All ammonia measurements, including the elevated value, were well below MWQSOGs for ammonia for the protection of aquatic life (MWQSOGs corresponding to conditions that occurred at LBRE1 in August 2001 are 2.36 mg/L (30-day averaging period), 5.89 mg/L (4-day averaging duration), and 7.02 mg/L (1-hour averaging duration).

Like ammonia, concentrations of nitrate/nitrite were generally low and in agreement with measurements taken at other locations in the study area. With one exception, concentrations fell in the range of < 0.005 to 0.03 mg/L in the open-water seasons of 2000 and 2001. A single elevated value of nitrate/nitrite, 0.112 mg/L, was measured on the lower Burntwood River just upstream of the confluence with the Manasan River (LBRE1) in September 2001, however, nitrate/nitrite was not detected in water collected downstream (LBRE) at this time, possibly due to dilution by the Manasan River. Consistent with conditions observed elsewhere in the study area, nitrate/nitrite concentrations were higher in the ice-cover season (0.072 – 0.104 mg/L), relative to the open-water season. All concentrations, including the elevated measurement upstream of the Manasan River, were well below the drinking water quality objective of 10 mg/L of nitrate-N (Williamson 2002).

TKN concentrations measured in Birch Tree Lake and the lower Burntwood River were similar to those measured at other locations in the study area. Site means downstream of Opegano Lake ranged from 0.4 mg/L (BLA and LBRE (one measurement)) to 0.6 mg/L (LBRF) in the open-water season 2001. TKN concentrations were slightly lower under ice cover conditions (< 0.2 – 0.3 mg/L).

Phosphorus

Total phosphorus concentrations in Birch Tree Lake and downstream in the lower Burntwood River were similar to those observed at most locations in the study area. Site means ranged from 0.031 mg/L in the Burntwood River downstream of Thompson (LBRF) to 0.035 mg/L in Birch Tree Lake (BLB) in the open-water season of 2001 (Figure 5-17). Mean dissolved phosphorus concentrations ranged from 0.010 mg/L (most sites) to 0.015 mg/L (BLB) in this area and comprised approximately 18-64% of total phosphorus. Relative to other sampling times at the same location and relative to other sampling locations, a high concentration of DP was measured in May 2001 in Birch Tree Lake (BLB) (0.025 mg/L).

There was no clear indication of seasonal differences in total and dissolved phosphorus downstream of Opegano Lake, based on data collected in March 2002. However, a high total phosphorus concentration (0.054 mg/L) was observed in the lower Burntwood River downstream of Thompson, in conjunction with a high TSS concentration (40 mg/L), possibly a reflection of upstream effluent inputs (total phosphorus is often positively correlated to TSS).

Organic Carbon

Organic carbon, which was largely in dissolved form, was similar in Birch Tree Lake and in the downstream reach of the lower Burntwood River, relative to most other sampling locations in the study area. Site mean TOC concentrations ranged from 6 mg/L (one measurement only LBRE) to 9 mg/L (multiple sites), the lowest value corresponding to a single measurement collected at a site on the lower Burntwood River (LBRE) (6 mg/L) and the highest (12 mg/L) to a sample collected in Birch Tree Lake (BLB) in 2001 (Figure 5-19). Concentrations were similar in March 2002 (8 – 9 mg/L). Organic carbon to organic nitrogen molar ratios ranged from 18 to 45 downstream of Opegano Lake in the open-water season of 2001, indicating the significance of allochthonous organic matter in this area at most sampling times.

Nutrient Status

Birch Tree Lake would be classified as meso-eutrophic to eutrophic on the basis of TP, organic carbon, and, to a lesser extent, TN concentrations (Table 5-3). Consistent with the study area as a whole, phosphorus concentrations are particularly high in the lower Burntwood River downstream of Opegano Lake and in Birch Tree Lake; all measurements of total phosphorus collected in the open-water seasons of 2000 and 2001 and ice-cover season of 2002 in Birch Tree Lake were above the proposed MWQSOG for phosphorus (0.025 mg/L) (Williamson 2002). In addition, total phosphorus in the lower Burntwood River downstream of Thompson was above the proposed guideline for streams in March 2002, but not in the open-water season. At the times sampled, DIN:DP ratios were generally low (i.e., < 10), indicating nitrogen-limiting conditions.

pH, Alkalinity, and Hardness

pH

Mean laboratory pH for the open-water season of 2001 was quite similar at Birch Tree Lake and lower Burntwood River sites, ranging from 7.85 (BLC) to 7.93 (BLA) (lab pH) (Figure 5-8). These values, indicative of the slightly alkaline conditions and low to extremely low sensitivity to acidification are typical for main stem sites in the study area as a whole. Also consistent with other main stem sites, pH is lower under ice cover, ranging from 7.46 to 7.57 (lab pH) in Birch Tree Lake and the lower Burntwood River downstream of Thompson (LBRF) in March 2002.

Alkalinity

The buffering capacity of the lower Burntwood River downstream of Opegano and Birch Tree lakes is moderately high, as indicated by alkalinity (Palmer and Trew 1987). Alkalinity values for this area were consistent with those obtained for the remainder of the study area, ranging from 67 - 70 mg/L as bicarbonate and from 55 - 58 mg/L as calcium carbonate in the open-water season 2001. Alkalinity was similar in winter (March 2002), ranging from 62 - 65 mg/L as bicarbonate and from 51 - 54 mg/L as calcium carbonate.

Hardness

As observed at other locations in the study area, waters can be classified as soft downstream of Opegano Lake, with mean values of water hardness (as $CaCO_3$) ranging from 56 - 63 mg/L in the open-water season, 2001. Similar measurements were obtained in March 2002 (49.6 – 62.2 mg/L).

Colour, Total Dissolved Solids, and Conductivity

True colour values were low in, and downstream of, Birch Tree Lake; means for the open-water season 2001 ranged from 23 to 30 TCU at all sites measured downstream of Opegano Lake except at the on-current site in Birch Tree Lake (BLB) where the mean was notably higher (55 TCU). This higher mean value is, however, largely a result of an unusually high measurement (120 TCU) obtained in May, the highest value measured in the study area. All measurements of true colour exceeded the aesthetic drinking water quality objective of 15 TCU. True colour measurements in winter 2002 were similar to those measured in the open-water season.

Concentrations of TDS were similar in Birch Tree Lake and the lower Burntwood River to other sites evaluated in the study area in the open-water season of 2001. Site means ranged from 68 mg/L (one value only at LBRE) to 94 mg/L (one measurement at BLC and LBRE1). Conductivity is similar in Birch Tree Lake to other main stem sites (Figure 5-10). Concentrations of TDS in March 2002 (ranging from 80 to 84 mg/L) were similar to the open-water season; temperature corrected conductivities measured in winter 2002 were also similar to the open-water season.

Bacteria and Parasites

Fecal coliform bacteria and the protozoan parasites *Cryptosporidium* and *Giardia* were not detected in surface water samples collected downstream of Opegano Lake in the open water season of 2001 (BLB, BLC, LBRE1, LBRE, and LBRF) or in March 2002 (BLB, BLC, and LBRF).

Inorganic Elements

Several sites were sampled for analysis of inorganic substances and hydrocarbons downstream of Opegano Lake in the open-water season of 2001, including two sites in Birch Tree Lake (Sites BLB and BLC) and three sites on the lower Burntwood River downstream of Birch Tree Lake (LBRE1, LBRE, and LBRF). Birch Tree Lake and the lower Burntwood River downstream of Thompson were also sampled for analysis of inorganic constituents in March 2002.

All samples exceeded MWQSOGs for the protection of aquatic life for aluminum and iron (Table 5-6). Iron also exceeded the aesthetic objective for drinking water quality.

Measurements of copper, lead, and nickel exceeded MWQSOGs for the protection of aquatic life at some locations at times. Copper exceeded MWQSOGs for aquatic life in Birch Tree Lake (BLC) in August 2001 (33 µg/L) and March 2002 (BLB 5 µg/l and BLC 6 µg/L). Three water samples contained lead at concentrations exceeding site-specific guidelines, two of which were measured in Birch Tree Lake and the third in the lower Burntwood River upstream of the confluence with the Manasan River (LBRE1) in the open-water season of 2001. One sample (48 µg/L) collected at Birch Tree Lake also exceeded the MWQSOG for nickel for the protection of aquatic life. All of these elements were found to occur at concentrations above MWQSOGs at times in the lower Burntwood River in Thompson for the period of 1980 to 2000 (Appendix 1), indicating that exceedences are not an unusual occurrence in this area.

As indicated for other sites evaluated, compliance with MWQSOGs could not be adequately assessed for mercury, selenium, and silver because analytical detection limits were above the criteria.

Table 5-6. Mean± SE concentrations of aluminum (Al), iron (Fe), copper (Cu), lead (Pb), and nickel (Ni) in surface water samples collected at sites downstream of Opegano Lake, 2000, 2001, and 2002.

Site	Averaging Period	Al (mg/L)	Fe (mg/L)	Cu (µg/L)	Pb (µg/L)	Ni (µg/L)
MWQSOG for aquatic life	-	0.10	0.30	Calculated from water hardness: 5-6	Calculated from water hardness: 1.2-1.8	Calculated from water hardness: 28-35
MWQSOG for drinking water	-	-[1]	0.300 [2]	1,000 [2]	10 [3]	-
Birch Tree Lake (BLB)	Open-water season 2001	1.69 ± 0.29	1.31 ± 0.18	2 ±0	1.3 ±0.4	< 2
Birch Tree Lake (BLC) [4]	August 2001	1.28	1.03	33	< 0.5	48
Lower Burntwood River (LBRE1)	Open-water season 2001	1.67 ±0.10	1.20 ±0.09	4 ±2	1.4 ±0.8	2 ±1
Lower Burntwood River (LBRE) [4]	August 2001	1.38	1.03	2	0.7	< 2

Site	Averaging Period	Al (mg/L)	Fe (mg/L)	Cu (µg/L)	Pb (µg/L)	Ni (µg/L)
Lower Burntwood River (LBRF)	Open-water season 2001	1.55 ±0.13	1.22 ±0.15	1 ±1	< 0.5	< 2
Birch Tree Lake (BLB) [4]	March 2002	1.11	0.87	5	< 0.5	< 2
Birch Tree Lake (BLC) [4]	March 2002	1.06	0.83	6	< 0.5	2
Lower Burntwood River (LBRF) [4]	March 2002	1.82	1.58	5	0.8	3

[1] "A health based guideline for aluminum in drinking water has not been established…Operational guidance values of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended." (CCME 2001b)

[2] Aesthetic guideline; no guideline for protection of human health.

[3] Maximum acceptable concentration.

[4] Single measurement.

Gross alpha and beta activity were below the CCME drinking water quality guidelines for the protection of human health (CCME 2001b); there are no guidelines for radiation for the protection of aquatic life.

Hydrocarbons

Most hydrocarbons occurred at concentrations below analytical detection limits at sites evaluated downstream of Opegano Lake in the open-water season of 2001 and March 2002. However, extractable hydrocarbons were detected at concentrations just above analytical DLs (100 µg/L) at two sites in Birch Tree Lake (BLB and BLC) in August 2001 and toluene and xylene (total, meta/para, and ortho) at one site in Birch Tree Lake (BLB) in May 2001. As previously suggested, it is likely that within Birch Tree Lake, the presence of detectable levels of hydrocarbons likely reflects the occurrence of highly localized sources with recent introduction (i.e., toluene and xylene are rapidly degraded).

Additionally, a number of hydrocarbons were detected in the surface water sample collected from the lower Burntwood River downstream of Thompson (LBRF) in October 2001. These parameters included benz(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(g)perylene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene. Benzo(a)pyrene exceeded the drinking water quality guideline and the guideline for the protection of aquatic life and benz(a)anthracene exceeded the MWQSOG for the protection of aquatic life. The presence of PAHs at this location is not unusual given that the lower Burntwood River at Thompson receives industrial and municipal effluents and would receive atmospheric deposition of PAHs released during combustion of fossil fuels in the area.

5.3.4.6 Stream Crossings

Water chemistry was evaluated at five stream crossings (SC2-2, SC4-2, SC5-2, SC6-2, and SC9-2) along the access road in June 2002. In addition, dissolved oxygen measurements were obtained from three stream crossings (SC2-2, SC5-2, and SC6-2) in March 2002 under ice cover. Furthermore, stream crossings SC9-2 and SC8-2 are located on the tributary streams 6 and 9 in Reach 3, respectively, that are discussed in Section 5.3.4.3. Observed water quality conditions are described below.

Crossings Along Tributary Streams to Birch Tree Creek (SC2-2, SC4-2, SC5-2, and SC6-2)

Conditions that were similar across all streams that discharge into Birch Tree Creek include moderate to high levels of dissolved oxygen (all concentrations were above 7.5 mg/L), moderate to high levels of organic carbon (17-26 mg/L), neutral to alkaline pH (6.87-7.50), low levels of suspended solids (2-11 mg/L), moderate levels of total phosphorus (0.015-0.033 mg/L), and generally nitrogen-limiting conditions (low DIN:DP ratios). At all of these stream crossings, the dissolved inorganic nitrogen fraction was relatively low, and with the exception of nitrate/nitrite nitrogen measured at crossing SC2-2, concentrations of ammonia and nitrate/nitrite nitrogen were low; most nitrogen was in the organic form.

There is evidence that these streams may experience significant DO depletion under ice-cover. Dissolved oxygen depletion was evident at the three stream crossing sites visited in March 2002 (SC2-2, SC5-2, and SC6-2), particularly at SC2-2 and SC6-2 where dissolved oxygen was 2.7 and 1.3 mg/L, respectively. Both of these values are below the MWQSOG instantaneous minimum objective of 3 mg/L for the protection of mature life stages of aquatic life in winter. Although a higher DO was measured at SC5-2 (7.4 mg/L), the measurement represented an estimated 55% saturation (assuming a water temperature of 0 ^{o}C) and was considerably lower than that measured in spring.

Crossings at Tributary Streams to the Lower Burntwood River (SC9-2)

Stream crossing SC9-2 is located on tributary stream 6 in Reach 3, which drains into the lower Burntwood River. This stream can be characterized as a well-oxygenated, turbid, nutrient-replete (based on total nitrogen and phosphorus concentrations) system, based on water chemistry conditions measured at the stream crossing site in June 2002.

Conditions for some water chemistry parameters differed from both other stream crossings and other water quality sampling sites in the study area. Relative to water chemistry conditions on the mainstem of the study area, conductivity, nitrate/nitrite nitrogen, organic nitrogen, total phosphorus, and organic carbon are moderately high, indicating a moderately productive system. TSS and turbidity were also notably higher than at other stream crossing sites and the entire study area. The concentration of TP measured at this site exceeded the MWQSOG for streams and was the single highest value of TP measured at any site in the entire study area.

Most data collected further downstream on this stream in September 2002, as a component of tributary stream assessment for Reach 3, were similar to data collected during the stream crossing assessment in June 2002. However, total phosphorus, TSS, turbidity, and pH were considerably lower in September, relative to June, 2002. Higher levels of phosphorus, TSS, and turbidity in the spring may reflect effects of the spring freshet and surface run-off on the suspension of solids, including phosphorus.

There was evidence of dissolved oxygen depletion at the stream crossing site, based on a single measurement (1.3 mg/L) obtained under ice in March 2002. Low DO concentrations under ice cover may be typical at this site due to lack of re-aeration as a result of ice cover and the presence of moderate to high levels of organic matter.

5.3.5 Sediments

5.3.5.1 Inorganic Substances

Concentrations of metals and trace elements, sediment particle size, and organic matter content measured in sediments collected from Wuskwatim Lake (WuLB) and Opegano Lake (OLB) in July, 2001 and at Wuskwatim Lake (WuLB), Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in August, 2002 are presented in Appendix 5. 'Background' concentrations for some inorganic substances in lake and stream sediments in Canada and sediment quality guidelines are provided in Appendix 6.

Comparison to Sediment Quality Criteria and 'Background' Concentrations

There are Manitoba sediment quality guidelines for arsenic, cadmium, chromium, copper, lead, mercury, and zinc (Williamson 2002). Ontario also has guidelines for iron, nickel, and manganese (Persaud et al. 1993) and BC has an interim guideline for selenium (**BCMOE** 2001). There is also an open-water disposal guideline for silver and cobalt for Ontario (Persaud et al. 1993).

Of the substances for which either Manitoba or other sediment quality criteria are available, cadmium, lead, mercury, selenium, and zinc were consistently below the existing criteria at all sites where sediment chemistry was measured in the study area (Williamson 2002). In addition, concentrations of cobalt were below the Ontario Open Water Disposal Guidelines (Persaud et al. 1993).

Substances for which at least one sub-sample (i.e., one of three samples collected at each site) measurement exceeded a guideline include arsenic, chromium, copper, iron, manganese, and nickel. Compliance with Ontario Open Water Disposal Guidelines (Persaud et al. 1993) for silver could not be assessed because analytical detection limits (< 1 µg/g) were higher than the guideline (0.5 µg/g).

Manitoba sediment quality criteria and site mean concentrations of cadmium, chromium, copper, lead, mercury, and zinc are summarized in Table 5-7. Site mean concentrations of chromium were consistently above MSQGs at all sites examined and site mean concentrations of arsenic were above the MSQG at Opegano Lake in 2002 and above the PEL at Taskinigup Falls in 2002. However, it should be advised that 'background' concentrations of chromium in lake and stream sediments are typically at or above the sediment quality guidelines (Appendix 6). High arsenic concentrations at Taskinigup Falls, relative to other sites examined, may be related to the relatively high organic matter content of sediments collected there (Appendix 5).

Table 5-7. Means of concentrations (µg/g) of selected metals and metalloids in sediments analysed at selected sites in the study area and comparison to sediment quality criteria. Means indicated in italics exceed Manitoba sediment quality guidelines (MSQG) and means indicated in bold exceed Manitoba Probable Effect Levels (PEL) for sediments.

Element	Wuskwatim Lake		Opegano Lake		Taskinigup Falls	Birch Tree Lake	MSQG	
	2001	2002	2001	2002	2002	2002	Guideline	PEL
Arsenic	2.57	3.78	3.02	*7.07*	**21.79**	2.80	*5.9*	**17**
Cadmium	0.18	0.22	0.16	0.24	0.17	0.10	*0.6*	**3.5**
Chromium	*50.5*	*59.0*	*44.1*	*41.6*	*42.7*	*38.2*	*37.3*	**90**
Copper	26.1	26.2	31.1	28.0	26.7	19.9	*35.7*	**197**
Lead	11.5	14.4	10.7	10.9	12.3	7.9	*35*	**91.3**
Mercury	0.03	0.04	< 0.02	< 0.02	0.03	< 0.02	*0.17*	**0.486**
Zinc	69	83	67	62	64	43	*123*	**315**

Site means of iron, manganese, and nickel and Ontario sediment quality criteria are summarized in Table 5-8. All but one site mean (Birch Tree Lake) exceeded the Ontario Lowest Effect Level for iron, indicating high 'natural' concentrations of iron in the study area; this observation is consistent with high concentrations of iron in surface water across the study area. Like chromium, it has been reported that 'background' concentrations of iron in Great Lakes sediments exceed the Ontario LOEL for this element (Appendix 6).

Concentrations of manganese in sediments were high, as compared to Ontario LOEL and Severe Effect Level, at all sites except Taskinigup Falls, indicating that the study area is also generally rich in manganese. All measurements of manganese from lake sites examined were in excess of the 'background' concentration for Great Lakes sediments (Appendix 6).

All site mean concentrations of nickel in sediments were in excess of the Ontario LOEL, indicating a high 'natural' occurrence and reasonably consistent spatial distribution of this element in the study area. All site means were also in excess of 'background' concentrations of nickel in the Great Lakes (Appendix 6). Naturally high levels of this metal in the aquatic environment would not be unexpected, as the study area is located in a nickel belt. The results presented herein are in agreement with those presented in Williamson (1980), in which concentrations of nickel measured in surficial sediments collected from the lower Burntwood River in Thompson in 1979 exceed the OMOE LOEL for sediment quality (Persaud et al. 1993).

Table 5-8. Mean concentrations (µg/g) of selected metals and metalloids in sediments analysed at selected sites in the study area and comparison to Ontario sediment quality criteria. Means indicated in italics exceed Ontario Lowest Effect Level (LOEL) and means in bold exceed Ontario Severe Effect Level for sediments (Persaud et al. 1993).

Element	Wuskwatim Lake		Opegano Lake		Taskinigup Falls	Birch Tree Lake	Ontario Sediment Quality Guidelines	
	2001	2002	2001	2002	2002	2002	LOEL	SEL
Iron	*28,967*	*32,400*	*26,333*	*33,000*	*25,367*	19,000	*20,000*	**40,000**
Manganese	**1,353**	**1,287**	*664*	**7,909**	389	*610*	*460*	**1,100**
Nickel	*40.1*	*44.2*	*37.6*	*38.6*	*35.1*	*39.6*	*16*	**75**

Although all site means for copper were below the Manitoba Sediment Quality Guidelines, a single measurement obtained from a sediment sub-sample from Opegano Lake in 2001 exceeded the MSQG.

5.3.5.2 Hydrocarbons

Individual aromatic hydrocarbons and PCP were not detected in sediment samples collected in Wuskwatim or Opegano lakes. However, as indicated in Appendix 6, it should also be noted that for several PAHs for which sediment quality criteria exist or have been accepted provisionally (i.e., CCME 1999, Williamson 2002, Persaud et al. 1993), compliance with criteria can not be adequately assessed because laboratory analytical detection limits frequently exceeded the guidelines. However, PELs for these substances are all above the detection limits; therefore, it can be stated that all PAHs were below Manitoba PELs. Those PAHs where analytical detection limits were lower than the MSQGs, and thus could be assessed for compliance include fluoranthene and pyrene.

The only parameters measured that exceeded analytical detection limits at any of the sites examined in 2001 and 2002 were volatile hydrocarbons (C5-C10) at Wuskwatim Lake in 2001 (but not in 2002) and extractable hydrocarbons (C11-C30) in two replicate samples obtained from Birch Tree Lake in 2002. There are no sediment quality criteria for these parameters.

5.3.6 Water Quality Index

The Canadian Water Quality Index is a tool that was recently developed (CCME 2001c) to simplify reporting of water quality data. The main purpose of the CWQI is to generate meaningful summaries of detailed, multi-parameter water quality data for use by non-technical lay people and senior managers. In general, the CWQI, which provides a broad overview of environmental performance, should be used as a supplement to detailed water quality data analysis (CCME 2001c).

The CWQI considers three ‘factors’, all in reference to compliance with specified water quality criteria, in the evaluation of water quality data: (1) scope; (2) frequency; and, (3) amplitude. Scope considers the extent of non-compliance with water quality guidelines over the time period of concern (i.e., the number of variables, of the total number of variables examined, that do not comply). Frequency refers to the fraction of individual ‘tests’ (i.e., individual data values) that do not comply with specified water quality objectives. The amplitude component considers the amount by which failed test values do not meet their objectives (i.e., the extent of the non-compliance). These three factors are then integrated into a single value, to provide an index of water quality. Values generated using the CWQI can then be assigned a rank according to the criteria provided by CCME (2001c) and indicated in Table 5-9.

Table 5-9. Categories and ranking of numerical values of the Canadian Water Quality Index (CWQI).

Category	CWQI Value Range	Description of Water Quality
Excellent	95-100	Water quality is protected with a virtual absence of threat or impairment; conditions very close to natural or pristine levels. These index values can only be obtained if all measurements are within objectives virtually all of the time.
Good	80-94	Water quality is protected with only a minor degree of threat or impairment; conditions rarely depart from natural or desirable levels.
Fair	65-79	Water quality is usually protected but occasionally threatened or impaired; conditions sometimes depart from natural or desirable levels.
Marginal	45-64	Water quality is frequently threatened or impaired; conditions often depart from natural or desirable levels.
Poor	0-44	Water quality is almost always threatened or impaired; conditions usually depart from natural or desirable levels.

The Province of Manitoba has recently applied the CWQI to water quality monitoring data collected in 27 streams in southern and central Manitoba (Hughes 2001). Manitoba Conservation also used the British Columbia Water Quality Index, the index upon which the CCME WQI was based, for summarizing water quality at monitoring stations province-wide in the last State of the Environment Report, generated in 1997 (MB Conservation 1997).

The CWQI was applied to water quality data collected in the study area during the open-water season 2001; as the CWQI requires a minimum sample size of four for each variable examined, data collected in previous years were inadequate and could not be used to generate CWQI values. Manitoba Conservation has used 24 to 25 water quality variables in previous applications of water quality indices (i.e., Hughes 2001, MB Conservation 1997). Where available, these variables were adopted here to provide consistency and because they were deemed appropriate descriptors for the study area. As pesticides were not measured in this study, only 17 of the province’s 25 variables were incorporated here. A list of the included variables and associated water quality guidelines applied in the index are provided in Table 5-10. Proposed MWQSOGs were applied, in accordance with the settings used for calculating CWQI values for southern Manitoba streams (Hughes 2001). The only exception is total phosphorus; a guideline of 0.025 mg/L was applied for the lake sites, according to water quality guidelines presented in Williamson (2002).

Table 5-10. Water quality variables and guidelines used in the derivation of values for the Canadian Water Quality Index (CWQI) in the Wuskwatim study area, open-water season 2001. Guidelines are based on proposed MWQSOGs (Williamson 2002) and Hughes (2001).

Variable	Units	Guideline	Guideline Use
Fecal Coliform MF	Bacteria/ 100 mL	200	Recreation
pH	-	6.5-9.0	Aquatic Life
Specific conductivity	µS/cm	1000	Greenhouse Irrigation
TSS	mg/L	25 (mid-range)	Aquatic Life
DO	mg/L	5 (mid-range)	Aquatic Life
Total cadmium	mg/L	Calculation based on hardness	Aquatic Life
Total copper	mg/L	Calculation based on hardness	Aquatic Life
Total arsenic	mg/L	0.025	Drinking water, Health
Total lead	mg/L	Calculation based on hardness	Aquatic Life
Total aluminum	mg/L	0.1 at pH > 6.5; 0.005 at pH < 6.5	Aquatic Life
Total nickel	mg/L	Calculation based on hardness	Aquatic Life
Total zinc	mg/L	Calculation based on hardness	Aquatic Life
Total manganese	mg/L	0.05	Drinking water, Aesthetic
Total iron	mg/L	0.3	Drinking water, Aesthetic and Aquatic Life

Variable	Units	Guideline	Guideline Use
Total ammonia (as N)	mg/L	Calculated based on pH and temperature	Aquatic Life
Dissolved nitrate/nitrite	mg/L	10	Drinking water, Health
Total phosphorus	mg/L	0.025 (lake sites) or 0.050 (river sites)	Nuisance plant growth

Values for the CWQI were calculated based on these 17 parameters at all sites where sufficient data were collected (i.e., minimum sample size of 4 for each variable). Four sampling sites in the study area qualified: the lower Burntwood River downstream of Early Morning Rapids (LBRB2); the lower Burntwood River downstream of Taskinigup Falls (TF); one site on Wuskwatim Lake Site (WuLB); and, one site on Birch Tree Lake (BLB). Results are presented in Table 5-11.

Table 5-11. Canadian Water Quality Index (CWQI) values for the lower Burntwood River, Wuskwatim Lake, and Birch Tree Lake, based on data collected in the open-water season, 2001.

Site	CWQI Value	Rank
Lower Burntwood River (LBRB2)	69.1	Fair
Lower Burntwood River (TF)	69.0	Fair
Wuskwatim Lake (WuLB)	67.8	Fair
Birch Tree Lake (BLB)	62.3	Marginal

The water quality index value for Birch Tree Lake, ranked as ‘marginal’, reflects consistent non-compliance with objectives for iron, phosphorus, and aluminum, and two measurements of lead above the water quality objectives. Aluminum concentrations were in the range of 10 – 25 times the water quality objective.

The water quality index value for Wuskatim Lake, ranked as ‘fair’, is slightly higher than that for Birch Tree Lake due mainly to a lower number of failed tests. All values for iron and aluminum and three of the four measurements of phosphorus were in non-compliance with objectives. Values for the water quality index for both sites on the lower Burntwood River for the year 2001 are ranked as ‘fair’. These values are a reflection of consistent non-compliance with objectives for iron and aluminum. One measurement of lead on the lower Burntwood River downstream of Early Morning Rapids (LBRB2) was also above the corresponding water quality objective. As observed at the two lake sites, all but one measurement (LBRB2) of aluminum fell in the range of 10 – 25 times the objective.

Although not directly comparable, water quality index values were derived for a number of monitoring sites in northern Manitoba for the years 1991 through 1994, using the B.C. Water Quality Index (MB Conservation 1997). Using the B.C. WQI and ranking scheme, the Burntwood River at Thompson was ranked as ‘fair’ for 1991 to 1994.

5.4 IMPACT ASSESSMENT AND MITIGATION

Effects of the Project on water quality were assessed in terms of the suitability of surface water for aquatic life and wildlife, the use of water for drinking, and for effects to recreational activities, aesthetics, and navigation as defined by standards, objectives, and guidelines specified in the MWQSOGs.

All parameters assessed are relevant to the integrity of aquatic life and many are pertinent to the aesthetic quality of water used for drinking or drinking water quality for the protection of human health. It should be noted that, as stated in the proposed MWQSOGs (Williamson 2002), “All surface waters…are susceptible to uncontrolled microbiological contamination. It is therefore assumed that all raw surface water supplies will be disinfected as the minimum level of treatment prior to consumption.” Furthermore, the MWQSOGs “apply to finished drinking water, but can be extrapolated to provide protection to raw drinking water sources.” Comparison to MWQSOGs for drinking water is used to assess potential effects to resource users who use surface waters in the study area for drinking and other domestic purposes.

The only numerical criterion applicable to the protection of recreational use of surface waters refers to coliform bacteria. In addition, the MWQSOGs indicate in narrative criteria that waters shall be free from materials that may impair colour, odour, taste, turbidity, or ‘other conditions’ that are relevant/pertinent to beneficial uses of surface waters, including recreation.

Parameters relevant from a purely aesthetic perspective include such factors as water clarity, water odour, water colour, excessive growth of phytoplankton or attached algae, and levels of some substances that alter the appearance and/or ‘feeling’ of water, such as iron (may affect water colour) or the hardness of water (which may cause ‘scaling’).

Water quality parameters that were considered relevant to navigation included water clarity/transparency (i.e., TSS and turbidity). Effects to water temperature may alter ice regimes, but these were considered in Volume 4 and are not considered further in this section.

Predicted effects to water quality were gauged against appropriate MWQSOGs to provide comparison of Project-related impacts against 'environmental thresholds'. Where effects of the Project would not result in exceedences of water quality criteria, the effect was considered negligible. Where Project-related effects pertain to a water quality parameter that is currently not in compliance with MWQSOGs, the significance of the effect was gauged against the current conditions and the projected incremental effect. Instances where a small incremental increase in a parameter that is currently far in excess of a water quality guideline (e.g., an order of magnitude above an MWQSOG) would occur were considered negligible to small effects, while a measurable increase in a variable near or just above the water quality guidelines was considered a moderate to large change (depending on the magnitude of change). In the first instance, the background conditions were already affecting the usage of the water, while in the second instance, the change as a result of the Project could affect the usage of the water. As guidelines incorporate a safety margin with respect to protecting the health of humans and aquatic life, any further increases above a guideline should be viewed as an increased risk of adverse effects.

To determine whether the changes would be considered 'significant' in terms of the environmental assessment, the magnitude of the change in the water quality parameter, in conjunction with the spatial and temporal scale of the effect, were considered, as described in Section 2.0. The assessment of 'significance' was adjusted to reflect whether potential effects would actually occur (e.g., effects to drinking water were not considered for reaches of the river where there is currently no resource use; the potential effect of nutrient enrichment on algal growth considered whether an increase in algal growth was likely to occur, given other environmental conditions).

A summary of relevant water quality objectives is provided in Appendix 6.

5.4.1 CONSTRUCTION

Major pathways for potential effects to water quality associated with the construction are presented in Table 5-12. Construction-related pathways considered in the impact assessment for water quality include: discharge of treated sewage effluent; blasting; leachate from waste rock piles and structures containing exposed rock (e.g., dam); construction and removal of cofferdams; runoff from the camp site and work areas;

discharge of wastewaters from processing of aggregate materials and concrete; flow changes as a result of river management; and access road construction (e.g., stream crossings).

5.4.1.1 Linkages to the Wuskwatim Project

Total Suspended Solids, Turbidity, and Colour

Construction activities that may lead to increased suspended sediments, turbidities, and/or colour in adjacent surface waters include:

- clearing and grubbing (i.e., removal of roots of vegetation and surface organic layer);
- construction of access road, including stream crossings;
- run-off from the construction camp and work areas;
- release of treated sewage effluent;
- release of effluent from settling ponds receiving wash water from aggregate washing and concrete processing;
- placement and removal of cofferdams; and
- increased erosion of riverbanks and riverbed during diversion of water through the spillway and initial operation.

Other activities identified in Table 5-12 as potentially releasing suspended sediments to surface waters were considered very minor sources (e.g., construction of GS structures will be conducted in-the-dry, therefore little, if any, sediments will be directly released to surface waters from this activity).

Dissolved Oxygen

Construction activities that may affect concentrations of dissolved oxygen in the aquatic environment include:

- the discharge of treated sewage effluent to the backwater inlet at stream 4; and
- blasting activities (introduction of ammonia, which is broken down by **aerobic** processes).

Table 5-12. Construction-related activities, potential effects to water quality, and proposed mitigation measures.

Action/Activity	First Order Effect/Pathway	Mitigation Measures
Clearing of access road ROW and borrow areas and associated grubbing	Inputs of sediments due to increased erosion as a result of the removal of the protective layer of vegetation.	Minimize clearing, hand clearing in sensitive areas, grubbing only where required (e.g., road embankment and ditch).
Construction of access road and development of borrow areas	Release of sediments from road, ditches and slopes of borrow areas.	Appropriately sloped banks; erosion control measures may include placement of slash on slopes, re-seeding, and erosion blankets; promotion of revegetation; silt curtains in ditches if required; buffer zones adjacent to water courses.
Stream crossings	Release of sediments due to: in-stream excavation, inputs from materials used for fill, and erosion from adjacent stream bed and banks.	Crossings constructed during winter when flow minimal, use of clean fill for crossings, riprap on stream banks and beds adjacent to culvert, culverts sized and positioned appropriately to pass flow.
Clearing and grubbing of sites for construction camp, work areas, and other infrastructure[2].	Increased erosion as a result of the removal of the protective layer of vegetation.	Minimize clearing and grubbing, provide erosion control measures (described for access road) as required, maintain vegetated buffers where possible.
Site drainage	Inputs of sediments and potentially other contaminants (e.g., metals, hydrocarbons) from runoff from parking lots, work areas, material stockpiles, and other sites.	Drainage plans will be developed to manage drainage from areas such as material stockpiles. Drainage waters will be monitored to ensure adequate quality prior to entering natural waterways. Buffer zones adjacent to water courses.
Water treatment plant	Installation of intake pipe and protective berms and discharge of treatment plant sludge and backwash.	Intake pipe placed on surface of lake bed from barge or ice (no excavation in lake bed), riprap on berms and other structures to minimize erosion, water treatment plant sludge discharged to sewage treatment system.
Sewage effluent	Inputs of BOD, pH, TSS/turbidity, nutrients, ammonia, metals, organic carbon, colour, (residual chlorines will not be discharged) to surface waters.	Sewage from main construction camp will be treated in a lagoon and tested as required prior to release to surface waters. Sewage from temporary starter camps will be collected in holding tanks and trucked out; gray water may be discharged to sullage pits.

[2] Area to be flooded by construction of the GS will only be cleared, not grubbed. Effects are considered under operation.

Action/Activity	First Order Effect/Pathway	Mitigation Measures
Placement and removal of cofferdams	Introduction of fine suspended materials (river bottom sediments and cofferdam material) to surface water during construction and removal of dams. Inputs of substances during dewatering.	Construction methods to minimize losses of fine material; riprap to reduce erosion from cofferdam surface; seepage and other water collected behind cofferdam after initial dewatering will be tested and treated, if required, prior to release to surface waters.
Blasting with ANFO.	Release of nitrogen (ammonia and nitrate) and TSS to surface waters; secondary effects from ammonia nitrification to DO.	Removal of unspent of ANFO explosives will leave minimal amounts of nitrogenous substances that may enter surface waters (residual amount from spent charges).
Placement of excavated rock materials on cofferdams, main dam, excavated materials placement area, and other structures.	Acid leachate generation from rock surfaces exposed to air potentially introducing metals and lowering pH in the aquatic environment.	Addressed through testing of materials and applying lime where required.
Construction of powerhouse, dykes, main dam and other structures.	Release of substances associated with construction (e.g., sediments) to surface waters.	Construction carried out in-the-dry (e.g., behind cofferdams or on land) minimizing potential for inputs to surface waters. Surfaces protected from erosion (e.g., rockfill) where required.
Placement of concrete in surface waters.	Contact of surface water with newly formed concrete structures can affect pH.	Concrete will not be poured in-the-wet.
Construction of channel excavation.	Release of suspended sediments to surface waters.	Most of channel excavation completed in-the-dry.
Release of wash water from aggregate washing and concrete processing to surface water environment.	Waters may contain suspended sediments, metals, and affect parameters such as pH.	Wash water treated in two-celled settlement pond; if discharge to surface waters required, effluent will be tested to assure acceptable quality prior to release.
Diversion, impoundment and initial operation, including removal of rock plugs.	Release of suspended matter, including erosion of riverbanks and riverbeds.	Areas within cofferdams will have as much loose material as practical removed. Armoring of the riverbed or riverbanks if required.
Accidental spills and releases of hazardous substances.	Direct or indirect introduction of contaminants to surface waters.	Transportation, storage, and handling of dangerous goods by established policies and regulations. Spill response programs and equipment will be in place.

Water Temperature

There will be no changes to hydrology, thermal regimes, or ice regimes that could affect water temperature during construction. Treated sewage effluent and other wastewaters (e.g., effluent released from settling pond) will be discharged at **ambient** temperatures and will not alter the temperature of receiving water bodies.

Nutrients

Concentrations of nutrients in the aquatic environment may be affected by a number of construction-related activities, including:

- discharge of treated sewage effluent;
- blasting (i.e., release of ammonia and nitrate); and
- activities that may release TSS (e.g., runoff from terrestrial areas following clearing, loss of fine materials during cofferdam placement and removal) as nutrients are also associated with these sources.

pH and Alkalinity

pH and alkalinity of adjacent surface waters could be altered through:

- discharge of treated sewage effluent;
- release of effluent from settling ponds receiving wash water from aggregate washing and concrete processing;
- accidental spills and releases; and
- acid leachate from placement of excavated rock materials on structures where they will remain exposed to air.

Other activities listed in Table 5-12 are expected to have a negligible effect (e.g., concrete structures will be placed in-the-dry and not in-the-wet and, therefore, are expected to have a negligible effect on pH).

Bacteria and Parasites

The occurrence and/or levels of bacteria, such as fecal coliform bacteria, and protozoan parasites, such as *Cryptosporidium* and *Giardia*, may be affected by the discharge of treated sewage effluent into surface waters.

Trace Elements

During construction, trace elements, including naturally-occurring radionuclides, could be introduced to the aquatic environment via the following activities:

- discharge of treated sewage effluent;
- release of effluent from settling ponds receiving wash water from aggregate washing and concrete processing;
- acid leachate from placement of excavated rock materials on structures where they will remain exposed to air;
- accidental spills and releases (trace elements are present in trace quantities in many substances such as hydrocarbons); and
- other activities that result in the inputs of suspended solids to surface waters as metals are also associated with these sources (described above).

Hydrocarbons and Other Hazardous Substances

The presence and levels of hydrocarbons in the local surface water environment could potentially be affected by accidental spills or releases of substances containing hydrocarbons (e.g., fossil fuels). Other hazardous substances will also be used at the site.

The release of significant quantities of hazardous substances to the aquatic environment as a result of accidental spills and releases is considered unlikely due to the development and implementation of good management practices, including:

- handling and storage of materials in accordance with established policies and regulations;
- transportation of dangerous goods as required by legislation/regulation; and

- having spill response programs and equipment in place to address spillage of oils or other contaminants.

The assessment related to accidental spills is applicable to all the reaches and the stream crossings and, therefore, is not considered in the reach-specific sections below.

<u>Sediments</u>

Sediment quality may be affected by construction activities that alter the introduction of contaminants and/or nutrients to the surface water environment and/or by activities that result in sediment resuspension or deposition, such as construction of stream crossings and/or excavation. As many substances tend to accumulate in sediments, alteration to water chemistry and/or introduction of contaminants as a result of the activities described above may lead to changes to sediment chemistry.

5.4.1.2 Reach 1: Wuskwatim

Construction-related activities that may significantly affect water and sediment quality are located downstream of Reach 1. Surface water run-off from the camp area may contain suspended sediments, but it is expected that management procedures will minimize the inputs of sediments. Likewise, installation of the water treatment plant intake is not expected to cause measurable increases in TSS. The sludge from the water treatment plant will be discharged to the sewage treatment system and not enter the lake.

5.4.1.3 Reach 2: Falls

<u>TSS and Turbidity</u>

Effects related to clearing of work areas, and run-off and discharges from these areas, will affect water quality in the upper segment of Reach 3 and, therefore, are not discussed with reference to Reach 2.

Excavated Materials Placement Area

This structure, situated on the north shore of the immediate forebay, will consist of a central portion largely composed of fine material, and will have very shallow outer slopes. Rock-filled berms will be used at the toe (i.e., adjacent to the immediate forebay) to minimize erosion and the inputs of sediments to surface waters.

Channel Excavation

The channel excavation, providing an additional connection between Wuskwatim Lake and the immediate forebay, will be largely completed in-the-dry, as most excavation will not extend to the pre-Project shoreline. Only during the final removal of the rock plug adjoining Wuskwatim Lake (fall 2008) will limited excavation occur in-the-wet. Initial operation of this channel would be associated with the mobilization of sediments from within the channel and possibly adjoining lake and river bottoms that are currently backwater bays and not exposed to flow.

Cofferdam Placement and Removal

In-stream excavation activities for the construction and removal of cofferdams would occur in the furthest downstream section of Reach 2. However, water flow would carry sediments downstream so most effects would occur in Reach 3; therefore this linkage is discussed under Reach 3.

Impoundment and Diversion during River Management

During construction of the Stage II cofferdams, it is expected that water levels in the immediate forebay will stage slightly, potentially resulting in the erosion of some riverbanks in the immediate forebay. In addition, flow will be redirected through the newly constructed spillway, which will result in the erosion of remnants of the Stage I cofferdam and portions of the riverbed not currently subject to high water velocity (Volume 4). The erodibility of the riverbed upstream of the spillway will be assessed during construction and, if unacceptable increases in TSS as a result of erosion are expected, mitigative measures, such as armoring the river bottom with rock material, will be considered.

Overall Effect to TSS

Overall effects as a result of the input of TSS from numerous sources will be managed by attempting to limit the net increase to 25 mg/L. This includes inputs in Reach 3 and is further discussed under Reach 3.

Dissolved Oxygen

DO levels in Reach 2 are not expected to be affected by construction. There will be a small amount of impoundment and flows will be redirected by cofferdams; in Phase II flows will be directed through the spillway (Volume 3). These alterations are not expected to affect DO concentrations.

Nutrients

Nutrients may be introduced in conjunction with TSS. Nitrogenous compounds may also be introduced by blasting, as discussed below.

Blasting

Blasting during construction of the channel excavation will use ammonium nitrate-fuel oil (ANFO), which has the potential to release ammonia and nitrate to the aquatic environment. Blasting in-the-dry will occur for approximately 3 months (May to July 2008), followed by a single blast in-the-wet for removal of the rock plug (fall 2008). Blasting will result in the release of negligible quantities of ammonia and nitrates because the Environmental Protection Plan (EnvPP, see Volume 3 for details) will specify that unspent charges (the source of most of the nitrogenous compounds) will be removed, leaving only residual amounts of ammonia and nitrate from spent charges to enter surface waters after the area is impounded. These residual quantities are expected to be rapidly diluted due to the large volume of flow.

pH and Alkalinity

Acid Leachate

The potential for waste rock placed in the Excavated Materials Placement Area and the main dam to generate acid leachate, which could subsequently enter the local surface water environment, was assessed through several testing procedures, as discussed in Volume 4. Based on the results of this testing, no effects on water quality are predicted. Testing of materials during construction that reveals a significant acid generation potential will be addressed through mitigation. Therefore, this linkage is not discussed in subsequent sections.

Bacteria and Parasites

Bacteria and parasites in surface waters will not be affected by construction activities in Reach 2.

Trace Elements

Concentrations of trace elements in surface waters in Reach 2 could be increased as a result of the input of TSS, either from fines used in cofferdam construction or by suspension of sediments on the river bottom, and as a result of acid leachate. As discussed above, it is expected that the potential for the generation of acid leachate can be mitigated.

Metals and metalloids that are of the greatest interest to the assessment are those that are at or near guideline levels in the existing environment. Levels of aluminum and iron are currently 12 to 28 times and 2 to 7 times above water quality criteria, respectively. Because these concentrations are much higher than MWQSOGs, small project-related increases in these substances would likely not cause further impairment of water usage. Elements such as selenium, copper, arsenic, lead, manganese, nickel, and thallium are currently found in concentrations in surface waters in the lower Burntwood River that are at or near the water quality criteria and would therefore be the parameters most vulnerable to exceedences of thresholds due to construction activities.

Cofferdam Placement and Removal and River Management

Cofferdam placement and removal will result in the inputs of metals associated with fines used during construction, as discussed in detail for Reach 3.

The limited in-stream excavation during the construction period and scouring of the river bottom following the opening of the spillway and channel improvement will result in suspension of bottom sediments and release of sediment porewater to the surface water environment. Sediments at Taskinigup Falls contain high concentrations of arsenic (above the probable effect level guideline), chromium (above the Manitoba Sediment Quality Guideline, Williamson 2002), iron, and nickel (both above the lowest effect level for sediments for province of Ontario, Persaud et al. 1993). Because iron and aluminum are both already high in surface waters throughout the study area, sediment suspension is not likely to cause further impairment of water quality. Concentrations of chromium, nickel, and arsenic measured at Taskinigup Falls (immediately downstream in Reach 3) in 2000 and 2001 were below water quality guidelines.

Relatively small loads of sediments need to be put in suspension to cause exceedences of criteria for some metals, notably copper and selenium and, to a smaller extent silver, lead, and manganese. However, any effects of sediment suspension would be short-term and, therefore, not expected to have a significant adverse effect on aquatic life.

The overall increase in metals as a result of the net effect of these construction activities will in part be mitigated by measures taken to limit increases in TSS (see Reach 3).

Sediment Quality

No effects to sediment quality are expected in Reach 2 due to the absence of point source discharges in this reach.

5.4.1.4 Reach 3: Burntwood

TSS and Turbidity

Sources of TSS discussed for Reach 2 will also affect water quality in Reach 3, as no settling of fines is expected in Reach 2 due to high water velocities.

Clearing and Grubbing of Sites for Work Areas and Other Infrastructure

Clearing of the work areas and sites for the GS structures will increase the potential for erosion from these areas. Inputs of sediments to the surface waters will be reduced by maintaining a buffer of vegetation wherever possible, and by providing other erosion control measures, as required.

Site Drainage

Natural streams and drains in the area will be maintained and protected with vegetated buffers and appropriately installed stream crossings. A drainage plan will be developed for the site. Runoff from the work areas that could contain high concentrations of suspended sediments (e.g., drainage from material stockpiles) will be monitored to ensure acceptable quality prior to entering natural waterways.

Treated Sewage Effluent

TSS and turbidity may be affected in the backwater inlet of tributary stream 4 due to the discharge of treated sewage effluent from the sewage lagoon (discharged in June for five days and October for 10 days). Water quality in the backwater inlet of Stream 4, examined in September 2002, was generally intermediate between the Burntwood River and the stream above the influence of the river and, as such, was moderately turbid.

Predicted effects of effluent on TSS are presented in Table 5-13. Calculations were based on a number of conservative assumptions including an absence of settling of TSS and an absence of inflow (other than the effluent) or outflow such that discharges of TSS accumulated in the backwater inlet.

Under these conditions, the predicted increase of TSS in late fall would be less than or equal to 8.7 mg/L, which would be reached by the end of the discharge period (i.e., by day 10) under the lowest flows (i.e., 5^{th} Percentile). In the spring, as effluent is to be released for only 5 days, the maximum effluent-induced increase in TSS is predicted to be 5.2 mg/L under 5^{th} percentile flows.

MWQSOGs specify an allowable increase of 5 mg/L of TSS above ambient discharge for a 30-day averaging period and a 25 mg/L increase in TSS for a 1-day averaging period, relative to ambient concentrations (Williamson 2002). Effluent would not cause TSS levels to rise above the level for the 1-day averaging period. The predicted increase in TSS by the end of the discharge period is greater than the 30-day MWQSOG of 5 mg/L. However, since the period of discharge is much less than 30 days, and the increase was calculated as the cumulative effect of the entire period of discharge and did not incorporate settling of TSS or outflow from the inlet, no exceedence of this objective is anticipated. As the MWQSOGs will be met within the inlet, they will also be met within the Burntwood River.

Cofferdam Placement and Removal

Placement of the Stage I cofferdams will occur during the open-water season of 2005. Loss of fine material during construction in high velocity areas will be reduced with the prior placement of rockfill deflector groins. Once in place, the cofferdams will be protected against erosion due to wave action with riprap, and areas subject to high flows will be protected by sections of rockfill outside of the impervious fill.

The Stage I upstream cofferdam will be removed during summer 2008. As much material as possible will be removed in-the-dry, and the work in-the-wet will occur under relatively low velocity conditions due to the presence of a rockfill deflector groin. Removal of the Stage I downstream cofferdam will be completed in-the-dry after construction of the Stage II cofferdams.

The Stage II cofferdams will be constructed and removed during the summer and fall of 2008. The Stage II upstream cofferdam above Taskinigup Falls (i.e., in Reach 2) will be constructed partially in-the-wet and partially in-the-dry. Erosion will be reduced during and after construction through diversion of flow through the spillway, and placement of a rockfill spur and riprap. This cofferdam will remain in place and become part of the shell of the Main Dam.

The Stage II downstream cofferdam will be constructed just south of the spillway channel outlet and will be removed in-the-wet using a backhoe and a dragline in fall 2008.

Initial dewatering of the cofferdams will involve the direct discharge of surface water enclosed by the cofferdam into the Burntwood River. Seepage and other water that collects within the cofferdam after the initial dewatering will be tested to ensure adequate quality prior to release to surface waters.

Release of Effluent from Settling Ponds for Aggregate Washing and Concrete Processing

Wastewater from aggregate washing and concrete processing will be treated in an adequately sized two-cell settling pond. If effluent from these ponds is discharged to surface waters, it will be tested prior to release to ensure that quality is acceptable.

River Diversion

TSS and turbidity will be temporarily increased in Reach 3 after diversion of flow through the spillway and removal of the rock plug on the channel excavation. These events will occur in summer and fall, 2008, respectively.

Overall Effects to TSS

Measures described in volumes 3 and 4, as well as standard practices that will be outlined in the EnvPP, will be taken with the intent of limiting the increase in TSS to less than 25 mg/L above background conditions at a fully mixed point in the Burntwood River (i.e., immediately upstream of Opegano Lake). This increase would represent the net effect of all construction-related activities affecting reaches 2 and 3, including cofferdam construction and removal, drainage from the work areas, discharge of effluents from the sewage lagoon and settling pond, and erosion in the riverbed and riverbanks as a result of diversion and impoundment.

Table 5-13. Predicted increases in total suspended solids (TSS) in the backwater inlet of Stream 4 due to discharge of treated sewage effluent in spring and late fall, during construction.

Flow Scenario	Backwater Inlet Volume	Effluent			Background concentration [1]	Predicted Increases in TSS: Due to Effluent Alone			Predicted Final Concentration: Incorporating Background		
		Discharge Rate	Period of Discharge	TSS Concentration		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
	(m^3)	(m^3/day)	(days)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Winter											
5th Percentile	53821	2850	10	25	13	1.3	5.2	8.7	13.6	15.5	17.2
50th Percentile	122291	2850	10	25	13	0.6	2.6	4.7	13.3	14.3	15.3
95th Percentile	173993	2850	10	25	13	0.4	1.9	3.5	13.2	13.9	14.7
Spring											
5th Percentile	53821	2850	5	25	13	1.3	5.2	-	13.6	15.5	-
50th Percentile	122291	2850	5	25	13	0.6	2.6	-	13.3	14.3	-
95th Percentile	173993	2850	5	25	13	0.4	1.9	-	13.2	13.9	-

[1] Based on measurement collected in the backwater inlet of Tributary Stream 4 in September, 2002.

This increase above background TSS is consistent with the Manitoba short-term water quality objective, which applies for a 1-day averaging duration for surface waters where total background concentrations of TSS are less than or equal to 250 mg/L (Williamson 2002). It is expected that there may be periods during construction when the 30-day averaging duration of an increase in TSS of 5 mg/L above background may be exceeded; however, exceedence of this 30 day guideline for several weeks during the construction period is not expected to cause a significant change in the aquatic biota due to its short-term nature and given the range of background concentrations of TSS in the Burntwood River. The construction schedule suggests that there will be two periods when TSS levels may approach 25 mg/L for several weeks: during the construction of the Stage I cofferdams in 2005; and for much of the open-water season of 2008 due primarily to the removal of the Stage I cofferdams, the placement and removal of the Stage II cofferdams, and erosion of the river banks and river bed as flow is redirected to pass through the spillway and portions of the river bed are exposed to higher velocities than under existing conditions. Smaller increases will occur during the remainder of the construction period due to the other inputs described above.

Although the intent will be to maintain the overall increase in TSS to less than 25 mg/L in the fully mixed portion of the river, concentrations will be considerably higher in plumes (e.g., immediately off the leading edge of a cofferdam during construction). However, it is expected that the spatial area affected by extremely high concentrations of TSS will be very small, affecting only a limited amount of habitat for benthic invertebrates and that fish will be able to avoid concentrated plumes. It should be noted that effects related to exposure to high levels of TSS in plumes will primarily occur in the main stem and not the backwater inlets, which are off the main flow.

Dissolved Oxygen

Hydraulics

Change in flow patterns as a result of river flow management (i.e., construction of cofferdams, diversion through spillway channel) is not expected to affect dissolved oxygen levels in Reach 3 due to the high velocities and large volumes of water.

Treated Sewage Effluent

Dissolved oxygen may be affected due to the discharge of treated sewage wastewater from the construction camp into the backwater inlet of tributary stream 4. The estimated load of **biochemical oxygen demand** (BOD) is 71 kg/day, which would be released for approximately 10 days in late fall and 5 days in spring. Predicted effects of this discharge were estimated assuming that the load of BOD continued to accumulate in the inlet over the course of effluent discharge; to be conservative, it was assumed that BOD was simply diluted by the volume of the inlet and none was lost to outflow or decay/settling processes.

In late fall, predicted effects of the effluent discharge on ambient concentrations of BOD in the backwater inlet range from 1.3 mg/L on day one of the discharge up to an 8.7 mg/L increase by day 10 of the discharges (5^{th} Percentile flows) (Table 5-14). In spring, the maximum predicted increase in BOD due to effluents is 5.2 mg/L above ambient, which would be incurred by day 5 of the discharges and under 5^{th} Percentile flows. These concentrations are elevated above background and indicate that inputs of organic materials may cause a decline in DO concentrations in the backwater inlet, particularly in late fall when higher loads of BOD are released.

At the time of planned effluent discharge in the late fall/early winter (i.e., October 1), MWQSOGs for the protection of mature life stages of cold-water aquatic life would be applicable. These objectives specify that DO should not be less than 6.5 mg/L over a 30-day averaging duration, the 7 day minimum should not be below 7.0 mg/L, and the instantaneous minimum should be no less than 4.0 mg/L (Williamson 2002). Objectives for the protection of early life stages of cool water species, which would be applicable in spring, are less stringent.

DO measured in the backwater inlet in September 2002 indicated the area is well-oxygenated (9.88 mg/L or 88% saturation). If a similar level of saturation were to occur at a water temperature of 0 ^{o}C, dissolved oxygen concentrations in the backwater inlet would approach 12 mg/L. Effluents will result in declines in DO in the backwater inlet of stream 4 due to decomposition of BOD; however, in the open-water season, this DO sink will be somewhat mitigated by re-aeration. Effects may be more pronounced in winter, when organic matter discharged in effluent that has settled out of the water column to the sediments will continue to consume dissolved oxygen over the winter, in the absence of re-aeration. However, DO concentrations were observed to be quite high in the winter 2002 (Section 5.3) and, therefore, would likely be able to stand small declines in DO without reaching the MWQSOGs.

Table 5-14. Predicted effects of treated sewage effluent discharges on concentrations of biological oxygen demand (BOD) in the backwater inlet of Tributary Stream 4 in spring and late fall.

Flow Scenario	Backwater Inlet Volume	Effluent			Background concentration [1]	Predicted Increases in BOD: Due to Effluent Alone			Predicted Final Concentration: Incorporating Background		
		Discharge Rate	Period of Discharge	BOD Concentration		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
	(m^3)	(m^3/day)	(days)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Late Fall											
5th Percentile	53821	2850	10	30	0.015	1.51	6.28	10.39	1.52	6.29	10.40
50th Percentile	122291	2850	10	30	0.015	0.68	3.13	5.67	0.70	3.14	5.68
95th Percentile	173993	2850	10	30	0.015	0.48	2.27	4.22	0.50	2.28	4.24
Spring											
5th Percentile	53821	2850	5	30	0.015	1.51	6.28	-	1.52	6.29	-
50th Percentile	122291	2850	5	30	0.015	0.68	3.13	-	0.70	3.14	-
95th Percentile	173993	2850	5	30	0.015	0.48	2.27	-	0.50	2.28	-

[1] Based on measurement collected in the backwater inlet of Tributary Stream 4 in September, 2002.

Nutrients

Treated Sewage Effluent

Effluent discharged to the backwater inlet of Stream 4 may affect concentrations of ammonia, which is toxic to aquatic fauna, as well as dissolved and particulate organic and inorganic forms of nitrogen, phosphorus, and carbon.

Discharge of effluents in late fall and spring is expected to have a measurable, short-term effect on TKN, nitrate, and total phosphorus in the backwater inlet of Stream 4. Smaller effects are expected with respect to ammonia.

These increases may lead to the development of nuisance growth of aquatic plants and algae. However, increases in nutrients would be short-term and would be associated with periods where other environmental conditions that limit aquatic plant and algal growth are less than favourable. In spring and late fall, when effluent will be discharged, water temperatures are reduced and the intensity and duration of solar radiation are limited. Under these conditions, primary production may be limited by light and temperature, rather than nutrients.

In terms of toxicity, predicted maximum increases in ammonia in the backwater inlet of Stream 4 vary from negligible to moderate, depending on the flow regime and the presence of early life stages of cool- or cold-water species. Table 5-16 presents site-specific objectives for ammonia, based on the observed pH (8.14) in September 2002 and an estimated water temperature of 0 ^{o}C in late fall and 10 ^{o}C in spring. None of the predicted concentrations of ammonia exceed the 4-day or 1-hour objectives for ammonia for the protection of early or mature life stages of cool- or cold-water species. The 30-day average objective of 2.0 mg/L is predicted to be exceeded by day 5 of effluent release under the lowest river discharge (i.e., 5th percentile flow). However, the 30-day objective will likely not be exceeded when averaged over a 30 day period. Furthermore, the predictions do not account for ammonia losses due to dilution, outputs in water, or nitrification.

Table 5-15. Predicted effects of treated sewage effluent discharges on concentrations of ammonia in the backwater inlet of Tributary Stream 4 in spring and late fall.

Flow Scenario	Backwater Inlet Volume	Effluent			Background Ammonia concentration [1]	Predicted Increases in Ammonia: Due to Effluent Alone			Predicted Final Concentration: Incorporating Background		
		Discharge Rate	Period of Discharge	Ammonia Concentration		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
	(m^3)	(m^3/day)	(days)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Winter											
5th Percentile	53821	2850	10	10	0.008	0.50	2.09	3.46	0.51	2.10	3.47
50th Percentile	122291	2850	10	10	0.008	0.23	1.04	1.89	0.24	1.05	1.90
95th Percentile	173993	2850	10	10	0.008	0.16	0.76	1.41	0.17	0.76	1.41
Spring											
5th Percentile	53821	2850	5	10	0.008	0.50	2.09	-	0.51	2.10	-
50th Percentile	122291	2850	5	10	0.008	0.23	1.04	-	0.24	1.05	-
95th Percentile	173993	2850	5	10	0.008	0.16	0.76	-	0.17	0.76	-

[1] Based on measurement collected in the backwater inlet of Tributary Stream 4 in September, 2002.

Table 5-16. Site-specific objectives for ammonia for spring and late fall for the interpretation of the predicted effects of treated sewage effluent on water quality in the backwater inlet of Stream 4, calculated from formulae provided in Williamson (2002).

Applicable Period		Assumed Water Temperature (^oC)	Averaging Duration		
			1 Hour	4 Days	30 Days
Spring					
	Cool-water Species	10	6.4	4.9	2.0
	Cold-water species	10	4.3	6.6	2.6
Late Fall					
	Cool-water Species	0	6.4	8.0	3.2
	Cold-water species	0	4.3	4.9	2.0

Blasting

Blasting during construction of the channel excavation will use ammonium nitrate-fuel oil (ANFO), which has the potential to release ammonia and nitrate to the aquatic environment. Blasting in-the-dry will occur for approximately 4 months (August to November 2005) during excavation of the spillway and intake channels, followed by a single blast in-the-wet for removal of the spillway rock plug (summer 2008). Blasting will result in the release of negligible quantities of ammonia and nitrates because the EnvPP will specify that unspent charges (the source of most of the nitrogenous compounds) will be removed from areas blasted in-the-dry, leaving only residual amounts of ammonia and nitrate from spent charges to enter surface waters after the area is impounded. These residual quantities are expected to be rapidly diluted due to the large volume of flow.

pH and Alkalinity

Treated Sewage Effluent

The backwater inlet of Stream 4, like other waters of the study area, is characterized by a moderately alkaline pH and a moderate alkalinity and, on the basis of these values, is considered to be highly insensitive to acidification (Palmer and Trew 1987). Measurable effects to pH due to discharge of treated sewage effluents are not anticipated.

Release of Effluent from Settling Ponds for Aggregate Washing and Concrete Processing

Effluent from the settling pond receiving wastewater from aggregate washing and concrete processing will have the potential to affect pH. Effects are expected to be negligible given the buffering capacity and large volume for dilution in the Burntwood River. However, effluent quality will be measured prior to discharge to ensure that quality is acceptable.

Bacteria and Parasites

Treated Sewage Effluent

Bacteria and parasites may be introduced into the backwater inlet of tributary stream 4 with the discharge of treated sewage wastewater.

Estimated maximum increases in the concentration of fecal coliform bacteria in the backwater inlet of Stream 4, due to release of treated sewage effluents in spring and late fall, are presented in Table 5-17. The treatment has been designed such that the actual concentration of fecal coliform bacteria in the effluent would be < 200 units/100 mL. To be conservative, the predicted effects to receiving waters presented in Table 5-17 are based on an effluent concentration of 200 units/100 mL.

The discharge of effluent, under the worst case scenario (i.e., 5th percentile flows, maximum concentration in effluent, and after 10 days of discharge, assuming no losses or dilution due to inflow or outflow), will cause a measurable increase in fecal coliform bacteria, relative to conditions observed in September 2002. However, all predicted increases would result in a final concentration well below the water quality objective for recreation, which is only applicable during the recreation usage period (May 1 to September 30), assuming the background water quality were similar to that observed in September 2002. Any discharge of fecal coliform bacteria would affect the quality of water as a drinking water source, as MWQSOGs indicate that no bacteria should be present for this usage; however, surface waters should be subject to a minimum level of treatment prior to use for drinking.

Trace Elements

Treated Sewage Effluent

Trace element concentrations may be affected in the backwater inlet of tributary stream 4 due to the discharge of treated sewage wastewater. These effects are predicted to be negligible to small (and likely not measurable) and short-term, occurring in association with brief periods of discharge in spring and late fall.

Placement and Removal of Cofferdams

Effects of the placement and removal of cofferdams in Reach 3 would be similar to effects discussed above for Reach 2.

Release of Effluent from Settling Ponds for Aggregate Washing and Concrete Processing

Release of water from processing of aggregate materials may result in the introduction of a small load of metals/metalloids to the Burntwood River. Wastewater from aggregate washing and concrete processing will be treated for TSS levels through the use of an adequately sized two-cell settling pond. Reduction in TSS levels will also reduce concentrations of metals associated with the particulate fraction. If effluent from this pond is discharged to surface waters, it will be tested prior to release to ensure that quality is acceptable.

Sediments

Sediment quality could be potentially affected in Reach 3 due to the release of treated sewage effluent into the backwater inlet of tributary stream 4, release of water from processing of aggregate, and sediment suspension and release of fine particulates during cofferdam placement and removal. Effects in the backwater inlet of Stream 4 may be measurable, given that settling may occur in the inlet. Effects of other activities on sediments in the Burntwood River are expected to be negligible as no significant settling of fine materials is expected in this reach.

Table 5-17. Predicted effects of treated sewage effluent discharges on concentrations of fecal coliform bacteria in the backwater inlet of Tributary Stream 4 in spring and late fall.

Flow Scenario	Backwater Inlet Volume	Effluent			Background Concentration [1]	Predicted Increases in Fecal Coliform Bacteria: Due to Effluent Alone			Predicted Final Concentration: Incorporating Background		
		Discharge Rate	Period of Discharge	Fecal Coliform Bacteria Concentration		Day 1	Day 5	Day 10	Day 1	Day 5	Day 10
	(m^3)	(m^3/day)	(days)	(CFU/ 100 mL)	(CFU/100 mL)	(CFU/100 mL)	(CFU/100 mL)	(CFU/100 mL)	(CFU/100 mL)	(CFU/100 mL)	(CFU/100 mL)
Winter											
5th Percentile	53,821	2,850	10	200	10	10	42	69	20	50	76
50th Percentile	12,2291	2,850	10	200	10	5	21	38	14	30	46
95th Percentile	173,993	2,850	10	200	10	3	15	28	13	24	37
Spring											
5th Percentile	53,821	2,850	5	200	10	10	42	-	20	50	-
50th Percentile	122,291	2,850	5	200	10	5	21	-	14	30	-
95th Percentile	173,993	2,850	5	200	10	3	15	-	13	24	-

5.4.1.5 Reaches 4, 5, and 6: Opegano and Downstream

No effects of construction activities on water quality are expected downstream of Reach 3, with the exception of effects to TSS/turbidity and related parameters. Mitigation measures will be undertaken with the intent of limiting increases in TSS to less than 25 mg/L above background as discussed for Reach 3. This magnitude of increase, given that it will only occur during a portion of the 2005 open water season and for much of the 2008 open water season, is not expected to have a significant effect on aquatic biota.

Overall, construction-related increases in TSS and related parameters are expected to cause negative and not significant (short-term, moderate (decreasing to small with distance downstream), local to regional) effects to the suitability of water for aquatic life. Effects to parameters such as ammonia, nutrients, and oxygen are also expected to be not significant (short-term, small to moderate, and site-specific). There is not likely to be a significant adverse effect due to spills, given the small potential for the release of harmful quantities to the environment.

5.4.1.6 Access Road, Stream Crossings and Borrow Areas

Construction of the access road will entail installation of eight permanent stream crossings on Mile 17 access road and one temporary crossing along the existing Mile 20 winter trail during the first winter of construction (Volume 4). Borrow pits will be located along the roadway (to provide material for the roadbed), as well as at a subset of the borrow sites described in Volume 3 (to provide material for the road surface, fill at the stream crossings, and fine aggregate for concrete production for the generating station). These latter sites are located in the upper watershed of Birch Tree Brook, near stream crossings SC4-2 and SC5-2, and near and north of SC3-3 (Figure 5-3).

The principal impact to water quality related to these activities is the input of sediments into natural watercourses (the potential for accidental spills was discussed in Section 5.4.1.1). These would be mitigated through procedures identified in Volume 4, as described below.

Erosion control measures along the roadway and in borrow areas will be consistent with the Manitoba Transportation and Government Services "Manual of Erosion and Sedimentation Control" and the "Manitoba Stream Crossing Guidelines for Protection of Fish and Fish Habitat" and may include:

- placing slash material and/or erosion control blankets on stockpiled topsoil and borrow pit slopes and bottoms;

- flattening slopes to reduce velocities of surface water runoff;
- diverting runoff to vegetated areas that will filter it en route to natural watercourses; and
- promoting vegetation growth where possible (e.g., borrow areas that are no longer required).

Where roadways are adjacent to water courses, buffer zones will be a minimum of 10 m plus 1.5 times the slope gradient in accordance with the "Manitoba Stream Crossing Guidelines". A minimum 100 m buffer will be maintained between borrow areas and active stream channels.

In-stream work for the installation of stream crossings will occur during low flow periods in winter or early spring prior to runoff. Procedures to minimize the introduction of sediments to streams identified in the "Manitoba Stream Crossing Guidelines" will be employed, including:

- installation of appropriately sized and positioned culverts to pass flows;
- maintenance of vegetated buffer zones for as much of the area as possible (i.e., not clearing the entire ROW);
- installation of riprap along the stream banks and rock aprons in the stream bed adjacent to the culvert(s);
- constructing the stream crossing embankments with clean granular fill;
- use of erosion control measures such as seeding of grass and erosion control blankets, where required; and
- installation of silt fences as required in ditches to prevent sediments from entering natural water courses.

As discussed in Volume 4, technical specifications for the protection of streams and groundwater will be stated in contract documents, as well as methods for rehabilitation of the areas after usage.

Overall, construction is expected to result in negative and not significant (short-term, small to moderate, site-specific) effects to water quality downstream of the crossings. There is not likely to be a significant adverse effect due to spills, given the small potential for the release of harmful quantities to the environment.

5.4.2 OPERATION

Operation-related pathways that were assessed for potential effects to water quality include: flooding of the terrestrial environment; increased erosion; changes to water levels and flows; conversion of intermittently wetted to permanently wetted habitat; generation of acid leachate from structures containing excavated rock materials; sewage effluent; maintenance of the road and other structures; and accidental spills (Table 5-18).

5.4.2.1 Rationale and Linkages to the Wuskwatim Project

Total Suspended Solids, Turbidity, and Water Colour

Operation of hydroelectric facilities can alter TSS, turbidities, and/or water colour, though the overall effect may be an increase or decrease depending on the net effect of the following:

- raising water levels and flooding generally results in increased erosion of the shoreline, which increases levels of TSS and turbidities and may affect colour;
- impoundment and subsequent increases in water residence times may increase deposition of suspended solids and particulates from the water column;
- alteration of water velocity downstream of reservoirs may lead to enhanced settling of suspended matter or increased erosion of riverbank; and,
- increased productivity due to nutrient inputs from flooding may increase TSS and/or turbidity due to increased densities of phytoplankton.

Dissolved Oxygen

Dissolved oxygen may be affected by a number of pathways, including:

- flooding of terrestrial environments and increased rates of erosion introduce organic matter to the aquatic environment which, in turn, may result in oxygen depletion due to aerobic decay processes;
- changes in thermal regimes due to creation of reservoirs may alter DO through effects to the capacity of water to hold oxygen (i.e., DO concentrations are affected by water temperature);

- changes to water levels, volumes, flows, and ice regimes may affect dissolved oxygen through reductions of atmospheric re-aeration rates, altered river travel times and increased lake residence times, and effects to stratification of the water column;

- trophic upsurges (i.e., increased production as a result of nutrient enrichment) may exacerbate diurnal fluctuations in dissolved oxygen; and,

- reservoirs with bottom-draw designs may affect downstream DO concentrations if the reservoir experiences pronounced stratification and low dissolved oxygen concentrations at depth, below the thermocline.

As the Wuskwatim GS will draw water from much of the water column (i.e., not a 'bottom-draw' design) and Wuskwatim Lake does not stratify, the last linkage is not applicable and was not considered further.

Water Temperature

Operation of hydroelectric generating stations may affect the thermal regimes upstream and downstream of the dam through the following pathways:

- increased erosion may increase water temperature because waters high in TSS retain more heat than waters with low levels of TSS; and,

- increased depths in reservoirs may affect temperature and temperature profiles in the reservoir.

Assessments related to potential ice regimes concluded that hydraulic changes as a result of the project would not affect water temperature (Volume 4). Predicted changes in TSS (see following sections) are also not sufficient to cause a change in temperature. Therefore, this linkage was not considered further.

Table 5-18. Operation-related impacts, potential effects to water quality, and summary of proposed mitigation measures.

Impact	First Order Effect/Pathway	Mitigation Measures
Flooding	Exposure of terrestrial plants and soils to water; introduction of organic matter (decomposition), nutrients and pH.	Clearing of trees prior to flooding.
Erosion	Increased inputs of soils to surface waters.	None
Changes to water levels and flows	Alters hydrological environment with potential effects to temperature regimes, including thermal stratification, and dissolved oxygen (re-aeration).	None
Conversion of intermittently to permanently wetted habitat	Inputs of organic substances and nutrients to surface waters.	None
Placement of excavated rock materials on the main dam, excavated materials placement area, and other structures.	Acid leachate generation from rock surfaces exposed to air potentially introducing metals and lowering pH in the aquatic environment.	Addressed through testing of materials and application of lime where required.
Maintenance of road and other facilities	Potential input of various substances to surface waters.	Various measures to prevent the input of harmful substances to the aquatic environment.
Sewage effluent	Inputs of BOD, pH, TSS/turbidity, nutrients, ammonia, and, colour to surface waters.	Sewage will be treated at the GS.
Accidental spills and releases of hazardous substances	Direct or indirect introduction of contaminants to surface waters	Transportation, storage and handling of dangerous goods by established policies and regulations. Containment equipment in design of GS. Spill response programs and equipment will be in place.

Nutrients

Nutrients may be introduced to surface waters due to operation of the project through:

- flooding of terrestrial habitat;
- conversion of intermittently wetted habitat to permanently wetted habitat; and,
- erosion.

In addition, creation of a reservoir may alter nutrient retention and transfer downstream.

pH and Alkalinity

Operation of hydroelectric generating stations may alter pH and alkalinity through:

- the flooding of soil (soil may be acidic);
- generation of acid leachate from excavated rock materials used on structures where they remain exposed to the air;
- decomposition of organic matter introduced through flooding and/or erosion; and,
- alterations to photosynthetic activities (i.e., increased photosynthesis stimulated by trophic upsurges may cause an increase in pH during daylight hours, with a subsequent decline in pH in non-daylight hours due to respiration).

Bacteria and Parasites

Negligible quantities of treated sewage effluent may be released to the Burntwood River during operation of the Wuskwatim GS, an activity that could potentially increase the levels of bacteria and parasites in local receiving waters. In addition, construction of the Project may lead to an increase in the number of cabins on Wuskwatim Lake, which could result in an increase in the release of human wastewaters, and potentially bacteria and parasites, to the local surface water environment. This latter point is considered as part of the cumulative effects assessment (Section 11).

Trace Elements

During operation, trace elements, including naturally-occurring radionuclides, could be introduced to the aquatic environment via the following activities:

- accidental spills and releases (metals are contained in many common substances, such as gasoline);
- generation of acid leachate from excavated rock materials used on structures where they remain exposed to the air;
- erosion; and,
- inundation of vegetation and soils in the newly flooded area, within the zone converted from intermittently exposed to permanently wetted habitat, and where peatlands may break down downstream of the GS due to water level changes.

Hydrocarbons

Hydrocarbons may be released to surface waters during operation of the Wuskwatim GS through:

- accidental spills and releases on site (e.g., from turbines and transformers); and,
- accidental spills and releases from increased boat traffic (assessed as part of the cumulative effects assessment).

During normal operations, about 5,000 gallons of petroleum materials will be stored in a designated area in the powerhouse with appropriate spill proof equipment. Measures to address spills were previously discussed for construction, and will not be considered in this section.

Other Hazardous Substances

Vegetation management (removal of new growth and disease and insect control) will be undertaken for ROWs, fire breaks, the station yard and earth-fill dams). Vegetation control will be by mechanical means if possible and chemicals would only be used if mechanical means were unsuccessful and proper authorization was obtained.

About every 25 years, exterior structures exposed to the elements will require stripping and resurfacing, and possibly other treatments. When adjacent to the aquatic environment, measures will be undertaken to ensure that by-products do not enter surface waters.

Measures to minimize adverse environmental effects of maintenance activities will be described in the EnvPP and will not be considered further in this section.

Sediments

Sediment quality may be affected by operation-related effects such as:

- erosion, which introduces suspended matter to surface waters that may, depending on the environment, settle on the lake or river bottom, thus affecting the chemistry of the sediments; and,
- flooding of the terrestrial environment which creates new sediments, the quality of which will depend in part on the chemistry of the soils prior to flooding.

5.4.2.2 Reach 1: Wuskwatim

Total Suspended Solids and Turbidity

Erosion

Operation of the Wuskwatim Project will stabilize water levels in Reach 1 at 234.0 m ASL. This change in water regime will cause an increase in erosion rates relative to existing rates for an estimated 25 years, with the largest relative increase occurring for approximately the first 5 years (Volume 4). Although rates will increase, the proportion of eroding shoreline is expected to remain constant. Most of the eroding shorelines are on Wuskwatim Lake main, where 75% of the shoreline is eroding, though a substantial portion of the shore of Cranberry Lakes is also eroding.

Effects of increased erosion on TSS levels were considered in two manners: (1) the predicted increase in TSS in Wuskwatim Lake main as a whole due to inputs of eroded material from all of Reach 1; and, (2) the predicted increase in TSS in the nearshore zone of Wuskwatim Lake main due to the inputs from eroding banks within this zone (note that the area of the nearshore zone was the combined area of the intermittently exposed and nearshore zones as defined in Section 6.0). Impacts to Wuskwatim Brook, Wuskwatim Lake south, and Sesep Lake were not considered due to the small amount of eroding shoreline in these areas (Volume 4).

With respect to increases in TSS in Wuskwatim Lake main as a whole, an estimated 50% of materials produced from erosion in Wuskwatim Lake main are expected to settle immediately in the nearshore, while the remaining 50% will enter deeper waters, where a further 25% will settle. Therefore, 25% of the total eroded material in suspension will be carried downstream (Volume 4). Predicted increases in TSS for Wuskwatim Lake main were calculated based on estimated loads of eroded materials that would be introduced over three time frames: 0-5 years; 6-25 years; and, 26-100 years for a scenario with the Project and without the Project (i.e., continuation of current conditions). Volumes of eroded material were calculated as part of the erosion study (Volume 4). The introduction of eroded materials was assumed to occur uniformly over the length of the open-water season (184 days/year). However, it is recognized that erosion is highest during high wave and wind energy events; this scenario was considered qualitatively relative to predicted increases in TSS under 'average' conditions (i.e., uniform erosion over the entire open-water period). Although increases in TSS would be incremental as the water moves through the lake, for assessment purposes a mass balance relationship between river discharge and 25% of the calculated total load of eroded materials in Reach 1 introduced over a 184-day open-water period was used.

To assess potential project-related increases in TSS in the nearshore zone of Wuskwatim Lake main, the entire load of eroded materials generated from the Wuskwatim Lake main shoreline was assumed to mix in the volume of the nearshore zone at an elevation of 234.0 m ASL. This mass-balance approach is based on the assumptions that erosion would occur over a period of 184 days (i.e., the length of the open-water season) and that the water residence time in the nearshore zone is 1 day.

Background concentrations of TSS in Wuskwatim Lake main, based on measurements collected in the open-water seasons of 1999 – 2001, and calculated site-specific water quality objectives are provided in Table 5-19. In general, MWQSOGs for TSS specify an allowable increase of TSS of 5 mg/L over a 30-day averaging period (chronic objective) and an allowable increase of 25 mg/L above background over a 1-day averaging period (acute objective) (where background TSS is ≤ 250 mg/L) (Williamson 2002). These objectives are provided to indicate the magnitude of change in projected TSS concentrations relative to existing conditions. However, the assessment of compliance with the water quality objectives for TSS was based on the incremental increase in TSS caused by the project, relative to projected concentrations of TSS in the absence of the project (i.e., project-induced increases). In other words, the 'background' condition against which compliance with the water quality objectives is gauged (i.e., against which an allowable increase is assessed) is the projected future TSS concentrations that would be incurred in the absence of the project.

Table 5-19. Statistical summary of measured concentrations of TSS during base-line studies (i.e., background concentrations) 1999 – 2001 in Wuskwatim Lake main and calculated MWQSOGs for Wuskwatim Lake.

	TSS (mg/L)		
	Wuskwatim Lake Base-line	Calculated MWQSOGs	
		1-Day Averaging Period	30-Day Averaging Period
Mean	9	34	14
Median	7	32	12
Maximum	24	49	29
Minimum	2	27	7
SE	1.3	-	-
N	22	-	-

The maximum predicted project-related increase in TSS within Wuskwatim Lake main (i.e., at the outlet of the lake) is 2.6 mg/L, under 5th Percentile flows with 75% settling for the first five years of operation; under median flows the predicted increase is 1.1 mg/L (Table 5-20). These levels of increase are well within the chronic MWQSOG for TSS (i.e., the 30-day averaging objective), which indicates an allowable increase of 5 mg/L above background and the acute one day MWQSOG, which allows for an increase of 25 mg/L above background. All other predicted project-related increases are equal to or less than 1 mg/L. It is likely that the incremental increases in TSS associated with the project would be too low to be detected and fall well within the range of natural variation (Table 5-19).

Effects of erosion on maximum TSS concentrations in Wuskwatim Lake main would be greater during storm events. Therefore, it is expected that there will be sporadic and infrequent occurrences when TSS would be greater than the predicted increases for the average open-water season. However, because predicted increases in TSS are low (less than or equal to 2.6 mg/L) under ‘average’ conditions, it is unlikely that the 1-day MWQSOG (an allowable increase of 25 mg/L above background) would be exceeded. Furthermore, high wind and wave energy events typically cause shoreline **slumping**, where most of the erodible materials are deposited in the immediate nearshore environment, proceeded by slow input into surface waters as a result of wave action, surface runoff, etc.

Table 5-20. Predicted increases in the concentrations of TSS at the outlet of Wuskwatim Lake, assuming 25% of the daily load of erodible materials is discharged downstream, under three post-project flow regimes, with the project, without the project, and the project-related increases in TSS. Calculations are based on the assumption that uniform loads of erodible materials are discharged over the open-water period (184 days). Mass of eroded materials derived from erosion analysis (Volume 4).

	Eroded Materials Produced			Discharge Burntwood River	Predicted Increase in TSS Downstream
	Volume (m^3)	Annual average (kg/yr)	Open-water (184 days) (kg/day)	(m^3/s)	(mg/L)
5th Percentile Flows					
Without Project					
0-5 year	260,000	62,400,000	339,130	588.4	1.7
6-25 year	1,030,000	61,800,000	335,870	588.4	1.7
26-100 year	3,830,000	61,280,000	333,043	588.4	1.6
With Project					
0-5 year	660,000	158,400,000	860,870	588.4	4.2
6-25 year	1,360,000	81,600,000	443,478	588.4	2.2
26-100 year	3,990,000	63,840,000	346,957	588.4	1.7
Project-related increase					
0-5 year	400,000	96,000,000	521,739	588.4	2.6
6-25 year	330,000	19,800,000	107,609	588.4	0.5
26-100 year	160,000	2,560,000	13,913	588.4	0.1
50th Percentile Flows					
Without Project					
0-5 year	250,000	60,000,000	326,087	980	0.8
6-25 year	1,010,000	60,600,000	329,348	980	0.8
26-100 year	3,800,000	60,800,000	330,435	980	0.8
With Project					
0-5 year	620,000	148,800,000	808,696	980	1.9
6-25 year	1,330,000	79,800,000	433,696	980	1.0
26-100 year	3,800,000	60,800,000	330,435	980	0.8
Project-related increase					
0-5 year	370,000	88,800,000	482,609	980	1.1
6-25 year	320,000	19,200,000	104,348	980	0.2
26-100 year	0	0	0	980	0.0

	Eroded Materials Produced			Discharge Burntwood River	Predicted Increase in TSS Downstream
	Volume (m^3)	Annual average (kg/yr)	Open-water (184 days) (kg/day)	(m^3/s)	(mg/L)
95th Percentile Flows					
Without Project					
0-5 year	250,000	60,000,000	326,087	1,115.4	0.7
6-25 year	1,010,000	60,600,000	329,348	1,115.4	0.7
26-100 year	3,800,000	60,800,000	330,435	1,115.4	0.7
With Project					
0-5 year	620,000	148,800,000	808,696	1,115.4	1.7
6-25 year	1,330,000	79,800,000	433,696	1,115.4	0.9
26-100 year	3,800,000	60,800,000	330,435	1,115.4	0.7
Project-related increase					
0-5 year	370,000	88,800,000	482,609	1,115.4	1.0
6-25 year	320,000	19,200,000	104,348	1,115.4	0.2
26-100 year	0	0	0	1,115.4	0.0

The predicted project-related increase in TSS in the nearshore zone, assuming full mixing in this zone, is 23 mg/L for the first five years of operation (Table 5-21). This increase exceeds the chronic water quality objective for TSS in which it is specified that an increase of 5 mg/L (and higher) above background is unacceptable, for a 30-day averaging period. Predicted effects are small for the 6 to 25 year period, decreasing to 5 mg/L above background; this level of increase is on the borderline for the chronic water quality objective.

Effects of erosion on TSS concentrations in the nearshore zone would be greater during storm events. Therefore, it is expected that there will be sporadic and infrequent occurrences where TSS would be greater than the predicted average increases for the open-water season. In terms of exceeding water quality objectives (an allowable increase of 25 mg/L above background for a 24-hour period), it is unlikely that these storm events would result in non-compliance after the first 5 years of operation, based on anticipated increases during 'average' conditions.

Table 5-21. Predicted increases in TSS for the short (5 year), moderate (25-year), and long-term (100-year) time frames in the nearshore zone of Wuskwatim Lake main without the project, with the project, and the project-related increases, where erosion occurs uniformly over the entire open-water period (184 days). Mass of eroded materials derived from erosion study (Volume 4).

Period	Eroded Materials Produced			Predicted Nearshore TSS: Open-water Season
	Total Volume (m^3)	Annual Average (kg/yr)	Open-water (184 days) (kg/day)	mg/L
Without the Project				
0-5 year	190,000	45,600,000	247,826	14
6-25 year	770,000	46,200,000	251,087	15
26-100 year	2,900,000	46,400,000	252,174	15
With Project				
0-5 year	490,000	117,600,000	639,130	37
6-25 year	1,040,000	62,400,000	339,130	20
26-100 year	2,900,000	46,400,000	252,174	15
Project-Related Increase				
0-5 year	300,000	72,000,000	391,304	23
6-25 year	270,000	16,200,000	88,043	5
26-100 year	0	0	0	0

Overall, effects to the nearshore zone of Wuskwatim Lake main during the open-water season would on average exceed MWQSOGs for TSS for the protection of aquatic life in the first five years, with smaller effects thereafter. This project-related increase in TSS will affect all water usages, but is short-term. A larger effect to TSS is expected during storm events; however, the frequency of these events is low.

Dissolved Oxygen

Hydraulics, Flow, and Thermal Regime

DO in Wuskwatim Lake main and other main stem sites (e.g., Cranberry Lakes) will not be measurably affected by operation of the Wuskwatim GS. The area is currently highly oxygenated under both open-water and ice-cover conditions and does not experience stratification or significant DO depletion at depth. It is expected that the present highly oxygenated conditions will be maintained due to the minimal change to hydrology, water residence times and water depths along the main stem caused by operation of the project and due to high dilution.

Erosion

Operation of the project will introduce more organic matter to Reach 1 due to an increase in erosion rates, which can lead to dissolved oxygen depletion through decay processes. Project-related increases in the loads of organic materials resulting from increased erosion will be undetectable in Wuskwatim Lake main due to high dilution of eroded materials and settling in the nearshore zone (as reported in Volume 4, approximately 50% of material will settle in the nearshore zone). There may be small effects to DO in the nearshore areas where eroded materials settle and subsequently decay. Measurable effects to DO are not expected in the open-water season due to dilution of organic matter by lake water and the mitigating effects of re-aeration processes. However, some effect to DO may occur under ice cover in the nearshore environment due to decay of organic materials that have settled onto the lake bottom and the concomitant absence of re-aeration. It is further predicted that these effects would likely be negligible to small because decomposition proceeds at a slower rate at low temperatures.

Conversion of Intermittently to Permanently Wetted Habitats

Although there will be no new flooding in Reach 1 due to the project, approximately 1600 ha of habitat comprising 18% of the total area of Reach 1 will be converted from intermittently exposed to permanently wetted habitat. The relative effect varies among waterbodies and is less in Wuskwatim Lake main (9% of total) and greater in the tributary waters (Wuskwatim Brook 36%, Sesep Lake 77%). It is expected that the permanent wetting of these areas will result in the increased decomposition of some organic matter in the aquatic environment (e.g., soil organic carbon). Approximately 19% of the area of the existing intermittently exposed zone is peat islands, so peatlands at some locations will also be more permanently inundated. Raising the water level to 234 m ASL will not result in the destruction of these peat islands; however, some organic material is expected to be released from these islands, which would result in an increase in DO consumption.

Trophic Upsurge

Increased productivity of algal and plant communities in the permanently wetted habitats could potentially exacerbate overnight declines in dissolved oxygen brought about by respiration processes. Effects of conversion to permanently wetted habitat are not expected to cause a measurable increase in phytoplankton concentrations and potentially a small increase in plant growth (i.e., in Sesep Lake and Wuskwatim Brook) (Section 7.0). Therefore, effects on diel swings in DO are not expected to be significant. DO may also be indirectly affected by trophic upsurge because the increase in aquatic plants and algae will result in a greater oxygen demand in winter, when they decay.

Overall, effects of operation are expected to result in more prolonged periods of dissolved oxygen depletion under ice cover and/or exacerbation of dissolved oxygen depletion in areas that currently experience critically low DO concentrations (i.e., below water quality objectives for the protection of aquatic life) in winter (i.e., Wuskwatim Brook, Sesep Lake, and some areas of Wuskwatim Lake south). These decreases may affect aquatic life in localized areas where DO concentrations are already near or below MWQSOGs.

Nutrients

Concentrations of nutrients are not expected to be affected in Wuskwatim Lake main (i.e., in the main basin), but may be affected in off-current areas, in nearshore areas that are affected by increased water levels (i.e., creation of permanently wetted habitat), and in water bodies adjacent to Wuskwatim Lake (i.e., Sesep Lake and Wuskwatim Brook) due to introduction of organic matter and subsequent decomposition by aerobic processes.

Wuskwatim Lake is classified as meso-eutrophic to eutrophic, and phosphorus levels in the lake (as well as elsewhere in the study area) are typically above the MWQSOG for lakes and reservoirs. Although there are no water quality criteria for nitrogen, levels are moderately high in Wuskwatim Lake but may be low enough to create nitrogen-limiting conditions. However, the relatively turbid environment of Wuskwatim Lake and to a lesser extent, adjacent waterbodies and Wuskwatim Lake south, also limits primary production. Therefore, incremental increases in nutrients are not expected to stimulate large increases in growth of phytoplankton and aquatic plants.

Conversion of Intermittently Wetted to Permanently Wetted Habitat

As discussed with respect to oxygen, the conversion of periodically wetted to permanently wetted habitat will introduce organic matter to the nearshore zone of the lake and surrounding water bodies. This will cause an increase in nutrient concentrations; however, this will not measurably affect nutrient concentrations in Wuskwatim Lake main due to high dilution along the main stem.

Effects may be more pronounced in adjacent water bodies (e.g., Sesep Lake and Wuskwatim Brook) and Wuskwatim Lake south; however, as these areas are currently relatively nutrient-rich, the effect is not anticipated to cause a change to aquatic biota.

Erosion

An increase in erosion in the Wuskwatim Lake area will result in increased loading of soils to surface waters, as described for TSS. Erosion of shorelines has been linked to increased total phosphorus levels in the Burntwood River at Thompson (Playle and Williamson 1986) and Footprint Lake, near Nelson House (Williamson and Ralley 1993), following CRD. These changes are typical following reservoir creation and are temporary (Hayeur 2001). However, the net effects of this increase in phosphorus on the growth of aquatic plants and algae will be counteracted to some extent by the reduced water transparency in the nearshore zone due to increases in TSS and turbidity related to erosion.

pH and Alkalinity

There would be no measurable effect of operation on pH and alkalinity to Wuskwatim Lake main or the lower Burntwood River upstream of Wuskwatim Lake due to high dilution and flushing rates, because these areas exhibit a moderate buffering capacity; and are characterized as systems with a low to very low sensitivity to acidification. Therefore, it is not expected that introduction of acidic materials to the nearshore zone adjacent to eroding shorelines would have a measurable effect. Furthermore, as there is no expected increase in primary production in the main stem of Reach 1, alterations to pH related to photosynthesis and respiration would not be expected.

The operation of the project may have short-term effects on pH in localized areas due to conversion of intermittently wetted to permanently wetted habitat, which may cause a small amount of acidification in these localized areas due to wetting of acidic soils (soils are typically acidic in the region, MB Conservation 1997) and decomposition of organic matter. The effects would be small and limited to surface water near the sediment-water interface.

Although characterized by a lower pH and buffering capacity, as well as lower flushing rates and dilution than Wuskwatim Lake main, effects in localized off-current areas in Wuskwatim Lake, Sesep Lake, and Wuskwatim Brook (i.e., in permanently wetted nearshore areas) are not expected to be measurable. These areas are not considered sensitive to acidification, based on pH and alkalinity. Therefore any changes to pH that would occur as a result of the permanent wetting of habitat, and due to an increase in photosynthesis, would be small and undetectable relative to natural variation, and would remain within water quality objectives for the protection of aquatic life and for drinking water quality. Overall, effects in areas not along the main stem in Reach 1 are expected to be negligible and short-term.

Bacteria and Parasites

There is no direct linkage related to operation of the project on bacteria and parasites in the aquatic environment in Reach 1.

Trace elements

Erosion

An increase in erosion in the Wuskwatim Lake area will result in increased loading of soils to surface waters, as described in detail for TSS. A portion of these loads of mineral and organic soils will be comprised of metals and metalloids that are pertinent to water quality with respect to protection of aquatic life and the quality of drinking water. Shoreline erosion along the Burntwood River at Thompson has been reported to be a source of iron, manganese, and zinc (Ramsey 1991).

Because aluminum and iron are currently found at concentrations well above water quality objectives for protection of aquatic life and drinking water, the predicted increases due to the project will not result in a change to the usages of water in the nearshore zone of Wuskwatim Lake. However, aluminum and iron are major components of the soils along the eroding shoreline, and increased erosion related to operation of the project (years 0-5 post-project) could cause a significant increase in nearshore concentrations.

Most metals and metalloids are not predicted to be increased to magnitudes that would cause exceedences of water quality criteria, when increases are considered in conjunction with existing levels in Wuskwatim Lake; these substances include arsenic, cadmium, copper, lead, molybdenum, nickel, mercury, selenium, and zinc. However, predicted increases in several substances, notably chromium, manganese, and silver, may cause or contribute to exceedences of water quality objectives for the protection of aquatic life. The effects of these predicted increases in chromium, manganese, and silver in terms of risks to aquatic biota is believed to be negligible to low because the anticipated increases are relatively small.

Sediments

Sediment quality will be affected in Reach 1 by creation of 'new' sediments from conversion of intermittently wetted habitat to permanently wetted habitat in localized areas and by settling of eroded materials in Wuskwatim Lake. It is expected that there will be short-term increases in the nutrient concentrations in sediments where permanently wetted habitat is created and possibly reduced pH due to the general acidity of boreal soils in the region (MB Environment 1997).

Assuming 50% of eroded materials settle in the nearshore zone (up to 300 m offshore) in Wuskwatim Lake, as indicated in Volume 4 (Section 8), sediment quality may be affected by increased erosion in nearshore depositional areas. However, because this area currently experiences erosion of shorelines, and subsequent deposition of erodible materials, no significant change in sediment chemistry would be expected (i.e., greater loads of eroding materials will settle in the nearshore zone during operation, relative to existing rates of erosion, but the chemical composition of the settling materials will not differ). Furthermore, the lake, particularly the nearshore zone, experiences considerable amounts of sediment resuspension and scouring which continuously influence sediment chemistry.

Overall, increases in TSS and related parameters are expected to have a negative and not significant (short-term, moderate, site-specific to local) effect on the use of water for drinking[3], suitability for aquatic life, navigation and aesthetics. Increases in nutrients and decreases in oxygen are expected to have a negative and not significant (short-term, moderate, site-specific to local) effect on use of water for drinking[2], suitability for aquatic life, and aesthetics.

5.4.2.3 Reach 2: Falls

Total Suspended Solids, Turbidity, and Colour

The incremental increase in TSS from Wuskwatim Lake is expected to be too low to be detected and fall well within the range of natural variation.

Erosion

[3] Drinking water use refers to use of surface waters by resource users. Note that all surface water should be sterilized prior to human consumption.

The increase in water level in Reach 2 (7 m) is expected to cause only a modest increase in erosion in comparison to Wuskwatim Lake proper. The majority of the north shore will not undergo erosion because of the placement of rock materials (Volume 4).

Flooding

Flooding of terrestrial land will introduce organic matter to the local aquatic environment, which may have a short-term localized effect on water colour. However, in terms of effects of the operation of the GS on the use of the local surface waters for drinking, the effect would be small to negligible due to the small area of land flooded and in consideration of the existing conditions in Reaches 1 and 3 (colour was not measured in Reach 2), which currently frequently exceed the aesthetic drinking water quality objective for true colour (see Section 5.3.4.3).

Dissolved Oxygen

Because no measurable change to dissolved oxygen concentrations in Wuskwatim Lake main are anticipated, no effect on DO in Reach 2 is expected due to changes upstream.

Hydraulics, Flow, and Thermal Regime

Operation of the Wuskwatim GS will result in formation of ice cover in Reach 2, where it currently remains open year-round (Volume 4). This effect is not expected to cause a significant decrease in DO in Reach 2 because incoming water from Wuskwatim Lake main is highly oxygenated in winter, the flow and volume of water are high, and the increase in ice cover is a relatively small change from existing conditions.

No change in the thermal regime is anticipated (Volume 4).

Erosion

As discussed for TSS, erosion within Reach 2 as a result of water level changes is not expected to result in the input of large amounts of soil with associated organic material; therefore no effect to oxygen levels as a result of this linkage is anticipated.

Flooding

Flooding of approximately 25 ha of natural terrestrial habitat (areas that are not excavated, stripped, or incorporated in GS structures) due to creation of the immediate forebay will cause moderate, short- to long-term reductions in dissolved oxygen in the near-shore flooded habitats due to decomposition of organic matter. The largest effects (i.e., moderate effects) will occur in flooded peat (approximately 4.4 hectares) and peatland habitats where there are large organic carbon stores (peat has been estimated to contain approximately 88,550 g C/m^2, see Section 2, Volume 4). DO depletion in these areas is expected to be moderate and long-term (carbon stores are large enough to supply decomposition processes for many years). However, relative to Wuskwatim Lake main, and the area of Reach 2, these localized effects are small.

Flooding of productive forest soils with high organic matter contents will also result in moderate reductions in dissolved oxygen in those habitats although the effect would be short-term in nature. Approximately 20.41 ha (or 82%) of the terrestrial environment that would be flooded by the project is hardwood and softwood habitat. In these flooded habitats, it is expected that DO depletion will be highest for the first several years post-impoundment and will decline thereafter. Typically, decomposition of labile carbon sources (e.g., leaves) occurs in several years following flooding (e.g., Gagnon and Varfalvy 2000, St. Louis et al. 2000). Emissions of greenhouse gases from newly formed reservoirs are typically highest in the first several years post-flood and reach a plateau after about a decade (Gagnon and Varfalvy 2000). Based on these observations, it can be speculated that a similar time course for dissolved oxygen depletion may be observed in flooded habitats.

Decomposition of organic matter in flooded peatlands and forests habitats may result in critical localized declines in DO in winter due to the combined effect of increased decomposition and the presence of ice-cover which prevents atmospheric aeration of surface waters. However, concomitant low water temperatures in winter will limit the rate of decomposition processes, thus reducing DO depletion. As upstream (i.e., Wuskwatim Lake main) DO concentrations have been measured at near saturation in winter (greater than 13 mg/L), the magnitude of the decomposition processes in these habitats would have to be substantively large to cause a decline in DO that would cause an ‘exceedence’ of a water quality objective for the protection of aquatic life (objectives range from 3 mg/L to 9.5 mg/L, depending on the presence of early life stages of aquatic biota).

Effects of flooding on DO are not expected to extend to the main portion of the forebay due to the large volume of water and the rapid flushing rates in this habitat.

Nutrients

As discussed for TSS, the incremental increase in suspended material, with associated nutrients, from Wuskwatim Lake is expected to be too low to be detected and fall well within the range of natural variation.

Erosion

As discussed for TSS, erosion within Reach 2 as a result of water level changes is not expected to result in the input of large amounts of soil; therefore no effect to nutrient levels as a result of this linkage is anticipated.

Flooding

Flooding of terrestrial habitat will cause a moderate, short-term increase in nutrient concentrations in the nearshore environment due to flooding of soils and decomposition of inundated organic matter. Phosphorus will be released from flooded soils and vegetation (Hayeur 2001) due to chemical processes and will be liberated from decomposition of organic matter. Following conversion of the river environment in Reach 2 to a forebay, current levels of phosphorus will exceed the criteria for reservoir environments, even without project-related increases in nutrients (i.e., current levels in the river are above the MWQSOG for reservoirs). Most measurements of total phosphorus collected upstream in Wuskwatim Lake have exceeded the MWQSOG for lakes in the baseline studies conducted over 1999 – 2002. Therefore, it is expected that the net effect of flooding in Reach 2 on phosphorus concentrations will not be significant in terms of compliance with water quality objectives, as conditions currently exceed the criterion and the incremental increase would be small.

Nitrogen concentrations in Reach 2 and upstream in Reach 1 are relatively high for an environment that receives little anthropogenic point and non-point sources of nitrogen. However, nutrient ratios indicate that nitrogen is the more limiting nutrient in this environment. Flooding of soils and the release of nitrogen from decomposing organic matter will cause a localized, moderate, and short-term increase in the flooded terrestrial habitat.

Carbon will also be released due to flooding in the localized flooded nearshore zone, causing a short-term increase in **detritus** in these areas.

Overall, the effects of flooding on increased levels of nutrients in the forebay of Reach 2 are expected to be localized (to nearshore flooded habitats), moderate, and short-term. There may be an initial (first several years post-flood) trophic upsurge in the nearshore zone due to the temporarily elevated concentrations of nutrients; however, because of high flows through this reach, the effect is not expected to be of large magnitude.

pH and Alkalinity

Acid Leachate

As discussed for construction, the potential for acid leachate generation from excavated rock materials used in structures that remain exposed to air was assessed and no effects were identified that could not be addressed through mitigation (Volume 4). Therefore, this linkage was not considered further for either effects to pH or metals.

Flooding

Flooding of terrestrial soils, organic matter, and peat may alter the pH and/or alkalinity of nearshore flooded terrestrial habitat zones. Soils in the boreal shield ecozone, which includes the Wuskwatim study area, are acidic (MB Environment 1997) and flooding may cause acidification of surface waters in the immediate flooded habitat, particularly near the sediment-water interface. Additionally, decomposition processes may lower pH in aquatic environments, as is observed in Quebec reservoirs (Hayeur 2001). However, pH of the lower Burntwood River, as well as Wuskwatim Lake upstream of Reach 2, is near neutral to slightly alkaline, has a moderate buffering capacity and is characterized by a very low sensitivity to acidification, indicating the environment is not vulnerable to effects of acidification. In consideration of the existing conditions in Reach 2 with respect to acid neutralizing capacity and the relatively low water residence times, effects to pH are expected to be small or negligible and highly localized to the nearshore flooded environment (i.e., off-current areas).

Bacteria and Parasites

Depending on the configuration of the station, treated sewage effluent may be either discharged into either Reach 2 or 3 with the potential to introduce bacteria and parasites. These effects will be mitigated to acceptable levels through the use of treatment to reach standards set out in the MWQSOGs.

Trace Elements

As discussed for TSS, the incremental increase in suspended material and associated metals from Wuskwatim Lake is expected to be too low to be detected and fall well within the range of natural variation.

Erosion

The increase in water level in Reach 2 (7 m) is expected to cause only a modest increase in erosion in comparison to Wuskwatim Lake main, which will result in the inputs of some sediments with associated metals. The majority of the north shore will not undergo erosion because of the placement of rock materials (Volume 4).

Flooding

There will be some initial release of trace elements from flooded peat and soils to the overlying surface water, causing a small increase in the concentrations of some metals and metalloids. The effect would be small, short-term, and localized to the flooded areas and would not extend to the main stem of Reach 2 due to the high volume and velocities along the main current.

Some elements have been measured at concentrations in exceedence of, or near, water quality criteria for the protection of aquatic life and for drinking water upstream in Reach 1 and downstream in Reach 3 (no measurements were collected in Reach 2 due to accessibility issues). Most notable are aluminum and iron, which are consistently above water quality criteria. Therefore, for these substances, effects of flooding and/or erosion on water quality are negligible because current conditions are already well above guidelines. For other substances, such as copper, nickel, lead, selenium, silver, and possibly mercury, some exceedences of water quality criteria for the protection of aquatic life may occur and/or exceedences may become more frequent due to operation of the project in Reach 2. There are no anticipated effects to drinking water quality, because current concentrations are well below the guidelines and because effects of flooding and/or erosion on metal levels in surface water are expected to be insufficient to cause an increase of the magnitude needed to cause an exceedence of these criteria.

Sediments

Erosion

As discussed in Section 6.0, water moving from Wuskwatim Lake to the immediate forebay will move from a lower to a higher velocity environment. Therefore, significant settling of eroded sediments within the immediate forebay (i.e., Reach 2) is not anticipated.

Flooding

Flooding of terrestrial habitat will create new sediments in the forebay of the Wuskwatim Reservoir. Flooded soils will initially be more acidic than sediments, as soils in this region are acidic (Manitoba Environment 1997). The chemical constituents (i.e., profiles and concentrations) of nutrients and trace elements may differ from those currently in the sediments of Reach 2, which may affect sediment quality in the newly flooded habitat.

Overall, changes to water quality in Reach 2 are expected to have a negative, not significant (long-term, moderate, site-specific) effect to the suitability of water for aquatic life.

5.4.2.4 Reach 3 - 6: Burntwood, Opegano and Downstream

TSS and Turbidity

As discussed for reaches 1 and 2, inputs of sediments due to erosion as a result of the Project generally are not expected to have a detectable effect on water quality; therefore, no changes due to upstream inputs are anticipated in reaches 3-6. However, as discussed in Section 5.3, increases in suspended sediments are expected during the initial operation of the station.

Erosion

In general, water level changes within the day as a result of GS operation are not expected to increase river bank erosion downstream of the GS except near the discharge from the GS (Volume 4). However, there may be a localized increase in bank erosion in areas affected by direct discharge from the spillway. This may cause negligible to small increases in TSS in the Burntwood River.

Effects of operation of the project on TSS levels in Opegano Lake or downstream of Opegano Lake will be, in general, negligible to small; increases in TSS are not predicted to exceed the MWQSOGs for the protection of aquatic life.

Dissolved Oxygen

In general, dissolved oxygen concentrations are not expected to change measurably in Reach 3 due to operation of the project because there are no anticipated effects to DO upstream of Reach 3 in the main stem and because open-water will be maintained in Reach 3 in winter (i.e., no change to ice regime).

However, there may be localized reductions in DO in the backwater inlets of tributary streams where peatlands may be broken down (i.e., decomposed) as a result of the increased frequency of water level fluctuations (Volume 6, Section 5.0). This effect may be more significant in winter, when affected areas develop full ice cover.

Anticipated effects of operation of the Wuskwatim GS on water quality downstream of Reach 3 are limited to small short-term changes in nearshore areas of Opegano Lake (primarily the north shore) and the lower Burntwood River, just downstream of Opegano Lake, where daily water level fluctuations may result in die-off of peatlands with the potential for site-specific depletion of oxygen as the peat decays, in particular during winter (Volume 6, Section 5).

Nutrients

No significant effects of operation on nutrient concentrations are expected in Reach 3 due to high flows and negligible effects to nutrients upstream in Reach 2. Small quantities of nutrients may be liberated in localized areas where water level fluctuations will affect peatlands (i.e., backwater inlet areas of some tributary streams and north shore of Opegano Lake, as well as a few areas immediately downstream of Opegano Lake).

Bacteria and Parasites

See Reach 2.

Trace Elements

Erosion

Effects of increased erosion are not expected to significantly increase concentrations of metals and metalloids in Reach 3.

Sediments

As no significant settling of particulates is expected in Reach 3, and any settling that occurs further downstream would be expected to occur over a wide area (i.e., negligible inputs at any one location), significant effects to sediment chemistry are not anticipated.

Overall changes to water quality in reaches 3-6 are expected to have a negative, not significant (long-term, moderate, site-specific) effect to the suitability of water for aquatic life. In addition, there may be some negative and not significant (short-term, small to moderate, and local to regional) effects to the suitability of water for aquatic biota during the period of initial station operation.

5.4.2.5 Stream Crossings

Minor increases in TSS may occur downstream of stream crossings in the open-water season; effects are expected to be negligible due to practices to minimize erosion at stream crossings (Volumes 3). Inspections will ensure that erosion control measures are effective.

Road maintenance activities will follow standard practice for northern Manitoba.

Negative and not significant (short to long-term, negligible, site-specific) effects to the suitability of water for aquatic life.

6.0 AQUATIC HABITAT

6.1 INTRODUCTION

Aquatic habitat may be defined as the water in which fish and other aquatic organisms live. However, aquatic habitat includes not only the physical presence of the water, but also the physical, chemical, and biological constituents of that water, which interact to form a particular **environment**. Physical habitat is generally classified on the basis of water depth and **velocity**, substrate type, and the presence or absence of cover (e.g., large rooted plants [**aquatic macrophytes**], terrestrial debris [e.g., tree branches and logs, moss], and **riparian** vegetation). Chemical constituents of aquatic habitat include water and **sediment** quality. Algae, rooted plants, invertebrates (zooplankton, benthic invertebrates), and fish together form the biota of a particular aquatic environment.

An aquatic habitat may be occupied by a number of **species** that have become adapted to the particular physical, chemical, and biological characteristics of that location. Mobile organisms may utilize more than one habitat to fulfil all requirements of their life cycle. Fish habitat is defined in the *Fisheries Act* as "**Spawning** grounds and **nursery**, **rearing**, food supply and migration areas on which fish depend directly or indirectly in order to carry out their life processes".

The majority of aquatic habitat investigations were conducted in the area (Section 3.0) extending from Early Morning Rapids in the west downstream to Opegano Lake in the east (Figure 6-1). The study area was defined by the extent of noticeable water level and flow changes resulting from construction and operation of the Project. The magnitude of physical change (e.g., changes in water levels and flows) differs substantially among areas (Volume 3) and, consequently, the study area was divided into four reaches on the Burntwood River and a fifth area encompassing the streams crossed by the access road, as follows (Section 3.0):

- Reach 1: Wuskwatim;
- Reach 2: Falls;
- Reach 3: Burntwood;
- Reach 4: Opegano; and
- Stream Crossings.

Draft for Discussion Purposes Only

Source: 1:250,000 NTS base.

North/South Consultants Inc.

Figure 6-1. Aquatic habitat study area for the Generation Project EIS.

This section describes the aquatic habitat in each of four reaches of the Burntwood River and provides a quantitative classification of habitat using the following categories: water level (defined by recorded elevation); substrata type; presence/absence of rooted aquatic plants; and water velocity. Qualitative habitat characteristics of the streams crossed by the proposed access road also are described. This assessment of aquatic habitat before and after the Project, in conjunction with information on water and sediment quality (Section 5.0) and lower trophic levels (Section 7.0), forms the basis for the assessment of impacts to the fish community (Section 8.0). It should be noted that descriptions of shoreline types and **peat** islands, and consideration of groups such as **emergent** plants (e.g., *Scirpus* spp. [bulrush], *Typha* spp. [cattail]) occupying a transitional area between aquatic and terrestrial environments, are provided within the terrestrial portion of the assessment (Volume 6).

6.2 APPROACH AND METHODOLOGY

The existing environment is described using several sources of information, including Traditional Knowledge (TK), existing published information, and studies conducted specifically as part of the environmental impact assessment of the Generation Project. Each of these data sources is described below.

6.2.1 Traditional Knowledge

As described in Volume 2, **NCN** and Manitoba Hydro have emphasized the importance of integrating TK into the **EIS**. TK was obtained from numerous sources, including commercial fishers, subsistence fishers, Elders, and field assistants working the EMT (Volume 2). With respect to the impact assessment, NCN stressed the need for a 'holistic' approach that considers all parts of the environment on which fish and wildlife depend. The difficulties NCN resource harvesters have encountered in accessing the study area since CRD has subsequently limited the extent of TK available today.

6.2.2 Existing Published Information

A pre-CRD assessment of **morphometry** of the Rat-Burntwood river system (Brown 1974) and a post-CRD **bathymetric survey** of Threepoint and Wuskwatim lakes were conducted (Cherepak 1989, Nortec Surveys Inc. 1990). However, neither study included aquatic habitat information other than water depth, and, as such, are not directly comparable to the present study.

Planning for the Project included the collection of bathymetric and water velocity data between Wuskwatim Falls and Opegano Lake by Manitoba Hydro (Volume 4). This information is incorporated in the current assessment of aquatic habitat for the study area. Historic and predicted post-Project water elevation data were also provided by Manitoba Hydro (Volume 4).

6.2.3 Environmental Assessment Studies

Bathymetric and aquatic habitat surveys of Wuskwatim Lake main were initiated in 1998 and continued in 1999 as part of the pre-EIS environmental **monitoring** studies in the Rat/Burntwood river system. Surveys continued in 2000 and 2001 under the **J**oint Study Program, with information collected from other waterbodies within Reach 1 (Cranberry Lakes, Wuskwatim Lake south, Wuskwatim Brook), the Burntwood River between Wuskwatim Falls and Opegano Lake (reaches 2 and 3), Opegano Lake (Reach 4), and the streams crossed by the access road.

Aquatic habitat in reaches 1 through 4 was surveyed during field studies and mapped with **Geographic Information System (GIS)**-based techniques, using the programs Microsurvey CAD (version 2001) and ESRIs ArcView (version 8.2). Key characteristics included: water level and level fluctuations (as defined by recorded elevations); substrata type (e.g., hard or soft **silt**/**clay**, **boulder**/**cobble**, flooded terrestrial); presence/absence of rooted **submergent** aquatic plants; and water velocity. The classification system for Wuskwatim (Reach 1) and Opegano lakes (Reach 4) differed somewhat from that for the Burntwood River (reaches 2 and 3) in terms of water elevation and velocity characteristics. The aquatic habitat of streams crossed by the access road also was surveyed and qualitatively assessed during field studies.

6.2.3.1 Reaches on the Burntwood River (1- 4)

Water Level

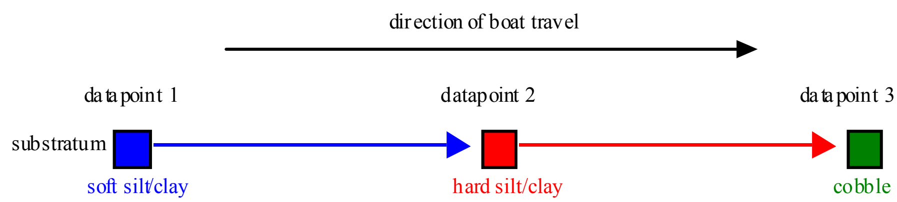
Bathymetric surveys of **lacustrine** (i.e., lakes) habitats were performed using differential global positioning system (DGPS) technology. This involves the collection of positional data along with continuously recorded water depth data.

The majority of the bathymetric survey of Wuskwatim Lake main was completed in August 1998, with supplemental data collected during August, 2000 (North/South Consultants Inc. unpublished data). Cranberry Lakes, Wuskwatim Lake south, Wuskwatim Brook, and Opegano Lake were also surveyed in August, 2000. Surveying effort was adaptive in that data collection was stratified with emphasis on nearshore areas, and areas where bottom complexity was highest. The bathymetric survey data was interpolated in Microsurvey CAD to create a three-dimensional lakebed surface, from which contour lines could be derived and water volume information calculated. Efforts were also made to locate and delineate **shoal**s. These data are sufficient to describe the general character of the lake and **riverbed**s. The bathymetric maps, however, cannot be considered as an aid for navigation. Wuskwatim Lake main water depth data were supplemented with existing data from systematic surveys bisecting the main basin of the lake (Nortec Surveys Inc. 1990). Water depth was standardized to lakebed elevation in meters above sea level (m ASL) using the daily water level record at Wuskwatim Lake. Water depth information was not collected from Sesep Lake or in the portion of the Burntwood River between Early Morning Rapids and approximately 1 **km** upstream of Cranberry Lakes.

Manitoba Hydro collected water surface elevation information on the Burntwood River between Wuskwatim Falls and Opegano Lake during September, 2001, using a real-time kinematic Global Positioning System (GPS) linked to an echosounder (Volume 4). The elevation of the backwater inlets was mapped using differential and kinematic grade positioning. Additional data was acquired by traversing the shoreline with DGPS, which was referenced to vertical controls determined by the kinematic GPS surveys (North/South Consultants Inc. unpublished data). Differential and kinematic grade positioning information had a horizontal precision of less than 1 m and 0.1 m, respectively. Water depth measurements had ± 0.1 m vertical accuracy.

Substrata Type

Substrata information downstream of Reach 1 was interpreted from sonar displays of a Meridata 100 echo-sounder and was stored in a Trimble TDC1 GPS datalogger. Changes in the echo-sounder display corresponded to changes in substrata type. These changes were verified with either an **Ekman** or a **Ponar dredge** (i.e., a device used to grab a sample of the bottom), or with a 20 lb. anchor (i.e., a device used to sense the substrata type and level of compaction). Information collected included the location of substrata changes, substrata classification, and the associated boat route (North/South Consultants Inc. unpublished data). When the information (points with corresponding substrata type) was plotted on a map, the area between two consecutively logged substrata types was classified the same as the first datapoint. In the GIS, polygons were plotted by connecting same-value substratum points, thereby allowing for perimeter and area calculations.



Reach 1 (Wuskwatim) and Reach 4 (Opegano) survey **transect**s were limited in number given the relatively large sizes of the areas. However, this information was supplemented with substrata information collected during lower trophic levels (Section 7.0) and fish community (Section 8.0) studies.

Substrata information for reaches 2 and 3 was collected along transects at cross-sections approximately 500 m apart, on average. Transect **density** increased where bottom complexity was higher. Areas adjacent to falls and/or with very high water velocities were excluded for safety reasons.

Substrata was visually graded by **particle size** using the following as a guide:

- Boulder: > 256 mm in diameter;
- Cobble: < 256 mm and > 64 mm in diameter;
- **Gravel**: < 64 mm and > 2 mm in diameter;
- **Sand**: < 2 mm and > 0.0625 mm in diameter; and
- Silt/Clay: < 0.0625 mm in diameter.

This classification was based on a system described in Gordon et al. (1992) that was adapted from Brakensiak et al. (1979). Substrata compaction was characterized as either hard or soft. Substrata information was then combined into five classifications:

- **Bedrock**;
- Boulder/cobble;
- Hard silt/clay-based;
- Soft silt/clay-based; and
- Flooded terrestrial.

The last category was established as many of the areas that had been flooded by CRD had **heterogeneous** substrata, consisting of organic material (e.g., flooded peat, fallen trees, branches) interspersed with silt/clay or rock.

Rooted Aquatic Plants

Information on rooted submergent aquatic plant abundance, **species composition**, and distribution (i.e., location of areas supporting rooted plants visible from the surface) was recorded during the boat-based aquatic habitat surveys. This information was supplemented with observations during aerial surveys. Distribution information was digitized into the GIS as polygons based on these observations. Detailed methodology for rooted aquatic plants is provided within the lower trophic levels, Section 7.2.3.2.

Rooted submergent aquatic plant presence/absence data are described with respect to the physical conditions that describe their distribution, including: wave (**hydraulic**) energy using fetch distance [exposure (m)] in lake environments; elevation (m); substratum slope (%); distance from shore (m); modelled water velocity (**m/s**) in flowing water areas; and water depth (m) (Section 7.0). Data **percentile**s were determined from the frequency distribution of values where rooted aquatic plants were observed.

Wave energy is an important variable influencing relatively shallow aquatic habitats. Fetch distance was used as a surrogate for wave energy to estimate the exposure (i.e., a measure of site openness) for Wuskwatim and Opegano lakes (North/South Consultants Inc. unpublished data). Exposure was estimated to gain an appreciation of the role wave energy has in influencing the distribution of rooted aquatic plants (Section 7.0).

For each lake location exposure was estimated as:

$$\text{Exposure}_{ij} = (\Sigma_{a=1\text{-}360} V_{ija})/360.$$

Where, V_{ija} is the fetch distance from the point i, j, to the shore at a specific angle, a, which can range from 0 to 360º. The interval of fetch measurement was 5 m for Wuskwatim Lake and 1 m for Opegano Lake.

Water Velocity

For reaches 2 and 3, the magnitude and distribution of water velocity were assessed by Manitoba Hydro (Volume 4). Manitoba Hydro selected two hydraulic **model**s to estimate water velocity distributions in the Burntwood River downstream of Wuskwatim Lake; the Flow-3D model was used for Reach 2 and the River2D model was used for Reach 3 (Volume 4). Velocity distributions were classified into categories in the GIS for area calculations and for use as a component of the aquatic habitat classifications.

Aquatic Habitat Classification

The study area encompasses a diverse range of aquatic habitats, from relatively large rivers to streams, a variety of sizes of lakes, and flooded terrestrial areas. To provide a framework for assessing and describing the represented habitat types, a comprehensive hierarchical classification system was devised. The classification system devised was based on one developed by the USGS (1998), which was modified to reflect the conditions in the study area. The classification system was divided for lacustrine (reaches 1 and 4) and riverine (reaches 2 and 3) aquatic habitats. It should be noted that estimates of the **spatial** extent of aquatic habitat types provided for the existing and post-Project environments are based on extrapolations from **topographic** and bathymetric maps. The accuracy of the estimates is reduced for those areas with shorelines characterized as having relatively low slope. All water elevation and flow data were derived from information presented in Volume 4.

Lacustrine Habitats

A classification system was developed for lacustrine habitats within the study area using the following categories: water level (defined by recorded elevation); substrata type; and presence/absence of rooted aquatic plants (Table 6-1).

Water levels in the study area are influenced by the flow regime of the Burntwood River, which has an irregular pattern (Volume 4). To describe the aquatic habitat that occupies a range of water level variations, criteria were identified to describe the habitat in specific water level zones. These zones were based on percentiles (ranges) of water levels from the post-CRD daily records (December 3, 1977 to June 30, 2001). Water levels at or near the extremes of the range in lakes and reservoirs occur infrequently. To simplify the description of water level variation and to exclude extremely infrequent events, ninety percent of the range in variation (1977-2001) is described; the 5th and 95th water level percentiles bind this range (Figure 6-2). A percentile is a number on a scale of one to 100 that indicates the percent of a distribution. For example, a water level at the 95th percentile is equal to, or greater than, 95 % of the water levels recorded during all years that measurements have been made.

Lacustrine habitats were classified into three zones with respect to water level (Figure 6-2):

- Intermittently Exposed Zone – the shore zone bounded by the 5th and 95th water level percentiles. This area represents a band along the edge of a lake that has experienced exposure, i.e., **dewatering**, 5 to 95 % of the time since 1977;
- Nearshore Zone – the shore zone that is effectively wetted all the time. The upper border of the zone corresponds to the 5th percentile water elevation and the lower border elevation of the nearshore zone was identified visually and defined using bathymetric data. The selected contour (229 m ASL for Wuskwatim Lake and 203 m ASL for Opegano Lake) separated most shallow water areas and bays from the main basin of the lake; and
- Offshore Zone – all areas of a lake between the nearshore zone and the deepest area of the lake (minimum lakebed elevation).

Table 6-1. The classification system developed for lacustrine habitats within the study area.

Classification of Lacustrine Habitats		
Zone	**Substratum/Vegetation**	
Intermittently Exposed **(E)**	Bedrock **(Br)**	
	Boulder/cobble **(Bc)**	
	Hard silt/clay-based **(Hc)**	
	Soft silt/clay-based **(Sc)**	No plants **(Sc)**
		Rooted vascular plants **(Rv)**
		Non-vascular plants **(Nv)**
	Flooded terrestrial **(Ft)**	No plants **(Sc)**
		Rooted vascular plants **(Rv)**
Nearshore **(NS)**	Bedrock **(Br)**	
	Boulder/cobble **(Bc)**	
	Hard silt/clay-based **(Hc)**	
	Soft silt/clay-based **(Sc)**	No plants **(Sc)**
		Rooted vascular plants **(Rv)**
		Non-vascular plants **(Nv)**
	Flooded terrestrial **(Ft)**	No plants **(Sc)**
		Rooted vascular plants **(Rv)**
Offshore **(OS)**	Bedrock **(Br)**	
	Boulder/cobble **(Bc)**	
	Hard silt/clay-based **(Hc)**	
	Soft silt/clay-based **(Sc)**	No plants **(Sc)**

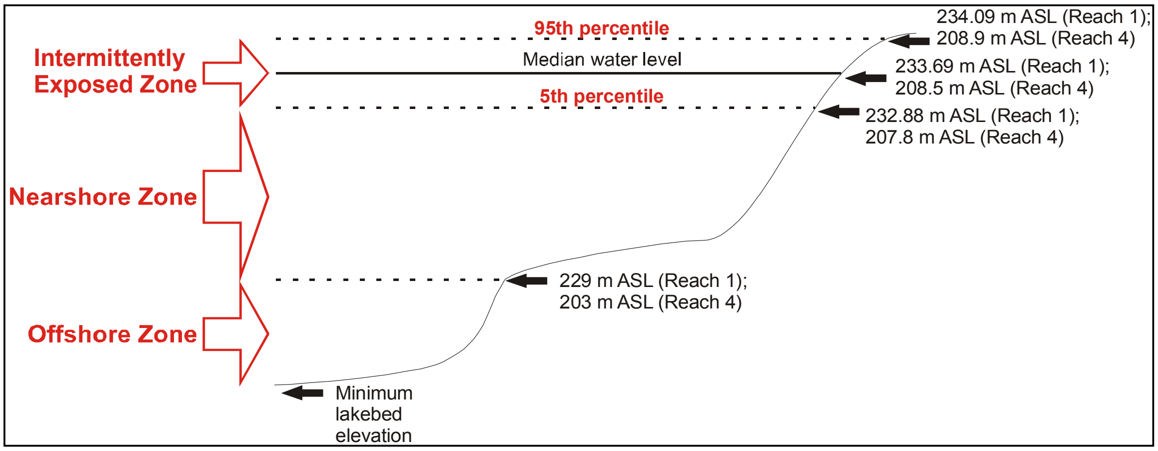


Figure 6-2. Classification of aquatic habitat into zones with respect to water level in reaches 1 and 4, pre-Project.

Each of these zones was divided into categories of substrata type present. Substrata information was combined into five classifications:

- Bedrock;
- Boulder/cobble;
- Hard silt/clay-based;
- Soft silt/clay-based; and
- Flooded terrestrial.

Flooded terrestrial substrata occur in areas flooded by CRD. Substrata within flooded terrestrial areas are generally high in organic material of **boreal forest** and **bog** origin.

Flooded terrestrial and soft silt/clay-based substrata were further divided into discrete areas of no aquatic plants (no plants) and areas with rooted submergent aquatic plants (rooted vascular plants); soft silt/clay-based substrata were further divided into areas with non-vascular plants (e.g., aquatic moss). Areas were calculated in the GIS by overlaying (i.e., combining) the three relevant mapping layers: habitat zones (defined by water level); substrata type present; and presence/absence of aquatic plants. Lacustrine habitats were classified based on the overlap of the components of the three layers.

It should be noted that this classification system was applied to most elements of the study area, but it did not preclude the use of other methods that were needed for specific purposes, such as estimating wave energy to better understand rooted aquatic plant distribution. In some instances, field observations that were uncommon in the study area did not merit adding additional classes to the hierarchy and, as such, these data were grouped with the most similar class in the hierarchy. A case in point is the single area of **filamentous** green algae observed in Wuskwatim Lake south. As it was not observed anywhere else in the study area, it is discussed in conjunction with rooted aquatic plants in Section 7.3.3.2. Similarly, substrata along the shoreline of Wuskwatim Lake main consisted primarily of fine sediments (i.e., soft silt/clay-based substrata); however, a narrow band of coarser materials (i.e., bedrock, boulder/cobble substrata) occurred along some shorelines and were also present as some offshore shoals. These habitats were mapped as features and were not included in the mapping of habitat zones or the quantification of habitat areas.

Riverine Habitats

A classification system was developed for riverine habitats within the study area using the following categories: water level (defined by elevation); position in the river, i.e., **mainstem** or backwater inlet; substrata type; presence/absence of rooted aquatic plants; and water velocity (Table 6-2). Riverine habitats were classified into two zones with respect to water level:

- Intermittently Exposed Zone – the shore zone bounded by the 5th and 95th water level percentiles. This area represents a band along the edge of the Burntwood River that has experienced exposure, i.e., dewatering, 5 to 95 % of the time since 1977; and
- Wetted Zone – the area that is effectively wetted all the time. The upper border of the zone corresponds to the 5th percentile water elevation and the lower border corresponds to the minimum riverbed elevation.

As the intermittently exposed zone (IEZ) of a river is more difficult to estimate when compared to lake systems, i.e., the water surface elevation of a river represents a **gradient** as the water flows downhill, two supporting methods were used (Volume 4). The elevation of the water surface was estimated using the hydraulic data generated by Manitoba Hydro (Volume 4). Additionally, the position of the shoreline on the riverbank was estimated by projecting the river surface profile from the centre of the river laterally to the bank, which was modelled as a triangulated irregular network (TIN) surface model.

The zones were divided into Burntwood River mainstem and backwater inlet subsystems, and further divided into substratum and vegetation categories similar to the lacustrine habitat classification.

Table 6-2. The classification system developed for riverine habitats within the study area.

Classification of Riverine Habitats				
Zone	**Subsystem**	**Substratum/Vegetation**		**Water Velocity**
Intermittently Exposed **(E)**	Mainstem **(M)**	Bedrock **(Br)**		Low **(L)**
				Medium **(M)**
				High **(H)**
		Boulder/cobble **(Bc)**		Low **(L)**
				Medium **(M)**
				High **(H)**
		Hard silt/clay-based **(Hc)**		Low **(L)**
				Medium **(M)**
				High **(H)**
		Soft silt/clay-based **(Sc)**	No plants **(Sc)**	Low **(L)**
				Medium **(M)**
			Rooted vascular plants **(Rv)**	Low **(L)**
			Non-vascular plants **(Nv)**	Low **(L)**
		Flooded terrestrial **(Ft)**	No plants **(Sc)**	Low **(L)**
			Rooted vascular plants **(Rv)**	Low **(L)**
	Backwater inlets **(B)**	Bedrock **(Br)**		Low **(L)**
		Boulder/cobble **(Bc)**		Low **(L)**
		Hard silt/clay-based **(Hc)**		Low **(L)**
		Soft silt/clay-based **(Sc)**	No plants **(Sc)**	Low **(L)**
			Rooted vascular plants **(Rv)**	Low **(L)**
			Non-vascular plants **(Nv)**	Low **(L)**
		Flooded terrestrial **(Ft)**	No plants **(Sc)**	Low **(L)**
			Rooted vascular plants **(Rv)**	Low **(L)**
Wetted **(W)**	Mainstem **(M)**	Bedrock **(Br)**		Low **(L)**
				Medium **(M)**
				High **(H)**
		Boulder/cobble **(Bc)**		Low **(L)**
				Medium **(M)**
				High **(H)**
		Hard silt/clay-based **(Hc)**		Low **(L)**
				Medium **(M)**
				High **(H)**
		Soft silt/clay-based **(Sc)**	No plants **(Sc)**	Low **(L)**
				Medium **(M)**
			Rooted vascular plants **(Rv)**	Low **(L)**
			Non-vascular plants **(Nv)**	Low **(L)**
		Flooded terrestrial **(Ft)**	No plants **(Sc)**	Low **(L)**
			Rooted vascular plants **(Rv)**	Low **(L)**
	Backwater inlets **(B)**	Bedrock **(Br)**		Low **(L)**
		Boulder/cobble **(Bc)**		Low **(L)**
		Hard silt/clay-based **(Hc)**		Low **(L)**
		Soft silt/clay-based **(Sc)**	No plants **(Sc)**	Low **(L)**
			Rooted vascular plants **(Rv)**	Low **(L)**
			Non-vascular plants **(Nv)**	Low **(L)**
		Organic debris **(Od)**		Low **(L)**

Water velocity categories were also determined for riverine habitat. These categories were based on swimming efficiencies of fish species occurring in the study area (Volume 5, Appendix 11) and are defined as:

- Low: < 0.5 m/s
- Medium: between 0.5 and 1.5 m/s; and
- High: > 1.5 m/s

Riverine habitats were mapped using the same methodology as for lacustrine habitats, but with the fourth component, water velocity, included.

6.2.3.2 Stream Crossings

Aquatic habitat assessments were conducted in June, 2002, after road routing was finalized, for the eight stream crossings and adjacent areas along the access road (Figure 6-3). The streams to be crossed by the access road were assessed within a reach extending 100 m upstream and 200 m downstream of the **right-of-way** (RoW). The exception to this was crossing R1, a **tributary** to the Odei River, which, due to its morphology (i.e., the stream consisted of multiple channels) was assessed 20 m upstream and 30 m downstream of the RoW. At this time, water **stage** in the streams was generally high due to the spring **freshet** and aquatic plant growth had just initiated.

Supplemental information for these streams is available from surveys conducted during road routing, i.e., along the access road corridor, in September 2001 (Figure 6-3, Section 7.0) and during winter studies conducted in March 2002 (North/South Consultants Inc. unpublished data).

Aquatic habitat characteristics including habitat type, channel characteristics, water velocity and **discharge**, substrata type, and cover were recorded. Potential fish habitats, including **over-wintering**, spawning, and rearing areas, were identified.

Assessments of fish habitat value and sensitivity for stream crossings were developed using the rationale described in Habitat Conservation and Protection Guidelines (**DFO** 1998). 'Fish Habitat Classification' refers to the aquatic habitat within the potentially impacted portion of the watercourse as it currently exists and 'Sensitivity to Disturbance' considers the potential immediate or residual impacts that may result from disturbance of the streambed, banks, or adjacent riparian areas.

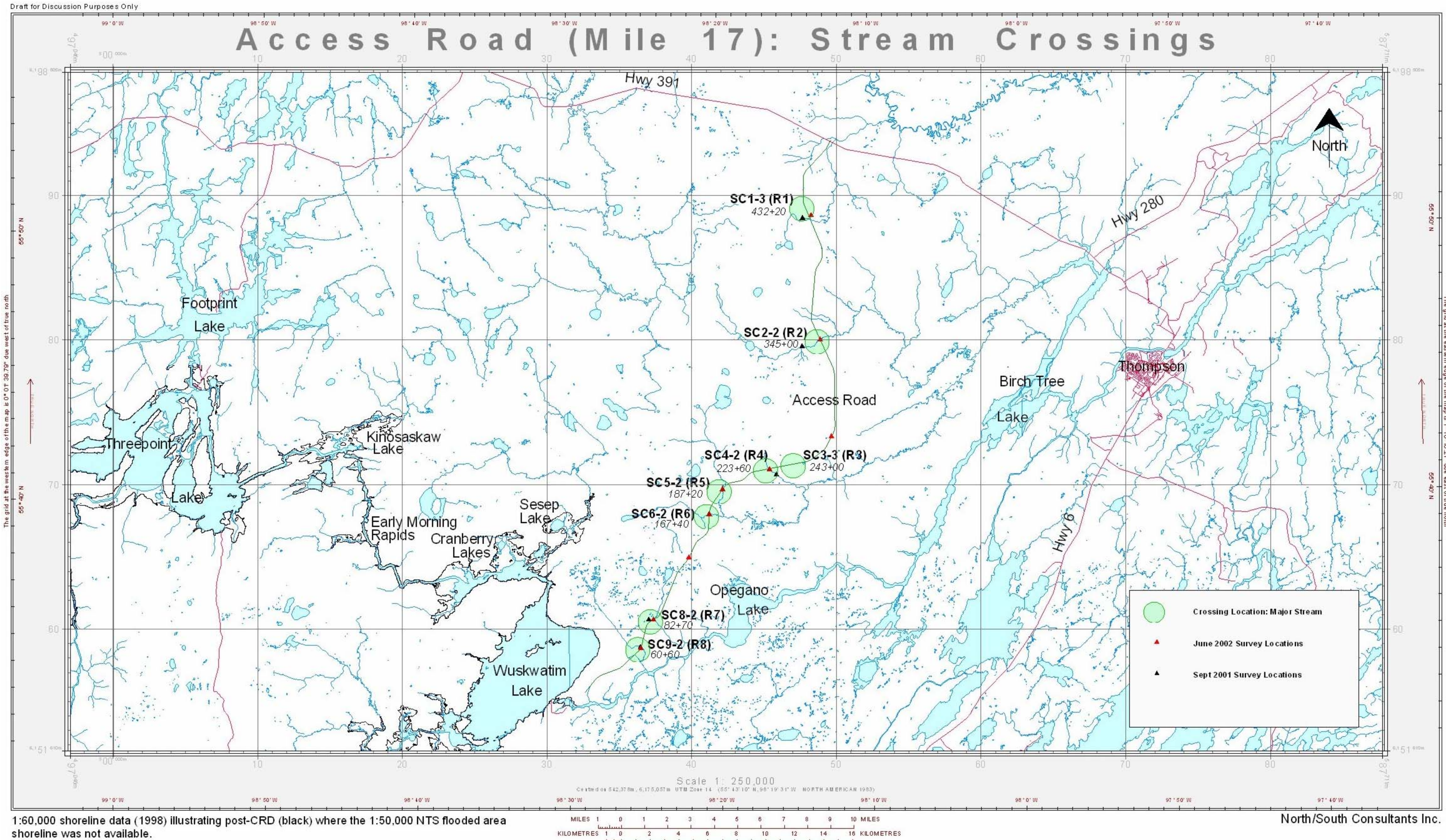


Figure 6-3. Eight major streams crossed by the Mile 17 access road.

Fish Habitat Classification

A conservative approach was taken in the assessment of fish habitat value, in that no watercourse was assigned a value of 'no fish habitat'. Stream crossings were assigned values of 'Marginal', 'Important', or 'Critical' based on the following criteria:

- importance in sustaining subsistence, commercial, or recreational fisheries;
- productive capacity;
- length of potential season in which habitat is provided;
- life stages of fish directly supported (including spawning, nursery, rearing, feeding, migration); and
- diversity of habitat.

'Critical' habitat was assigned to those streams crossed that:

- support a valued domestic, commercial, or recreational fishery;
- locally provide a high capacity for fish production within the stream itself, by providing year-round habitat for a variety of fish species through all or most life stages (including over-wintering, spawning, nursery, rearing, and feeding habitat); or
- are important to the overall productive capacity of the local system, by providing critical habitat (such as spawning habitat or a migration route) which was otherwise rare within the local system.

'Important' habitat was assigned to those streams that:

- are utilized by fish for feeding, growth, and migration which, while important to the fish stock, are not critical;
- have a relatively large amount of similar habitat that is readily accessible to the fish stock; or
- locally provide a significant capacity for fish production for a limited portion of the year, or for only part of the life cycles of local fish. For instance, streams in the study area may provide productive habitat during spring, but are dry or frozen for the remainder of the year.

‘Marginal’ habitat was assigned to those streams that:

- provide habitat for only a short period of each year, if at all; or
- provide habitat for a limited number of fish or fish species, and would not contribute significantly to the overall productive capacity of the system.

Sensitivity to Disturbance

Assessments of ‘High’ sensitivity were assigned to those streams in which disturbance of the streambed, banks, or adjacent riparian areas would result in the immediate disturbance of fish, and in which natural recovery of the streambed, banks, and/or riparian areas would be insufficient to avoid residual impacts.

Assessments of ‘Moderate’ sensitivity were assigned to those streams in which in-stream work would disrupt fish habitat for a short time, but in which residual impacts of disturbance of the streambed, banks, and/or riparian areas would be negligible, due to anticipated rapid natural recovery.

Assessments of ‘Low’ sensitivity were assigned if minimal immediate disturbance of fish would occur at the time of construction, and natural recovery following construction would minimize the potential for residual impacts.

To facilitate the ranking of fish habitat and sensitivity classifications, the habitat requirements of fish present or fish species potentially utilizing these streams were assessed. A score from ‘Low’ to ‘High’ was determined for spawning, over-wintering, and rearing habitat present in the surveyed reaches. Habitat requirements of some of the fish species (VECs) in the study area are provided within the fish community and movements section (Section 8.0).

6.3 EXISTING ENVIRONMENT

6.3.1 Reach 1: Wuskwatim

The water level in this reach was raised approximately 3 m due to CRD (Volume 4). The majority of resultant flooding occurred in Cranberry Lakes, Sesep Lake, Wuskwatim Brook, and Wuskwatim Lake south. These flooded terrestrial areas are at various stages of vegetation decay and **erosion** depending on the type of terrestrial vegetation and substrata flooded, and are generally characterized by peat islands and flooded forest areas. Peat islands occupy approximately 19 % of the surface area in the intermittently exposed zone (IEZ) and are described within the terrestrial portion of this assessment

(Volume 6). Substrata within flooded terrestrial areas is generally high in organic material of boreal forest and bog origin and, due to varying rates of erosion, ranges from soft silt/clay-based to bedrock. Since these areas are shallow and typically sheltered, they support the majority of rooted aquatic plant growth for this reach. Rooted submergent aquatic plant distribution, however, is variable and growth is patchy. Poorly established **littoral** zones often occur in a regulated system as the frequency and extent of water level fluctuations preclude the development of extensive aquatic plant **bed**s. Lake regulation may also affect plant density and distribution, as altering lake levels can influence both light regime, and substrata availability or stability (Rørslett 1984).

Aquatic habitat in this section is described at the 95th percentile water level (shoreline elevation 234.09 m ASL). Reach 1 has a surface area of 8972 **ha**, a maximum water depth of 14.1 m, a mean water depth of 5.5 m, and a water volume of 469 million m^3 (Table 6-3, Figure 6-4). All aquatic habitats in Reach 1 were classified based on the lacustrine system (Table 6-1). The extents of the intermittently exposed, nearshore, and offshore zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants for Reach 1 are presented in Figure 6-5. Within Reach 1, the intermittently exposed, nearshore, and offshore zones each occupy approximately 2022 ha (23 %), 2579 ha (29 %), and 4372 ha (49 %), respectively (Table 6-4).

The flooded terrestrial area in Reach 1 is approximately 2913 ha, excluding the very small flooded margin of Wuskwatim Lake main. The majority of nearshore and offshore areas are predominantly soft silt/clay-based substrata, with a narrow band of boulder/cobble visible along a portion of some shorelines when water levels are relatively low. Shoals are typically hard substrata (i.e., bedrock, boulder/cobble).

Table 6-3. Existing surface area, water depth and volume, and residence time of water for waterbodies in Reach 1.

Waterbody	**95th Water Level Percentile**				
	Surface Area (ha)	**Maximum Depth (m)**	**Mean Depth (m)**	**Volume (m^3)**	**Residence Time (days)**
Cranberry Lakes	1764.2	14.1	2.6	45841278	0.5
Sesep Lake	445.4	3.0	-	-	-
Wuskwatim Lake Main	4814.0	13.5	8.0	383018850	4.0
Wuskwatim Lake South	1106.9	6.3	2.2	24405903	-
Wuskwatim Brook	841.8	7.3	1.8	15508353	-
Reach 1 Total	8972.3	14.1	5.5	468774384	-

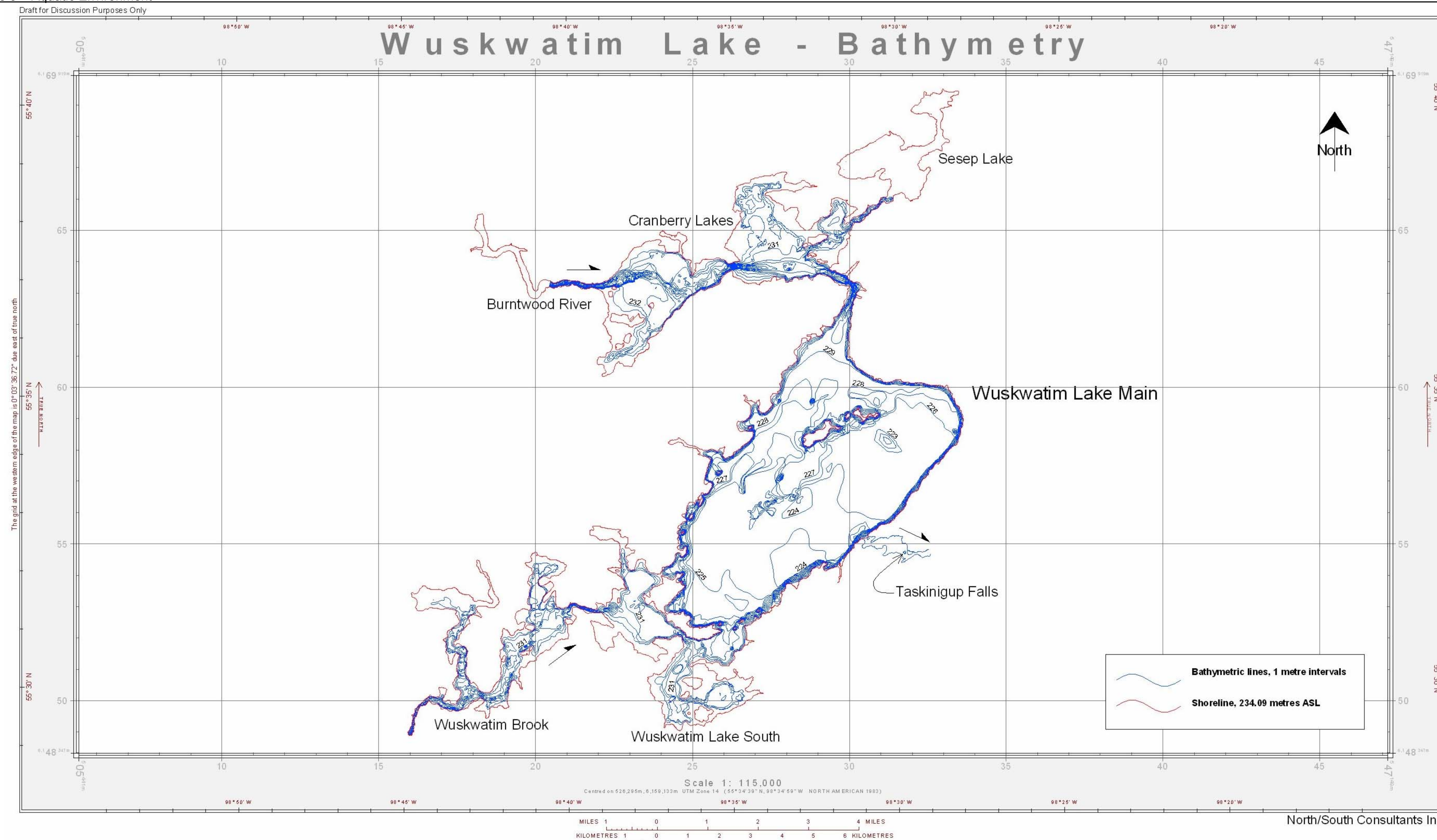


Figure 6-4. Existing bathymetric contours for Reach 1 (shoreline at 234.09 m ASL).

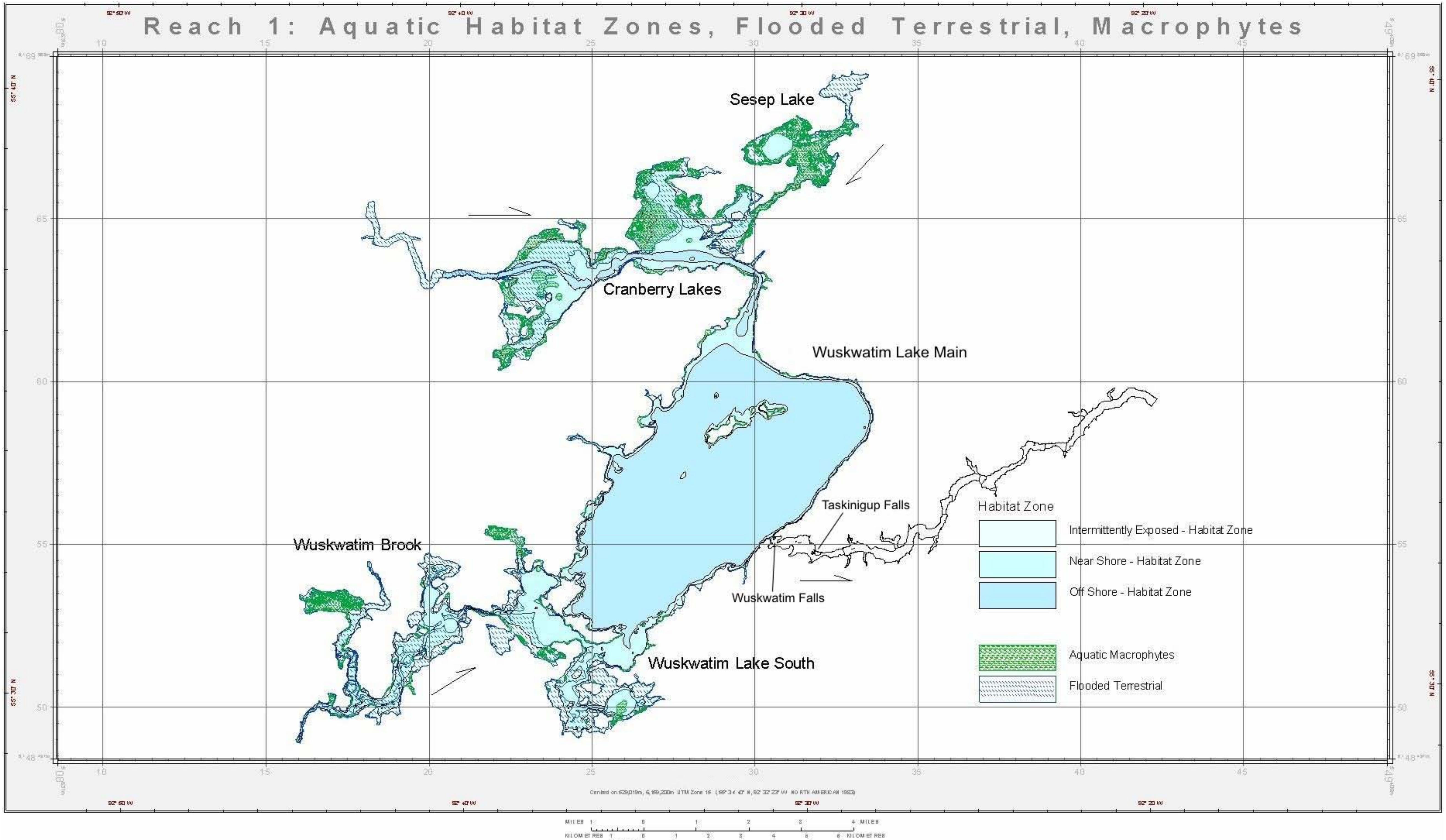


Figure 6-5. Existing aquatic habitat zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants in Reach 1 (shoreline at 234.09 m ASL).

Table 6-4. Existing areas for the intermittently exposed, nearshore, and offshore habitat zones by waterbody in Reach 1.

Habitat Zone Waterbody	Intermittently Exposed Area (ha)	Nearshore Area (ha)	Offshore Area (ha)
Cranberry Lakes	597.1	991.8	175.2
Sesep Lake	388.9	56.5	0.0
Wuskwatim Lake Main	167.0	465.7	4181.3
Wuskwatim Lake South	473.4	623.8	9.7
Wuskwatim Brook	395.1	441.5	5.3
Reach 1 Total	2021.5	2579.4	4371.5

Rooted submergent aquatic plants occupy approximately 744 ha (9 %) of the area of Reach 1 (Table 6-5). The majority of submergent aquatic plants are found within the IEZ (77 %), with the remainder found in the nearshore.

Table 6-5. Existing areas for rooted submergent aquatic plants in Reach 1.

Waterbody	Rooted Aquatic Plants		
	Intermittently Exposed Area (ha)	Nearshore Area (ha)	Total Area (ha)
Cranberry Lakes	275.3	168.5	443.8
Sesep Lake	196.8	0.0	196.8
Wuskwatim Lake Main	26.6	2.1	28.7
Wuskwatim Lake South	71.0	5.8	76.7
Wuskwatim Brook	24.2	3.6	27.7
Reach 1 Total	593.9	179.9	773.8

The major inflow to the Cranberry Lakes is the Burntwood River, which enters the west basin. Cranberry Lakes are relatively small (surface area 1764 ha), resulting in detectable water current through the lakes and a relatively low water residence time of approximately 0.5 days (Table 6-3). A secondary tributary to Cranberry Lakes is the Muskeseu River, which enters the east end of the lakes and drains Sesep Lake and several smaller ponds. Cranberry Lakes have a maximum depth of approximately 14.1 m, but most of the area is around 2.6 m deep (Figure 6-4). The majority of aquatic habitat is found within the intermittently exposed (597 ha) and nearshore (992 ha) areas (Table 6-4). Approximately 16 % of the shoreline in Cranberry Lakes had a rocky component. Flooded terrestrial area occupies approximately 1156 ha and is characterized by peat islands, flooded forest, patchy aquatic plant beds, and soft silt-clay substrata rich in detritus (Figure 6-6). Outside of the flooded terrestrial areas, the substrata are generally hard packed silt-clay in the areas with current and soft silt-clay in off-current areas. The majority of rooted submergent aquatic plants are found in the flooded terrestrial areas of Cranberry Lakes, where they occupy approximately 444 ha (Table 6-5).

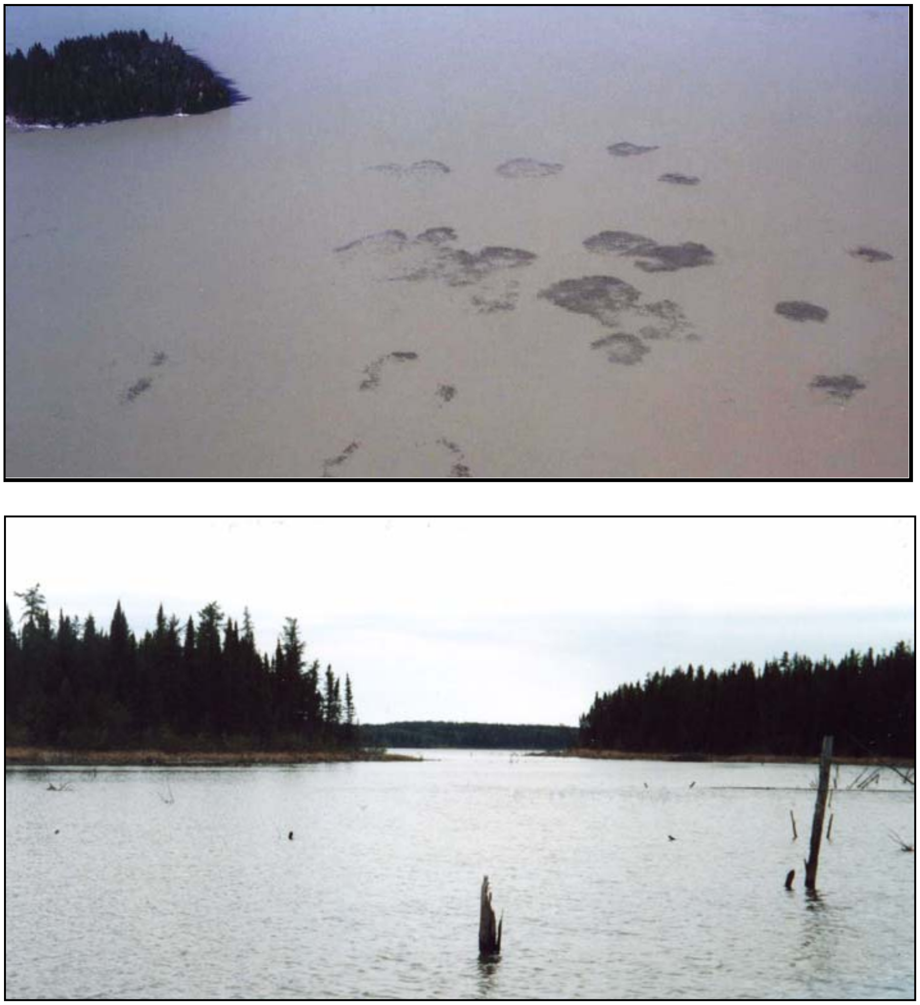


Figure 6-6. Existing flooded terrestrial areas in Cranberry Lakes with rooted submergent aquatic plant beds in the western basin (top) and flooded forest in the north-eastern basin (bottom).

Sesep Lake is situated upstream of Cranberry Lakes on the Muskeseu River. It is a relatively small lake with a surface area of approximately 445 ha (Table 6-3). Most of Sesep Lake's inflow comes from the Muskeseu River with an additional amount from a small drainage creek (Figure 6-7). Sesep Lake has a maximum observed water depth of 3 m (Table 6-3). The majority of aquatic habitat is found within the intermittently exposed zone (389 ha), with no habitat represented in the offshore zone (Table 6-4). Sesep Lake is surrounded by low elevation, boggy terrain and, as such, the majority of the lake was formed due to flooding by CRD (391 ha). Approximately 1 % of the shoreline contains a rocky component. Peat islands and aquatic plants encompass the majority of the lake margin, with the substrata being predominantly soft silt/clay-based, relatively high in organic content. All rooted submergent aquatic plants are found in intermittently exposed, flooded terrestrial habitat, occupying an area of approximately 197 ha (Table 6-5).

Figure 6-7. Existing intermittently exposed, flooded terrestrial habitat near the inlet of the Muskeseu River at Sesep Lake.

Wuskwatim Lake is approximately 12 km long and 5 km wide. The lake is divided into two areas, Wuskwatim Lake main and Wuskwatim Lake south, by a peninsula extending almost the full width across the southern portion of the lake. In addition to the Burntwood River and Wuskwatim Brook, there are seven small drainage creeks that enter Wuskwatim Lake; two enter midway up the west side of the lake, one enters from the east near the outflow at Wuskwatim Falls, and four enter the south basins of Wuskwatim Lake. The creeks that enter the main basin are associated with bays that were inundated by CRD (backwater inlets). Wuskwatim Lake main is relatively large (surface area 4814 ha), and has a maximum water depth of 13.5 m and a mean depth of 8.0 m (Table 6-3, Figure 6-4). The majority of water volume in Reach 1 is contained within Wuskwatim

Lake main (383 million m^3), leading to a water residence time of 4.0 days under 95^{th} percentile water level conditions. Unlike other waterbodies in Reach 1, the majority of aquatic habitat in Wuskwatim Lake main is found within the offshore zone (4181 ha); relatively little is found within the intermittently exposed area (167 ha) (Table 6-4).

Compared with other waterbodies, the majority of Wuskwatim Lake main is contained by steeper banks. As a result, the amount of flooded terrestrial area is proportionally lower (26 ha). Approximately 72 % of the shoreline contains a component of rocky material, however, less than 1 % is exclusively bedrock. The remainder of the shoreline is composed of soft silt/clay overlying bedrock. A portion of these shores have scattered boulder/cobble deposits. Shoals and rocky-bottomed areas are most numerous in the southern half of the lake within the intermittently exposed and nearshore zones. Generally, banks along the south-western shore of Wuskwatim Lake main consist of exposed silt/clay, while bedrock is more prevalent along the north-eastern shore (Figure 6-8). Within the offshore area, substrata are predominantly soft silt/clay-based, relatively low in organic content. Rooted submergent aquatic plant growth in Wuskwatim Lake main is relatively limited (29 ha) (Table 6-5), due to fluctuating water levels and exposure to **wave action**. Patchy growth occurs in sheltered bays along the west and north shores of the lake, and adjacent to the larger islands in the northern half of the lake (Figure 6-8), with the majority of growth occurring in the intermittently exposed zone (93 %).

Wuskwatim Lake south is smaller (surface area 1107 ha) than the main portion of the lake, and has maximum water depth of 6.3 m and a mean depth of 2.2 m (Table 6-3, Figure 6-4). The majority of aquatic habitat is found within the intermittently exposed (473 ha) and nearshore (624 ha) areas (Table 6-4). In contrast to the main lake, the portion of the shoreline with a rocky component is considerably lower (about 13 %). As bank elevation is lower in comparison to the main lake, the flooded terrestrial area occupies a proportionately larger area (about 652 ha) and is characterized by peat islands, flooded forest, patchy aquatic plant beds, and soft silt/clay-based substrata rich in detritus (Figure 6-9). Outside of the flooded terrestrial areas, the substrata are generally soft silt/clay, with a relatively lower organic content, and fewer submergent aquatic plants are observed. As in Wuskwatim Lake main, submergent aquatic plant growth is relatively limited (77 ha), and is generally restricted to sheltered bays and tributary inlets with the majority (84 %) found in intermittently exposed, flooded terrestrial habitat (Table 6-5).

Figure 6-8. Existing exposed silt/clay bank along the south-western shore (top), bedrock along the north-eastern shore near the outlet at Wuskwatim Falls (middle), and rooted submergent aquatic plant beds adjacent to a large island in the north end of Wuskwatim Lake main (bottom).

Figure 6-9. Existing floating peat islands and flooded forest in Wuskwatim Lake south.

Wuskwatim Brook flows into the southwest portion of Wuskwatim Lake. The study area extends 10 km upstream of Wuskwatim Lake to a small series of falls (Figure 6-10). Two smaller tributaries enter the north side of the brook and two enter from the south that drain local low areas. Prior to CRD, the brook consisted of a meandering channel with small **pool** areas along its margin. At present, it is an expansive flooded area about 842 ha in size (Table 6-3). Wuskwatim Brook has a maximum depth of 7.3 m, but the majority is about 1.8 m deep (Figure 6-4). Aquatic habitat is predominantly found within the intermittently exposed (395 ha) and nearshore (442 ha) zones, with relatively little represented in the offshore (5 ha) (Table 6-4). Approximately 4 % of the shoreline has a rocky component. Flooded terrestrial area comprises about 688 ha and is characterized by peat islands, flooded forest, patchy submergent aquatic plant beds, and soft silt/clay-based substrata rich in detritus (Figure 6-10). Outside of the flooded terrestrial areas, substrata are also soft silt/clay, remaining high in organic content. Rooted submergent aquatic plants are generally restricted to sheltered bays and tributary inlets, with the majority (24 ha) found in intermittently exposed, flooded terrestrial habitat (Table 6-5).

Figure 6-10. Existing small series of falls at the upstream end of the study area (top), and peat islands and flooded forest in the intermittently exposed zone of Wuskwatim Brook (bottom).

There are two small sections of the Burntwood River in Reach 1: upstream of Cranberry Lakes to Early Morning Rapids; and between Cranberry Lakes and Wuskwatim Lake main. Generally, high (up to 30 m), exposed silt/clay banks along the outside bends and more gradually sloped forested banks along the inside bends characterize the Burntwood River upstream of Cranberry Lakes (Figure 6-11). Here the river reaches depths greater than 17 m. The Burntwood River between Cranberry Lakes and Wuskwatim Lake has lower banks that are bedrock controlled at the water's edge and has a maximum depth of about 15 m (Figure 6-4). The substrata for both are bedrock with some hard silt/clay-based in areas of reduced flow. Four small drainage creeks enter these areas; three enter the Burntwood River between Early Morning Rapids and Cranberry Lakes and one enters the north side of the downstream section of river. These creeks are less than 5 km long and discharge into bays inundated by CRD. The bays are typically shallow (water depth less than 4 m) with areas of flooded forest around the margin and woody debris on shore. The substrata of the creeks and associated bays are soft silt/clay-based mixed with terrestrial detritus.

Figure 6-11. Existing Burntwood River between Early Morning Rapids and Cranberry Lakes.

6.3.2 Reach 2: Falls

The crest of Wuskwatim Falls is the upper extent of this reach and the base of Taskinigup Falls is the lower boundary (Figure 6-12). Wuskwatim Falls is about 6 m high from crest to the water surface downstream and Taskinigup Falls is about 15 m high.

Figure 6-12. Aerial views of Wuskwatim Falls (top) and Taskinigup Falls (bottom) looking upstream.

Data could not be collected safely near the base of Wuskwatim Falls or the area immediately upstream of Taskinigup Falls. Consequently, the area of Reach 2 that represents the limits of data collected is smaller in size (43.6 ha) than the actual area of the reach (53.3 ha). Aquatic habitat in this section is described at the 95th percentile flow event (discharge at 1066 $\mathbf{m^3/s}$). Reach 2 has a surface area of 43.6 ha, a maximum water depth of 19.0 m, a mean water depth of 6.3 m, and a water volume of about 3 million m^3

(Table 6-6). All aquatic habitats in Reach 2 were classified based on the riverine system (Table 6-2). The extents of the intermittently exposed and wetted zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants are presented in Figure 6-13. Aquatic habitat is predominantly found within the wetted zone (90.4 %), with relatively little in the intermittently exposed area (Table 6-7).

Table 6-6. Existing surface area, and water depth and volume in Reach 2.

Waterbody	95th Percentile Flow Event			
	Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Volume (m^3)
Main Channel	29.9	19.0	7.8	2345236
North Bay	7.4	14.8	2.7	202269
South Bay	6.3	8.4	3.1	197201
Reach 2 Total	43.6	19.0	6.3	2744706

Table 6-7. Existing areas for the intermittently exposed and wetted habitat zones in Reach 2.

Habitat Zone Waterbody	Intermittently Exposed Area (ha)	Wetted Area (ha)	Total Area (ha)
Main Channel	0.9	29.0	29.9
North Bay	2.0	5.4	7.4
South Bay	1.3	5.0	6.3
Reach 2 Total	4.2	39.4	43.6

The substrata of Reach 2 generally reflect the distribution of water velocities. Off-current areas along the riverbanks and in bays have soft silt/clay-based substrata (22.6 %), in on-current areas within the upstream half of the reach (where water velocities are greatest) the centre of the river is bedrock (20.3 %), and the lower half, including the pools and **scour** channels, is hard silt/clay-based (29.6 %). The majority of boulder/cobble (13.0 %) is located between the substrata types found in the on-and-off current areas (Figure 6-14). Existing areas of substrata types in Reach 2 are presented in Table 6-8.

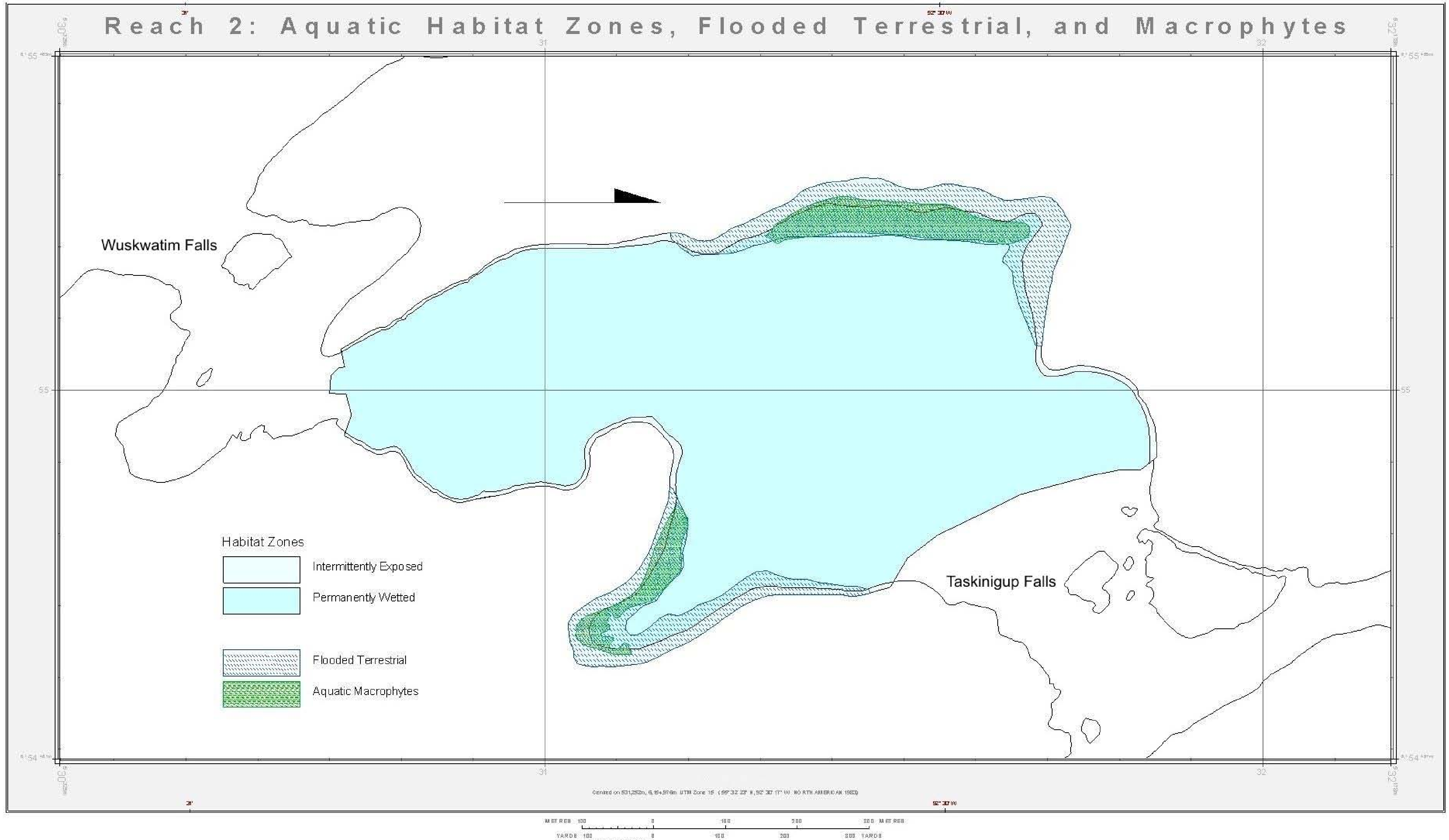


Figure 6-13. Existing aquatic habitat zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants in Reach 2 (95th percentile flow event).

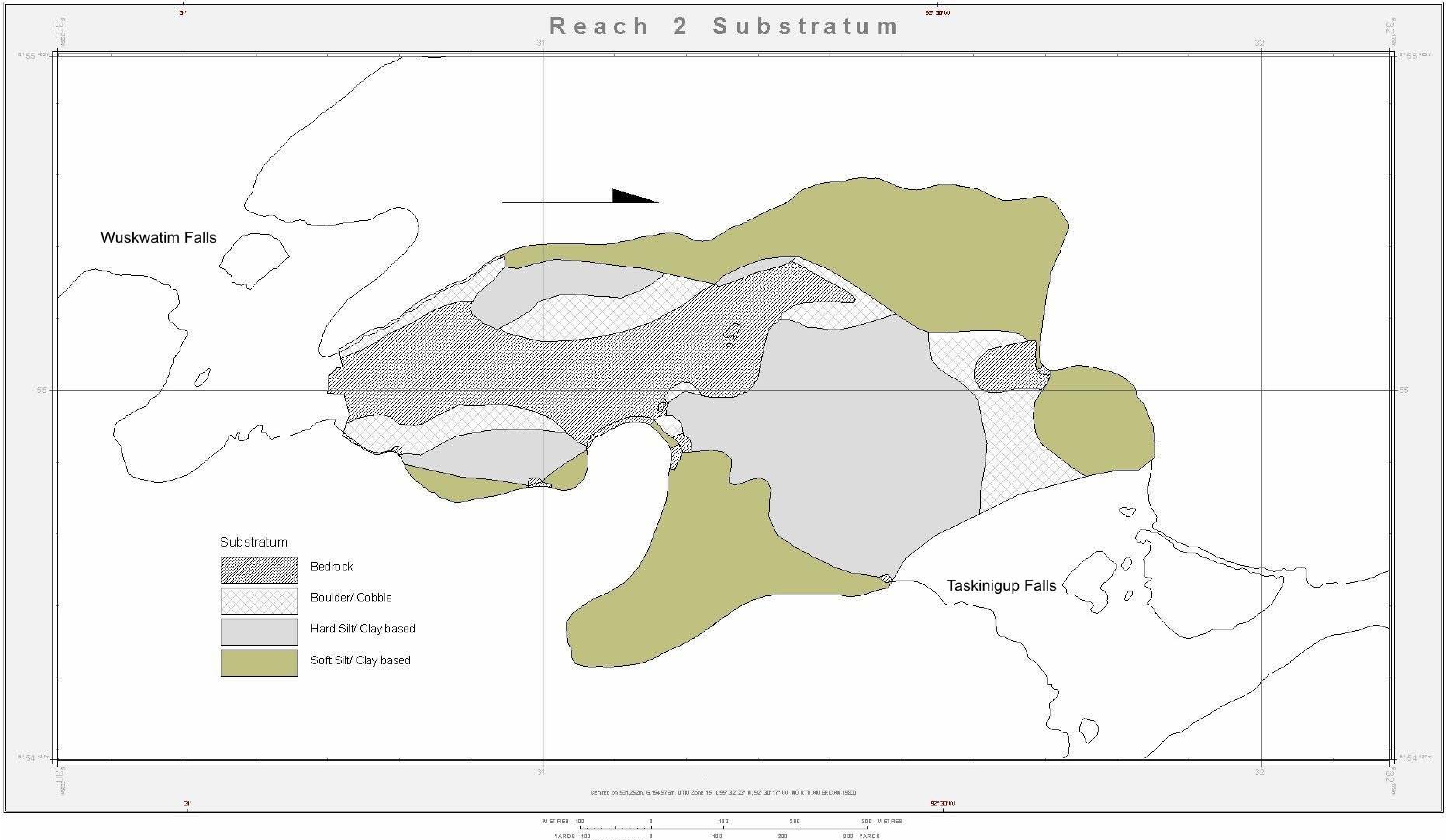


Figure 6-14. Existing substrata types in Reach 2.

Table 6-8. Existing areas of substrata types in Reach 2.

Substrata Type Waterbody	Bedrock Area (ha)	Boulder/cobble Area (ha)	Hard silt/clay-based Area (ha)	Soft silt/clay-based Area (ha)	Flooded terrestrial Area (ha)
Main Channel	8.6	5.3	12.1	3.8	0.1
North Bay	0.2	0.3	0.0	3.1	3.7
South Bay	0.1	0.0	0.8	3.0	2.5
Reach 2 Total	8.8	5.7	12.9	9.8	6.4

There is substantial current through the majority of this reach. Maximum water velocities occur closest to Wuskwatim Falls and dampen out towards Taskinigup Falls (Figure 6-15). Existing areas of low, medium, and high water velocities in Reach 2 are presented in Table 6-9. Areas with reverse flow (i.e., back eddies) are also classified with respect to low, medium, and high water velocities, providing an overall total area for each of the water velocity categories between the falls.

Table 6-9. Existing areas of low, medium, and high water velocities in Reach 2.

Water Velocity Waterbody	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Main Channel	8.4	13.2	1.2
North Bay	4.8	0.3	0.0
South Bay	1.3	0.0	0.0
Reach 2 Total	14.5	13.5	1.2

Reverse Flow Water Velocity Waterbody	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Main Channel	5.4	0.8	0.1
North Bay	0.3	0.0	0.0
South Bay	3.7	0.0	0.0
Reach 2 Total	9.4	0.8	0.1

Overall Total Water Velocity Waterbody	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Main Channel	13.8	14.0	1.2
North Bay	5.1	0.3	0.0
South Bay	5.0	0.0	0.0
Overall Reach 2 Total	23.8	14.3	1.2

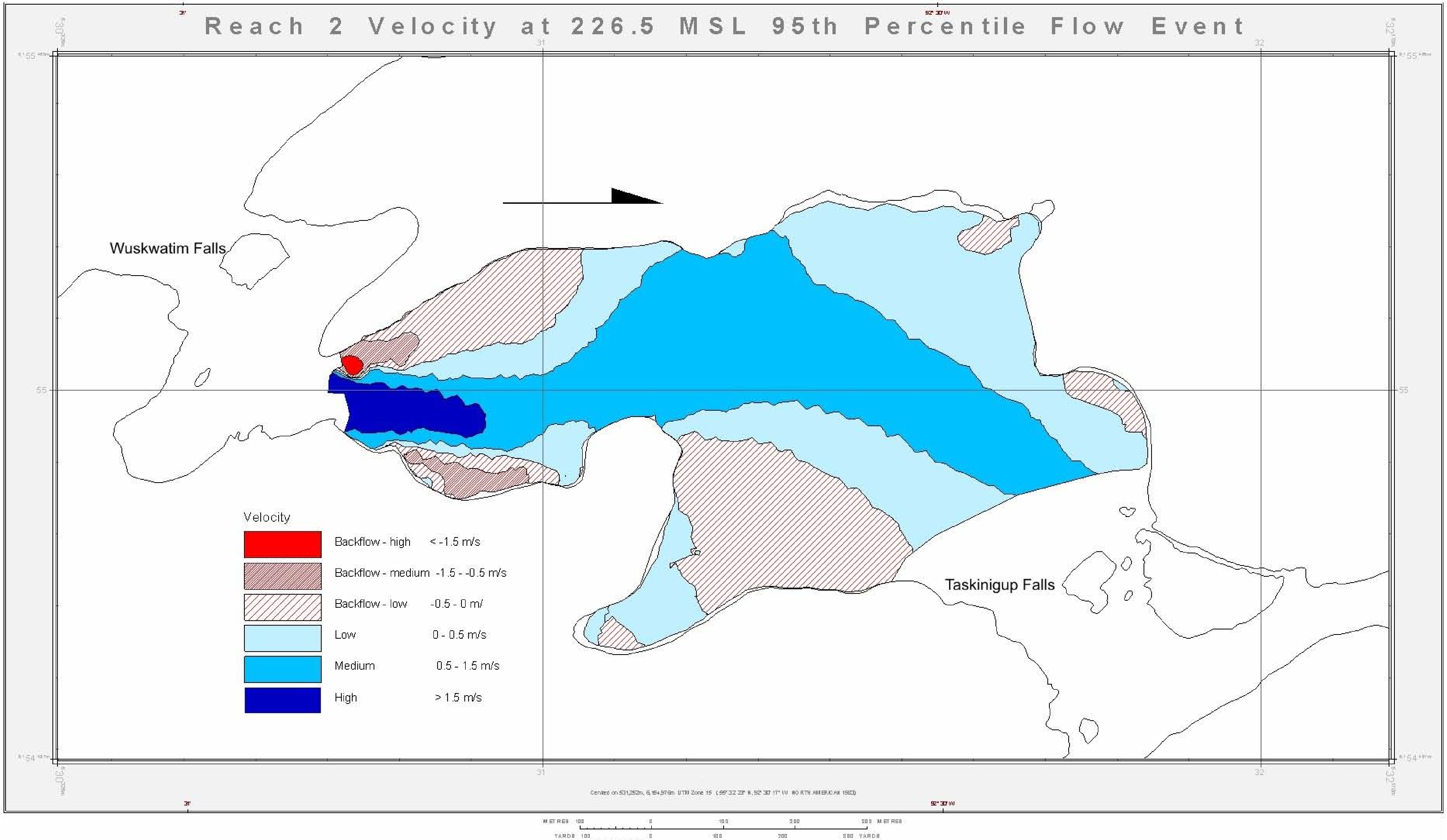


Figure 6-15. Existing water velocities in Reach 2 (at water elevation 226.5 m ASL).

There are two larger bays midway through the reach, one on the north-side (Figure 6-16) and one on the south (Figure 6-17), that were low **relief** terrestrial areas inundated as a result of CRD. The flooded terrestrial area in Reach 2 occupies approximately 6.4 ha, with the majority (98.0 %) in these two bays (Table 6-8). Local **runoff** enters into each of these bays via small **ephemeral** creeks that have minimal discharge after the spring freshet. Each creek is less than one kilometre in length, has indeterminate channels at the **confluence** with the river mainstem, and has poorly defined upstream channel margins. Associated with these sheltered bay areas is sparse aquatic plant growth. Relatively high water velocities preclude aquatic macrophyte growth in the remainder of the reach. Rooted submergent aquatic plants occupy an area of 2.2 ha in Reach 2 (Table 6-10). The majority of submergent aquatic plants are found within the wetted zone (81.2 %).

Table 6-10. Existing areas for rooted submergent aquatic plants in Reach 2.

Habitat Zone Waterbody	**Intermittently Exposed Area (ha)**	**Wetted Area (ha)**	**Total Area (ha)**
Main Channel	0.0	0.0	0.0
North Bay	-	-	1.5
South Bay	-	-	0.7
Reach 2 Total	0.4	1.8	2.2

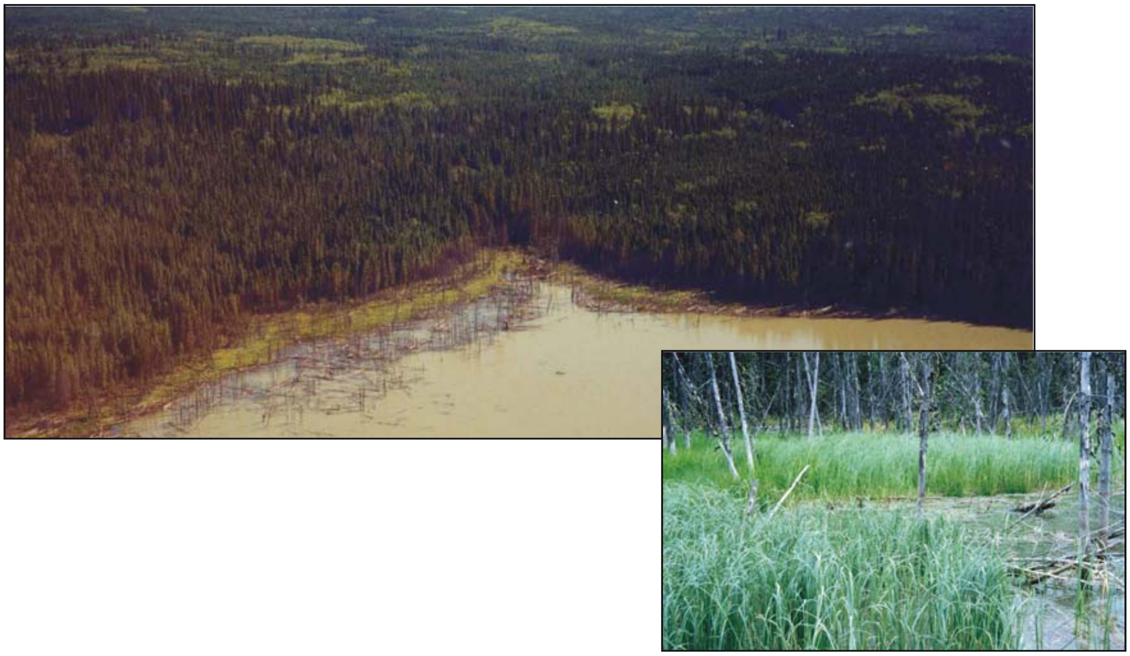


Figure 6-16. Existing north-side bay with flooded terrestrial area and aquatic plants (inset).

Figure 6-17. Existing south-side bay with flooded terrestrial area and aquatic plants (inset).

6.3.3 Reach 3: Burntwood

The base of Taskinigup Falls is the upper extent of this reach and the inlet to Opegano Lake is the lower boundary (Figure 6-18). The Burntwood River between Taskinigup Falls and Opegano Lake is 14 km long with a width ranging from 60 to 300 m. Reach 3 has 10 backwater inlets that receive inflow from **first-order streams**. The exception to this is inlet 9, which receives water from a **second-order stream**. Drainage areas for these streams are relatively small and discharge into the inlets is low after the spring freshet.

Figure 6-18. The bay on the south-side of the Burntwood River, immediately downstream of Taskinigup Falls, at the upper extent of Reach 3. (Note: this bay will be part of the post-Project backwater area.)

Aquatic habitat in this section is described at the 95th percentile flow event (discharge at 1066 m^3/s). Reach 3 has a surface area of 297 ha, a maximum water depth of 25.3 m, a mean water depth of 6.9 m, and a water volume of about 20 million m^3 (Table 6-11, Figure 6-19). All aquatic habitats in Reach 3 were classified using the riverine system (Table 6-2). The extents of the intermittently exposed and wetted zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plant beds are presented in Figure 6-20.

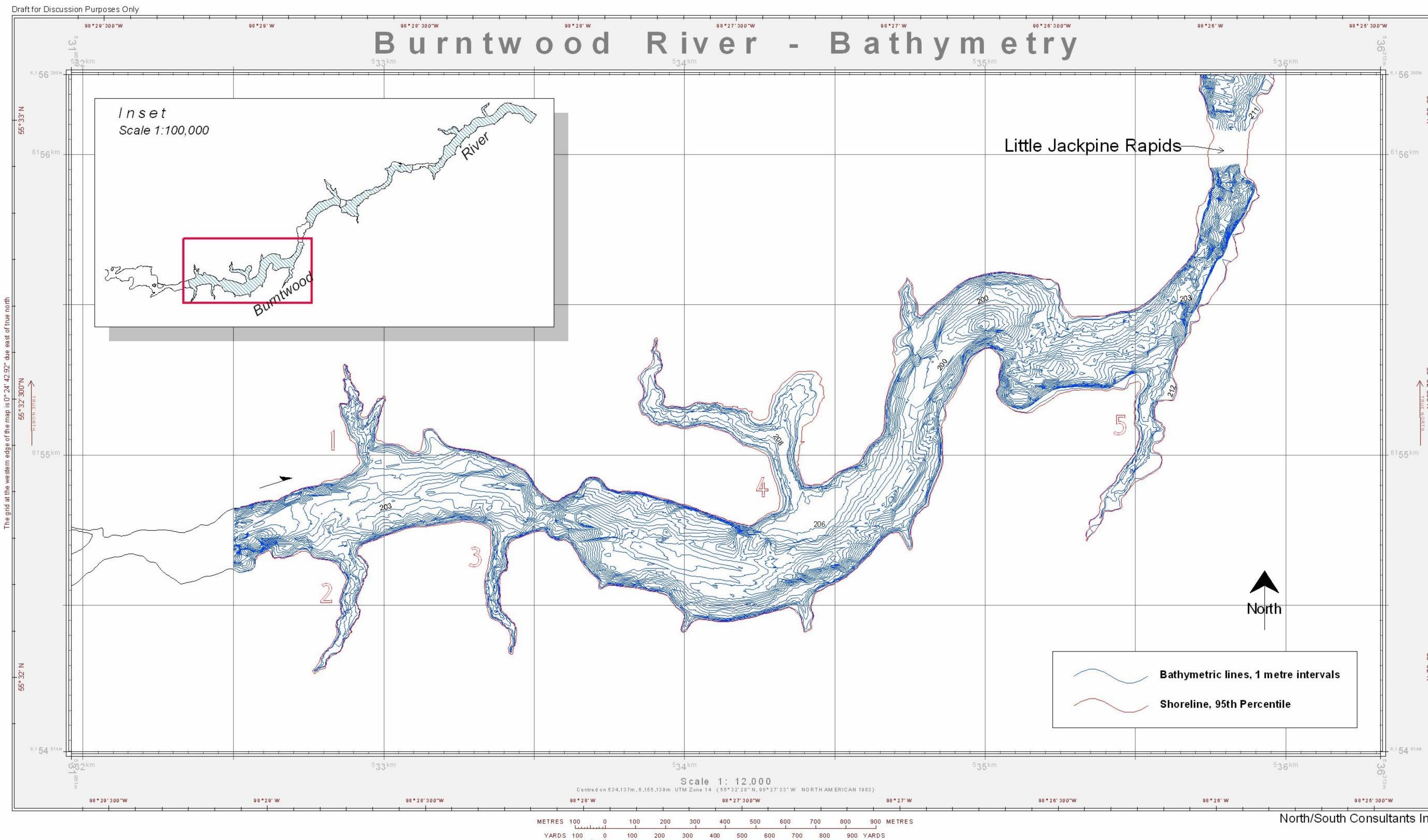


Figure 6-19A. Existing bathymetric contours for Reach 3: Taskinigup Falls to Little Jackpine Rapids.

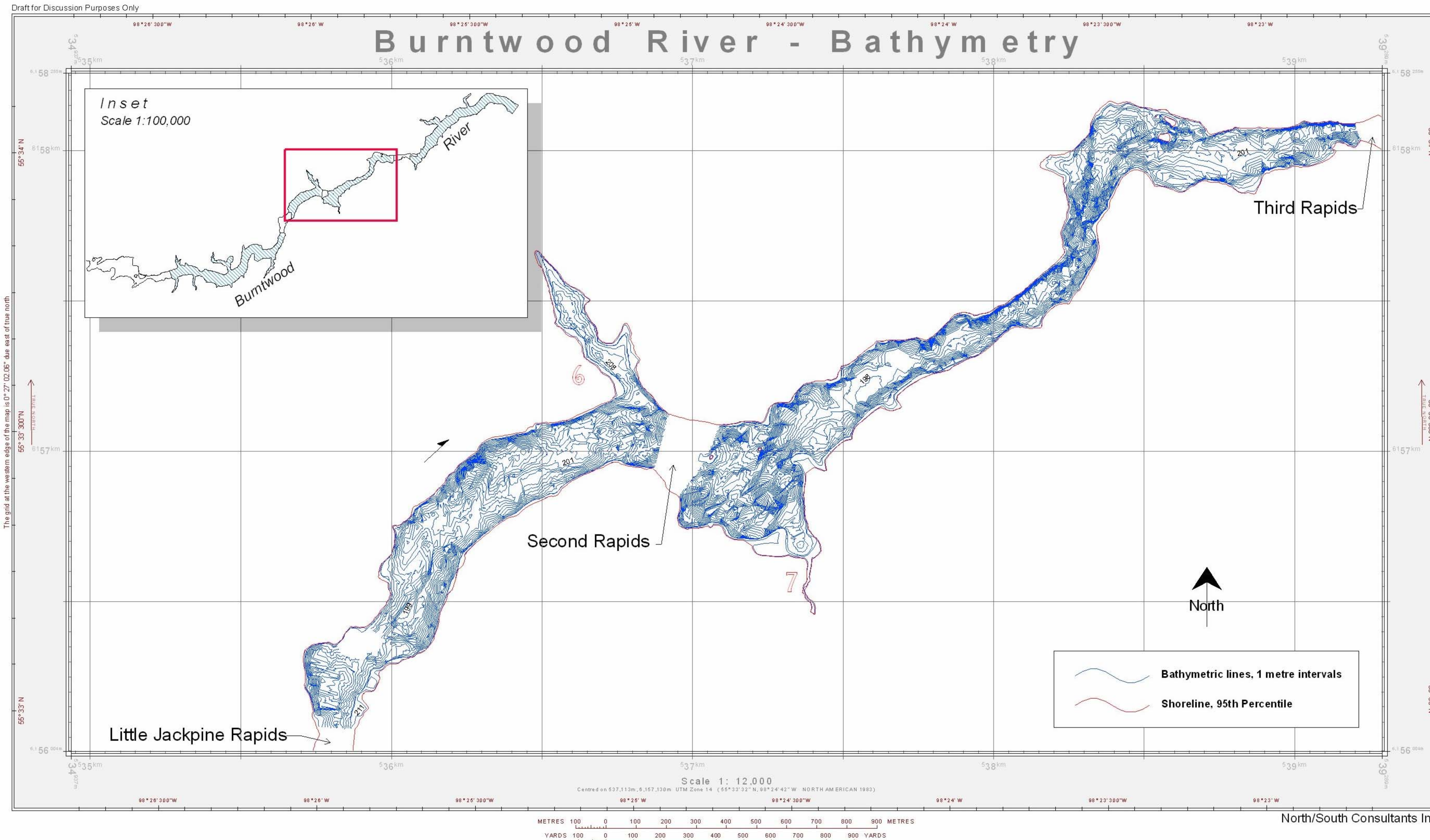


Figure 6-19B. Existing bathymetric contours for Reach 3: Little Jackpine Rapids to Third Rapids.

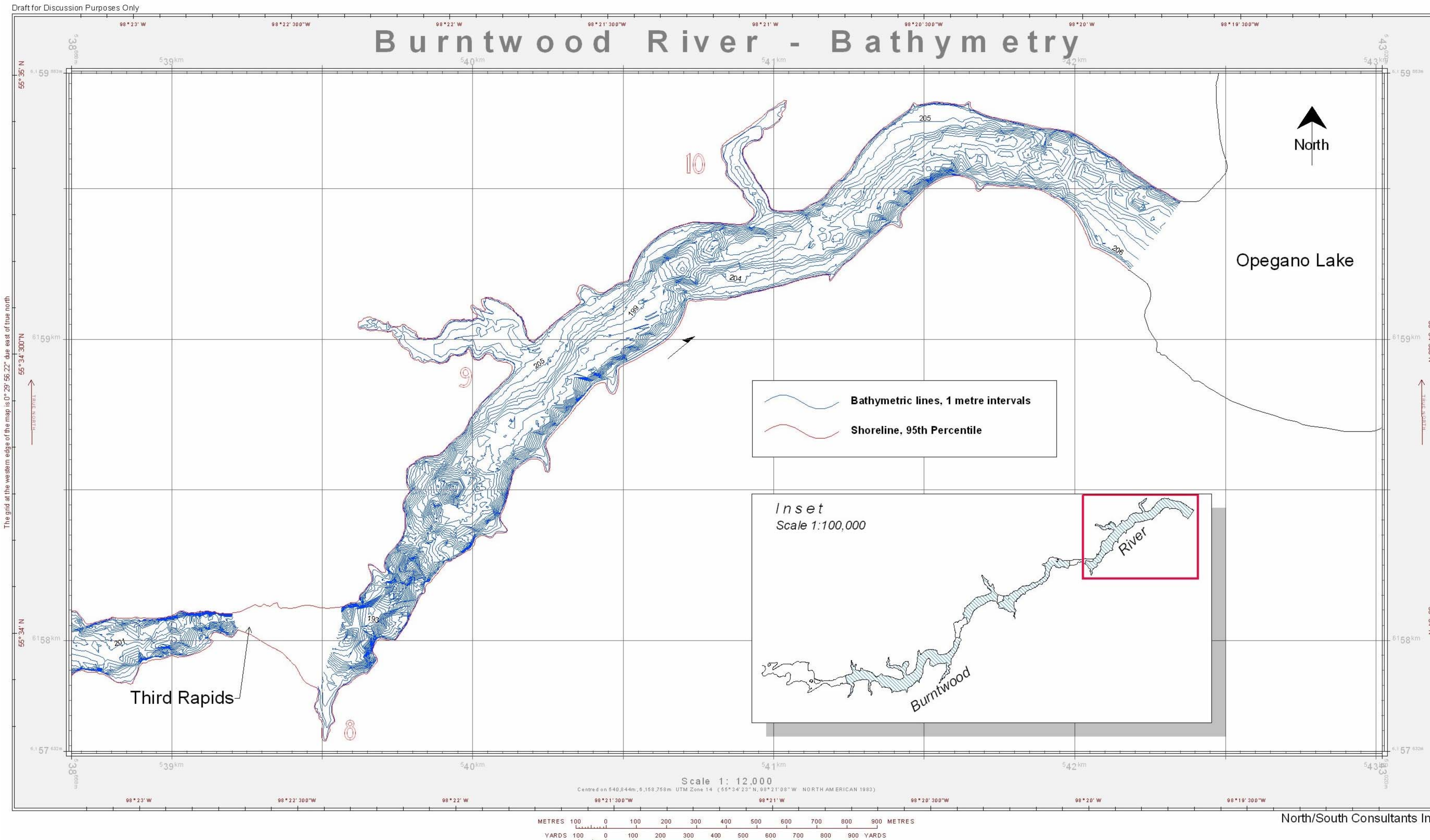


Figure 6-19C. Existing bathymetric contours for Reach 3: Third Rapids to Opegano Lake.

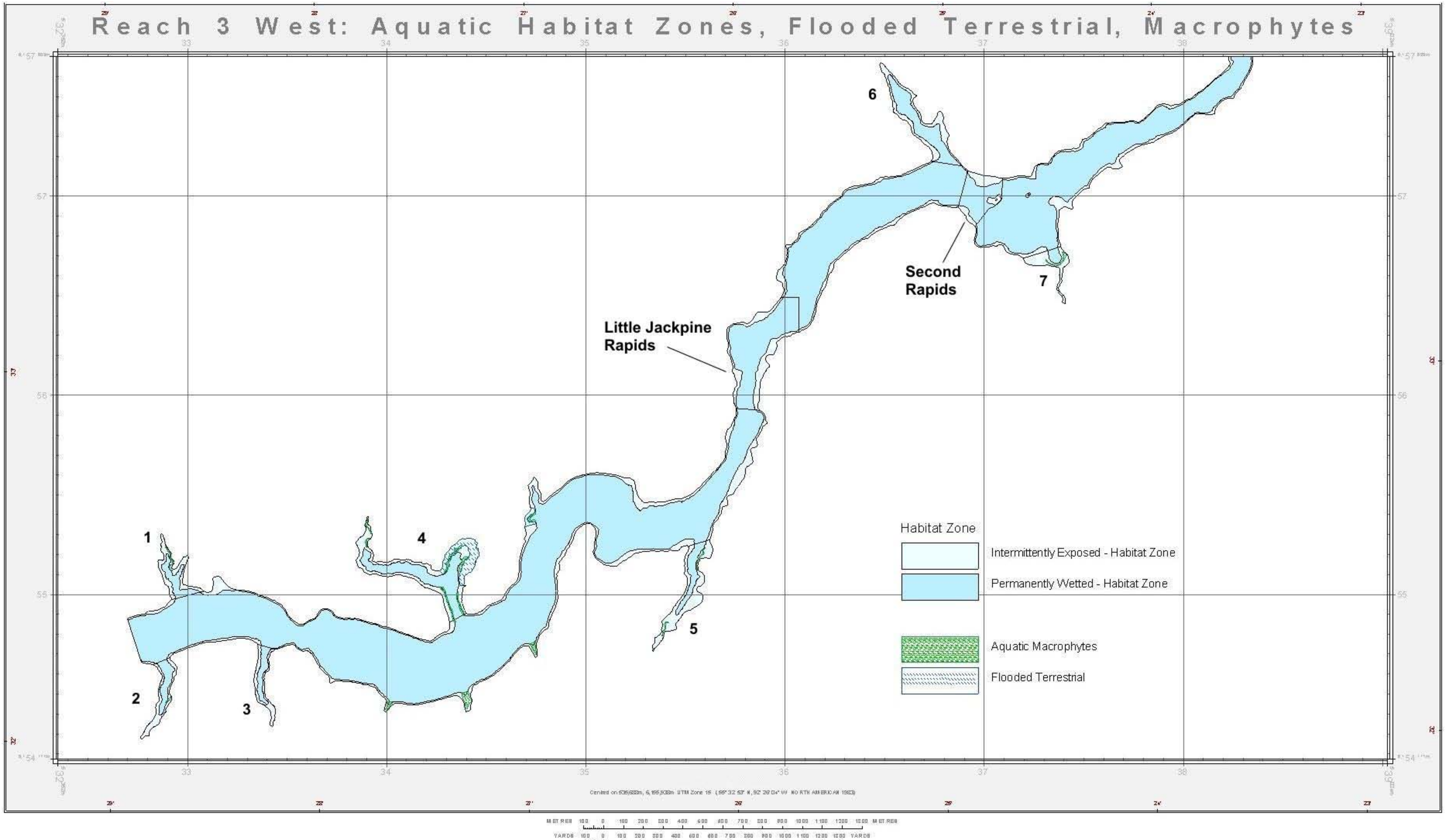


Figure 6-20A. Existing aquatic habitat zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants in the upper portion of Reach 3 (95th percentile flow event).

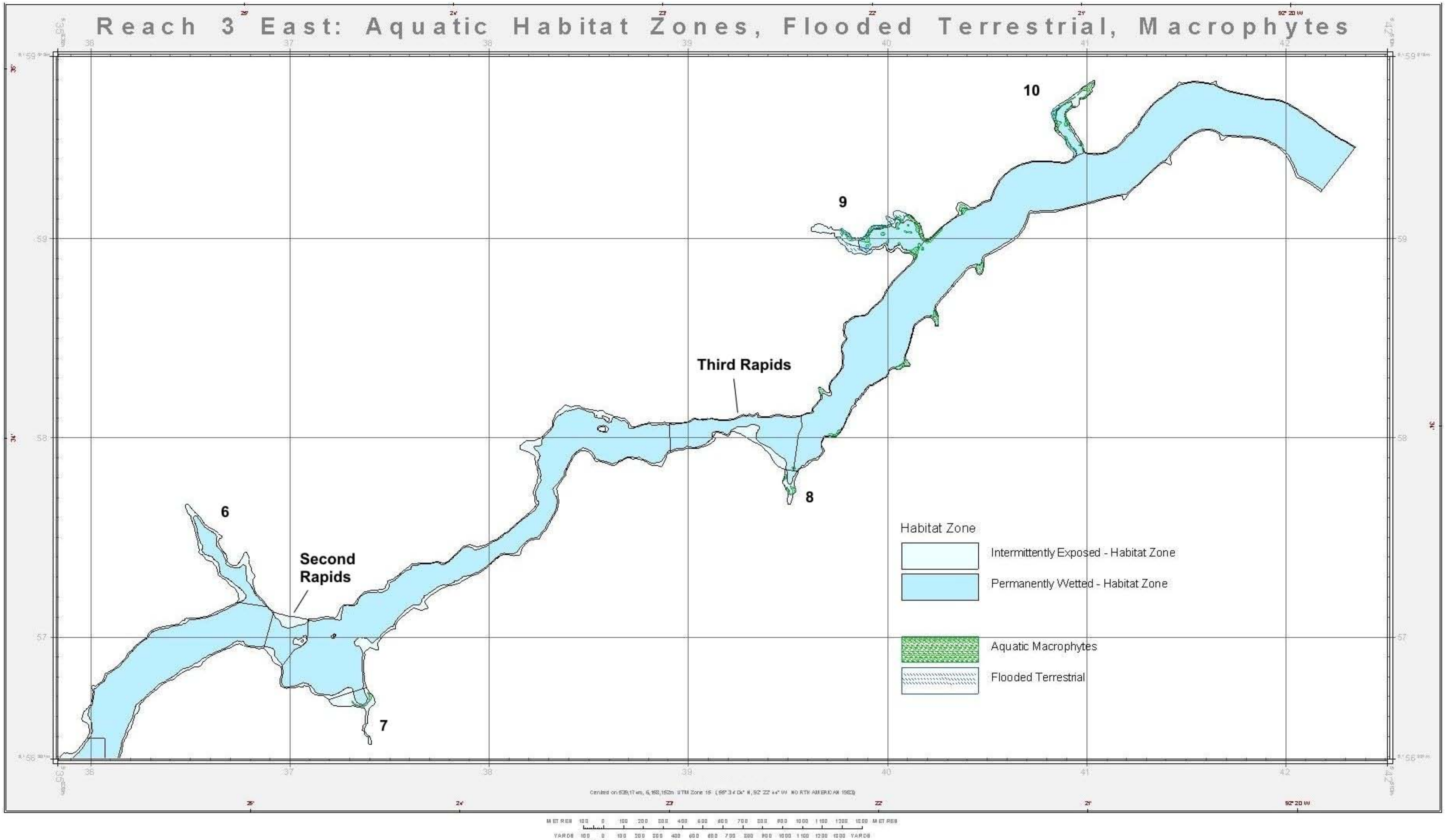


Figure 6-20B. Existing aquatic habitat zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants in the lower portion of Reach 3 (95th percentile flow event).

Aquatic habitat is predominantly found within the wetted portion of the river mainstem (Table 6-12, Figure 6-20). The IEZ occupies a larger area within the mainstem than in the backwater inlets; however, a greater proportion of aquatic habitat in the backwater inlets is intermittently exposed (53 %) due to the lower relief and shallower water depths (Table 6-12).

Table 6-11. Existing surface area, and water depth and volume in Reach 3.

Subsystem	95th Percentile Flow Event			
	Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Volume (m^3)
Mainstem	260.1	25.3	7.6	19765236
Backwater inlets	36.6	6.6	1.9	695215
Reach 3 Total	296.7	25.3	6.9	20460451

Table 6-12. Existing areas for the intermittently exposed and wetted habitat zones in Reach 3.

Habitat Zone Subsystem	Intermittently Exposed Area (ha)	Wetted Area (ha)	Total Area (ha)
Mainstem	24.8	235.4	260.1
Backwater inlets	19.3	17.2	36.6
Reach 3 Total	44.1	252.6	296.7

The Burntwood River mainstem is characterized by a gentle gradient with greater changes in surface elevation occurring at three series of **rapids**: Little Jackpine Rapids (downstream of backwater inlet 5); Second Rapids (immediately downstream of inlet 6); and Third Rapids (immediately upstream of inlet 8) (Figure 6-21). As in Reach 2, the substrata generally reflect the distribution of water velocities. Throughout the length of Reach 3, the central channel and outside bends of the river are either bedrock (20.7 %) or boulder/cobble (20.5 %), as the river is relatively narrow and water velocity is higher (Figure 6-22). The substrate is generally hard silt/clay-based (24.9 %) in portions of the river where the channel is wider and there is reduced water velocity. Immediately downstream of Taskinigup Falls, the river channel is entirely bedrock with boulder/cobble and some gravel lining the banks (Figure 6-23). At the margins of the river and in the backwater inlets, the majority of substrata are soft silt/clay-based (32.7 %). Existing areas of substrata types in Reach 3 are presented in Table 6-13.

Figure 6-21. Aerial views of Little Jackpine Rapids (top), Second Rapids (middle), and Third Rapids (bottom) in Reach 3. Arrow indicates direction of water flow.

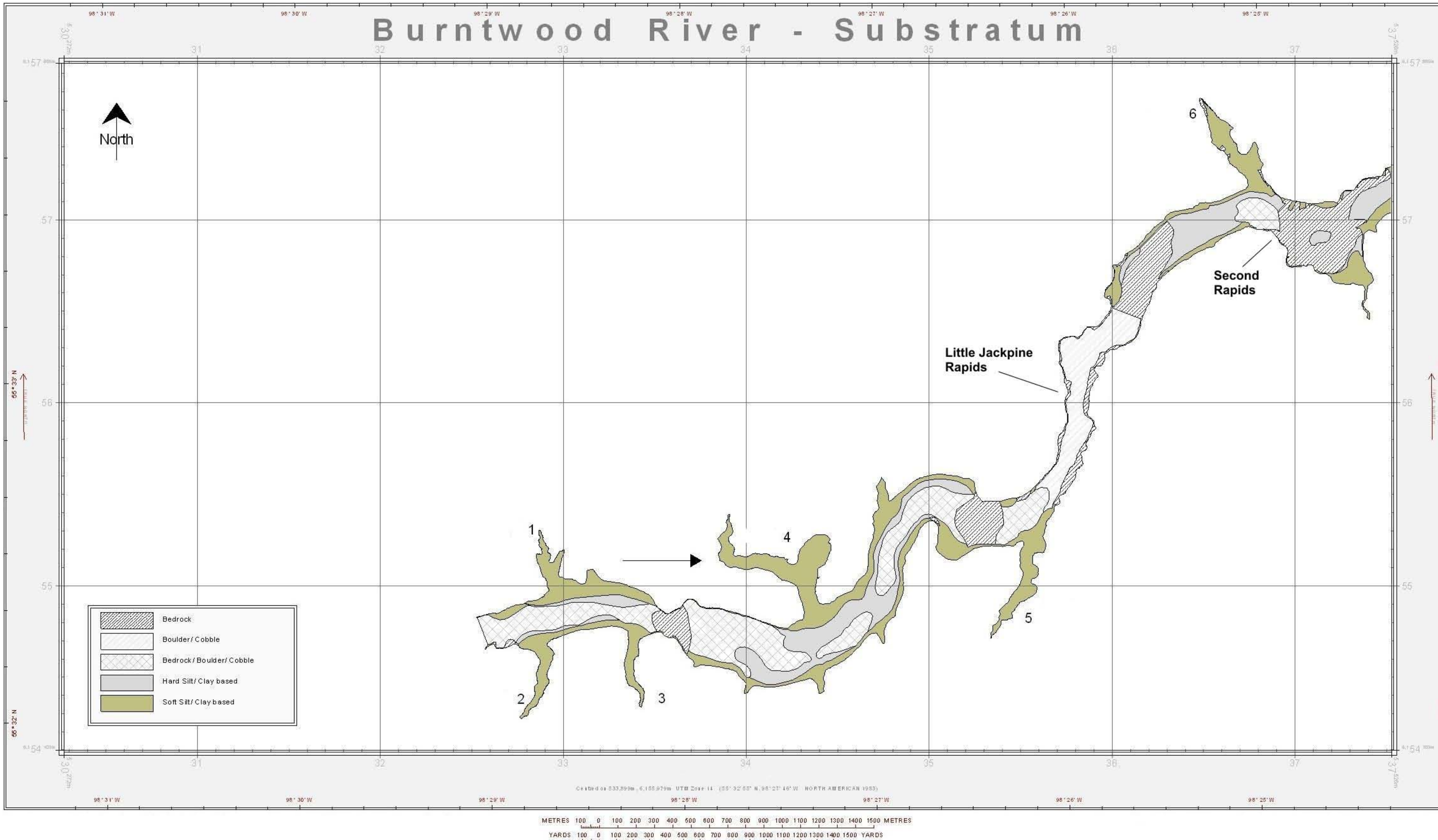


Figure 6-22A. Existing substrata types in the upper portion of Reach 3.

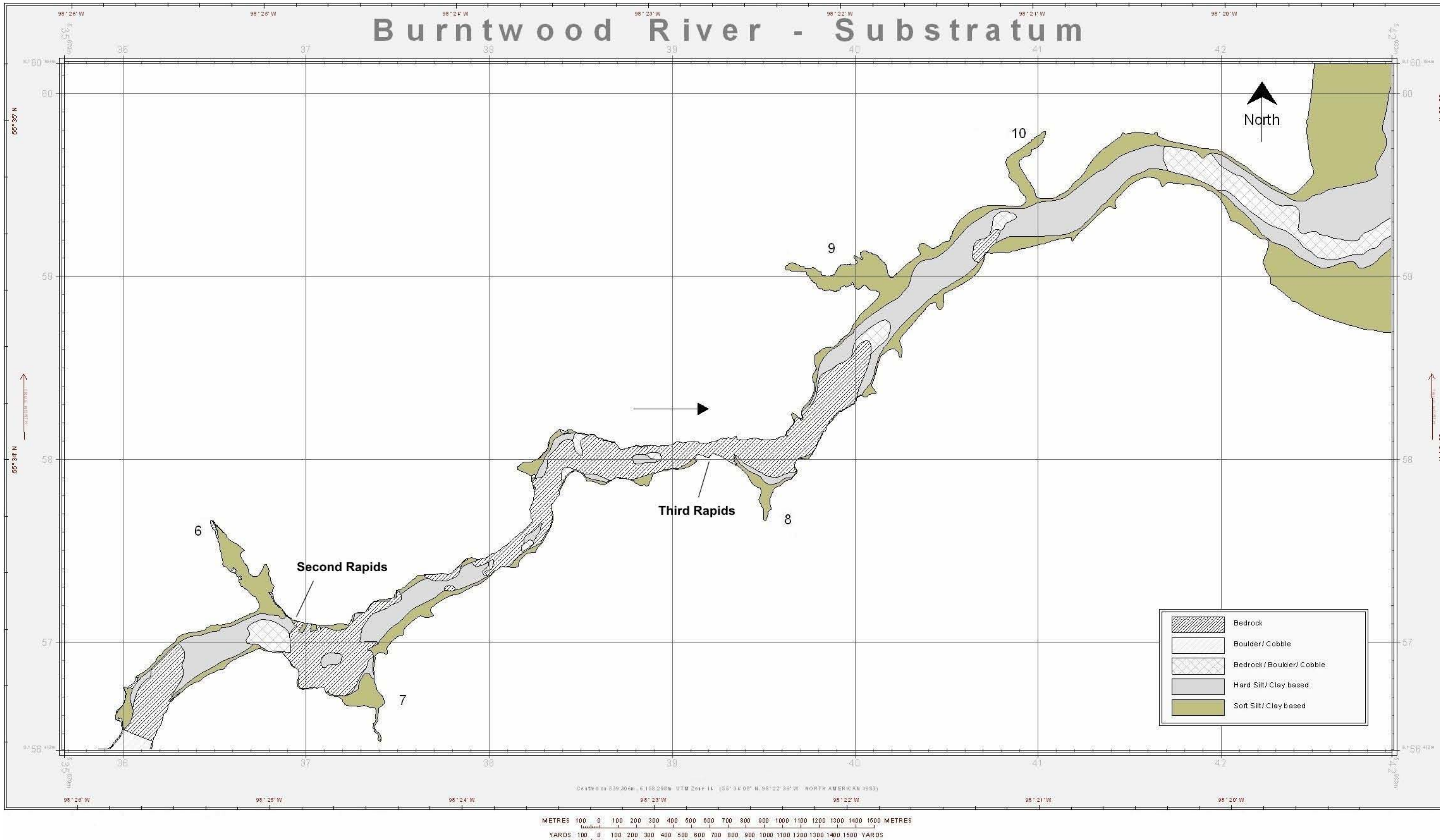


Figure 6-22B. Existing substrata types in the lower portion of Reach 3.

Figure 6-23. Bedrock with boulder/cobble and gravel deposit typical of the north-side bank near the base of Taskinigup Falls.

Table 6-13. Existing areas of substrata types in Reach 3.

Substrata Type Subsystem	Bedrock Area (ha)	Boulder/cobble Area (ha) [1]	Hard silt/clay- based Area (ha)	Soft silt/clay- based Area (ha)	Flooded terrestrial Area (ha)
Mainstem	61.2	60.9	73.9	63.9	0.2
Backwater inlets	0.3	0.0	0.0	33.1	3.2
Reach 3 Total	61.5	60.9	73.9	97.0	3.4

[1] includes Bedrock/Boulder/cobble classification (6.3 ha in mainstem)

The general horizontal pattern of water velocity in the river mainstem is a central band of higher velocities that diminishes towards the banks (Figure 6-24). In general, faster moving water is associated with the three series of rapids (Figure 6-21) and is visible as a higher velocity tailrace downstream of each set of narrows. Water velocity in the backwater inlets is restricted to areas adjacent to the mainstem and, as such, water movements in the inlets are limited. Existing areas of low, medium, and high water velocities in Reach 3 are presented in Table 6-14.

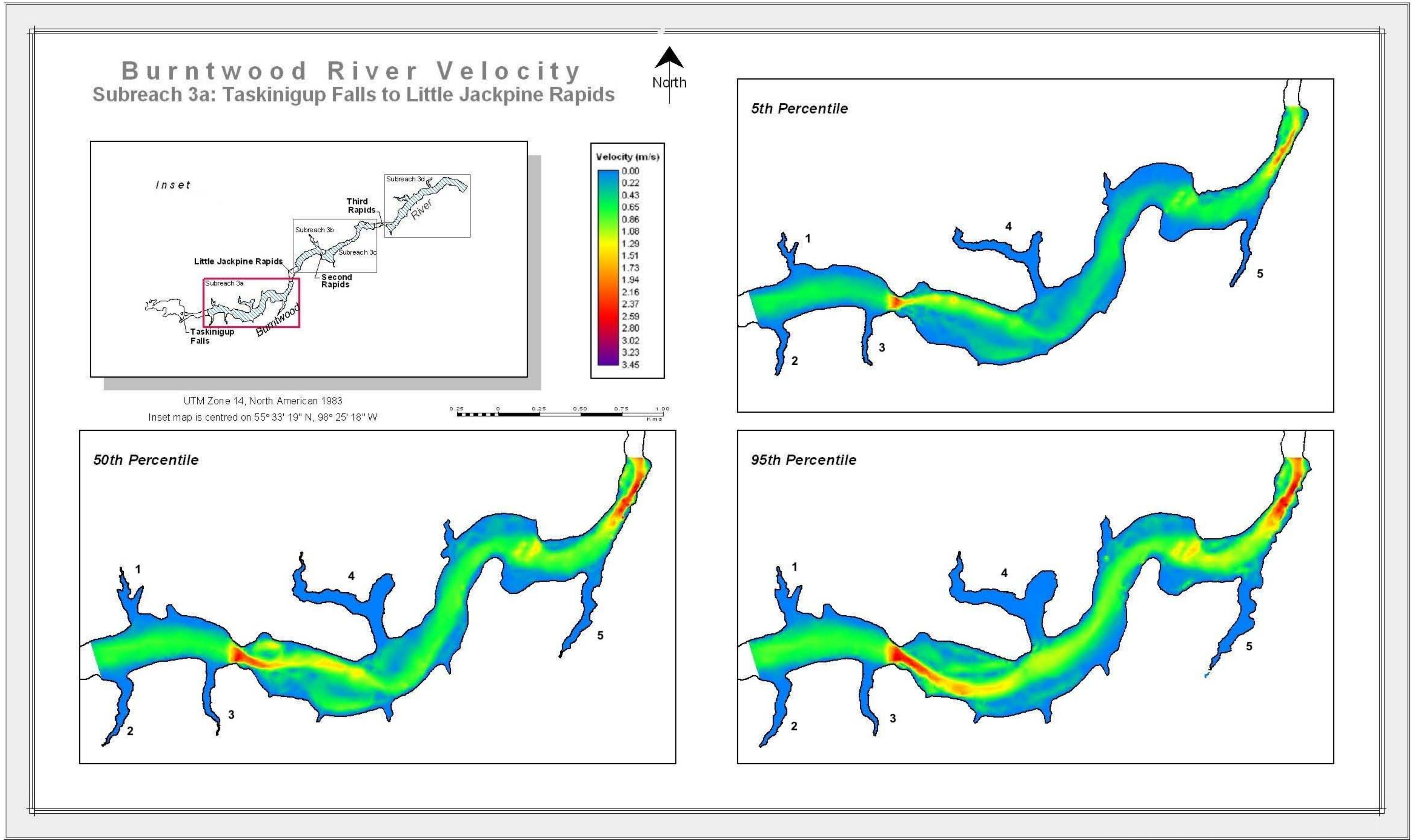


Figure 6-24A. Existing water velocities in Reach 3: Taskinigup Falls to Little Jackpine Rapids.

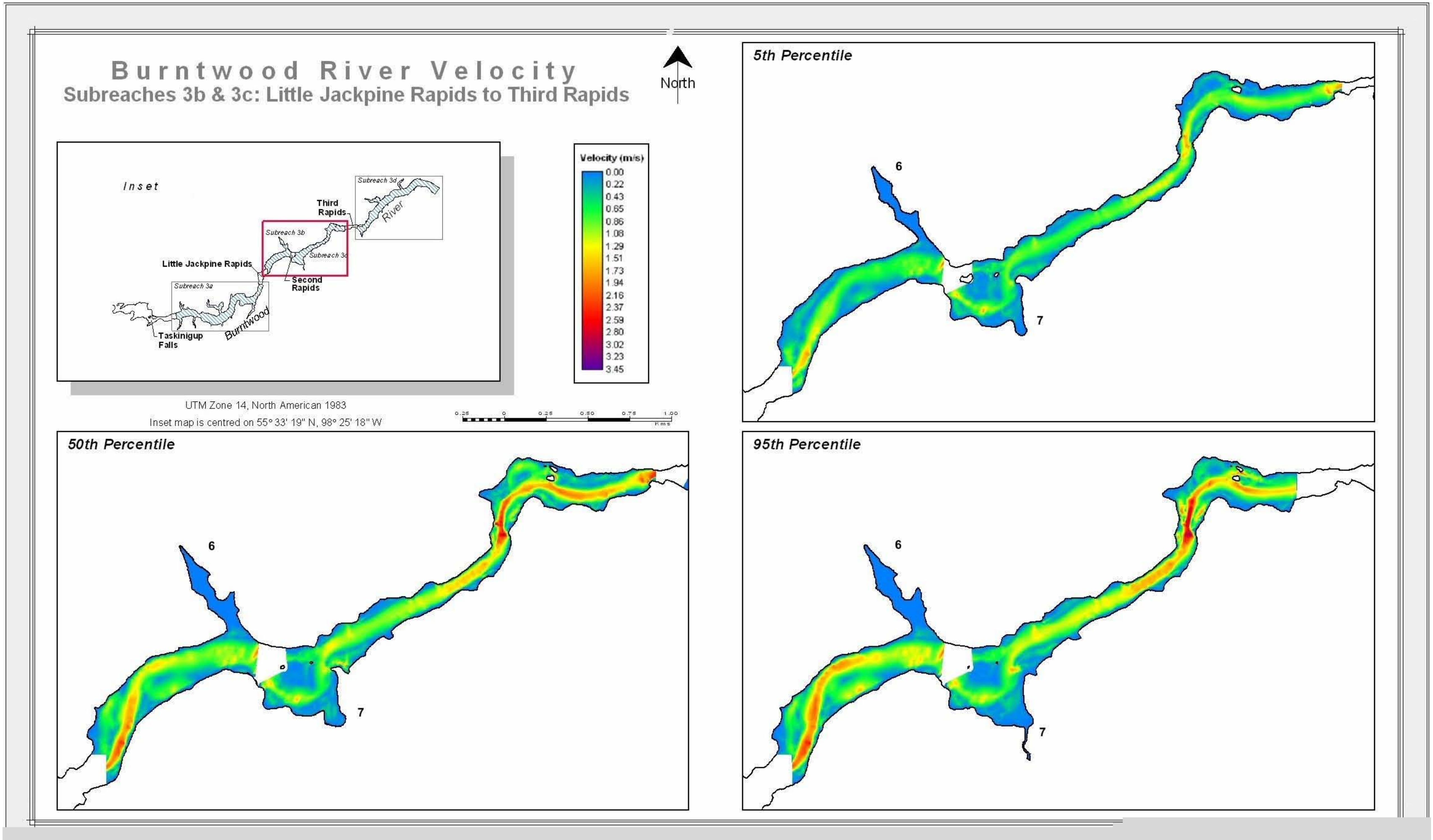


Figure 6-24B. Existing water velocities in Reach 3: Little Jackpine Rapids to Third Rapids.

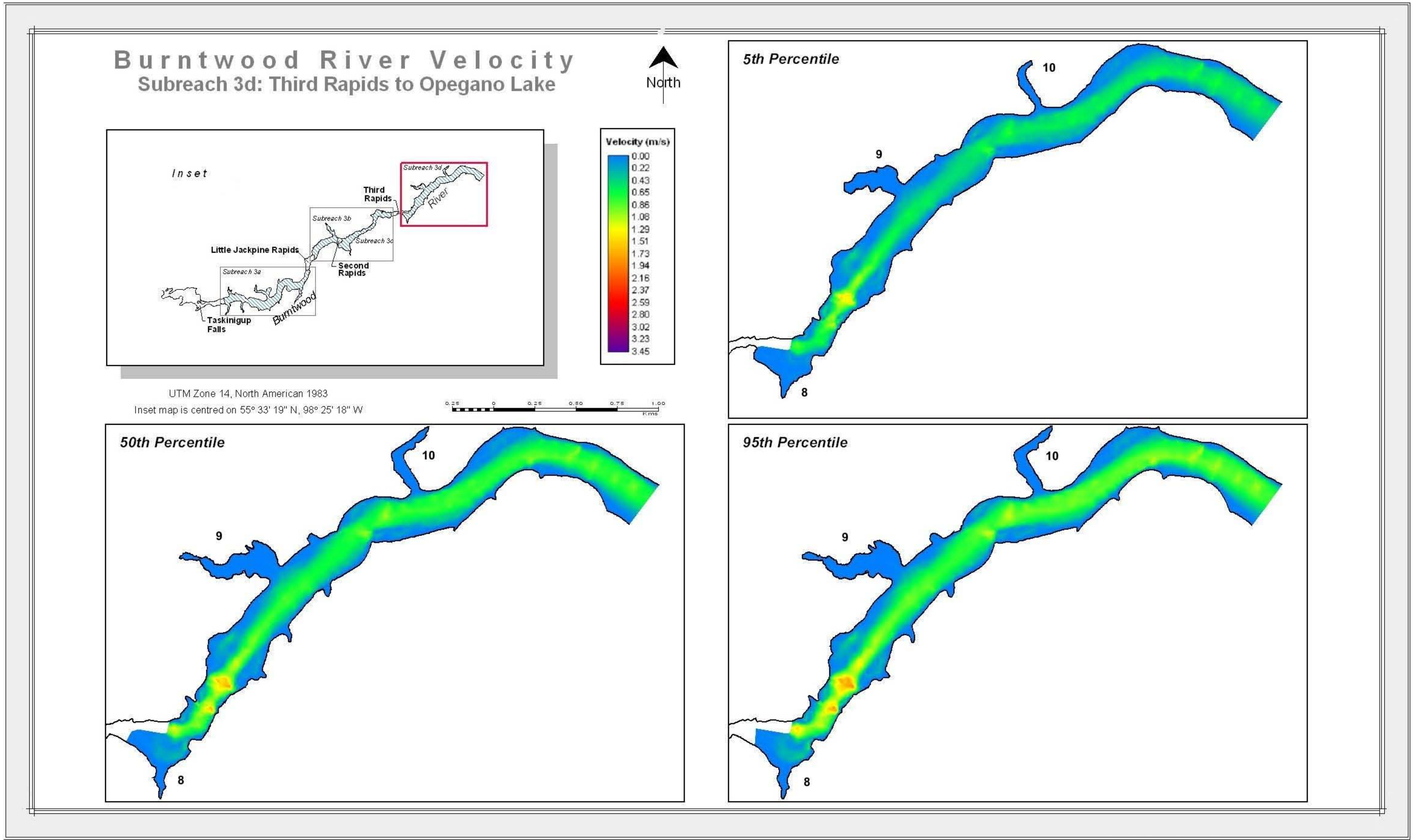


Figure 6-24C. Existing water velocities in Reach 3: Third Rapids to Opegano Lake.

Table 6-14. Existing areas of low, medium, and high water velocities in Reach 3.

Water Velocity Subsystem	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Mainstem	121.9	126.0	12.2
Backwater inlets	36.6	0.0	0.0
Reach 3 Total	158.5	126.0	12.2

Except for inlets 4, 9, and 10, the backwater inlets have relatively small flooded terrestrial areas in their upper ends where relief is low. Inlets 4 and 10 have more extensive flooded **marsh**-like areas characterized by grasses and **sedges** (Figure 6-25) and inlet 9 has flooded terrestrial areas characterized by flooded peat and trees. The flooded terrestrial area in Reach 3 occupies approximately 3.4 ha, with the majority (93.0 %) in the backwater inlets (Table 6-13). The backwater inlets have soft silt/clay-based substrata throughout; however, inlet 6 has an area of boulder/cobble where the tributary enters the inlet (Figure 6-26). Typically, the banks of the inlets are silt/clay-based, with the majority having large woody debris (e.g. logs, branches) on shore (Figure 6-27).

Figure 6-25. Flooded terrestrial areas of backwater inlet 10 characterized by grasses and sedges.

Figure 6-26. Boulder/cobble area where the tributary enters backwater inlet 6.

Figure 6-27. Representative silt/clay-based banks of inlet with large woody debris.

Rooted submergent aquatic plants occupy an area of 3.9 ha in Reach 3, predominantly in the IEZ (Table 6-15). Areas within the backwater inlets support the majority of submergent aquatic plant growth (64.5 %). Aquatic plants occupy the greatest area in inlets 4, 9 (Figure 6-28), and 10 (Figure 6-29). The majority of aquatic plants within the mainstem reside in small notch inlets where water depth is shallower and water velocities are reduced.

Table 6-15. Existing areas for rooted submergent aquatic plants in Reach 3.

Habitat Zone Subsystem	Intermittently Exposed Area (ha)	Wetted Area (ha)	Total Area (ha)
Mainstem	0.9	0.4	1.4
Backwater inlets	1.8	0.7	2.5
Reach 3 Total	2.7	1.1	3.9

Figure 6-28. Aerial view of backwater inlet 9 with rooted submergent aquatic plant beds.

Figure 6-29. Aerial view of backwater inlet 10 with rooted submergent aquatic plant beds.

6.3.4 Reach 4: Opegano

Opegano Lake is approximately 5 km long by 1.5 km wide. The reach extends approximately 3.4 km downstream of Opegano Lake to Jackpine Falls (Figure 6-30).

Figure 6-30. Aerial view of Jackpine Falls looking east in a downstream direction.

Aquatic habitat in this section is described at the 95th percentile water level (shoreline elevation 208.6 m ASL). Opegano Lake has a surface area of 788 ha, a maximum water depth of approximately 12.2 m, a mean water depth of 4.3 m, and a water volume of 34 million m^3 (Table 6-16, Figure 6-31). The Burntwood River flows through the lake in a deeper channel (up to 12.2 m in depth) (Figure 6-31). All aquatic habitats in Opegano Lake were classified using the lacustrine system (Table 6.1). The extents of the intermittently exposed, nearshore, and offshore zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants are presented in Figure 6-32. Within Opegano Lake, the intermittently exposed, nearshore, and offshore zones each occupy approximately 49.8 ha (6.3 %), 497.9 ha (63.2 %), and 240.6 ha (30.5 %), respectively (Table 6-17).

Table 6-16. Existing surface area, and water depth and volume in Reach 4.

Waterbody	95th Water Level Percentile			
	Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Volume (m^3)
Opegano Lake	788.2	12.2	4.3	34279608

Table 6-17. Existing areas for the intermittently exposed, nearshore, and offshore habitat zones in Reach 4.

Habitat Zone	Area (ha)
Intermittently Exposed	49.8
Nearshore	497.9
Offshore	240.6
Total	788.2

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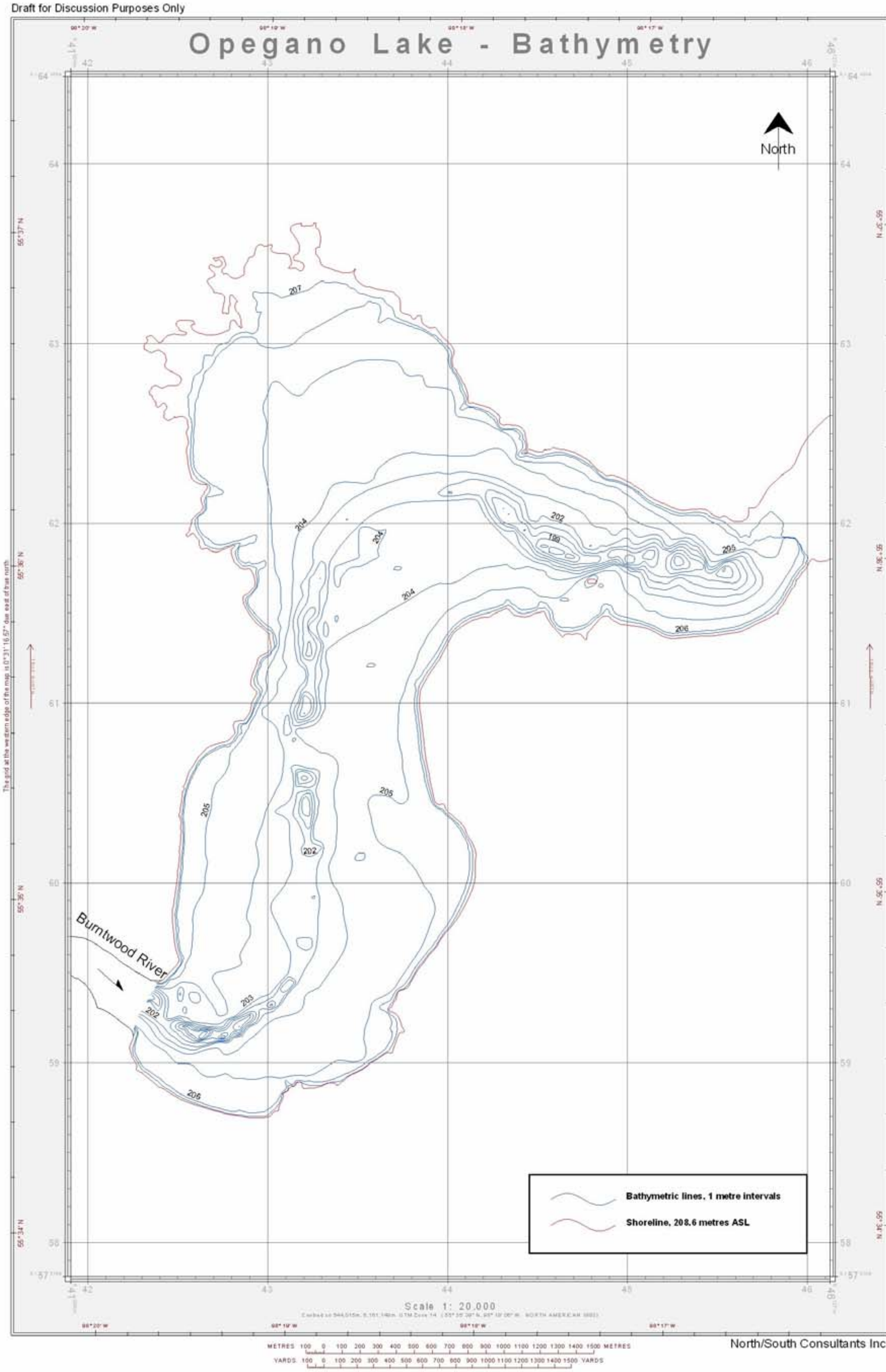


Figure 6-31. Existing bathymetric contours for Reach 4 (shoreline at 208.6 m ASL).

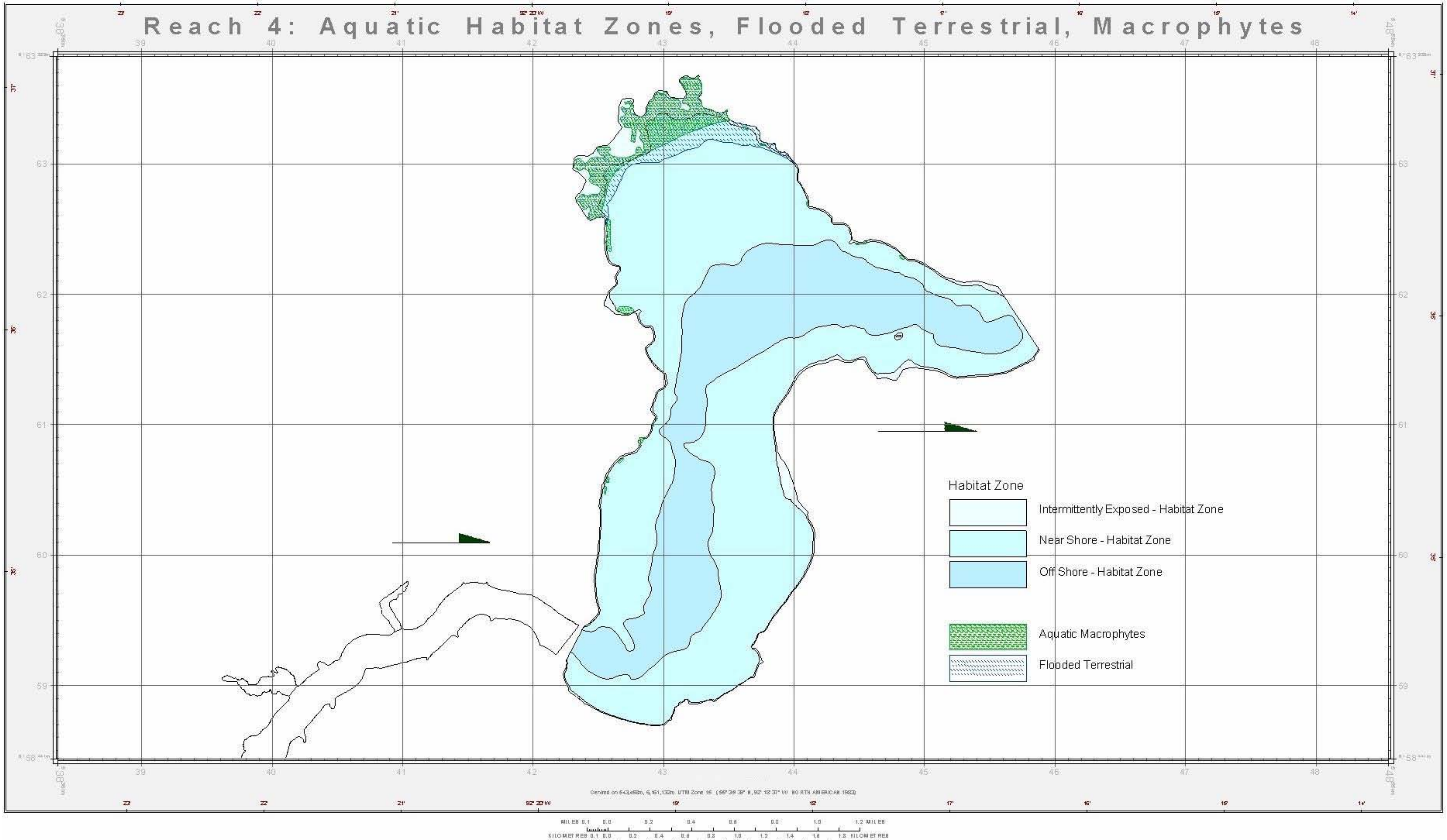


Figure 6-32. Existing aquatic habitat zones, flooded terrestrial areas, and distribution of rooted submergent aquatic plants in Reach 4 (shoreline at 208.6 m ASL).

The majority of Opegano Lake's shoreline consists of steep, exposed, silt/clay-based banks. A narrow band of bedrock occurs along the southern shoreline at the water's edge with **shrub**s and trees above the level of wave action. There are a few small bedrock shoals along the margin of the lake and one mineral island situated near the outlet. The majority of the bottom substrata in shallower water is soft silt/clay-based (63.5 %), except in the deeper water within the middle channel where the bottom is either boulder/cobble (3.2 %) or hard silt/clay-based (26.2 %) (Figure 6-33). The flooded terrestrial area in Opegano Lake occupies about 45.5 ha, with the majority in the north end of the lake where relief is lower. Existing areas of substrata types in Reach 4 are presented in Table 6-18.

Table 6-18. Existing areas of substrata types in Reach 4.

Substrata Type	Area (ha)
Bedrock	9.9
Boulder/cobble	25.6
Hard silt/clay-based	206.4
Soft silt/clay-based	500.9
Flooded terrestrial	45.5
Total	788.2

Rooted submergent aquatic plants are present in 45.5 ha in Opegano Lake, with about 48 % in the IEZ and 52 % in the nearshore. Aquatic plants are predominantly found in the flooded terrestrial areas in the north end of Opegano Lake (Figure 6-34), with small patches of aquatic plants growing in sheltered areas along the west and east shores. As in other reaches, the flooded terrestrial areas support the majority of submergent aquatic plant growth.

Figure 6-34. Rooted submergent aquatic plants in the flooded terrestrial area in the north end of Opegano Lake.

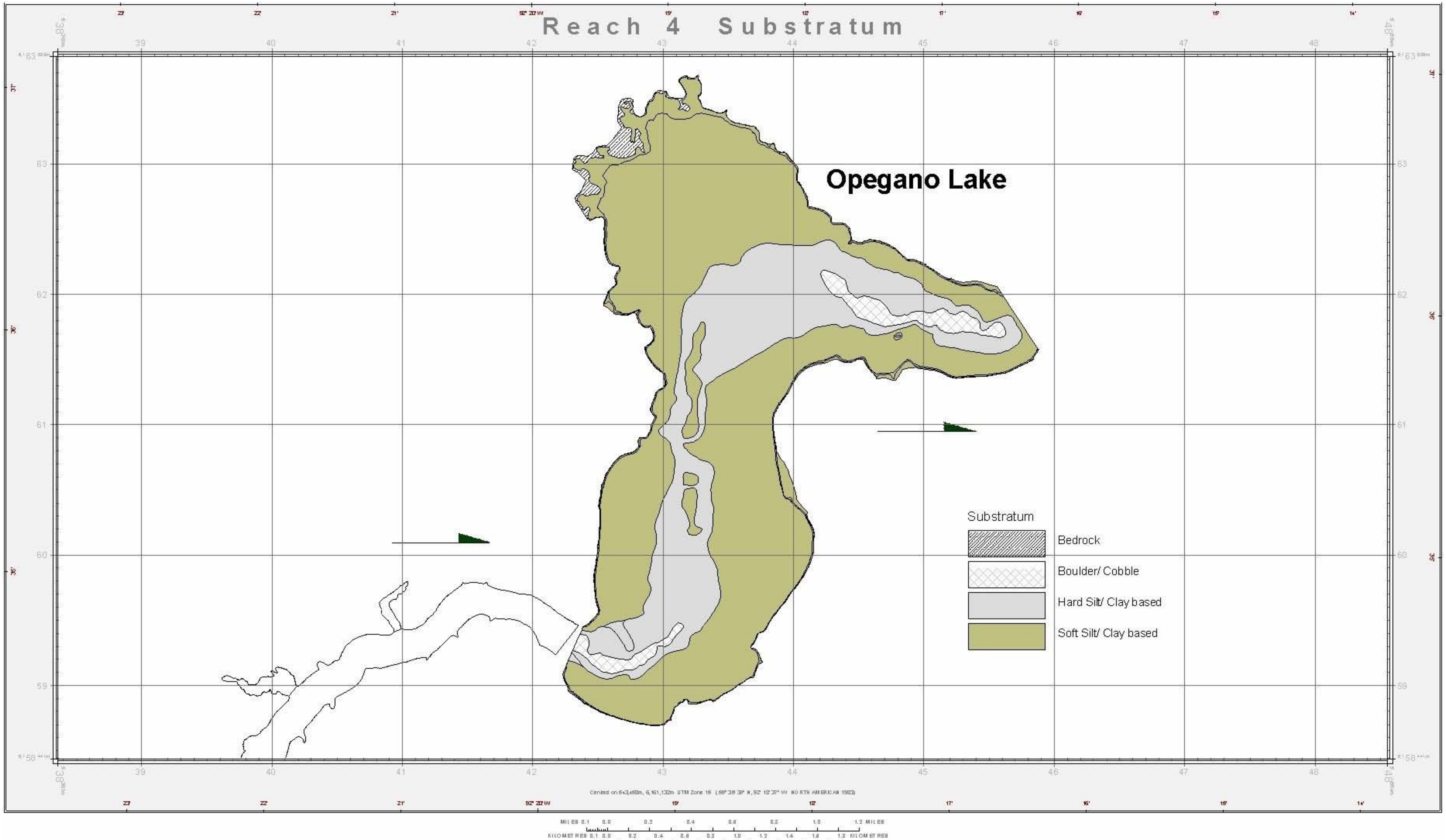


Figure 6-33. Existing substrata types in Reach 4.

6.3.5 Stream Crossings

The aquatic habitat of streams crossed by the access road is summarized in Table 6-19. These streams originate in poorly drained **fen**s, with the majority classified as having marginal fish habitat and all with a low environmental sensitivity rating. The two exceptions were the stream at R5, a tributary of Birch Tree Brook, and the stream at R8, a tributary of the Burntwood River (backwater inlet 6 in Reach 3). The habitat within these two streams is considered adequate to support and over-winter spring-spawners (e.g., white sucker, northern pike); however, spawning potential for fish is probably limited by beaver dams and other obstructions to movements. Information for crossings investigated in winter (March, 2002), are presented within water and sediment quality (Section 5.0), and fish community and movements (Section 8.0) sections.

Table 6-19. Stream classifications for access road crossings.

Crossing No.	Station No. [1]	UTM Zone	UTM Easting	UTM Northing	Stream Description	Fish-Bearing [2]	Stream Order [3]	Fish Habitat	Sensitivity
R1	432+20	14U	548247	6188627	Originates in poorly drained fen; low flows after the freshet	Forage fish	1	Marginal	Low
R2	345+00	14U	548855	6180026	Originates in poorly drained fen	Forage fish	3	Marginal	Low
R3	243+00	14U	549649	6173337	Originates in poorly drained fen; low flows after the freshet	Forage fish	1	Marginal	Low
R4	223+60	14U	545372	6171063	Originates in poorly drained fen	Forage fish	1	Marginal	Low
R5	187+20	14U	542112	6169678	Originates in poorly drained fen	Forage fish; WHSC	2	Important	Low
R6	167+40	14U	541197	6167937	Originates in poorly drained fen	Forage fish; WHSC	2	Marginal	Low
R7	82+70	14U	537350	6160669	Originates in poorly drained fen	Forage fish	1	Marginal	Low
R8	60+60	14U	536478	6158672	Originates in poorly drained fen	Forage fish; WHSC	1	Important	Low

[1] Station No. = Manitoba Hydro crossing designation
[2] WHSC = white sucker
[3] Stream order based on 1:50 000 NTS map

6.3.5.1 Stream Crossing R1

Stream crossing R1 intersects a tributary to the Odei River (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-20. The RoW crossed the stream at a beaver dam-created flooded terrestrial area. The stream contained multiple channels downstream of the RoW and featured a flooded fen area with **submerged** willows upstream. At the survey transect, about 12 m downstream of the RoW where the stream formed a single channel, the stream had a maximum depth, mean water velocity, and measured discharge of 1.0 m, 0.19 m/s, and 0.23 m^3/s, respectively. The surveyed reach consisted of 70 % pool, 25 % **glide**, and 5 % **riffle** habitat and had poorly compacted silt/clay-based substrata. Other cover included large organic debris (LOD), mostly in the form of submerged willows (15 %). The wetted width (6.5 m) at the RoW was similar to the channel width due to flooding.

The fish habitat assessment for the stream was 'Low-Moderate' for forage fish species. After the spring freshet, water levels and flows would become reduced and the stream could potentially freeze to the bottom in the winter. However, if water stage remained near what was observed during the spring survey, the stream would provide pool and beaver pond habitats that might be adequate for over-wintering of brook stickleback. The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners (e.g., northern pike and white sucker). Spawning potential for these fish is probably limited by beaver dams and other obstructions to movements, and dissolved oxygen levels would likely be less than suitable for over-wintering.

The stream is classified as having 'Marginal' fish habitat and a 'Low' environmental sensitivity.

6.3.5.2 Stream Crossing R2

The stream at R2 is a tributary of Birch Tree Brook (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-21. The RoW transverses a saturated fen and stream with poorly defined channel margins. At a location where the stream was contained in one channel, it had an average wetted width of 7.7 m with a similar channel width due to the high stage. Floodplain width at the RoW was 44 m. Maximum depth, mean velocity, and measured discharge was 1.0 m, 0.14 m/s, and 0.64 m^3/s, respectively. The entire reach consisted of pools and pool-glides with poorly compacted silt/clay-based substrata. Although early in the growing season, rooted aquatic plants were present and contributed 1 % cover. Other cover included LOD (10 %) and pools (20 %).

The fish habitat assessment for the stream was 'Moderate' for forage fish species. There are pool and beaver pond habitats potentially adequate for over-wintering of forage fish that can tolerate low dissolved oxygen levels. The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners; beaver dams and other obstructions to movements probably limit spawning potential for these fish, and over-wintering habitat is poor.

The stream is classified as having 'Marginal' fish habitat and a 'Low' environmental sensitivity.

6.3.5.3 Stream Crossing R3

Stream crossing R3 intersects a tributary of Birch Tree Brook (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-22. The RoW crosses the stream at a beaver pond that is 9.0 m wide and has maximum depth of 1.0 m. The dam for this pond is 10 m downstream of the RoW. The reach below the dam had a channel width of 2.8 m, a wetted width of 2.2 m, and a maximum depth of 0.65 m. Water velocity and discharge measurements were taken 150 m downstream of the RoW where the flow was contained in a defined channel. At this point, the stream had a maximum depth, mean velocity, and measured discharge of 0.65 m, 0.26 m/s, and 0.13 m^3/s, respectively. Floodplain width at the RoW was 15 m. The surveyed reach consisted of pool and pool-glide habitat. Substrata were variable, consisting of unconsolidated fines at the RoW, boulder/cobble and gravel 10 m downstream, and unconsolidated fines further downstream. Immediately upstream of the RoW were two consecutive beaver dams, with a large beaver pond created by the furthest one. Beyond this point the stream was ephemeral.

The fish habitat assessment for the stream was 'Moderate' for forage fish species. The stream provides pool and beaver pond habitats that may be adequate for over-wintering of forage fish. The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners. As at R1 and R2, spawning potential for these fish is probably limited.

The stream is a poorly drained fen stream classified as having 'Marginal' fish habitat with a 'Low' environmental sensitivity rating.

6.3.5.4 Stream Crossing R4

Stream crossing R4 is upstream of R3 along the same tributary to Birch Tree Brook (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-23. The RoW intersects the stream at a beaver dam that maintains a large, 70 m wide pond with a maximum depth of 1.7 m. The pond empties into a meandering stream with poorly defined channel margins and large off-channel pools. Water velocity and discharge measurements were taken 50 m downstream where the flow was contained in a defined channel. At this point, the stream had a maximum depth, mean velocity, and discharge of 1.1 m, 0.10 m/s, and 0.27 m^3/s, respectively; channel width and wetted width were both 3.9 m (due to high stage), and floodplain width was 70 m. The surveyed reach consisted mainly of pool-glide habitat with small riffle areas below dams (about 1 %) and poorly compacted silt/clay-based substrata. In-stream cover included submerged grasses and shrubs at the channel margins (5 %) and LOD (1 %).

The fish habitat assessment for the stream was 'Moderate' for forage fish species. The stream provides pool and beaver pond habitats that may be adequate for over-wintering of forage fish that can tolerate low dissolved oxygen levels. The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners. As at preceding crossings, spawning potential for these fish is likely limited.

The stream is classified as having 'Marginal' fish habitat and a 'Low' environmental sensitivity.

6.3.5.5 Stream Crossing R5

Stream Crossing R5 intersects a tributary of Birch Tree Brook and is in the same drainage as the streams crossed by R3 and R4 (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-24. At the RoW, the stream had a distinct channel and an average channel width of 5.9 m with a similar wetted width (5.5 m) due to the high stage. Floodplain width at the RoW was 60 m. Maximum water depth, mean velocity, and measured discharge were 1.3 m, 0.14 m/s, and 0.67 m^3/s, respectively. Upstream and downstream reaches consisted of multiple channels. The surveyed reach consisted of pool-glide habitat with some riffle areas below beaver dams (1%) and poorly compacted silt/clay-based substrata. In-stream cover included submerged grasses and shrubs at the channel margins (10 %) and LOD (1 %).

The fish habitat assessment for the stream was 'Moderate-High' for forage fish species. The stream provides pool and beaver pond habitats that would be adequate for over-wintering of forage fish (i.e., adequate dissolved oxygen levels). The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners. Although there is adequate habitat to support and over-winter spring-spawners, spawning potential for these fish is probably limited by beaver dams and other obstructions to movements.

The stream is classified as having 'Important' fish habitat and a 'Low' environmental sensitivity.

6.3.5.6 Stream Crossing R6

The access road intersects a tributary of Birch Tree Brook at stream crossing R6 (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-25. This stream is part of the same drainage as the streams crossed at R3, R4, and R5. At the RoW, the stream has a distinct channel, and an average wetted width of 4.4 m and a channel width of 5.3 m. Floodplain width at the RoW was 57 m. Maximum water depth, mean velocity, and measured discharge were 1.1 m, 0.22 m/s, and 0.71 m^3/s, respectively. Upstream and downstream reaches of the stream split into side channels and partially isolated oxbows. Pool/glide habitat was the dominant hydraulic feature and substrata were poorly compacted silt/clay-based. In-stream cover included LOD (1 %) and submerged grasses and shrubs at the channel margins (5 %).

The fish habitat assessment for the stream was 'Moderate' for forage fish species, as pools (up to 2.0 m water depth at high stage) are present that could provide adequate over-wintering habitat. The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners. Beaver dams and other obstructions to movements probably limit spawning potential for these fish, and over-wintering habitat is sub-optimal (i.e., inadequate dissolved oxygen levels).

The stream is classified as having 'Marginal' fish habitat and a 'Low' environmental sensitivity.

6.3.5.7 Stream Crossing R7

Stream crossing R7 occurs at a tributary of the Burntwood River (flows into backwater inlet 9 in Reach 3) (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-26. At the RoW, the stream has a distinct channel, and an average wetted width of 2.0 m and a channel width of 3.3 m. Floodplain width at the RoW was 14 m. Maximum water depth, mean velocity, and measured discharge were 0.5 m, 0.33 m/s, and 0.25 m^3/s, respectively. At the RoW, the stream flowed in a single channel and was all shallow run with no riffles. The substrata were poorly compacted silt/clay-based, and in-stream cover included LOD (1 %) and some pool areas (2 %).

The fish habitat assessment for the stream was 'Moderate' for forage fish species. The stream provides pool and beaver pond habitats that may be adequate for over-wintering of forage fish that can tolerate low dissolved oxygen levels. The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners. Beaver dams and other obstructions to movements probably limit spawning potential for these fish, and over-wintering habitat is likely sub-optimal (i.e., inadequate dissolved oxygen levels).

The stream is classified as having 'Marginal' fish habitat and a 'Low' environmental sensitivity.

6.3.5.8 Stream Crossing R8

Stream crossing R8 occurs at a tributary of the Burntwood River (flows into backwater inlet 6 in Reach 3) (Figure 6-3). A detailed aquatic habitat description and photographic documentation of the surveyed reach is presented in Table 6-27. The stream has a distinct channel at the RoW, however, upstream and downstream reaches had multiple channels. At the RoW, the average wetted width was 3.4 m, the channel width was 3.8 m, and the floodplain width was 14 m. Maximum water depth, mean velocity, and measured discharge were 0.9 m, 0.26 m/s, and 0.56 m^3/s, respectively. Pool-glide habitat was the dominant hydraulic feature with riffle habitat occurring in 5 % of the survey reach. The substrata were poorly compacted silt/clay-based, and in-stream cover included LOD (2 %), undercuts (1 %), and pools (5 %).

The fish habitat assessment for the stream was 'Moderate-High' for forage fish species. The stream provides pool and beaver pond habitats that would be adequate for over-wintering of forage fish. The fish habitat assessment was 'Low-Moderate' for large bodied spring-spawners. The habitat in this stream is likely adequate to support and over-winter spring-spawners at the observed high stage, however, spawning potential for these fish is probably limited by beaver dams and other obstructions to movements.

The stream is classified as having 'Important' fish habitat and a 'Low' environmental sensitivity.

Table 6-20. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R1.

Background Information

UTM (NAD83) at RoW:
14U 548247 **E** 6188627 **N**

Date of Survey:	10-Jun-02
Survey Type:	Field
Stream Order:	1
Length Surveyed	
Upstream (m):	20
Downstream (m):	30

Water Quality

Temperature (°C):	15
Conductivity (µS/cm):	n/a
pH:	n/a
Turbidity (NTU):	n/a
Dissolved Oxygen:	n/a
Stage:	High
Discharge (m^3/s):	0.23

Aerial view (line indicates location of proposed crossing).

Upstream view.

Downstream view.

RoW Transect Summary

Channel Width (m):	6.5 (flooded at RoW)
Wetted Width (m):	6.5 @ RoW; 2.9 @ velocity transect 12 m downstream of RoW
Maximum Depth (m):	1.0
Average Velocity (m/s):	0.19 @ 12 m downstream of RoW
Cover Type and Composition:	LOD – 15%; pools – 70%
Substrate:	unconsolidated fines
Floodplain Width (m):	45
Morphology:	RoW was a shallow beaver pond area with submerged willows/shrubs; downstream of RoW were multiple channels through willow/shrub area with mostly riffle and glide habitat in the main channel and small, shallow (<0.4 m deep) pools off-channel; upstream of RoW was a flooded willow/bog area.
Comments:	15% LOD; numerous beaver dams: 2 small dams 5 and 13 m downstream of RoW; a large dam 200 m downstream; and a large old dam immediately upstream of RoW.

From right bank looking at left bank (line indicates location of proposed crossing).

From left bank looking at right bank (line indicates location of proposed crossing)

Sensitivity to Disturbance

Low:	Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

Fisheries Assessment

Capture Method:	no fish inventory
Survey Length:	no fish inventory
Species Present:	BRST observed
Life History Stages:	adult
Abundance CPUE (fish/min):	no fish inventory

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:

Spawning Habitat:	low-moderate
Overwintering Habitat:	low
Rearing Habitat:	moderate
Comments:	Spawning potential limited by beaver dams and other obstructions to upstream movement.

Forage Fish:

Spawning Habitat:	moderate
Overwintering Habitat:	low
Rearing Habitat:	moderate
Comments:	After the spring freshet, water levels and flows would become reduced and the stream could potentially freeze to the bottom in the winter.

Fish Habitat Classification: Marginal

Table 6-21. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R2.

Background Information

UTM (NAD83) at RoW:
14U 548855 **E** 6180026 **N**

Date of Survey: 10-Jun-02

Survey Type: Field

Stream Order: 3

Length Surveyed
Upstream (m): 100
Downstream (m): 200

Water Quality

Temperature (°C): 15

Conductivity (μS/cm): 135

pH: 7

Turbidity (NTU): 8.9

Dissolved Oxygen: 8.31

Stage: High

Discharge (m^3/s): 0.64


Aerial view (line indicates location of proposed crossing).


Upstream view.


Downstream view.

RoW Transect Summary

Channel Width (m): 7.7

Wetted Width (m): 7.7

Maximum Depth (m): 1.0

Average Velocity (m/s): 0.14 (channel had some flow over/through fen at transect resulting in underestimation of discharge)

Cover Type and Composition: aquatic macrophytes – 1%; LOD – 10% (pushed in by exploration road); pools – 20 %; undercuts – unidentifiable due to high stage

Substrate: unconsolidated fines

Floodplain Width (m): 44

Morphology: Flooded fen with channel margins poorly defined (high stage); entire reach consisted of pools and glide-pools with poorly compacted substrates of silt/clay.

Comments: Beaver dam 80 m upstream approximately 0.25 m above water surface; large pool areas downstream; maximum depth upstream was 1.4 m; maximum depth downstream was 1.7 m.


From right bank looking at left bank (line indicates location of proposed crossing).


From left bank looking at right bank (line indicates location of proposed crossing)

Sensitivity to Disturbance

Low: Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

Fisheries Assessment

Capture Method: boat assisted backpack electrofishing
Survey Length: 230 m
Species Present: BRST, FHMN, LKCH, PRDC
Life History Stages: juvenile/adult
Abundance CPUE (fish/min): 2.3

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:
Spawning Habitat: low-moderate
Overwintering Habitat: low
Rearing Habitat: moderate
Comments: Spawning potential limited by beaver dams and other obstructions to upstream movement. Poor overwinter habitat.

Forage Fish:
Spawning Habitat: moderate
Overwintering Habitat: moderate
Rearing Habitat: moderate-high
Comments: The stream provides pool and beaver pond habitats that could be adequate for overwintering forage fish.

Fish Habitat Classification: Marginal

Table 6-22. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R3.

Background Information

UTM (NAD83) at RoW:
14U 549649 **E** 6173337 **N**

Date of Survey: 10-Jun-02

Survey Type: Field

Stream Order: 1

Length Surveyed
Upstream (m): 100
Downstream (m): 200

Water Quality

Temperature (°C): 10

Conductivity (μS/cm): n/a

pH: n/a

Turbidity (NTU): n/a

Dissolved Oxygen: n/a

Stage: High

Discharge (m^3/s): 0.13

Aerial view (line indicates location of proposed crossing).

Upstream view.

Downstream view.

RoW Transect Summary

Channel Width (m): 9.0
Wetted Width (m): 9.0
Maximum Depth (m): 1.0
Average Velocity (m/s): RoW is a beaver pond with low discharge – no velocity measurements taken
Cover Type and Composition: pools – 100%; LOD – 5%; submerged shrubs – 5%
Substrate: unconsolidated fines
Floodplain Width (m): 15
Morphology: flooded fen; beaver pond.
Comments: Beaver dam 10 m downstream of RoW; downstream of this dam the surveyed stream reach narrowed (channel width less than 3 m); 30% LOD in the surveyed reach with 70% soft silt/clay, 20% boulder/cobble, and 10% gravel substrate; stream downstream of RoW initially runs through forested area, with a narrow floodplain, then switches to an open area with a 30 m floodplain; beaver dam 4 m upstream of RoW - 0.35 m above the water surface; a second dam 10 upstream of RoW - 0.7 m above the water surface with a large pond behind it.

Velocity/Discharge Transect Summary – 150 m downstream of RoW

Channel Width (m): 2.8
Wetted Width (m): 2.2
Maximum Depth (m): 0.65
Average Velocity (m/s): 0.26
Cover Type and Composition: pools – 1%; LOD – 2%; undercuts – 2%
Substrate: unconsolidated fines
Floodplain Width (m): 29

Sensitivity to Disturbance

Low: Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

From right bank looking at left bank (line indicates location of proposed crossing).

From left bank looking upstream towards crossing (line indicates location of proposed crossing)

Fisheries Assessment

Capture Method: backpack electrofishing
Survey Length: 100 m
Species Present: BRST
Life History Stages: juvenile/adult
Abundance CPUE (fish/min): 0.2

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:
Spawning Habitat: low-moderate
Overwintering Habitat: low
Rearing Habitat: moderate
Comments: Spawning potential limited by beaver dams and other obstructions to upstream movement.

Forage Fish:
Spawning Habitat: moderate
Overwintering Habitat: moderate
Rearing Habitat: moderate
Comments: The stream provides pool and beaver pond habitats that could be adequate for overwintering BRST.

Fish Habitat Classification: Marginal

Table 6-23. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R4.

Background Information

UTM (NAD83) at Survey Transect:
14U 545372 **E** 6171063 **N**

Date of Survey: 09-Jun-02

Survey Type: Field

Stream Order: 1

Length Surveyed
Upstream (m): 100
Downstream (m): 200

Water Quality

Temperature (°C): 13.1

Conductivity (μS/cm): 74.5

pH: 7

Turbidity (NTU): 2.6

Dissolved Oxygen: 7.52

Stage: High

Discharge (m^3/s): 0.27


Aerial view (line indicates location of RoW; double line indicates survey transect).


Upstream view from survey transect.


Downstream view.

Survey Transect Summary

Channel Width (m): 3.9

Wetted Width (m): 3.9

Maximum Depth (m): 1.1

Average Velocity (m/s): 0.10

Cover Type and Composition: LOD – 1%; submerged grass and shrubs at channel margins – 5%

Substrate: unconsolidated fines

Floodplain Width (m): 70

Morphology: RoW crosses a beaver dam (1.0 m above the water surface) with a large (70 m wide) pond upstream that had a maximum depth of 1.7 m; downstream it is a narrow meandering stream with large off-channel pools; channel margins poorly defined (high stage).

Comments: 20 m downstream of RoW is a beaver dam (0.5 m above the water surface), followed by another beaver dam 25 m downstream (0.2 m above the water surface); mostly pool/glide habitat with small riffle areas below dams (riffle area – 1% of surveyed reach).


From right bank looking at left bank at survey transect.


From left bank looking at right bank at survey transect.

Sensitivity to Disturbance

Low: Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

Fisheries Assessment

Capture Method: boat assisted backpack electrofishing
Survey Length: 135 m
Species Present: BRST; PRDC
Life History Stages: juvenile/adult
Abundance CPUE (fish/min): 1.0

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:
Spawning Habitat: low-moderate
Overwintering Habitat: low
Rearing Habitat: moderate
Comments: Spawning potential limited by beaver dams and other obstructions to upstream movement.

Forage Fish:
Spawning Habitat: moderate
Overwintering Habitat: moderate
Rearing Habitat: moderate
Comments: The stream provides pool and beaver pond habitats that could be adequate for overwintering forage fish.

Fish Habitat Classification: Marginal

Table 6-24. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R5.

Background Information

UTM (NAD83) at RoW:
14U 542112 **E** 6169678 **N**

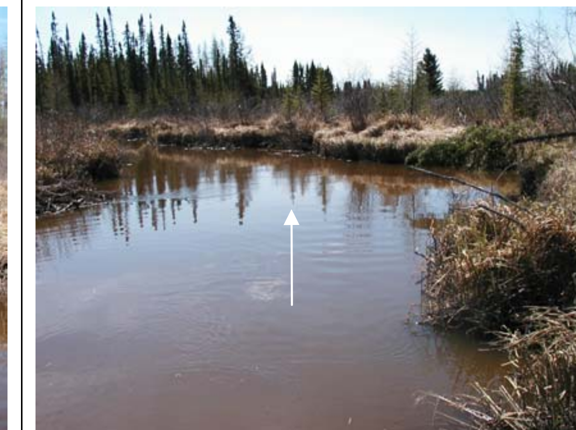
Date of Survey:	09-Jun-02
Survey Type:	Field
Stream Order:	2
Length Surveyed	
Upstream (m):	100
Downstream (m):	200

Water Quality

Temperature (°C):	14.6
Conductivity (µS/cm):	176.6
pH:	8
Turbidity (NTU):	16
Dissolved Oxygen:	8.16
Stage:	High
Discharge (m^3/s):	0.67

Aerial view (line indicates location of proposed crossing).

Upstream view.



Downstream view.

Survey Transect Summary

Channel Width (m):	5.9
Wetted Width (m):	5.5
Maximum Depth (m):	1.3
Average Velocity (m/s):	0.14
Cover Type and Composition:	LOD – 1%; submerged grass and shrubs at channel margins – 10%
Substrate:	unconsolidated fines
Floodplain Width (m):	60
Morphology:	Stream had a distinct channel at RoW, but upstream and downstream reaches had multiple channels; pool/glide habitat with some riffle areas (1%) below beaver dams.
Comments:	75 m and 140 m upstream of RoW were beaver dams, each 0.4 m above the water surface; downstream of RoW were two old beaver pools with maximum depths of 1.0 m.

From right bank looking at left bank at survey transect.

From left bank looking at right bank at survey transect.

Sensitivity to Disturbance

Low:	Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

Fisheries Assessment

Capture Method:	boat assisted backpack electrofishing
Survey Length:	250 m
Species Present:	WHSC; BRST; PRDC
Life History Stages:	juvenile/adult
Abundance CPUE (fish/min):	1.0

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:

Spawning Habitat:	low-moderate
Overwintering Habitat:	low-moderate
Rearing Habitat:	moderate
Comments:	Spawning potential limited by beaver dams and other obstructions to upstream movement. There is adequate habitat to support and overwinter spring-spawners.

Forage Fish:

Spawning Habitat:	moderate-high
Overwintering Habitat:	moderate-high
Rearing Habitat:	moderate-high
Comments:	The stream provides pool and beaver pond habitats that would be adequate for overwintering forage fish.

Fish Habitat Classification: Important

Table 6-25. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R6.

Background Information

UTM (NAD83) at Survey Transect:
14U 541197 **E** 6167937 **N**

Date of Survey:	08-Jun-02
Survey Type:	Field
Stream Order:	2
Length Surveyed	
Upstream (m):	100
Downstream (m):	200

Water Quality

Temperature (°C):	15.0
Conductivity (µS/cm):	131.7
pH:	7
Turbidity (NTU):	11
Dissolved Oxygen:	9.67
Stage:	High
Discharge (m^3/s):	0.71


Aerial view (line indicates location of proposed crossing).


Upstream view.


Downstream view.

Survey Transect Summary

Channel Width (m):	5.3
Wetted Width (m):	4.4
Maximum Depth (m):	1.1
Average Velocity (m/s):	0.22
Cover Type and Composition:	LOD – 1%; submerged grass and shrubs at channel margins – 5%
Substrate:	unconsolidated fines
Floodplain Width (m):	57
Morphology:	Stream has a distinct channel at RoW, but splits into side channels and partially isolated oxbows elsewhere, especially downstream; pool/glide habitat was the dominant hydraulic feature.
Comments:	Beaver dam 90 m upstream of RoW; beaver dam 150 m downstream of RoW; two pool areas immediately downstream of RoW with maximum depths of 0.7 and 2.0 m.


From right bank looking at left bank at survey transect.


From left bank looking at right bank at survey transect.

Sensitivity to Disturbance

Low: Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

Fisheries Assessment

Capture Method:	boat assisted backpack electrofishing
Survey Length:	240 m
Species Present:	WHSC; BRST; PRDC
Life History Stages:	juvenile/adult
Abundance CPUE (fish/min):	1.4

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:

Spawning Habitat: low-moderate
Overwintering Habitat: low
Rearing Habitat: moderate
Comments: Spawning potential limited by beaver dams and other obstructions to upstream movement. There is adequate, though sub-optimal, habitat to support and overwinter spring-spawners.

Forage Fish:

Spawning Habitat: moderate-high
Overwintering Habitat: moderate
Rearing Habitat: moderate-high
Comments: The stream provides pool and beaver pond habitats that would be adequate for overwintering forage fish.

Fish Habitat Classification: Marginal

Table 6-26. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R7.

Background Information

UTM (NAD83) at Survey Transect:
14U 537350 **E** 6160669 **N**

Date of Survey:	07-Jun-02
Survey Type:	Field
Stream Order:	1
Length Surveyed	
Upstream (m):	100
Downstream (m):	200

Water Quality

Temperature (°C):	11.5
Conductivity (µS/cm):	n/a
pH:	n/a
Turbidity (NTU):	n/a
Dissolved Oxygen:	n/a
Stage:	Moderate-High
Discharge (m^3/s):	0.25


Aerial view (line indicates location of proposed crossing).


Upstream view.


Downstream view.

Survey Transect Summary

Channel Width (m):	3.3
Wetted Width (m):	2.0
Maximum Depth (m):	0.5
Average Velocity (m/s):	0.33
Cover Type and Composition:	LOD – 1%; pools – 2%
Substrate:	unconsolidated fines
Floodplain Width (m):	14
Morphology:	Average bank height was 0.3 m; floodplain varied through survey reach from 9 to 24 m; at the RoW the stream flowed in a single channel and was all shallow run with no riffles.
Comments:	Large beaver dam (1.5 m above the water surface) 30 m upstream of RoW was breached and the preceding pond drained; dam (1.1 m above the water surface) 100 m downstream of RoW was breached and the preceding pond was reduced; RoW area previously a flooded area between the two dams.


From right bank looking at left bank at survey transect.


From left bank looking at right bank at survey transect.

Sensitivity to Disturbance

Low:	Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

Fisheries Assessment

Capture Method:	backpack electrofishing
Survey Length:	200 m
Species Present:	BRST; FTMN
Life History Stages:	juvenile/adult
Abundance CPUE (fish/min):	1.4

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:

Spawning Habitat:	low-moderate
Overwintering Habitat:	low
Rearing Habitat:	moderate
Comments:	Spawning potential limited by beaver dams and other obstructions to upstream movement. Winter dissolved oxygen levels suspected to be sub-optimal for overwintering large bodied fish.

Forage Fish:

Spawning Habitat:	moderate
Overwintering Habitat:	moderate
Rearing Habitat:	moderate
Comments:	The stream provides pool and beaver pond habitats that could be adequate for overwintering forage fish.

Fish Habitat Classification: Marginal

Table 6-27. Detailed aquatic habitat description and photographic documentation of the surveyed reach for stream crossing R8.

Background Information

UTM (NAD83) at Survey Transect:
14U 536478 **E** 6158672 **N**

Date of Survey:	08-Jun-02
Survey Type:	Field
Stream Order:	1
Length Surveyed	
Upstream (m):	100
Downstream (m):	200

Water Quality

Temperature (°C):	13.0
Conductivity (µS/cm):	164
pH:	8
Turbidity (NTU):	84
Dissolved Oxygen:	9.61
Colour:	turbid brown
Stage:	High
Discharge (m^3/s):	0.56


Aerial view (line indicates location of proposed crossing).


Upstream view.


Downstream view.

Survey Transect Summary

Channel Width (m):	3.8
Wetted Width (m):	3.4
Maximum Depth (m):	0.9
Average Velocity (m/s):	0.26
Cover Type and Composition:	LOD – 2%; undercuts – 1%; pools – 5%
Substrate:	unconsolidated fines
Floodplain Width (m):	14
Morphology:	Average bank height was 0.3 m; floodplain varied through survey reach from 20 to 40 m; surveyed reach mostly pool-glide habitat with 5% riffle; channel wider and deeper in downstream portion of surveyed reach (channel width 5.7 m, wetted width 4.0 m, maximum depth 1.3 m).
Comments:	Small overflowing dams 80 and 100 m downstream of RoW.


From right bank looking at left bank at survey transect.


From left bank looking at right bank at survey transect.

Sensitivity to Disturbance

Low: Moderate streambed disturbance would not significantly alter or diminish existing fish habitat; potential disturbance of fish reduced to localized periods (spring freshet).

Fisheries Assessment

Capture Method:	boat assisted backpack electrofishing
Survey Length:	175 m
Species Present:	WHSC; BRST; FTMN; PRDC
Life History Stages:	juvenile/adult
Abundance CPUE (fish/min):	2.1

Large Bodied Spring-Spawners (northern pike/suckers) Assessment:

Spawning Habitat: low-moderate
Overwintering Habitat: low-moderate
Rearing Habitat: moderate
Comments: Spawning potential limited by beaver dams and other obstructions to upstream movement. There is adequate, though sub-optimal, habitat to support and overwinter spring-spawners.

Forage Fish:

Spawning Habitat: moderate-high
Overwintering Habitat: moderate-high
Rearing Habitat: moderate-high
Comments: The stream provides pool and beaver pond habitats that would be adequate for overwintering forage fish.

Fish Habitat Classification: Important

6.4 IMPACT ASSESSMENT AND MITIGATION

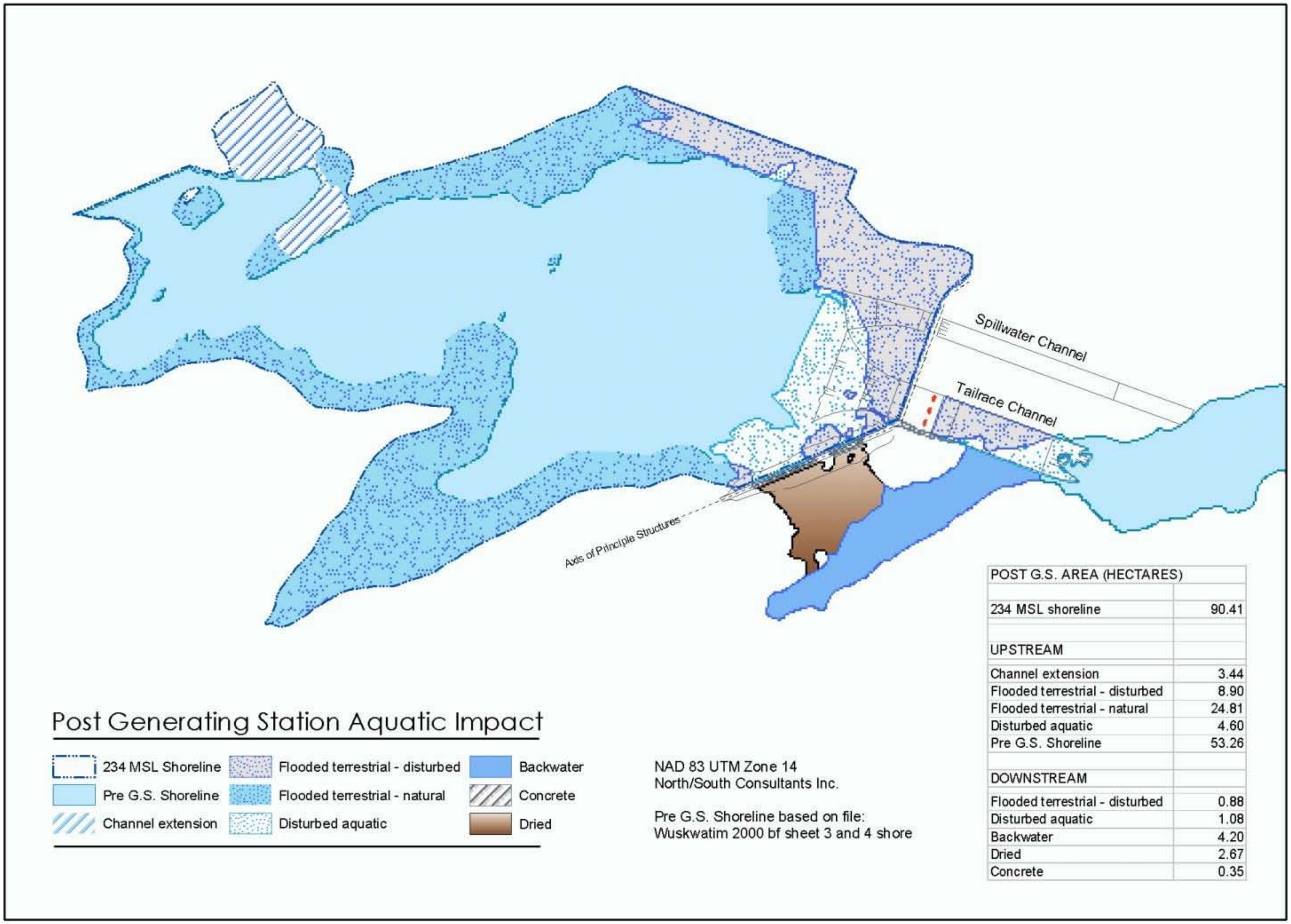
6.4.1 Construction

During construction, aquatic habitat will be directly affected in Reach 2 only. The majority of aquatic habitat area disturbed by **cofferdam** placement is part of an area (about 4.6 ha) that will either be occupied by the GS structure, or within aquatic habitat that will either be modified as part of the intake channel (powerhouse) or the approach channel (**spillway**) (Volume 3) (Figure 6-35).

At each of the eight stream crossings, the **footprint** of the road, combined with the installation of the **culvert**(s), will result in several changes in aquatic habitat including the following:

- loss of aquatic habitat due to the footprint of the road;
- depending on the size and method of installation, some changes in water depth for the length of the culvert at some sites, and an increase in depth immediately upstream and downstream of the culvert at most sites;
- introduction of **rip-rap** at the upstream and downstream ends of the culvert to reduce erosion;
- some increase in sedimentation downstream of the culvert at most sites;
- loss of rooted submergent aquatic plant habitat in the immediate footprint of the road at most sites; and
- depending on the size and method of installation, some increase in average water velocity for the length of the culvert, and a short-length immediately upstream and downstream at all sites.

Impacts related to construction will be minimized due to control measures outlined in the Project Description (Volume 3) and practices that will be described in the **Environmental Protection Plan** (EnvPP).



POST G.S. AREA (HECTARES)	
234 MSL shoreline	90.41
UPSTREAM	
Channel extension	3.44
Flooded terrestrial - disturbed	8.90
Flooded terrestrial - natural	24.81
Disturbed aquatic	4.60
Pre G.S. Shoreline	53.26
DOWNSTREAM	
Flooded terrestrial - disturbed	0.88
Disturbed aquatic	1.08
Backwater	4.20
Dried	2.67
Concrete	0.35

Figure 6-35. Post-Project aquatic habitat in Reach 2.

6.4.2 Operation

6.4.2.1 Reach 1: Wuskwatim

Aquatic habitat is described at the post-Project shoreline elevation 234.0 m ASL (Table 6-28). As water level elevation will fluctuate during normal operation of the GS, an IEZ will exist between 233.75 m and 234.0 m (Figure 6-36). The IEZ will decrease in size from 2022 ha to 342 ha (Table 6-29). The majority of the pre-Project IEZ will be converted to nearshore habitat; however, a small amount (92 ha) at the upper extent of the zone will become permanently dry.

Table 6-28. Post-Project surface area, and water depth and volume for waterbodies in Reach 1.

Waterbody	234.0 m ASL			
	Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Volume (m^3)
Cranberry Lakes	1733.5	14.0	2.6	44275150
Sesep Lake	432.0	-	-	-
Wuskwatim Lake Main	4790.2	13.4	7.9	378704650
Wuskwatim Lake South	1091.0	6.2	2.1	23417050
Wuskwatim Brook	832.9	7.2	1.8	14754947
Reach 1 Total	8879.6	14.0	5.5	461151797

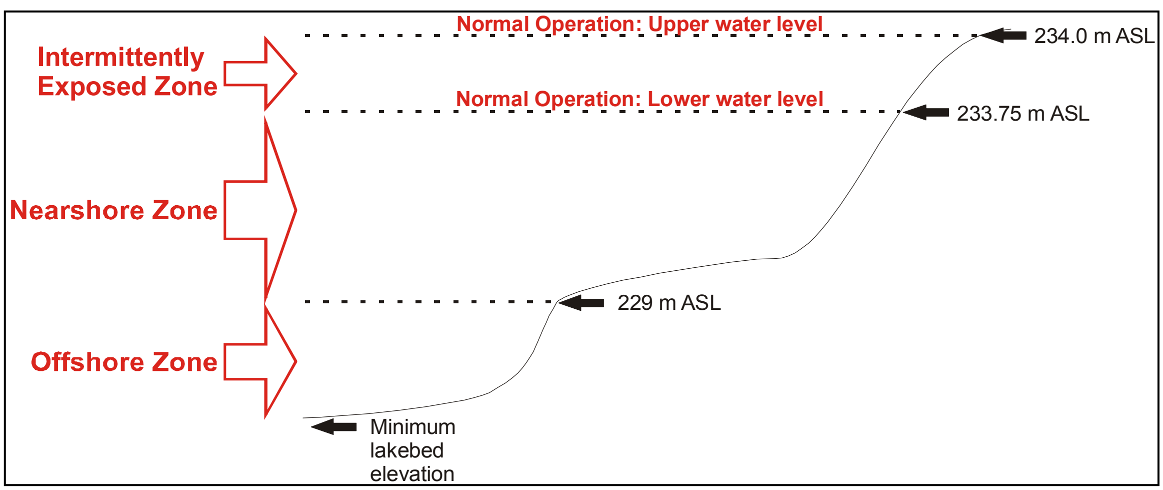


Figure 6-36. Classification of aquatic habitat into zones with respect to water level in Reach 1, post-Project.

Table 6-29. Areas for the intermittently exposed, nearshore, and offshore habitat zones by waterbody in Reach 1.

	Pre-Project (95th percentile)		
Habitat Zone Waterbody	**Intermittently Exposed Area (ha)**	**Nearshore Area (ha)**	**Offshore Area (ha)**
Cranberry Lakes	597.1	991.8	175.2
Sesep Lake	388.9	56.5	0.0
Wuskwatim Lake Main	167.0	465.7	4181.3
Wuskwatim Lake South	473.4	623.8	9.7
Wuskwatim Brook	395.1	441.5	5.3
Reach 1 Total	2021.5	2579.4	4371.5

	Post-Project (234.0 m ASL)		
Habitat Zone Waterbody	**Intermittently Exposed Area (ha)**	**Nearshore Area (ha)**	**Offshore Area (ha)**
Cranberry Lakes	102.2	1456.1	175.2
Sesep Lake	49.0	383.0	0.0
Wuskwatim Lake Main	31.1	577.8	4181.3
Wuskwatim Lake South	76.5	1004.7	9.7
Wuskwatim Brook	82.6	745.0	5.3
Reach 1 Total	341.5	4166.6	4371.5

The nearshore zone will increase in size by 1588 ha, as it will be bounded by the 229 m and the 233.75 m. The area of the offshore zone will not be changed.

Peat islands currently occupy approximately 19 % of the surface area of the IEZ, and are described in Volume 6.

The majority of nearshore and offshore areas are expected to remain predominantly soft silt/clay (i.e., fine sediments). However, sedimentation rates in the nearshore off eroding banks and in the offshore are expected to increase, resulting in the **deposition** of sediments on existing areas of fine sediments and on portions of the narrow, nearshore band of boulder/cobble that currently exists off some eroding shorelines (i.e., in Wuskwatim Lake main). The greatest relative increase in sedimentation rates will be in the first five years following construction; however, sedimentation rates will decrease in subsequent years and are expected to return to levels comparable to pre-Project conditions approximately 25 years after Project construction (Volume 4). An estimated 75 % of the eroded sediments will be deposited in the nearshore environment, with the remaining sediments deposited in deep waters (i.e., offshore environment) or transported downstream (Volume 4). Therefore, the greatest effect will be experienced in the nearshore areas of Wuskwatim Lake main and along approximately one-third the shoreline of Cranberry Lakes, where eroding shorelines are widespread. The majority of shorelines in Sesep Lake, Wuskwatim Lake south, and Wuskwatim Brook, as well as the northern portion of Cranberry Lakes, are non-eroding, low gradient shores that are not expected to be affected by increased inputs of sediments.

The reduction in water level fluctuations due to the Project may also affect the pattern of deposition and resuspension of sediments in the nearshore environment, as the width and depth of mixing by surface waves will be reduced (i.e., areas that are currently affected by mixing from surface waves when lake level is low will no longer be periodically affected by wave action). However, zones of deposition and resuspension in the nearshore environment are also affected by the slope of the lake bottom; generally, fine particles do not accumulate where the slope is greater than 3 to 4 %, as the force of gravity results in the transport of sediments down-slope. Therefore, the lakeshore typically consists of a shallow, wave-washed zone, where coarse substrates may be present, and a deeper, depositional zone, with fine sediments. The position of the fine sediment boundary depends on the depth of wave washing and the slope of the shoreline, as well as on whether inputs of fine sediments from eroding banks are occurring.

Based on information gathered at 18 transects off eroding banks on Wuskwatim Lake main, the majority of transects (about 70 %) evidenced a transition from coarse to fine substrates at less than 2.5 m water depth (i.e., 231.1 m ASL), although on a few steeper shorelines the transition did not occur until 223 m ASL (North/South Consultants Inc. unpublished data). About 27 % of transects revealed a humocky profile, and an alternating pattern of fine sediment and coarse substrates below 231.1 m ASL. Fine sediments were generally found only in low slope portions of transects; however, off highly eroding banks sediment was also present on high slope areas, indicating that the system was in transition (i.e., not stable). Over time, these high slope areas are expected to continue to transport sediments offshore, and thereby will not remain sites of pronounced accumulation as adjacent eroding banks stabilize and inputs of sediments decrease. Following construction of the Project, it is expected that steep shorelines where there is currently coarse substrate may temporarily become covered with fine sediments, if the input from adjacent eroding banks exceeds the rate at which sediment is transported offshore. As erosion rates on the adjacent banks decrease, fine sediments would be transported offshore and coarse substrates would again be exposed. This condition applies to much of Wuskwatim Lake main. Most areas that were flooded due to CRD are low slope and can be expected to experience deposition at higher elevations than occurs at present (i.e., reduction in wave-washed zone); however, these areas are predominantly fine sediments currently and altering the local pattern of deposition will not change the substrate type. Additionally, most of the shoreline in these areas is not eroding so there will not be an abundant source of sediments to be deposited.

As the post-Project reservoir ages and eroding shorelines recede, the slope of the littoral zone in the main basin is expected to decrease (Volume 4). However, it is not possible to predict the condition of substrates in the littoral zone in the very long-term (i.e., as the reservoir ages), because the ultimate composition of the substrata in the nearshore will depend on material underlying as of yet not eroded banks as well as the factors affecting sediment deposition and resuspension discussed above.

The spatial extent of the area where rooted submergent aquatic plants occur now will not change post-Project, however, there may be changes in overall abundance within existing plant beds (Section 7.4).

6.4.2.2 Reach 2: Falls

Aquatic habitat is described at the post-Project shoreline elevation of 234.0 m (Table 6-30). As in Reach 1, water level elevation will fluctuate during normal operation of the GS and an IEZ will exist between 233.75 m and 234.0 m. The IEZ will occupy an area of 0.8 ha and the wetted portion of the reach will be 89.6 ha (Table 6-31).

After construction of the GS, the increase in area of aquatic habitat will be 37.2 ha. Of this increase, 3.4 ha will be part of the channel extension adjacent to the existing Wuskwatim Falls, 8.9 ha will be disturbed (due to **dyke** construction on the north-side), newly flooded terrestrial, and 24.8 ha will be natural (undisturbed), newly flooded terrestrial habitat (Figure 6-35). The newly flooded terrestrial will occupy 0.8 ha (100 %) of the IEZ and 33.8 ha (38 %) of the wetted area.

Prior to construction of the GS, the substrata of Reach 2 generally reflected the distribution of water velocities. This distribution of substrata types will likely not be noticeably altered post-Project, except for the increase in flooded terrestrial area. The rate of shoreline erosion post-Project is not expected to be higher than existing rates. As suspended sediments will be transported from Reach 1 into an area with relatively higher flow and water velocity, deposition of these sediments in Reach 2 is not expected to occur.

Table 6-30. Post-Project surface area, and water depth and volume for Reach 2.

Waterbody	234.0 m ASL Surface Area (ha)	Maximum Depth (m) [2]	Mean Depth (m) [2]	Volume (m^3) [2]
Reach 2	90.4	-	-	-
Reach 2a [1]	68.3	25.4	9.4	6378508

[1] the portion of Reach 2 where safe data collection was possible
[2] water depths and volume do not take into account increased depth due to excavation of existing aquatic and terrestrial surfaces

Table 6-31. Areas for the intermittently exposed and wetted habitat zones in Reach 2.

Waterbody	Intermittently Exposed Area (ha)	Wetted Area (ha)	Total Area (ha)
Pre-Project Reach 2a [1]	4.2	39.4	43.6
Pre-Project Reach 2	-	-	53.3
Post-Project Reach 2a [1]	0.6	67.8	68.3
Post-Project Reach 2	0.8	89.6	90.4

[1] the portion of Reach 2 where safe data collection was possible

Post-Project water velocities in Reach 2 will be reduced in comparison to existing ones, as this reach will be characterized by deeper, slower moving water (Figure 6-37). As a result, there will be a change in the overall relative proportions of low, medium, and high water velocities (Table 6-32). Areas with reverse flow (i.e., back eddies) are also classified with respect to low, medium, and high water velocities, providing an overall total area for each of the water velocity categories in Reach 2 post-Project. The existing high water velocities closest to Wuskwatim Falls will be reduced. Water velocities near the GS intake will be reduced in comparison to the existing condition at Taskinigup Falls. Under an operating outflow of about 1100 m^3/s, velocities approximately 1 m upstream of the intake gates will range from 0.75 to 1.0 m/s (medium velocity) (Volume 4). These velocities would be consistent across the entire intake opening, extending from an elevation of 207.2 to 227.1 m. Under the same outflow operation, velocities about 30 m upstream of the intake gates will range from 0.5 to 0.75 m/s (medium velocity) (Volume 4).

After construction of the GS, there will be a net loss of about 1.5 ha (about 3 % of existing Reach 2 area) of rooted submergent aquatic plants from Reach 2 (Section 7.4).

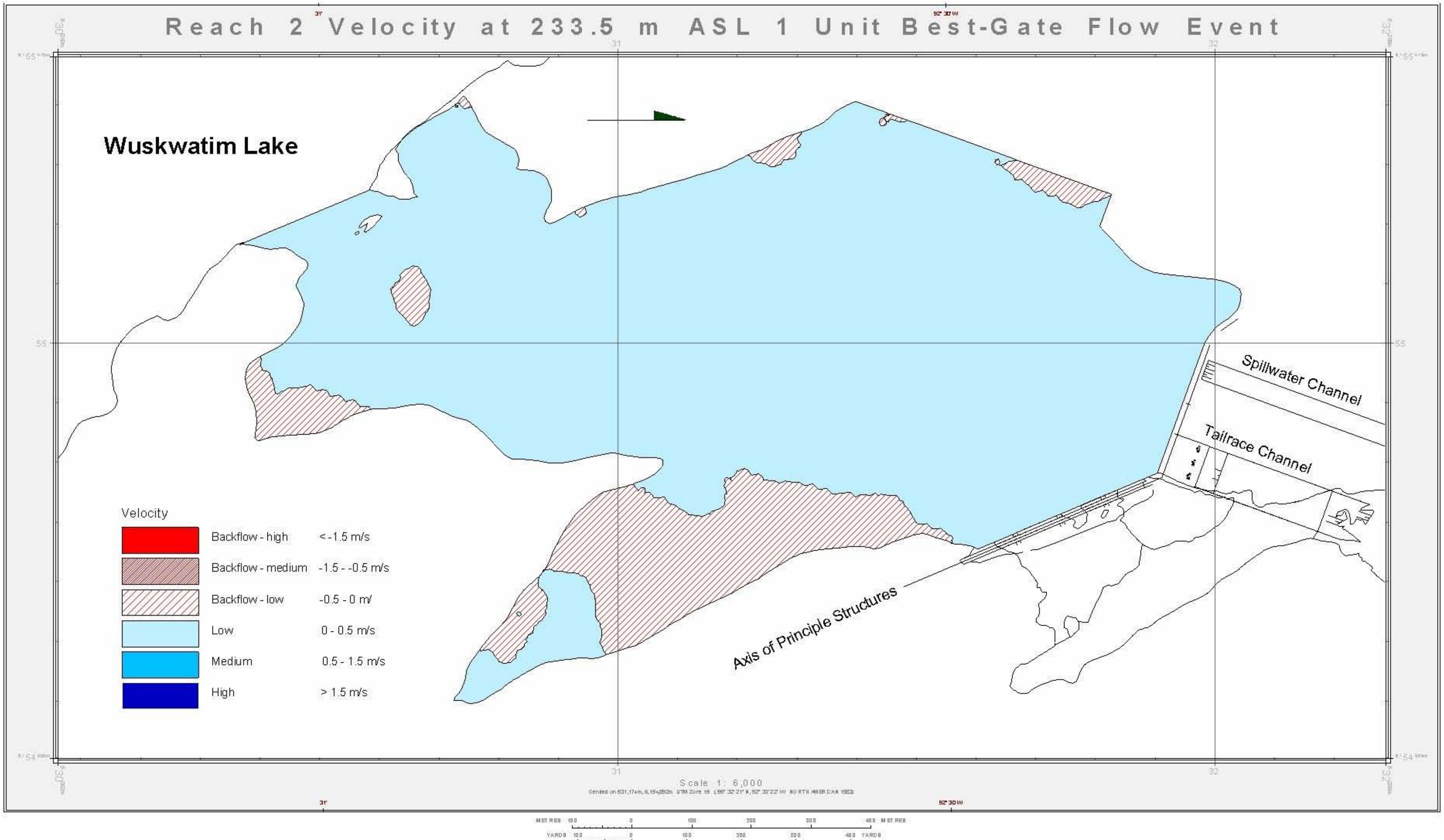


Figure 6-37A. Post-Project water velocities in Reach 2 at water elevation 233.5 m ASL: 1 unit best-gate flow event.

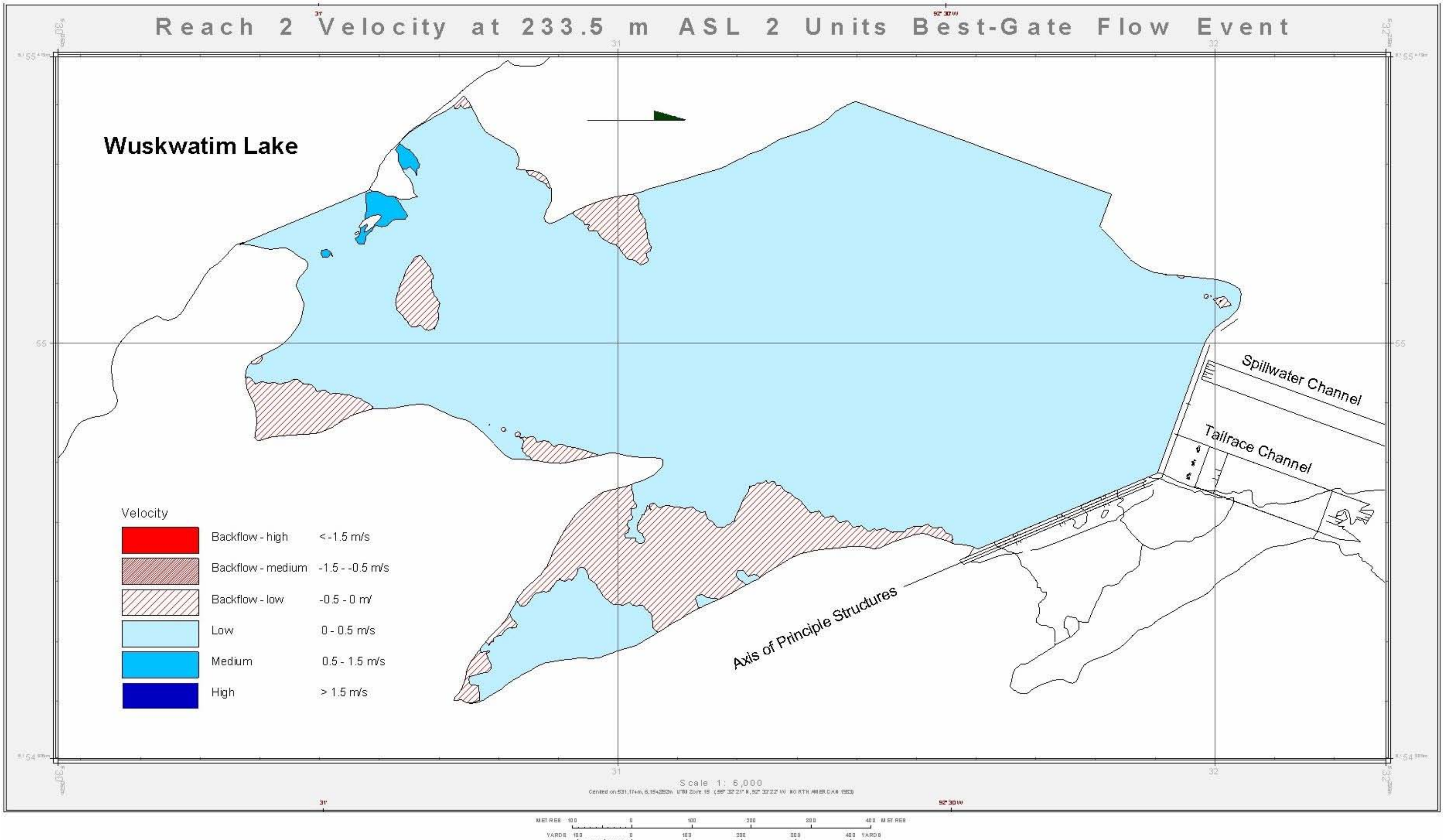


Figure 6-37B. Post-Project water velocities in Reach 2 at water elevation 233.5 m ASL: 2 units best-gate flow event.

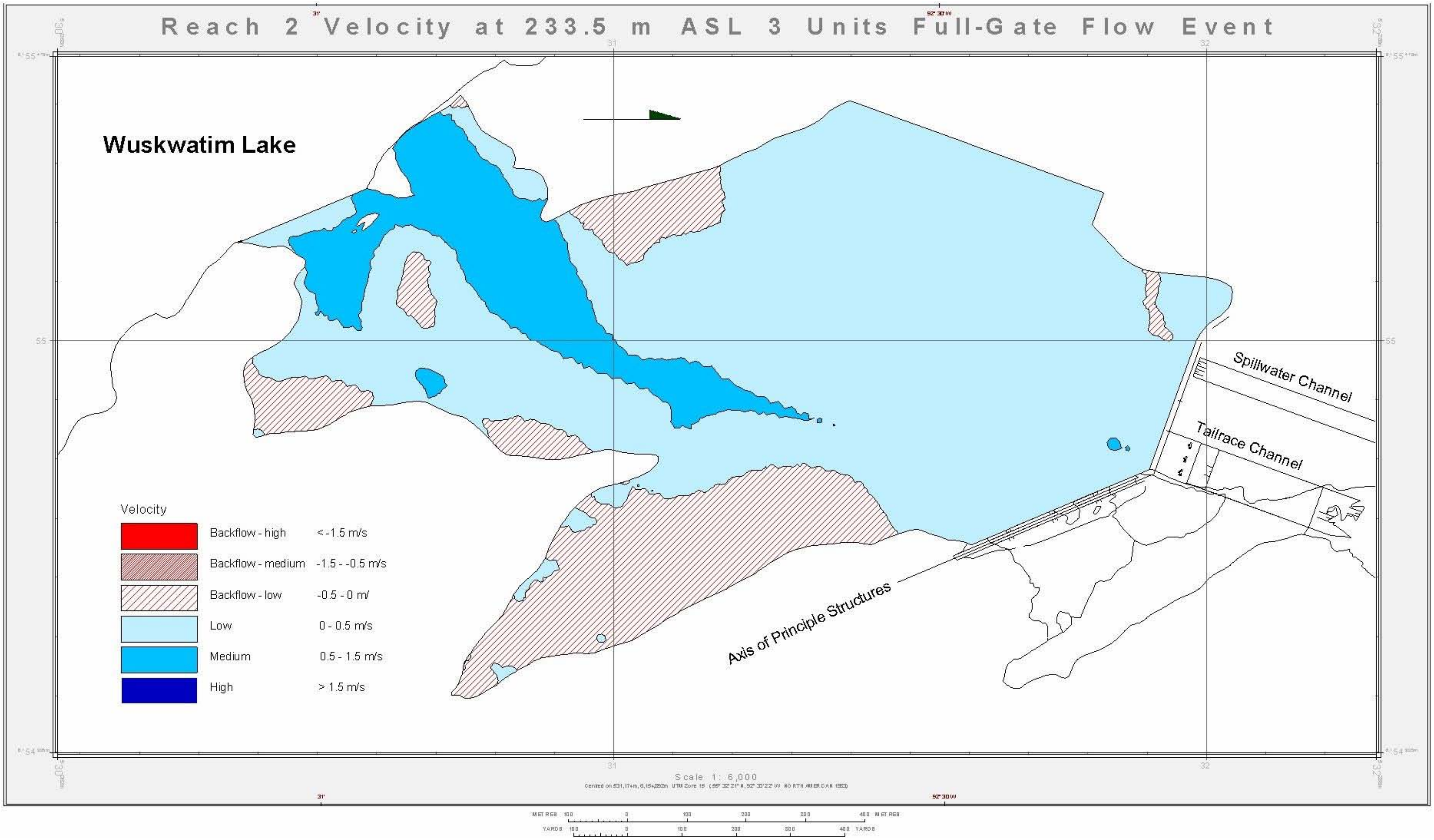


Figure 6-37C. Post-Project water velocities in Reach 2 at water elevation 233.5 m ASL: 3 units full-gate flow event.

Table 6-32. Post-Project areas of low, medium, and high water velocities in Reach 2 (at water elevation 233.5 m ASL).

1 Unit Best-Gate								
Water Velocity			Reverse Flow Water Velocity			Overall Total Water Velocity		
Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
77.8	0.0	0.0	12.6	0.0	0.0	90.4	0.0	0.0

2 Units Best-Gate								
Water Velocity			Reverse Flow Water Velocity			Overall Total Water Velocity		
Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
79.4	0.4	0.0	10.6	0.0	0.0	90.0	0.4	0.0

3 Units Full-Gate								
Water Velocity			Reverse Flow Water Velocity			Overall Total Water Velocity		
Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)	Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
62.0	11.2	0.0	17.2	0.0	0.0	79.2	11.2	0.0

6.4.2.3 Reach 3: Burntwood

After construction of the GS, about 3 ha of aquatic habitat will be lost from the upper extent of Reach 3 due to the concrete footprint of the structure (0.4 ha) and the dewatering of present-day Taskinigup Falls (2.7 ha) (Figure 6-35). Immediately downstream of the GS in the tailrace channel, about 0.9 ha will be disturbed, newly flooded terrestrial and 1.1 ha will be disturbed aquatic habitat. The bay on the south-side of the river (Figure 6-18), immediately downstream of the existing Taskinigup Falls, will become part of the post-Project backwater area (4.2 ha) created downstream of the main dam.

Aquatic habitat is described under the post-Project operating regime (Volume 3) of 1 unit best-gate (1-BG), 2 units best-gate (2-BG), 3 units best-gate (3-BG), and 3 units full-gate (3-FG) (Table 6-33, Figure 6-38). Volume 3 provides a description of the GS operation, including the use of best-gate and full-gate flows for the three turbine units. During operation, water level elevation will fluctuate depending on the inflow and changes in the number of units operating. The IEZ will increase in size from 44 ha to 64 ha (Table 6-34). The intermittently exposed area gained consists of 17 ha of aquatic habitat that was permanently wetted the majority of the time pre-Project (will become lower quality habitat). The quality of the post-Project IEZ will be degraded in comparison to the pre-Project due to the increased frequency of water level fluctuations. The wetted zone will occupy a smaller area post-Project (236 ha), as it will extend up to the water level elevation a 1-BG, representing a decrease of 17 ha of aquatic habitat that was more permanently wetted (higher quality) pre-Project.

Peatlands potentially affected by the Project currently occupy about 27 ha within the backwater inlets and a number of notch inlets in the mainstem, and are described in Volume 6.

As in Reach 2, prior to construction and operation of the GS, the substrata of Reach 3 generally reflected the distribution of water velocities. This distribution of substrata types will not be noticeably altered post-Project, except for the small increase in area (3 ha) that was exposed greater than 95 % of the time pre-Project (will become newly flooded terrestrial). The small increase in sedimentation that may occur in the post-Project backwater area immediately downstream of the GS is not expected to be sufficient to noticeably change the substrata.

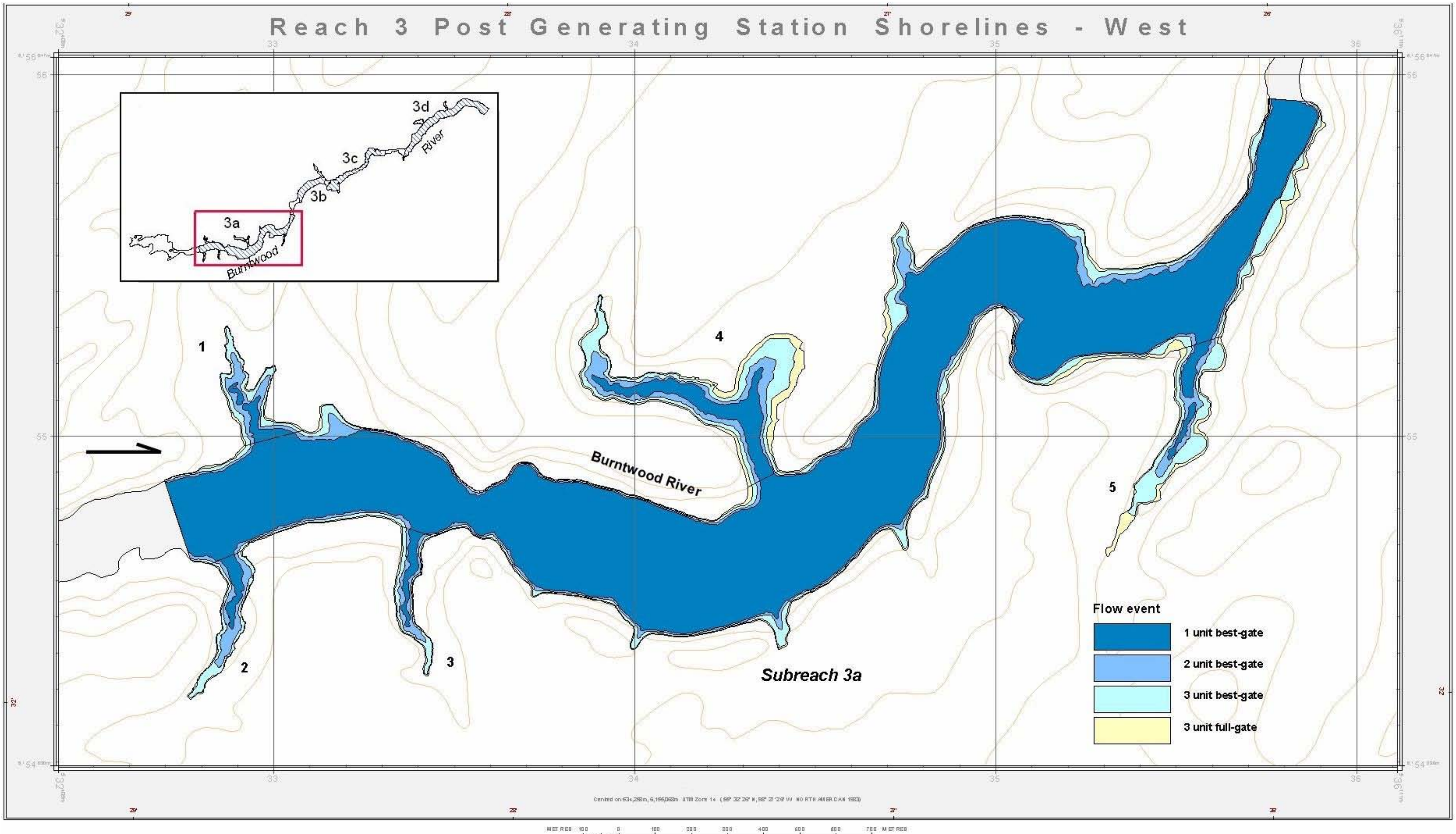


Figure 6-38A. Post-Project shorelines in the upper portion of Reach 3 under several flow conditions.

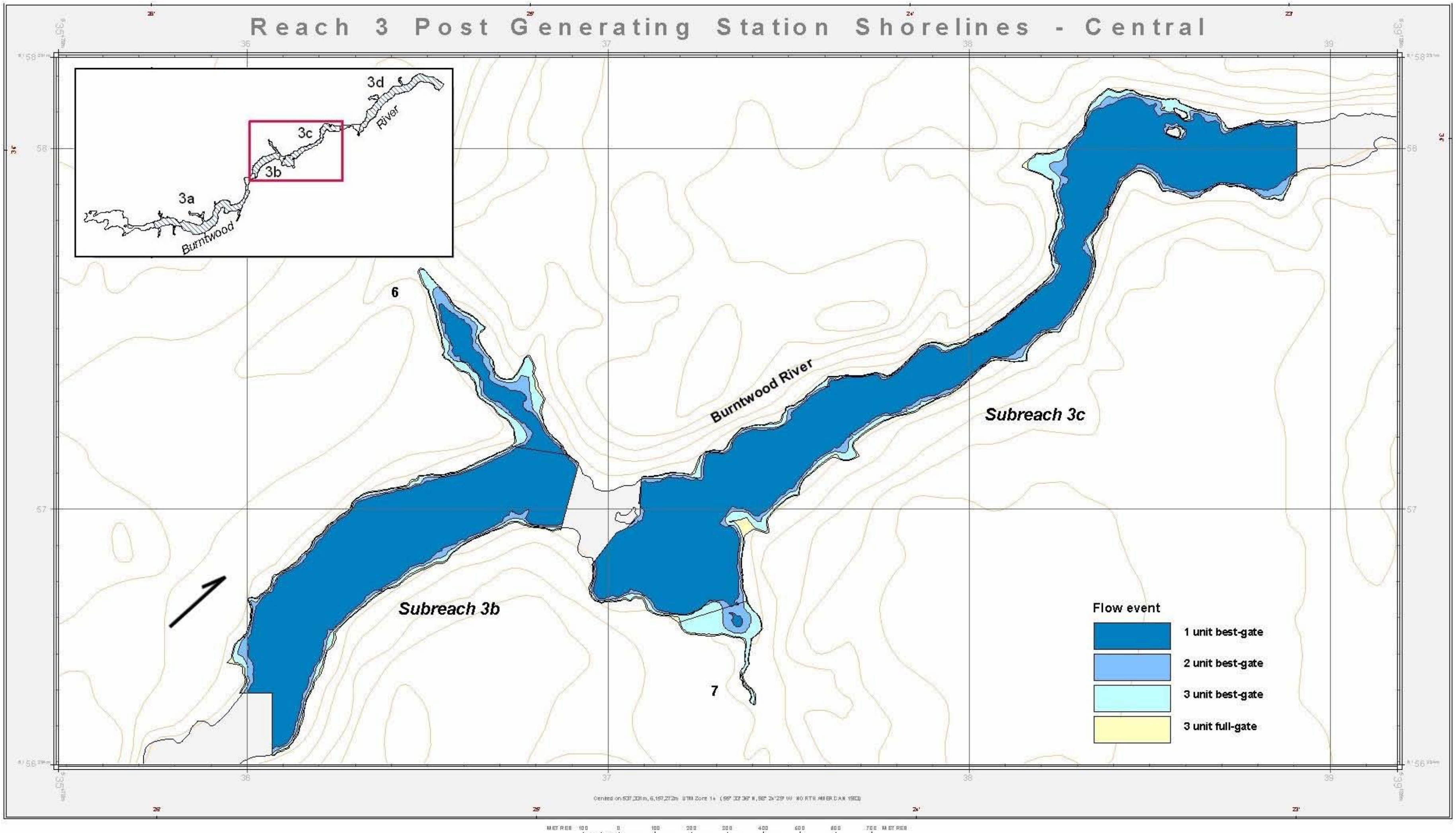


Figure 6-38B. Post-Project shorelines in the middle portion of Reach 3 under several flow conditions.

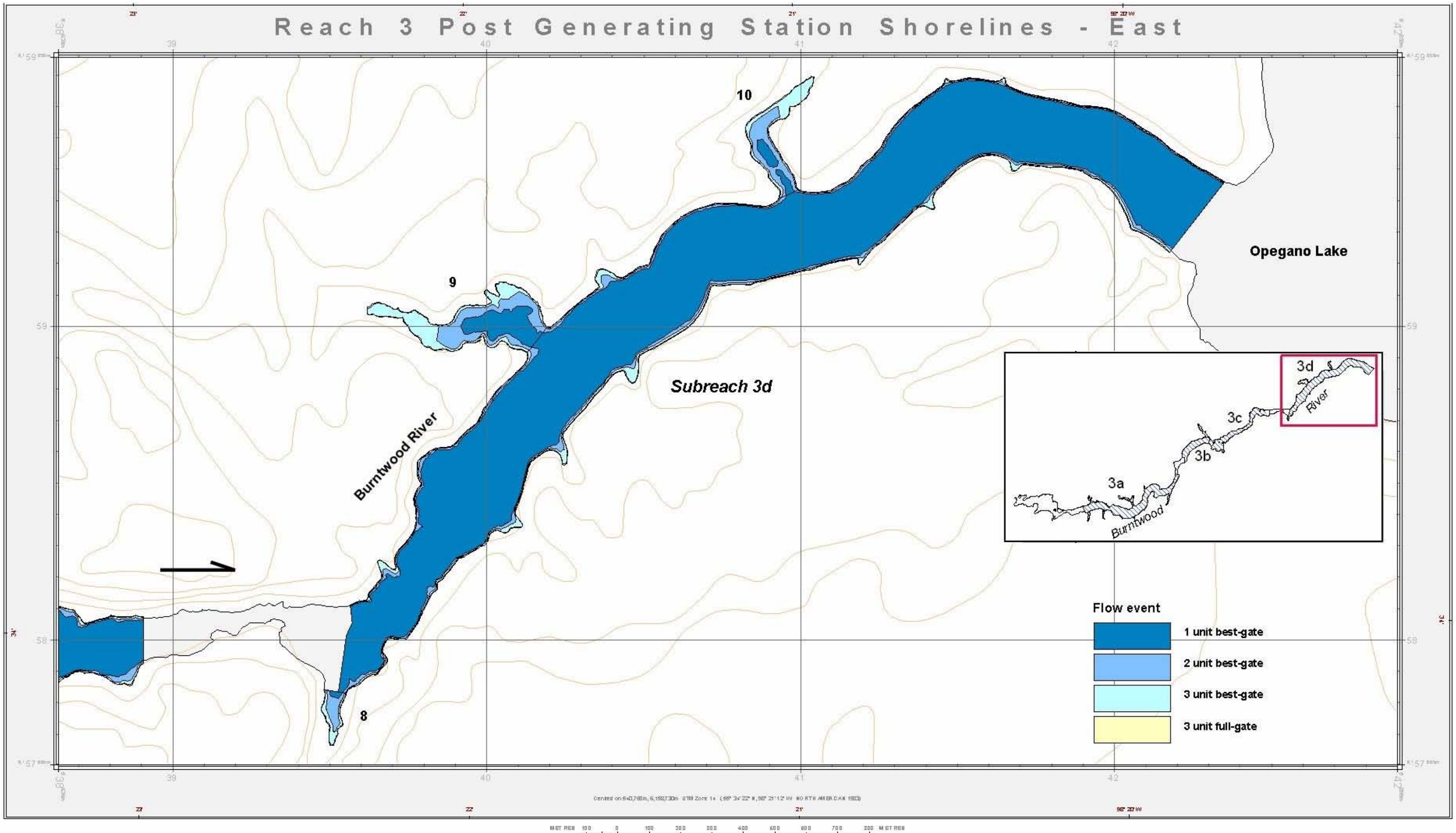


Figure 6-38C. Post-Project shorelines in the lower portion of Reach 3 under several flow conditions.

Table 6-33. Post-Project surface area, and water depth and volume for Reach 3.

Subsystem	3 Units Full-Gate			
	Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Volume (m^3)
Mainstem	261.8	25.4	7.6	19983273
Backwater inlets	37.8	6.7	1.9	736030
Reach 3 Total	299.7	25.4	6.9	20719304

Table 6-34. Areas for the intermittently exposed and wetted habitat zones in Reach 3.

Habitat Zone Subsystem	Pre-Project (95th percentile)		
	Intermittently Exposed Area (ha)	Wetted Area (ha)	Total Area (ha)
Mainstem	24.8	235.3	260.1
Backwater inlets	19.3	17.2	36.6
Reach 3 Total	44.1	252.6	296.7

Habitat Zone Subsystem	Post-Project (3 Units Full-Gate)		
	Intermittently Exposed Area (ha)	Wetted Area (ha)	Total Area (ha)
Mainstem	36.3	225.5	261.8
Backwater inlets	27.8	10.1	37.8
Reach 3 Total	64.1	235.6	299.7

The general horizontal pattern of post-Project water velocity will be similar in comparison to the existing one (Figure 6-39); however, daily fluctuations in water velocity at certain points within the reach will change considerably following construction of the GS. Water movements in the backwater inlets will remain limited. Post-Project areas of low, medium, and high water velocities in Reach 3 are presented in Table 6-35.

After construction of the GS, the altered water regime may result in the loss of a substantial portion of the existing 3.9 ha (about 1 % of existing Reach 3 area) of rooted submergent plant beds (Section 7.4).

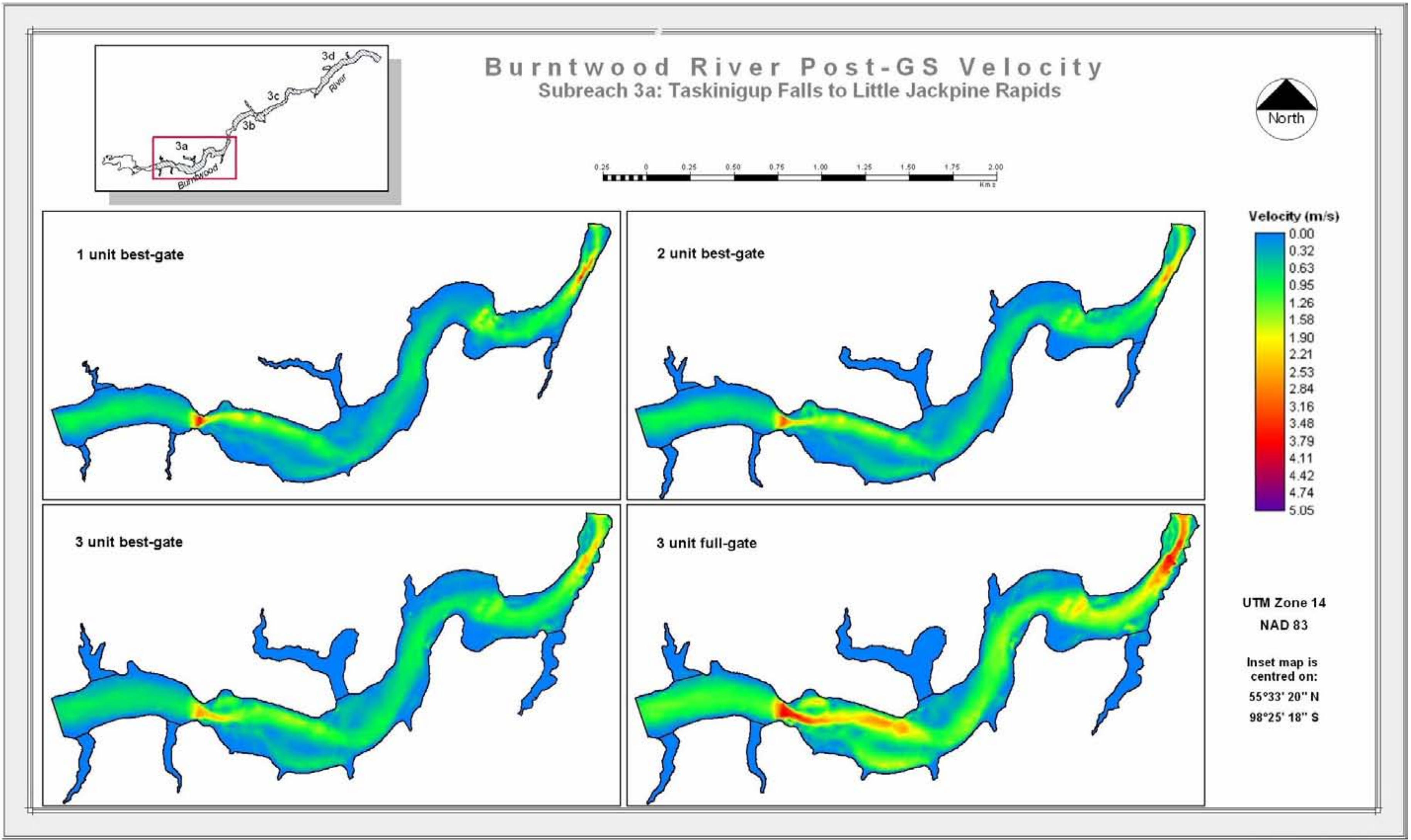


Figure 6-39A. Post-Project water velocities in Reach 3: Taskinigup Falls to Little Jackpine Rapids.

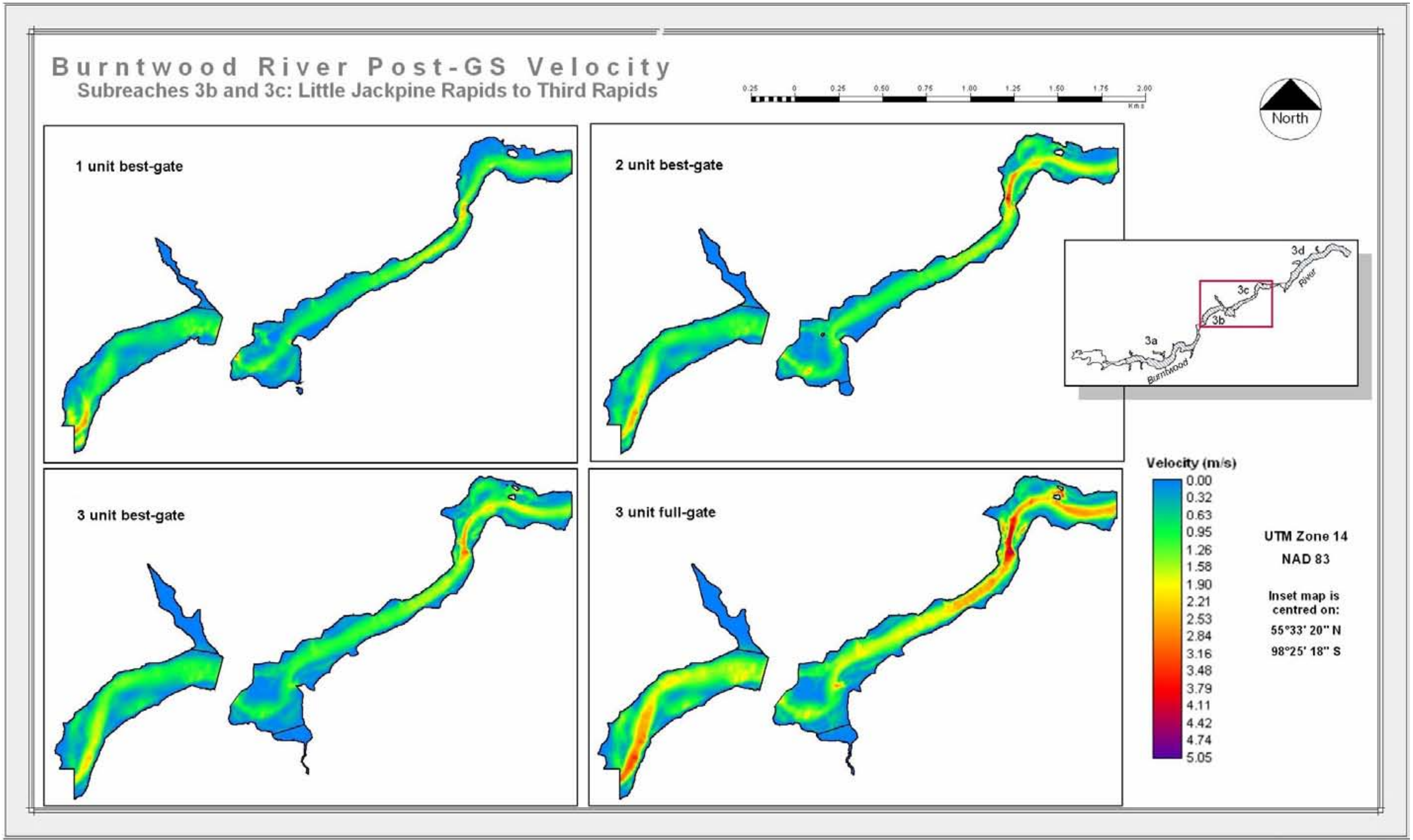


Figure 6-39B. Post-Project water velocities in Reach 3: Little Jackpine Rapids to Third Rapids.

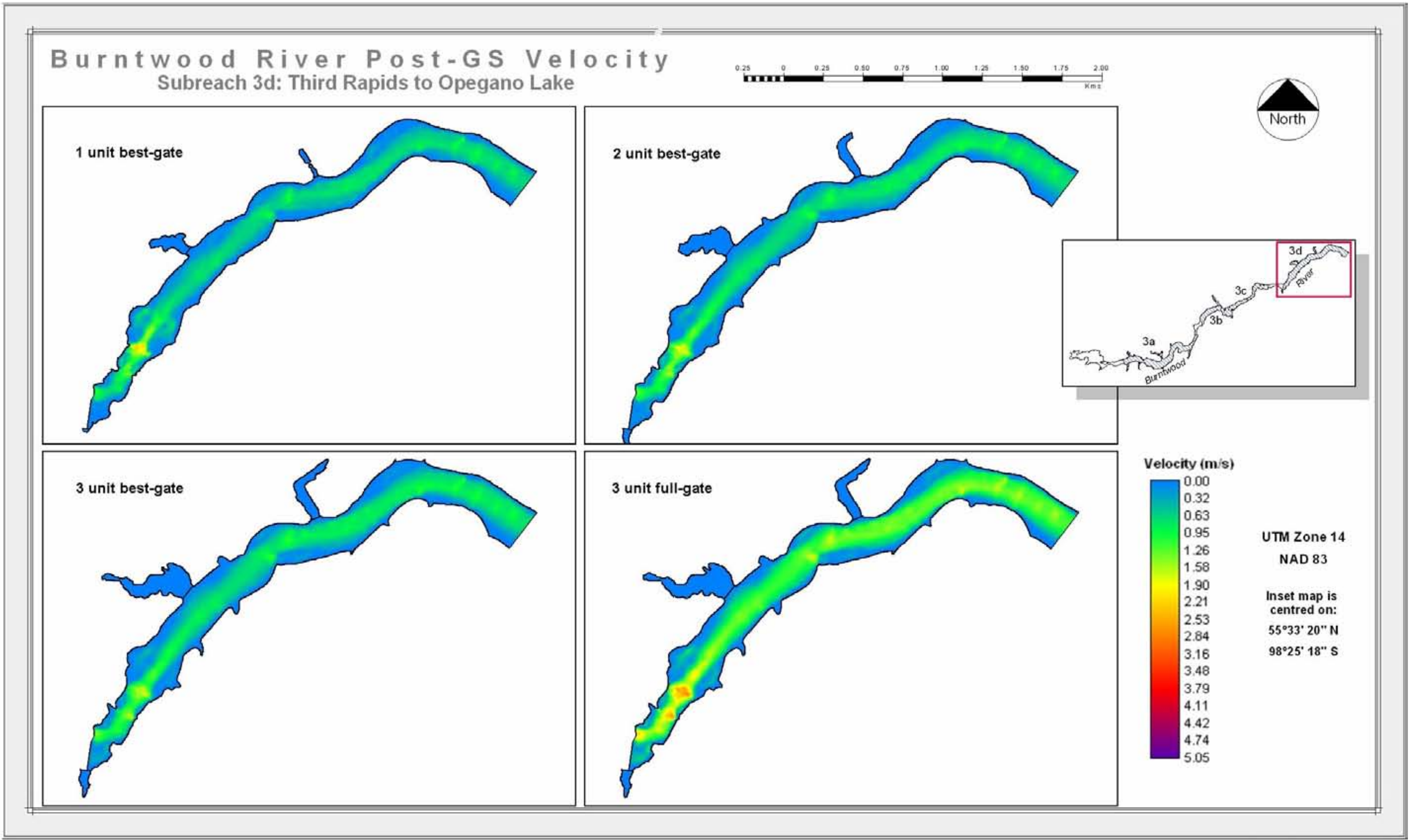


Figure 6-39C. Post-Project water velocities in Reach 3: Third Rapids to Opegano Lake.

Table 6-35. Post-Project areas of low, medium, and high water velocities in Reach 3.

Water Velocity Subsystem	1 Unit Best-Gate Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Mainstem	197.4	27.8	0.3
Backwater inlets	10.1	0.0	0.0
Reach 3 Total	207.4	27.8	0.3

Water Velocity Subsystem	2 Units Best-Gate Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Mainstem	139.6	96.5	3.8
Backwater inlets	20.4	0.0	0.0
Reach 3 Total	160.0	96.5	3.8

Water Velocity Subsystem	3 Units Best-Gate Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Mainstem	122.1	123.8	9.9
Backwater inlets	33.6	0.0	0.0
Reach 3 Total	155.7	123.8	9.9

Water Velocity Subsystem	3 Units Full-Gate Low (< 0.5 m/s) Area (ha)	Medium (0.5-1.5 m/s) Area (ha)	High (> 1.5 m/s) Area (ha)
Mainstem	119.8	129.0	13.0
Backwater inlets	37.8	0.0	0.0
Reach 3 Total	157.7	129.0	13.0

6.4.2.4 Reach 4: Opegano

As for Reach 3, aquatic habitat in Reach 4 is described under the post-Project operating regime (Table 6-36, Figure 6-40). During operation, water level elevation will fluctuate depending on the number of units operating. The IEZ will increase in size from about 50 ha to 86 ha (Table 6-37). The intermittently exposed area gained consists of 27.9 ha of aquatic habitat that was permanently wetted nearshore habitat the majority of the time pre-Project (will become lower quality habitat) and 8.5 ha of habitat that was considered terrestrial habitat (will remain very low quality habitat). The quality of the post-Project intermittently exposed habitat will be degraded in comparison to the existing situation due to the increased frequency of water level fluctuations. The nearshore zone will decrease in size post-Project due to the conversion of 27.9 ha that were more permanently wetted (higher quality) pre-Project to intermittently exposed post-Project. The area of the offshore zone will not be changed.

Table 6-36. Post-Project surface area, and water depth and volume for Reach 4.

Waterbody	3 Units Full-Gate			
	Surface Area (ha)	Maximum Depth (m)	Mean Depth (m)	Volume (m^3)
Opegano Lake	796.8	12.3	4.4	35185120

Table 6-37. Areas for the intermittently exposed, nearshore, and offshore habitat zones in Reach 4.

Waterbody	Pre-Project (95th percentile)			
	Intermittently Exposed Area (ha)	Nearshore Area (ha)	Offshore Area (ha)	Total Area (ha)
Opegano Lake	49.8	497.9	240.6	788.2

Waterbody	Post-Project (3 Units Full-Gate)			
	Intermittently Exposed Area (ha)	Nearshore Area (ha)	Offshore Area (ha)	Total Area (ha)
Opegano Lake	86.2	470.0	240.6	796.8

Peatlands potentially affected by the Project currently occupy about 30 ha in Opegano Lake, and are described in Volume 6.

This distribution of substrata types will not be noticeably altered post-Project, except for the small increase in area (8.5 ha) that was exposed greater than 95 % of the time pre-Project (i.e., considered terrestrial habitat) (will become newly flooded terrestrial).

After construction of the GS, the altered water regime may result in the loss of a substantial portion of the existing 45.5 ha (about 6 % of existing Reach 4 area) of rooted submergent aquatic plant beds (Section 7.4).

6.4.2.5 Stream Crossings

Impacts related to operation will be minimized due to control measures outlined in the Project Description (Volume 3) and practices that will be described in the EnvPP.

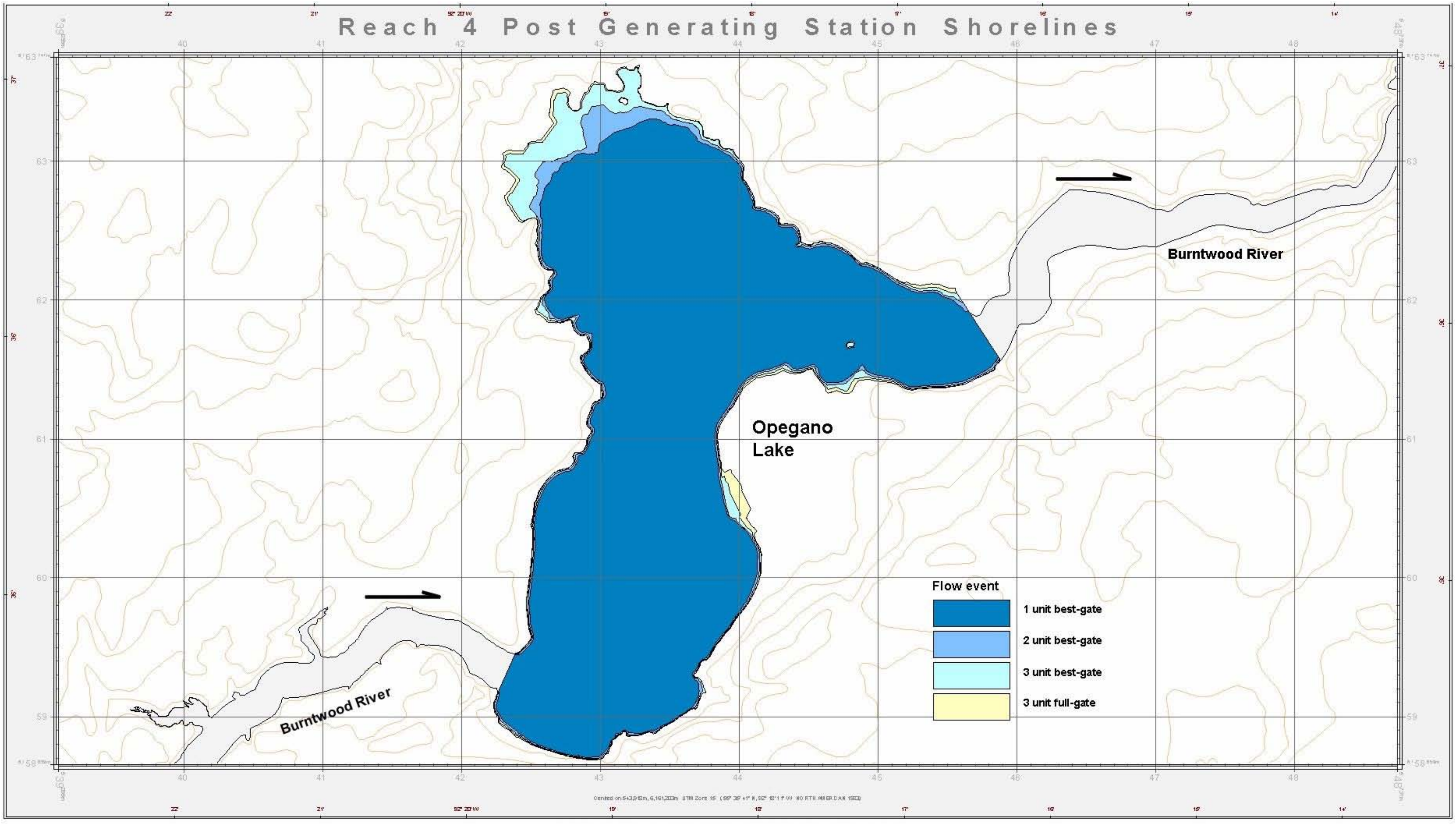


Figure 6-40. Post-Project shorelines in Reach 4 under several flow conditions.

7.0 LOWER TROPHIC LEVELS

7.1 INTRODUCTION

Lower trophic levels, as discussed in this document, are defined as all **aquatic** organisms that support the fish community. As such, lower trophic levels include organisms such as bacteria, algae (large filamentous algae and microscopic phytoplankton), large rooted plants (aquatic macrophytes), and invertebrates (zooplankton and benthic invertebrates). Lower trophic levels form the basis of the **food web** and, therefore, are important to higher trophic levels such as fish. As discussed in Section 6.0, the importance of lower trophic levels to fish communities is recognized in the *Fisheries Act*, which includes in the definition of fish habitat, the food sources (e.g., zooplankton, benthic invertebrates) on which fish depend to carry out their life processes (e.g., growth).

An evaluation of phytoplankton, rooted submergent aquatic plants, zooplankton, and benthic invertebrate communities was conducted to determine the production mechanisms and pathways in lower trophic level communities. Some components of the lower trophic levels, such as **microorganisms**, were not measured directly, but rather were evaluated indirectly through the measurements of closely associated parameters, such as dissolved and suspended organic carbon (detritus) (Section 5.0), and the quantification of bottom substrata types (e.g., the relative organic content of bottom sediments) (Section 6.0). Changes in the abundance and distribution of lower trophic groups as a result of chemical and physical changes in habitat (sections 5.0 and 6.0) are an important linkage to the effects to fish. An understanding of the existing lower trophic level community structure will allow more accurate prediction of potential impacts of the proposed Generation Project on fish populations. Groups such as emergent plants (e.g., *Scirpus* spp. [bulrush], *Typha* spp. [cattail]) occupy a transitional area between aquatic and terrestrial environments and are considered within the terrestrial portion of the assessment (Volume 6).

7.1.1 Lower Trophic Levels Study Area

The majority of lower trophic levels investigations were conducted in the area (Section 3.0) extending from Early Morning Rapids in the west downstream to Opegano Lake in the east (Figure 7-1). The study area was defined by the extent of water level and flow changes resulting from construction and operation of the Project. The magnitude of physical change (e.g., changes in water levels and flows) differs substantially among

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Source: 1:250,000 NTS base.

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Figure 7-1. Lower trophic levels study area, 1998 – 2001.

areas (Volume 3) and, consequently, the study area was divided into four reaches on the Burntwood River and a fifth area encompassing the streams crossed by the access road, as follows (Section 3.0):

- Reach 1: Wuskwatim;
- Reach 2: Falls;
- Reach 3: Burntwood;
- Reach 4: Opegano; and
- Stream Crossings.

Organic matter in water was investigated as part of the water and sediment quality studies (Section 5.0) in the area from the Burntwood River at the outlet of Kinosaskaw Lake (downstream of Threepoint Lake) to the lower Burntwood River at the inlet to Split Lake (Figure 5-1 [Section 5.0]). As discussed in Section 5.0, the study area for water quality was somewhat larger, extending from an upstream control site (outlet of Kinosaskaw Lake) to upstream of Split Lake.

A summary of the approach and methodology employed to collect information for the lower trophic level communities investigated is discussed in Section 7.2. A general description of the lower trophic level communities in the study area is presented in Section 7.3.1. An overview of the biology, and information on abundance, composition, and distribution or habitat use for each of the communities are presented in sections 7.3.2 to 7.3.5. Construction and operation impacts, and mitigation are discussed in Section 7.4.

7.2 APPROACH AND METHODOLOGY

The existing environment is described using several sources of information, including Traditional Knowledge (TK), existing published information, and studies conducted specifically as part of the environmental impact assessment of the Generation Project. Each of these data sources is described below.

7.2.1 Traditional Knowledge

As described in Volume 2, NCN and Manitoba Hydro have emphasized the importance of integrating TK in the EIS. TK was obtained from numerous sources, including commercial fishers, subsistence fishers, Elders, and field assistants working with the EMT (Volume 2). During the initial workshops held in February, 2000, and in subsequent discussions, NCN identified several concerns. Certain species of aquatic plants that grow in the nearshore environment are used by NCN for medicinal purposes;

these species are considered in Volume 6. NCN members also indicated that certain type(s) of clams are (were) used for medicinal purposes; however, subsequent interviews with resource users have not reported that these organisms are present in the study area. With respect to the impact assessment, NCN stressed the need for a 'holistic' approach that considers all parts of the environment including the small organisms and plants on which fish and wildlife depend.

7.2.2 Scientific Studies

Historical data for locations relevant to this study are not available for algae, aquatic plants, and zooplankton.

The Department of Fisheries and Oceans (Central and Arctic Region) collected benthic invertebrate data at three sites in Wuskwatim Lake during summer, 1973, 1977, 1981, 1983, and 1987 (Wiens and Rosenberg 1994). The study conducted by the Department of Fisheries and Oceans was concerned with describing the responses of the benthic invertebrates to the diversion of the Churchill River and to test predictions made by Hamilton and McRae (1974) in the original environmental impact statement. Three sites located in open areas of Wuskwatim Lake were sampled during summer (June), 1973, 1977, 1983, and 1987. Sieve size for washing samples free of mud was 400 µm.

Benthic invertebrate collection during the present study was conducted during fall (September – October), 1998 – 2001, in order to sample the community during a time of year when populations were not fluctuating substantially due to emergence of adult insects. Sieve size used to wash samples was 500 µm, as is currently recommended for the collection of benthic organisms from sediments (APHA 1998). Results obtained during the present study and that conducted by Wiens and Rosenberg (1994) are not directly comparable due to differences in sampling season and methodology. Therefore, the current assessment will be based on samples collected between 1998 and 2001.

7.2.3 Environmental Assessment Studies

An **ecosystem**-based approach was employed to assess the potential impacts of the Generation Project on the lower trophic communities. Information presented incorporates findings from other components of the aquatic studies (i.e., water and sediment quality, aquatic habitat, and fish community and movement studies). Organic matter (detritus), algae (e.g., phytoplankton), and rooted submergent aquatic plants provide the basis of the aquatic food web upon which all other organisms depend. Algae and plants are the primary producers, as they use energy from sunlight to convert carbon dioxide and water to organic compounds. Some of the primary producers are consumed directly by other organisms (**herbivore**s), but the majority die and enter the detrital **food chain**. Organic particles are colonized by bacteria and other microorganisms, which in turn are consumed by higher organisms (**detritivores**). Rooted submergent aquatic plants are also important in that they provide the physical habitat for many organisms. The plants provide **cover** for invertebrates and smaller fish species, which are food items of some larger fish species. Certain species of fish, such as yellow perch and northern pike, also inhabit aquatic plant beds. Invertebrates (e.g., zooplankton, benthic invertebrates) typically feed on organic matter, algae, other invertebrates, and, to a lesser extent, aquatic plants. In turn, invertebrates are important as food for larger animals, particularly **juvenile** and adult fish. Changes in abundance or species composition of invertebrates in an aquatic ecosystem may influence the fish community and/or the quality of aquatic habitat available for use by other organisms, including resource users. This understanding is consistent with the view of NCN that all components of the aquatic environment are important to maintaining the whole, and that all organisms are inter-dependent and, therefore, of importance and value.

A summary of the approach and methodology used for lower trophic levels studies conducted between 1998 and 2001 is presented in Volume 5, Appendix 7. The field program was comprised of four primary studies, as follows:

- phytoplankton;
- attached algae and rooted aquatic plants;
- zooplankton; and
- benthic invertebrates.

7.2.3.1 Phytoplankton

The objective of this study was to provide a semi-quantitative description of the phytoplankton community in terms of biomass, composition, and **chlorophyll** *a* concentration within study area waterbodies.

Phytoplankton samples were collected during the open-water seasons in 1999, 2000, and 2001. As phytoplankton abundance and community composition can vary during the season due to changes in environmental conditions (e.g., water temperature, availability of nutrients), sampling was conducted several times. The sampling periods were as follows:

- 1999: late May/early June, late June, August, September;
- 2000: late May/early June, July, August, September; and

- 2001: late May, July, August, late September.

Phytoplankton samples were collected from all lake sites that were selected for water quality studies in reaches 1 and 4, as illustrated in Figure 7-2. Phytoplankton biomass and composition were not assessed in reaches 2 and 3, as the water residence times in these reaches is relatively short and the water tends to be quite turbulent. These conditions reduce the potential for notable increases in the phytoplankton population. Chlorophyll ***a*** (a pigment found in phytoplankton cells), which is frequently used as an indirect measure of phytoplankton biomass, was quantified at the majority of lake and river locations selected for water quality studies (Figure 7-2). This provides a relative estimate of phytoplankton biomass for all locations.

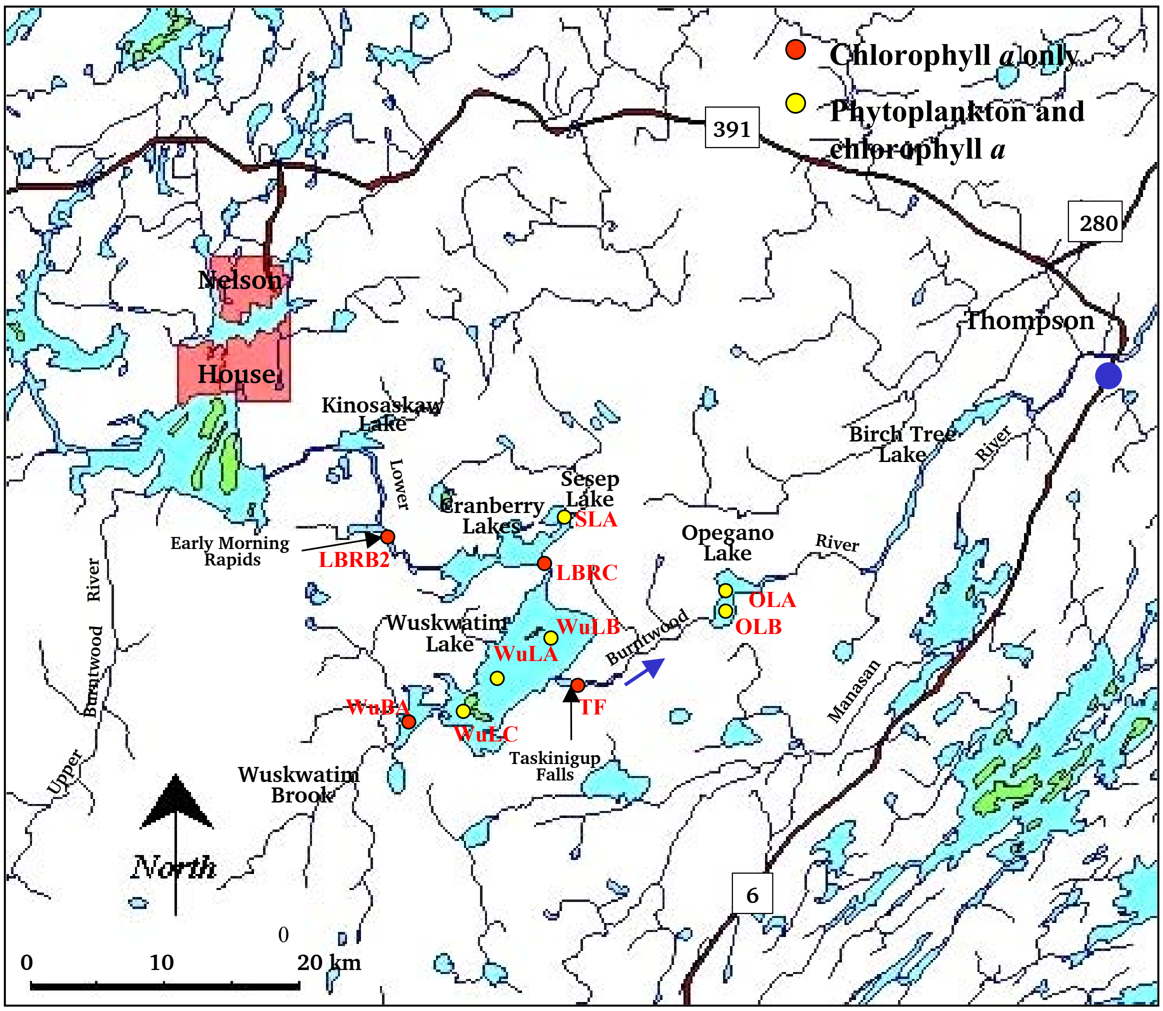


Figure 7-2. Phytoplankton and chlorophyll *a* sampling sites in the study area, 1999 – 2001.

Additionally, samples for chlorophyll *a* analysis were collected in June, 2002, for a portion of the stream crossings and adjacent areas along the access road.

Samples for the identification and enumeration of phytoplankton were collected directly into sample bottles from a depth of approximately 0.10 m. Immediately after collection, phytoplankton samples were preserved with Lugol's solution and sent to Enviro-Test Laboratories (Winnipeg, MB) for analysis. Algal cells were identified and counted in 10 mL of sample at 156X and 500X magnification (Utermohl technique modified by Nauwerck 1963). Cell biovolume (10 cells per species) was determined by applying the geometric formula best fitted to the cell shape (Vollenweider 1968). Phytoplankton biomass in mg/m^3 wet weight was determined from total sample biovolume (Fm^3), assuming a specific gravity of one for cellular mass.

Water samples for assessment of chlorophyll *a* were collected directly into laboratory supplied bottles and held on ice in the dark until receipt and analysis by Enviro-Test Laboratories (ETL method #8290).

7.2.3.2 Attached Algae and Rooted Aquatic Plants

The objective of this study was to provide a description of attached algae and rooted submergent aquatic plants in terms of relative abundance, composition, and distribution within study area waterbodies. Groups such as emergent plants (e.g., *Scirpus* spp. [bulrush], *Typha* spp. [cattail]) occupying a transitional area between aquatic and terrestrial environments are being considered within the terrestrial portion of the assessment (Volume 6).

General information on rooted submergent aquatic plant abundance, composition, and distribution in all reaches was obtained in conjunction with aquatic habitat surveys (Section 6.0). The presence/absence of aquatic plants during aquatic habitat surveys was noted; however, the level of detail collected was not sufficient to delineate the edges of beds. As rooted submergent aquatic plant distribution differs over time in response to inter-annual variation in water levels and other growing conditions, aerial surveys were conducted for all reaches in August and September, 2001, to better delineate aquatic plant distribution. Additionally, in September, 2001, boat-based surveys were conducted in reaches 1, 2, and 3, and ground-based surveys were carried out to assess eight major streams that crossed the access road corridor (Figure 7-3). Further aquatic habitat and fisheries assessments were conducted in June, 2002, after road routing was finalized, for the stream crossings and adjacent areas identified along the access road. Aquatic plant abundance, composition, and distribution were not properly assessed during the June, 2002, survey as growth of aquatic plants had just begun and was not representative of the

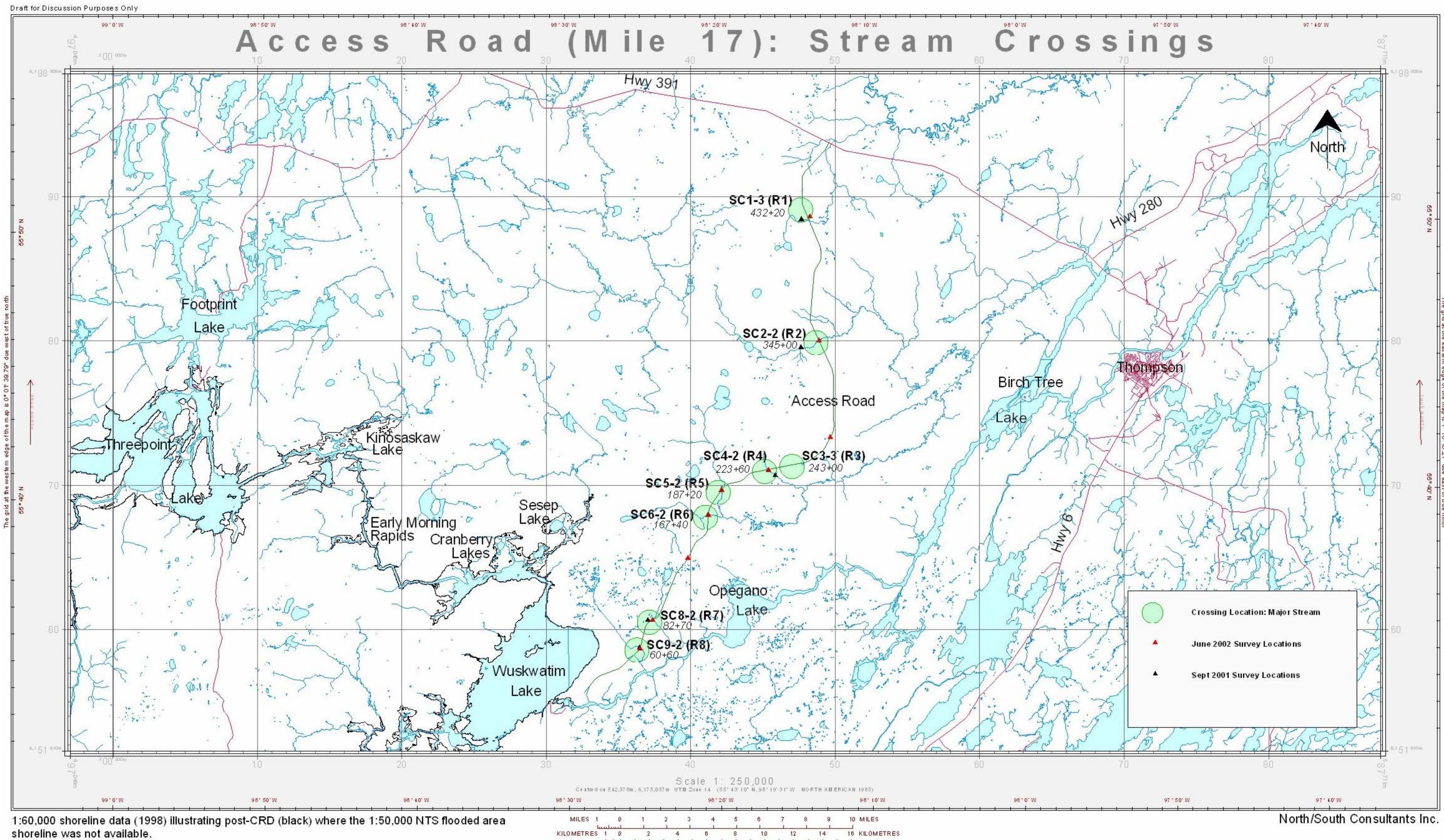


Figure 7-3. Eight major streams crossed by the Mile 17 access road.

community. Information from all surveys was transcribed directly onto field maps and included species composition and relative densities. Photographs were taken to provide a record of representative plant communities. Plants were either identified on site or preserved for identification in the laboratory.

Based on the aerial surveys, a total of 14 transects with 63 individual sites were selected for more detailed boat-based surveys in Reach 1 (Figure 7-4). These surveys were conducted from September 20 to 24, 2001. Transect locations were selected to: 1) ensure aquatic plants were sampled at various locations in the study area; and 2) provide plant community information from representative locations. The distribution of transects and sites included:

- three transects, consisting of 20 sites, within Cranberry Lakes;
- five transects, consisting of 20 sites, within Wuskwatim Lake south (south bay and south-west bay); and
- six transects, consisting of 23 sites, within Wuskwatim Brook.

A general description was recorded for each sampling site and three samples of aquatic macrophytes were collected. Aquatic macrophyte sampling consisted of three throws and retrievals of a multi-pronged hook attached to a length of rope. Plants were either identified on site or preserved for identification in the laboratory. Field data recorded at each sampling site included:

- plant species visible at the surface;
- plant species retrieved with the hook;
- a combined list of plants (arranged in order of relative abundance);
- UTM co-ordinates determined using a hand-held navigational quality GPS;
- total water depth; and
- Secchi depth.

The depth of the euphotic zone (z_1) (defined as the depth at which 1% of surface radiation still remains) was estimated from the measured Secchi depth (z_{sd}) at sampling sites using the following relationship for turbid (i.e., turbidity > 5 NTU) systems: $z_1 = z_{sd} \times 3.3$ (Kalff 2002).

Rooted submergent aquatic plant presence/absence data are described with respect to the physical conditions that describe their distribution, including: wave (hydraulic) energy

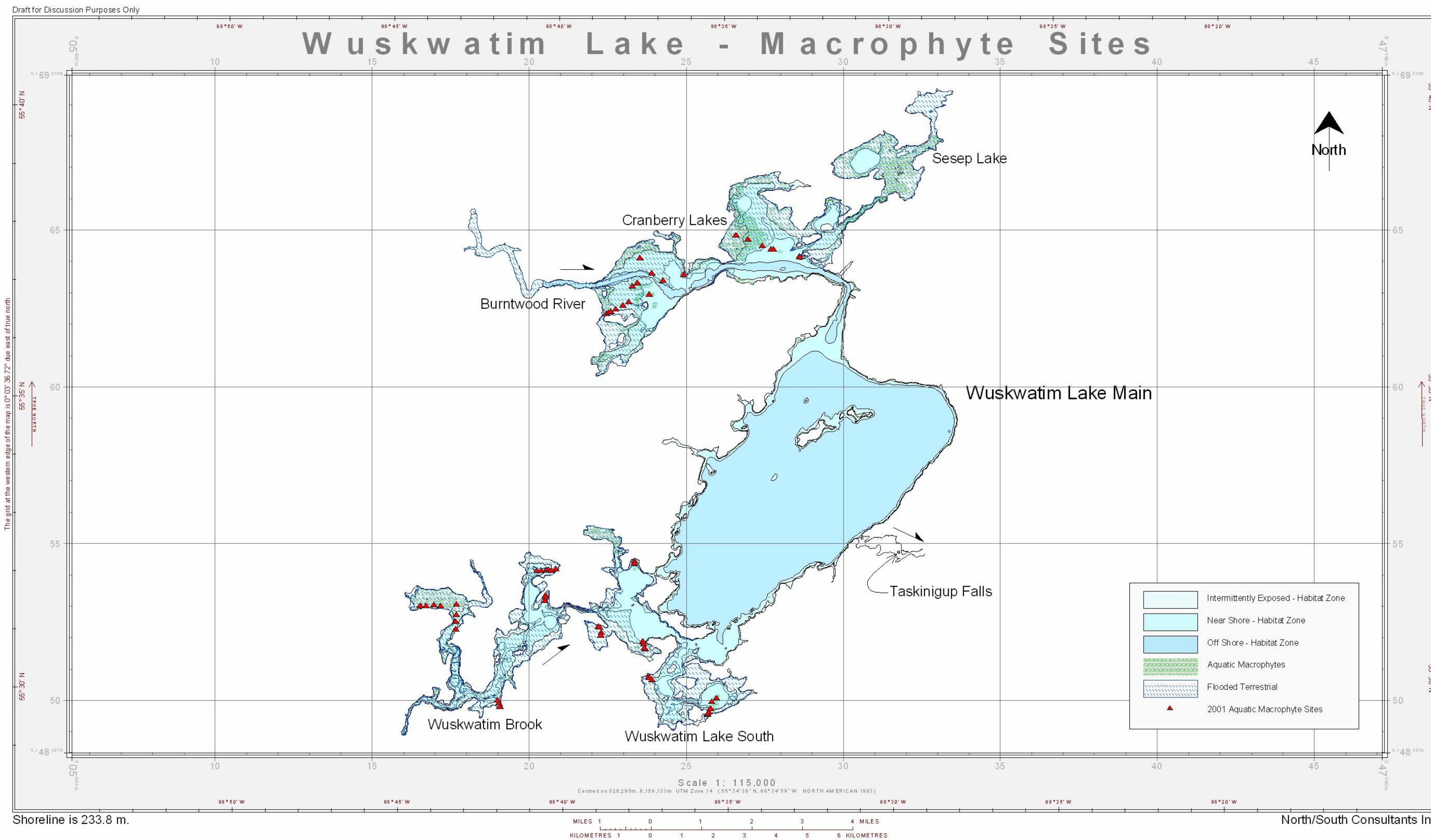


Figure 7-4. Rooted submergent aquatic plant sampling sites in Reach 1, 2001.

using fetch distance [exposure (m)] in standing water; elevation (m); substratum slope (%); distance from shore (m); modelled water velocity (m/s) in flowing water areas; and water depth (m) (Section 6.0). All plant species identifications were based on Brayshaw (1989, 2000), Crow and Hellquist (2000), Fassett (1960), and Scoggan (1957).

7.2.3.3 Zooplankton

The objective of this study was to provide a semi-quantitative description of the zooplankton community in terms of abundance, composition, and distribution within study area waterbodies.

Zooplankton samples were collected during the open-water seasons in 1999, 2000, and 2001. As zooplankton abundance and community composition can vary during the season due to changes in environmental conditions (e.g., water temperature, availability and quality of food), sampling was conducted several times. The sampling periods were as follows:

- 1999: late May/early June, late June, August, September;
- 2000: late May/early June, July, August, September; and
- 2001: late May, July, August, late September.

Zooplankton samples were collected at a portion of the lake sites in reaches 1 and 4 selected for water quality studies, as illustrated in Figure 7-5. Zooplankton samples were not collected at water quality sites in reaches 2 and 3, as the water residence times are relatively short and the water in these areas tends to be quite turbulent, particularly in Reach 2. These conditions reduce the potential for notable increases in zooplankton populations, as zooplankton cannot maintain positive net growth rates due to downstream losses. Samples in lakes were collected at both off-current (e.g., secluded bays that remain relatively isolated from the flow in the Burntwood River) and on-current ('mainstem') sites, as the abundance of these organisms is closely related to water residence time.

Zooplankton were collected in vertical, bottom to surface tows with a 63 µm mesh, 0.25 m diameter conical net. Tows were collected until at least approximately 100 organisms were visible in the sample bottle. Depth and number of tows were recorded to permit estimation of the total volume of water filtered for each sample. Zooplankton were identified to species using standard references, including Balcer et al. (1984), Edmondson (1959), Pennak (1978), and Smith and Fernando (1978). **Cladocera** were identified to species and enumerated. **Copepoda** were counted as either Cyclopoida and Calanoida copepodites, or Cyclopoida and Calanoida adults; only adults were identified to species. When possible, at least 200 individuals were counted in each sample. Large samples were sub-sampled depending on the density of specimens in each sample. Larger and/or relatively rare specimens were enumerated for the entire sample prior to sub-sampling. An estimate of density of each **taxon** captured in a given tow was calculated as the number of individuals per cubic metre of water filtered (individuals/m^3).

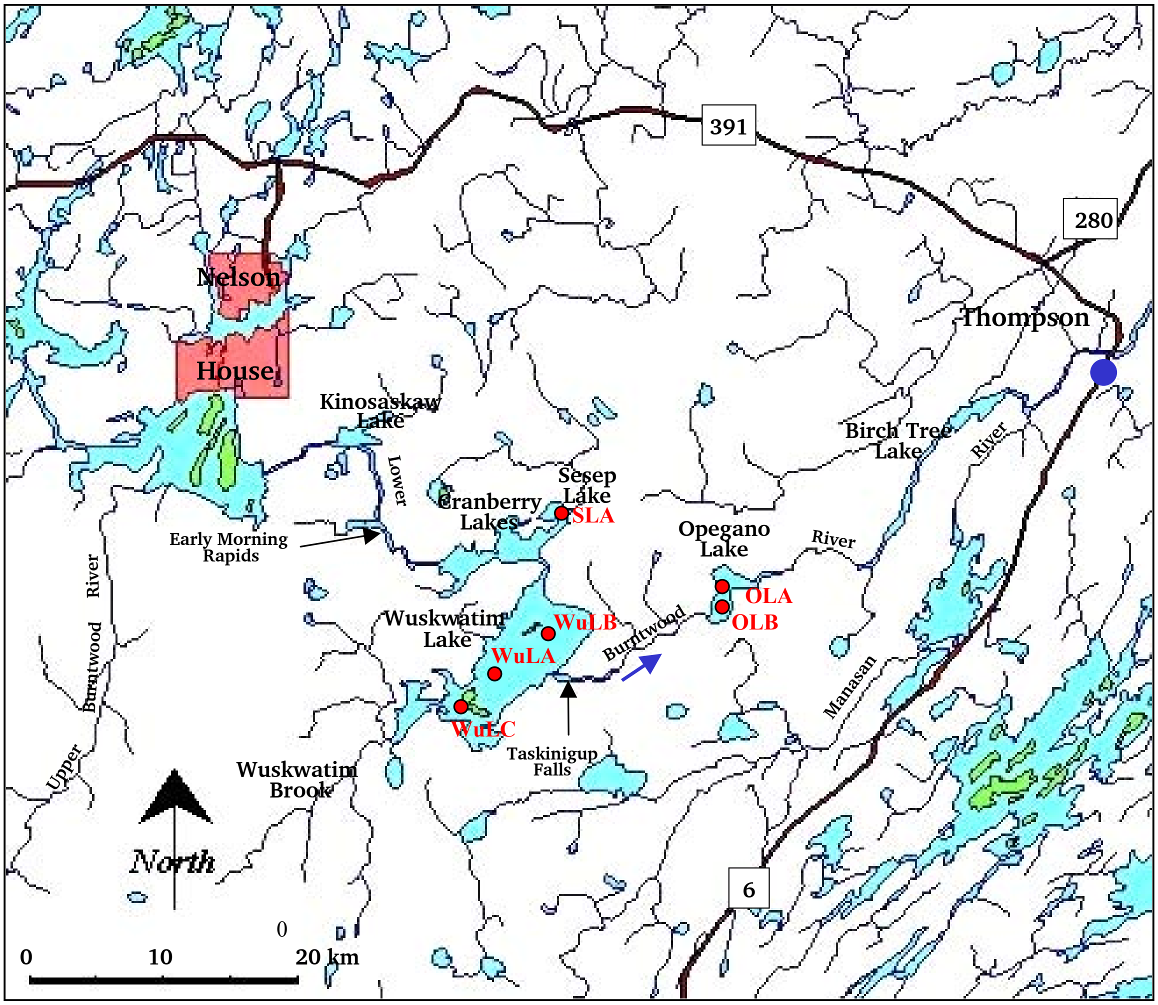


Figure 7-5. Zooplankton sampling sites in the study area, 1999 – 2001.

7.2.3.4 Benthic Invertebrates

Habitat-Based Community Assessment

The objective of this study was to provide a replicable, habitat-based, quantitative description of benthic invertebrate community abundance, composition, and distribution within study area waterbodies.

Benthic invertebrate samples at most sites were collected in at least two separate years during fall. The number and type of benthic invertebrates in a water body continually fluctuates during the summer months as organisms reproduce and as some (particularly aquatic larval insects, e.g., mayflies) periodically mature and emerge from the water as terrestrial adults. However, populations tend to stabilize in fall, permitting the community to be better represented by samples collected at a single time. Therefore, to make better comparisons among populations from one year to the next, sampling was conducted during this season. The majority of sites within Reach 1 (Wuskwatim Lake main) were sampled in 1999, 2000, and 2001, with additional sites sampled in 1998 (Figure 7-6). Adjacent waterbodies in Reach 1 (Cranberry Lakes, Sesep Lake, Wuskwatim Brook) (Figure 7-6), and sites in reaches 2 (Figure 7-7) and 3 (Burntwood) (Figure 7-8) are represented by data collected in 2001. Samples were collected at sites in Opegano Lake (Reach 4) in 2000 and 2001 (Figure 7-9).

The sampling periods were as follows:

- 1998: October 8 to October 10;
- 1999: September 15 to October 5;
- 2000: September 14 to September 23; and
- 2001: September 15 to September 27.

The distribution of benthic invertebrates within the aquatic environment can be highly variable among habitat types, and abundance can vary even among similar habitat types. Therefore, to achieve a better estimate of overall composition and abundance, to make inter-annual comparisons possible, and because different habitat types will be affected differently by the Project, sampling areas were chosen to encompass the range of habitats within the aquatic environment (e.g., shallow, nearshore versus deep, offshore areas, areas with and without rooted aquatic macrophytes, and areas with and without current). Due to logistical considerations, sampling sites were positioned along a transect that encompassed a number of different types of habitat. Aquatic habitat classification methodology is described in detail in Section 6.2. Lacustrine habitat in reaches 1 (Wuskwatim) and 4 (Opegano), and riverine habitat in reaches 2 (Falls) and 3 (Burntwood) were classified primarily based on water level criteria (Section 6.2). Further classification within all reaches was based on the type of bottom substrate, including flooded terrestrial vegetation, and the presence and type of rooted submergent aquatic plants. For riverine habitats, aquatic habitat was further delineated based on water velocity.

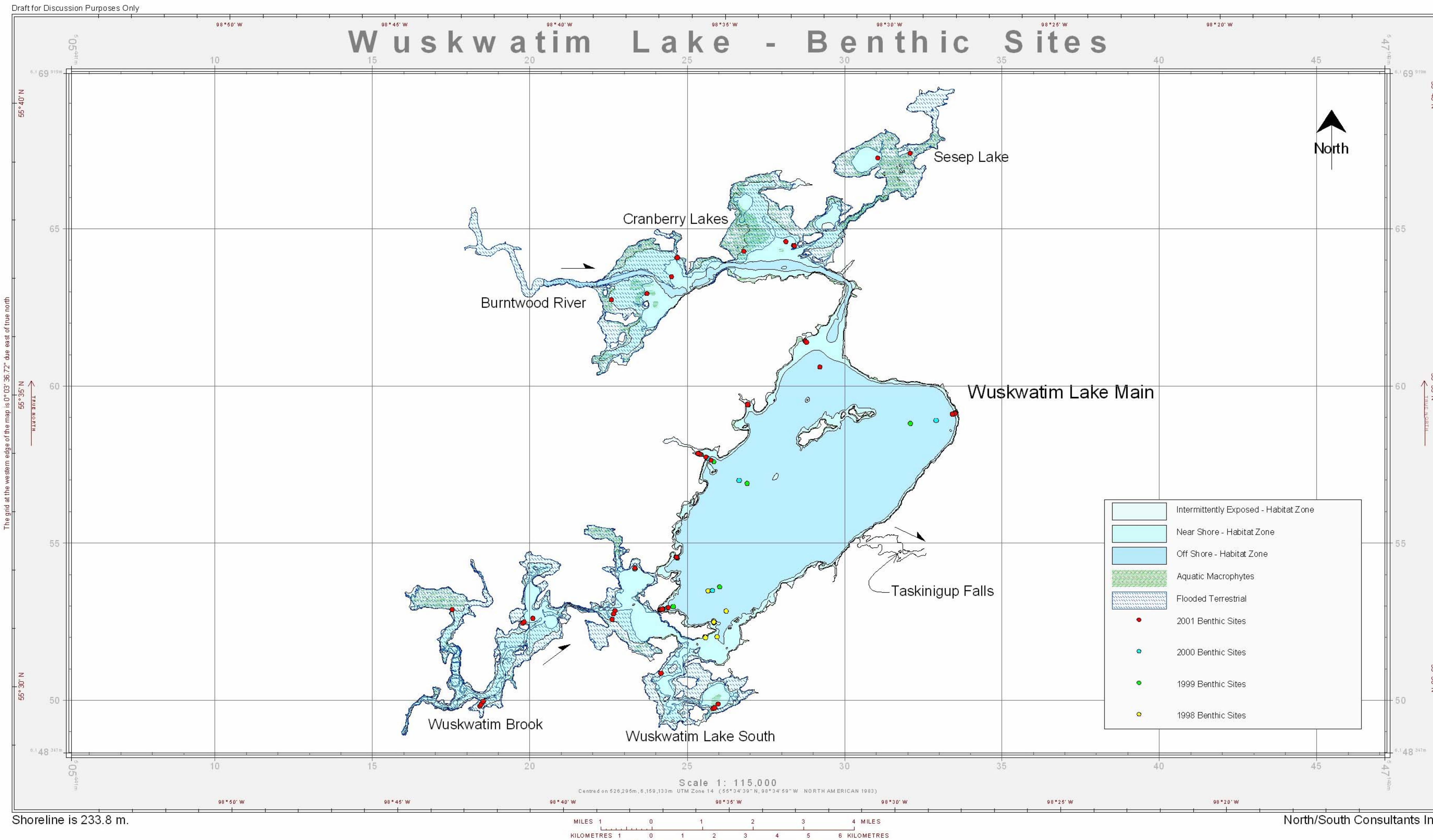


Figure 7-6. Benthic invertebrate sampling sites in Reach 1, 1998 – 2001.

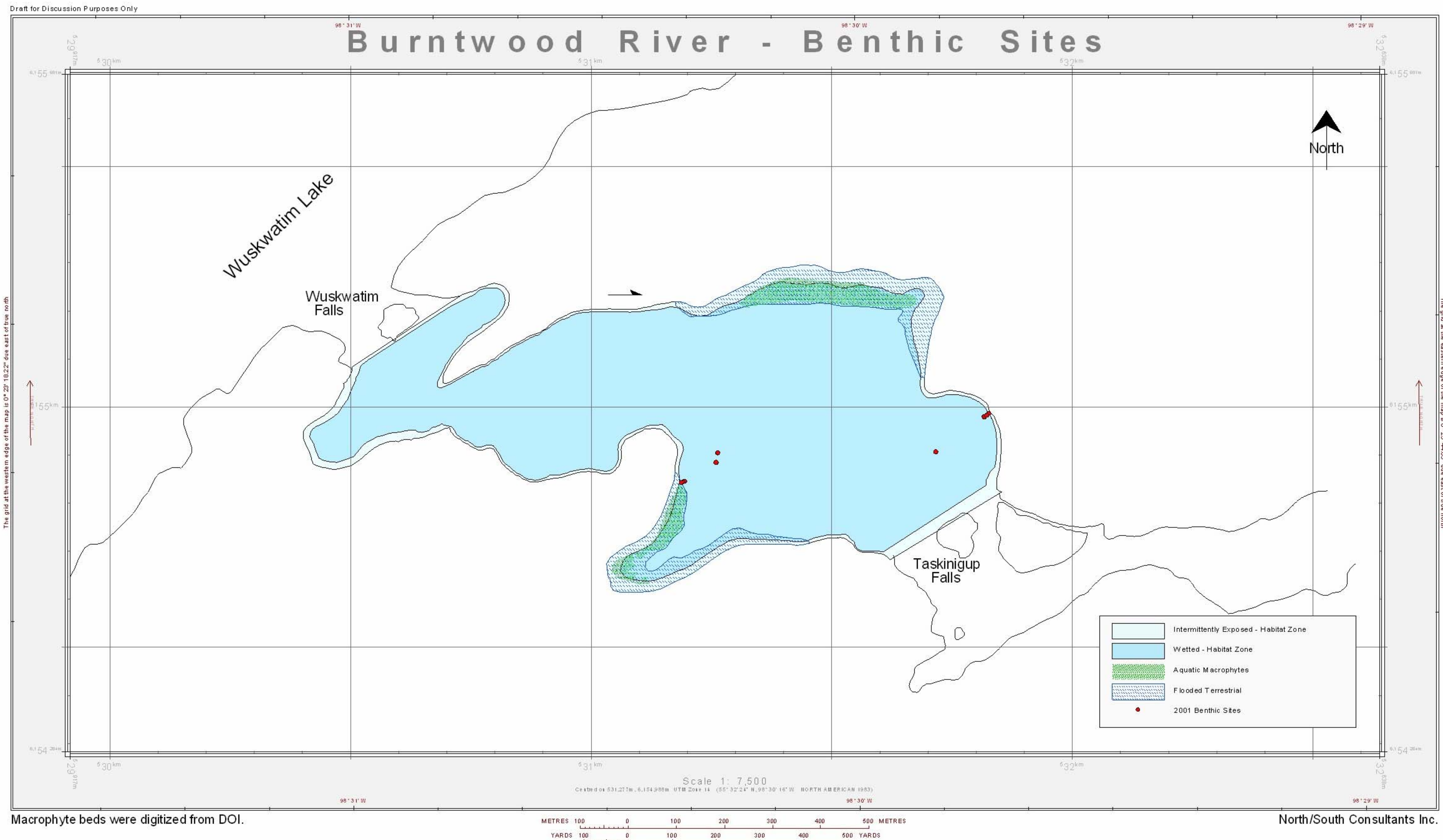


Figure 7-7. Benthic invertebrate sampling sites in Reach 2, 2001.

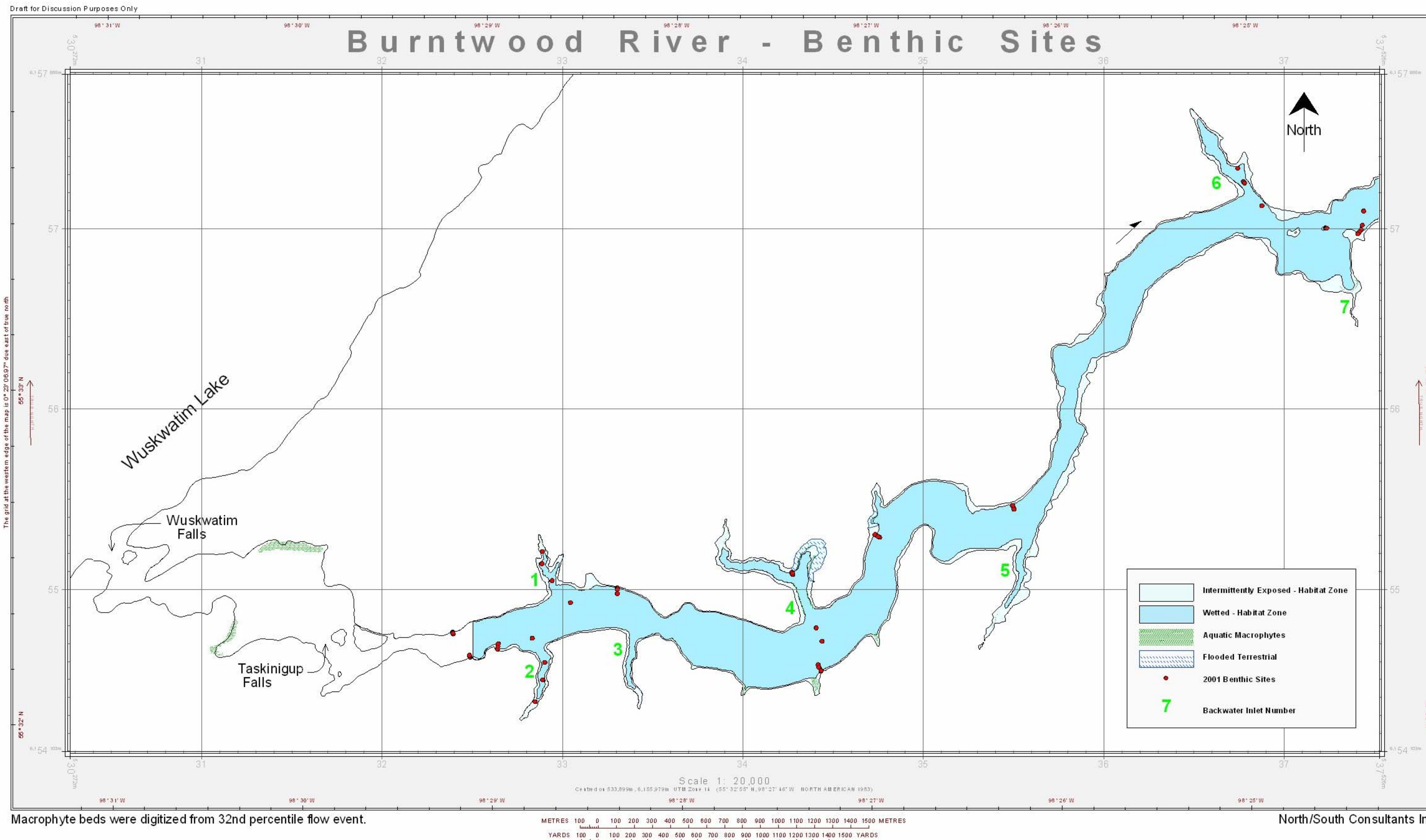


Figure 7-8A. Benthic invertebrate sampling sites in the upper portion of Reach 3, 2001.

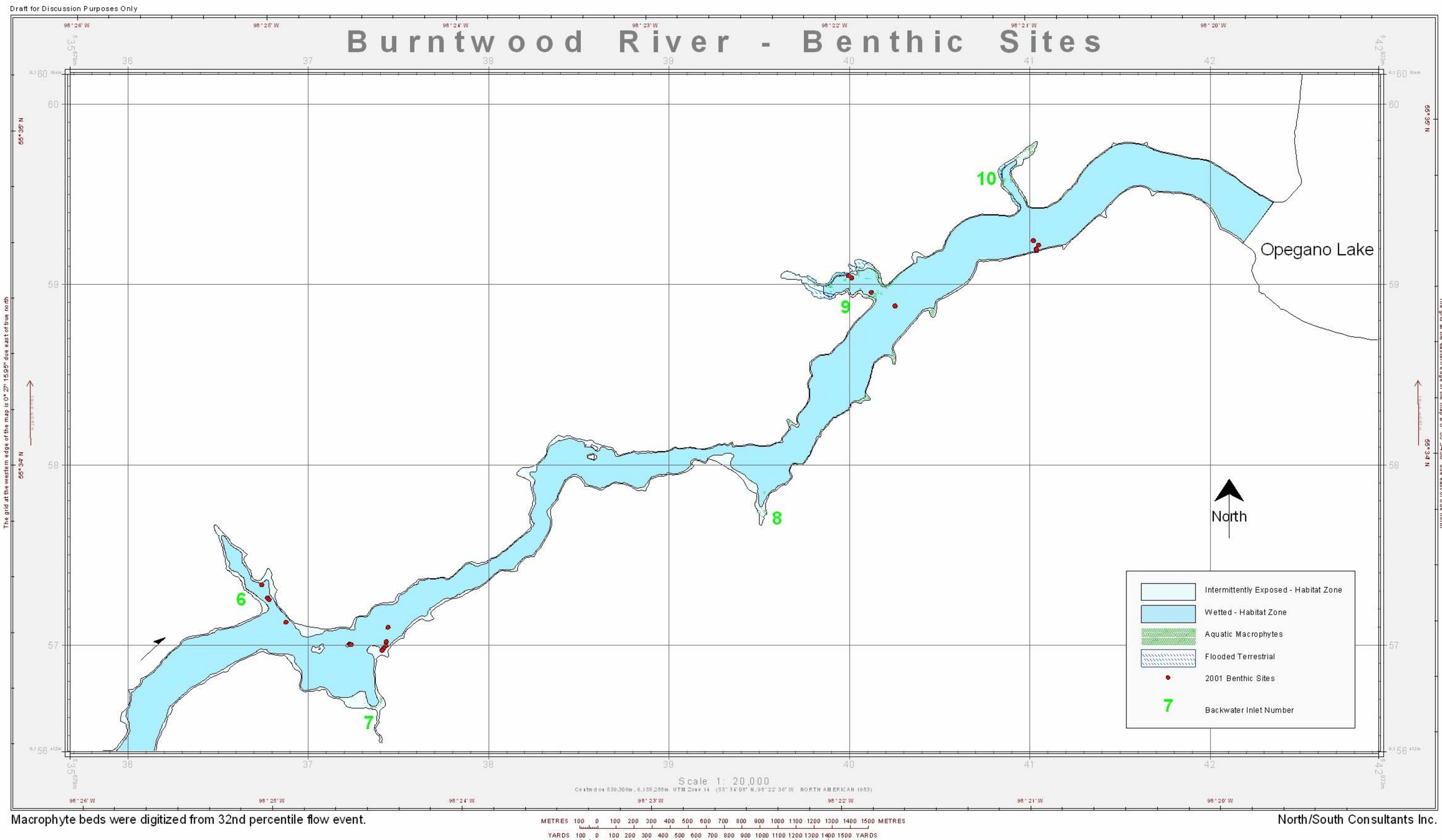


Figure 7-8B. Benthic invertebrate sampling sites in the lower portion of Reach 3, 2001.

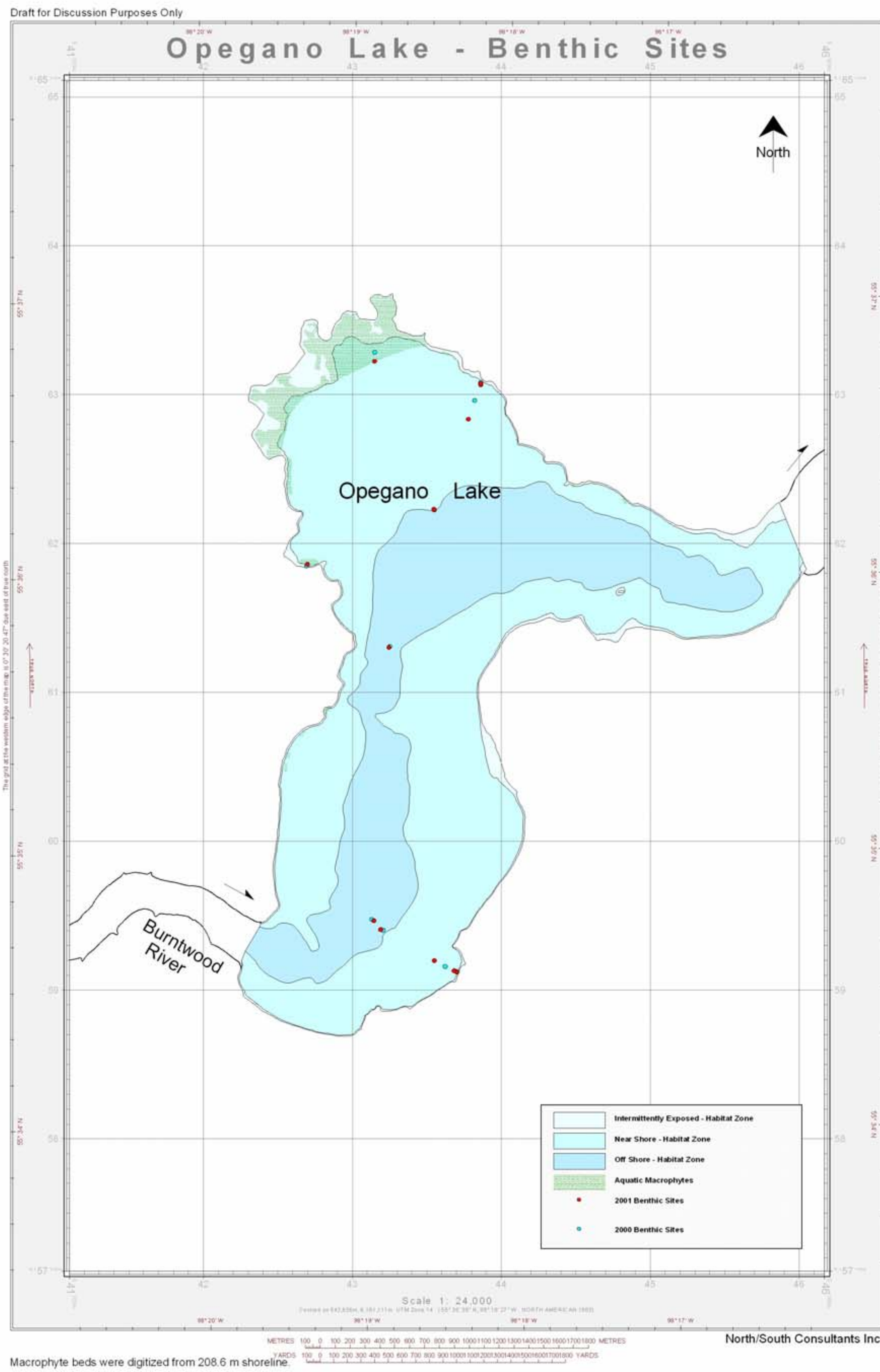


Figure 7-9. Benthic invertebrate sampling sites in Reach 4, 2000 – 2001.

Benthic invertebrate samples were collected in reaches 1 and 4 in lacustrine aquatic habitats with hard silt/clay- and soft silt/clay-based, and flooded terrestrial substrates using a 'tall' Ekman dredge (0.023 m^2 opening). Benthic samples were collected in reaches 2 and 3 using a 'petit' Ponar dredge (0.023 m^2 opening) in riverine aquatic habitats with boulder/cobble, and hard silt/clay- and soft silt/clay-based substrates. Additionally, an air-lift sampler (0.032 m^2 opening) was used in Reach 3 to sample riverine aquatic habitats with bedrock and boulder/cobble substrates. The air-lift sampler was constructed based on a design provided by the Department of Fisheries and Oceans (Winnipeg, MB) (pers. comm. W. Franzin and D. Watkinson).

Typically, four dredge or air-lift samples (replicates) were taken at each site to determine within-site benthic organism variability. Duration of each air-lift sample was 10 seconds (pers. comm. W. Franzin and D. Watkinson). Each replicate was sieved through a 500 μm mesh rinsing bag. Invertebrates were identified to major group and quantified. An estimate of density of each taxon captured in each replicate was calculated on an **areal** basis as the number of individuals per square metre of bottom substrate sampled (individuals/m^2).

A sub-set of benthic invertebrate samples collected in reaches 1, 2, and 3 in September, 2001, were further identified to genus and/or species to create an index of biodiversity for selected aquatic habitat types. Benthic invertebrates were identified to genus and/or species using an extensive list of references: Bednarik and McCafferty (1979); Brinkhurst (1986); Burks (1953); Clarke (1981); Clifford (1991); Dosdall and Lehmkuhl (1979); Edmondson (1959); Herrington (1962); Lewis (1974); Mackie et al. (1980); Mason (1973); Merritt and Cummins (1996); Provonsha (1990); Ross (1944); Schefter and Wiggins (1986); and Wiggins (1977). The Shannon-Weiner biodiversity index was calculated for 13 sites representing five aquatic habitat types in Reach 1, nine sites representing four habitat types in Reach 2, and 23 sites representing eight habitats in Reach 3.

A biodiversity index is a summary statistic used to describe a complex ecosystem or environment. The two fundamental characteristics of a community used in calculating a biodiversity index are species richness and evenness. Species richness is the number of species occurring in a community. Species diversity increases as species richness increases. Species evenness, on the other hand, is a measure of how evenly distributed abundances are among species within a community. Diversity is higher in communities characterized by having most of the species represented by roughly equal numbers of individuals (high evenness) and diversity is lower in communities within which a few species are dominant and the rest are represented by only a few individuals (low evenness). Both of these characteristics (species richness and evenness) must be taken into account in measuring species diversity. A more diverse population consisting of many species has a higher probability of including individuals that may be able to adapt to changes in the environment.

Qualitative Community Assessment

Drifting by benthic invertebrates is a relatively poorly understood phenomenon (Hynes 1970). Sudden high water velocities or large sediment loads increase drift, apparently because organisms are washed away or escape unfavourable conditions, but small numbers of drifting invertebrates are found even under favourable conditions. Drifting does allow the rapid colonization of newly created or cleared habitat.

Drift traps (designed after Burton and Flannagan 1976) were employed to provide a supplemental qualitative description of the benthic invertebrate community in reaches 1, 2, and 3, where sampling by other methods was otherwise not feasible due to logistical or safety concerns (i.e., high flows immediately upstream and downstream of Wuskwatim and Taskinigup falls).

The downstream drift of benthic invertebrates in late-June, 2001, was monitored in Reach 1, immediately downstream of the first rapids on Wuskwatim Brook (WB), and in reaches 2 and 3, downstream of Wuskwatim Falls (DT1) and Taskinigup Falls (DT3), respectively. In late-July, 2001, drift was again monitored at DT1 and DT3, with an additional site located in Reach 2, immediately upstream of Taskinigup Falls (DT2) (Figure 7-10).

Each drift trap was constructed with a 15 x 15 cm opening and a one metre-long cod end (i.e., net) of 500 μm mesh. Depending on current speed, the drift trap opening was at a water depth from 0.1 to 1.0 m. Drift traps were emptied daily and invertebrates were identified to major group. Drift trap information is used to provide a qualitative description of the benthic invertebrate community, and data are expressed as presence/absence of **taxa**.

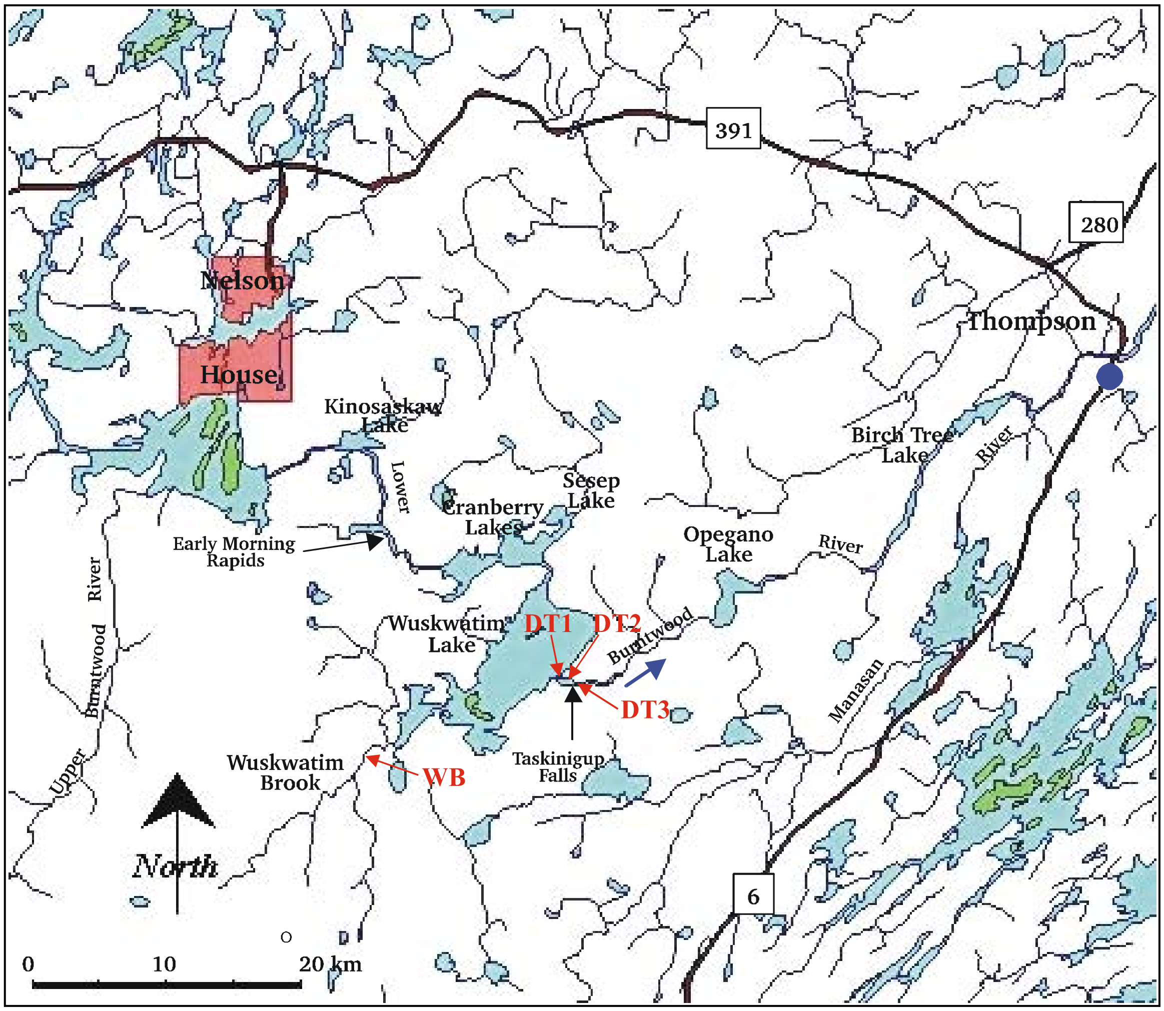


Figure 7-10. Drift trap sampling sites in the study area, 2001.

7.3 EXISTING ENVIRONMENT

7.3.1 Overview of Lower Trophic Level Communities

The study area encompasses a diverse range of habitats, from relatively large rivers to streams, a variety of sizes of lakes, and flooded terrestrial areas, and as such harbours many lower trophic groups. An overview of these different lower trophic groups among study reaches is presented Volume 1, Section 6.7. The detailed results for studies conducted for each group between 1998 and 2001 are discussed in sections 7.3.2 to 7.3.5.

From a **biodiversity** and **conservation** perspective, the aquatic environment of the study area is not unique. The area is similar to the aquatic environment in much of the northern boreal forest of Manitoba, Ontario, and western Quebec. Within the lower trophic communities investigated between 1998 and 2001 no 'species of conservation concern' were identified. This term includes species that are rare, disjunct (discontinuous or separated distribution), or at risk throughout their range, or the portion of their range within Manitoba, and in need of further research. Also included are species listed under the Manitoba Endangered Species Act (MBESA) and the Species At Risk Act (SARA), and those that have special designation by the Committee On the Status of Endangered Wildlife In Canada (COSEWIC). Concern was raised by an external expert with respect to the distribution of the showy pond snail (*Bulimnaea megasoma*) within Manitoba; however, this species has not been evaluated and ranked by the Manitoba Conservation Data Centre and was not observed within the study area.

7.3.2 Phytoplankton

7.3.2.1 Overview of Biology

The most important source of energy in the aquatic environment is solar radiation from the sun. This energy may flow directly to photosynthetic organisms such as plants and algae within the waterbody itself, or reach the lake indirectly via organic material transported by inflowing waters from terrestrial or adjacent aquatic systems. The relative importance of these two sources of energy input depends on the size of the lake relative to its watershed, and the nature of the watershed.

The availability of light is the primary determinant of the distribution of photosynthetic organisms. The growth of photosynthetic organisms is limited to the **photic** zone, which extends from the lake surface to the lower limit at which there is sufficient light for photosynthesis. The lower limit of the photic zone depends on the clarity of the water. Rates of production by photosynthetic organisms are also strongly affected by the availability of nutrients, temperature, and water movement. Of the nutrients, nitrogen and phosphorus tend to be required in the largest amounts and their supply frequently determines the quantity and type of producers observed. The rates of physiological processes (photosynthesis, assimilation, respiration, and reproduction) tend to increase with temperature to an upper limit, after which warmer temperatures are harmful. Water movement plays a key role in determining the productivity of photosynthetic organisms. A certain degree of wave action or mixing within the photic zone is essential to maintain supplies of nutrients and carbon dioxide; however, excessive mixing can decrease the extent of the photic zone by increasing turbidity.

There are typically three primary groups of photosynthetic organisms present in the aquatic environment: microscopic algae known as phytoplankton that live suspended in the water column; attached algae (periphyton) that grow on rocks, along the mud surface, and on aquatic plants; and rooted plants that live along the shorelines where conditions, such as substrate and light availability, are suitable.

Several groups of freshwater algae comprise the phytoplankton: chrysophytes (Chrysophyceae [yellow-green or yellow-brown algae] and Diatomaceae [diatoms]), chlorophytes (green algae), cyanophytes (blue-green algae or cyanobacteria), Peridiniaceae (dinoflagellates), cryptophytes (cryptomonads) and euglenophytes (Figure 7-11). Phytoplankton abundance and species composition vary spatially and temporally in response to changes in light, nutrient availability, and other growing conditions.

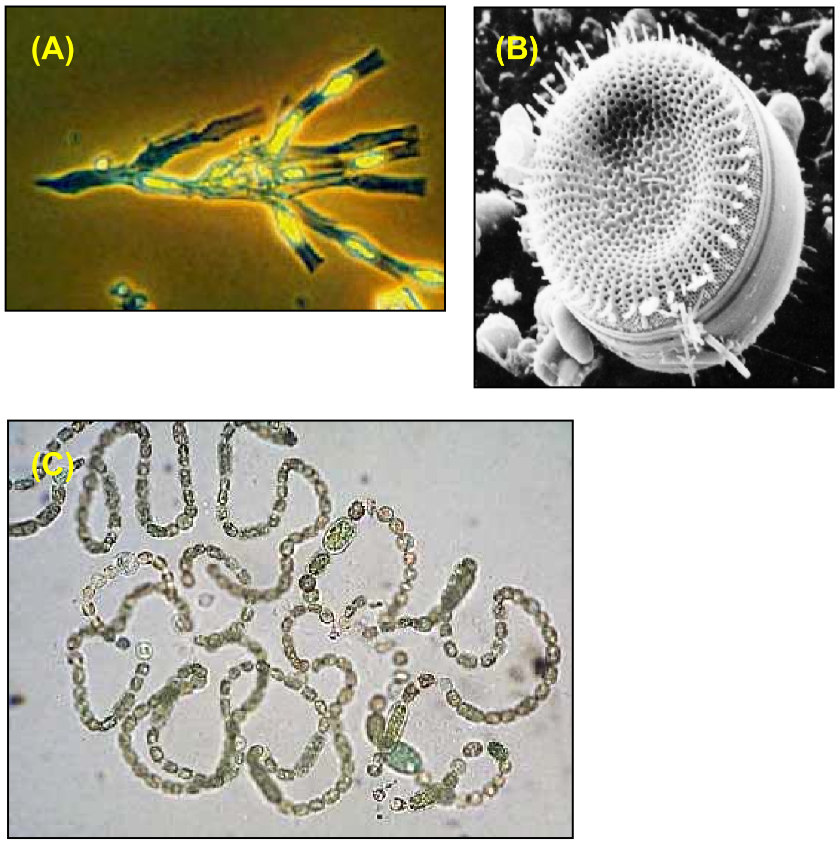


Figure 7-11. Representatives of the freshwater phytoplankton: (A) chrysophyte; (B) diatom; and (C) blue-green algae.

The degree to which the photic zone offers suitable growing conditions for phytoplankton is strongly influenced by the stability of the water column. Studies in several northern Manitoba lakes and reservoirs have indicated that phytoplankton biomass does not develop sufficiently to utilize the available phosphorous (e.g., Southern Indian Lake, Hecky and Kilham 1988). Rather, phytoplankton growth is limited by wind-induced turbulence in combination with turbid water. It is unlikely that phytoplankton are a major source of production in most regions in the study area given that the water is turbid, wind-induced wave action causes considerable mixing, and retention time of water is relatively low.

7.3.2.2 Biomass, Composition, and Chlorophyll a

The following presents results from 1999, 2000, and 2001; however, only 2001 data is presented graphically, as samples were obtained from all sites (North/South Consultants Inc. unpublished data).

Reach 1

In 1999 and 2000, samples for analysis of phytoplankton biomass and species composition were obtained from Wuskwatim Lake mainstem sites (WuLA and WuLB) (Figure 7-2). In 2001, samples were obtained from the same Wuskwatim Lake main sites and also from Wuskwatim Lake south (WuLC) and Sesep Lake (SLA) (Figure 7-2).

Phytoplankton biomass was lowest in 2001 (range of 243 to 2908 mg/m^3) and highest in 2000 (range of 1215 to 7190 mg/m^3) (Table 7-1). Mean biomass for all sites and years ranged from 592 mg/m^3 (SLA in 2001) to 4025 mg/m^3 (WuLB in 2000). The average biomass for all sites and years was 1950 mg/m^3 (Table 7-1).

Although results were somewhat variable, levels of phytoplankton biomass at mainstem sites WuLA and WuLB were similar and tended to be highest in spring (period 1) and lowest in early summer (period 2) (Figure 7-12). This was somewhat different from the seasonal pattern at tributary sites, SLA and WuLC. These sites had lower levels of spring biomass than mainstem sites, with maximum levels occurring in late summer (period 3) (Figure 7-12).

In spring of 1999 and 2000, diatoms were the dominant algal species at WuLA and WuLB, ranging from 70 to 90 % (Table 7-2). In spring 2001, diatoms were somewhat less dominant, comprising 49 to 51 % of the biomass, and were nearly co-dominant with the Chrysophyceae, which ranged from 39 to 45 % (Table 7-2, Figure 7-12). Chrysophyceae were generally dominant at WuLA and WuLB at all other sampling times, ranging from 78 to 95 % at WuLA and from 36 to 95% at WuLB (Table 7-2). Cyanophytes were identified at both sites at all times, but notable biomass only occurred in the months of July and August (periods 2 and 3), with levels ranging from 2.5 % at WuLA (July, 2000) to 58 % at WuLB (August, 1999). Cyanophytes tended to be higher at WuLB throughout the summer, and dominated the biomass (58 %) at this site in August, 1999 (Table 7-2). Cryptophytes were present in most samples from WuLA and

WuLB, but only consistently exceeded 1 % of biomass when sampled in September (period 4). Chlorophytes were usually present in samples from WuLA and WuLB, but only exceeded 1% of biomass in a few samples. Other species identified belonged to the Euglenophyta and Pyrrophyta. These groups were generally only identified at WuLA and WuLB at one or two sampling times per year, with maximum combined levels of less than 0.5 % in 1999, 3.3 % in 2000, and 7.5 % in 2001 (Table 7-2).

Table 7-1. Summary of phytoplankton biomass (mg/m^3) by reach or site, and year, 1999 – 2001.

Reach	Site	Year	Mean	Minimum	Maximum	n [1]
1	SLA	2001	592	460	716	3
1	WuLA	1999	2257	1096	3564	4
1	WuLA	2000	3611	1215	6973	3
1	WuLA	2001	1037	243	2908	4
1	WuLB	1999	2820	1152	4719	3
1	WuLB	2000	4025	1691	7190	3
1	WuLB	2001	1015	279	2632	4
1	WuLC	2001	1059	527	1625	4
1	All Sites	1999	2498	1096	4719	7
1	All Sites	2000	3818	1215	7190	6
1	All Sites	2001	948	243	2908	15
1	All Sites	1999-2001	1950	243	7190	28
4	OLA	2000	2497	2412	2582	2
4	OLA	2001	839	287	2356	4
4	OLB	2000	2835	2095	3574	2
4	OLB	2001	867	195	2372	4
4	All Sites	2000	2666	2095	3574	4
4	All Sites	2001	853	195	2372	8
4	All Sites	2000-2001	1457	195	3574	12

[1] number of samples collected/year

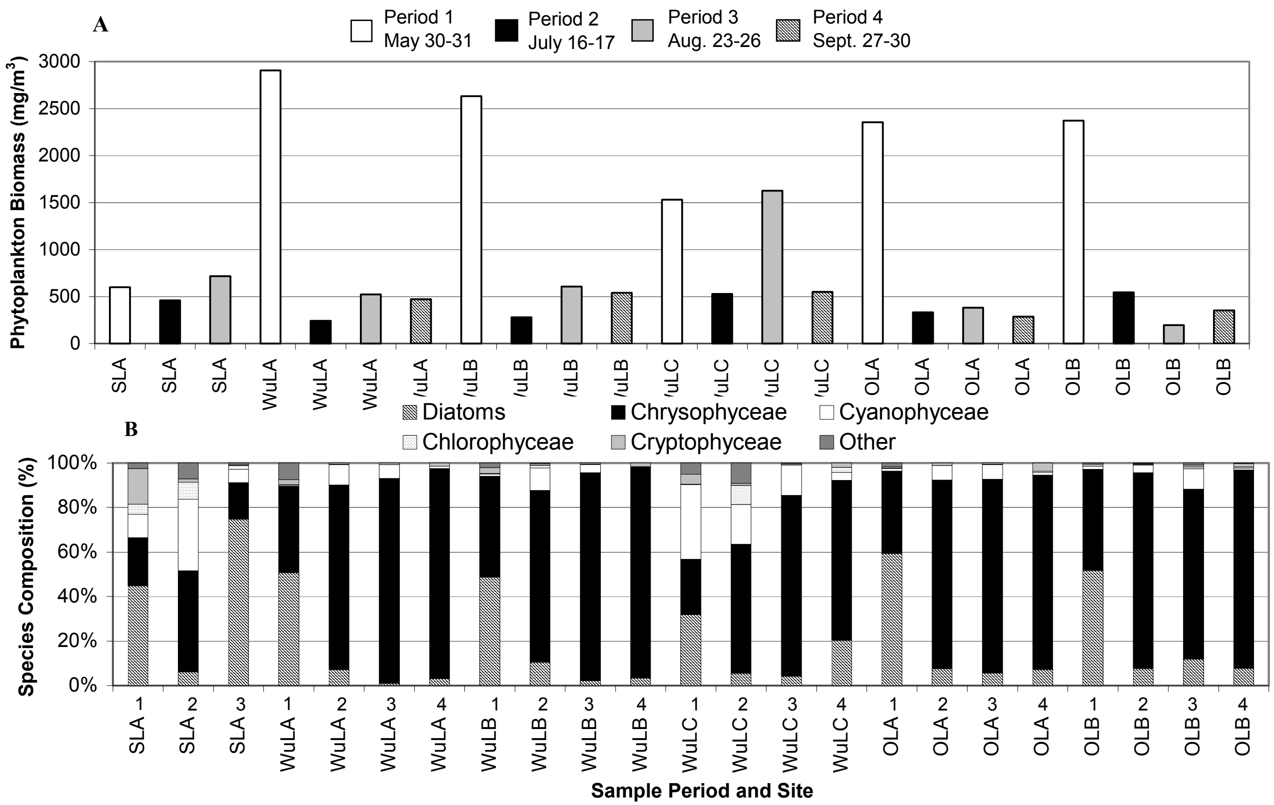


Figure 7-12. Phytoplankton biomass (A) and composition (B) in samples collected from study reaches 1 (SLA – WuLC) and 4 (OLA – OLB), 2001.

Table 7-2. Percent composition of phytoplankton groups, 1999 – 2001.

Reach	Site	Year	Chlorophyta *Chlorophyceae* (%)				Cyanophyta *Cyanophyceae* (%)				Chrysophyta *Diatomaceae* (%)				Chrysophyta *Chrysophyceae* (%)			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	SLA	2001	4.6	7.7	1.7	-	10	32	5.9	-	45	6.2	75	-	22	46	17	-
1	WuLA	1999*	0.02	0.05	0.01	0.40	0.49	1.4	11	0.52	89	90	11	9.4	10	8.3	78	84
1	WuLA	2000	0.00	0.32	-	8.6	0.03	2.5	-	0.25	74	10	-	6.5	26	82	-	82
1	WuLA	2001	0.04	0.11	0.01	0.03	0.61	9.1	6.1	1.0	51	7.1	0.98	3.0	39	83	92	95
1	WuLB	1999*	-	0.18	2.3	1.5	-	4.5	58	0.75	-	70	2.7	36	-	24	36	54
1	WuLB	2000	0.42	0.09	-	0.06	0.02	21	-	1.3	80	2.2	-	10	20	74	-	86
1	WuLB	2001	0.28	1.1	0.26	0.02	1.0	10	3.6	0.26	49	10	2.3	3.3	45	77	93	95
1	WuLC	2001	0.25	8.4	0.05	2.3	33	18	14	3.5	32	5.5	4.1	20	25	58	81	72
4	OLA	2000	-	-	0.62	0.72	-	-	1.6	2.1	-	-	4.4	16	-	-	88	78
4	OLA	2001	0.11	0.08	0.01	0.58	1.1	6.5	6.6	1.2	59	7.5	5.6	7.2	37	85	87	87
4	OLB	2000	-	-	0.76	1.8	-	-	0.85	1.4	-	-	8.3	8.1	-	-	87	81
4	OLB	2001	0.02	0.15	0.87	0.56	1.3	3.5	9.0	0.74	52	7.7	12.0	7.8	45	88	76	89

Reach	Site	Year	Cryptophyta *Cryptophyceae* (%)				Euglenophyta *Euglenophyceae* (%)				Pyrrophyta *Peridineae* (%)				Others - Euglenophyta and Pyrrophyta Combined (%)			
			1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
1	SLA	2001	16	1.5	0.30	-	2.5	0.20	0.00	-	0.00	7.0	0.82	-	2.5	7.1	0.80	-
1	WuLA	1999*	0.00	0.01	0.30	5.0	0.00	0.13	0.00	0.05	0.00	0.00	0.00	0.28	0.00	0.13	0.00	0.34
1	WuLA	2000	0.27	1.8	-	3.0	0.00	3.3	-	0.00	0.00	0.00	-	0.00	0.00	3.3	-	0.00
1	WuLA	2001	2.2	0.66	0.77	1.4	0.23	0.00	0.00	0.00	7.3	0.00	0.00	0.00	7.5	0.00	0.00	0.00
1	WuLB	1999*	-	0.02	0.14	7.7	-	0.46	0.33	0.00	-	0.00	0.00	0.00	-	0.46	0.33	0.00
1	WuLB	2000	0.17	1.5	-	2.8	0.00	1.4	-	0.00	0.00	0.00	-	0.00	0.00	1.4	-	0.00
1	WuLB	2001	2.5	0.79	0.47	1.6	1.2	0.34	0.00	0.00	0.91	0.00	0.00	0.00	2.1	0.34	0.00	0.00
1	WuLC	2001	4.4	1.0	0.43	1.9	3.5	5.7	0.00	0.00	1.6	3.5	0.39	0.00	5.1	9.1	0.39	0.00
4	OLA	2000	-	-	5.0	3.3	-	-	0.14	0.14	-	-	0.00	0.00	-	-	0.14	0.14
4	OLA	2001	0.63	1.1	0.68	3.6	0.68	0.00	0.00	0.00	1.0	0.00	0.00	0.00	1.7	0.00	0.00	0.00
4	OLB	2000	-	-	1.5	7.2	-	-	1.4	0.81	-	-	0.00	0.00	-	-	1.4	0.81
4	OLB	2001	0.93	0.40	0.89	1.6	0.51	0.25	0.87	0.19	0.00	0.00	0.00	0.00	0.51	0.25	0.87	0.19

In 1999, sampling periods 1, 2, 3, and 4 correspond to sampling dates of June 2, June 26, August 19, and September 29, respectively.

In 2000, sampling periods 1, 2, 3, and 4 correspond to sampling dates of June 14, July 24, August 15, and September 18-24, respectively.

In 2001, sampling periods 1, 2, 3, and 4 correspond to sampling dates May 30-31, July 16-17, August 23-26, and September 27-30, respectively.

\- indicates no sample collected.

* note that sampling period 2 in 1999 has been considered to be representative of spring conditions.

Phytoplankton species composition differed somewhat at SLA and WuLC relative to the mainstem sites. Similar to Wuskwatim main sites, diatom biomass in spring was relatively high (45 and 32 % at SLA and WuLC, respectively); however, the remainder of the spring biomass was more diverse than at the mainstem sites. For example, there were fewer Chrysophyceae (22 and 25 % at SLA and WuLC, respectively), and more cyanophytes (10 % and 33 % at SLA and WuLC, respectively) and cryptophytes (16 and 4.4 % at SLA and WuLC, respectively) at SLA and WuLC when compared to WuLA and WuLB (Table 7-2, Figure 7-12). In spring, chlorophytes were also present in relatively high numbers in SLA (4.6%), relative to other sites (Figure 7-12).

Phytoplankton composition at SLA and WuLC also differed in early and late summer (periods 2 and 3) relative to Wuskwatim main sites. While the Chrysophyceae were the most abundant group in Sesep Lake in early summer (46 %), they were not as dominant as at mainstem sites. Within Sesep Lake there was a relatively large percentage of cyanophytes (32 %), chlorophytes (7.7%), diatoms (6.2%), and others (7.1), when compared to Wuskwatim main sites. In late summer, SLA differed from all other sites, with diatoms being dominant (75 %), and a majority of the remaining biomass consisting of Chrysophyceae, cyanophytes, and chlorophytes (17, 5.9, and 1.7 %, respectively) (Table 7-2, Figure 7-12). Similar to mainstem sites, WuLC was dominated by Chrysophyceae from early summer to fall (periods 2 to 4), with biomass ranging from 58 to 81 % (Table 7-2, Figure 7-12). In early summer (period 2), WuLC differed from mainstem sites, with cyanophytes (18 %), chlorophytes (8.4 %), and other species (9.1 %) comprising a larger proportion of the biomass (Table 7-2, Figure 7-12). In late summer and fall (periods 3 and 4), phytoplankton composition at WuLC was more similar to that at mainstem sites than in early summer (period 2) (Table 7-2, Figure 7-12).

Chlorophyll *a* was measured in the lower Burntwood River (LBRC) and Wuskwatim Lake mainstem (WuLA and WuLB) in 1999 and 2000, and at these same sites and the following additional sites in 2001:

- LBRB2 – lower Burntwood River near Early Morning Rapids;
- SLA – Sesep Lake;
- WuLC – Wuskwatim Lake south; and
- WuBA – Wuskwatim Brook (Figure 7-2).

Concentrations at all sites ranged from 1 to 10 µg/L in 1999, 2 to 5 µg/L in 2000, and 1 to 16 µg/L in 2001 (Table 7-3). There was little difference in concentrations at LBRC, WuLA, and WuLA between years and maximums generally occurred in fall (period 4) (Table 7-3, Figure 7-13).

Table 7-3. Summary of chlorophyll *a* concentration (µg/L) by reach or site, and year, 1999 – 2001.

Reach	Site	Year	Mean	Minimum	Maximum	n[1]
1	LBRB2	2001	4	2	6	4
1	LBRC	1999	4	2	10	4
1	LBRC	2000	4	4	4	3
1	LBRC	2001	3	2	4	4
1	SLA	2001	10	1	16	4
1	WuLA	1999	3	1	4	4
1	WuLA	2000	4	2	5	3
1	WuLA	2001	4	3	5	4
1	WuLB	1999	3	2	4	4
1	WuLB	2000	3	2	5	3
1	WuLB	2001	4	2	4	4
1	WuLC	2001	8	3	12	4
1	WuBA	2001	8	3	15	4
1	All Sites	1999	3	1	10	12
1	All Sites	2000	4	2	5	9
1	All Sites	2001	6	1	16	28
1	All Sites	1999-2001	5	1	16	49
3	TF	2001	3	2	4	4
4	OLA	2000	4	3	4	2
4	OLA	2001	4	3	4	4
4	OLB	2000	4	2	6	2
4	OLB	2001	4	2	5	4
4	All Sites	2000	4	2	6	4
4	All Sites	2001	4	2	5	8
4	All Sites	2000-2001	4	2	6	12

[1] number of samples collected/year

Chlorophyll *a* levels at LBRB2 in 2001 were similar to those further downstream at LBRC, in three of four sampling periods, but were somewhat higher in fall (period 4) (Table 7-3, Figure 7-13). Chlorophyll *a* concentrations at SLA, WuLC, and WuBA were notably higher than those at Wuskwatim main sites in late summer and fall (periods 3 and 4), but were similar (low) when compared to these sites in spring and early summer (periods 1 and 2) (Figure 7-13). Based on mean chlorophyll *a* concentrations, all sites in Reach 1 would be considered meso-eutrophic (Wetzel 1983), which is in agreement with water quality results discussed in Section 5.0.

Reach 2

Phytoplankton and chlorophyll *a* data were not collected in this riverine reach as the water residence time is extremely short and the water in this area tends to be quite turbulent. These conditions reduce the potential for notable increases in resident phytoplankton populations, which cannot maintain positive net growth due to downstream losses.

Reach 3

As in Reach 2, phytoplankton data were not collected, however, chlorophyll *a* data were obtained near the base of Taskinigup Falls (TF) in 2001 (Figure 7-2). Chlorophyll *a* concentrations near the base of Taskinigup Falls were 2 μg/L on May 30 and August 23, and 4 μg/L on July 16 and September 27 (Table 7-3, Figure 7-13), within the range of concentrations observed at mainstem riverine and lake sites in the study area. If any substantial changes in phytoplankton populations were to occur in reaches 2 or 3, they may be detectable at the nearest downstream sampling site on Opegano Lake. Phytoplankton abundance and composition in the lower portion of Reach 3 were likely similar to those obtained from Opegano Lake, as both Opegano Lake sites are located within the 'on-current' portion of the lake.

Reach 4

Samples for analysis of phytoplankton biomass and species composition, and chlorophyll *a* concentration were obtained from Opegano Lake (OLA and OLB) in 2000 and 2001 (Figure 7-2).

Phytoplankton biomass ranged from 2095 to 3574 mg/m^3 in 2000 (Table 7-1). Biomass levels at both sites were slightly lower than those in Wuskwatim Lake main in 2000 (Table 7-1). In 2001, phytoplankton biomass in Opegano Lake ranged from 195 mg/m^3 (OLB in late summer, period 3) to 2372 mg/m^3 (OLB in spring, period 1), again, slightly lower than in Wuskwatim Lake main (Table 7-1, Figure 7-12). Similar to Wuskwatim mainstem sites, peak phytoplankton biomass occurred in spring (2356 and 2373 mg/m^3 at OLA and OLB, respectively) (Table 7-1, Figure 7-12). It should be noted that if samples had been obtained in spring and early summer of 2000, a higher level of productivity might have been obtained in that year.

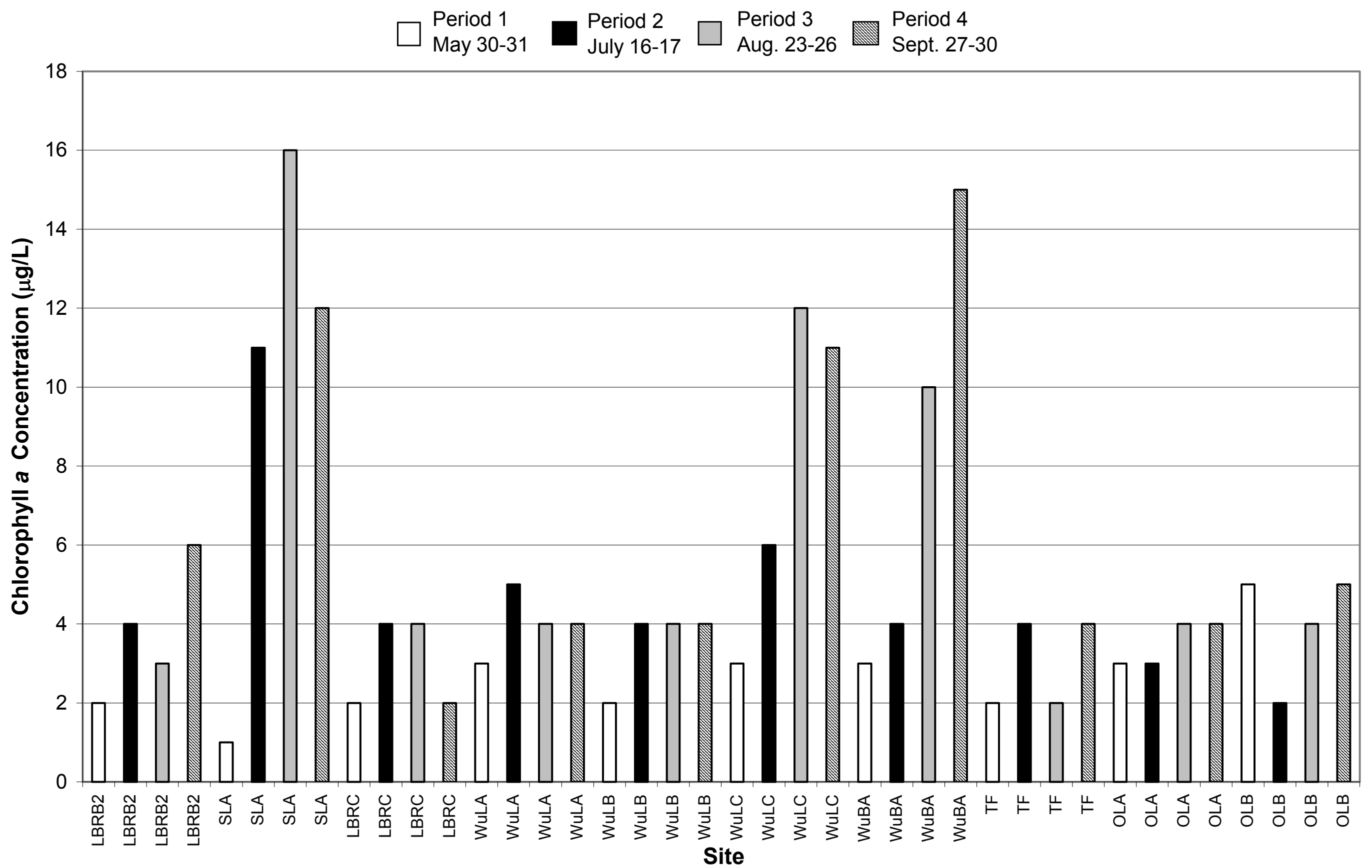


Figure 7-13. Chlorophyll *a* concentration in samples collected from reaches 1 (LBRB2 – WuBA), 3 (TF), and 4 (OLA – OLB), 2001.

Phytoplankton species composition was similar between Opegano Lake sites and was similar to that at Wuskwatim main sites. In spring 2001, phytoplankton biomass was largely composed of diatoms (59 and 52 % at OLA and OLB, respectively) and Chrysophyceae (37 and 45 % at OLA and OLB, respectively). Biomass was strongly dominated by Chrysophyceae at all other sampling periods, ranging between 76 to 89 % (Table 7-2, Figure 7-12). Cyanophytes and cryptophytes were the next most abundant groups (Table 7-2, Figure 7-12). In 2000, there tended to be more cryptophytes than cyanophytes, while in 2001, the pattern generally was reversed (Table 7-2). Chlorophytes were present at low levels during all sampling periods, ranging from 0.01 to 1.8 %, and other species (mostly euglenophytes) were present in nine out of 12 samples, comprising a maximum of 1.7 % of the phytoplankton community.

Chlorophyll *a* concentrations in Opegano Lake ranged from 2 to 6 µg/L, with the highest levels generally obtained in fall (Table 7-3, Figure 7-13). Based on these chlorophyll *a* readings, Opegano Lake would be considered meso-eutrophic (Wetzel 1983), in agreement with water quality results discussed in Section 5.0.

Stream Crossings

Samples for phytoplankton analysis were not obtained from stream crossing locations as phytoplankton tend to be relatively unimportant in small streams. Phytoplankton species cannot generally maintain positive net growth rates in flowing streams for a variety of reasons, including rapid downstream losses. Furthermore, algae found within the water column of streams are typically benthic diatom species that have been sloughed from the stream bed (Hynes 1970). Within small streams, the infrequent presence of truly planktonic algal species occurs primarily in summer, consisting largely of diatoms. These algae are considered true plankton in that they are normally found in lakes, and likely originate from other waterbodies draining into the streams (Hynes 1970).

To obtain some measure of algal biomass, chlorophyll *a* samples were obtained at stream crossings R2, R4, R5, R6, and R8 on June 14, 2002 (Figure 7-3). Chlorophyll *a* concentrations ranged from less than 1 (at R4) to 2 µg/L (at remaining sites), similar to results obtained from other sampling locations in the spring of 1999, 2000, and 2001.

7.3.3 Attached Algae and Rooted Aquatic Plants

7.3.3.1 Overview of Biology

The littoral zone is defined as the area of a lake near the shore from the region of the highest seasonal water level to the deepest point at which rooted aquatic plants occur, i.e., where the euphotic zone reaches the bottom. This zone typically supports a greater variety of photosynthetic organisms than the water column. Within this zone, attached algae and rooted aquatic plants can grow if other conditions, such as substrate type, and nutrient and light availability, are suitable (Figure 7-14).

In general, the surfaces of plants, rocky substrates such as boulder and bedrock shorelines, and open areas of fine sediment (i.e., mud flats) are colonized by algae. The extent of growth of attached algae depends largely on the stability of the substrate (e.g. shifting sand limits the growth of algae) and on water level fluctuation. Algae will not grow if exposed to air for prolonged periods at low water levels, or if increased water depth reduces light availability below required levels for extended periods.

The extent to which the littoral zone can support rooted plants depends on the availability of bottom sediments sufficiently fine-textured and stable to permit roots to take hold, the degree of wave exposure, and water levels stable enough to minimize disruption of the roots by ice scour during the winter months or desiccation due to exposure (periodic dewatering) during the open-water season. Emergent plants (e.g., bulrush and cattail) are found in the uppermost part of the littoral zone, while submergent plants (e.g., pond weed and water milfoil) may grow at considerable water depth.

Figure 7-14. Rooted submergent aquatic plants growing in the littoral zone of a lake.

However, the clarity of the water column is an important factor in determining the distribution of submergent plants. Biomass, and spatial and vertical distribution of aquatic plants may be influenced by a variety of environmental factors, including underwater light regime, substrate, nutrients, thermal stratification, and pressure (Spence 1982). Lake regulation can affect plant density and distribution, as altering lake levels can influence both light regime, and substrate availability or stability.

Production by attached algae can be comparable to production by rooted vascular plants due to the rapid growth and turnover time of these microscopic organisms. Many herbivorous invertebrates consume algal cells directly rather than the plants to which the algae are attached. Algal cells that grow on the surface of plants often provide the basis for a rich community consisting of the algal cells, detrital particles trapped by the matrix of algal cells, bacteria and fungi digesting the detritus and organic material released by the plant, and microfauna such as protozoa consuming the detritus, decomposers, and algae. This mix of producers, consumers, and decomposers provides nutrition for many kinds of herbivorous and deposit-feeding animals such as snails, certain minnows, and aquatic insect larvae.

7.3.3.2 Relative Abundance, Composition, and Distribution

A list of the 24 aquatic plant and one **macroalgae** species collected and identified in the four study reaches on the Burntwood River is presented in Table 7-4.

Reach 1

Rooted submergent aquatic plant distribution differs over time in response to inter-annual variation in water levels and growing conditions. Aquatic plants in Reach 1 were found in areas of relatively low exposure and slope, and at a distance from the shore that generally was similar to the peat islands (Table 7-5). Data percentiles were determined from the frequency distribution of values where rooted aquatic plants were observed. Aquatic plant distribution generally was sparse with isolated patches of denser growth in each area where they were observed, but was typically widespread as were the peat islands. Aquatic plants typically followed the mineral shoreline closely except for relatively large areas of shallower water depths, such as the central areas of the Cranberry Lakes (Figure 7-6). In areas where submergent aquatic plants and peat islands were found together, the plants were usually observed adjacent to the areas of peat rather than interspersed within the voids of the peat.

Table 7-4. Aquatic plant and macroalgae species observed in the four reaches on the Burntwood River, 2001.

Scientific Name	Alternate Scientific Name	Common Name
Callitriche verna	*Callitriche palustris* *C. palustris* var. *verna*	vernal water-starwort common water-starwort
Callitriche hermaphroditica	*Callitriche autumnalis* *C. bifida*	autumnal water-starwort northern water-starwort
Caltha natans		floating marsh-marigold
Ceratophyllum demersum		hornwort
Eleocharis acicularis		needle spike rush hairgrass least spike rush slender spike rush
Glyceria sp.		manna grass
Hippuris vulgaris		mares-tail
Lemna trisulca		ivy leaf duckweed star duckweed
Megalodonta beckii	*Bidens beckii*	water marigold water beggarticks Beck's beggarticks
Myriophyllum exalbescens	*Myriophyllum sibiricum* *M. spicatum* subsp. *exalbescens* *M. spicatum* var. *exalbescens*	northern watermilfoil common watermilfoil
Nitella sp.		stonewort (macroalgae)
Nuphar lutea	*Nuphar lutea* subsp. *variegatum* *Nymphozanthus variegatus*	yellow water-lily cow lily spatterdock
Polygonum amphibium	*Polygonum amphibium* var. *stipulaceum* *P. natans*	water smartweed
Potamogeton gramineus	*Potamogeton gramineus* var. *maximus* *P. gramineus* var. *myriophyllus*	variable pondweed
Potamogeton natans		floating-leaved pondweed floatingleaf pondweed broad-leaved pondweed floating brownleaf
Potamogeton praelongis		whitestem pondweed
Potamogeton richardsonii	*Potamogeton perfoliatus* var. *richardsinii* *P. perfoliatus* subsp. *richardsonii*	clasping-leaved pondweed
Potamogeton zosteriformis	*Potamogeton zosterifolius* subsp. *zosteriformis* *P. zosterifolius* var. *americanus*	flatstem pondweed flat-stemmed pondweed eel-grass pondweed
Ranunculus aquatilis	*Ranunculus heterophyllus* *R. grayanus* *Batrachium aquatile*	white water-crowfoot common water-crowfoot
Ranunculus gmelinii var. *hookeri*		small yellow water-crowfoot small yellow water-buttercup Gmelin's buttercup
Sparganium angustifolium	*Sparganium angustifolium* subsp. *emersum* *S. emersum* var. *angustifolium* *S. emersum* *S. multipedunculatum* *S. affine*	floating bur-reed narrow-leaf bur-reed
Sparganium natans	*Sparganium natans* var. *minimum* *S. minimum*	small bur-reed floating bur-reed least bur-reed
Stukenia pectinata	*Potamogeton pectinatus* *Coleogeton pectinatus*	sago pondweed
Stukenia vaginata	*Potamogeton vaginatus* *Coleogeton vaginatus*	bigsheath pondweed
Utricularia vulgaris	*Utricularia macrorhiza*	common bladderwort greater bladderwort

Table 7-5. Data distribution percentiles for exposure, elevation, slope, and distance from shore determined from areas where rooted submergent aquatic plants were observed in Reach 1.

	5th Percentile	50th Percentile	95th Percentile	Minimum	Maximum
Exposure (m)	109.0	564.0	1946.8	0.0	2448.6
Elevation (m ASL)	232.4	233.4	233.8	230.5	234.3
Slope (%)	0.5	2.7	13.1	0.1	20.5
Distance from Shore (m)	3.6	20.9	217.8	0.0	578.5

* shoreline as at 233.8 m ASL

Rooted submergent aquatic plant growth varied among the waterbodies in Reach 1. Of the 15 species observed in Reach 1, *Potamogeton richardsonii* (clasping-leaved pondweed) was the most common, inhabiting an area of approximately 659 ha, or 73 % of the area occupied by aquatic plants and 8 % of Reach 1 by area (Table 7-6). The next most common species was *Myriophyllum exalbescens* (northern watermilfoil), followed by *Sparganium* spp. (bur-reeds), *Nuphar lutea* (yellow water-lily), and *Stukenia vaginata* (bigsheath pondweed). These species occupied approximately 139 to 522 ha, or 15 to 58 % of the area occupied by aquatic plants and 2 to 6 % of Reach 1 by area. The remaining 10 species were relatively less common, each occupying less than 11 % of the area where aquatic plants were observed and less than 2 % of Reach 1 by area. The least common species in Reach 1 was *Callitriche hermaphroditica* (autumnal water-starwort), followed by *Utricularia vulgaris* (common bladderwort), *Ranunculus aquatilis* (white water-crowfoot), *Megalodonta beckii* (water marigold), and *Potamogeton natans* (floating-leaved pondweed).

The aquatic habitats of the Cranberry Lakes area are strongly influenced by the Burntwood River, which passes through the central portion. Currents tend to be relatively strong, although there are quieter backwaters in off-current areas. Average water depth at sites visited during rooted aquatic plant boat-based surveys was 1.4 m (Table 7-7, North/South Consultants Inc. unpublished data). Although water clarity was relatively low (Secchi depth range: 0.3 – 0.5 m), the calculated euphotic zone was on average 1.3 m deep, similar to the observed average water depth (Table 7-7, North/South Consultants Inc. unpublished data). The bottom sediments of the Cranberry Lakes consisted largely of compacted or scoured silt/clay (Section 6.0). Cranberry Lakes also has several large areas dominated by "floating" *Typha*/sedge islands and patches of decomposing trees and shrubs, the result of CRD-related inundation of fens, bogs, and woodlands.

Table 7-6. Areas occupied by rooted aquatic plant species observed in Reach 1.

Scientific Name	Cranberry Lakes (ha) [1]	Sesep Lake (ha)	Wuskwatim Lake Main (ha)	Wuskwatim Lake South (ha)	Wuskwatim Brook (ha)	Total Macrophyte Area (ha)	% of Total Macrophyte Area	% of Total Area in Reach 1
Callitriche hermaphroditica	0.0	0.0	0.0	0.4	0.0	0.4	0.0	0.0
Hippuris vulgaris	0.0	0.0	0.0	0.0	71.0	71.0	7.8	0.8
Megalodonta beckii	0.0	0.0	0.0	6.0	1.0	7.0	0.8	0.1
Myriophyllum exalbescens	239.8	206.3	0.0	6.0	70.0	522.1	57.6	6.0
Nuphar lutea	59.9	206.3	0.0	0.0	70.0	336.2	37.1	3.9
Potamogeton gramineus	79.9	0.1	0.0	1.0	5.6	86.6	9.5	1.0
Potamogeton natans	11.5	0.0	0.0	0.0	0.0	11.5	1.3	0.1
Potamogeton richardsonii	223.6	248.0	28.7	80.0	78.2	658.5	72.6	7.6
Potamogeton zosteriformis	0.0	0.0	0.0	0.0	70.0	70.0	7.7	0.8
Ranunculus aquatilis	5.1	0.0	0.0	0.0	1.0	6.1	0.7	0.1
Aquatic moss spp.	0.0	0.0	0.0	6.0	71.0	77.0	8.5	0.9
Sparganium spp.	212.6	14.5	0.0	24.3	90.1	341.5	37.6	3.9
Stukenia pectinata	96.6	0.0	0.5	0.0	0.0	97.0	10.7	1.1
Stukenia vaginata	139.4	0.0	0.0	0.0	0.0	139.4	15.4	1.6
Utricularia vulgaris	0.0	0.0	0.0	0.0	1.0	1.0	0.1	0.0
Total No. of Species	**9**	**5**	**2**	**7**	**11**	**15**	**-**	**-**

[1] areas derived from polygons in which several species may occupy the same polygon; shoreline as at 233.8 m ASL.

Table 7-7. Water depth, secchi depth, and the extent of the euphotic zone determined from areas where rooted aquatic plants were observed in reaches 1 and 4, 2001.

Waterbody	Water Depth (m) [1]			Secchi Depth (m)			Euphotic Zone (m)		
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
Cranberry Lakes [2]	1.4	0.6	2.1	0.4	0.3	0.5	1.3	1.0	1.7
Sesep Lake (SLA) [3]	3.0	3.0	3.0	2.0	1.6	2.7	6.5	5.3	8.9
Wuskwatim Lake Main (WuLA) [3]	8.8	8.5	9.0	0.5	0.4	0.6	1.7	1.3	2.0
Wuskwatim Lake Main (WuLB) [3]	7.8	7.5	8.0	0.6	0.4	0.7	1.8	1.3	2.3
Wuskwatim Lake South [2]	1.6	0.6	3.4	1.0	0.3	2.8	3.3	1.0	9.2
Wuskwatim Brook [2]	1.4	0.5	2.3	1.2	0.5	1.7	4.1	1.0	5.6
Opegano Lake (OLA) [3]	3.6	2.5	4.5	0.5	0.4	0.6	1.7	1.3	2.0
Opegano Lake (OLB) [3]	3.9	3.0	5.0	0.5	0.4	0.5	1.5	1.3	1.7

[1] water depth as at an approximate water level of 233.7 m ASL
[2] water quality parameters measured during rooted aquatic plant boat-based surveys
[3] water quality parameters measured *in situ* during water quality sampling (Section 5.0)

The Cranberry Lakes supports nine of the 15 species observed in Reach 1 (Table 7-6). Three types of aquatic plant communities were observed in the Cranberry Lakes. Large patches of *Potamogeton gramineus* (variable pondweed), *P. richardsonii*, and *M. exalbescens* dominated sheltered off-current areas, especially in the western half of the lake (Figure 7-6, North/South Consultants Inc. unpublished data). Extensive beds of *M. exalbescens* and *P. richardsonii* dominated similar areas in the eastern half of the lake (Figure 7-6, North/South Consultants Inc. unpublished data). Although the deepest part of the main channel area was clear of aquatic plants, on-current areas adjacent to the main channel had numerous vegetated areas dominated by *S. vaginata* and *Stukenia pectinata* (sago pondweed) (Figure 7-6, North/South Consultants Inc. unpublished data). A discontinuous band of *Sparganium* spp. occurred along the shore.

Sesep Lake is relatively removed from direct influence by the Burntwood River. Average water depth at the water quality sampling site (SLA) was 3.0 m (Table 7-7). The water was among the clearest in the area (Secchi depth range: 1.6 – 2.7 m), the calculated euphotic zone was on average 6.5 m deep, and the bottom substrates consisted primarily of soft silt/clay rich in organic material of terrestrial origin (Section 6.0). Despite these favourable aquatic habitat parameters, plant growth was typically sparse and the aquatic plant community consisted of only five species, likely due to the presence of organic debris (e.g., logs, branches, flooded terrestrial moss) on the bottom. *P. richardsonii* was most common, followed by *M. exalbescens* and *N. lutea* (Table 7-6). Similar to the Cranberry Lakes, a discontinuous, but sparse, band of *Sparganium* spp. occurred along the shore (Figure 7-6).

Wuskwatim Lake main was characterized by a low abundance and diversity of aquatic plants. Aquatic plants were restricted to a narrow band of nearshore, shallow water (less than 1.0 m water depth), mostly in relatively sheltered areas such as bays and stream mouths, and in areas with relatively high exposure that remain sheltered from wave action by shallow shelves that diminish wave energy (Figure 7-15). Areas adjacent to the larger islands in the northern half of the lake are representative of the latter (Figure 7-6). Water clarity was among the lowest observed in Reach 1 (Secchi depth range: 0.4 m – 0.7 m) and the calculated euphotic zone ranged between 1.3 and 2.3 m, considerably less than the average water depths at the water quality sampling sites (WuLA and WuLB) (Table 7-7). Western and northern shores are leeward to the prevailing winds, and these typically supported more aquatic plant growth than exposed eastern shores. There were no substantial aquatic plant beds in the open-water areas of the lake, likely due in part to the frequent water level fluctuations and relatively high wave energy. By far, the most common species was *P. richardsonii* (Table 7-6), which was found in small patches spread out along shallow and sheltered shorelines with soft silt/clay bottom sediments.

Figure 7-15. Rooted submergent aquatic plants adjacent to the shoreline in Wuskwatim Lake main.

In Wuskwatim Lake south, the aquatic plant community was more widespread, diverse, and robust. Generally, however, aquatic plants were concentrated in bays and other sheltered areas, while open-water areas were most commonly free of plant growth (Figure 7-6). Most plants were located in water less than 1.5 m deep, reflecting the somewhat greater water clarity (Secchi depth range: 0.3 – 2.8 m), as compared to Wuskwatim Lake main. The euphotic zone was on average 3.3 m deep, approximately twice as deep as the observed average water depth (1.6 m) (Table 7-7, North/South Consultants Inc. unpublished data).

P. richardsonii and *Sparganium* spp. dominated the aquatic plant community in Wuskwatim Lake south, followed by *M. beckii*, *M. exalbescens*, and aquatic moss species (Table 7-6). Patches of *Sparganium* spp. were widespread, but sparsely distributed in nearshore shallow water throughout the area. The relatively deeper water sites along Transect 12 in the easternmost portion of the south bay all indicated a continuous layer of filamentous green algae covering the soft silt/clay-based bottom sediments, a unique feature observed nowhere else in the study area (North/South Consultants Inc. unpublished data).

The Wuskwatim Brook area encompasses the chain of small lakes and wetlands to the south of Wuskwatim Lake, up to the first set of falls on Wuskwatim Brook. This area was characterized by relatively high water transparency (Secchi depth range: 0.5 – 1.7 m) with a calculated average euphotic zone of 4.1 m, approximately three times as deep as the observed average water depth (1.4 m) (Table 7-7, North/South Consultants Inc. unpublished data). Although the aquatic plant community was relatively diverse (11 species), plant distribution was discontinuous (Figure 7-6). Aquatic plants were generally restricted to sheltered bays and stream inlets with *Sparganium* spp. and *P. richardsonii* being the most common (Table 7-6). *Sparganium* sp. was most often observed growing in water less than 1.5 m deep throughout the area, although its distribution was sparse (North/South Consultants Inc. unpublished data). A defining feature for much of this area was the relatively dense growth of aquatic moss in water up to 2.1 m deep (Table 7-6, North/South Consultants Inc. unpublished data). Much of the shoreline in the Wuskwatim Brook area is comprised of marsh and fen vegetation with isolated islands and "floating" islands of *Typha*/sedge communities. Detailed descriptions of emergent vegetation are provided in Volume 6.

Submergent aquatic plants were not common in the draw down zone of Reach 1, resulting in many areas an undercolonized band of aquatic habitat in the intermittently exposed zone. The upper extent of the aquatic plant distribution is variable, and appears to be related to the character of the intermittently exposed or nearshore zones and the plant species present. In general, low gradient shores with low exposure tend to be near low land areas where water sources are abundant and have more plants in the intermittently exposed zone. In areas of higher slope and exposure, the upper limit to plant growth was more apparent. In Reach 1, one aquatic macrophyte species more resistant to exposure, or periodic episodes of dewatering, and ice scour stress was found. *Hippuris vulgaris* (mares-tail) was relatively common in Wuskwatim Brook, inhabiting an area of approximately 71 ha, or 8 % of the area occupied by aquatic plants and 1 % of Reach 1 by area (Table 7-6). This plant species can tolerate relatively long periods of exposure and disturbance through ice scouring of the shore, and is adapted to thrive in wet soil as well as in shallow water. In Wuskwatim Brook, this species was sometimes found in association with relatively less resilient aquatic plants, such as *Sparganium* spp. and *U. vulgaris*, which can grow in shallow water but are intolerant of prolonged periods of exposure. *Sparganium* spp. was found in shallow waters throughout Reach 1, with the exception of Wuskwatim Lake main.

Areas of emergent grasses, sedges, and rushes were not common in the area; however, they were locally abundant in Sesep Lake and Wuskwatim Brook. Where emergents did occur, they generally were in dense stands along the margins of sheltered bays, or in patches immediately offshore in similarly sheltered areas. Robust stands of emergents were sometimes observed at a maximum water depth of approximately 0.8 m (as at 233.8

m ASL), where the stands ended abruptly. Rooted submergent aquatic plants seldom grew in association with these emergents. Where aquatic plants were found in the vicinity of emergents, an area several metres wide separated the two types of vegetation and was relatively devoid of any plants. This was most notable for associations between aquatic plants and relatively pure stands of *Typha*. Further descriptions of the emergent plant community are provided in Volume 6.

Reach 2

Rooted submergent aquatic plants in Reach 2 were observed in areas with slopes less than 4.6 %, low water velocities (less than 0.1 m/s), and where water depths were less than approximately 1.6 m (Table 7-8). Data percentiles were determined from the frequency distribution of values where rooted aquatic plants were observed.

Table 7-8. Data distribution percentiles for slope, water depth averaged water velocity, and water depth determined from areas where rooted submergent aquatic plants were observed in Reach 2.

	5th Percentile	50th Percentile	95th Percentile	Mean	STDEV [1]
Slope (%)	2.2	3.9	8.7	4.6	2.2
Water Velocity (m/s) (5th) [2]	0.0	0.1	0.2	0.1	0.1
Water Velocity (m/s) (95th) [2]	0.0	< 0.1	0.2	0.1	0.1
Water Depth (m) (5th) [2]	0.1	0.6	1.4	0.7	0.4
Water Depth (m) (50th) [2]	0.5	1.2	2.1	1.3	0.5
Water Depth (m) (95th) [2]	0.9	1.6	2.5	1.6	0.5

[1] ± 1 standard deviation

[2] refers to conditions at the 5th, 50th, and 95th percentile water levels

Of the four species observed in Reach 2, *M. exalbescens* and *P. richardsonii* were the most common (Table 7-9). These two species each inhabited an area of approximately 2 ha, or 100 % of the area occupied by aquatic plants and 5 % of Reach 2 by area. The abundance of aquatic plants in Reach 2 was relatively low. The plant community was of low diversity and restricted to two bays, one on the north shore of the study reach and one on the south, where the water was relatively shallow and sheltered from currents (Figure 7-7). Relatively high water velocities precluded the growth of aquatic plants in the remainder of this reach (Section 6.0). The north and south bays had soft silt/clay bottom sediments with variable amounts of decaying plant material present (Section 6.0). Within these bays, plant distribution was relatively sparse with aquatic plants inhabiting areas of approximately 1.5 and 0.7 ha in the north and south bays, respectively. *M. exalbescens* and *P. richardsonii* were observed in both bays, and *Glyceria* sp. (manna grass) and *P. gramineus* were observed only in the south bay (Table 7-9).

Table 7-9. Areas occupied by rooted aquatic plant species observed in Reach 2.

Scientific Name	South Bay (ha) [1]	North Bay (ha)	Total Macrophyte Area (ha)	% of Total Macrophyte Area	% of Total Area in Reach 2a [1]
Glyceria sp.	0.2	0.0	0.2	10.5	0.6
Myriophyllum exalbescens	0.7	1.5	2.2	100.0	5.4
Potamogeton gramineus	0.2	0.0	0.2	10.5	0.6
Potamogeton richardsonii	0.7	1.5	2.2	100.0	5.4
Total No. of Species	**4**	**2**	**4**	-	-

[1] areas derived from polygons in which several species may occupy one polygon; total area is based on a digitized shoreline from DOIs covering Reach 2a (Section 6.0).

Reach 3

Rooted submergent aquatic plants in Reach 3 were observed mostly in areas with slopes less than 8.0 %, low water velocities (less than 0.1 m/s), and where water depths were less than approximately 1.6 m (Table 7-10). Data percentiles were determined from the frequency distribution of values where rooted aquatic plants were observed.

Of the 12 species observed in Reach 3, *P. richardsonii* was the most common species, inhabiting an area of approximately 3 ha, or 80 % of the area occupied by aquatic plants and 1 % of Reach 3 by area (Table 7-11). The next most common species was *P. gramineus*, followed by *M. exalbescens*, *Glyceria* sp., and *Callitriche verna* (vernal water-starwort). These species occupied approximately 0.6 to 1.0 ha, or 16 to 26 % of the area occupied by aquatic plants and 0.2 to 0.3 % of the reach by area. The remaining seven species were relatively less common. Each occupied less than 16 % of the area where aquatic plants were observed, or less than 0.2 % of Reach 3 by area. By far, the least commonly observed species in Reach 3 was *Caltha natans* (floating marsh-marigold), occupying less than 1 % of the area where aquatic plants were found.

Table 7-10. Data distribution percentiles for slope, water depth averaged water velocity, and water depth determined from areas where rooted submergent aquatic plants were observed in Reach 3.

	5th Percentile	**50th Percentile**	**95th Percentile**	**Mean**	**STDEV [1]**
Slope (%)	1.4	6.1	20.5	7.8	6.4
Water Velocity (m/s)	0.0	0.0	<0.1	<0.1	<0.1
Water Depth (m) (5th) [2]	<0.1	0.4	1.7	0.5	0.5
Water Depth (m) (50th) [2]	0.3	0.8	2.3	1.0	0.6
Water Depth (m) (95th) [2]	0.9	1.5	2.8	1.6	0.5

[1] ± 1 standard deviation

[2] refers to conditions at the 5th, 50th, and 95th percentile water levels

Aquatic plants in Reach 3 were typically restricted to the shallow margins of stream mouths, or adjacent areas within the mainstem; to a few small, sheltered bays within the mainstem; and occasionally to more extensive areas within the backwater inlets where the water was relatively shallow and sheltered from currents, particularly in inlets 4, 9, and 10 (Figure 7-8). These backwater inlets and mainstem areas have been inundated since CRD and had soft silt/clay bottom sediments with variable amounts of decaying plant material present where aquatic plants were observed (Section 6.0). Typically, plant distribution was sparse within these areas, and the abundance of plants was relatively low and limited to shallow water (less than 1.0 m deep).

The Burntwood River mainstem is characterized by a fairly steep gradient, resulting in relatively high water velocities through this portion of the river (Section 6.0). Water velocity is reduced along the margins of the mainstem and in the few small, off-current, shallow bays. Typically, the bottom sediments in these areas were soft, silt/clay-based (Section 6.0). The mainstem supported 10 of the 12 species observed in Reach 3, with the majority of plant beds occurring in the lower portion of this reach nearer to Opegano Lake (Figure 7-8). *P. richardsonii* was by far the most common species observed, inhabiting approximately 1 ha of area within the mainstem portion of Reach 3 (Table 7-11).

Table 7-11. Areas occupied by rooted aquatic plant species observed in Reach 3.

Scientific Name	Backwater Inlet 1 (ha) [1]	Backwater Inlet 2 (ha)	Backwater Inlet 3 (ha)	Backwater Inlet 4 (ha)	Backwater Inlet 5 (ha)	Backwater Inlet 6 (ha)	Backwater Inlet 7 (ha)	Backwater Inlet 8 (ha)	Backwater Inlet 9 (ha)	Backwater Inlet 10 (ha)	Mainstem River (ha)	Total Macrophyte Area (ha)	% of Total Macrophyte Area	% of Total Area in Reach 3
Callitriche verna	0.0	0.0	0.0	0.1	< 0.1	0.0	0.0	0.0	0.5	0.0	< 0.1	0.6	16.4	0.2
Caltha natans	0.0	0.0	0.0	0.0	< 0.1	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1	0.7	0.0
Eleocharis acicularis	0.0	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	8.0	0.1
Glyceria sp.	0.0	0.0	0.0	0.5	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0.7	18.5	0.2
Hippuris vulgaris	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.5	0.0	< 0.1	0.6	15.7	0.2
Myriophyllum exalbescens	< 0.1	< 0.1	0.0	0.5	0.1	0.0	0.1	0.0	0.0	0.2	< 0.1	0.9	23.2	0.3
Potamogeton gramineus	0.0	0.0	0.0	0.5	< 0.1	0.0	0.0	0.0	0.5	0.0	< 0.1	1.0	25.6	0.3
Potamogeton natans	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1	0.2	3.9	0.1
Potamogeton richardsonii	< 0.1	0.0	0.0	0.5	< 0.1	0.0	0.0	0.1	1.0	0.6	0.9	3.1	80.1	1.1
Ranunculus aquatilis	< 0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1	0.3	7.3	0.1
Ranunculus gmelinii	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1	0.2	3.9	0.1
Sparganium spp.	< 0.1	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	< 0.1	0.5	13.0	0.2
Total No. of Species	**4**	**1**	**0**	**11**	**6**	**0**	**1**	**1**	**4**	**2**	**10**	**12**	**-**	**-**

[1] areas derived from polygons in which several species may occupy one polygon; area is based on the 32nd percentile flow shoreline.

The backwater inlets associated with this reach have been numbered from one (nearest to Taskinigup Falls) to 10 (nearest to Opegano Lake) (Section 6.0). The streams enter bays off the mainstem and are inundated with water from the Burntwood River. The extent of flooding in the inlets by CRD varies depending on their topographic relief. A number of backwater inlets, particularly inlets 4 and 5 between Taskinigup Falls and Little Jackpine Rapids, and inlets 9 and 10 near Opegano Lake, supported fairly diverse and/or dense plant communities, although the distribution was always limited (Table 7-11). Within the remaining inlets, plant distribution was sparse, and typically the abundance of plants was low and fewer species were observed (Figure 7-8). *P. richardsonii* was the most common species observed in the inlets, inhabiting a total area of approximately 2 ha (Table 7-11). Other common plants observed in the inlets included, *P. gramineus*, *M. exalbescens*, *C. verna*, *H. vulgaris*, and *Glyceria* sp. (Table 7-11). Inlet 4 supported the greatest variety of aquatic plant species observed in Reach 3, with 11 species recorded.

In Reach 3, a number of aquatic plant species more resilient to periodic dewatering and ice scour stress were observed. *C. verna*, *Eleocharis acicularis* (needle spike rush), and *H. vulgaris* were found in inlets 4, 5, and 9, and/or the mainstem (Table 7-11). *E. acicularis* was only observed in inlet 4 and was the most common of these species in this inlet, occupying an area of approximately 0.3 ha. In inlet 9 and the mainstem, *C. verna* and *H. vulgaris* were equally abundant, but, only *C. verna* was found in inlet 5.

Reach 4

Rooted submergent aquatic plants in Reach 4 were observed in areas with slopes averaging approximately 1.3 %, an average exposure of 750.0 m, an average elevation of approximately 208.0 m ASL (near the lower limit of the intermittently exposed zone), and less than 50.0 m from shore (Table 7-12). Data percentiles were determined from the frequency distribution of values where rooted aquatic plants were observed.

Water clarity in Opegano Lake was relatively low (Secchi depth range: 0.4 m – 0.6 m), similar to Wuskwatim Lake main, and the calculated euphotic zone ranged between 1.3 and 2.0 m, noticeably less than the average water depths at the water quality sampling sites (OLA and OLB) (Table 7-7).

Table 7-12. Data distribution percentiles for exposure, elevation, slope, distance from shore, and water depth determined from areas where rooted submergent aquatic plants were observed in Reach 4.

	5th Percentile	50th Percentile	95th Percentile	Minimum	Maximum
Exposure (m)	187.8	756.3	934.1	0.0	1010.5
Elevation (m ASL)	206.8	208.1	208.6	205.1	208.8
Slope (%)	0.1	0.8	4.6	0.0	22.6
Distance from Shore (m)	7.4	19.0	43.1	6.9	60.2
Water Depth (m)	0.0	0.5	1.8	0.0	3.5

* shoreline as at 206.8 m ASL

Aquatic macrophytes were not markedly abundant anywhere in Opegano Lake. Discontinuous aquatic plant beds with sparse growth were confined to several small bays along the northwest shore and the wetland area on the north end of the lake where the water was relatively shallow and sheltered from currents (Figure 7-9). Of the seven species observed in Reach 4, *M. exalbescens*, *P. richardsonii*, and *Sparganium* spp. were the most common (Table 7-13). These four species each inhabited an area of approximately 32 ha, or 100 % of the area occupied by aquatic plants and 4 % of Reach 4 by area. The resilient, shallow water species *H. vulgaris* was relatively common in Opegano Lake, inhabiting an area of approximately 30 ha, or 94 % of the area occupied by aquatic plants and 4 % of the lake by area. This aquatic plant was found in association with the relatively less resilient species *Sparganium* spp. and *U. vulgaris* in the wetland area on the north end of the lake.

Stream Crossings

A list of the nine aquatic macrophyte and one macroalgae species collected and identified at the streams crossed by the access road and in adjacent areas in September, 2001 (Figure 7-3), is presented in Table 7-14. Aquatic plant abundance, composition, and distribution were not assessed during the June, 2002, survey as the growth of aquatic plants had just begun and was not representative of the community.

With the exception of the macroalgae *Chara* sp., all species observed at the stream crossings were also identified in the four reaches on the Burntwood River. *Chara* sp. and *Nitella* sp., found in the other study reaches (Table 7-4), belong to the same class of macroalgae known as the Charophycea (‘charophytes’).

Table 7-13. Areas occupied by rooted aquatic plant species observed in Reach 4.

Scientific Name	Total Macrophyte Area (ha)	% of Total Macrophyte Area	% of Total Area in Reach 4
Hippuris vulgaris	30.0	93.9	3.8
Myriophyllum exalbescens	31.9	100.0	4.1
Polygonum amphibium	30.0	93.9	3.8
Potamogeton gramineus	30.0	93.9	3.8
Potamogeton richardsonii	31.9	100.0	4.1
Sparganium spp.	31.9	100.0	4.1
Utricularia vulgaris	30.0	93.9	3.8
Total No. of Species	**7**	**-**	**-**

[1] areas derived from polygons in which several species may occupy one polygon; shoreline as at 206.8 m ASL.

Table 7-14. Aquatic plant and macroalgae species observed at or near stream crossings, 2001.

Scientific Name	Alternate Scientific Name	Common Name
Callitriche verna	*Callitriche palustris* *C. palustris* var. *verna*	vernal water-starwort common water-starwort
Chara sp.		stonewort (macroalgae)
Hippuris vulgaris		mares-tail
Myriophyllum exalbescens	*Myriophyllum sibiricum* *M. spicatum* subsp. *exalbescens* *M. spicatum* var. *exalbescens*	northern watermilfoil common watermilfoil
Potamogeton natans		floating-leaved pondweed floatingleaf pondweed broad-leaved pondweed floating brownleaf
Potamogeton richardsonii	*Potamogeton perfoliatus* var. *richardsinii* *P. perfoliatus* subsp. *richardsonii*	clasping-leaved pondweed
Ranunculus aquatilis	*Ranunculus heterophyllus* *R. grayanus* *Batrachium aquatile*	white water-crowfoot common water-crowfoot
Ranunculus gmelinii var. *hookeri*		small yellow water-crowfoot small yellow water-buttercup Gmelin's buttercup
Sparganium angustifolium	*Sparganium angustifolium* subsp. *emersum* *S. emersum* var. *angustifolium* *S. emersum* *S. multipedunculatum* *S. affine*	floating bur-reed narrow-leaf bur-reed
Utricularia vulgaris	*Utricularia macrorhiza*	common bladderwort greater bladderwort

The number of species observed at the stream crossings ranged from none at R1 and R3 to seven at R6 (Table 7-15). Although no aquatic plants were recorded at R1 and R3, woody debris was observed within the stream channel. Generally, the margins of the remaining streams had sparse aquatic plant growth with approximately 10 % of the stream bottom covered; however, R6, R7, and R8 had over 80 % aquatic plant coverage. Additionally, at R4 and R7, attached filamentous green algae, as well as woody and other organic debris were abundant.

The resilient, shallow water species *C.verna* was relatively common, being observed at six of the stream crossings; however, the other resilient species observed, *H. vulgaris*, was found at only two. These aquatic plant species were found in association with the relatively less resilient species *Sparganium* spp. and *U. vulgaris* at a number of the crossings. Due to the small size of these streams and their relatively shallow water depths (Section 6.0), aquatic plants that are more tolerant of relatively long periods of periodic dewatering and disturbance through ice scouring of the shore were expected to be common.

Table 7-15. Aquatic plant and macroalgae species identified at or near each of the eight major stream crossings, 2001.

Scientific Name	Stream Crossing							
	R1	R2	R3 [1]	R4	R5	R6	R7	R8
Callitriche verna		√		√	√	√	√	√
Chara sp.								√
Hippuris vulgaris		√				√		
Myriophyllum exalbescens						√		
Potamogeton natans						√		
Potamogeton richardsonii					√	√		
Ranunculus aquatilis		√						√
Ranunculus gmelinii		√				√		
Sparganium angustifolium					√		√	√
Utricularia vulgaris						√		
Total No. of Species	**0**	**4**	**0**	**1**	**3**	**7**	**2**	**4**

√ species present at or near stream crossing
[1] R3 was surveyed in June, 2002. No aquatic plants were observed at this time of year.

7.3.4 Zooplankton

7.3.4.1 Overview of Biology

Aquatic invertebrates include a diverse array of herbivores (which eat primary producers, e.g., algae and plants), detritivores (which eat detritus), and carnivores (which eat consumers, e.g., animals). Many aquatic invertebrates are opportunistic omnivores, i.e., they eat primary producers, detritus, and/or consumers.

The meiofauna are microscopic animals often defined as organisms that are retained by a 63 µm mesh. Meiofauna live in the water column (where they form the majority of the zooplankton), on the surfaces of plants, and in the sediments. Zooplankton (e.g., Cladocera, Copepoda) are very small animals without backbones (invertebrates) living in the water column and are consumed by larval, juvenile, and adult (e.g., lake cisco) fish. Three important groups in the open water are Cladocera (water fleas), and calanoid and cyclopoid Copepoda (Figure 7-16). Meiofauna on the surfaces of plants are generally consumed by larger invertebrates or indirectly ingested by plant-eating animals (e.g., moose and ducks). Meiofauna in the sediments are consumed by larger invertebrates and also may be ingested by bottom-feeding fish (e.g., suckers, lake whitefish). Nematoda (round worms) are the major meiofaunal group of the sediments, with harpacticoid copepods (small crustaceans) often also being abundant. These groups live primarily by ingesting detritus, although some are predatory. Meiofauna are typically abundant in fine-textured sediments, but are usually not enumerated in benthic collections because of their small size.

Most species of cladocerans and copepods (small crustaceans) feed by filtering or grazing particles (bacteria, detritus, and phytoplankton) from the water, though there are a few predatory species. The availability and quality of food (e.g., amount and kinds phytoplankton), the number of predators (e.g., other invertebrates, fish), and water residence time affect the abundance of zooplankton; in rapidly flushed lakes and rivers little zooplankton biomass accumulates except in areas where there is little current. Impoundment of rivers to form reservoirs may lead to an increase in zooplankton production.

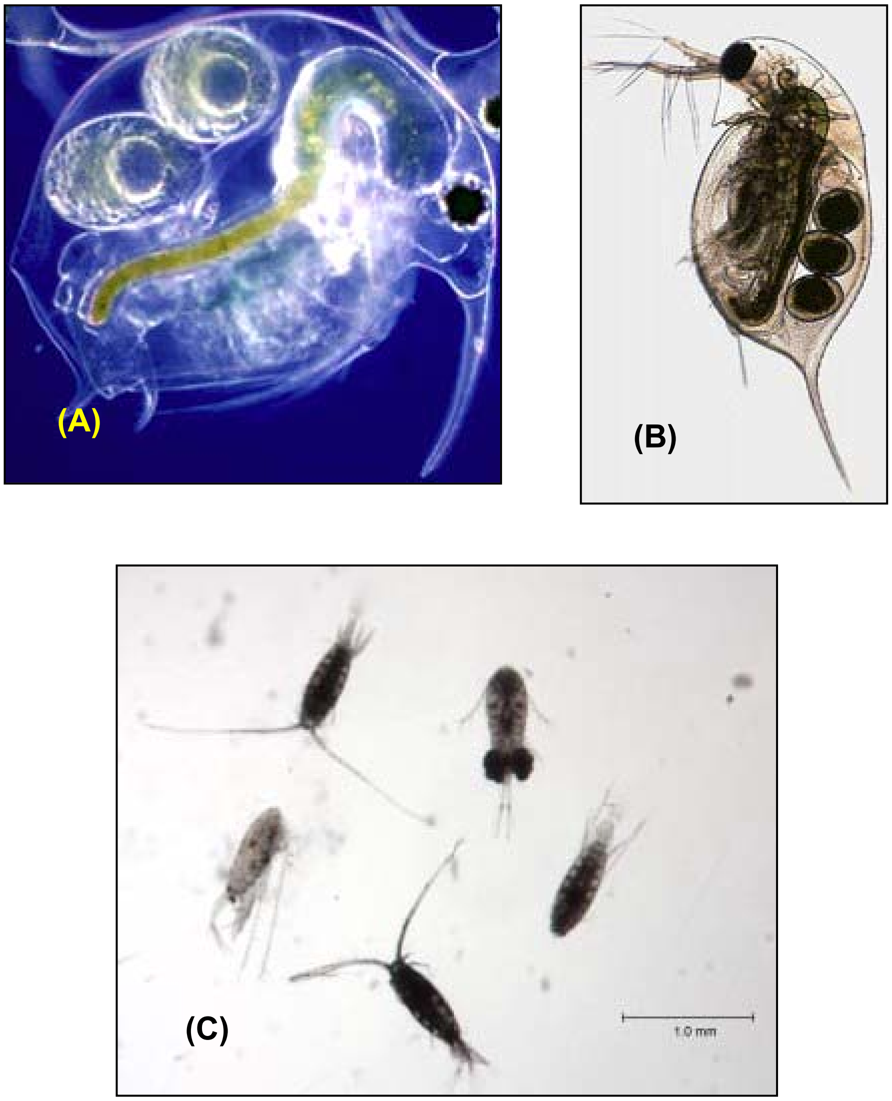


Figure 7-16. Representatives of three important zooplankton groups: (A) cladoceran; (B) cladoceran; and (C) calanoid and cyclopoid copepods.

7.3.4.2 Abundance, Composition, and Distribution

<u>Reach 1</u>

Semi-quantitative descriptions of the zooplankton community at two sites on Wuskwatim Lake main (WuLA and WuLB) were obtained in 1999, 2000, and 2001 (Figure 7-5). Additionally, during the 2001 open-water season, samples were collected at one site on Sesep Lake (SLA) and one on Wuskwatim Lake south (WuLC) (Figure 7-5). All sites, with the exception of WuLB, were considered as off-current.

Twenty different Cladocera and Copepoda taxa were found in Wuskwatim Lake main in 1999 (Table 7-16, North/South Consultants Inc. unpublished data). Results of the analyzed samples are presented in Table 7-17.

Table 7-16. The number of Cladocera and Copepoda taxa found in the study area, 1999-2001.

Lake	**1999**	**2000**	**2001**
Sesep	-	-	21
Wuskwatim Main	20	22	25
Wuskwatim South	-	-	22
Opegano	-	19	25

Zooplankton abundance and composition varied between the two sites in Wuskwatim Lake main and between sampling periods (Figure 7-17). In samples collected in early-June, 1999, zooplankton densities ranged from 743 individuals/m^3 at WuLA to 2294 individuals/m^3 at WuLB with copepods dominating the zooplankton community (Figure 7-17). Density of cladocerans was relatively low during this sampling period, which is typical of temperate lakes in the early spring as cladoceran species over-winter in low population densities as either adult females or as resting eggs (Wetzel 1983). In late-June, composition of the community at WuLA was similar to the early-June sample (Figure 7-17). Abundance had declined noticeably at WuLB and cladocerans dominated the community (Figure 7-17). In mid-August cyclopoid density had declined substantially at WuLA and calanoids along with cladocerans dominated the community. Cladoceran density had increased considerably at WuLB and contributed to the higher total abundance compared with late-June (Figure 7-17). Zooplankton abundance in the late-September sample at WuLA was the highest recorded during the growing season (7318 individuals/m^3), with cladocerans and cyclopoids dominant. The abundance of cladocerans at WuLB had declined slightly, however, these zooplankters continued to dominate the community (Figure 7-17).

Twenty-two different cladoceran and copepod taxa were found in Wuskwatim Lake main in 2000, slightly higher than the number observed in 1999 (Table 7-16, North/South Consultants Inc. unpublished data). Results of the analyzed samples are presented in Table 7-17. As in 1999, zooplankton abundance and composition varied between the sites and among sampling periods (Figure 7-17). In samples collected at the end of May, zooplankton densities ranged from 934 individuals/m^3 at WuLB to 2153 individuals/m^3 at WuLA and calanoid copepods dominated the community (Figure 7-17). Similar to 1999, density of cladocerans was low at this sampling time. By mid-July, the community composition had shifted and cladocerans were dominant. Abundance at on-current WuLB was the highest recorded during the growing season (9099 individuals/m^3) due to a substantial increase in cladocerans and calanoid copepods (Figure 7-17). In contrast to 1999, the community in mid-September was dominated by calanoids and cladocerans were relatively unimportant (Figure 7-17).

Twenty-five different cladoceran and copepod taxa were found in Wuskwatim Lake main in 2001, slightly higher than the number observed in 1999 and 2000 (Table 7-16, North/South Consultants Inc. unpublished data). Results of the analyzed samples are presented in Table 7-17. As in previous years, zooplankton abundance and composition varied between the sites and among sampling periods (Figure 7-17). In samples collected at the end of May, zooplankton densities ranged from 3463 individuals/m^3 at WuLB to 3540 individuals/m^3 at WuLA and calanoid copepods dominated the community (Figure 7-17). Similar to previous years, the density of cladocerans was low at this sampling time. By mid-July, composition of the community had shifted to a dominance of cladocerans. Total abundance at WuLA was considerably lower (871 individuals/m^3) than the value observed in late-May; however, as in 2000, abundance at on-current WuLB was the highest recorded during the growing season (6456 individuals/m^3) due to a substantial increase in cladocerans (Figure 7-17). In late-August, total abundance in the sample collected at WuLA had increased (3037 individuals/m^3) and the community was dominated by cladocerans. As in 1999, cladoceran density had declined considerably at WuLB; however, community composition was similar to the mid-July sample and cladocerans remained dominant (Figure 7-17). Similar to 2000, abundances in the mid-September samples at WuLA and WuLB were the lowest recorded (580 and 224 individuals/m^3, respectively). Community composition at WuLA was similar to that observed in mid- August, as cladocerans were relatively important. The abundance of cladocerans at WuLB had continued to decline, however, they remained the dominant zooplankter (Figure 7-17).

Table 7-17. Zooplankton (individuals/m^3) collected in vertical net tows from Wuskwatim Lake, 1999-2001.

Location	**Off-Current**											
Site	**WuLA**											
Sample Period	**1**			**2**			**3**			**4**		
Sample Date	**02-Jun-99**	**26-May-00**	**30-May-01**	**26-Jun-99**	**24-Jul-00**	**16-Jul-01**	**19-Aug-99**	**n.s.**	**23-Aug-01**	**29-Sep-99**	**18-Sep-00**	**27-Sep-01**
Cladocera	216	193	280	425	1433	414	286	-	1287	3163	20	392
Copepoda												
Calanoida	192	1509	2457	279	995	225	291	-	972	1313	65	134
Cyclopoida	336	451	802	553	190	231	98	-	778	2841	17	54
Total Copepoda	527	1960	3259	832	1184	456	390	-	1750	4155	81	188
TOTAL	**743**	**2153**	**3540**	**1257**	**2618**	**871**	**676**	**-**	**3037**	**7318**	**102**	**580**

Location	**On-Current**											
Site	**WuLB**											
Sample Period	**1**			**2**			**3**			**4**		
Sample Date	**02-Jun-99**	**26-May-00**	**30-May-01**	**26-Jun-99**	**24-Jul-00**	**16-Jul-01**	**19-Aug-99**	**n.s.**	**23-Aug-01**	**29-Sep-99**	**18-Sep-00**	**27-Sep-01**
Cladocera	423	64	116	429	3694	4121	1055	-	1248	766	98	96
Copepoda												
Calanoida	1268	736	1775	344	3667	1066	664	-	547	134	175	82
Cyclopoida	604	134	1572	290	1738	1269	145	-	441	383	81	45
Total Copepoda	1871	870	3347	634	5405	2335	809	-	989	517	256	127
TOTAL	**2294**	**934**	**3463**	**1062**	**9099**	**6456**	**1863**	**-**	**2237**	**1283**	**354**	**224**

Location	**Off-Current**											
Site	**WuLC**											
Sample Period	**1**			**2**			**3**			**4**		
Sample Date	**n.s**	**n.s.**	**30-May-01**	**n.s**	**n.s.**	**16-Jul-01**	**n.s**	**n.s.**	**23-Aug-01**	**n.s**	**n.s.**	**27-Sep-01**
Cladocera	-	-	4618	-	-	27665	-	-	41864	-	-	37700
Copepoda												
Calanoida	-	-	4448	-	-	2404	-	-	8964	-	-	4400
Cyclopoida	-	-	8013	-	-	28602	-	-	16909	-	-	10600
Total Copepoda	-	-	12461	-	-	31006	-	-	25872	-	-	15000
TOTAL	**-**	**-**	**17078**	**-**	**-**	**58671**	**-**	**-**	**67736**	**-**	**-**	**52700**

n.s. not sampled

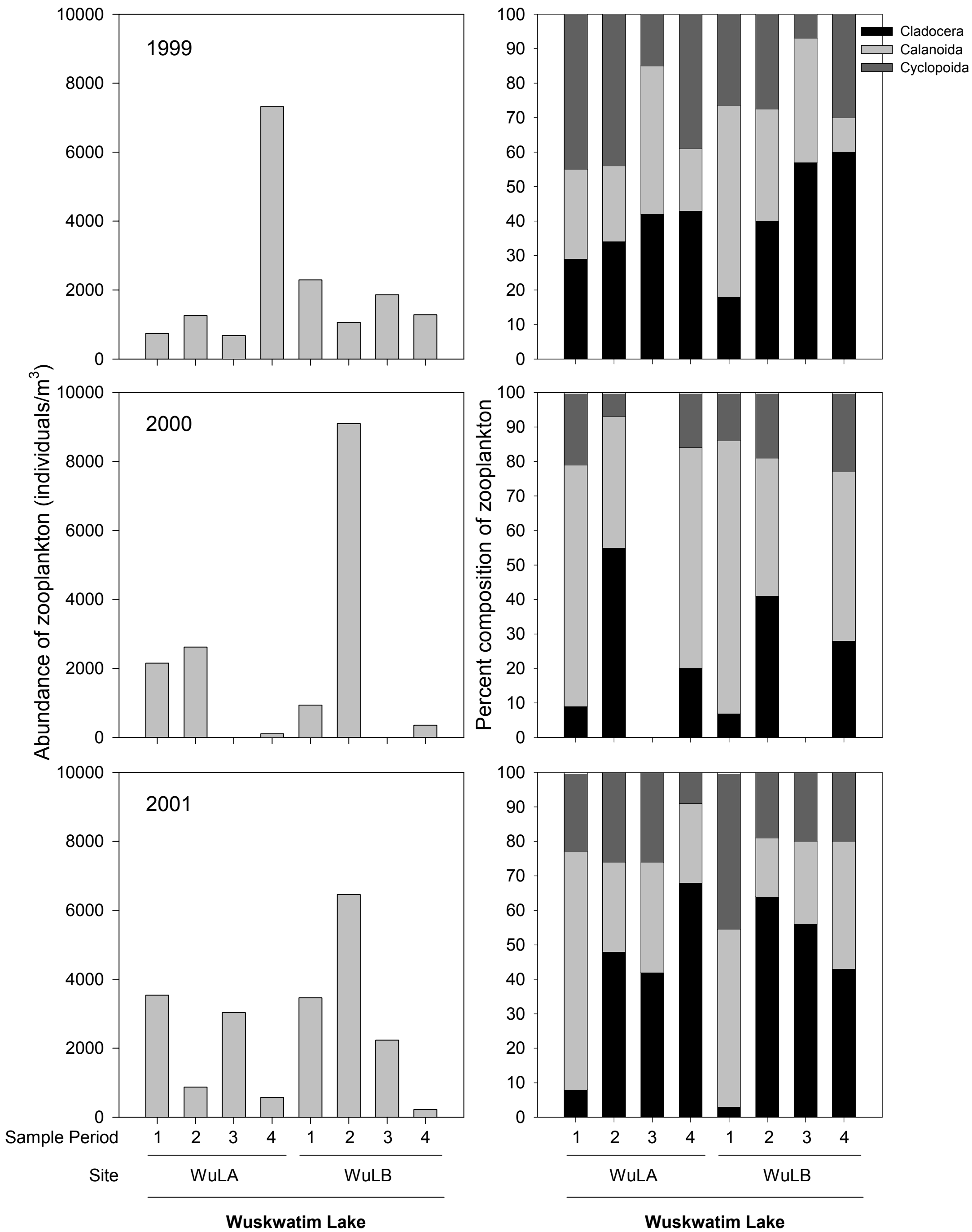


Figure 7-17. Total abundance and percent composition of zooplankton collected in vertical net tows from Wuskwatim Lake main, 1999-2001.

Twenty-two different cladoceran and copepod taxa were found in Wuskwatim Lake south in 2001 (Table 7-16, North/South Consultants Inc. unpublished data). Results of the analyzed samples are presented in Table 7-17. Similar to other sites in the study area, zooplankton abundance and composition varied among sampling periods (Figure 7-18). In late-May, total abundance was relatively high with 17078 individuals/m^3. Similar to Wuskwatim Lake main samples, copepods dominated the community at this time and the density of cladocerans was relatively low (Figure 7-18). Total abundance in mid-July had increased to 58671 individuals/m^3, largely due to substantial increases in cladoceran and cyclopoid numbers (Figure 7-18). Cyclopoids remained dominant at this time, however cladocerans now contributed a greater portion of the catch. The highest abundance in the study area was recorded in late-August when total zooplankton abundance in Wuskwatim Lake south was 67736 individuals/m^3 and cladocerans formed the majority of the zooplankton. The September sample was also characterized by a dominance of cladocerans and a high total abundance (52700 individuals/m^3) (Figure 7-18).

Twenty-one different cladoceran and copepod taxa were found in Sesep Lake in 2001 (Table 7-16, North/South Consultants Inc. unpublished data). Results of the analyzed samples are presented in Table 7-18. Similar to other sites in the study area, zooplankton abundance and composition varied among sampling periods (Figure 7-18). In the sample collected at the end of May, total abundance was considerably higher (37280 individuals/m^3) than any values observed for Wuskwatim Lake main and the community was already dominated by cladocerans (Figure 7-18). By mid-July, cladocerans remained dominant and total abundance had increased to 46091 individuals/m^3. For August and September samples, the pattern remained the same; cladocerans were dominant and total abundance remained high, ranging from 41429 individuals/m^3 in late-August to 48100 individuals/m^3 in late-September.

The greater total abundances of zooplankton observed in both Wuskwatim Lake south (WuLC) and Sesep Lake (SLA), in comparison to Wuskwatim Lake main (WuLA and WuLB), was likely primarily due to the relatively sheltered conditions at these sites (off-current) and longer water residence times in these areas. The differences in zooplankton abundance and community composition observed among sites in Reach 1 during any given sampling period are most likely due to the effects of water movements (e.g., wind direction and strength, currents) on these small organisms resulting in a non-random horizontal distribution of individuals. Horizontal patchiness is a characteristic of the zooplankton community (Horne and Goldman 1994).

Table 7-18. Zooplankton (individuals/m^3) collected in vertical net tows from Sesep Lake, 2001.

Location	**Off-Current**			
Site	**SLA**			
Sample Period	**1**	**2**	**3**	**4**
Sample Date	**30-May-01**	**16-Jul-01**	**23-Aug-01**	**27-Sep-01**
Cladocera	21798	34581	28204	36500
Copepoda				
Calanoida	1120	4584	7837	9100
Cyclopoida	14362	6926	5388	2500
Total Copepoda	15483	11510	13224	11600
TOTAL	**37280**	**46091**	**41429**	**48100**

Reach 2

Zooplankton data were not collected in this riverine study reach as the water residence time is extremely short and the water in this area tends to be quite turbulent. These conditions reduce the potential for notable increases in zooplankton populations, as these populations cannot maintain positive net growth rates due to downstream losses.

Reach 3

As in Reach 2, zooplankton data were not collected in the upper section of this riverine reach. It is anticipated that any notable changes in zooplankton populations occurring within the lower section of this reach would be detected at the nearest downstream sampling site on Opegano Lake. Zooplankton abundance and community composition in the lower section immediately upstream of Opegano Lake were likely similar to that observed in Opegano Lake, as both sites on Opegano Lake were within the on-current portion of the lake.

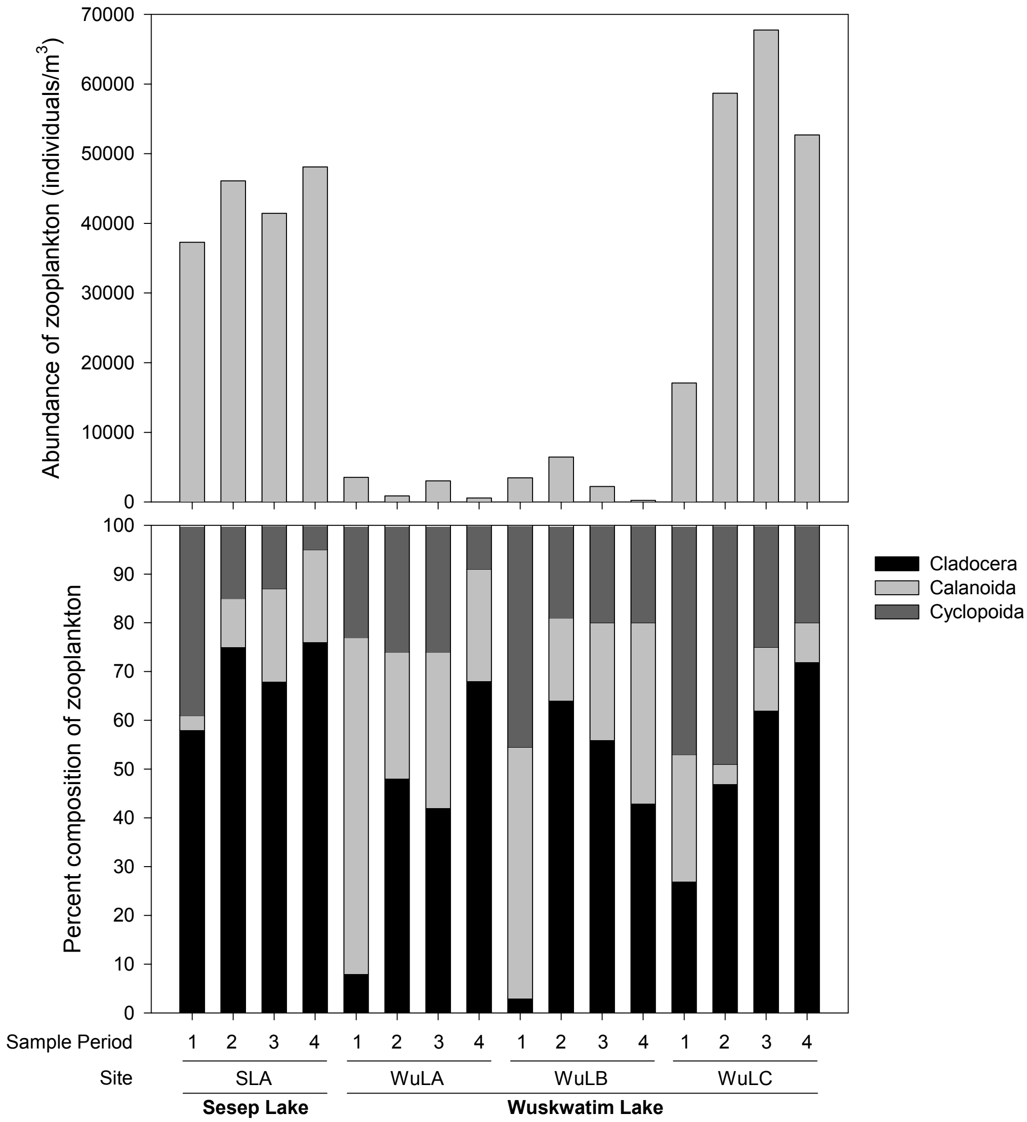


Figure 7-18. Total abundance and percent composition of zooplankton collected in vertical net tows from Reach 1, 2001.

Reach 4

Semi-quantitative descriptions of the zooplankton community at two sites (OLA and OLB) on Opegano Lake were obtained in 2000 and 2001 (Figure 7-5). Both sites were within the main, on-current portion of the lake.

Nineteen different Cladocera and Copepoda taxa were found in Opegano Lake in 2000 (Table 7-16, North/South Consultants Inc. unpublished data). Results of the analyzed samples are presented in Table 7-19. As in Reach 1, zooplankton abundance and composition varied between the two sites in Opegano Lake and between sampling periods (Figure 7-19). The highest density was recorded in mid-August at OLB (1775 individuals/m^3) in the southern portion of the lake. At this time, cladocerans dominated the zooplankton community at both sites (Figure 7-19). By late-September, zooplankton abundance had declined considerably at OLB (198 individuals/m^3); however, abundance at OLA had increased and was approximately twice as high as at OLB. Cladoceran density was substantially less, particularly at OLB, and calanoid copepods dominated the community at both sites (Figure 7-19).

Twenty-five different cladoceran and copepod taxa were found in 2001, slightly higher than the number observed in 2000 (Table 7-16, North/South Consultants Inc. unpublished data). The increased quantity of taxa seen in 2001 was likely due to the larger number of samples collected during the growing season. Results are presented in Table 7-19. As in 2000, zooplankton abundance and composition varied between the sites and among sampling periods (Figure 7-19). The highest density was recorded in mid-July at OLB (677 individuals/m^3). In samples collected at the end of May, zooplankton densities ranged from 458 individuals/m^3 at OLA to 616 individuals/m^3 at OLB and cyclopoid copepods dominated the community (Figure 7-19). Density of cladocerans was low during this sampling period. By mid-July, composition of the community had shifted to a dominance of cladocerans, but, total abundance was similar to that observed at the end of May (Figure 7-19). In contrast to 2000, total abundance was lower in the sample collected in late-August at OLB (122 individuals/m^3). Cladocerans remained the dominant zooplankter at OLB, but calanoid copepod density had increased at OLA, accounting for the higher total abundance compared to 2000 (Figure 7-19). In contrast to 2000, abundance in the late-September sample at OLA was the lowest recorded at this site (129 individuals/m^3); however, a slight increase was noted at OLB (335 individuals/m^3). Although, the importance of cyclopoids had increased at both sites, cladocerans remained well represented, particularly at OLA (Figure 7-19).

Table 7-19. Zooplankton (individuals/m^3) collected in vertical net tows from Opegano Lake, 2000-2001.

Location	**On-Current**							
Site	**OLA**							
Sample Period	**1**		**2**		**3**		**4**	
Sample Date	**n.s.**	**31-May-01**	**n.s.**	**17-Jul-01**	**15-Aug-00**	**28-Aug-01**	**24-Sep-00**	**30-Sep-01**
Cladocera	-	48	-	280	82	84	45	59
Copepoda								
Calanoida	-	146	-	53	55	224	193	12
Cyclopoida	-	265	-	115	25	109	120	59
Total Copepoda	-	411	-	168	81	334	313	71
TOTAL	**-**	**458**	**-**	**448**	**163**	**418**	**358**	**129**

Location	**On-Current**							
Site	**OLB**							
Sample Period	**1**		**2**		**3**		**4**	
Sample Date	**n.s.**	**31-May-01**	**n.s.**	**17-Jul-01**	**15-Aug-00**	**28-Aug-01**	**24-Sep-00**	**30-Sep-01**
Cladocera	-	10	-	402	960	56	32	112
Copepoda								
Calanoida	-	145	-	153	713	28	134	12
Cyclopoida	-	461	-	122	102	38	32	212
Total Copepoda	-	606	-	275	815	66	166	224
TOTAL	**-**	**616**	**-**	**677**	**1775**	**122**	**198**	**335**

The lower total abundances of zooplankton observed at both sites in Opegano Lake (OLA and OLB), in comparison to Wuskwatim Lake main (WuLA and WuLB), were likely primarily due to conditions in Opegano Lake being more riverine, as the volume of water is smaller leading to reduced water residence times.

Growth and production of zooplankton are strongly influenced by water temperature and level of trophy/nutrient status of a waterbody. Variations in the abundances of cladocerans and copepods throughout the open-water season (i.e., at different sampling times) and among years are most likely due to the effects of annual weather variation on growth and development of zooplankton species.

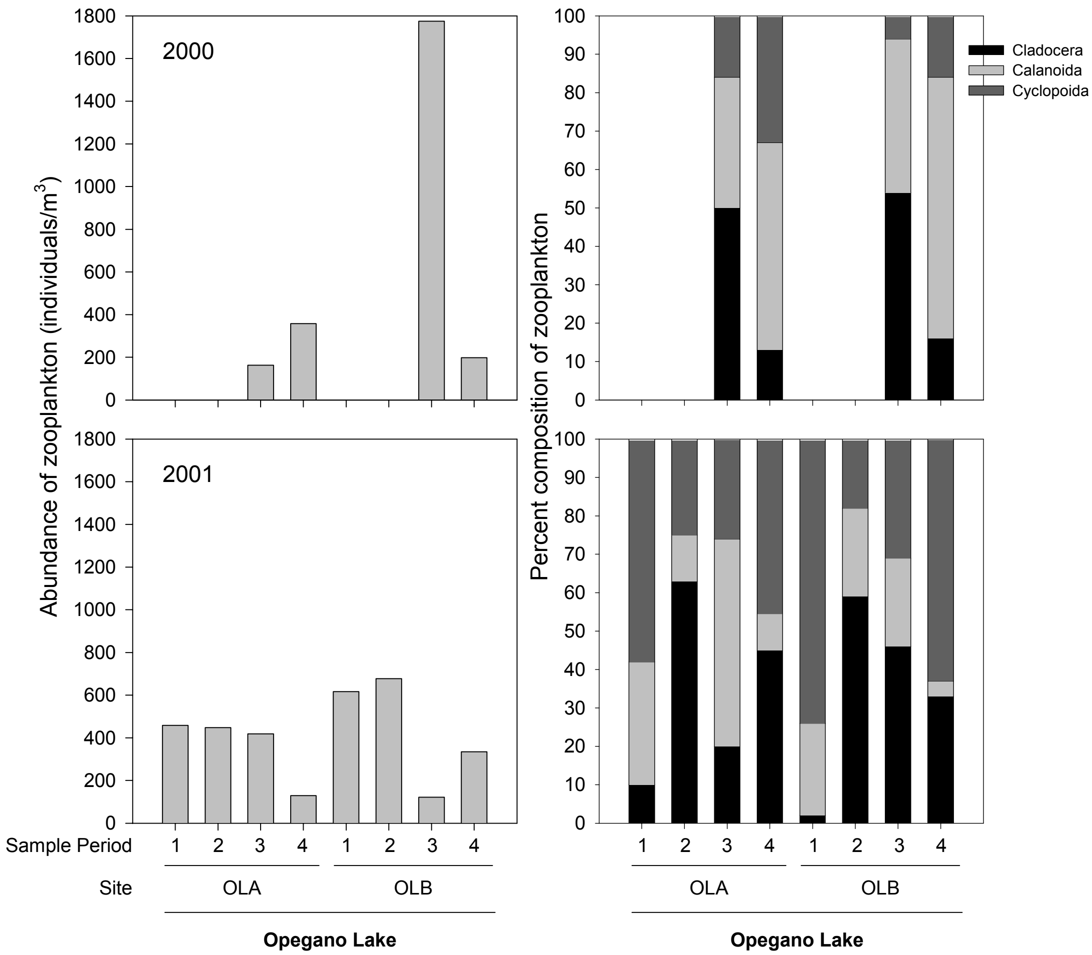


Figure 7-19. Total abundance and percent composition of zooplankton collected in vertical net tows from Opegano Lake, 2000-2001.

The overwintering zooplankton community typically consists of adult and immature copepods, and small numbers of adult female cladocerans. Cladoceran species usually over-winter in low population densities as either adult females or as resting eggs (Wetzel 1983). The reproductive strategies of cladocerans and copepods differ and are strongly influenced by a number of environmental parameters, including water temperature, and food availability and quality. Cladocerans reproduce asexually for the majority of the year in most habitats, enabling this group to increase rapidly in density in response to favourable environmental conditions (e.g., warming water temperatures, increasing food availability). Copepod reproduction is exclusively sexual. Their life cycle is quite prolonged to accommodate several developmental stages. In comparison to cladocerans, copepods are slow reproducers requiring several months to years to complete a life cycle. A consequence of this prolonged lifecycle is that copepods, unlike the asexually reproducing cladocerans, are not able to take advantage of favourable growing conditions and peak in abundance. Thus, throughout the growing season, cladoceran populations tend to fluctuate in abundance with changing food availability, while copepod populations tend to remain more stable.

Stream Crossings

Data were not collected at streams crossed by the access road as truly planktonic crustacean zooplankton tend to be relatively unimportant in small streams as these organisms cannot maintain positive net growth rates due to a variety of reasons, including downstream losses (Hynes 1970). The irregular occurrence of planktonic cladocerans and copepods in small streams, mainly during summer, has been reported. These zooplankton species are thought of as true plankton in that they are normally found in lakes, and they likely originate from other waterbodies draining into the streams (Hynes 1970). Invertebrate production in small streams tends to be dominated by the benthic community (Horne and Goldman 1994).

7.3.5 Benthic Invertebrates

7.3.5.1 Overview of Biology

The macrofauna are invertebrates that are retained on 400-500 µm screens and are generally the subject of benthic invertebrate studies because of their importance as food to vertebrates (particularly fish). Benthic invertebrates (benthos) are small animals without backbones living on or in the substrates of lakes and rivers. The benthos are typically a diverse assemblage, and are adapted to the range of substrate types and water flow regimes (e.g., fast-flowing rivers, sheltered bays in lakes with no discernable flow) found in the aquatic environment. Beds of rooted vegetation usually harbour the greatest density and variety of benthos, living on the leaf surfaces as well as on and within the sediments beneath the plants. These include grazers of attached algae (e.g., gastropods, chironomids, and ephemeropterans), organisms that consume the organic-rich sediment (e.g., oligochaetes), animals that eat the plants themselves (e.g., crayfish), and a few carnivores (dragonfly nymphs) (Figure 7-20). Amphipods, which consume a variety of decaying plant and animal matter, are also present (Figure 7-20). Shallow areas with mud or mud-sand bottoms provide habitat for filter-feeding bivalves, sediment-feeding oligochaetes, and a variety of insect larvae, many of which have terrestrial adult forms (Figure 7-20). Emergence of larval insects to terrestrial adults results in a loss of numbers and biomass from the aquatic system. Substrates such as sand or gravel usually harbour fewer animals because water currents readily disturb these substrates. Deeper areas of lakes are typically depositional environments with fine-textured sediments. Organisms that feed on sediment and detritus (e.g., oligochaetes and chironomids) usually dominate in these areas. Many of these animals are adapted to low-oxygen conditions that can develop at greater water depths.

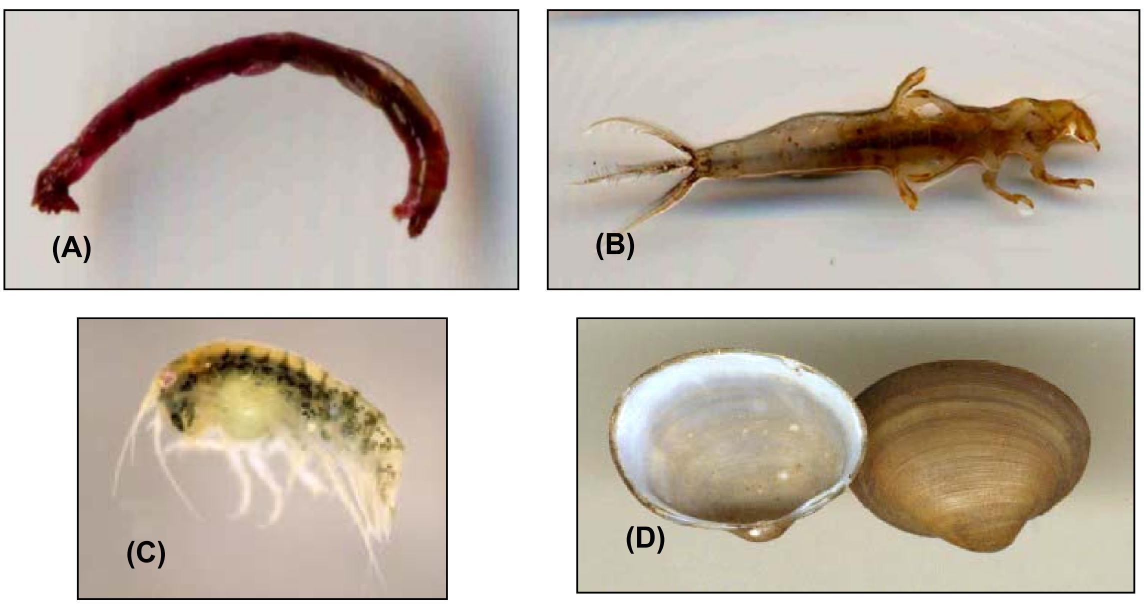


Figure 7-20. Representatives of benthic invertebrate groups: (A) chironomid larva; (B) ephemeropteran larva; (C) amphipod; and (D) bivalve.

In a regulated system, such as Wuskwatim Lake, water level fluctuations reduce benthic invertebrate abundance in intermittently exposed areas along the shoreline.

7.3.5.2 Abundance, Composition, and Distribution

Reach 1

Habitat-Based Community Assessment

A quantitative description of the benthic invertebrate community was obtained in seven different lacustrine habitat types in Reach 1 between 1998 and 2001 (Table 7-20, North/South Consultants Inc. unpublished data).

Mean total abundance of benthic invertebrates (benthos) in Reach 1 ranged from 1276 individuals/m^2 in habitat type E-Sc-Sc (intermittently exposed, soft silt/clay-based substrate, no plants) to 12551 individuals/m^2 in NS-Ft-Rv (nearshore, flooded terrestrial substrate, rooted vascular plants) (Table 7-20). Wuskwatim Lake is a regulated system and, as such, water level fluctuations tend to reduce benthic invertebrate abundance in intermittently exposed areas along the shoreline.

Beds of aquatic plants offer habitat for benthos, as they provide surfaces for attachment and feeding, and a refuge from predation by other invertebrates and fish. Other habitat types in the nearshore habitat zone tended to support higher abundances of benthos than either the intermittently exposed or offshore zones. There was substantial variability in abundances within habitat types and among replicates from individual sites (North/South Consultants Inc. unpublished data). Chironomidae (midges) was the most common taxon in all habitat types, with the exception of the OS-Sc-Sc (offshore, soft silt/clay-based substrate, no plants) habitat type, and comprised between approximately 25 and 60 % of the benthic invertebrate community (Table 7-20). Amphipoda (scuds) and Sphaeriidae (fingernail clams) were most common in the OS-Sc-Sc habitat type, contributing to approximately 31 and 32 % of the community, respectively. The insect group Ephemeroptera (mayflies) was a relatively important component of the benthos in the nearshore habitat zone, particularly in the NS-Ft-Rv habitat type where it comprised 25 % of the community.

Table 7-20. Summary benthic invertebrate information for lacustrine habitat types in Reach 1, 1998-2001.

Habitat Type [1]	Years Investigated	n [2]	Total Abundance (individuals/m^2)			Mean Percent Composition of Major Groups [3]								
			Mean	Min.	Max.	OLIGO	AMPH	CHIRON	CERATO	EPHEM	TRICH	GAST	SPHAER	OTHER
E-Sc-Sc	1998, 2000	18	1276	239	2452	7.4	8.0	36.0	2.5	5.7	1.4	26.3	5.8	6.8
NS-Sc-Sc	1998-2001	178	2066	152	25022	8.4	8.0	24.9	1.8	16.5	2.0	16.1	13.4	8.8
NS-Sc-Rv	1999-2001	32	2611	815	8022	5.1	13.5	42.0	5.0	10.0	4.0	3.3	11.9	5.1
NS-Sc-Nv	2001	4	10174	-	-	1.7	19.7	30.8	4.3	10.3	2.6	12.0	7.7	11.1
NS-Ft-Sc	2001	40	8241	1587	31533	7.0	5.5	59.7	2.7	11.6	1.6	1.6	8.2	2.1
NS-Ft-Rv	2001	24	12551	2989	27207	5.2	4.7	30.9	0.9	25.1	2.6	18.9	8.8	2.8
OS-Sc-Sc	1998-2001	73	2521	663	10924	2.4	30.9	11.9	0.3	10.2	0.2	1.6	31.7	10.8

[1] Habitat Type:

E-Sc-Sc	intermittently exposed, soft silt/clay-based substrate, no plants
NS-Sc-Sc	nearshore, soft silt/clay-based substrate, no plants
NS-Sc-Rv	nearshrore, soft silt/clay-based substrate, rooted vascular plants
NS-Sc-Nv	nearshore, soft silt/clay-based substrate, non-vascular plants
NS-Ft-Sc	neashore, flooded terrestrial substrate, no plants
NS-Ft-Rv	nearshore, flooded terrestrial substrate, rooted vascular plants
OS-Sc-Sc	offshore, soft silt/clay-based substrate, no plants

[2] number of replicates collected/habitat type

[3] Major Groups:

OLIGO	Oligochaeta
AMPH	Amphipoda
CHIRON	Chironomidae
CERATO	Ceratopogonidae
EPHEM	Ephemeroptera
TRICH	Trichoptera
GAST	Gastropoda
SPHAER	Sphaeriidae
OTHER	Other Groups

In 1998, benthic invertebrate samples were collected in three habitat types: E-Sc-Sc; NS-Sc-Sc (nearshore, soft silt/clay-based substrate, no plants); and OS-Sc-Sc. These habitat types were characterized as having soft, silt/clay-based bottom substrate and no plants, but differed with respect to water level criteria. Overall abundance of benthic invertebrates was relatively similar among these three habitats, ranging from 1389 individuals/m^2 in the offshore to 2249 individuals/m^2 in the nearshore (Figure 7-21, North/South Consultants Inc. unpublished data).

Intermittently exposed habitat was not sampled in 1999, as the water level on Wuskwatim Lake resulted in the exposure of this habitat type during the period of sample collection. However, samples were collected in two habitat types sampled in 1998 (NS-Sc-Sc and OS-Sc-Sc) and an additional one, NS-Sc-Rv (nearshore, soft silt/clay-based substrate, rooted vascular plants). These habitat types were characterized as having soft, silt/clay-based bottom substrate, but differed with respect to presence of aquatic plants and water level criteria. Overall abundance differed slightly among these habitats, ranging from 1171 individuals/m^2 in NS-Sc-Sc to 2377 individuals/m^2 in the OS-Sc-Sc (Figure 7-21, North/South Consultants Inc. unpublished data). NS-Sc-Rv had a slightly higher abundance (1902 individuals/m^2) than otherwise comparable habitat with no plants (NS-Sc-Sc).

The four habitat types sampled in previous years were visited in 2000. The water level elevation of Wuskwatim Lake was higher during the sampling period allowing collection of samples in intermittently exposed habitat. The pattern of overall abundance among habitats in 2000 was similar to that observed in 1999. Abundance ranged from 1606 individuals/m^2 in NS-Sc-Sc to a high of 3080 individuals/m^2 in OS-Sc-Sc (Figure 7-21, North/South Consultants Inc. unpublished data). NS-Sc-Rv had a higher abundance (2484 individuals/m^2) than comparable habitat without plants (NS-Sc-Sc). Abundance was lowest in the intermittently exposed habitat type (1043 individuals/m^2).

In 2001, the sampling program was expanded to include sites in Cranberry Lakes, Sesep Lake, and Wuskwatim Brook. As a result, an increased number of habitat types were investigated. Intermittently exposed habitat was not sampled in 2001, as the water level on Wuskwatim Lake resulted in the exposure of this habitat type during the period of sample collection. However, samples were collected in three habitat types sampled in previous years (NS-Sc-Sc, NS-Sc-Rv, and OS-Sc-Sc) and three additional ones: NS-Sc-Nv (nearshore, soft silt/clay-based substrate, non-vascular plants); NS-Ft-Sc (nearshore, flooded terrestrial substrate, no plants); and NS-Ft-Rv (nearshore, flooded terrestrial substrate, rooted vascular plants).

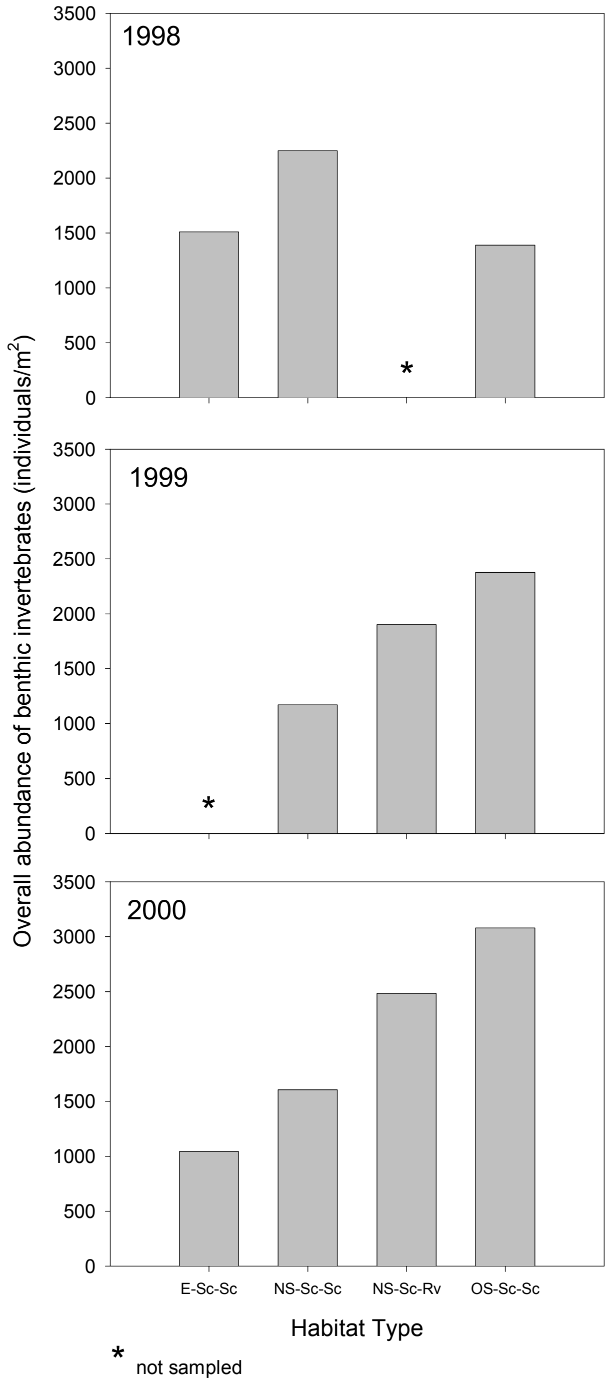


Figure 7-21. Overall abundance of benthic invertebrates in Reach 1, 1998-2000. (Note: additional habitat types sampled in 2001 are not shown)

The pattern of overall abundance among habitats sampled in previous years was similar to that observed in 1999 and 2000. Overall abundance differed slightly among these three habitats, ranging from 3236 individuals/m^2 in NS-Sc-Sc to 3448 individuals/m^2 in NS-Sc-Rv (Figure 7-22, North/South Consultants Inc. unpublished data). Abundance in the three additional nearshore habitat types sampled was substantially higher than that observed in either previous years or in the other habitat types investigated in 2001. Overall abundance was similar among these nearshore habitats, ranging from 8241 individuals/m^2 in NS-Ft-Sc to 12551 individuals/m^2 in NS-Ft-Rv.

A sub-set of benthic invertebrate samples collected in September, 2001, were further identified to genus and/or species to create an index of **biodiversity** for selected aquatic habitat types in Reach 1. A list of benthic invertebrate taxa identified in reaches 1, 2, and 3 is presented in Volume 5, Appendix 8.

Species richness of benthos in Reach 1 ranged from 14 individual taxa represented in habitat type NS-Sc-Sc to 26 represented in habitat types NS-Ft-Sc and OS-Sc-Sc (Table 7-21). For the NS-Sc-Sc habitat type, the Shannon-Weiner biodiversity index (H') was determined for seven different sites. The median H' for this habitat type was 2.85, with a minimum of 2.41 and a maximum of 3.06; an H' of 3.06 was the highest observed for all sites in Reach 1 (Table 7-21). Biodiversity of the benthic invertebrate community in the NS-Sc-Rv, NS-Ft-Rv, and OS-Sc-Sc habitat types fell within the range observed for the NS-Sc-Sc habitat type, with the exception of one site classified as OS-Sc-Sc, which had a lower H' of 2.37. Diversity of the community at the two sites classified as NS-Ft-Sc was the lowest observed in Reach 1. However, the NS-Ft-Sc habitat type and the one site classified as OS-Sc-Sc had the highest total invertebrate abundances observed and relatively high species richness, indicating that a few species were dominant at these sites and the remainder were represented by relatively few individuals (low species evenness), resulting in lower biodiversity.

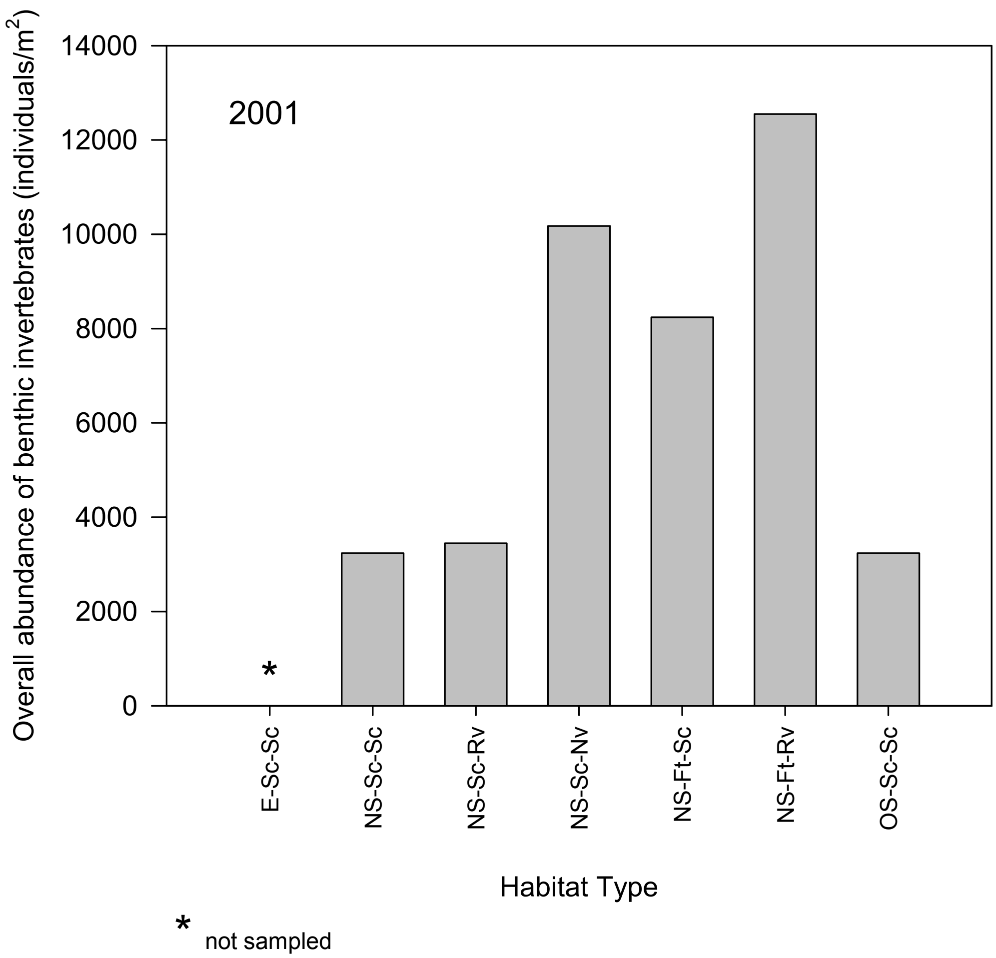


Figure 7-22. Overall abundance of benthic invertebrates in Reach 1, 2001.

Qualitative Community Assessment

A qualitative description of the benthic invertebrate community was obtained at one drift trap site in the Wuskwatim Brook (WB) (Figure 7-10) during late-June, 2001 (Table 7-22). From June 23 to 25, there were 17 different invertebrate taxa observed. Amphipods were the only crustacean represented in the drift trap samples. Insects comprised the majority of drifting invertebrate groups, representing 12 of the taxa found. All insect groups present in the drift trap samples were also observed in Ekman dredge samples from the Wuskwatim Lake area, with the exception of Simuliidae (black flies). Black fly larvae and pupae are found wherever there is permanent or semi-permanent running water, which the larval and pupal stages require for their development (Peterson 1996).

Table 7-21. Biodiversity of benthic invertebrates in samples from Reach 1, by habitat type, 2001.

Habitat Type [1]	Date Sampled	Waterbody	Section	Transect	Site	n [2]	Total Abundance (individuals/m^2) Mean	STD [3]	Species Richness [4]	Biodiversity Index (H') [5]
NS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	3	1	4	978	509	19	2.90
NS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	3	2	4	946	693	22	2.95
NS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	3	3	4	2467	967	24	3.06
NS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	5	1	4	1043	295	15	2.41
NS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	5	2	4	2054	1027	21	2.52
NS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	5	3	4	1196	226	20	2.85
NS-Sc-Sc	26-Sep-01	Wuskwatim Brook	-	2	3	4	1293	1265	14	2.52
								maximum =	24	3.06
								median =	20	2.85
								minimum =	14	2.41
NS-Sc-Rv	25-Sep-01	Wuskwatim Lake	-	-	M1	4	826	112	16	2.74
NS-Ft-Sc	26-Sep-01	Wuskwatim Brook	-	2	1	4	5054	967	26	2.31
NS-Ft-Sc	26-Sep-01	Wuskwatim Brook	-	2	2	4	6446	2712	20	1.98
NS-Ft-Rv	26-Sep-01	Wuskwatim Lake	-	-	M3	4	4228	1691	23	2.46
OS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	3	4	4	978	103	16	2.91
OS-Sc-Sc	25-Sep-01	Wuskwatim Lake	-	5	4	4	9630	3235	26	2.37

[1] Habitat Type:
- NS-Sc-Sc nearshore, soft silt/clay-based substrate, no plants
- NS-Sc-Rv nearshrore, soft silt/clay-based substrate, rooted vascular plants
- NS-Ft-Sc neashore, flooded terrestrial substrate, no plants
- NS-Ft-Rv nearshore, flooded terrestrial substrate, rooted vascular plants
- OS-Sc-Sc offshore, soft silt/clay-based substrate, no plants

[2] number of replicates collected/site
[3] +/- 1 standard deviation
[4] number of individual taxa represented at each site
[5] Shannon-Weiner biodiversity index determined at each site

Table 7-22. Drifting invertebrates found in Reach 1, 2001.

Study Reach	**Wuskwatim**		
Site	**WB**		
Sample Date	**23-Jun-01**	**24-Jun-01**	**25-Jun-01**
Annelida			
Oligochaeta	√	√	-
Hirudinea	-	√	-
Crustacea			
Ostracoda	-	-	-
Amphipoda	√	√	√
Conchostraca	-	-	-
Mysidacea	-	-	-
Decapoda	-	-	-
Arachnida			
Hydracarina	√	√	√
Insecta			
Megaloptera	-	-	-
Odonata			
Anisoptera	-	-	-
Zygoptera	√	-	-
Coleoptera	√	√	√
Hemiptera	√	√	√
Ephemeroptera	√	√	√
Trichoptera	√	√	-
Plecoptera	-	√	√
Diptera			
Chironomidae			
larva	√	√	-
pupa	√	√	√
Ceratopogonidae	-	-	-
Tipulidae	-	-	-
Simuliidae			
larva	√	√	√
pupa	-	√	-
Chaoboridae			
larva	√	-	-
pupa	-	-	√
Mollusca			
Bivalvia			
Unionidae	-	-	-
Sphaeriidae	-	-	-
Gastropoda	-	-	-
Nematoda	-	-	-
Platyhelminthes	-	-	√
Hydrozoa	-	-	-
Total No. of Taxa	**12**	**13**	**10**

√ taxa present in sample

Reach 2

Habitat-Based Community Assessment

In 2001, a quantitative description of the benthic invertebrate community was obtained in four different riverine habitat types in Reach 2: E-M-Sc-Sc-L (intermittently exposed, mainstem, soft silt/clay-based substrate, no plants, low water velocity); W-M-Sc-Sc-L (wetted, mainstem, soft silt/clay-based substrate, no plants, low water velocity); W-M-Hc-L (wetted, mainstem, hard silt/clay-based substrate, low velocity); and W-M-Bc-M (wetted, mainstem, boulder/cobble substrate, medium water velocity) (Table 7-23, North/South Consultants Inc. unpublished data). It is likely that the bottom substrate in habitat type W-M-Bc-M is transitional in nature between soft silt/clay-based and boulder/cobble (i.e., the substrate is heterogeneous, or a mixture of different types). These habitat types were characterized as occurring in the mainstem portion of the Burntwood River with no aquatic plants present, but differed with respect to water level criteria, bottom substrate type, and water velocity.

Mean total abundance of benthos in Reach 2 ranged from 2071 individuals/m^2 in habitat type W-M-Hc-L to 4793 individuals/m^2 in W-M-Bc-M. Abundances were similar in habitat types characterized as having silt/clay-based bottom sediments (Figure 7-23). Large, stable bottom substrates, such as boulders and cobble, tend to support relatively more productive benthic invertebrate populations. There was substantial variability in abundances within habitat types and among replicates from individual sites (North/South Consultants Inc. unpublished data). Sphaeriidae (fingernail clams) was the most common taxon in the majority of habitat types sampled, comprising approximately 45 to 65 % of the benthic invertebrate community (Table 7-23). In the E-M-Sc-Sc-L habitat type, amphipods were most common (30 %); ephemeropterans, chironomids, and Oligochaeta (aquatic earthworms) were also relatively common, comprising 18, 17, and 14 % of the community, respectively (Table 7-23). Within the insect groups, mayflies and midges were most common in the habitat types characterized as having soft silt/clay-based bottom sediments and lacking aquatic plants, and Trichoptera (caddisflies) were most common (45 %) in the habitat types with either boulder/cobble or hard silt/clay-based bottom substrate.

Table 7-23. Summary benthic invertebrate information for riverine habitat types in Reach 2, 2001.

Habitat Type [1]	Years Investigated	n [2]	Total Abundance (individuals/m^2)			Mean Percent Composition of Major Groups [3]								
			Mean	Min.	Max.	OLIGO	AMPH	CHIRON	CERATO	EPHEM	TRICH	GAST	SPHAER	OTHER
E-M-Sc-Sc-L	2001	4	2957	-	-	13.6	29.8	16.5	5.5	18.4	4.4	2.9	6.3	2.6
W-M-Sc-Sc-L	2001	20	2774	739	5587	2.7	3.9	17.0	3.8	10.2	4.0	1.4	54.9	2.1
W-M-Hc-L	2001	8	2071	1826	2315	0.5	0.5	10.8	1.0	3.9	14.7	0.5	64.6	3.4
W-M-Bc-M	2001	4	4793	-	-	0.0	0.2	0.9	0.0	4.5	44.9	0.0	44.9	4.5

[1] Habitat Type:
- E-M-Sc-Sc-L intermittently exposed, mainstem, soft silt/clay-based substrate, no plants, low water velocity
- W-M-Sc-Sc-L wetted, mainstem, soft silt/clay-based substrate, no plants, low water velocity
- W-M-Hc-L wetted, mainstem, hard silt/clay-based substrate, low water velocity
- W-M-Bc-M wetted, mainstem, boulder/cobble substrate, medium water velocity

[2] number of replicates collected/habitat type

[3] Major Groups:
- OLIGO Oligochaeta
- AMPH Amphipoda
- CHIRON Chironomidae
- CERATO Ceratopogonidae
- EPHEM Ephemeroptera
- TRICH Trichoptera
- GAST Gastropoda
- SPHAER Sphaeriidae
- OTHER Other Groups

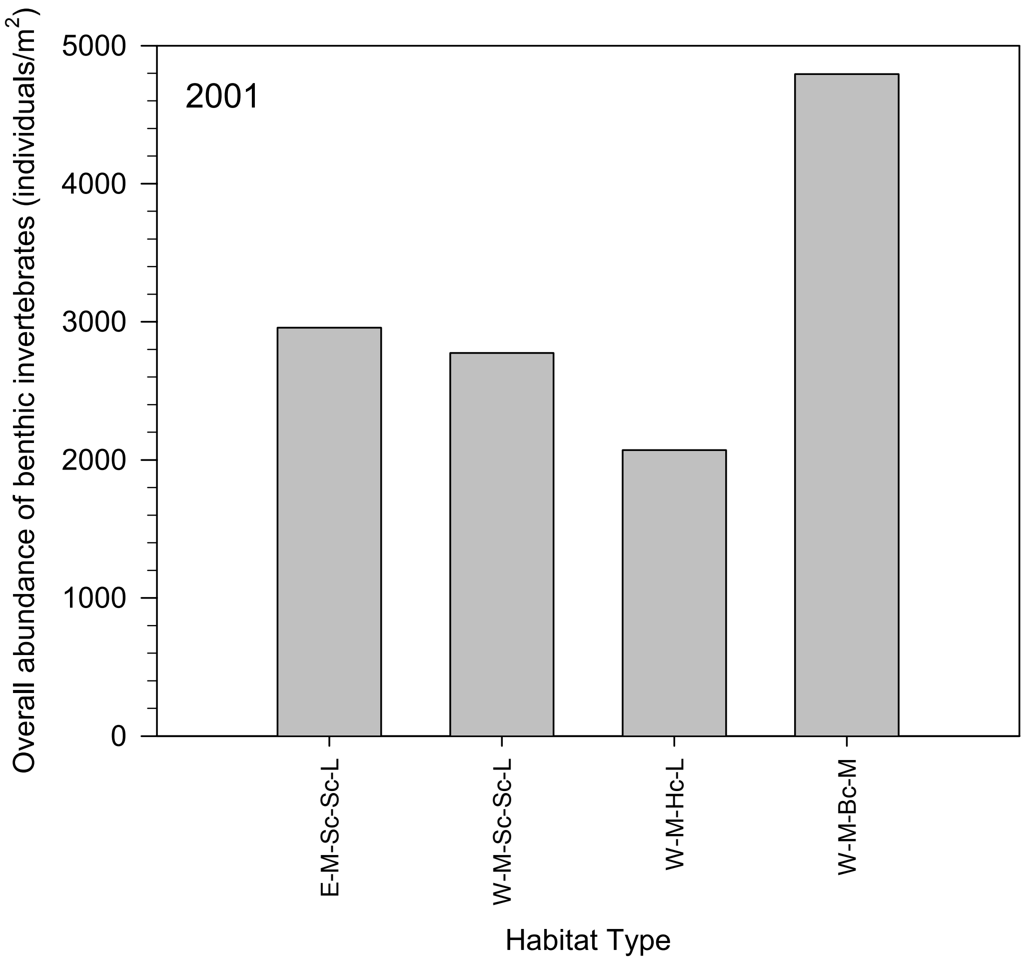


Figure 7-23. Overall abundance of benthic invertebrates in Reach 2, 2001.

Benthic invertebrate samples collected in September, 2001, were further identified to genus and/or species for all aquatic habitat types investigated in Reach 2. A list of benthic invertebrate taxa identified in reaches 1, 2, and 3 is presented in Volume 5, Appendix 8.

Species richness of benthos in Reach 2 ranged from 19 individual taxa represented in habitat type W-M-Hc-L to 33 in habitat type W-M-Sc-Sc-L (Table 7-24). For the W-M-Sc-Sc-L habitat type, the biodiversity index (H') was determined for five different sites. This habitat type had a median H' of 2.84, a minimum of 2.34, and a maximum of 2.99. Diversity at the site with an H' of 2.34 was the lowest observed in Reach 2. However, this site had one of the highest total invertebrate abundances observed and a relatively high species richness (28), indicating that the community at this site was dominated by relatively few taxa. Biodiversity of the benthic invertebrate community in the other habitat types also characterized as wetted and within the mainstem portion of the river

Table 7-24. Biodiversity of benthic invertebrates in samples from Reach 2, by habitat type, 2001.

Habitat Type [1]	Date Sampled	Waterbody	Section	Transect	Site	n [2]	Total Abundance (individuals/m^2) Mean	STD [3]	Species Richness [4]	Biodiversity Index (H') [5]
E-M-Sc-Sc-L	23-Sep-01	Burntwood River	1	P2	1	4	2957	992	29	3.03
W-M-Sc-Sc-L	22-Sep-01	Burntwood River	1	P1	1	4	2554	828	24	2.84
W-M-Sc-Sc-L	22-Sep-01	Burntwood River	1	P1	2	4	739	79	20	2.92
W-M-Sc-Sc-L	22-Sep-01	Burntwood River	1	P1	3	4	2261	642	20	2.38
W-M-Sc-Sc-L	23-Sep-01	Burntwood River	1	P2	2	4	3391	1205	33	2.99
W-M-Sc-Sc-L	23-Sep-01	Burntwood River	1	P2	3	4	5402	2824	28	2.34
								maximum =	33	2.99
								median =	24	2.84
								minimum =	20	2.34
W-M-Hc-L	23-Sep-01	Burntwood River	1	P1	5	4	2130	1322	23	2.81
W-M-Hc-L	23-Sep-01	Burntwood River	1	P1	8	4	1598	483	19	2.44
W-M-Bc-M	23-Sep-01	Burntwood River	1	P2	5	4	6011	2371	24	2.54

[1] Habitat Type:
E-M-Sc-Sc-L intermittently exposed, mainstem, soft silt/clay-based substrate, no plants, low water velocity
W-M-Sc-Sc-L wetted, mainstem, soft silt/clay-based substrate, no plants, low water velocity
W-M-Hc-L wetted, mainstem, hard silt/clay-based substrate, low water velocity
W-M-Bc-M wetted, mainstem, boulder/cobble substrate, medium water velocity

[2] number of replicates collected/site

[3] +/- 1 standard deviation

[4] number of individual taxa represented at each site

[5] Shannon-Weiner biodiversity index determined at each site

fell within the range observed for the W-M-Sc-Sc-L habitat type. Diversity at the one site characterized as intermittently exposed was the highest observed in Reach 2 (H' of 3.03).

Qualitative Community Assessment

A qualitative description of the benthic invertebrate community was obtained at one drift trap site immediately downstream of Wuskwatim Falls (DT1) (Figure 7-10) during late-June, 2001 (Table 7-25).

From June 23 to 25, there were 12 different invertebrate taxa observed. Amphipods and mysids (opossum shrimp) were the crustacean groups identified in the drift trap samples. Insects were represented by nine taxa and comprised the majority of drifting invertebrate groups. Drifting insect groups not observed in Ponar dredge samples from the study reach were Coleoptera (beetles), and Chaoboridae (phantom midges) larvae and pupae.

In late-July, drifting invertebrates were again collected at DT1 and at an additional site located immediately upstream of Taskinigup Falls (DT2) (Figure 7-10). Results of the analyzed samples are presented in Table 7-25.

From July 22 to 27 at DT1, 11 different invertebrate taxa were observed. Crustacean groups identified in the drift samples were amphipods, conchostracans (clam shrimp), and mysids. Insects were represented by six taxa and comprised the majority of drifting invertebrate groups. All insect groups in the drift trap samples were also observed in Ponar dredge samples from the study reach.

At DT2 during the same time period, 16 different taxa were observed. The crustacean groups found at DT1 were also present in DT2 samples and insects again comprised the majority (nine taxa) of taxa found. All insect groups present in the drift trap samples were also observed in Ponar dredge samples, with the exception of coleopterans and black flies.

Table 7-25. Drifting invertebrates found in Reach 2, 2001.

Study Reach	**Falls**														
Site	**DT1**			**DT1**						**DT2**					
Sample Date	**23-Jun-01**	**24-Jun-01**	**25-Jun-01**	**22-Jul-01**	**23-Jul-01**	**24-Jul-01**	**25-Jul-01**	**26-Jul-01**	**27-Jul-01**	**22-Jul-01**	**23-Jul-01**	**24-Jul-01**	**25-Jul-01**	**26-Jul-01**	**27-Jul-01**
Annelida															
Oligochaeta	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	√	-	-
Hirudinea	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Crustacea															
Ostracoda	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Amphipoda	√	√	√	√	-	n.s.	n.s.	√	√	-	-	n.s.	-	√	√
Conchostraca	-	-	-	-	-	n.s.	n.s.	√	√	√	√	n.s.	√	√	√
Mysidacea	√	√	√	-	-	n.s.	n.s.	√	√	√	√	n.s.	-	√	√
Decapoda	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Arachnida															
Hydracarina	-	-	√	-	-	n.s.	n.s.	√	-	√	-	n.s.	-	-	-
Insecta															
Megaloptera	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	√	-	-
Odonata															
Anisoptera	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Zygoptera	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Coleoptera	-	√	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	√	-	-
Hemiptera	-	√	√	-	-	n.s.	n.s.	-	-	√	√	n.s.	-	√	-
Ephemeroptera	√	√	√	-	√	n.s.	n.s.	√	√	-	√	n.s.	√	√	√
Trichoptera	√	√	√	-	√	n.s.	n.s.	√	√	√	√	n.s.	√	√	√
Plecoptera	√	√	√	-	√	n.s.	n.s.	-	√	-	-	n.s.	-	-	√

Table 7-25. (continued)

Study Reach	**Falls**														
Site	**DT1**			**DT1**						**DT2**					
Sample Date	**23-Jun-01**	**24-Jun-01**	**25-Jun-01**	**22-Jul-01**	**23-Jul-01**	**24-Jul-01**	**25-Jul-01**	**26-Jul-01**	**27-Jul-01**	**22-Jul-01**	**23-Jul-01**	**24-Jul-01**	**25-Jul-01**	**26-Jul-01**	**27-Jul-01**
Diptera															
Chironomidae															
larva	-	√	√	-	-	n.s.	n.s.	√	√	√	√	n.s.	√	√	√
pupa	√	√	√	√	-	n.s.	n.s.	√	√	√	√	n.s.	√	√	√
Ceratopogonidae	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Tipulidae	-	-	-	-	-	n.s.	n.s.	√	-	-	-	n.s.	-	-	-
Simuliidae															
larva	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	√	-	-
pupa	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Chaoboridae															
larva	√	√	√	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
pupa	√	√	√	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Mollusca															
Bivalvia															
Unionidae	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Sphaeriidae	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Gastropoda	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	√	-	√
Nematoda	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	√	-	-
Platyhelminthes	-	-	-	-	-	n.s.	n.s.	-	-	-	-	n.s.	-	-	-
Hydrozoa	-	-	-	-	-	n.s.	n.s.	-	√	-	-	n.s.	-	-	-
Total No. of Taxa	**8**	**11**	**11**	**2**	**3**	**n.s.**	**n.s.**	**9**	**9**	**7**	**7**	**n.s.**	**11**	**8**	**9**

√ taxa present in sample
n.s. not sampled

Reach 3

Habitat-Based Community Assessment

In 2001, a quantitative description of the benthic invertebrate community was obtained in 11 different riverine habitat types in Reach 3 (Table 7-26, North/South Consultants Inc. unpublished data). These habitat types were characterized as having no plants, but differed with respect to water level criteria, position in the river (i.e., in either backwater inlets or mainstem), bottom substrate type, and water velocity.

Mean total abundance of benthos in Reach 3 ranged from a low of 70 individuals/m^2 in habitat type W-M-Bc-M (wetted, mainstem, boulder/cobble substrate, medium water velocity) to a high of 4652 individuals/m^2 in E-M-Sc-Sc-L (intermittently exposed, mainstem, soft silt/clay-based substrate, low water velocity) (Figure 7-24). There was substantial variability in abundances within habitat types and among replicates from individual sites (North/South Consultants Inc. unpublished data). Abundances were substantially less in habitat types characterized as having either boulder/cobble or bedrock bottom substrates (range of 70 to 129 individuals/m^2). It is unlikely that the benthic invertebrate community associated with these bottom substrates was sampled effectively using the air-lift sampler, as the abundances in these habitat types was much reduced in comparison to what is known from other studies of coarse bottom substrates in Manitoba, and to results obtained for the Reach 2 habitat type characterized as having boulder/cobble substrate.

The E-B-Sc-Sc-L (intermittently exposed, backwater inlets, soft silt/clay-based substrate, no plants, low water velocity) and E-M-Sc-Sc-L habitat types were comparable except with respect to their position in the river. These two intermittently exposed habitat types were dominated by midges, mayflies, and fingernail clams; midges were most common in the backwater inlets (37 %) and fingernail clams in the mainstem (51 %) (Table 7-26). These shallow areas with soft silt/clay bottom sediments provide habitat for filter-feeding fingernail clams and a variety of insect larvae. Mayflies were most common in the remaining intermittently exposed habitat type, E-M-Bc-L (intermittently exposed, mainstem, boulder/cobble substrate, low water velocity).

Midges, followed by mayflies and fingernail clams, were most common in the W-B-Sc-Sc-L (wetted, backwater inlets, soft silt/clay-based substrate, no plants, low water velocity) habitat type, similar to the otherwise comparable intermittently exposed habitat type (Table 7-26). Fingernail clams were most common in the wetted habitat types in the

Table 7-26. Summary benthic invertebrate information for riverine habitat types in Reach 3, 2001.

Habitat Type [1]	Years Investigated	n [2]	Total Abundance (individuals/m^2)			Mean Percent Composition of Major Groups [3]								
			Mean	Min.	Max.	OLIGO	AMPH	CHIRON	CERATO	EPHEM	TRICH	GAST	SPHAER	OTHER
E-C-Sc-Sc-L	2001	12	3272	1130	6022	1.2	0.0	36.5	5.8	26.7	1.0	7.6	20.2	1.0
E-M-Sc-Sc-L	2001	8	4652	4348	4957	4.6	0.4	9.9	0.8	16.1	0.2	12.4	50.7	4.9
E-M-Bc-L	2001	12	96	31	227	27.0	5.4	0.0	0.0	32.4	2.7	13.5	8.1	10.8
W-C-Sc-Sc-L	2001	48	1726	598	6467	4.6	0.4	51.3	4.1	26.3	1.7	3.1	6.6	1.8
W-M-Sc-Sc-L	2001	48	2828	413	7935	7.1	0.7	10.9	1.9	5.7	1.9	5.6	61.6	4.6
W-M-Sc-Sc-M	2001	16	2679	2065	3348	2.2	0.0	9.1	1.2	5.2	12.4	8.1	58.6	3.1
W-M-Hc-L	2001	32	1455	587	3478	0.8	0.0	3.9	0.4	3.0	18.1	1.5	67.4	4.9
W-M-Hc-M	2001	12	1283	283	2674	3.7	0.0	17.2	0.6	1.7	15.3	1.4	54.8	5.4
W-M-Bc-L	2001	28	129	0	383	3.4	0.0	1.7	0.9	24.1	6.9	4.3	11.2	47.4 [4]
W-M-Bc-M	2001	4	70	-	-	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0	66.7 [5]
W-M-Br-L	2001	16	86	8	258	15.9	0.0	9.1	0.0	52.3	4.5	2.3	0.0	15.9

[1] Habitat Type:
- E-B-Sc-Sc-L intermittently exposed, backwater inlets, soft silt/clay-based substrate, no plants, low water velocity
- E-M-Sc-Sc-L intermittently exposed, mainstem, soft silt/clay-based substrate, no plants, low water velocity
- E-M-Bc-L intermittently exposed, mainstem, boulder/cobble substrate, low water velocity
- W-B-Sc-Sc-L wetted, backwater inlets, soft silt/clay-based substrate, no plants, low water velocity
- W-M-Sc-Sc-L wetted, mainstem, soft silt/clay-based substrate, no plants, low water velocity
- W-M-Sc-Sc-M wetted, mainstem, soft silt/clay-based substrate, no plants, medium water velocity
- W-M-Hc-L wetted, mainstem, hard silt/clay-based substrate, low water velocity
- W-M-Hc-M wetted, mainstem, hard silt/clay-based substrate, medium water velocity
- W-M-Bc-L wetted, mainstem, boulder/cobble substrate, low water velocity
- W-M-Bc-M wetted, mainstem, boulder/cobble substrate, medium water velocity
- W-M-Br-L wetted, mainstem, bedrock substrate, low water velocity

[2] number of replicates collected/habitat type

[3] Major Groups:
- OLIGO Oligochaeta
- AMPH Amphipoda
- CHIRON Chironomidae
- CERATO Ceratopogonidae
- EPHEM Ephemeroptera
- TRICH Trichoptera
- GAST Gastropoda
- SPHAER Sphaeriidae
- OTHER Other Groups

[4] comprised primarily of the group Hydrozoa (40.5 %)

[5] comprised of the groups Hydrozoa (55.6 %) and Platyhelminthes (11.1 %)

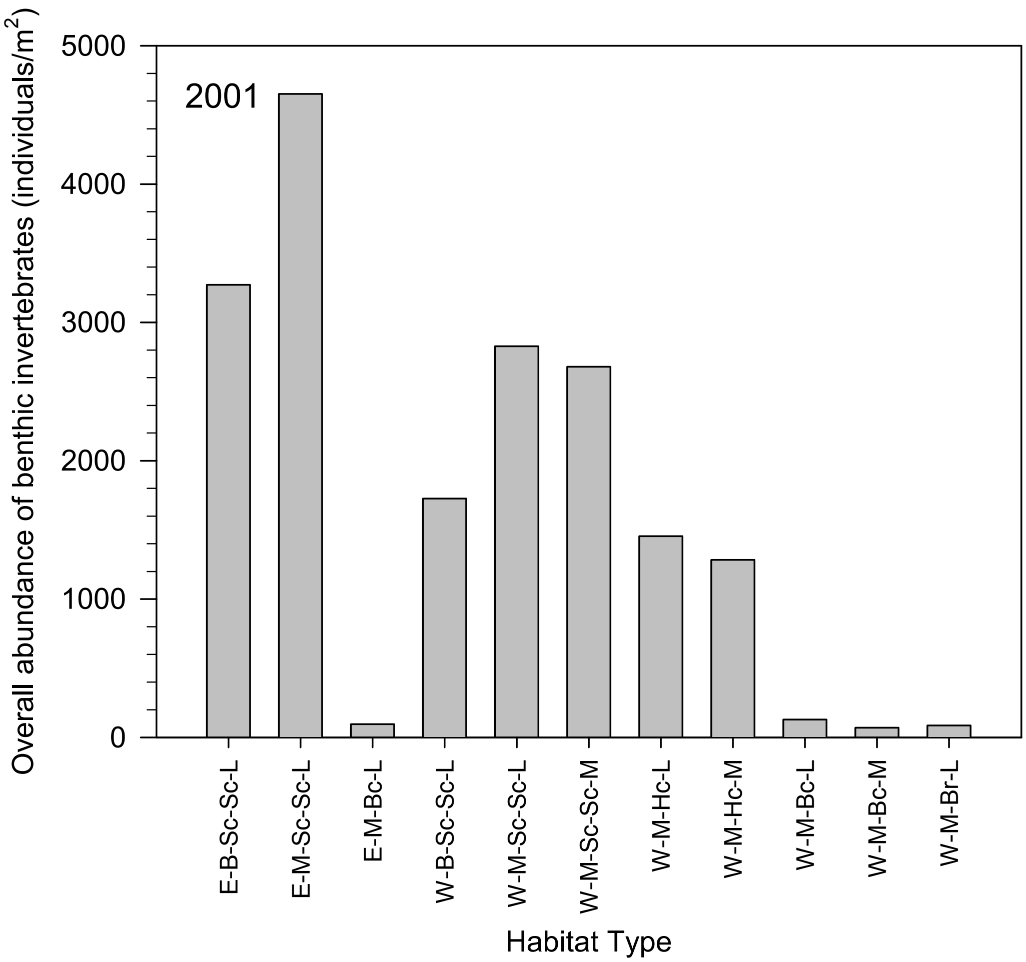


Figure 7-24. Overall abundance of benthic invertebrates in Reach 3, 2001.

mainstem with soft silt/clay-based bottom sediments and no plants, and hard silt/clay-based bottom sediments, regardless of water velocity.

The W-M-Bc-L (wetted, mainstem, boulder/cobble substrate, low water velocity), W-M-Bc-M (wetted, mainstem, boulder/cobble substrate, medium water velocity), and W-M-Br-L (wetted, mainstem, bedrock substrate, low water velocity) habitat types were comparable except with respect to either substrate type and/or water velocity. Hydrozoa and mayflies were most common on the boulder/cobble substrate regardless of water velocity; mayflies alone were most common on bedrock (52 %) (Table 7-26).

A sub-set of benthic invertebrate samples collected in September, 2001, were further identified to genus and/or species for selected aquatic habitat types in Reach 3. A list of benthic invertebrate taxa identified in reaches 1, 2, and 3 is presented in Volume 5, Appendix 8.

Species richness of benthos in Reach 3 ranged from one taxon in habitat type W-M-Br-L to 29 taxa in habitat type W-M-Sc-Sc-L (Table 7-27). In general, species richness (range of 1 to 10 taxa) and biodiversity (range of 0.59 to 2.47) was reduced in habitat types characterized as having either boulder/cobble (E-M-Bc-L and W-M-Bc-L) or bedrock (W-M-Br-L) bottom substrates. As discussed above, it is unlikely that the benthic invertebrate community was sampled effectively using the air-lift sampler, as the species richness and biodiversity in these habitat types was reduced in comparison to what is known from other studies of coarse bottom substrates in Manitoba, and to results obtained for the Reach 2 habitat type characterized as having boulder/cobble substrate.

The W-B-Sc-Sc-L habitat type had a median H’ of 2.67, a minimum of 2.41, and a maximum of 2.93 (Table 7-27). Biodiversity for the comparable habitat type in the intermittently exposed zone (E-B-Sc-Sc-L) was 2.81, within the range observed in the wetted zone. Corresponding wetted habitat in the mainstem (W-M-Sc-Sc-L) had a slightly lower median H’ (2.64), but had the highest maximum H’ value (3.02) in Reach 3. Wetted mainstem habitat with hard silt/clay-based bottom sediments and low water velocity (W-M-Hc-L) had a median biodiversity (H’) of 2.72, slightly higher than in like habitat in the backwater inlets and mainstem with soft silt/clay-based sediments, and in comparable mainstem habitat with medium water velocity (W-M-Hc-M).

Qualitative Community Assessment

A qualitative description of the benthic invertebrate community was obtained during late-June, 2001, at one drift trap site immediately downstream of Taskinigup Falls (DT3) (Figure 7-10). Results of the analyzed samples are presented in Table 7-28.

On June 24 and 25, there were 16 different invertebrate taxa observed. Amphipods and mysids (opossum shrimp) were the crustacean groups present in the drift trap samples. Insects comprised the majority (10 taxa) of drifting invertebrate groups. All insect groups in the drift trap samples were also observed in Ponar dredge samples, but, fewer taxa were found in the air-lift samples from the study reach.

In late-July, drifting invertebrates were again collected at DT3. Results of the analyzed samples are presented in Table 7-28.

Table 7-27. Biodiversity of benthic invertebrates in samples from Reach 3, by habitat type, 2001.

Habitat Type [1]	Date Sampled	Waterbody	Section	Transect	Site	n [2]	Total Abundance (individuals/m²) Mean	STD [3]	Species Richness [4]	Biodiversity Index (H') [5]
E-B-Sc-Sc-L	14-Sep-01	Burntwood River	2	P1	1	4	6304	1739	23	2.81
E-M-Bc-L	19-Sep-01	Burntwood River	2	B1	1	4	43	87	4	1.95
W-B-Sc-Sc-L	14-Sep-01	Burntwood River	2	P1	2	4	3337	833	21	2.67
W-B-Sc-Sc-L	14-Sep-01	Burntwood River	2	P1	3	4	739	427	12	2.41
W-B-Sc-Sc-L	25-Sep-01	Burntwood River	3	P1	1	4	3130	1747	26	2.64
W-B-Sc-Sc-L	25-Sep-01	Burntwood River	3	P1	2	4	1109	573	15	2.77
W-B-Sc-Sc-L	25-Sep-01	Burntwood River	3	P1	3	4	1261	128	20	2.93
								maximum =	26	2.93
								median =	20	2.67
								minimum =	12	2.41
W-M-Sc-Sc-L	18-Sep-01	Burntwood River	2	P3	1	4	500	285	9	2.02
W-M-Sc-Sc-L	18-Sep-01	Burntwood River	2	P3	2	4	576	431	13	2.54
W-M-Sc-Sc-L	18-Sep-01	Burntwood River	2	P3	3	4	370	285	9	2.29
W-M-Sc-Sc-L	25-Sep-01	Burntwood River	4	P2	1	4	2576	486	29	3.02
W-M-Sc-Sc-L	25-Sep-01	Burntwood River	4	P2	2	4	2163	500	22	2.84
W-M-Sc-Sc-L	25-Sep-01	Burntwood River	4	P2	3	4	6120	2526	27	2.73
								maximum =	29	3.02
								median =	18	2.64
								minimum =	9	2.02
W-M-Hc-L	14-Sep-01	Burntwood River	2	P1	5	4	1891	1435	21	2.81
W-M-Hc-L	18-Sep-01	Burntwood River	2	P3	5	4	598	182	12	2.71
W-M-Hc-L	25-Sep-01	Burntwood River	3	P1	5	4	1522	312	16	2.73
W-M-Hc-L	26-Sep-01	Burntwood River	4	P2	5	4	3370	2637	22	2.70
								maximum =	22	2.81
								median =	19	2.72
								minimum =	12	2.70
W-M-Hc-M	18-Sep-01	Burntwood River	2	P3	8	4	261	177	10	2.59
W-M-Bc-L	19-Sep-01	Burntwood River	2	B1	2	4	272	345	10	2.47
W-M-Bc-L	19-Sep-01	Burntwood River	2	B1	3	4	54	82	4	1.90
W-M-Br-L	24-Sep-01	Burntwood River	3	B1	1	4	11	22	1	0.59
W-M-Br-L	24-Sep-01	Burntwood River	3	B1	2	4	43	87	2	1.14
W-M-Br-L	24-Sep-01	Burntwood River	3	B1	3	4	65	56	5	2.34

[1] Habitat Type:
E-B-Sc-Sc-L intermittently exposed, backwater inlets, soft silt/clay-based substrate, no plants, low water velocity
E-M-Bc-L intermittently exposed, mainstem, boulder/cobble substrate, low water velocity
W-B-Sc-Sc-L wetted, backwater inlets, soft silt/clay-based substrate, no plants, low water velocity
W-M-Sc-Sc-L wetted, mainstem, soft silt/clay-based substrate, no plants, low water velocity
W-M-Hc-L wetted, mainstem, hard silt/clay-based substrate, low water velocity
W-M-Hc-M wetted, mainstem, hard silt/clay-based substrate, medium water velocity
W-M-Bc-L wetted, mainstem, boulder/cobble substrate, low water velocity
W-M-Br-L wetted, mainstem, bedrock substrate, low water velocity

[2] number of replicates collected/site
[3] +/- 1 standard deviation
[4] number of individual taxa represented at each site
[5] Shannon-Weiner biodiversity index determined at each site

Table 7-28. Drifting invertebrates found in Reach 3, 2001.

Study Reach	Burntwood								
Site	DT3								
Sample Date	23-Jun-01	24-Jun-01	25-Jun-01	22-Jul-01	23-Jul-01	24-Jul-01	25-Jul-01	26-Jul-01	27-Jul-01
Annelida									
Oligochaeta	n.s.	-	√	-	n.s.	n.s.	-	-	-
Hirudinea	n.s.	√	-	-	n.s.	n.s.	-	-	√
Crustacea									
Ostracoda	n.s.	-	-	-	n.s.	n.s.	-	-	-
Amphipoda	n.s.	√	√	-	n.s.	n.s.	√	√	√
Conchostraca	n.s.	-	-	-	n.s.	n.s.	√	√	√
Mysidacea	n.s.	-	√	-	n.s.	n.s.	√	√	√
Decapoda	n.s.	-	-	-	n.s.	n.s.	-	-	-
Arachnida									
Hydracarina	n.s.	√	√	-	n.s.	n.s.	-	-	-
Insecta									
Megaloptera	n.s.	-	-	-	n.s.	n.s.	-	-	-
Odonata									
Anisoptera	n.s.	-	-	-	n.s.	n.s.	-	-	-
Zygoptera	n.s.	-	-	-	n.s.	n.s.	-	-	-
Coleoptera	n.s.	√	-	-	-	n.s.	-	-	-
Hemiptera	n.s.	√	-	-	n.s.	n.s.	-	√	-
Ephemeroptera	n.s.	√	√	-	n.s.	n.s.	√	√	√
Trichoptera	n.s.	√	√	√	n.s.	n.s.	√	√	√
Plecoptera	n.s.	√	√	-	n.s.	n.s.	-	-	√
Diptera									
Chironomidae									
larva	n.s.	√	√	√	n.s.	n.s.	√	√	√
pupa	n.s.	√	√	-	n.s.	n.s.	√	√	√
Ceratopogonidae	n.s.	-	-	-	n.s.	n.s.	-	-	-

Table 7-28. (continued)

Study Reach	**Burntwood**								
Site	**DT3**								
Sample Date	**23-Jun-01**	**24-Jun-01**	**25-Jun-01**	**22-Jul-01**	**23-Jul-01**	**24-Jul-01**	**25-Jul-01**	**26-Jul-01**	**27-Jul-01**
Tipulidae	n.s.	-	√		n.s.	n.s.	-	-	-
Simuliidae									
larva	n.s.	-	-	-	n.s.	n.s.	√	-	-
pupa	n.s.	-	-	-	n.s.	n.s.	√	-	√
Chaoboridae									
larva	n.s.	√	√	-	n.s.	n.s.	-	-	-
pupa	n.s.	√	√	-	n.s.	n.s.	-	-	-
Mollusca									
Bivalvia									
Unionidae	n.s.	-	-	-	n.s.	n.s.	-	-	-
Sphaeriidae	n.s.	-	-	-	n.s.	n.s.	√	-	√
Gastropoda	n.s.	-	√	-	n.s.	n.s.	-	-	-
Nematoda	n.s.	-	-	-	n.s.	n.s.	√	-	-
Platyhelminthes	n.s.	-	-	-	n.s.	n.s.	-	-	-
Hydrozoa	n.s.	-	-	-	n.s.	n.s.	-	-	-
Total No. of Taxa	**n.s.**	**12**	**13**	**2**	**n.s.**	**n.s.**	**11**	**8**	**11**

√ taxa present in sample
n.s. not sampled

From July 22 to 27, there were 14 different invertebrate taxa observed. Crustacean groups present in the drift samples were amphipods, conchostracans, and mysids. Insects comprised the majority (eight taxa) of drifting invertebrate groups. All insect groups in the drift trap samples were also observed in Ponar dredge samples, with the exception of black flies. As in late-June, fewer taxa were found in the air-lift samples from the study reach.

Reach 4

Habitat-Based Community Assessment

A qualitative description of the benthic invertebrate community was obtained in five different lacustrine habitat types in Reach 4 during 2000 and 2001 (Table 7-29, North/South Consultants Inc. unpublished data).

Mean total abundance of benthos in Reach 4 ranged from 2409 individuals/m^2 in habitat type NS-Sc-Sc (nearshore, soft silt/clay-based substrate, no plants) to 9106 individuals/m^2 in OS-Sc-Sc (offshore, soft silt/clay-based substrate, no plants) (Table 7-29). There was considerable variability in abundances within habitat types and among replicates from individual sites (North/South Consultants Inc. unpublished data). Sphaeriidae (fingernail clams) was the most common taxon in the majority of habitat types (44 to 76 % of the community), with the exception of the NS-Sc-Rv (nearshore, soft silt/clay-based substrate, rooted vascular plants) and NS-Ft-Rv (nearshore, flooded terrestrial substrate, rooted vascular plants) habitat types (Table 7-29). Oligochaeta (aquatic earthworms) were most common (54 %) in the nearshore zone with soft silt/clay sediments and aquatic plants, whereas chironomids (midges) were prevalent (60 %) in areas with flooded terrestrial substrate and aquatic plants. Other insects were relatively less important in the benthos, with the exception of Trichoptera (caddisflies), which comprised 27 % of the community in the offshore zone with hard silt/clay-based bottom sediments (OS-Hc).

In 2000, overall abundance ranged from 1451 individuals/m^2 to 3663 individuals/m^2 in the nearshore zone, with higher abundances recorded in areas having rooted vascular plants (Figure 7-25). In the offshore zone, total abundance in the habitat type with hard silt/clay-based bottom sediments was considerably lower than in habitat with soft silt/clay-based sediments and no plants. Overall abundances in 2001 were considerably higher in all habitat types and followed a different pattern (Figure 7-25). The lowest abundance was again recorded in the NS-Sc-Sc habitat type, but overall abundances in

Table 7-29. Summary benthic invertebrate information for riverine habitat types in Reach 4, 2000-2001.

Habitat Type [1]	Years Investigated	n [2]	Total Abundance (individuals/m^2)			Mean Percent Composition of Major Groups [3]								
			Mean	Min.	Max.	OLIGO	AMPH	CHIRON	CERATO	EPHEM	TRICH	GAST	SPHAER	OTHER
NS-Sc-Sc	2000, 2001	48	2409	141	9837	9.6	7.5	10.4	1.8	7.8	2.1	12.9	43.8	4.2
NS-Sc-Rv	2000, 2001	8	5125	3663	6587	53.7	2.3	7.4	5.3	1.2	0.3	5.5	2.3	22.0
NS-Ft-Rv	2000, 2001	8	6467	2489	10446	8.1	8.6	59.8	5.4	6.8	1.5	2.9	3.9	3.0
OS-Hc	2000, 2001	12	7959	1717	12272	0.6	0.1	1.5	0.4	2.1	26.5	1.0	65.7	2.0
OS-Sc-Sc	2000, 2001	16	9106	5348	11663	0.5	0.1	1.6	0.2	5.1	4.6	3.0	76.1	8.7

[1] Habitat Type:
NS-Sc-Sc nearshore, soft silt/clay-based substrate, no plants
NS-Sc-Rv nearshrore, soft silt/clay-based substrate, rooted vascular plants
NS-Ft-Rv nearshore, flooded terrestrial substrate, rooted vascular plants
OS-Hc offshore, hard silt/clay-based substrate
OS-Sc-Sc offshore, soft silt/clay-based substrate, no plants

[2] number of replicates collected/habitat type

[3] Major Groups:
OLIGO Oligochaeta
AMPH Amphipoda
CHIRON Chironomidae
CERATO Ceratopogonidae
EPHEM Ephemeroptera
TRICH Trichoptera
GAST Gastropoda
SPHAER Sphaeriidae
OTHER Other Groups

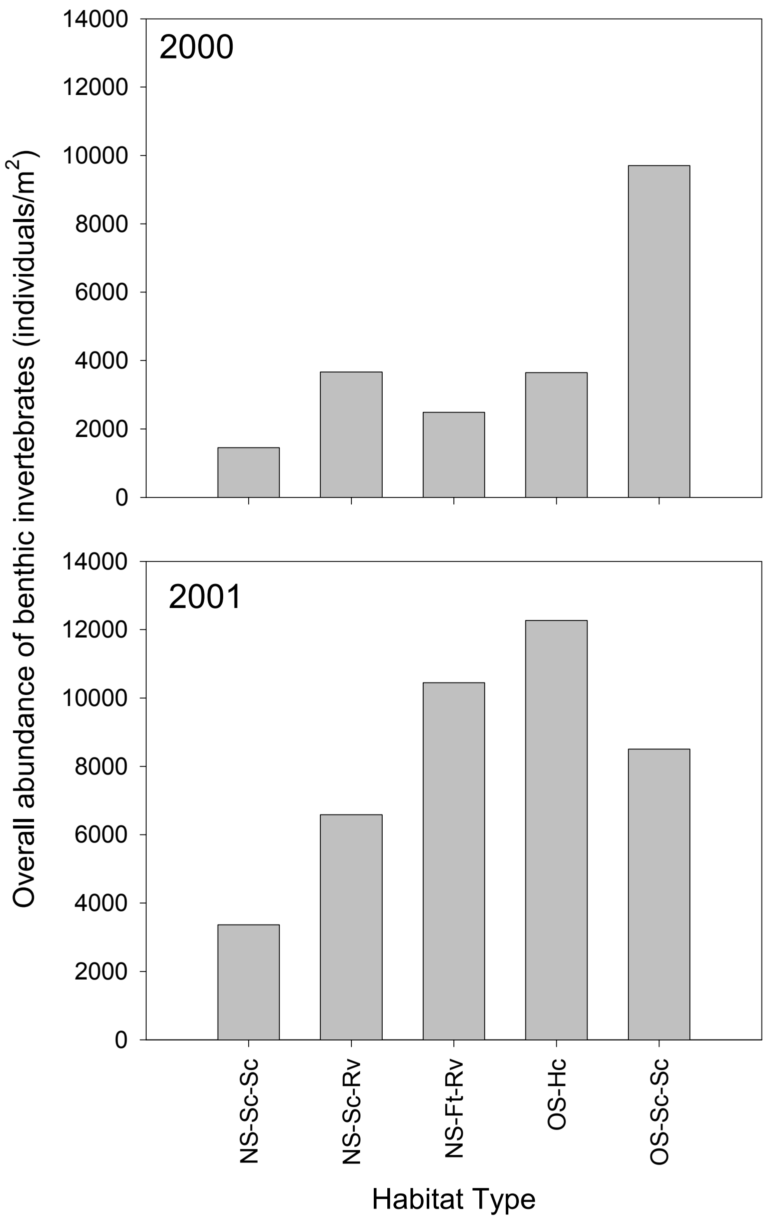


Figure 7-25. Overall abundance of benthic invertebrates in Reach 4, 2000-2001.

the NS-Ft-Rv and OS-Hc habitat types had increased dramatically, and the highest abundance was recorded in the habitat type with hard silt/clay-based bottom sediments (12272 individuals/m^2).

The relative abundance of certain taxa was determined for selected aquatic habitat types in reaches 1, 2, and 3 to provide an indication of the general aquatic habitat preferences of these taxa, which can be extended to comparable lacustrine habitat types in Reach 4 (Table 7-30).

Table 7-30. General aquatic habitat preferences of selected benthic invertebrate taxa in samples from reaches 1, 2, and 3, 2001. Refer to Volume 5, Appendix 8 for taxonomic classification.

General Preference	Fine Sediments [1]	Coarse Sediments [2]	Rooted Vascular Plants [3]	Shallower Water Depth Detritus Rooted Vascular Plants [4]	Deeper Water Depth Detritus [5]
	Pisidium spp. *Sphaerium* spp. *Caenis* spp. *Ephemera simulans* *Hexagenia limbata* *Hexagenia rigida* Chironomidae	*Heptagenia flavascens* *Stenacron interpuctatum* *Stenonema* spp. *Isoperla transmarina* *Cheumatopsyche* spp. *Hydropsyche* spp. *Potomyia flava*	*Callibaetis* spp. *Ophiogomphus* spp. *Lestes* spp. *Neureclipsis* spp. *Polycentropus* spp.	*Hyallela azteca* *Gammarus lacustris*	*Diporeia brevicornis*

[1] taxa generally prefer fine bottom sediments such as silt/clay; taxa present may also be representative of heterogeneous bottom sediments (e.g., silt/clay, boulder/cobble mixture)

[2] taxa generally prefer coarse bottom sediments such as boulder/cobble; typically found in waters with some flow

[3] taxa generally prefer rooted vascular plants; taxa associate with plants either as grazers, predators, or from which to construct filtering nets for food collection

[4] taxa generally prefer relatively shallower water depths such as intermittently exposed and nearshore areas; taxa are shredders/grazers and/or scavenging omnivores often found associated with aquatic plants

[5] taxa generally prefer relatively deeper water depths such as nearshore and offshore areas; taxa are detritivores

Associations of the Sphaeriidae (fingernail clams), Amphipoda (scuds), and select insect taxa with certain habitat types were generalized (Table 7-30). The fingernail clam genera *Pisidium* and *Sphaerium* were typically most abundant and diverse in habitats with fine sediments (i.e., soft silt/clay-based) found in Wuskwatim Lake and the Burntwood River (Table 7-30, Volume 5, Appendix 8). The amphipod *Gammarus lacustris* was found in association with shallow water depths (less than 2.0 m) and with either rooted vascular plants or flooded terrestrial substrates in Wuskwatim Brook (Table 7-30, Volume 5, Appendix 8). The amphipod *Hyallela azteca* was also a shallow water (less than 3.0 m) species, while *Diporeia brevicornis*, a glacial relict amphipod species, was generally associated with deeper water (greater than 3.0 m), presumably due to a preference for colder water temperatures. Burrowing mayflies (*Hexagenia* spp. and *Ephemera simulans*) were absent at the sites further investigated in Wuskwatim Brook (Volume 5, Appendix 8), as these sites were within or adjacent to flooded terrestrial substrates, which likely did not have suitable soft silt/clay-based sediments required by these species for burrowing (Table 7-30). These species occurred in Wuskwatim Lake and the Burntwood River in relative abundances and proportions typical of other lakes and large river systems in Manitoba. Species typical of coarse sediments (i.e., boulder/cobble and bedrock), such as stoneflies (e.g., *Isoperla transmarine*) and filter-feeding caddisflies (e.g., *Hydropsyche* spp., *Cheumatopsyche* spp., Heptageniidae) were most common at those sites on the Burntwood River classified as such (Table 7-30, Volume 5, Appendix 8). It is unlikely that the benthic invertebrate community associated with these bottom substrates was sampled effectively using the air-lift sampler, as abundances in these habitat types were much reduced in comparison to what is known from other studies of coarse bottom substrates in Manitoba. Insect taxa associated with rooted vascular plants are either grazers (e.g., *Callibaetis* spp.), predators (e.g., Odonata [*Ophiogomphus* spp., *Lestes* spp.]), or use the plants as a structure from which to construct filtering nets for food collection (e.g., Polycentropodidae [*Neureclipsis* spp., *Polycentropus* spp.]) (Table 7-30).

With a few exceptions (e.g., habitat type W-M-Br-L in Reach 3), the majority of habitat types investigated could be considered representative of relatively healthy and diverse aquatic habitat. Despite further taxonomic classification of only 2001 data, there is an extensive list of taxa identified in reaches 1, 2, and 3. Taxa expected to be observed in intermittently exposed, nearshore, and offshore zones were present, and their relative proportions were as in other waterbodies. At some sites, the taxa present were representative of a heterogeneous substrate (a mixture of substrate types). The co-occurrence of *Hexagenia*, *Ephemera*, *Caenis*, and *Polycentropus* species at a site is typical of a mixture of silt/clay-based, and gravel and cobble substrates, such as those found in the transitional nearshore zone of Lake Winnipeg (MB) (pers. comm. D.G.

Cobb). This can make a clear, single characterization of a site with respect to substrata type difficult, as they are complex in nature. Riverine sites with coarse substrates (hard silt/clay-based, boulder/cobble, bedrock) were more difficult to sample effectively; however, where sites were sampled effectively, they were well represented by taxa typically associated with those substrata types.

Stream Crossings

The benthic invertebrate community in streams crossed by the access road was not investigated. Water velocity and temperature (including effects of season), dissolved substances in the water, and type of bottom material (including aquatic plants) are involved in regulating the occurrence and distribution of benthic invertebrates in streams (Hynes 1970). It is likely that diversity and/or abundance of benthos in the eight streams are lower in comparison to the four reaches on the Burntwood River. The smaller extent of wetted area could lower the availability of aquatic habitats and place limitations on the types of benthic invertebrates that could occupy the streams (i.e., fewer taxa present).

7.4 IMPACT ASSESSMENT AND MITIGATION

The majority of impacts to lower trophic levels during construction are related to indirect effects arising from a change in water quality (Section 5.0). Operation-related impacts that are assessed include: flooding of the terrestrial environment; conversion of intermittently exposed to more wetted habitat; changes to water levels and flows (water regime); erosion and sedimentation; and road maintenance activities. Summaries of predicted responses of lower trophic communities to changes resulting from the operation of the Generation Project are presented in Tables 7-31 (Reach 1), 7-32 (Reach 2), 7-33 (Reach 3), 7-34 (Reach 4), and 7-35 (Stream Crossings).

7.4.1 Construction

The majority of impacts to lower trophic levels during construction will be associated with effects to water and sediment quality (Section 5.0), and many will be associated with episodic activities (e.g., cofferdam removal, discharge of sewage lagoon). All construction related activities that may affect water and sediment quality are located downstream of Reach 1. The duration and magnitude of impacts is not expected to have a substantial effect on lower trophic levels, though there may be some temporary effects. The downstream movement of some benthic invertebrates and the loss of other individuals exposed to a concentrated suspended sediment plume may occur over a number of weeks during construction. However, benthic invertebrates would likely recolonize any affected areas by the following growing season.

Table 7-31. Summary of predicted responses of lower trophic levels in Reach 1 to chemical and physical changes resulting from the operation of the Generation Project.

Impact	Predicted Responses			
	Phytoplankton	**Attached Algae and Rooted Aquatic Plants**	**Zooplankton**	**Benthic Invertebrates**
Increase in TSS/Turbidity	Too small to measure	Too small to measure	Too small to measure	Small decrease in abundance and distribution in Wuskwatim Lake main
Increase in Nutrient Concentrations	Small increase in production in tributary waterbodies	Too small to measure	No response	No response
Decrease in [DO]	No response	No response	Too small to measure	Too small to measure
Increase in Water Depth and Volume	Small increase in production in tributary waterbodies	Small increase in abundance of plants in Wuskwatim Lake main; moderate[1] increase in tributary waterbodies	Small increase in production in tributary waterbodies	Small increase in abundance and distribution in Wuskwatim Lake main; moderate increase in tributary waterbodies
Stabilization of Water Levels	Small increase in production in tributary waterbodies	Small increase in abundance of plants in Wuskwatim Lake main; moderate increase in tributary waterbodies	Small increase in production in tributary waterbodies	Small increase in abundance and distribution in Wuskwatim Lake main; moderate increase in tributary waterbodies
Decrease in Water Velocity	Too small to measure	Too small to measure	Too small to measure	Too small to measure
Increase in Erosion/Sedimentation	No response	Too small to measure	No response	Small decrease in abundance and distribution in Wuskwatim Lake main
Water Temperature	N/A	N/A	N/A	N/A
Ice Processes	N/A	N/A	N/A	N/A
Increase in Phytoplankton	N/A	N/A	Too small to measure	No response
Increase in Rooted Aquatic Plants	N/A	N/A	No response	Too small to measure
NET RESPONSE	Small increase in production in tributary waterbodies	Small increase in abundance of plants in Wuskwatim Lake main; moderate increase in tributary waterbodies	Small increase in production in tributary waterbodies	Small increase in abundance and distribution in Wuskwatim Lake main; moderate increase in tributary waterbodies

[1] moderate impacts are defined as those which would require a well planned sampling program, using conventional instrumentation and normal statistical procedures, to detect predicted changes
N/A not applicable

Table 7-32. Summary of predicted responses of lower trophic levels in Reach 2 to chemical and physical changes resulting from the operation of the Generation Project.

Impact	Predicted Responses			
	Phytoplankton	**Attached Algae and Rooted Aquatic Plants**	**Zooplankton**	**Benthic Invertebrates**
Accidental Spills	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP
Increase in TSS/Turbidity	Too small to measure	Too small to measure	Too small to measure	Small decrease in abundance and distribution
Increase in Nutrient Concentrations	Too small to measure	Too small to measure	No response	No response
Direct Loss of Aquatic Habitat	No response	Moderate[1] decrease in abundance and distribution (north bay)	No response	Moderate decrease in abundance and distribution (north bay)
Increase in Water Depth and Volume (Gain of Aquatic Habitat)	Too small to measure	Growth of rooted aquatic plant bed in the south bay	Too small to measure	Colonization of the south bay; moderate increase in abundance and distribution within reach
Stabilization of Water Levels	Too small to measure	Growth of rooted aquatic plant bed in the south bay	Too small to measure	Colonization of the south bay; moderate increase in abundance and distribution within reach
Decrease in Water Velocity	Too small to measure	Small increase in abundance and distribution	Too small to measure	Change in species composition
Increase in Erosion/Sedimentation	No response	Too small to measure	No response	Too small to measure
Water Temperature	N/A	N/A	N/A	N/A
Ice Processes	N/A	N/A	N/A	N/A
Increase in Phytoplankton	N/A	N/A	Too small to measure	No response
Decrease in Rooted Aquatic Plants	N/A	N/A	No response	Small decrease in abundance and distribution
NET RESPONSE	Too small to measure	Moderate decrease in abundance and distribution; growth of rooted aquatic plant bed in the south bay	Too small to measure	Colonization of the south bay; moderate increase in abundance and distribution; change in species composition

[1] moderate impacts are defined as those which would require a well planned sampling program, using conventional instrumentation and normal statistical procedures, to detect predicted changes
N/A not applicable

Table 7-33. Summary of predicted responses of lower trophic levels in Reach 3 to chemical and physical changes resulting from the operation of the Generation Project.

Impact	**Predicted Responses**			
	Phytoplankton	**Attached Algae and Rooted Aquatic Plants**	**Zooplankton**	**Benthic Invertebrates**
Accidental Spills	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP
Fluctuation in Water Levels	No response	Moderate[1] decrease in abundance and distribution	No response	Moderate decrease in abundance and distribution
Fluctuation in Water Velocities	No response	Too small to measure	No response	Change in species composition
Increase in Sedimentation	No response	Too small to measure	No response	Too small to measure
Water Temperature	N/A	N/A	N/A	N/A
Ice Processes	N/A	N/A	N/A	N/A
Changes in Rooted Aquatic Plants	N/A	N/A	N/A	Small decrease in abundance and distribution
NET RESPONSE	No response	Moderate decrease in abundance and distribution	No response	Moderate decrease in abundance and distribution**;** change in species composition

[1] moderate impacts are defined as those which would require a well planned sampling program, using conventional instrumentation and normal statistical procedures, to detect predicted changes

N/A not applicable

Table 7-34. Summary of predicted responses of lower trophic levels in Reach 4 to chemical and physical changes resulting from the operation of the Generation Project.

Impact	**Predicted Responses**			
	Phytoplankton	**Attached Algae and Rooted Aquatic Plants**	**Zooplankton**	**Benthic Invertebrates**
Accidental Spills	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP
Fluctuation in Water Levels	No response	Moderate[1] decrease in abundance and distribution	No response	Moderate decrease in abundance and distribution
Water Velocity	No response	No response	No response	No response
Sedimentation	No response	No response	No response	No response
Water Temperature	N/A	N/A	N/A	N/A
Ice Processes	N/A	N/A	N/A	N/A
Changes in Rooted Aquatic Plants	N/A	N/A	N/A	Small decrease in abundance and distribution
NET RESPONSE	No response	Moderate decrease in abundance and distribution	No response	Moderate decrease in abundance and distribution

[1] moderate impacts are defined as those which would require a well planned sampling program, using conventional instrumentation and normal statistical procedures, to detect predicted changes

N/A not applicable

Table 7-35. Summary of predicted responses of lower trophic levels in streams to chemical and physical changes resulting from the construction and maintenance of the access road.

Impact	Predicted Responses			
	Phytoplankton	**Attached Algae and Rooted Aquatic Plants**	**Zooplankton**	**Benthic Invertebrates**
Accidental Spills	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP	Control measures in Volume 3 and to be described in the EnvPP
Increase in TSS/Turbidity	No response	Too small to measure	No response	Too small to measure
Increase in Nutrient Concentrations	No response	Too small to measure	No response	Too small to measure
Increase in Metal Concentrations	No response	Too small to measure	No response	Too small to measure
Direct Loss of Aquatic Habitat	No response	Small decrease due to road and culvert footprint	No response	Small decrease due to road and culvert footprint
Decrease in Water Depth	N/A	N/A	N/A	N/A
Increase in Water Velocity	No response	No response	No response	No response
Increase in Sedimentation	N/A	Too small to measure	N/A	Too small to measure
Water Temperature	N/A	N/A	N/A	N/A
Ice Processes	N/A	N/A	N/A	N/A
Decrease in Rooted Aquatic Plants	N/A	N/A	N/A	Small decrease due to road and culvert footprint
NET RESPONSE	No response	Small decrease due to road and culvert footprint	No response	Small decrease due to road and culvert footprint

N/A not applicable

Within Reach 2, a small additional amount of aquatic habitat will be impacted by cofferdam construction, but the majority of habitat affected during construction is also affected by the permanent works (Section 7.4.2).

7.4.2 Operation

It should be noted that changes to the water regime and flooding, two impacts discussed under the operation of the Generation Project, actually begin during the construction phase; however, as these changes last for the lifespan of the Project (rather than just the construction period) they are discussed under operation. Impacts resulting from accidental oil, fuel, or hazardous waste spills into the aquatic environment in the vicinity of the Generation Project during operation will be minimized due to control measures outlined in the Project Description (Volume 3) and to be described in the EnvPP.

7.4.2.1 Responses of Phytoplankton

Light availability is believed to be the primary factor limiting phytoplankton production in Reach 1. Existing relatively low water retention times for Wuskwatim Lake main and the Cranberry Lakes likely also limits the net growth of phytoplankton. The anticipated small increase post-Project in retention time for these two waterbodies is not expected to be sufficient to result in an increase in phytoplankton biomass or alteration in phytoplankton species composition. However, there may be a small increase in the total amount of phytoplankton in tributary waterbodies (e.g., Sesep Lake, Wuskwatim Lake south, Wuskwatim Brook), as these areas will experience relatively greater effects from increases in retention times and water volumes, and slight nutrient enrichment. Based on anticipated impacts for mainstem waterbodies in Reach 1, downstream reaches should not experience any notable changes in phytoplankton biomass due to differences in inputs.

Phytoplankton tend to be relatively unimportant in small streams as these planktonic organisms cannot maintain positive net growth rates due to a variety of reasons, including downstream losses, and the algae in the water column are typically benthic species sloughed from the stream bed.

7.4.2.2 Responses of Attached Algae and Rooted Aquatic Plants

Reach 1: Wuskwatim

The spatial extent of the area in Reach 1 where rooted submergent aquatic plants presently occur is not expected to change post-Project, as growing conditions (i.e., extent of euphotic zone, bottom substrata type) will not be noticeably changed (Figure 7-6). The increased water depth and reduction in the frequency of water level fluctuations post-

Project will provide improved growing conditions for plants where they occur now. Ice scour presently occurs down to an elevation of about 231.5 m in some years, hence aquatic plants experience variable growing conditions among years, which likely contributes to their sparse, patchy distribution. Increased water depth and reduced frequency of water level fluctuations post-Project will substantially decrease the extent of the shallow water area that experiences ice scour stress, thereby allowing the density of plant growth to increase in existing plant beds. The overall abundance of plants is expected to increase in areas with a reduction in the extent of ice scour and dewatering. The distribution of submergent aquatic plants is not expected to be affected by increased rates of shoreline erosion, as plant growth is sparse in Wuskwatim Lake main where the majority of the incremental increase in erosion will occur. There is not expected to be any detectable change in the species composition of rooted submergent aquatic plant beds. Emergent plants (e.g., bulrush, cattail) occupying a transitional area between aquatic and terrestrial environments are considered in Volume 6.

Reach 2: Falls

Existing rooted submergent aquatic plant beds in the north and south bays in Reach 2 (total area occupied 2.2 ha) will experience die-off due to the large increase in water depth (Figure 7-7). It is expected that over time a bed comparable to the existing one in the south bay (0.7 ha) will develop within the flooded bay at a suitable elevation as a result of stabilization of water levels. Rooted aquatic plants in the north bay (1.5 ha) will not be replaced as the disturbed newly flooded habitat in this area post-Project will largely consist of the surface of a dyke (i.e., rocky substrata), thereby not providing conditions suitable for rooted aquatic plant growth. This will result in a net loss of 1.5 ha of plant beds (about 3 % of existing Reach 2 area). The relative abundance and distribution of rooted aquatic plants may increase in the south bay where other conditions (e.g., water clarity, bottom substrata type) are suitable, as water velocity will decrease. There is not expected to be any detectable change in the species composition of rooted aquatic plant beds.

Reach 3: Burntwood

Presently, there are 3.9 ha (about 1 % of existing Reach 3 area) of rooted submergent aquatic plant beds in Reach 3 (Figure 7-8). Rooted aquatic plants are expected to noticeably decrease in relative abundance and distribution as the quality of the IEZ will be degraded in comparison to the existing condition due to the increased frequency of water level fluctuations. Additionally, plants found in the permanently wetted zone will experience poorer growing conditions due to the increased frequency and extent of variations in water depth. The small increase in sedimentation that may occur due to the decrease in water velocity in the backwater aquatic habitat created immediately downstream of present day Taskinigup Falls will not be sufficient to promote the establishment of rooted aquatic plant beds in that area.

Reach 4: Opegano

Existing rooted submergent aquatic plants in Reach 4 occupy 45.5 ha (about 6 % of existing Reach 4 area), with about 48 % found in the IEZ and 52 % in the nearshore (Figure 7-9). As in Reach 3, there is expected to be a decrease in the relative abundance and distribution of aquatic plants due to an increase in the frequency of water level fluctuations.

Stream Crossings

Any rooted submergent aquatic plants present at the stream crossings are not expected to be affected by potential small increases in levels of TSS, nutrients, or metals downstream of culverts at most crossings. Any rooted aquatic plant beds in the immediate footprint of the access road and culvert(s) would be lost. Remaining plant beds in adjacent areas are likely to remain undisturbed and experience no change in relative abundance, composition, or distribution. Alteration of water velocity immediately upstream and downstream of culverts is not expected to affect plant beds. Very low water velocities characterize the existing aquatic habitats, and the anticipated increase in water velocity will not be sufficient to affect any existing beds. The deposition of additional fine material will not affect any existing plant beds, as the quantity deposited is expected to be small and the existing substrata supporting aquatic plants is unconsolidated fines.

7.4.2.3 Responses of Zooplankton

The anticipated post-Project increase in retention time for Wuskwatim Lake main and the Cranberry Lakes is not expected to be sufficient to result in an increase in zooplankton abundance or alteration in zooplankton species composition. However, there may be a small increase in the total amount of zooplankton in tributary waterbodies (e.g., Sesep Lake, Wuskwatim Lake south, Wuskwatim Brook), as these areas will experience relatively greater effects from increases in retention times and water volumes, and slight nutrient enrichment. Based on anticipated impacts for mainstem waterbodies in Reach 1, downstream reaches should not experience any notable changes in zooplankton abundance due to differences in inputs.

Truly planktonic crustacean zooplankton tend to be relatively unimportant in small streams as these organisms cannot maintain positive net growth rates due to a variety of reasons, including downstream losses.

7.4.2.4 Responses of Benthic Invertebrates

Reach 1: Wuskwatim

The conversion of about 1588 ha (18 %) of the existing total lake area in Reach 1 that is periodically dewatered as a result of water level fluctuations to more wetted nearshore aquatic habitat is expected to increase the total abundance of benthic invertebrates in this reach. An increase is expected, as the abundance of invertebrates is currently greater in the existing nearshore habitat than in the intermittently exposed areas (Figure 7-21). The total abundance of benthic invertebrates is expected to increase in the nearshore aquatic habitats investigated between about 5 % (NS-Sc-Nv) and 381 % (NS-Ft-Rv) (Table 7-36). Most of the increase in more wetted area changes to the abundance and distribution of benthic invertebrates will occur in Cranberry Lakes, Sesep Lake, Wuskwatim Lake south, and Wuskwatim Brook, which are currently the most productive environments for benthic invertebrates. As the aquatic habitats investigated in Reach 1 are lacustrine in nature, noticeable changes in the composition of the benthic invertebrate community are not expected to occur.

Approximately 30 % of the shoreline on Wuskwatim Lake main and in adjacent waterbodies is currently eroding and is expected to experience an increase in the rate of erosion and sedimentation. Increased frequency of exposure to highly turbid waters adjacent to eroding shorelines and increased deposition of fine sediments over areas of boulder/cobble and/or bedrock substrates could affect benthic invertebrate abundance and distribution. However, the overall proportion of habitat affected is expected to be relatively small and this effect would generally be limited to the first five years of operation when the increase in erosion rates is predicted to be the greatest.

Reach 2: Falls

After construction of the Project, approximately 37 ha of new aquatic habitat in Reach 2 will be created due to the construction of the channel extension and the flooding of terrestrial areas. The higher, more stable water level will permit the colonization of the south bay and lead to a moderate increase in benthic invertebrate production by approximately 2100 % within the reach (Table 7-37). A change in benthic invertebrate species composition from that typical of riverine aquatic habitat, as occurs now, to a community resembling that of Wuskwatim Lake main is expected. However, the level of

Table 7-36. Summary of predicted changes to benthic invertebrates for lacustrine habitat types investigated in Reach 1.

Habitat Type [1]	Pre-Project Area (ha) [2]	Pre-Project Mean Abundance (individuals/ha)	Pre-Project Total Abundance (individuals/ habitat type)	Post-Project Area (ha) [3]	Predicted Post-Project Mean Abundance (individuals/ha)	Post-Project Total Abundance (individuals/ habitat type)	Loss (-)/Gain (+) Area (ha) [4]	Loss (-)/Gain (+) Total Abundance (individuals/ habitat type)	Percentage Loss (-)/Gain (+) Total Abundance (%)
E-Sc-Sc	149.4	1.28E+07	1.91E+09	18.1	1.28E+07	2.31E+08	-131.3	-1.68E+09	-87.9
NS-Sc-Sc	1472.4	2.07E+07	3.04E+10	1595.5	2.07E+07	3.30E+10	123.1	2.54E+09	8.4
NS-Sc-Rv	27.7	2.61E+07	7.23E+08	69.8	2.61E+07	1.82E+09	42.1	1.10E+09	152.0
NS-Sc-Nv	9.2	1.02E+08	9.36E+08	9.7	1.02E+08	9.87E+08	0.5	5.09E+07	5.4
NS-Ft-Sc	917.0	8.24E+07	7.56E+10	1787.2	8.24E+07	1.47E+11	870.2	7.17E+10	94.9
NS-Ft-Rv	152.2	1.26E+08	1.91E+10	731.5	1.26E+08	9.18E+10	579.3	7.27E+10	380.6
OS-Sc-Sc	4357.7	2.52E+07	1.10E+11	4357.7	2.52E+07	1.10E+11	0.0	0.00E+00	0.0

[1] Habitat Type:
- E-Sc-Sc intermittently exposed, soft silt/clay-based substrate, no plants
- NS-Sc-Sc nearshore, soft silt/clay-based substrate, no plants
- NS-Sc-Rv nearshrore, soft silt/clay-based substrate, rooted vascular plants
- NS-Sc-Nv nearshore, soft silt/clay-based substrate, non-vascular plants
- NS-Ft-Sc neashore, flooded terrestrial substrate, no plants
- NS-Ft-Rv nearshore, flooded terrestrial substrate, rooted vascular plants
- OS-Sc-Sc offshore, soft silt/clay-based substrate, no plants

[2] using the 234.09 m ASL shoreline (95th percentile water level elevation using historic data)

[3] using the 234.0 m ASL shoreline

[4] due to the conversion of lake area that is periodically dewatered as a result of water level fluctuations to more permanently wetted nearshore aquatic habitat

Table 7-37. Summary of predicted changes to benthic invertebrates for riverine habitat types investigated in Reach 2.

Habitat Type [1]	Pre-Project Area (ha) [2]	Pre-Project Mean Abundance (individuals/ha)	Pre-Project Total Abundance (individuals/ habitat type)	Post-Project Area (ha) [3]	Predicted Post-Project Mean Abundance (individuals/ha)	Post-Project Total Abundance (individuals/ habitat type)	Loss (-)/Gain (+) Area (ha) [4]	Loss (-)/Gain (+) Total Abundance (individuals/ habitat type)	Percentage Loss (-)/Gain (+) Total Abundance (%)
E-M-Sc-Sc-L	0.6	2.96E+07	1.73E+07	0.0	2.96E+07	0.00E+00	-0.6	-1.73E+07	-100.0
W-M-Sc-Sc-L	8.4	2.77E+07	2.33E+08	9.5	2.77E+07	2.65E+08	1.1	3.19E+07	13.7
W-M-Hc-L	7.9	2.07E+07	1.63E+08	12.5	2.07E+07	2.60E+08	4.7	9.63E+07	59.0
W-M-Bc-M	3.0	4.79E+07	1.44E+08	0.6	4.79E+07	2.93E+07	-2.4	-1.15E+08	-79.7
W-M-Ft-Sc-L [5]	1.2	8.24E+07	1.00E+08	29.0	8.24E+07	2.39E+09	27.8	2.29E+09	2288.3
W-M-Ft-Rv-L [6]	1.8	1.26E+08	2.23E+08	0.7	1.26E+08	9.35E+07	-1.0	-1.29E+08	-58.0

[1] Habitat Type:
- E-M-Sc-Sc-L intermittently exposed, mainstem, soft silt/clay-based substrate, no plants, low water velocity
- W-M-Sc-Sc-L wetted, mainstem, soft silt/clay-based substrate, no plants, low water velocity
- W-M-Hc-L wetted, mainstem, hard silt/clay-based substrate, low water velocity
- W-M-Bc-M wetted, mainstem, boulder/cobble substrate, medium water velocity
- W-M-Ft-Sc-L wetted, mainstem, flooded terrestrial substrate, no plants, low water velocity
- W-M-Ft-Rv-L wetted, mainstem, flooded terrestrial substrate, rooted vascular plants, low water velocity

[2] using the 95th percentile flow event (discharge at 1066 m^3/s)

[3] using the 234.0 m ASL shoreline (water velocity at 3 units full-gate)

[4] due to the conversion of area that is periodically dewatered as a result of water level fluctuations to more permanently wetted aquatic habitat and the flooding of terrestrial habitat

[5] as this habitat was not sampled directly, the NS-Ft-Sc habitat type from Reach 1 was used as a surrogate for pre-Project mean abundance

[6] as this habitat was not sampled directly, the NS-Ft-Rv habitat type from Reach 1 was used as a surrogate for pre-Project mean abundance

species biodiversity is not expected to noticeably change post-Project, as benthic invertebrate samples collected from a variety of aquatic habitat types in the existing Reach 1 and Reach 2 indicated that species diversity is comparable between the two reaches.

Reach 3: Burntwood

After construction of the Project, about 3 ha of existing aquatic habitat in the most upper extent of Reach 3 will be lost (due to the concrete footprint of the structure and the dewatering of the cataract of present-day Taskinigup Falls) and about 0.9 ha will be gained (disturbed newly flooded terrestrial in the tailrace channel), resulting in a small decrease in benthic invertebrate production.

Benthic invertebrates are expected to noticeably decrease in abundance and distribution in Reach 3 during operation of the Project, as the quality of the IEZ will be degraded in comparison to the existing condition due to the increased frequency of water level fluctuations. Additionally, benthic invertebrates found in the permanently wetted zone will experience poorer growing conditions due to the increased frequency and extent of variation in water depth. The daily fluctuations in water velocity in the mainstem are expected to occur rapidly during operation of the Project, thereby reducing the suitability of a portion of the mainstem for benthic invertebrates, which may not be able to adapt to the rapidly changing water velocity regime.

The small increase in sedimentation that may occur due to the decrease in water velocity in the backwater aquatic habitat created immediately downstream of present day Taskinigup Falls will not be sufficient to noticeably affect benthic invertebrate abundance.

Reach 4: Opegano

As in Reach 3, benthic invertebrates are expected to noticeably decrease in abundance and distribution in Reach 4 during operation of the Project, as the quality of the IEZ will be degraded in comparison to the existing condition due to the increased frequency of water level fluctuations.

Stream Crossings

Benthic invertebrates are not expected to be affected by potential small increases in levels of TSS, nutrients, or metals downstream of culverts at most stream crossings. Any benthic invertebrates in the immediate footprint of the road and culvert(s) would be lost.

The benthic invertebrate community in adjacent areas is likely to remain undisturbed and experience no change in abundance, composition, or distribution. Alteration of water velocity immediately upstream and downstream of culverts is not expected to affect the benthic invertebrate community. Very low water velocities characterize these existing aquatic habitats and the anticipated increase in water velocity will not be sufficient to affect the benthic invertebrate community. The deposition of additional fine material will not affect the benthic invertebrate community, as the quantity deposited is expected to be small and the existing substrate at the eight major stream crossings was predominantly unconsolidated fines.

8.0 FISH COMMUNITY AND MOVEMENTS

8.1 INTRODUCTION

Fish play a key role in ecosystem function and are important to Nisichawayasihk Cree Nation members as a domestic and commercial resource. Although NCN members indicated that all fish species are considered important (Section 2.0), for the purposes of decision-making related to the Project, it was necessary to distinguish those species that are of specific interest to resource users. Key domestic and commercial fish species, including walleye (pickerel/okaw/*Stizostedion vitreum*), lake whitefish (whitefish/ atehkamihk/*Coregonus clupeaformis*), lake cisco (tullibee/otunibis, *Coregonus artedii*) and northern pike (jackfish/osaskwabith/*Esox lucius*), were identified as Valued Ecosystem Components (Section 2.0), and were the focus for assessing the significance of Project-related effects on the fish community.

The study area (Section 3.0) extends along the Burntwood River from Early Morning Rapids in the west downstream to Opegano Lake in the east (Figure 8.1). The study area was defined by: (i) water level and flow changes resulting from operation of the Project; and (ii) by the extent of fish movements within the Burntwood River and its tributaries (Section 8.3). The degree of physical change (e.g., water level fluctuations) differs substantially among different regions (Volume 3) and, consequently, the study area was divided into four reaches on the Burntwood River and a fifth area encompassing the streams crossed by the access road, as discussed below:

Reach 1 - Wuskwatim

This reach extends from the Burntwood River at Early Morning Rapids to the crest of Wuskwatim Falls and includes Cranberry Lakes, Sesep Lake, Wuskwatim Brook, and Wuskwatim Lake.

Reach 2 –The Falls

This reach includes the Burntwood River from the crest of Wuskwatim Falls to the tail waters of Taskinigup Falls. It includes the site where the generating station (GS) will be constructed and the area immediately upstream of the generating station including the area that will be flooded.

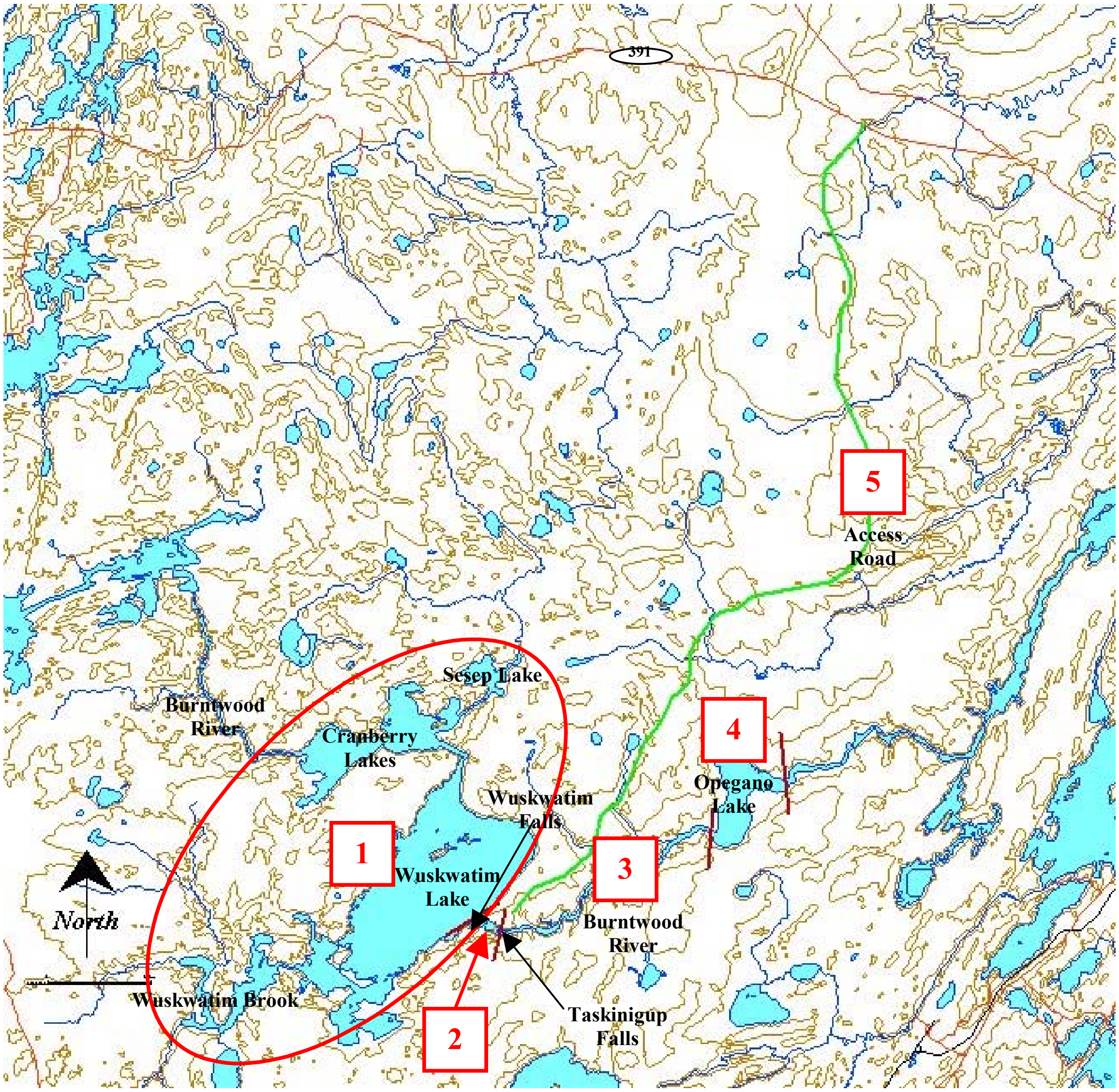


Figure 8-1. Wuskwatim Generation Project, aquatic study area.

Reach 3 - Burntwood

This reach, from downstream of Taskinigup Falls to the inlet of Opegano Lake will be subject to daily water level and discharge fluctuations superimposed on the existing seasonal fluctuations. It includes the Burntwood River and the mouths of several small tributaries.

Reach 4 - Opegano

Reach 4 extends from the inlet of Opegano Lake to Jackpine Falls, located approximately 3.4 km downstream of Opegano Lake. This reach will also be subjected to daily water level and discharge fluctuations, although the magnitude of the fluctuations is expected to be minor.

Mile 17 Access Road Stream Crossings

This area includes the streams crossed by the access road linking the proposed generating station site to Provincial Road (PR) #391.

Fish and fish habitat receive protection under the federal *Fisheries Act*, the federal *Species at Risk Act*, the Manitoba Fishery Regulations, and the Manitoba *Endangered Species Act*. A description of the regulatory process for the Project and the relevant provincial and federal legislation are provided in Volume 1.

A summary of the methodology employed to collect the information presented in this section is discussed in Section 8.2. General descriptions of the fish community in each of the five reaches are presented in Section 8.3.1. General life histories, and information on abundance, habitat use, biological information, and movements for each of the four VECs are presented in sections 8.3.2 to 8.3.5. Construction and operation impacts and mitigation are discussed in Section 8.4 and **residual impacts**, **cumulative impacts**, and monitoring and follow-up are provided in sections 8.5 to 8.7.

8.2 METHODS

The existing environment is described using several sources of information, including Traditional Knowledge, existing published information, and studies conducted specifically as part of the environmental assessment of the proposed Project. Each of these data sources is described below.

8.2.1 Traditional Knowledge

As discussed in Volume 2, NCN and Manitoba Hydro have identified the importance of incorporating Traditional Knowledge (TK) into the Environmental Impact Statement. Traditional Knowledge was obtained from numerous sources, including commercial fishers, domestic fishers, Elders, and field assistants working with the study team (Volume 2). However, most NCN resource harvesters stated that their knowledge of the fish community and fish movements in the study area was limited due to the difficulty in accessing the area since the completion of the CRD. Most TK related to the current conditions in the study area was provided by NCN members who currently, or have recently, commercially fished on Wuskwatim Lake. This information is incorporated into Section 8.3.

8.2.2 Existing Published Information

Limited pre-CRD and post-CRD fish population information exists for Notigi, Wapisu, Threepoint, and Footprint lakes (Ayles et al. 1974). However, prior to the conduct of the environmental assessment studies for the Project, no post-CRD fish population studies had been conducted for the reach between Early Morning Rapids and Opegano Lake. Pre-CRD fish population data existed only for Wuskwatim Lake. Consequently, no previously published scientific studies of fish populations were used to describe current conditions in the study area.

8.2.3 Environmental Assessment Studies

An ecosystem-based approach was used to assess the potential effects of the Project on the fish community. Information presented in this section incorporates findings of other aquatic components (i.e., water quality, aquatic habitat, and lower trophic levels). This approach is consistent with NCN's, and widely held ecological views, that all components of the aquatic environment are important to maintaining the whole, and that all fish species are inter-dependant and, therefore, of importance and value.

A summary of fish community and movement studies conducted between 1998 and 2002 is presented in Table A9-1. The field program was grouped into six primary components (though activities among the components often overlapped), as follows:

- habitat-based fish community assessment;
- spring-spawning;
- fall-spawning;
- overwintering;
- tributary streams; and
- fish movements.

Habitat-Based Fish Community Assessment

This study was conducted to provide a replicable, habitat-based description of the fish community; habitat types fished are described fully in Section 6.0. A **standard-gang index gill net**, which is the standard sampling gear used by Manitoba Conservation Fisheries Branch to inventory **lentic** fish communities, was used for the study. The gillnets consisted of six panels with mesh sizes ranging from 1.5” (38 mm) to 5.0” (127 mm).

In reaches 1 and 4, index-gillnetting sites were chosen to sample available habitat types, with emphasis on the most common habitat types. In some cases, an experimental gillnet was set in a composite of habitat types, and the overall designation for that site was the predominant habitat type. For example, sites 19 and 20 (Sesep Lake) were comprised of both nearshore and intermittently exposed habitats but were designated nearshore habitat since this was the predominant habitat type over the length of the index gill net. As Wuskwatim Lake supports a commercial fishery, sampling effort within a given year was limited to a maximum of 200 individuals of each VEC. In reaches 2 and 3, where there is an abundance of medium and high water velocity **lotic** habitat, index gillnets were set in areas where water velocities were low (primarily in backwater inlets in Reach 3). The small size of the tributaries crossed by the Mile 17 Access Road precluded the setting of index gill nets in this area, so sampling was conducted using electrofishing techniques (see below).

In addition to providing an assessment of fish species composition, relative abundance, and quantitative **catch-per-unit-effort** data, information on fish size, age, condition, sex and state of maturity, and diet were also obtained from fish captured in index gill nets.

The focus of the remaining studies was on the four VEC species, though supplementary information was also collected on other species.

Spring Spawning

This study was conducted to provide information on spawning locations for walleye and northern pike. Initially, Traditional Knowledge was used to identify potential spawning habitat for walleye and northern pike; this was supplemented by results of field sampling as the study progressed. Short duration (2-4 hours) sets of large mesh gill nets (3.0 in [76 mm] to 5.0 in [127 mm]) were employed in mid-May to mid-June to capture target species. Fish captured were assessed for sexual maturity to infer the location of spawning habitat. Potential spawning habitat in tributaries and backwater inlets was assessed with **larval drift traps** (Burton and Flannagan 1976) and **kick-nets** to capture eggs and larvae. Larval drift traps were also set in the mainstem of the Burntwood River at selected locations between Wuskwatim Falls and Opegano Lake and in Wuskwatim Lake immediately upstream of Wuskwatim Falls.

Fall Spawning

This study was conducted to provide information on spawning locations for lake whitefish and lake cisco. As with the spring spawning study, Traditional Knowledge, supplemented by field study results, were used to identify potential spawning locations. At the onset of the open water season (usually mid-May), sampling was conducted to capture larval cisco and whitefish as they emerged from the substrate. A **modified neuston sampler** (Mason and Philips 1986, Mota et al. 2000) was used from 1999 to 2002 in lentic habitats and floating drift traps (designed after Burton and Flannagan 1976) were used during 2001 and 2002 to sample lotic habitats.

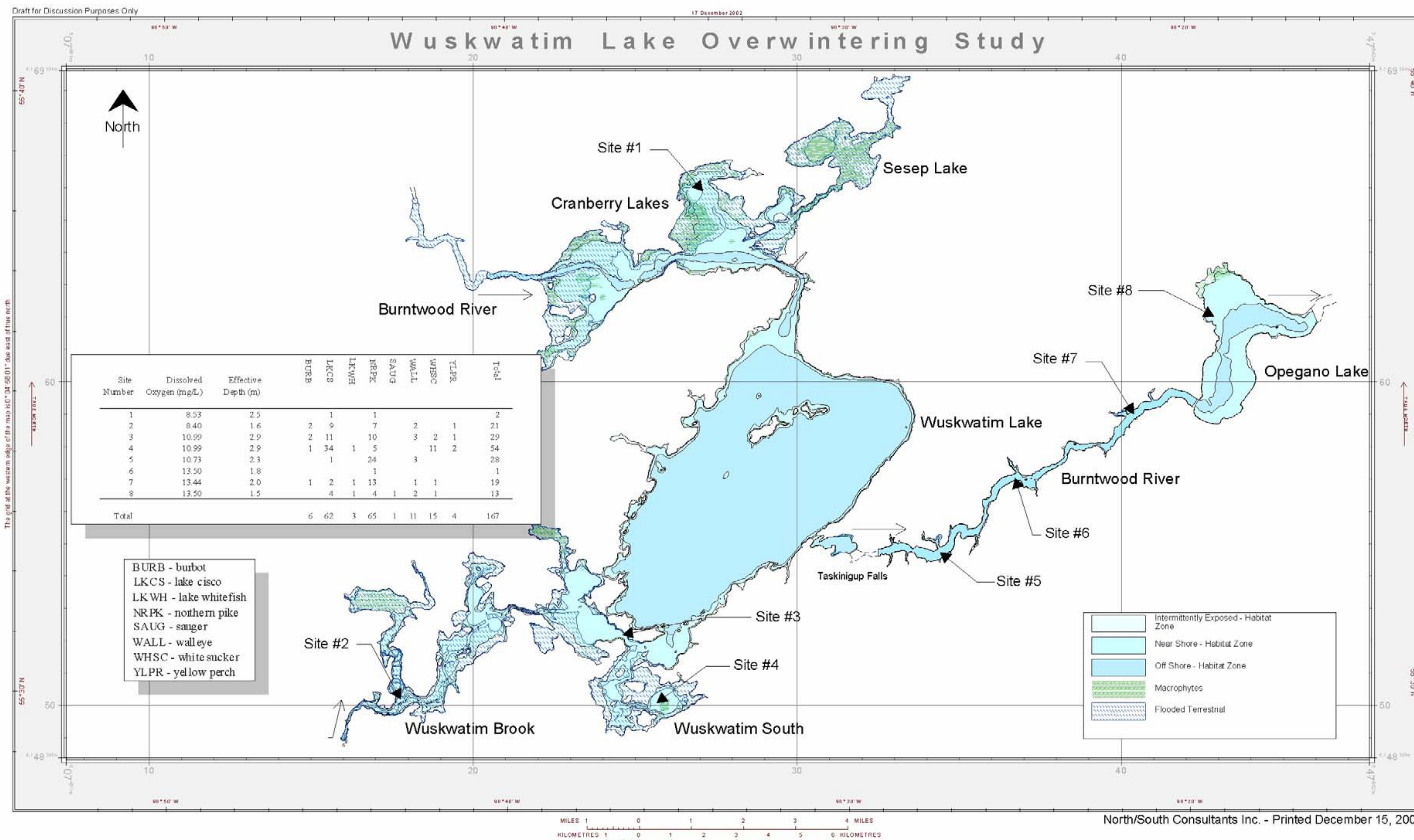
Potential spawning sites were also assessed through tracking of radio-tagged fish (sections 8.3.3.3 and 8.3.4.3).

Overwintering

This study was conducted to provide information on overwintering habitat. Effort was focused on areas where it is felt that the Project could potentially adversely affect some characteristic of overwintering habitat (e.g., water velocity, dissolved oxygen (DO)). At each location, dissolved oxygen was measured using a Yellow Spring Instruments meter (no gill nets were set at **anoxic** sites (DO less than 3.0 mg/L)). Gillnet gangs, consisting of two 25 yd (22.9 m) panels of each of 1.5 in (38 mm) and 4.25 in (108 mm) stretched twisted nylon mesh, were set under the ice at eight sites. Radio-tagging studies also helped to identify overwintering habitat for lake whitefish, lake cisco, and walleye (sections 8.3.3.3 and 8.3.4.3).

Tributary Streams

The tributary stream study was conducted to assess fish use of tributaries, including streams flowing into the Burntwood River between Taskinigup Falls and Opegano Lake (Reach 3) and streams crossed by the proposed Mile 17 Access Road (Figure 8-2). Due to the small size of these streams, it was not possible to set gill nets and, therefore, backpack electrofishing was used to assess the fish community. Fish species composition



Site Number	Dissolved Oxygen (mg/L)	Effective Depth (m)	BURB	LKCS	LKWH	NRPK	SAUG	WALL	WHSC	YLPR	Total
1	8.53	2.5		1		1					2
2	8.40	1.6	2	9		7		2		1	21
3	10.99	2.9	2	11		10		3	2	1	29
4	10.99	2.9	1	34	1	5			11	2	54
5	10.73	2.3		1		24		3			28
6	13.50	1.8				1					1
7	13.44	2.0	1	2	1	13		1	1		19
8	13.50	1.5		4	1	4	1	2	1		13
Total			6	62	3	65	1	11	15	4	167

Figure 8-2. Stream crossings along the proposed Mile 17 Access Road.

and abundance within the most downstream 100 m of each stream flowing into Reach 3 was fished during September 2001, using a Smith Root Model 15–C **backpack electrofisher** (300 Watts, 600 Volts, frequency 4, pulse width H).

Data on open-water fish species composition and abundance within the streams crossed by the access road was obtained from 100 m to 300 m long sections of each stream in early spring, 2002. During winter, the streams crossed by the access road were sampled for the presence of flowing water. Dissolved oxygen concentrations were measured at three of the eight crossings in March 2002 to provide information on the potential of these streams to overwinter fish.

Fish Movements

The study was conducted to: a) determine if, and to what extent, VEC fish species are moving within and between the different reaches of the study area; and b) to document concentrated movements of fish which can be used to identify important habitat, such as spawning sites. Information on fish movements was obtained from recaptures of relatively large numbers of individually **Floy-tagged** fish and through repeated tracking of a relatively small number of **radio-tagged** fish.

During a two-week period in the spring and fall of 1999-2002, fish were marked with individually numbered plastic Floy FD-94 T-bar anchor tags, applied between the **basal pterygiophores** of the dorsal fin using a Dennison Mark II tagging gun. A total of 1,259 fish were tagged, including 69 lake whitefish, 361 lake cisco, 146 northern pike, and 683 walleye. The majority of fish (1,057 individuals) were tagged in Wuskwatim Lake main. Small numbers of whitefish, cisco, pike, and walleye were tagged in Cranberry Lakes, Sesep Lake, and Birch Tree Lake. Fish selected to receive tags were captured using gill nets at numerous locations in each lake. The return of Floy-tags (or the tag number), and the associated catch information (i.e., where and when fish was captured), was promoted by posters offering rewards in Nelson House and Thompson.

Fourteen walleye, 20 lake whitefish, and eight lake cisco captured in Wuskwatim Lake were tagged with radio-transmitters (models MBFT-3 and MBFT-4, Lotek Engineering Inc., Newmarket, Ontario) in fall 1999, and spring and fall, 2000. Tagged fish were relocated from the air using a helicopter equipped with a Lotek model SRX-400 receiver and "H" antenna assembly.

8.3 EXISTING ENVIRONMENT

8.3.1 Overview of Fish Community

A total of 20 fish species were captured in the study area (Table 8-1). Generally, the fish community is fairly typical of relatively shallow, turbid, northern waterbodies. The principal fish species include walleye, sauger, northern pike, yellow perch, lake whitefish, lake cisco, white sucker, burbot, spottail shiner, and emerald shiner. Longnose sucker are also abundant in lotic environments.

From a biodiversity and conservation perspective, the aquatic environment in the study area is not unique. The area is similar to that of much of the northern boreal forest of Manitoba, Ontario, and western Quebec. No fish species listed as endangered, threatened, or of special concern by COSEWIC (Committee on the Status of Endangered Wildlife in Canada) were captured during field studies conducted between 1998 and 2002. However, it was felt that shortjaw cisco (*Coregonus zenithicus*), a species of fish that has been listed as threatened by COSEWIC since 1987 (Houston 1988), may occur in the Rat/Burntwood River system, including Wuskwatim and Opegano lakes. This species was first described from most of the Laurentian Great Lakes, and subsequently has been discovered in many smaller lakes in central North America (Scott and Crossman 1998). In Manitoba, shortjaw cisco have been identified from Lake of the Woods, George Lake, Lake Winnipeg, Lake Athapapuskow, and Clearwater Lake in the Nelson River drainage basin and in Reindeer Lake in the Churchill River drainage basin (Clarke 1973). Presently, the status of the shortjaw cisco in Manitoba waters is being re-examined with confirmation of the species in George, Athapapuskow and Clearwater lakes (Murray and Reist 2001). While virtually all shortjaw cisco have been found in deep water lakes, there is evidence from Barrow Lake in Alberta that *C. zenithicus* can also be found in shallower water (Steinhilber 2001).

Shortjaw cisco is difficult to distinguish from smaller forms of lake cisco (*Coregonus artedii*), which is a polymorphic (i.e., several distinct forms) species. In Manitoba it appears that lakes where *C. zenithicus* is present also contain *C. artedii* (Dr. K.W. Stewart, University of Manitoba, pers. comm.). While *C. zenithicus* carries separate species status, there appears to be little other than gill raker counts that separate it from *C. artedii*. Shortjaw cisco generally have 40 or less gill rakers on the first arch whereas lake cisco have more than 40 (L. Murray, University of Manitoba, pers. comm.). However, while such a separation based on gill raker counts seems to work for individuals from one

Table 8-1. Fish species captured in the study area, 1998-2002.

Common Name	Cree Name	Scientific Name	Abbreviation
Northern pike (jackfish)	Osawuskwapis	*Esox lucius*	NRPK
Lake cisco (tullibee)	Ochonipis	*Coregonus artedii*	LKCS
Lake whitefish (whitefish)	Atihkamek	*Coregonus clupeaformis*	LKWH
Goldeye	Wepitcheesis	*Hiodon alosoides*	GOLD
Lake chub		*Couesius plumbeus*	LKCH
Pearl dace		*Margariscus margarita*	PRDC
Emerald shiner		*Notropis atherinoides*	EMSH
Spottail shiner		*Notropis hudsonius*	SPSH
Fathead minnow		*Pimephales promelas*	FTMN
Longnose (red) sucker	Mehkwamepith	*Catostomus catostomus*	LNSC
White sucker	Namepith	*Catostomus commersoni*	WHSC
Shorthead redhorse		*Moxostoma macrolepidotum*	SHRD
Burbot (maria)	Methachos	*Lota lota*	BURB
Brook stickleback		*Culaea inconstans*	BRST
Ninespine stickleback		*Pungitius pungitius*	NNST
Troutperch		*Percopsis omiscomaycus*	TRPR
Yellow perch (perch)	Asawisis	*Perca flavescens*	YLPR
Sauger		*Stizostedion canadense*	SAUG
Walleye (pickerel)	Okow	*Stizostedion vitreum*	WALL
Slimy sculpin		*Cottus cognatus*	SLSC

lake it does not necessarily hold true over a range of different lakes (Dr. K.W. Stewart, University of Manitoba, pers. comm.).

Lakes within the Rat/Burntwood River system, including Wuskwatim and Opegano lakes, support a “dwarf” form of cisco that mature sexually at a much smaller size (as small as 130 mm) than “typical” *C. artedii*. A sample of 56 cisco were collected from Wuskwatim Lake and **meristic** and **morphological** analyses were conducted on the fish. None of the fish had first arch gill raker counts of less than 40 and, consequently, it has been determined that all these fish were of a dwarf variety of lake cisco and not *C. zenithicus* (Table 8-2, Table A10-1).

Table 8-2. Morphological and meristic analysis of 56 lake cisco captured in Wuskwatim Lake, spring 2002.

Meristic or Morphologic Character	Mean	Mode	Std[1]	Range
Fork Length (mm)	287	397	87	127 – 417
Weight (g)	517	180	390	27 – 1304
Condition Factor (K)	1.61	0.25	-	1.11 – 2.18
Upper Gillraker Count	16	16	1	14 – 18
Lower Gillraker Count	30	30	1	27 – 33
Total Gillraker Count	46	46	2	42 – 50
Dorsal Ray Count	11	11	1	10 – 12
Anal Ray Count	12	12	1	11 – 13
Pectoral Ray Count	16	15	1	14 – 17
Pelvic Ray Count	11	11	1	10 - 12

[1] – Standard deviation

Wuskwatim Lake

Based on Traditional Knowledge, the fish community of Wuskwatim Lake appears to have changed since CRD (Volume 7, Appendix 6). Approximately fifteen years ago, walleye were the most abundant species in the lake but were subsequently replaced by lake cisco as the most abundant species. Based on the results of index gillnetting, it appears that walleye have now become more abundant in recent years (Volume 7, Appendix 6).

Index gillnetting on Wuskwatim Lake and adjacent waterbodies focused on Wuskwatim Lake main in 1998 and 2000 (North/South Consultants Inc. unpublished data). In 2001 and 2002 the program was expanded to include sites in Wuskwatim Brook, Cranberry Lakes, and Sesep Lake (Figure 8-3).

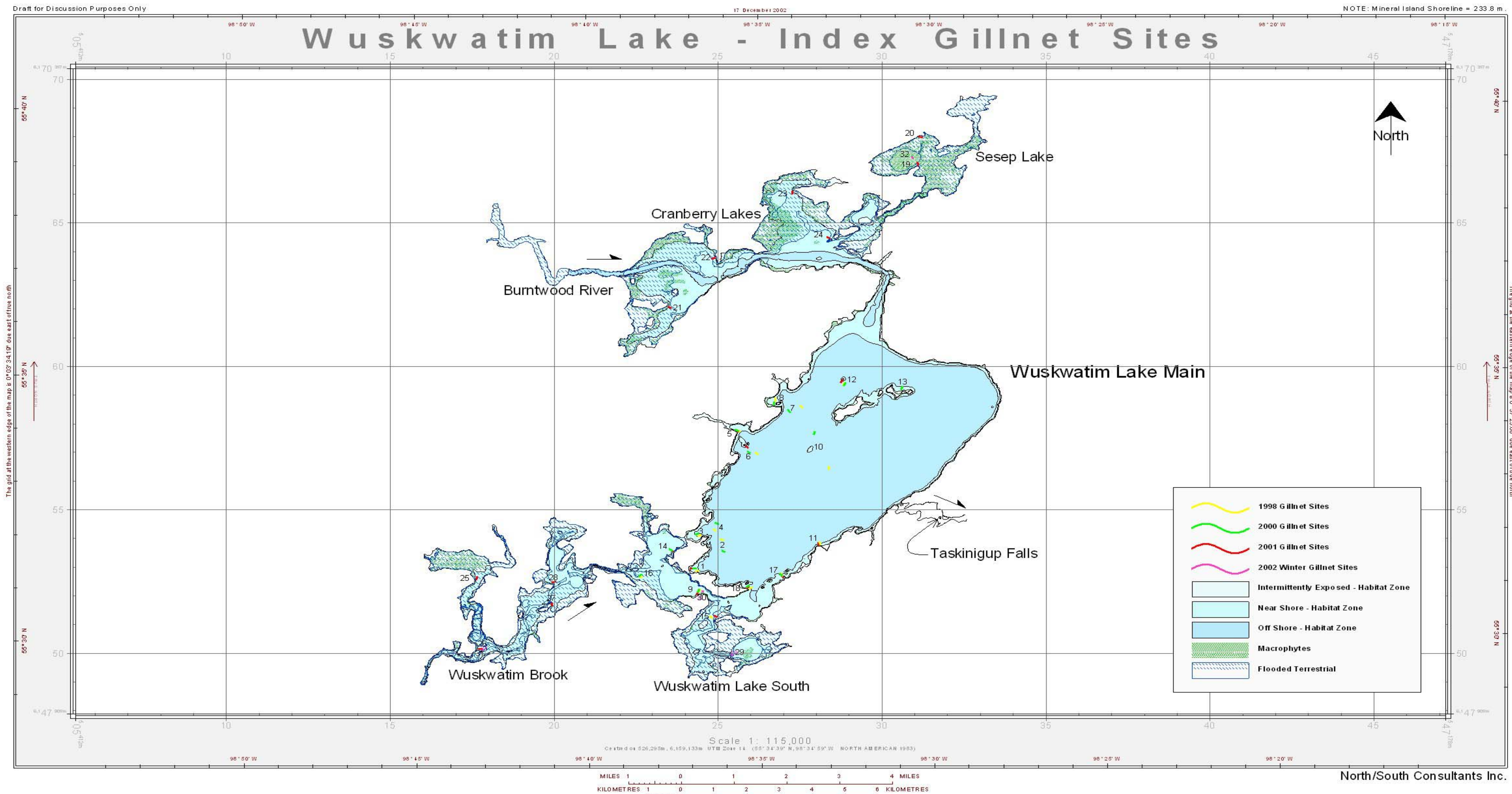


Figure 8-3. Habitat types present in Wuskwatim Lakes and adjacent water bodies showing locations of index gillnetting sites, 1998-2002.

A total of 16 species were captured in Wuskwatim Lake and adjacent waterbodies between 1998 and 2002 (Table 8-3). Eleven species, including northern pike, lake cisco, lake whitefish, longnose sucker, white sucker, shorthead redhorse, burbot, troutperch, yellow perch, sauger, and walleye were captured during index gillnet surveys. White sucker, sauger, lake cisco, and walleye were the most abundant species in the reach, however, some variability was observed in species composition from year to year (Table 8-4). While overall CPUE varied between years, it was generally high with a value greater than all other reaches (Table 8-4). Slimy sculpin, emerald shiner, spottail shiner, brook stickleback, and ninespine stickleback were collected from larval fish sampling programs and through dietary analysis of predators.

Table 8-3. Fish species captured in the study area, by reach, 1998 - 2002.

Species	Reach 1[1]	Reach 2[2]	Reach 3[3]	Reach 4[4]	Stream Crossings[5]
Northern pike	Y	Y	Y	Y	-
Lake cisco	Y	Y	Y	Y	-
Lake whitefish	Y	Y	Y	Y	-
Goldeye	-	-	Y	Y	-
Lake chub	-	-	Y	-	Y
Pearl dace	-	-	Y	-	Y
Emerald shiner	Y	Y	Y	Y	-
Spottail shiner	Y	Y	Y	Y	-
Fathead minnow	-	-	Y	-	Y
Longnose sucker	Y	Y	Y	Y	-
White sucker	Y	Y	Y	Y	Y
Shorthead redhorse	Y	-	Y	Y	-
Burbot	Y	Y	Y	Y	-
Brook stickleback	Y	-	-	-	Y
Ninespine stickleback	Y	Y	Y	Y	-
Trout-perch	Y	Y	Y	-	-
Yellow perch	Y	Y	Y	Y	-
Sauger	Y	Y	Y	Y	-
Walleye	Y	Y	Y	Y	-
Slimy sculpin	Y	-	Y	-	-

Note: Y = presence documented in Wuskwatim GS environmental studies
[1] - Wuskwatim Lake and adjacent waterbodies (Cranberry Lakes, Sesep Lake, and Wuskwatim Brook)
[2] - Burntwood River between Wuskwatim Falls and Taskinigup Falls
[3] - Burntwood River between Taskinigup Falls and Opegano Lake
[4] - Opegano Lake
[5] - Mile 17 Access Road Stream Crossings

Table 8-4. Relative abundance (RA; %) and catch-per-unit-effort (CPUE; number of fish per 100m of net per 24 hours) by reach, of fish captured in index gillnets, 1998 – 2002

Species	Reach 1[a]											
	1998			2000			2001[e]			Mean		
	n	RA	CPUE	n	RA	CPUE	n	RA	CPUE	n	RA	CPUE
Northern pike		6.9	4.5		2.6	2.1		8.4	5.2		5.9	4.0
Lake cisco		21.6	13.4		17.8	14.1		15.3	9.9		18.1	12.3
Lake whitefish		5.5	3.4		4.5	3.4		5.2	3.3		5.1	3.4
Goldeye		-	-		-	-		-	-		-	-
Longnose sucker		1.4	0.9		4.1	3.1		-	-		1.9	1.2
White sucker		29.8	18.5		29.2	23.0		17.2	10.6		25.4	16.9
Shorthead redhorse		-	-		-	-		0.1	0.04		0.02	0.01
Burbot		0.7	0.4		1.4	1.1		0.4	0.2		0.8	0.6
Trout-perch		-	-		0.1	0.05		-	-		0.02	0.01
Yellow perch		4.4	2.7		6.4	5.2		10.1	6.1		7.0	4.7
Sauger		23.4	14.4		27.4	21.3		14.7	9.0		21.9	14.4
Walleye		6.4	3.9		6.6	5.1		28.6	17.6		13.9	9.3
Total	18	100	62.1	16	100	78.4	20	100	62.0	54	100	66.9

Species	Reach 2[b]								
	2001			2002			Mean		
	n	RA	CPUE	n	RA	CPUE	n	RA	CPUE
Northern pike		7.1	5.7		7.9	3.8		7.4	4.8
Lake cisco		10.2	8.3		9.4	4.6		9.9	6.4
Lake whitefish		1.3	1.1		-	-		0.9	0.5
Goldeye		-	-		-	-		-	-
Longnose sucker		36.9	30.3		20.5	9.9		31.0	20.1
White sucker		0.9	0.8		0.8	0.4		0.9	0.6
Shorthead redhorse		-	-		-	-		-	-
Burbot		2.2	1.9		1.6	0.8		2.0	1.3
Trout-perch		-	-		-	-		-	-
Yellow perch		0.4	0.4		1.6	0.8		0.9	0.6
Sauger		6.7	5.4		15.0	7.2		9.7	6.3
Walleye		34.2	27.5		43.3	20.9		37.5	24.2
Total	2	100	81.2	2	100	48.3	4	100	64.8

Species	Reach 3[c]								
	2001			2002			Mean		
	n	RA	CPUE	n	RA	CPUE	n	RA	CPUE
Northern pike		19.9	5.2		10.2	4.3		14.4	4.7
Lake cisco		10.3	2.9		7.3	2.9		8.6	2.9
Lake whitefish		5.0	1.4		6.3	2.7		5.7	2.0
Goldeye		-	-		-	-		-	-
Longnose sucker		6.8	2.1		11.5	4.6		9.5	3.3
White sucker		14.9	4.7		14.4	5.9		14.7	5.3
Shorthead redhorse		3.2	1.0		3.4	1.3		3.3	1.2
Burbot		1.1	0.4		1.0	0.4		1.1	0.4
Trout-perch		-	-		-	-		-	-
Yellow perch		1.4	0.4		1.0	0.4		1.2	0.4
Sauger		2.1	0.6		8.7	3.3		5.9	1.9
Walleye		35.2	9.9		36.0	14.2		35.6	12.1
Total	8	100	28.5	8	100	40.1	16	100	34.3

Species	Reach 4[d]								
	2000			2001			Mean		
	n	RA	CPUE	n	RA	CPUE	n	RA	CPUE
Northern pike		10.2	3.7		9.1	4.2		9.6	4.0
Lake cisco		2.5	0.9		2.2	0.9		2.3	0.9
Lake whitefish		9.5	3.5		8.8	4.1		9.1	3.8
Goldeye		0.4	0.1		-	-		0.2	0.1
Longnose sucker		1.8	0.7		0.6	0.3		1.2	0.5
White sucker		23.9	8.9		30.3	13.0		27.3	11.0
Shorthead redhorse		2.5	0.9		0.9	0.4		1.7	0.7
Burbot		-	-		-	-		-	-
Trout-perch		-	-		-	-		-	-
Yellow perch		3.2	1.1		4.7	2.1		4.0	1.6
Sauger		29.6	10.9		15.9	6.6		22.4	8.7
Walleye		16.5	6.2		27.5	11.9		22.4	9.0
Total	6	100	37.0	6	100	43.5	12	100	40.3

n = number of net sets
a = Wuskwatim Lake and adjacent water bodies
b = Burntwood River between Wuskwatim Falls and Taskinigup Falls
c = Burntwood River between Taskinigup Falls and Opegano Lake
d = Opegano Lake
e = includes 4 sets in Wuskwatim Brook, 2 sets in Sesep Lake, and 4 sets in Cranberry Lakes

Wuskwatim Lake and adjacent waterbodies were classified into habitat types (Section 6.0) to examine the relationship between habitat and fish species composition, abundance, and size. Index gillnetting indicated that fish abundance was highest in "nearshore, soft silt/clay-based, no plants" habitat (CPUE of 78.3), followed by "offshore, soft silt/clay-based, no plants" habitat (CPUE of 59.5), "nearshore flooded terrestrial, no plants" habitat (CPUE of 50.3), and "nearshore flooded terrestrial, rooted vascular plants" habitat (CPUE of 32.2) (Table 8-5).

Table 8-5. Relative abundance (RA; %) and catch-per-unit-effort (CPUE; number of fish per 100m of net per 24 hrs) by habitat type, for fish species captured in Wuskwatim Lake and adjacent water bodies, 1998 - 2001.

Species	Number of net sets	Habitat 1[2] n[1]	Habitat 1[2] RA[5]	Habitat 1[2] CPUE	Number of net sets	Habitat 2[3] n[1]	Habitat 2[3] RA	Habitat 2[3] CPUE	Number of net sets	Habitat 3[4] n[1]	Habitat 3[4] RA	Habitat 3[4] CPUE	Number of net sets	Habitat 4[5] n[1]	Habitat 4[5] RA	Habitat 4[5] CPUE
Burbot		28	2.3	1.4		9	0.3	0.3		-	-	-		1	0.2	0.1
Lake cisco		174	14.5	8.7		521	18.6	14.6		13	15.7	5.1		119	25.0	13.1
Lake whitefish		155	12.9	7.6		34	1.2	0.9		18	21.7	7.0		24	5.0	2.5
Longnose sucker		84	7.0	3.9		2	0.1	0.1		-	-	-		-	-	-
Northern pike		13	1.1	0.6		147	5.3	4.3		31	37.3	12.0		76	16.0	7.9
Shorthead redhorse		-	-	-		-	-	-		-	-	-		1	0.2	0.1
Sauger		348	29.0	17.2		635	22.7	17.6		-	-	-		15	3.2	1.5
Trout-perch		1	0.1	0.1		-	-	-		-	-	-		-	-	-
Walleye		78	6.5	3.9		391	14.0	10.9		15	18.1	5.8		149	31.3	15.7
White sucker		319	26.5	16.0		784	28.0	21.9		-	-	-		53	11.1	5.4
Yellow perch		2	0.2	0.1		273	9.8	7.7		6	7.2	2.3		38	8.0	4.1
TOTAL	16	1202	100.0	59.5	28	2796	100.0	78.3	2	83	100.0	32.2	8	476	100.0	50.3

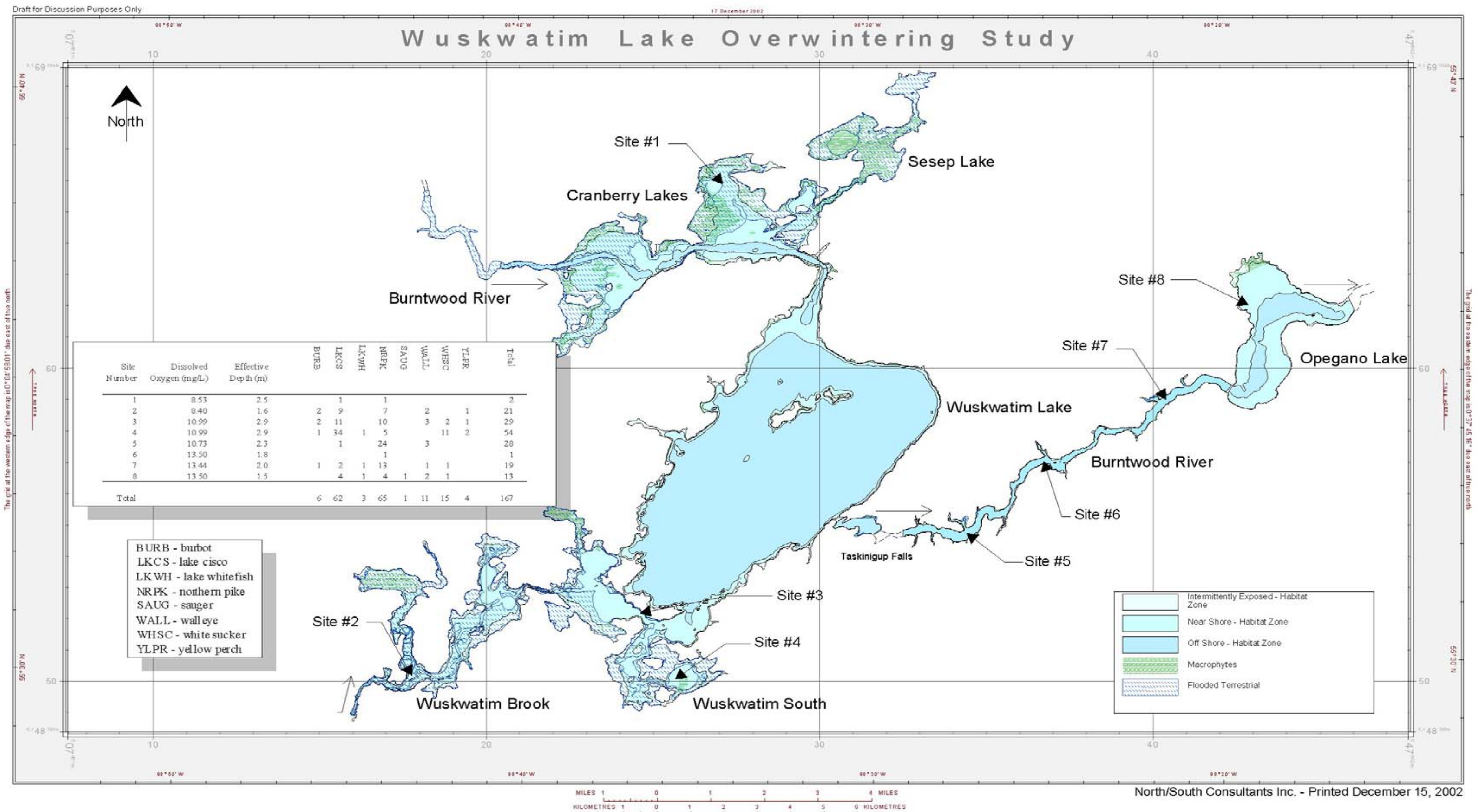
[1]n = number of fish captured
[2]Habitat 1 = Offshore, Soft silt/clay-based, No plants
[3]Habitat 2 = Near shore, Soft silt/clay-based, No plants
[4]Habitat 3 = Near shore, Flooded terrestrial, Rooted vascular plants
[5]Habitat 4 = Near shore, Flooded terrestrial, No plants

A total of seven species were captured in gillnets set in Wuskwatim Lake and adjacent water bodies during March, 2002. Lake cisco was the most abundant species followed by northern pike and white sucker (Figure 8-4).

To put the study area into a regional context, a comparison of the CPUE for the total catch and four VECs for Wuskwatim Lake and adjacent water bodies and other Manitoba water bodies is presented in Table 8-6. Wuskwatim Lake and adjacent water bodies were among the most productive water bodies compared.

The Falls

Sampling conditions in the Wuskwatim Falls to Taskinigup Falls reach are both difficult and dangerous (i.e., working between two sets of falls) and as a result the reach did not receive the same level of sampling effort as other reaches. Due to the dangerous conditions, 43.6 ha of the 53.3 ha of aquatic habitat present within this reach were classified and quantified (Section 6.0). Under 95 percentile flow conditions, 23.8 ha were classified as low velocity (<0.5 m/s), 14.3 ha were classified as medium velocity (0.5-1.5 m/s) and 1.2 ha were classified as high velocity (>1.5 m/s). It is presumed that the majority of the 9.7 ha of unclassified aquatic habitat would be considered medium or high velocity. In the upper half of the reach, most of the centre **thalweg** is classified as medium or high water velocity, while the river margins are characterized by lower water



Site Number	Dissolved Oxygen (mg/L)	Effective Depth (m)	BURB	LKCS	LKWH	NRPK	SAUG	WALL	WHSC	YLPR	Total
1	8.53	2.5		1		1					2
2	8.40	1.6	2	9		7		2		1	21
3	10.99	2.9	2	11		10		3	2	1	29
4	10.99	2.9	1	34	1	5			11	2	54
5	10.73	2.3		1		24		3			28
6	13.50	1.8				1					1
7	13.44	2.0	1	2	1	13		1	1		19
8	13.50	1.5		4	1	4	1	2	1		13
Total			6	62	3	65	1	11	15	4	167

Figure 8-4. Location and results of overwintering studies conducted in the study area, March 2002.

Table 8-6. Comparison of mean catch-per-unit-effort (CPUE; number of fish per 100 m of net per 24 hrs) for VEC species and total catch for Wuskwatim Lake and adjacent water bodies and selected Manitoba water bodies.

Species	Wuskwatim Lake (1998 - 2001)	Churchill River[1] Pre-project (1994 - 1996)	Churchill River[1] Post-project (1999 - 2001)	Leftrook Lake[2] 1998	Split Lake[3] 1997	Split Lake[3] 1998	Cross Lake[4] (1992 - 2002)
Walleye	9.3	0.0	0.4	32.8	9.2	8.4	5.1 - 35.6
Lake whitefish	3.4	1.8	3.2	9.0	2.6	1.2	0.2 - 5.3
Lake cisco	12.3	0.2	0.2	14.1	2.5	1.6	0.6 - 21.8
Northern pike	4.0	2.9	3.6	16.7	6.9	5.2	6.0 - 22.4
Total Catch	**66.9**	**7.1**	**8.5**	**104.9**	**42.6**	**30.0**	**30.1 - 95.0**

1 - after Bernhardt (2002)
2 - Fazakas 2000
3 - Lawrence et al. 1999
4 - Cross Lake consists of East and West Cross Lakes (MacDonald and MacDonell in prep.)

Note: ranges are expressed as min and max values observed during the time period

velocities. As the river widens in the lower half of the reach, velocities are lower except in the last 150 m or so just upstream of Taskinigup Falls (Section 6.0).

Medium to high water velocities precluded the setting of gill nets in much of the reach with the exception of peripheral off-current areas; the two sites where index gill nets could be set are illustrated in Figure 8-5a. Consequently, the fish sampling results obtained from this reach are indicative of fish inhabiting off-channel habitat and not the areas of medium and high water velocity that comprise a large portion of the reach.

Overall index gillnet CPUE was 64.8 (Table 8-4), which was second highest of the four reaches sampled. However, as noted above, fish in Reach 2 likely congregate in the lower velocity habitats and, consequently, overall fish abundance within this reach is believed to be lower than the CPUE suggests.

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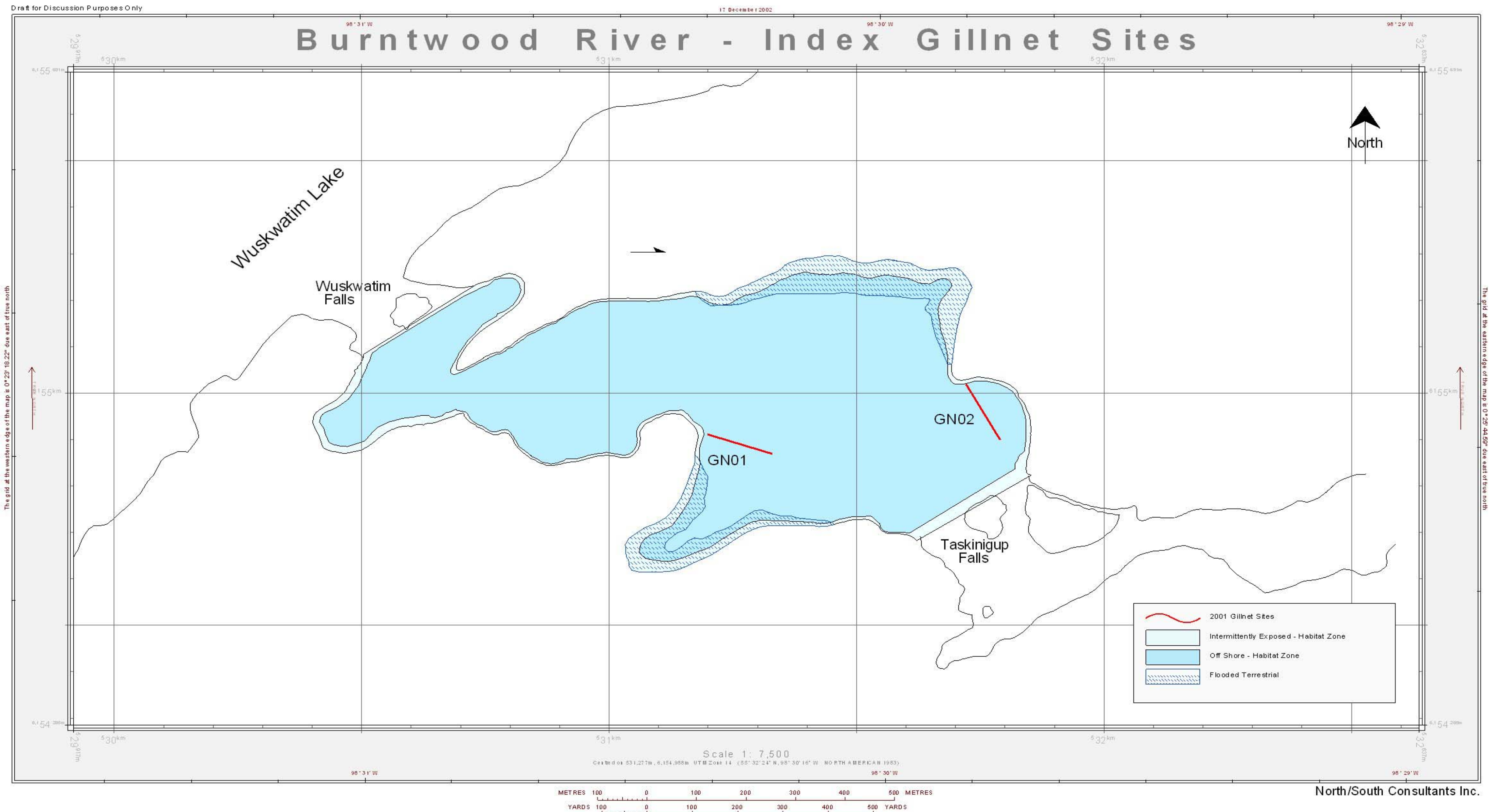


Figure 8-5a. Habitat types present in the reach of the Burntwood River between Wuskwatim Falls and Taskinigup Falls showing location of index gillnetting sites.

A total of 13 species were captured in this reach, with walleye and longnose sucker comprising the greatest proportion of the index gillnet catch (37.5% and 31.0%, respectively; Table 8-4). Lake cisco, lake whitefish, white sucker, burbot, northern pike, sauger, and yellow perch were also captured in index gill nets. Emerald shiner, spottail shiner, troutperch, and slimy sculpin were captured in larval drift traps.

Nets were set in two habitat types in this reach with the only difference in the habitat being substrate (Table 8-7). The majority of the fish species in this reach preferred the soft silt/clay-based substrate to the hard silt/clay-based substrate.

Table 8-7. Relative abundance (RA; %) and catch-per-unit-effort (CPUE; number of fish per 100 m of net per 24 hrs), by habitat type, for fish species captured in the Burntwood River between Wuskwatim Falls and Taskinigup Falls, 2001 and 2002.

Species	Number of net sets	Habitat 1[1]			Number of net sets	Habitat 2[2]		
		n	RA	CPUE		n	RA	CPUE
Burbot		5	4.4	1.9		2	0.8	0.8
Lake cisco		9	7.9	3.4		26	10.9	9.4
Lake whitefish		-	-	-		3	1.3	1.1
Longnose sucker		43	37.7	16.3		66	27.7	23.8
Northern pike		10	8.8	3.8		16	6.7	5.7
Sauger		12	10.5	4.5		22	9.2	8.1
Walleye		33	28.9	12.5		99	41.6	36.0
White sucker		2	1.8	0.8		1	0.4	0.4
Yellow perch		-	-	-		3	1.3	1.1
Total	2	114	100.0	43.2	2	238	100.0	86.3

[1] - Habitat 1 = Wetted, Mainstem, Hard silt/clay-based, No plants, Low water velocity
[2] - Habitat 2 = Wetted, Mainstem, Soft silt/clay-based, No plants, Low water velocity

Presently an unknown proportion of the Wuskwatim Lake fish community moves downstream over Wuskwatim and, in most cases, Taskinigup Falls. The results of radio- and Floy-tagging data have shown that walleye, lake whitefish, and lake cisco, and likely several other species, move downstream over Wuskwatim Falls from Reach 1 into the downstream reaches. While numbers are not known, larval fish also drift downstream out of Reach 1.

Burntwood River

The Taskinigup Falls to Opegano Lake reach is relatively deep and narrow. Ten tributaries flow into the reach and create backwater inlets that have lower water velocities than the mainstem. Below 95 percentile flow conditions, 158.5 of the 296.7 ha were classified as low velocity, 126.0 ha as medium velocity, and 12.2 ha as high velocity (Section 6). The majority of the thalweg is classified as medium or high velocity habitat while the low velocity areas are found along the stream margins and in the backwater inlets, particularly near the downstream end of the reach.

All index gillnet sites were located in low velocity habitat in the mainstem and backwater inlets (Figures 8-5b and 8-5c). Consequently, the fish sampling results are indicative of fish inhabiting lower velocity habitat, and would be expected to overestimate overall fish abundance within the reach.

The overall CPUE from this reach (34.3) was the lowest of all reaches sampled (Table 8-4). A total of 19 species were captured in this reach, including the backwater inlets (Table 8-3). Ten species were captured in index gill nets, including burbot, lake cisco, lake whitefish, longnose sucker, white sucker, northern pike, sauger, shorthead redhorse, walleye, and yellow perch. Walleye comprised 35.6% of the index gillnet catch, followed by white sucker (14.7%), and northern pike (14.4%). The remaining fish species comprised less than 10% of the catch (Table 8-4). Goldeye, lake chub, pearl dace, emerald shiner, spottail shiner, fathead minnow, ninespine stickleback, troutperch, and slimy sculpin were captured in the backwater inlets or tributary mouths in incidental gillnetting and backpack electrofishing programs.

Index gillnet sites were classified into two habitat types in this reach based on whether they were set in the mainstem of the river or within the backwater inlets. Mainstem sites consisted of various substrates from soft silt/ clay to boulder/cobble. The majority of fish species within this reach preferred backwater inlet habitat to mainstem habitat (Table 8-8).

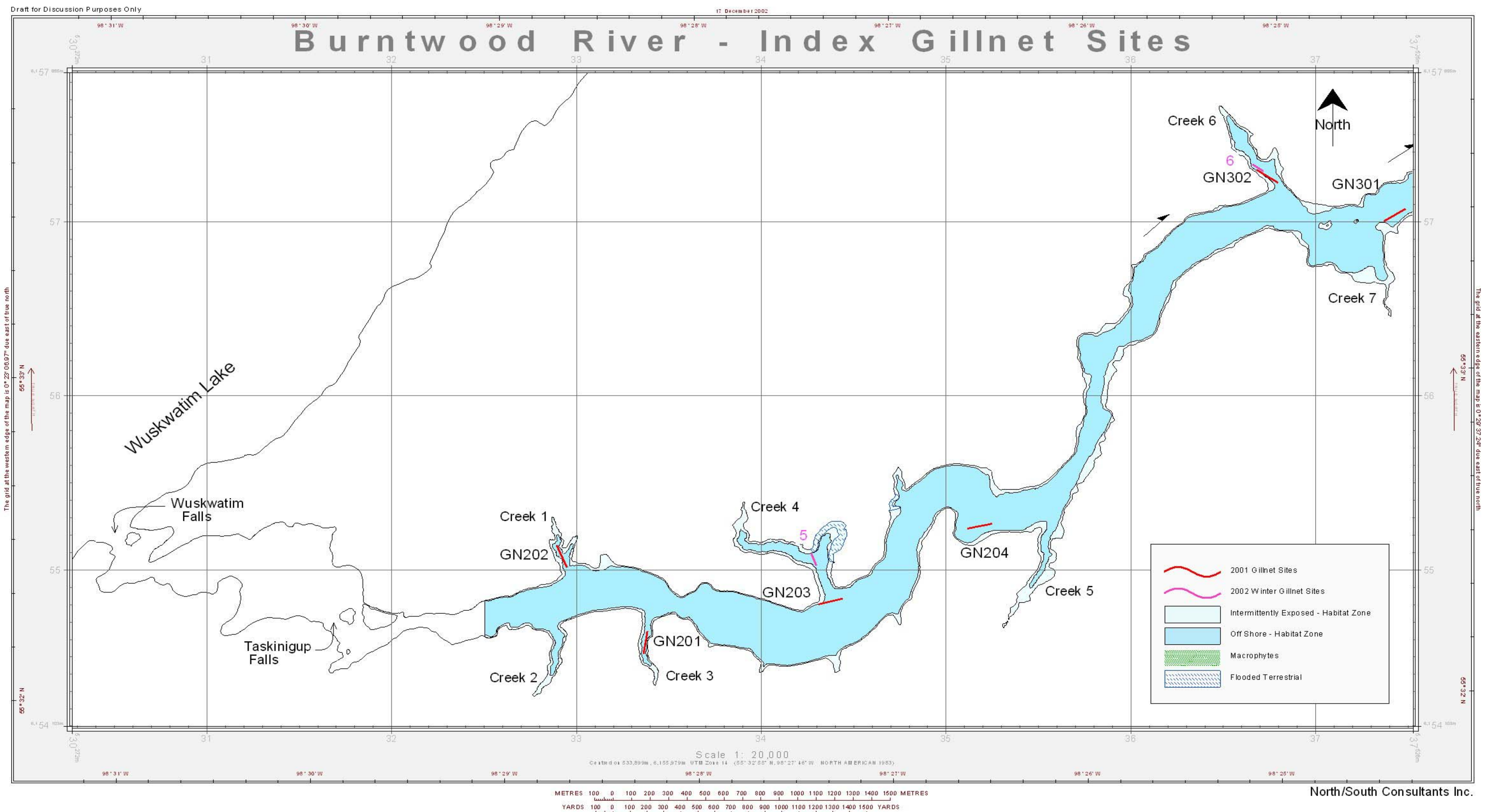


Figure 8-5b. Habitat types present in the reach of the Burntwood River between Wuskwatim Falls and Backwater Inlet 6 showing locations of index gillnetting sites.

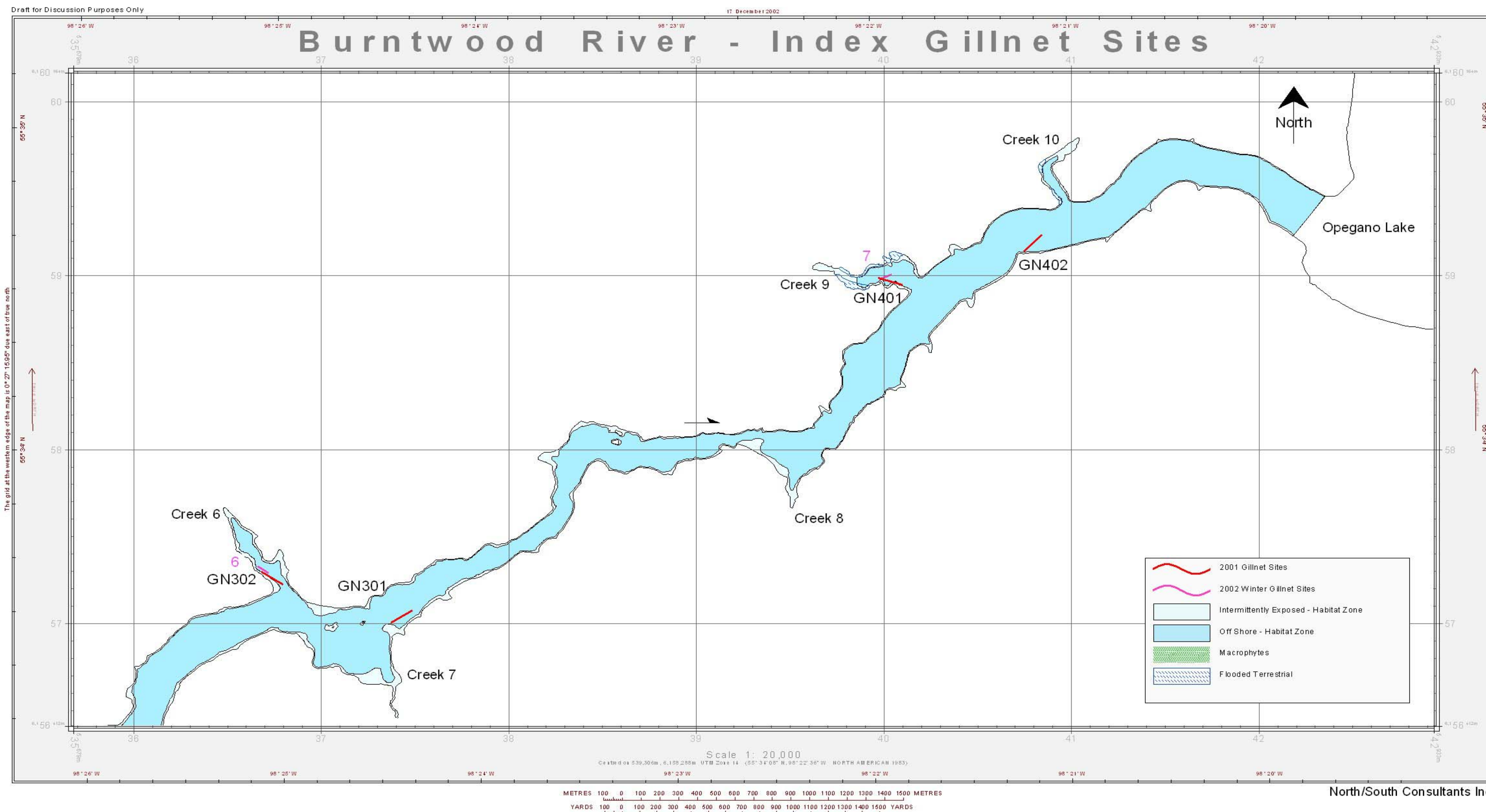


Figure 8-5c. Habitat types present in the reach of the Burntwood River between Backwater Inlet 6 and Opegano Lake showing location of index gillnetting sites.

Table 8-8. Relative abundance (RA; %) and catch-per-unit-effort (CPUE; number of fish per 100 m of net per 24 hrs), by habitat type, for fish species captured in the Burntwood River between Taskinigup Falls and Opegano Lake, 2001 and 2002.

Species	Number of net sets	Habitat 1[1]			Number of net sets	Habitat 2[2]		
		n	RA	CPUE		n	RA	CPUE
Burbot		1	0.2	0.1		6	2.9	0.6
Lake cisco		44	9.7	4.3		13	6.2	1.5
Lake whitefish		21	4.6	2.3		17	8.1	1.7
Longnose sucker		35	7.7	3.7		28	13.3	3.0
Northern pike		86	19.0	8.5		9	4.3	1.0
Sauger		24	5.3	2.4		15	7.1	1.5
Shorthead redhorse		15	3.3	1.5		7	3.3	0.8
Walleye		170	37.6	16.8		66	31.4	7.4
White sucker		52	11.5	5.6		45	21.4	5.1
Yellow perch		4	0.9	0.4		4	1.9	0.4
Total	8	452	100.0	45.6	8	210	100.0	23.1

[1] - Habitat 1 = Wetted, Backwater inlets, Soft silt/clay-based, No plants, Low water velocity

[2] - Habitat 2 = Wetted, Mainstem, Low water velocity (represents one pooled value for sites in Boulder/cobble (2 net sets), Hard silt/clay-based (2 net sets), and Soft silt/clay-based, No plants (4 net sets) substrates).

The majority of NCN members who provided Traditional Knowledge on fish movements felt that fish did not move upstream over Wuskwatim Falls or Taskinigup Falls either before or after CRD. However, there were several Elders who were familiar with the area who thought fish had been able to move upstream over Taskinigup Falls prior to CRD. Based on both Traditional Knowledge and the environmental assessment studies (radio- and Floy-tagging results), it is felt that fish do not currently move upstream over either Taskinigup Falls or Wuskwatim Falls.

Opegano

Opegano Lake is a widening of the Burntwood River channel and provides fish habitat that is intermediate between lentic and lotic conditions. Index gillnet locations are presented in Figure 8-6. Overall CPUE from index gillnetting in Opegano Lake in 2000 and 2001 was 40.3 (Table 8-4). Opegano Lake CPUE was lower than the more lentic environments of Wuskwatim Lake and adjacent water bodies (66.9), but higher than the more lotic environments of the Burntwood River between Taskinigup Falls and Opegano Lake (34.3) (Table 8-4).

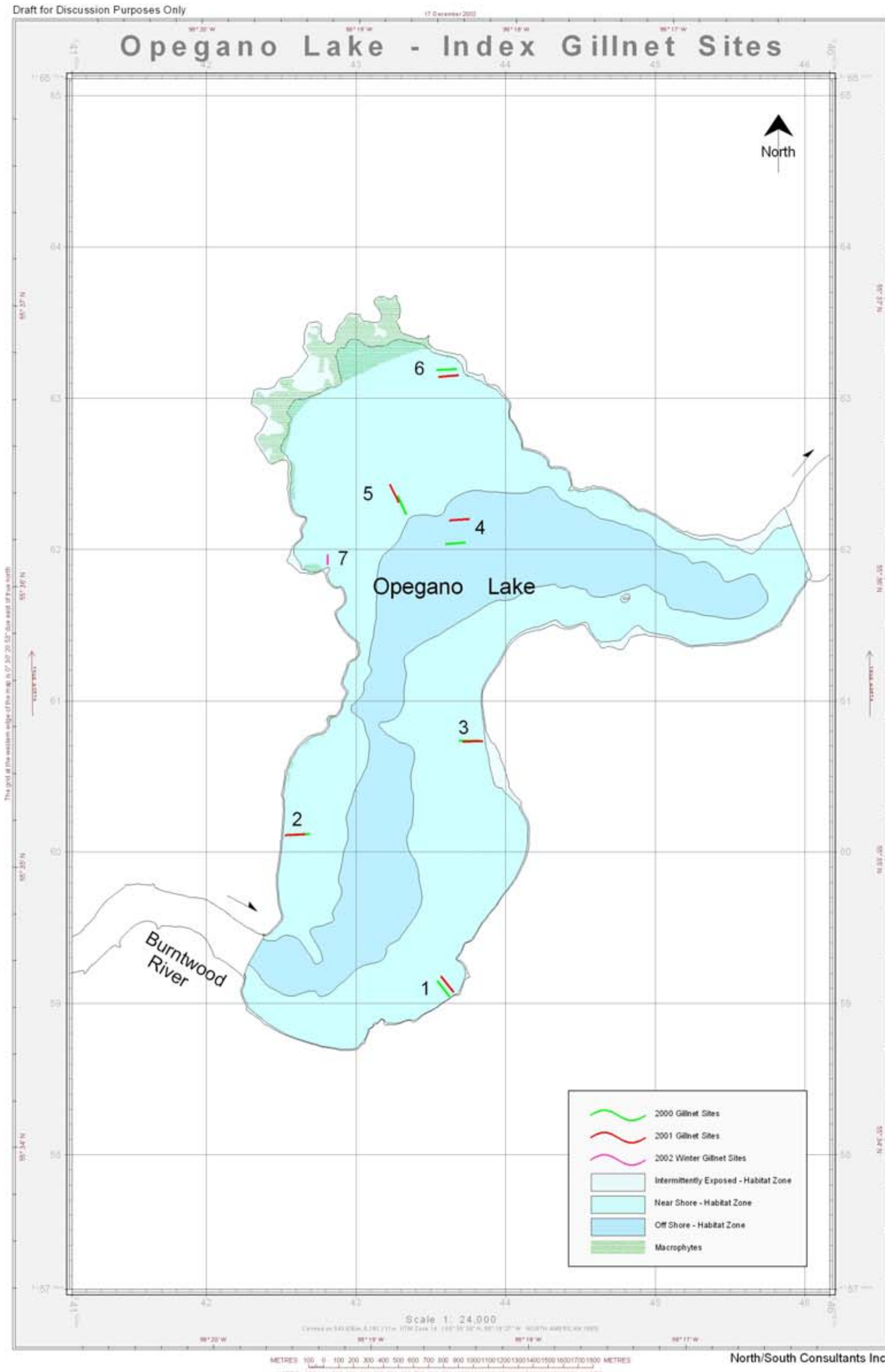


Figure 8-6. Habitat types in Opegano Lake showing locations of index gillnetting sites.

A total of 14 species were captured in Opegano Lake (Table 8-3). White sucker was the most abundant species captured in the lake, comprising 27.3% of the gillnet catch. Sauger and walleye were also fairly abundant, each comprising 22.4% of the gillnet catch (Table 8-4). Emerald shiner, spottail shiner, and ninespine stickleback were captured in larval drift traps and burbot were found in stomach contents.

Opegano Lake was classified into habitat types (Section 6.0) to examine the relationship between habitat and fish species composition, abundance, and size. Index gillnetting indicated that fish abundance was similar in the two nearshore habitat types and somewhat lower in offshore habitat (Table 8-9).

Table 8-9. Relative abundance (RA; %) and catch-per-unit-effort (CPUE; number of fish per 100m of net per 24 hrs), by habitat type, for fish species captured in Opegano Lake, 2000-2001.

Species	Number of nets	Habitat 1[1]			Number of nets	Habitat 2[2]			Number of nets	Habitat 3[3]		
		n	RA	CPUE		n	RA	CPUE		n	RA	CPUE
Lake cisco		1	1.3	0.3		11	2.5	1.1		2	2.2	0.9
Lake whitefish		7	9.1	2.5		37	8.4	3.8		11	12.4	5.6
Longnose sucker		4	5.2	1.6		3	0.7	0.3		-	-	-
Northern pike		-	-	-		40	9.1	3.8		18	20.2	8.5
Shorthead redhorse		4	5.2	1.6		6	1.4	0.6		-	-	-
Sauger		11	14.3	4.4		106	24.2	10.0		18	20.2	8.1
Goldeye		-	-	-		-	-	-		1	1.1	0.4
Walleye		13	16.9	4.7		92	21.0	8.7		30	33.7	14.7
White sucker		36	46.8	13.5		121	27.6	12.1		8	9.0	3.8
Yellow perch		1	1.3	0.3		22	5.0	2.2		1	1.1	0.5
TOTAL	2	77	100.0	29.0	8	438	100.0	42.5	2	89	100.0	42.5

[1] - Habitat 1 = Offshore, Soft silt/clay-based, No plants
[2] - Habitat 2 = Near shore, Soft silt/clay-based, No plants
[3] - Habitat 3 = Nearshore, Flooded terrestrial, No plants

Road Crossings

A total of five species were captured using backpack electrofishing at the eight road crossings during early spring, 2002. All eight sites contained fish, with a maximum of four species recorded at any one site. Water **conductivity** was measured at five of the crossings and ranged from 74.5 to 177.0 µS/cm (Appendix 5), which is in the range of conductivities (100 to 500 µS/cm (Reynolds 1983)) most effective for electrofishing. No VECs were captured at any of the eight sites during spring, likely because these sites are isolated from larger tributaries due to impassable debris and beaver dams (Section 6). The species captured were brook stickleback, fathead minnow, pearl dace, lake chub, and white sucker (Table 8-10). Information collected during fall, 2001, also suggests that these streams provide minimal fish habitat (Section 6).

Table 8-10. Distribution of fish species captured in the Mile 17 Access Road Stream Crossings during May 2002.

Stream Crossing	Lake chub	Pearl dace	Fathead minnow	White sucker	Brook stickleback
R1	-	-	-	-	Y
R2	Y	-	Y	-	Y
R3	-	-	-	-	Y
R4	-	Y	-	-	Y
R5	-	-	-	Y	Y
R6	-	Y	-	Y	Y
R7	-	-	Y	-	Y
R8	-	Y	Y	Y	Y

Due to the small size of the streams it was not possible to assess fish populations in winter with gill nets. To provide an assessment of overwintering potential, dissolved oxygen concentrations were measured at crossings 2, 5, and 6 in March 2002. Dissolved oxygen at Crossing 5 (7.40 mg/L) was below the water quality objectives for protection of early life stages of cold-water species (9.5 mg/L for seven day average; Williamson 2001). Dissolved oxygen concentrations at crossings 2 (2.68 mg/L) and 6 (1.28 mg/L) were well below the Manitoba Water Quality Objectives for both cool- and cold-water species (Williamson 2001), suggesting poor quality overwintering habitat.

8.3.2 Walleye

8.3.2.1 General Life History and Biology

Walleye spawn in the spring generally close to ice break-up (water temperature 6 to 9^{o}C), with lake populations spawning either in tributary streams or within the lake itself (Ford et al. 1995). Spawning typically occurs in streams or shallow inshore areas (water depth < 2 m) over gravel, boulder, or rubble substrates where water flow is adequate for oxygenation and to remove waste products (i.e., at the base of rapids, falls, or riffles in streams or wind-swept shorelines in lakes) (McPhail and Lindsey 1970, Scott and Crossman 1998). Less commonly, walleye have been observed spawning over organic substrate and dead vegetation (e.g., Paimusk Creek, northern Manitoba [T. Smith, Manitoba Conservation, pers. comm.]), and over dead vegetation in marshes in Wisconsin (Priegel 1970). Walleye may not spawn in some years when water temperature is not favourable (Scott and Crossman 1998). Male walleye generally become sexually mature at two to four years of age and at approximately 340 mm, and females at three to six years of age and at approximately 370 mm (Scott and Crossman 1998). Walleye may live to 20 years in northern waters (Scott and Crossman 1998).

Walleye are tolerant of a wide range of environmental situations, but generally prefer large, shallow, semi-turbid lakes. They seek cover from sunlight under banks, sunken trees, rocky outcrops, weed beds, and by moving into deeper or more turbid waters during the day (Ryder 1977, Scott and Crossman 1998). As a result, walleye undergo diel changes in activity, migrating into shallows at night to feed and retreating to cover during the day. During summer months, walleye move into deeper water, possibly to avoid warming lake temperatures, or in response to prey movements (Bodaly 1980, Ford et al. 1995, Scott and Crossman 1998). Summer movements generally do not exceed 8 km, but movements of 100 km or more have been observed (Magnin and Beaulieu (1968) in Scott and Crossman 1998). Winter habitat preference does not change from summer, except for an avoidance of strong currents (Scott and Crossman 1998). Young walleye are opportunistic feeders, feeding predominantly on various invertebrates and smaller fish species. As they mature, their diet shifts to fish, but still take advantage of various insect hatches and crayfish (Scott and Crossman 1998).

Walleye tend to prefer turbid slow moving water in lakes and rivers, often remaining near the bottom (Scott and Crossman 1998). A 200 mm long walleye switches from a sustained swimming speed (can be maintained indefinitely) to a prolonged swimming speed (can be maintained for a period of time up to 30 minutes) at a water velocity of approximately 0.5 m/s and moves from a prolonged swimming speed to a burst swimming speed (can be maintained for a period of time up to 10 seconds) at a velocity of about 0.9 m/s (Katopodis 1993; Appendix 11). A 500 mm long walleye makes the same changes at approximately 0.85 and 1.4 m/s (Katopodis 1993; Appendix 11). The pooled critical velocity (velocity at which fish moves from sustained to prolonged swimming) for 54 walleye of various sizes was found to be 0.56 m/s (Katopodis and Gervais 1991; Appendix 11).

Walleye populations are vulnerable to overexploitation, as they are highly sought after in domestic, commercial, and recreational fisheries. Walleye are also sensitive to effects on spawning habitat which is often limited to a few locations.

8.3.2.2 Distribution, Abundance, and Habitat Use

Wuskwatim

Walleye are important to Wuskwatim Lake commercial fishers, with an average annual harvest of 1,688 kg between 1976 and 2001.

Walleye are an important component of the fish community in Wuskwatim Lake and adjacent water bodies, accounting for 6.4 and 6.6% of the index gillnet catch in 1998 and 2000, and 28.6% of the catch in 2001 (Table 8-4, Figure 8-7). The high value obtained in 2001 is due, in part, to the exclusion of some of the offshore sites in 2001 and the addition of the sites in Cranberry Lakes, Sesep Lake, and Wuskwatim Brook, where walleye were relatively more abundant. As with relative abundance, the CPUE of walleye in Reach 1 was much higher in 2001 than in 1998 or 2000 (Figure 8-8). The CPUE for walleye in Reach 1 for 1998 and 2000 was lower than that of all other reaches (Table 8-4), but with the exclusion of the offshore sites in 2001 and the inclusion of the nearshore adjacent water bodies sites, the CPUE for 2001 was higher than all other reaches except for The Falls.

Walleye in Wuskwatim Lake and adjacent water bodies appear to favour the "nearshore, no plants" habitats with the highest CPUEs recorded in "nearshore, flooded terrestrial, no plants" (CPUE of 15.7) and "nearshore, soft silt/clay-based, no plants" (CPUE of 10.9) habitats (Table 8-5). The abundance of walleye was appreciably lower in "offshore, soft silt/clay-based, no plants" habitat (CPUE of 3.9).

Telemetry studies (Section 8.3.2.3) found that the majority of radio-tagged walleye remained in the south end of Wuskwatim Lake from October to May, although two individuals moved out into the main basin of the lake. Gill nets set in Sesep Lake, Wuskwatim Brook, and Wuskwatim Lake south during March 2002 (Figure 8-4) to assess overwintering habitat in off-system areas (potentially subject to lower oxygen levels), captured small numbers of walleye in Wuskwatim Brook and the southwest bay of Wuskwatim Lake. It is expected that Wuskwatim Lake main provides an abundance of overwintering habitat and that such habitat is not limiting within this reach.

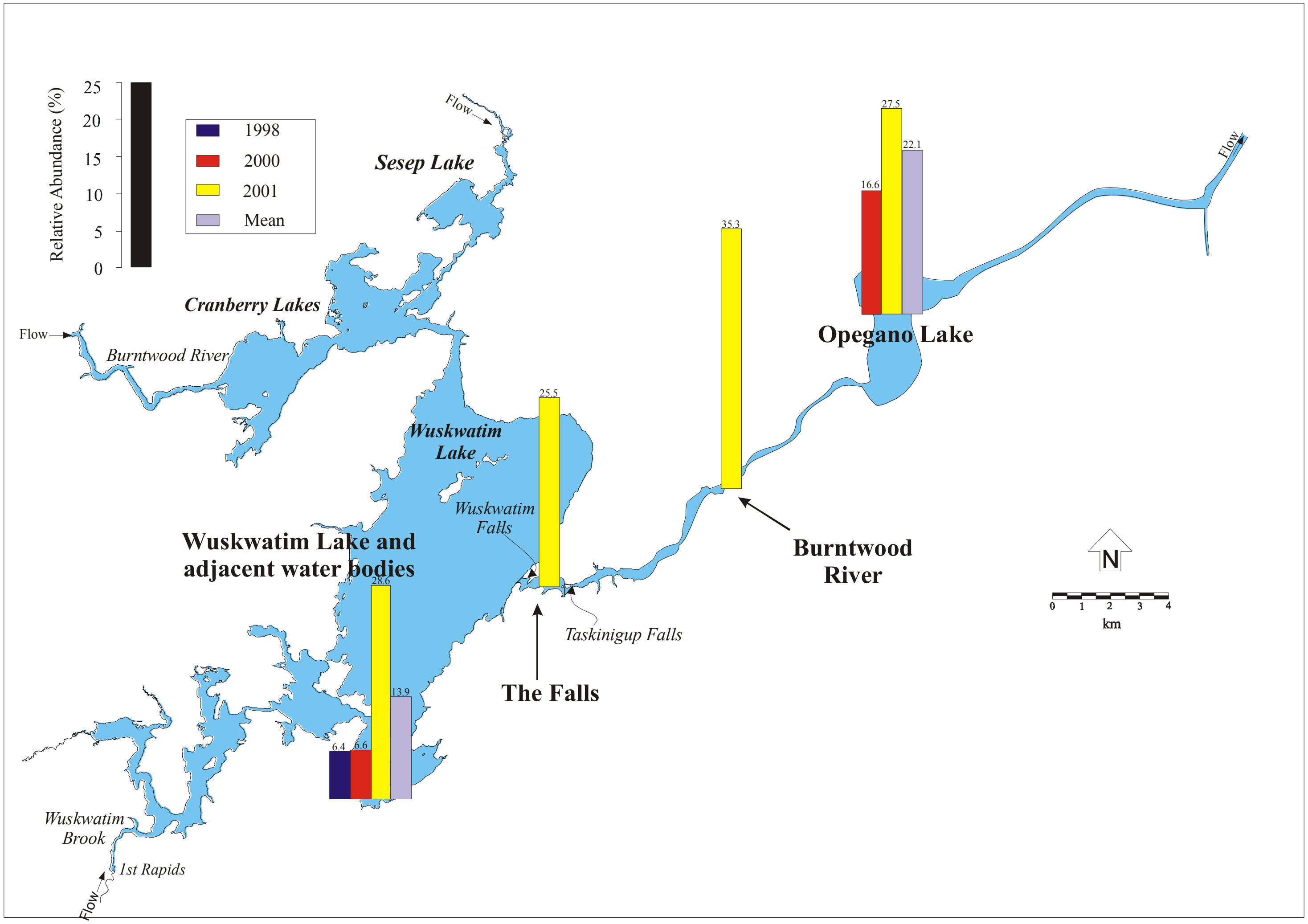


Figure 8-7. Relative abundance of walleye from index gillnetting programs conducted in the study area, 1998 – 2001.

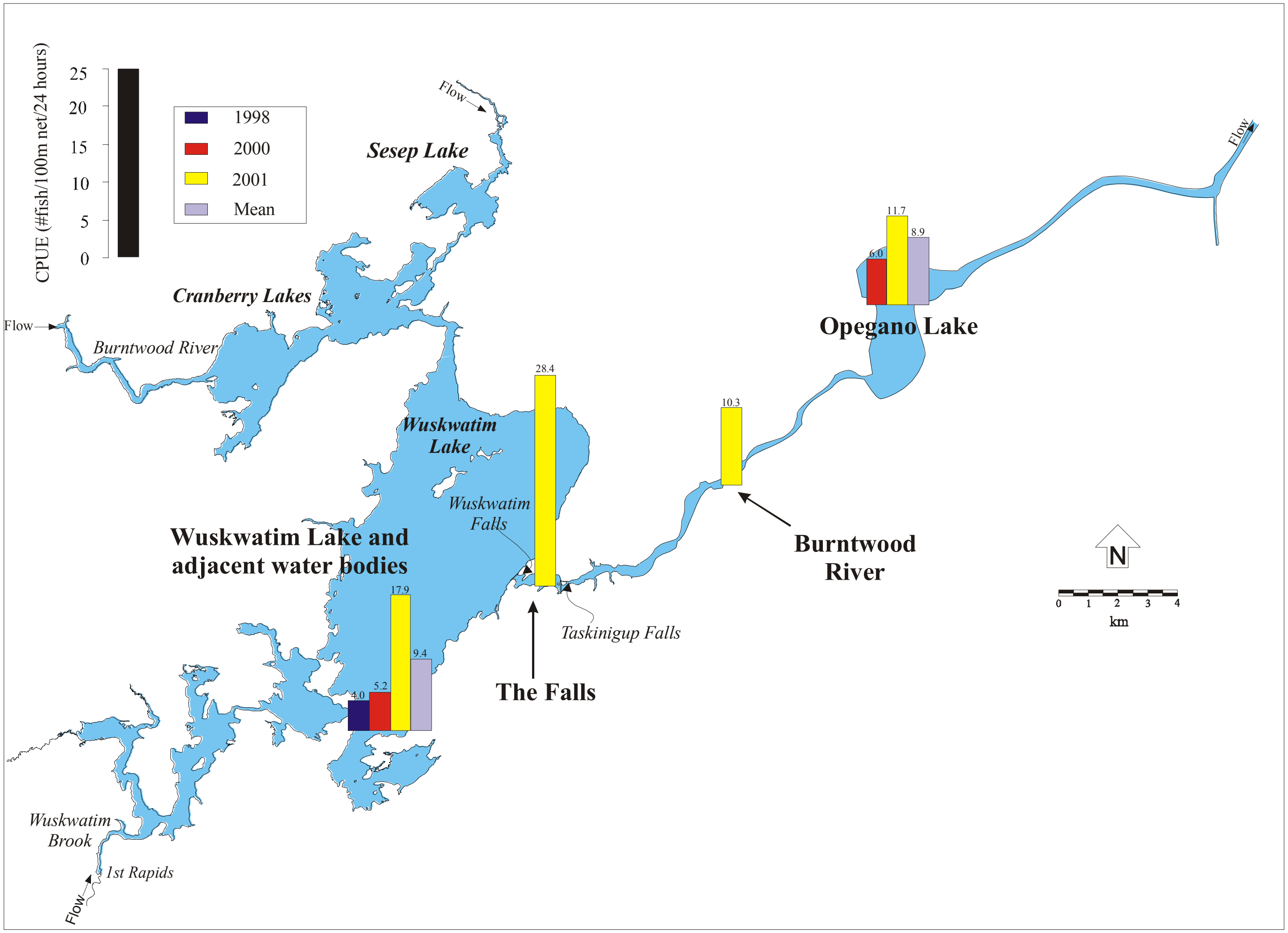


Figure 8-8. Catch-per-unit-effort of walleye from index gillnetting programs conducted in the study area, 1998 - 2001.

Based on Traditional Knowledge, Wuskwatim Brook (Figure 8-8, including upstream of the first set of rapids and in the constriction just downstream of the southwest bay of Wuskwatim Lake) was identified as a major spawning location (NCN field assistants, pers. comm., 2000). Traditional Knowledge also indicated that spawning used to occur in the Burntwood River at sites downstream of Early Morning Rapids, but not since CRD (NCN field assistant, pers. comm., 2000). Traditional Knowledge did not identify any other potential walleye spawning habitat in Wuskwatim Lake and adjacent water bodies.

During EIA studies, larval walleye were captured in drift traps set in Wuskwatim Brook, just downstream of the first set of rapids, and adult walleye in ripe and running condition were captured in downstream portions of Wuskwatim Brook and in the southwest bay of Wuskwatim Lake (Figure 8-8). Based on habitat characteristics, spawning may also occur in the lower Muskeseu River, lower velocity areas of the Burntwood River upstream of Cranberry Lakes, and along the east shoreline of Wuskwatim Lake just north of Wuskwatim Falls, although field studies have not found evidence of extensive spawning at these locations. One walleye, maturing to spawn later that spring, was captured in spring 2002 in the Muskeseu River, and a few larval walleye were collected in drift traps immediately upstream and downstream of Wuskwatim Falls in spring, 2001 and 2002. A map of potential walleye spawning habitat is presented in Figure 8-9, and a detailed description of potential spawning sites is provided in Appendix 12, Table A12-1.

Walleye captured in Wuskwatim Lake and adjacent water bodies ranged from 151 to 570 mm in length for the three years of data (Table A13-1). Mean lengths were 310 mm in 1998, 268 mm in 2000, and 378 mm in 2001, suggesting that the adjacent water bodies supported larger walleye. The mean length of walleye captured in offshore habitats was considerably smaller than that of walleye captured in nearshore habitats (Table A14-1).

Approximately half (49%) of the stomachs examined from walleye captured in Wuskwatim Lake contained fish (slimy sculpin, ninespine stickleback, yellow perch, lake cisco). Invertebrates were frequently consumed, with Ephemeroptera (mayflies) occurring in 34% of the stomachs and other invertebrates (Amphipoda [scuds], Hemiptera [water bugs], Conchostraca [clam shrimp], Decapoda [crayfish], and Odonata [dragonflies/damselflies]) occurring in the remaining stomachs with identifiable contents. Walleye captured in the adjacent waterbodies also primarily consumed fish (particularly yellow perch), with invertebrates (Amphipoda, Ephemeroptera, and Odonata) occurring in the remainder of the stomachs with identifiable contents.

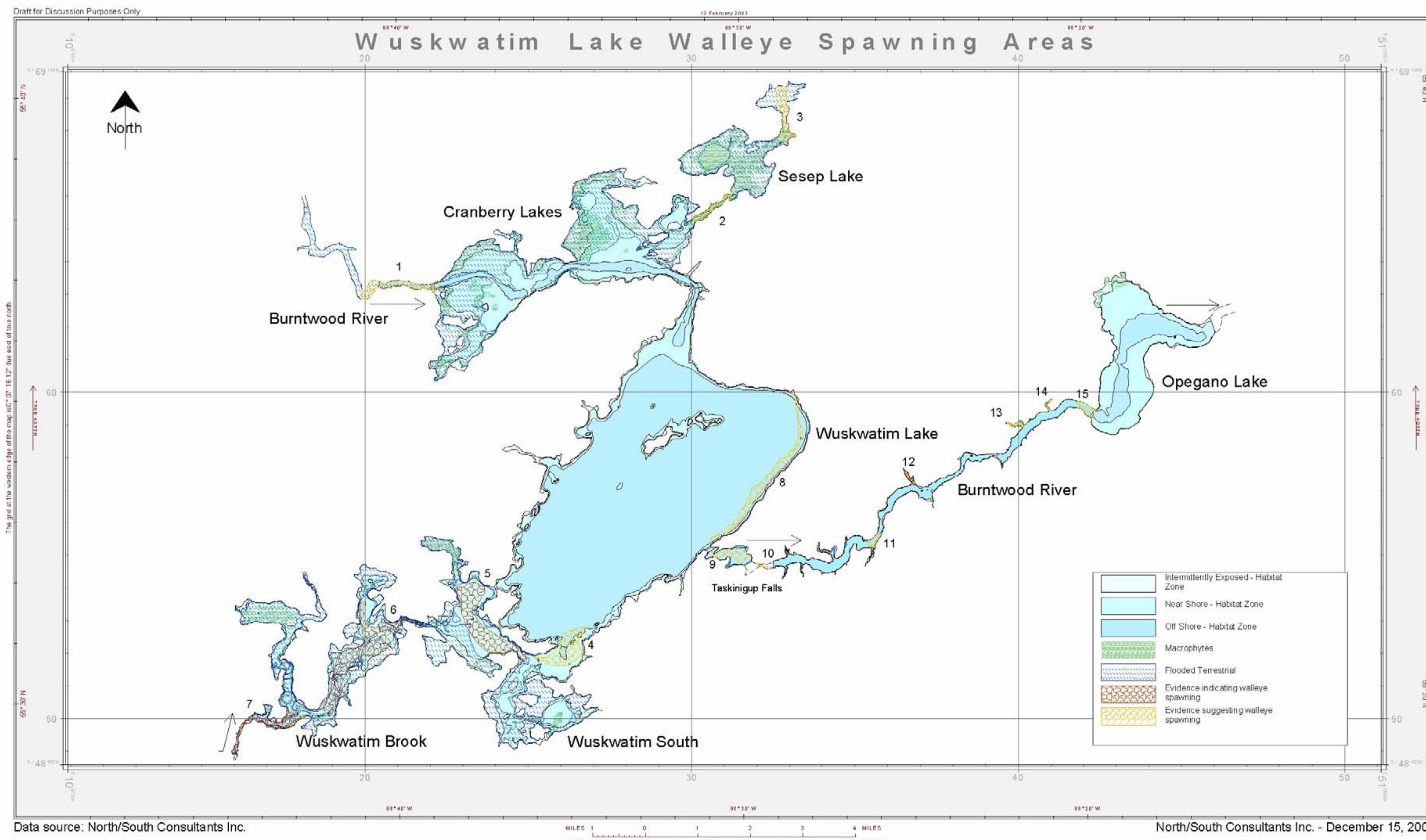


Figure 8-9. Potential walleye spawning habitat in the study area.

The Falls

The reach between Wuskwatim Falls and Taskinigup Falls provides some suitable habitat for all life stages of walleye. However, much of this small reach is characterized by medium and high water velocities and bordered by impassable barriers. Consequently, it is unlikely that individual walleye carry out their entire life cycle within the reach.

Walleye was the most abundant species in the reach in 2001 and 2002, comprising 37.5% of the index gillnet catch. Walleye CPUE (24.2) was higher in this reach than in any other reach surveyed (i.e., mean CPUE in Wuskwatim Lake and adjacent water bodies, the Burntwood River, and Opegano Lake was 9.3, 12.1, and 9.0, respectively (Table 8-4)). However, as discussed in Section 8.3.1, sampling was limited to low velocity off-channel habitat where walleye likely congregate and, consequently, the abundance of walleye within the entire reach is likely lower than the CPUE indicates. Of the two sites where nets were set, walleye preferred habitat with soft silt/clay-based substrate (CPUE = 36.0) to hard silt/clay-based substrate (CPUE = 12.5; Table 8-7).

Preferred water velocities for walleye spawning are 0.3 - 1.0 m/s (Liaw 1991), suggesting that spawning would be limited to nearshore areas and offshore portions of the lower half of the reach. Information to suggest that walleye spawned in Reach 2 was collected during spring, 2002 (North/South Consultants Inc. unpublished data). Larger numbers of larval walleye were captured downstream of Wuskwatim Falls as compared to upstream of Wuskwatim Falls and one male walleye in ripe and running condition was captured in Reach 2. While this reach does support some suitable off-current nursery habitat, it is expected that the majority of the larvae hatched in this reach drift downstream over Taskinigup Falls.

Walleye in this reach did not appear to be limited by a poor food supply, as the **condition factor (K)** of 1.19 was higher than for any other reach sampled (Table A14-4). Diet was primarily composed of fish, including northern pike and burbot.

It was not possible to assess overwintering habitat within Reach 2 due to unsafe conditions. However, it is expected that there is little suitable walleye overwintering habitat present within the reach.

Floy-tagging data showed movement of two tagged walleye from Wuskwatim Lake downstream over Wuskwatim Falls. One was caught upstream and one downstream of Taskinigup Falls (Section 8.3.2.3).

Burntwood River

Walleye were the most abundant species captured and comprised 35.6% of the index gillnet catch from the Burntwood River between Taskinigup Falls and Opegano Lake during 2001 and 2002 (Table 8-4). This section of the river appears to offer habitats suitable to fulfil all life-history requirements of walleye.

Similar to the adjacent upstream reach, gillnets could only be set in lower velocity areas (i.e., backwater inlets and embayments) (Figures 8-5b and 8-5c). Catch-per-unit-effort for walleye (12.1) was greater than Wuskwatim Lake and adjacent water bodies (9.3) and Opegano Lake (9.0), but lower than the Falls (24.2). Similar to Reach 2, walleye abundance is probably overestimated since gill nets could only be set in low velocity habitats. Walleye preferred habitat within the backwater inlets (CPUE = 16.8) to habitat within the mainstem of the river (CPUE = 7.4; Table 8-8). Walleye use these low velocity habitats, which occur within the backwater inlets and as small pockets along the margins of the main channel (figures 8-5b and 8-5c), to conserve energy and to feed.

A gillnetting survey conducted during spring 2002 found no evidence that walleye were utilizing tributaries in this reach for spawning. However, a single larval walleye was subsequently captured in a drift trap set in the tributary draining into Backwater Inlet 6, indicating that at least some walleye spawning occurs in the tributaries. Larval walleye were also captured in drift traps set at several locations in the mainstem of the Burntwood River during spring 2002. The location of these catches and the presence of suitable spawning habitat suggests that walleye spawning may occur near the base of the north channel of Taskinigup Falls, near the base of Little Jackpine Rapids, and just upstream of Opegano Lake.

Despite adequate depth and oxygen levels, medium and high water velocities would limit the suitability of much of this reach for overwintering. Walleye were captured in two of the three backwater inlets where gill nets were set during March 2002 (Figure 8-4), indicating that at least some walleye overwinter within the reach.

Opegano

Walleye comprised an average of 22.4% of the index gillnet catch from Opegano Lake in 2000 and 2001, and, together with sauger, were the second most abundant species captured (white sucker were the most abundant [27.3%]) (Table 8-4). Walleye CPUE from Opegano Lake (9.0) was lower than all other reaches in the study area (Table 8-4). Walleye preferred nearshore to offshore habitat, and showed a strong preference for "nearshore, flooded terrestrial, no plants" habitat (Table 8-9).

Although specific walleye spawning habitat was not identified in Opegano Lake, the Burntwood River inlet appears to provide suitable conditions. Walleye in Opegano Lake may also travel further up the Burntwood River to spawn. Two walleye were captured in Opegano Lake during March 2002 (Figure 8-4), indicating that at least some walleye overwinter in Reach 4.

Dietary analysis revealed that in Opegano Lake, walleye consumed several species of fish (emerald shiner, ninespine stickleback, burbot, white sucker, lake cisco, northern pike, yellow perch and sauger), as well as several groups of invertebrates (Amphipoda, Hemiptera, Chironomidae [midges], Decapoda, Trichoptera [Caddisflies], Odonata, and Ephemeroptera).

Road Crossings

No walleye were captured at any of the eight stream crossings and are not expected to be present due to the numerous blockages to fish passage and the absence of suitable habitat.

8.3.2.3 Movements

Of the 683 walleye that were Floy-tagged between 1999 and 2002, 33 individuals were recaptured by fall 2002 (Table 8-11). Six individuals had moved into a different water body from that of tagging. Two moved from the southwest bay of Wuskwatim Lake downstream into the Burntwood River between May and September of 2001. One of these walleye was recaptured upstream of Taskinigup Falls; the other downstream of Taskinigup Falls. The remaining four fish moved between Cranberry Lakes and Wuskwatim Lake. One of these fish moved approximately 19.4 km within three days after being tagged.

Table 8-11. Number of walleye Floy-tagged and recaptured in the study area, 1999-2002.

Tagging Location	Location code	Number Tagged	Number Recaptured/Location 1	2	3	4	5	6	7	Total Number Recaptured	Percent Recaptured
Cranberry Lakes	1	22	-	-	1	-	-	-	-	1	4.55
Sesep Lake	2	26	-	-	-	-	-	-	-	0	0
Wuskwatim Lake (including (Wuskwatim Brook)	3	584	3	-	26	1	1	-	-	31	5.31
Wuskwatim F. to Taskinigup F.	4	9	-	-	-	-	-	-	-	0	0
Taskinigup F. to Opegano Lake	5	32	-	-	-	-	1	-	-	1	3.13
Opegano Lake	6	6	-	-	-	-	-	-	-	0	-
Birch Tree Lake	7	4	-	-	-	-	-	-	-	0	0
Total		683	3	0	27	1	2	0	0	33	4.83

Floy-tagging and gillnetting studies were also conducted in areas upstream of Early Morning Rapids, including Notigi, Wapisu, Threepoint, Footprint, and Leftrook lakes, as part of the NCN/Manitoba Hydro Environmental Monitoring Program. One walleye tagged in Notigi Lake in June 2000, was recaptured in Wuskwatim Lake in September 2001, a downstream movement of 115 km.

Fourteen walleye were radio-tagged in the fall of 1999 in Wuskwatim Lake main and all 14 of these fish were relocated at least once. None moved upstream or downstream out of Wuskwatim Lake main (Table 8-12, Figure 8-10), although at least two fish moved extensively within the lake (Figure 8-11).

Table 8-12. Summary of movements of walleye radio-tagged in Wuskwatim Lake, 1999.

Year	Number Tagged	Number relocated at least once	Remained within Wuskwatim Lake	Moved upstream into another part of Reach I[2]	Moved downstream over Wuskwatim Falls only	Moved downstream over Wuskwatim and Taskinigup Falls
1999	14	14	14	0	0	0

[1]Fish were tagged in September/October 1999 and tracked between October 1999 and May 2000.
[2]No tagged fish were recaptured upstream of Early Morning Rapids. These movements include those fish that moved upstream into Wuskwatim Brook, Cranberry Lakes, or into the Muskeseu River system.

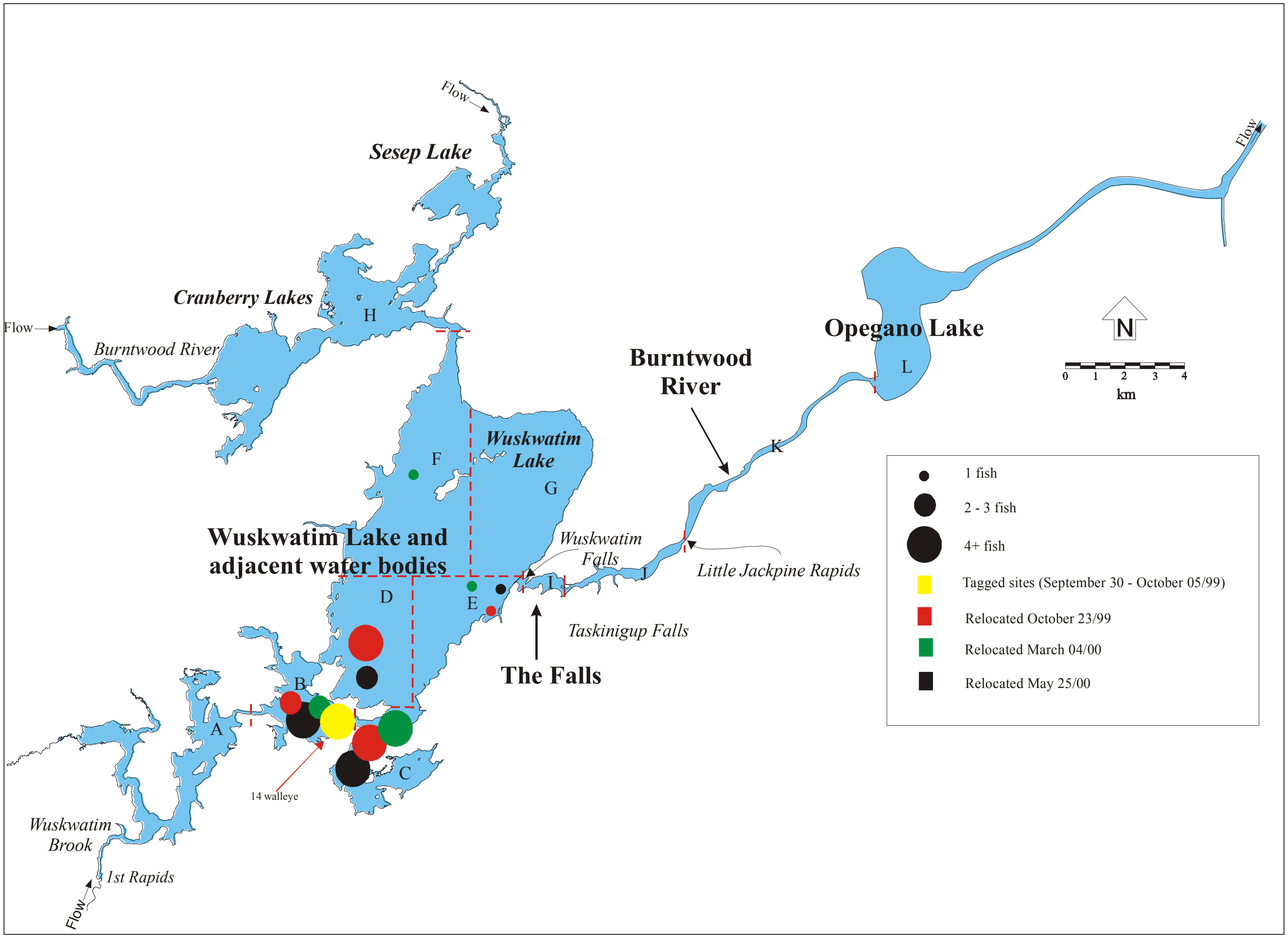


Figure 8-10. Tagging and relocation sites of all 14 walleye radio-tagged in the study area, 1999.

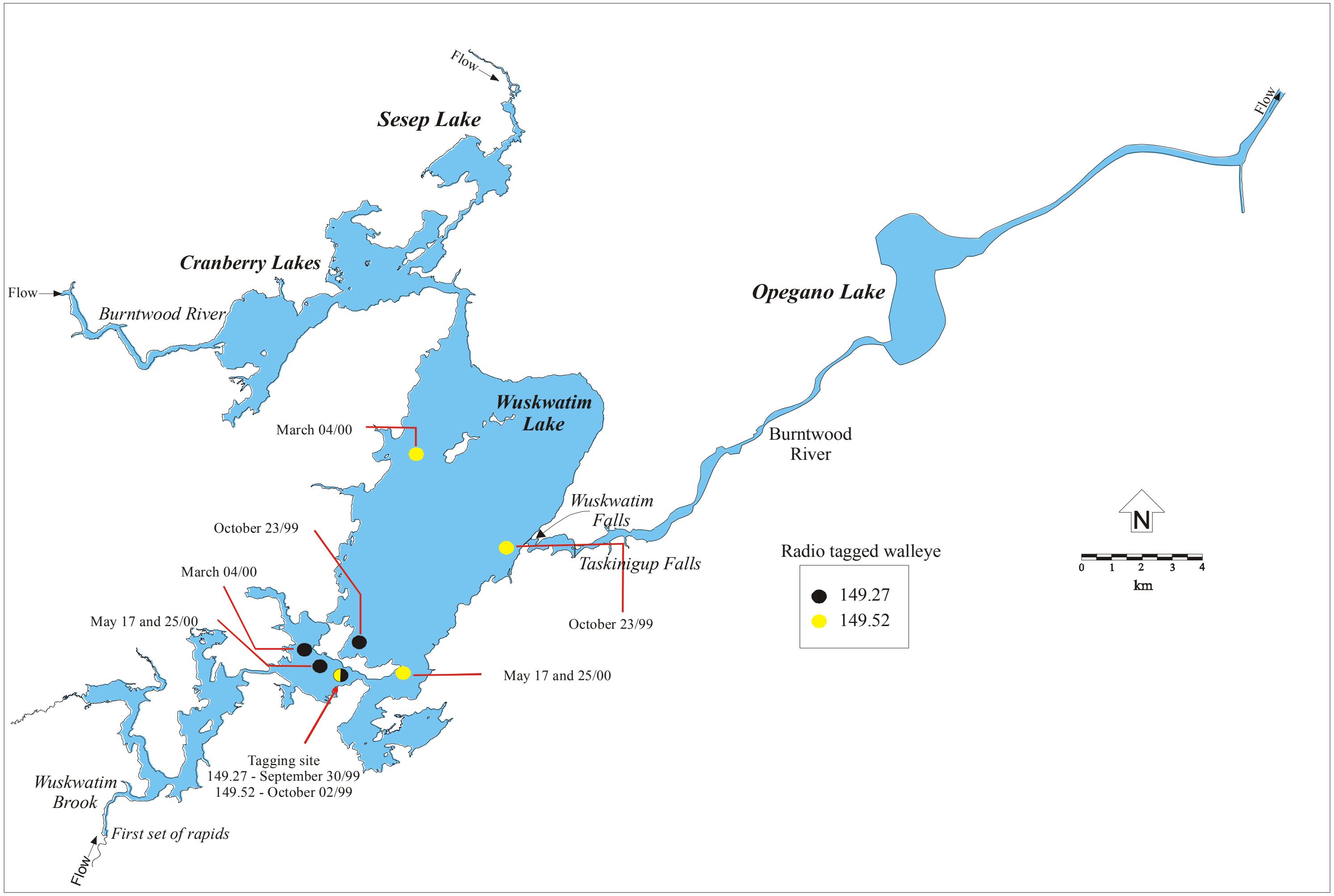


Figure 8-11. Movements observed by two walleye radio-tagged at Wuskwatim Lake, 1999.

8.3.3 Lake Whitefish

8.3.3.1 General Life History and Biology

Lake whitefish spawn during fall once water temperatures drop below 8^{o}C (Scott and Crossman 1998). Spawning occurs in lakes (Ford et al. 1995) and in rivers (Scott and Crossman 1998). In lakes, lake whitefish generally spawn in water less than 5 m deep (Ford et al. 1995, Anras et al. 1999), with depths as shallow as 1.5 m having been documented (Weagle and Baxter 1974). In rivers, water depth for lake whitefish spawning may be as shallow as 1 m (Green and Derksen 1987). A wide variety of substrates are used for spawning, ranging from large boulders to gravel and sand (Lawrence and Davies 1978, Fudge and Bodaly 1984, Anras et al. 1999); use of silt substrates with emergent vegetation has also been documented (Bryan and Kato 1975). Lake whitefish reach sexual maturity between ages six and seven at approximately 360 mm in length, with individuals not necessarily spawning every year (Scott and Crossman 1998).

Lake whitefish eggs incubate over winter, hatching some time between March and May (Scott and Crossman 1998). After emerging from the substrate, lake whitefish larvae are planktonic for a period that may last several weeks. Initially located in the vicinity of the spawning location, they soon become widely distributed by wind and currents. During their larval period, lake whitefish have little control over their direction of movement, although they are able to control their buoyancy, typically rising to the surface in the evening and descending again in the morning (Cucin and Faber 1985 *In* Richardson et al. 2001). Post-larval juveniles remain in shallow water where they can use a variety of substrates, provided that cover is available (Ford et al. 1995). Young-of-the-year whitefish generally move from shallow inshore waters to deeper water by early summer (Scott and Crossman 1998).

Adult lake whitefish typically occur in deep, cold-water lakes, where they are found at depths greater than 10 m over a wide variety of substrates. Whitefish are a **demersal** species, spending most of their time near bottom. However, they have been observed moving into shallow water habitats periodically, usually at night, to feed (Anras et al. 1999). Lake whitefish are a schooling species, with large schools often found in a very small area. Movements greater than 150 km have been observed, but movements are generally considerably less (Scott and Crossman 1998). Lake whitefish are typically bottom feeders, but pelagic feeding and surface feeding have been observed (Scott and

Crossman 1998). Benthic invertebrates are the preferred dietary item, but fish, zooplankton, and terrestrial invertebrates are also consumed.
As a species that uses **sub-carangiform locomotion**, lake whitefish swimming speeds are very similar to those of walleye, with shifts from sustained to prolonged swimming and from prolonged to burst swimming at comparable velocities (See Section 8.3.2.1; Appendix 11). Critical velocity for whitefish is 0.55 m/s (Katopodis and Gervais 1991; Appendix 11).

Lake whitefish prefer cold water and, consequently, are sensitive to increases in water temperature at depth, as well as oxygen depletion. Spawning areas are particularly vulnerable, as eggs remain on the substrate for the entire winter where they are vulnerable to water level fluctuations (eggs may become exposed and frozen if water levels decline significantly between late fall and late winter), oxygen depletion, and sedimentation. Lake whitefish may also be affected by changes in the abundance of benthic invertebrates, which are their primary food source.

8.3.3.2 Distribution, Abundance, and Habitat Use

Wuskwatim Lake

Traditional Knowledge indicates that lake whitefish are not abundant in most of Wuskwatim Lake presently, with the population scattered amongst the reefs and deeper holes. One of these areas of concentration is just southwest of Wuskwatim Falls (Volume 7, Appendix 6). Data collected from index gillnetting also indicate that lake whitefish are not a major component of the fish community of Wuskwatim Lake and adjacent water bodies, never accounting for more than 5.5% of the index gillnet catch (Table 8-4, Figure 8-12). Catch-per-unit-effort remained fairly constant at 3.3 to 3.4, a figure comparable with that of Opegano Lake and higher than that of the river reaches (Table 8-4, Figure 8-13).

Occasional large catches of lake whitefish were made (in Sesep Lake, [Habitat 3] lake whitefish were 21.7% of the catch with a CPUE of 7.0), suggesting that some concentrations do occur (Table 8-5) in Reach 1. Additionally, when only the larger panels (4.25” and 5.0” mesh) of the index gillnets were examined, lake whitefish accounted for 36% of the catch (section 8.2.2). Similarly, between 1976 and 2001, lake whitefish formed the largest component of the Wuskwatim Lake commercial catch, with an average annual harvest of 4,993 kg.

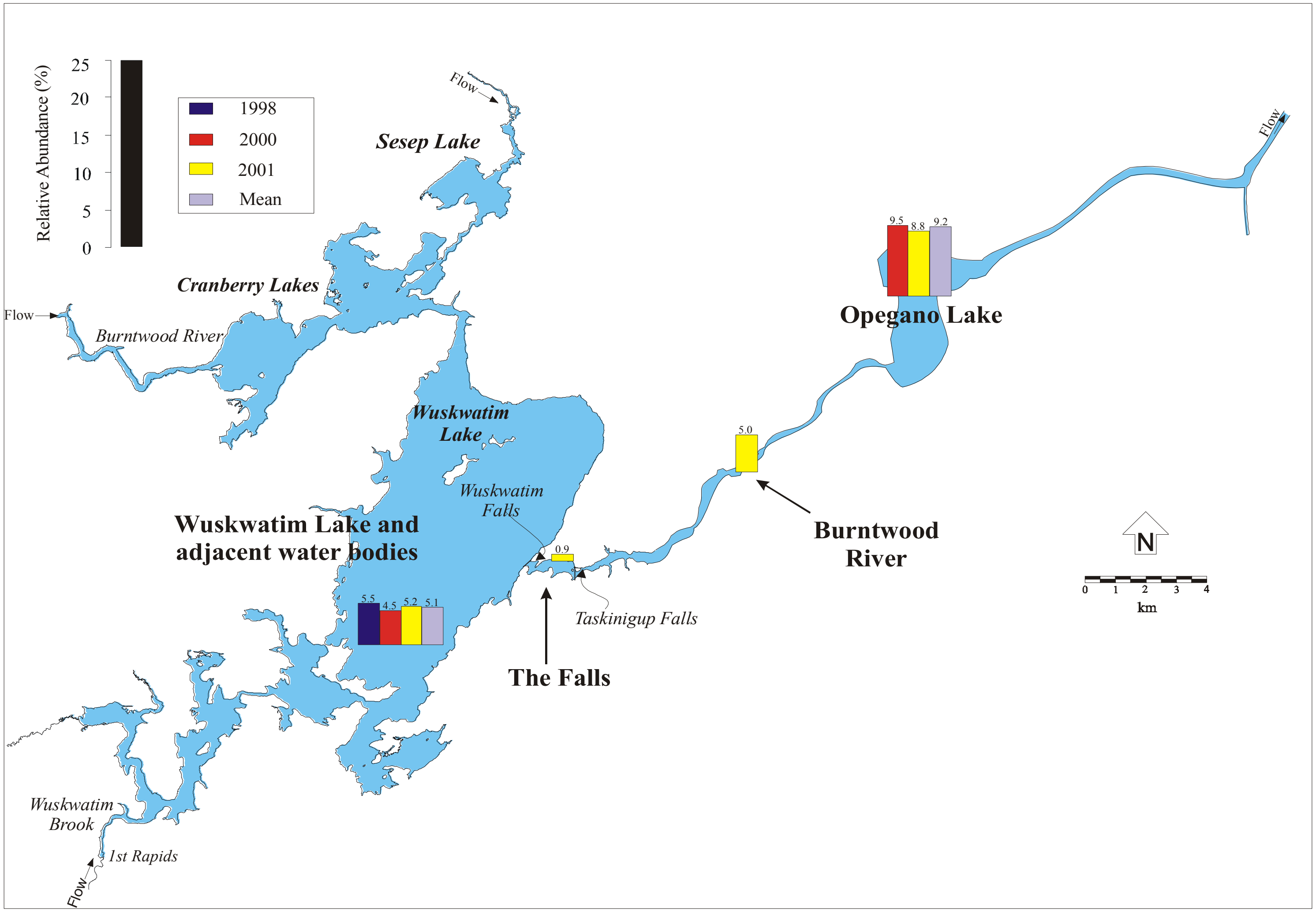


Figure 8-12. Relative abundance of lake whitefish from index gillnetting programs conducted in the study area, 1998 - 2001.

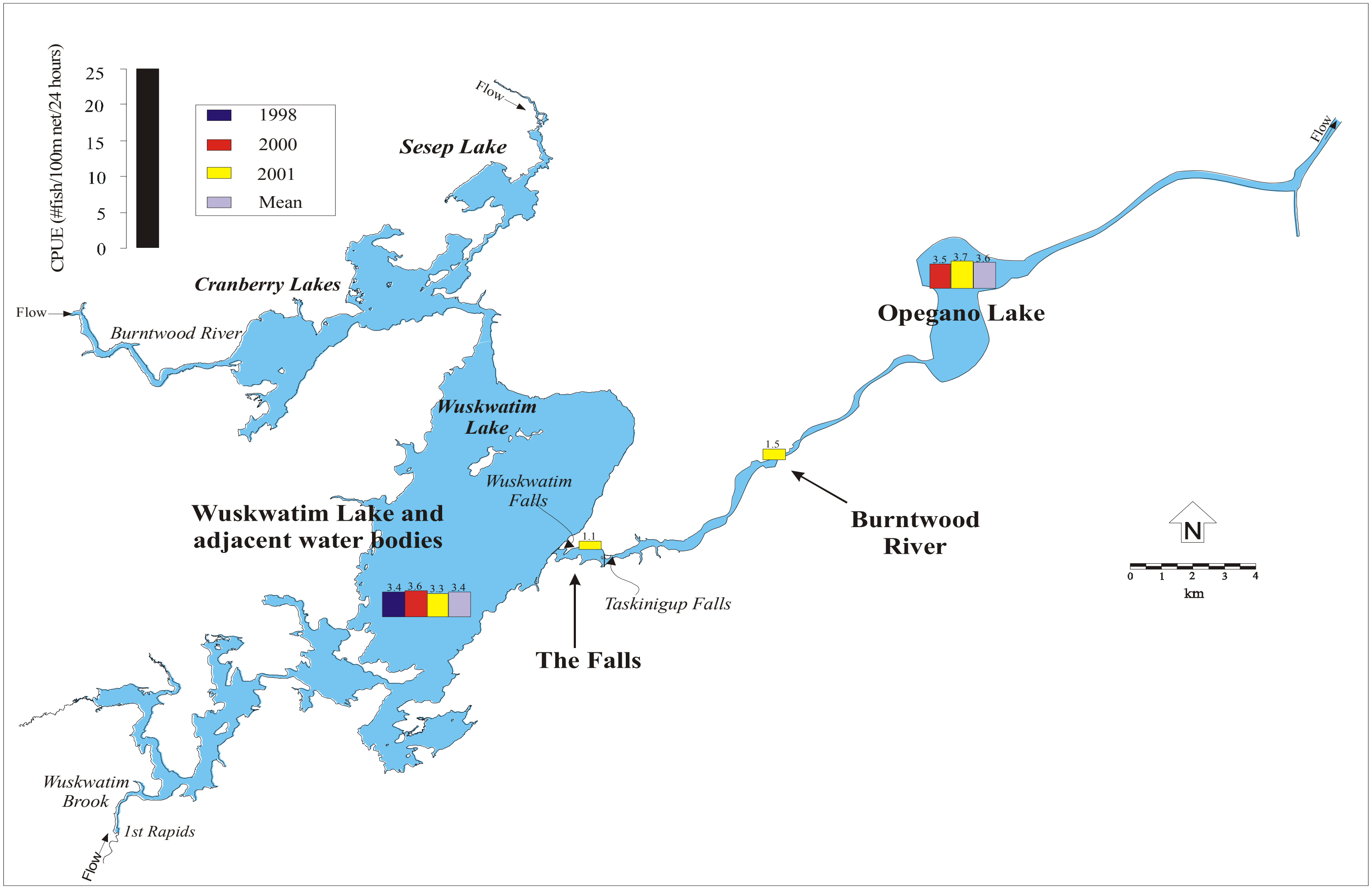


Figure 8-13. Catch-per-unit-effort of lake whitefish from index gillnetting programs conducted in the study area, 1998 - 2001.

Lake whitefish were most abundant in "offshore, soft silt/clay-based, no plants" habitat, with a CPUE of 7.6 (Table 8-5). They were much less abundant in "nearshore, soft silt/clay-based, no plants" (CPUE of 0.9) and "nearshore, flooded terrestrial, no plants" (CPUE of 2.5) habitats. Information collected from the small amount of available "nearshore, flooded terrestrial, rooted vascular plants" habitat suggests that whitefish also favour this habitat type.

Only one lake whitefish was captured in winter gillnetting of Wuskwatim Lake and adjacent water bodies (Figure 8-4). Radio-tagging data suggest that whitefish overwinter in the deeper waters of Wuskwatim Lake main (Section 8.3.3.3).

Traditional Knowledge identified the reach of the Burntwood River immediately downstream of Early Morning Rapids as a pre-CRD spawning location for lake whitefish (NCN commercial fisherman, pers. comm.). Its current status as spawning habitat was not confirmed by Traditional Knowledge, nor were any other areas in Wuskwatim Lake and adjacent water bodies identified as potential spawning habitat for lake whitefish.

Radio-tagged lake whitefish showed no overall pattern of movement to discrete areas during fall, 1999 or 2000 (Section 8.3.3.3). Tracking in 2000 showed little movement after the first week of October, suggesting that lake whitefish were in the vicinity of their spawning sites by that time. Whitefish larvae were found at many different inshore locations during early spring (i.e., recently emerged), particularly in Cranberry Lakes and along the western and southeastern shores of Wuskwatim Lake (Figures 8-14 and 8-15). Larval lake whitefish were not collected from either Sesep Lake or Wuskwatim Brook, and only small numbers of larvae were captured from Wuskwatim Lake south in 2000, making these areas unlikely lake whitefish spawning habitat. Potential spawning habitat for lake whitefish is identified in Figure 8-16, and explanations for these identifications are found in Appendix 12, Table A12-2.

The mean lengths of lake whitefish captured in index gill nets set in Wuskwatim Lake in 1998 and 2000 were consistent, with a mean length of 361 mm in both years (Table A13-1). However, the mean length of lake whitefish captured in 2001 was considerably larger (405 mm), suggesting that sites within the adjacent water bodies support a greater proportion of adult fish. There appeared to be little difference in the size of lake whitefish among habitat types (Table A14-2).

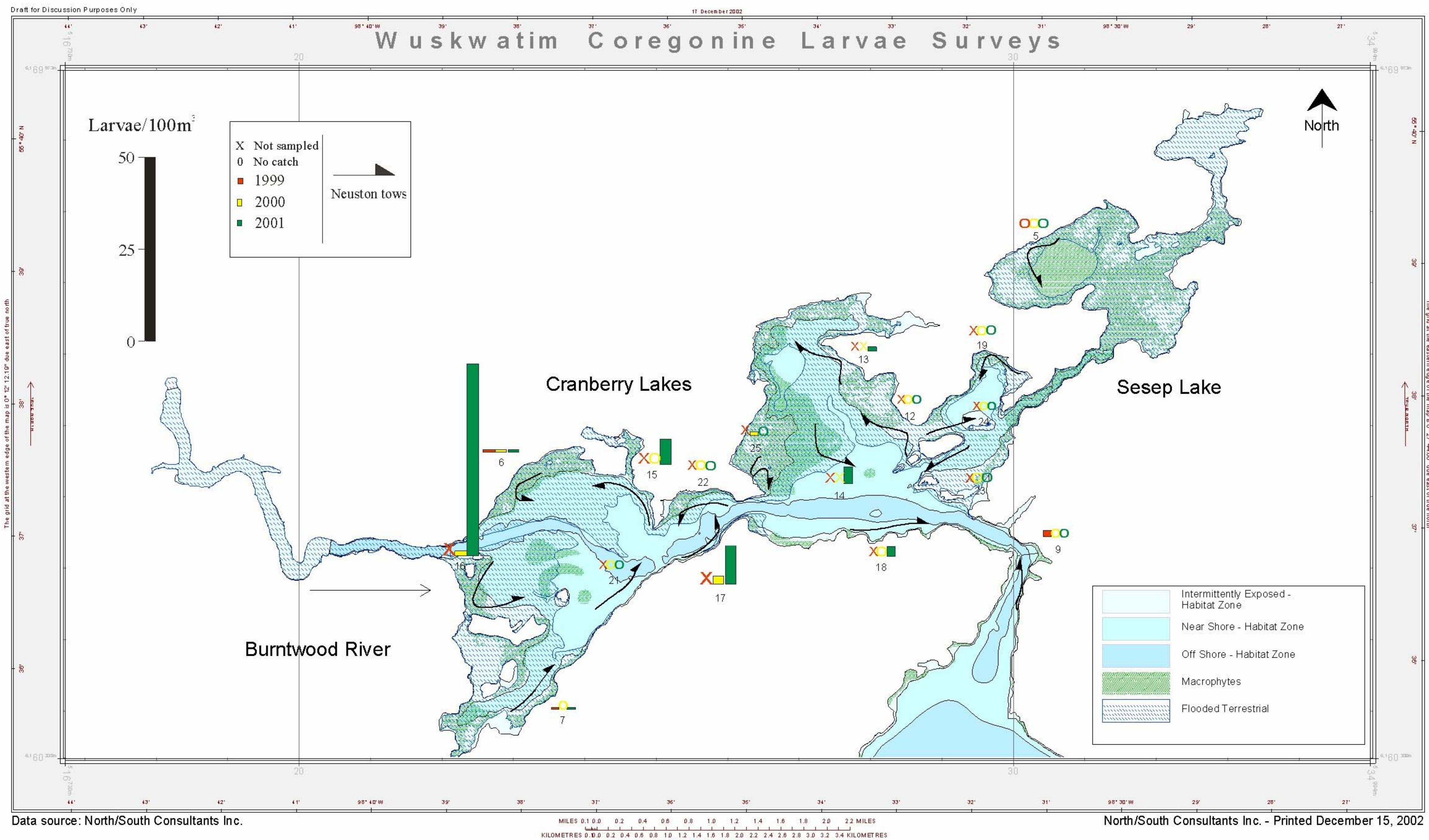


Figure 8-14. Catch-per-unit-effort of larval lake whitefish in neuston tows conducted in the Cranberry Lakes and Sesep Lake in 1999, 2000, and 2001.

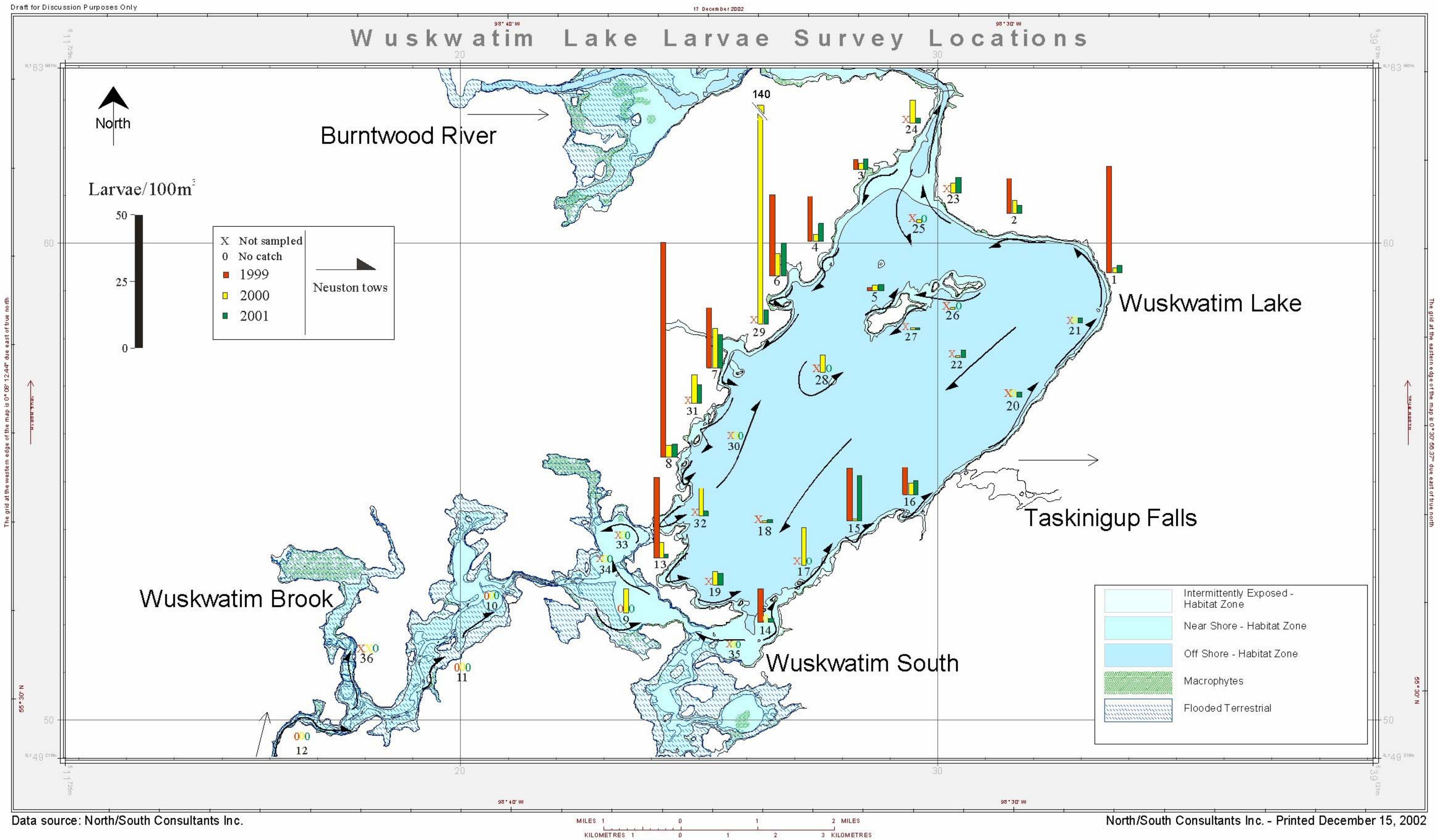


Figure 8-15. Catch-per-unit-effort of larval lake whitefish in neuston tows conducted in Wuskwatim Lake and Wuskwatim Brook in 1999, 2000, and 2001.

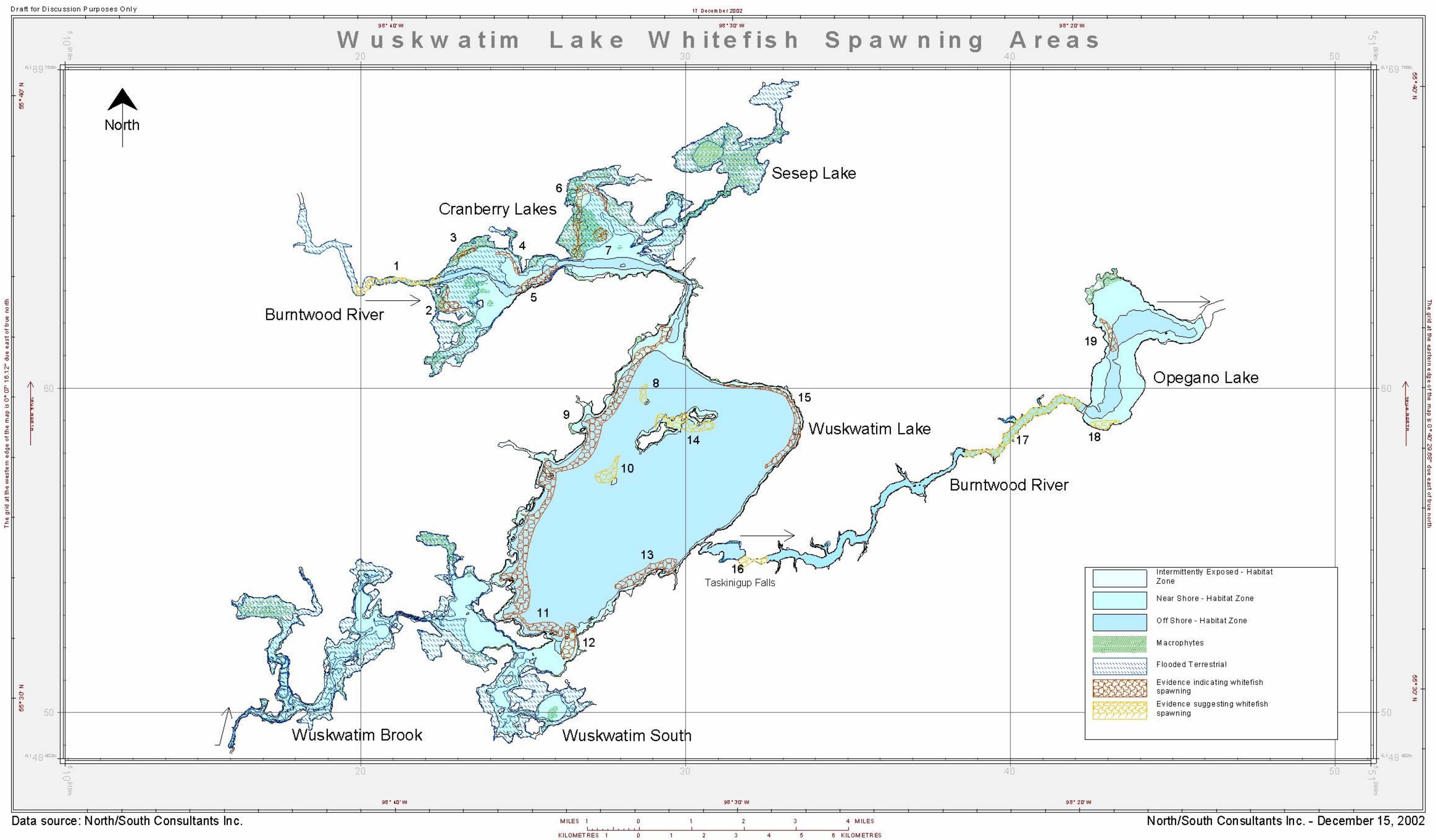


Figure 8-16. Potential lake whitefish spawning habitat in the study area.

Lake whitefish captured from 1998 to 2001 fed almost exclusively on aquatic invertebrates. Twelve taxa of invertebrates were identified from stomachs of lake whitefish captured in Wuskwatim Lake main, with Bivalvia (clams) occurring in 70% of the stomachs and accounting for 45% of the total biomass. Amphipoda were found in 19% of lake whitefish stomachs and accounted for 41% of the total biomass. The remainder of the dietary biomass was composed of Gastropoda (snails), Hemiptera, Conchostraca, Ephemeroptera, Trichoptera, Chironomidae, Ceratopogonidae (biting midges), Plecoptera (stoneflies), Chaoboridae (phantom midges), and zooplankton.

The Falls

As with most species, lake whitefish would generally avoid the medium and high water velocities found in much of this reach (Section 8.3.1). No lake whitefish were captured in two experimental gillnet sets during September 2002 (North/South Consultants Inc. unpublished data), while only three lake whitefish were captured at these same two sites in September 2001. Lake whitefish CPUE in this reach (0.5) was the lowest of any reach sampled (Table 8-4). Whitefish were only captured in "wetted, mainstem, soft silt/clay-based, no plants, low water velocity" habitat (Table 8-7). The lake whitefish that were captured were small, ranging from 300 to 350 mm in length. Conchostraca comprised 100% of the stomach contents.

Lake whitefish captured between the falls are probably transients and downstream migrants from Wuskwatim Lake and adjacent water bodies. Five of 19 (26%) successfully tracked lake whitefish radio-tagged in Wuskwatim Lake in 1999 and 2000 moved downstream over Wuskwatim Falls (Section 8.3.3.3). The large percentage of radio-tagged lake whitefish that moved downstream over Wuskwatim Falls is not believed to accurately depict movements of the population in general, and is partially attributed to stress due to the radio-tagging procedure. Of the five fish that moved downstream over Wuskwatim Falls, three (16%) continued downstream over Taskinigup Falls. The other two fish were last located in The Falls; one was relocated there once while the other fish was relocated there on six consecutive tracking flights, indicating some degree of residency (Section 8.3.3.3).

It is unlikely that any individual lake whitefish would carry out their entire life cycle between Wuskwatim Falls and Taskinigup Falls. Downstream migrations to spawning areas are uncommon, and, therefore, it is unlikely that many lake whitefish would move into the area during fall to spawn. No larval lake whitefish were captured in this reach during spring 2001 or 2002. If lake whitefish spawning did occur in the reach, it probably would occur in the peripheral off-current areas. However, larvae emerging from any successfully incubated eggs would be susceptible to being swept downstream in the current. Any juveniles that remained in the reach would also be susceptible to being swept downstream during their move to deeper water during early summer (See Section 8.3.3.1).

It was not possible to assess overwintering habitat in Reach 2 due to unsafe conditions.

Burntwood River

Lake whitefish comprised 5.7% of the index gillnet catch from this reach in 2001 and 2002 (Table 8-4). Catch-per-unit-effort for lake whitefish (2.0) was higher than the reach between Wuskwatim Falls and Taskinigup Falls (0.5), but lower than the other two reaches sampled (Table 8-4).

As discussed in Section 8.3.1 much of the habitat within this reach is classified as medium or high velocity, areas where index gill nets could not be set. Index gillnet sites were limited to backwater inlet habitat and low velocity mainstem habitat. Lake whitefish within this reach showed a slight preference for "wetted, backwater inlet, soft silt/clay-based, no plant, low water velocity" habitat (CPUE = 2.3) over "wetted, mainstem (a composite of three substrate types), no plants, low water velocity" habitat (CPUE = 1.7; Table 8-8).

No larval lake whitefish were captured in this reach during spring 2001 or 2002. Water velocities within much of the reach are likely too fast (>0.5 m/s) to provide suitable spawning habitat for lake whitefish. Critical velocity for lake whitefish (the velocity at which fish move from sustained to prolonged swimming) is 0.55 m/s (Katopodis & Gervais 1991). However, given that adult lake whitefish are found in this reach during fall, it is likely that some spawning occurs. It is suspected that some spawning may occur in low velocity habitat near the base of the north channel of Taskinigup Falls, and in the lower 5 km of Reach 3 (Figure 8-17). It is doubtful that much nursery habitat occurs within the reach as any emerging larvae are likely swept downstream in the current.

Lake whitefish comprised only 2.0% (n=1) of March 2002 gillnet catches from this reach (Figure 8-4). Although the backwater inlets would provide suitable refuge from high water velocities, lake whitefish may avoid this habitat in winter due to the high densities of predators such as northern pike. Lake whitefish using the lower portion of Reach 3 may overwinter in Opegano Lake.

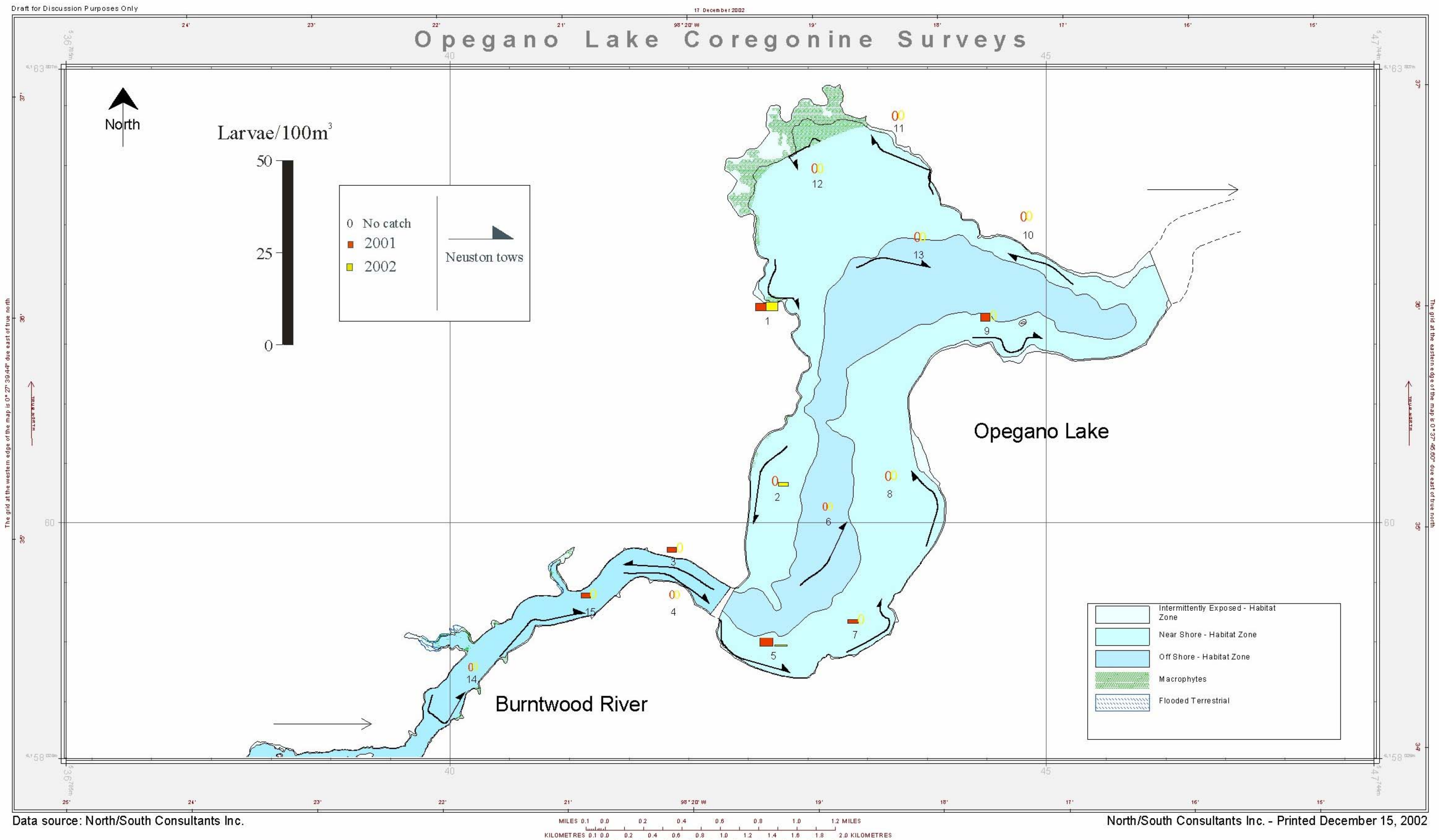


Figure 8-17. Catch-per-unit-effort of larval lake whitefish captured in neuston tows conducted in Opegano Lake, 2001 and 2002.

Opegano

Lake whitefish comprised 9.2% of the index gillnet catch from Opegano Lake in 2000 and 2001 (Table 8-4). Catch-per-unit-effort was 3.8, which was higher than that of all other reaches (Table 8-4). Lake whitefish were captured in all gillnet set locations and in all habitat types. While suitable offshore habitat was not abundant in Opegano Lake (Figure 8-6) and, consequently, did not receive much sampling effort, lake whitefish did not appear to prefer this habitat type. Lake whitefish were most abundant in flooded terrestrial habitat (Table 8-9).

Lake whitefish diet in Opegano Lake was primarily comprised of molluscs (98.6%), including *Sphaerium* sp. (fingernail clams 57.5%) and Gastropoda (41.1%). Hemiptera, Amphipoda, Ceratopogonidae, Plecoptera, Trichoptera, Hirudinae (leeches), Oligochaeta (aquatic earthworms), Chironomidae, and Conchostraca were also consumed.

Small numbers of larval lake whitefish were captured from several parts of Opegano Lake during spring 2001 and 2002 (Figure 8-17). Based on neuston sampler catches, and available habitat, a rocky shoal along the northwest shoreline of Opegano Lake was identified as spawning habitat (Figure 8-16). Other potential spawning habitat for lake whitefish inhabiting Opegano Lake include the south shoreline of the lake and lower velocity habitat within the lower 5 km of Reach 3 (Figure 8-16).

Opegano Lake has relatively deep, well-oxygenated water, with moderate to low water velocities and likely provides overwintering habitat for some of the lake whitefish inhabiting the Burntwood River between Taskinigup Falls and Jackpine Falls. One of 13 fish captured in Opegano Lake during March 2002 was a lake whitefish (Figure 8-4).

Road Crossings

No lake whitefish were captured at any of the eight stream crossings and are not expected to be present due to the numerous blockages to fish passage and the absence of suitable habitat.

8.3.3.3 Movements

A total of 69 lake whitefish were Floy-tagged in the study area between 1999 and 2002 (Table 8-13). Two of these fish were subsequently recaptured within Wuskwatim Lake main; one had been tagged in Wuskwatim Lake while one had moved downstream from the Cranberry Lakes.

Table 8-13. Number of lake whitefish Floy-tagged and recaptured in the study area, 1999-2002.

Tagging Location	Location code	Number Tagged	Number Recaptured/Location 1	2	3	4	5	6	7	Total Number Recaptured	Percent Recaptured
Cranberry Lakes	1	13	-	-	1	-	-	-	-	1	7.69
Sesep Lake	2	26	-	-	-	-	-	-	-	0	0
Wuskwatim Lake (including Wuskwatim Brook)	3	25	-	-	1	-	-	-	-	1	4.00
Wuskwatim Falls to Taskinigup Falls	4	0	-	-	-	-	-	-	-	0	-
Taskinigup Falls to Opegano Lake	5	1	-	-	-	-	-	-	-	0	-
Opegano Lake	6	4	-	-	-	-	-	-	-	0	-
Birch Tree Lake	7	0	-	-	-	-	-	-	-	0	-
Total		69	0	0	2	0	0	0	0	2	2.90

Nineteen of the 20 lake whitefish fitted with radio-transmitters in the fall of 1999 and in the spring and fall of 2000 in Wuskwatim Lake were relocated at least once. While the majority of these lake whitefish showed limited movement during October 1999 and between 24 September and 30 November 30 2000, five individuals moved downstream out of Wuskwatim Lake, with three of these five lake whitefish last located downstream of Taskinigup Falls (Table 8-14, Figures 8-18, 8-19, and 8-20). Additionally, one lake whitefish tagged in Cranberry Lakes in May 2000 moved up the Muskeseu River over the summer into a small, unnamed lake where it remained between 06 October and 30 November (Figure 8-19).

Table 8-14. Summary of movements of lake whitefish radio-tagged in Wuskwatim Lake, 1999 and 2000.

Year	Number Tagged	Number relocated at least once	Remained within Wuskwatim Lake	Moved upstream into another part of Reach I[3]	Moved downstream over Wuskwatim Falls only	Moved downstream over Wuskwatim and Taskinigup Falls
1999	4	4	2	1	0	1
2000	16	15	10	1	2	2

[1]Fish were tagged in September/October 1999 and tracked between October 1999 and May 2000.
[2]Fish were tagged from May to September 2000 and tracked between September and Novermber 2000.
[3]No tagged fish were recaptured upstream of Early Morning Rapids. These movements include those fish that moved upstream into Wuskwatim Brook, Cranberry Lakes, or into the Muskeseu River system.

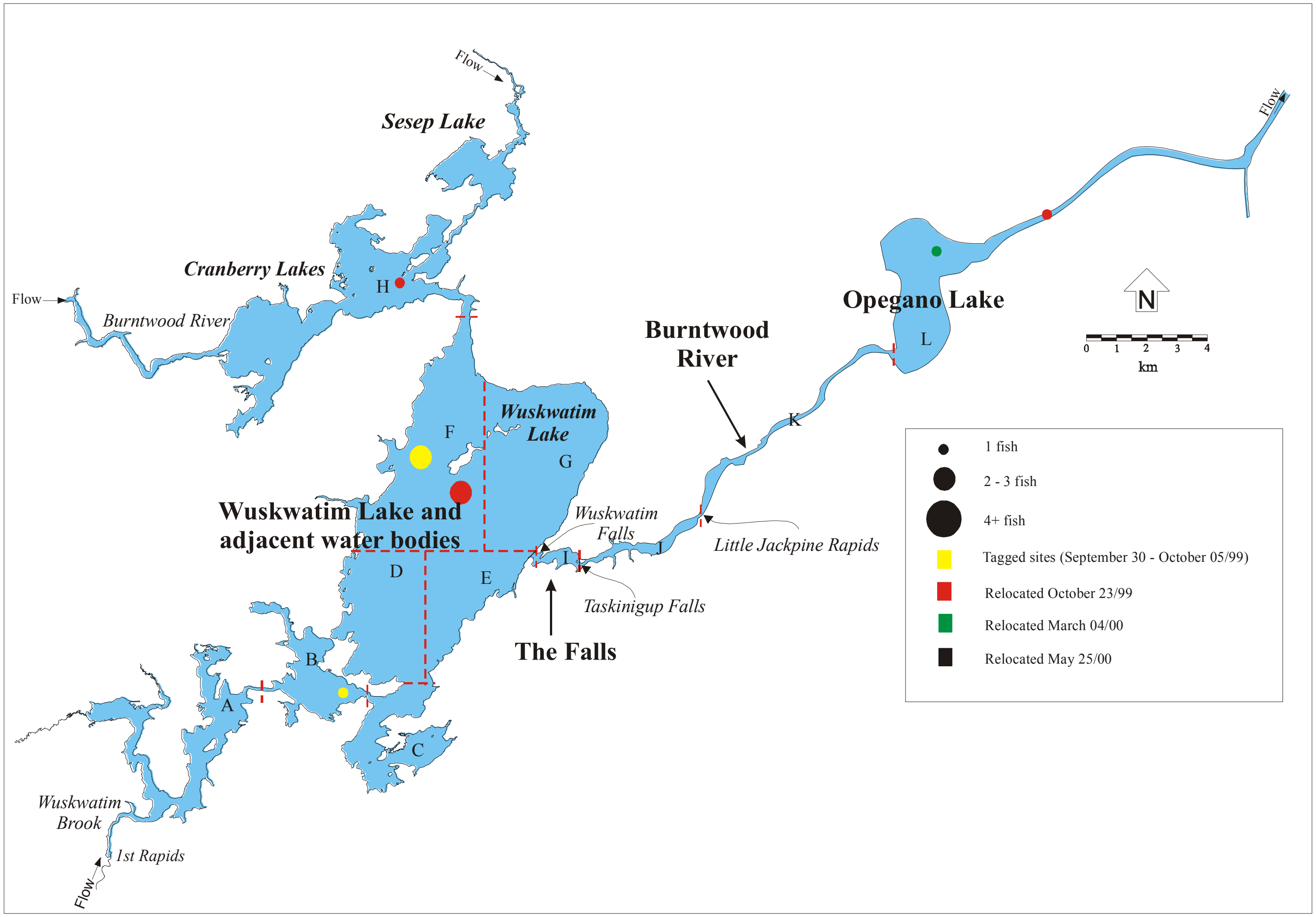


Figure 8-18. Tagging and relocation sites for four lake whitefish radio-tagged in the study area, 1999.

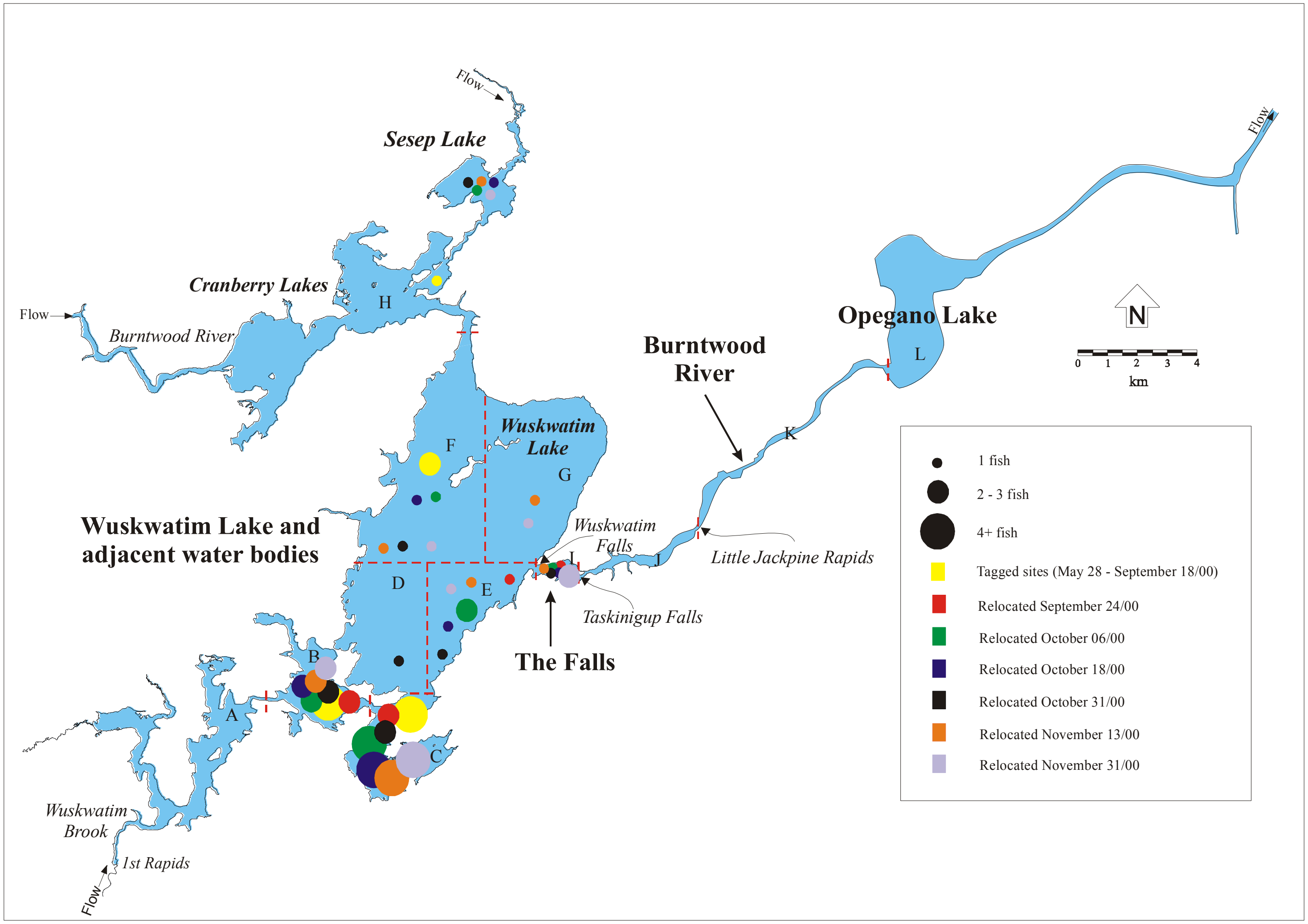


Figure 8-19. Tagging and relocation sites for 16 lake whitefish radio-tagged in the study area, 2000.

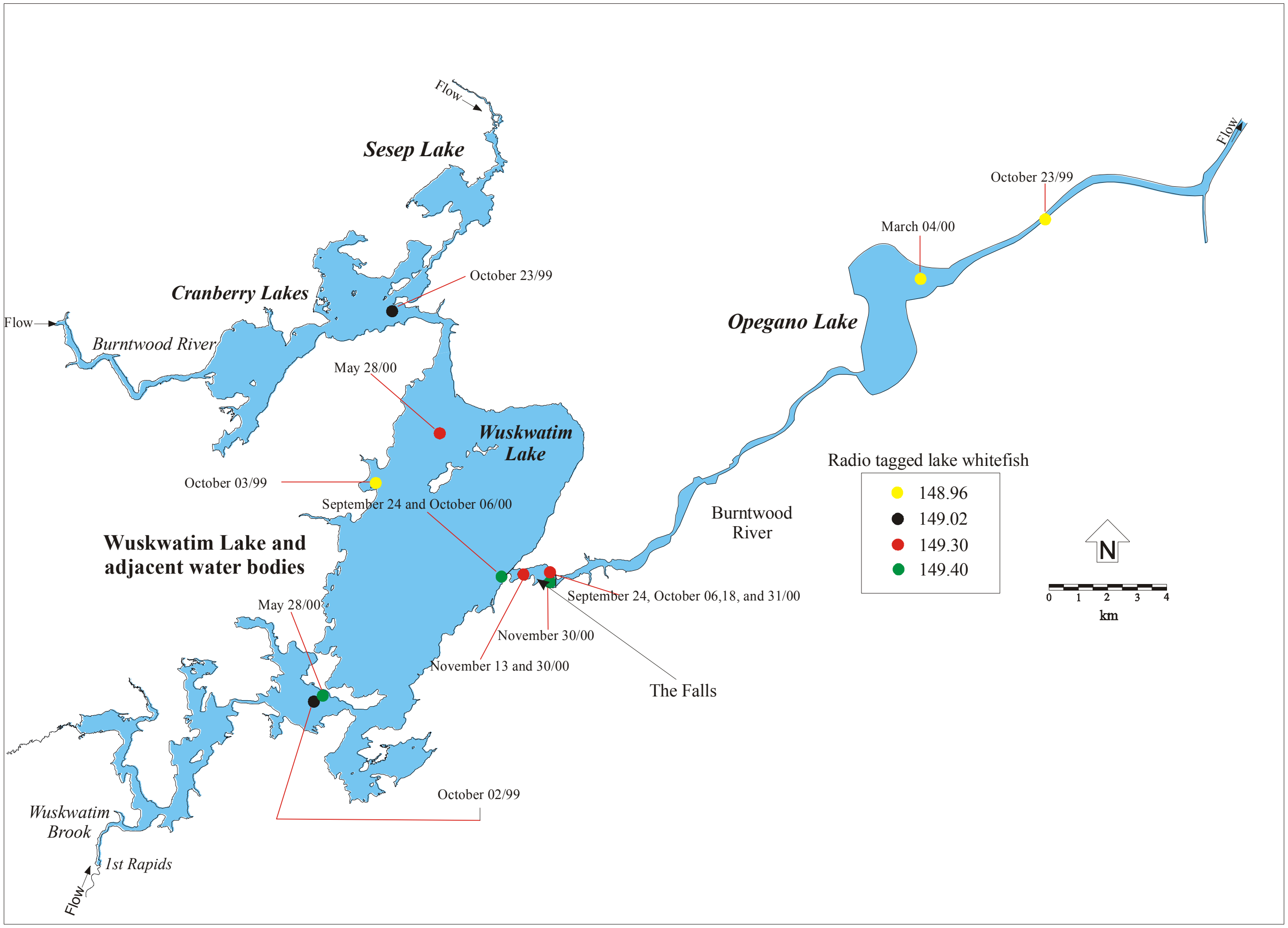


Figure 8-20. Movements observed by four lake whitefish radio-tagged at Wuskwatim Lake, 1999 and 2000.

The results of radio-tagging studies suggest that lake whitefish movements during fall are limited, with no consistent direction and distance of movement. There was no apparent migration to one or a few spatially well-defined areas during fall, suggesting that fish were already near or at potential spawning sites. Final tracking locations on 30 November 2000 suggested that the majority of lake whitefish would overwinter in Wuskwatim Lake main or Wuskwatim Lake south (Figure 8-19). No radio-tagged or Floy-tagged lake whitefish moved upstream over Wuskwatim Falls, Taskinigup Falls, or Early Morning Rapids, although one fish did move upstream into the Muskeseu River system from the Cranberry Lakes. Five lake whitefish moved downstream out of Wuskwatim Lake, two over Wuskwatim Falls, and three over both Wuskwatim Falls and Taskinigup Falls.

8.3.4 Lake Cisco

8.3.4.1 General Life History and Biology

Lake cisco spawn in fall when water temperatures fall below 6°C in lakes (Goodyear et al. 1982, Ford et al. 1995) and rivers (Roberge et al. 1985, Ford et al. 1995, Scott and Crossman 1998). In inland lakes, spawning generally occurs in water 1-3 m deep over a variety of substrates, but often gravel or boulders (Scott and Crossman 1998). In larger lakes, lake cisco spawning has been recorded in deeper water and may occur in mid-water in the Great Lakes (Scott and Crossman 1998). Lake cisco also have been shown to spawn on emergent vegetation (Colby and Brooke 1973, Cucin and Faber 1985). Eggs hatch the following spring just before ice breakup (Goodyear et al. 1982). Lake cisco tend to reach sexual maturity between the ages of two and six at approximately 250 mm in length. Males and females grow at the same rate, although females tend to live longer and obtain a larger size. Maximum age in lake cisco is approximately 15 years (Scott and Crossman 1998).

Lake cisco are predominantly a lacustrine species, although they may be found in large rivers (McPhail and Lindsey 1970, Scott and Crossman 1998). They are a **pelagic** species occurring in both shallow and deepwater areas, although they prefer deeper, cooler waters where available. Lake cisco generally move from shallower water in spring to deeper water in summer, likely in response to temperature (Scott and Crossman 1998). The diet of lake cisco follows with their pelagic nature, with the predominant food items consisting of zooplankton, drifting insects, and crustaceans, although small fish and fish eggs are consumed on occasion (Scott and Crossman 1998).

Lake cisco also employ sub-carangiform locomotion and, consequently, possess swimming speeds very comparable to those of walleye and lake whitefish. Critical velocity is not available for lake cisco.

Lake cisco are sensitive to increased temperature at depth and oxygen depletion, but less so than whitefish because lake cisco are less confined to the bottom of a water body. As with lake whitefish, lake cisco spawning areas are vulnerable due to potential egg desiccation, oxygen depletion, and sedimentation (Section 8.3.3.1).

8.3.4.2 Abundance, Habitat Use, and Biological Data

Wuskwatim Lake

Lake cisco are an important component of the Wuskwatim Lake commercial fishery (Volume 7, Section 3) and, while their numbers in the lake fluctuate, are considered one of the most abundant species in Wuskwatim Lake (Volume 7, Appendix 3).

Lake cisco are an important component of the Wuskwatim Lake and adjacent water bodies fish community, accounting for an average of 18.1% of the index gillnet catch (Table 8-4, Figure 8-21). The mean CPUE in Wuskwatim was higher than that in any other reach (Table 8-4, Figure 8-22). In the adjacent waterbodies, the catch was variable in 2001, with lake cisco forming approximately 40.0% of the Wuskwatim Brook index gillnet catch but only 5.0% of the Cranberry Lakes catch (North/South Consultants Inc. unpublished data).

Lake cisco in Wuskwatim Lake and adjacent water bodies were most abundant in "nearshore, soft silt/clay-based, no plants" habitat (CPUE = 14.6), followed by "nearshore, flooded terrestrial, no plants" habitat (CPUE = 13.1), and "offshore, soft silt/clay-based, no plants" habitat (CPUE = 8.7; Table 8-5).

Gill nets were set in Sesep Lake, Wuskwatim Brook, and Wuskwatim Lake south during March 2002 to assess overwintering habitat (Figure 8-4). While lake cisco were captured in all four locations, only one fish was captured in Sesep Lake. They were moderately abundant in Wuskwatim Brook and the southwest bay of Wuskwatim Lake and very abundant in the south bay of Wuskwatim Lake, indicating that these areas provide overwintering habitat. Wuskwatim Lake main is also expected to provide overwintering habitat for lake cisco.

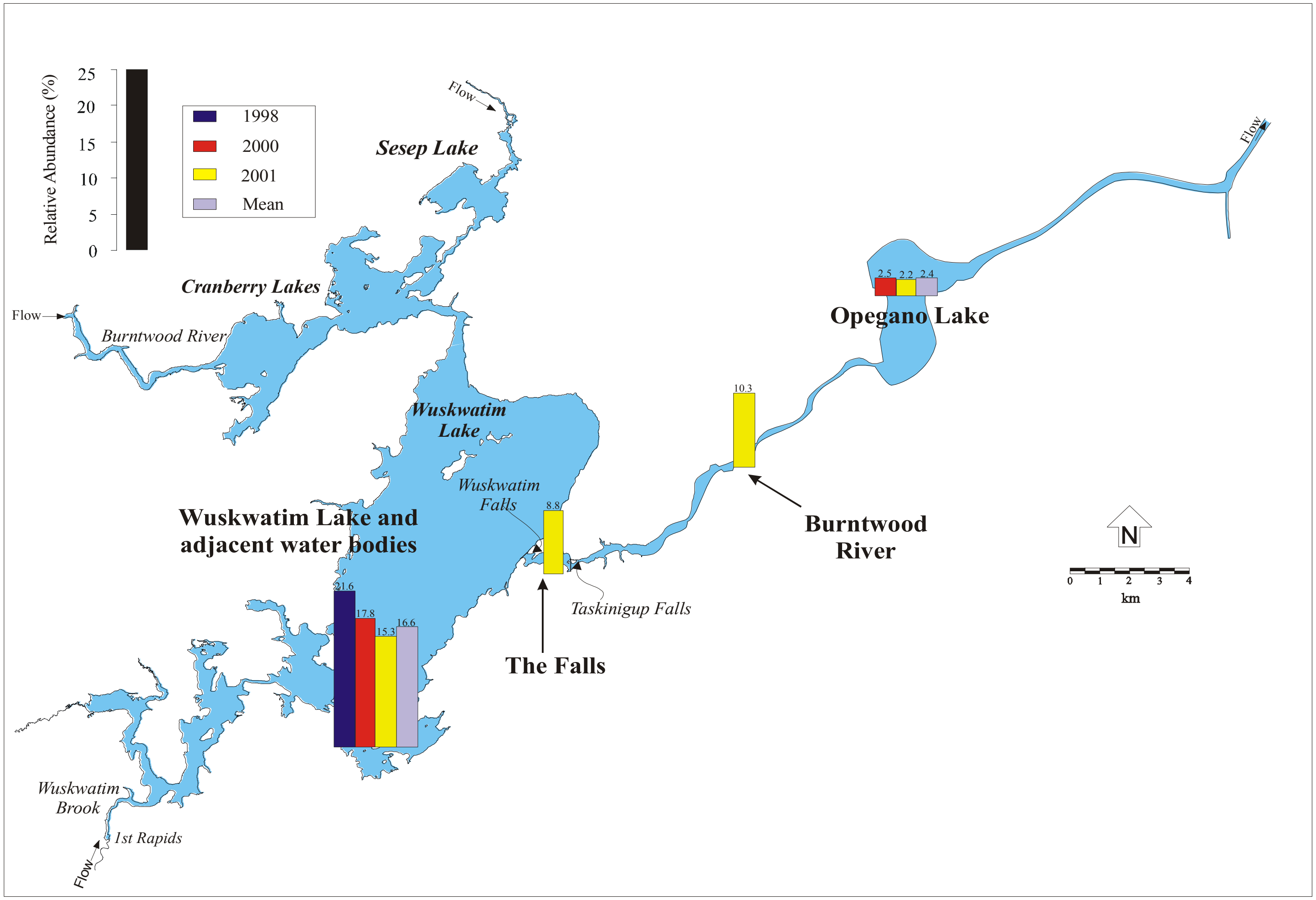


Figure 8-21. Relative abundance of lake cisco from index gillnetting programs conducted in the study area, 1998 - 2001.

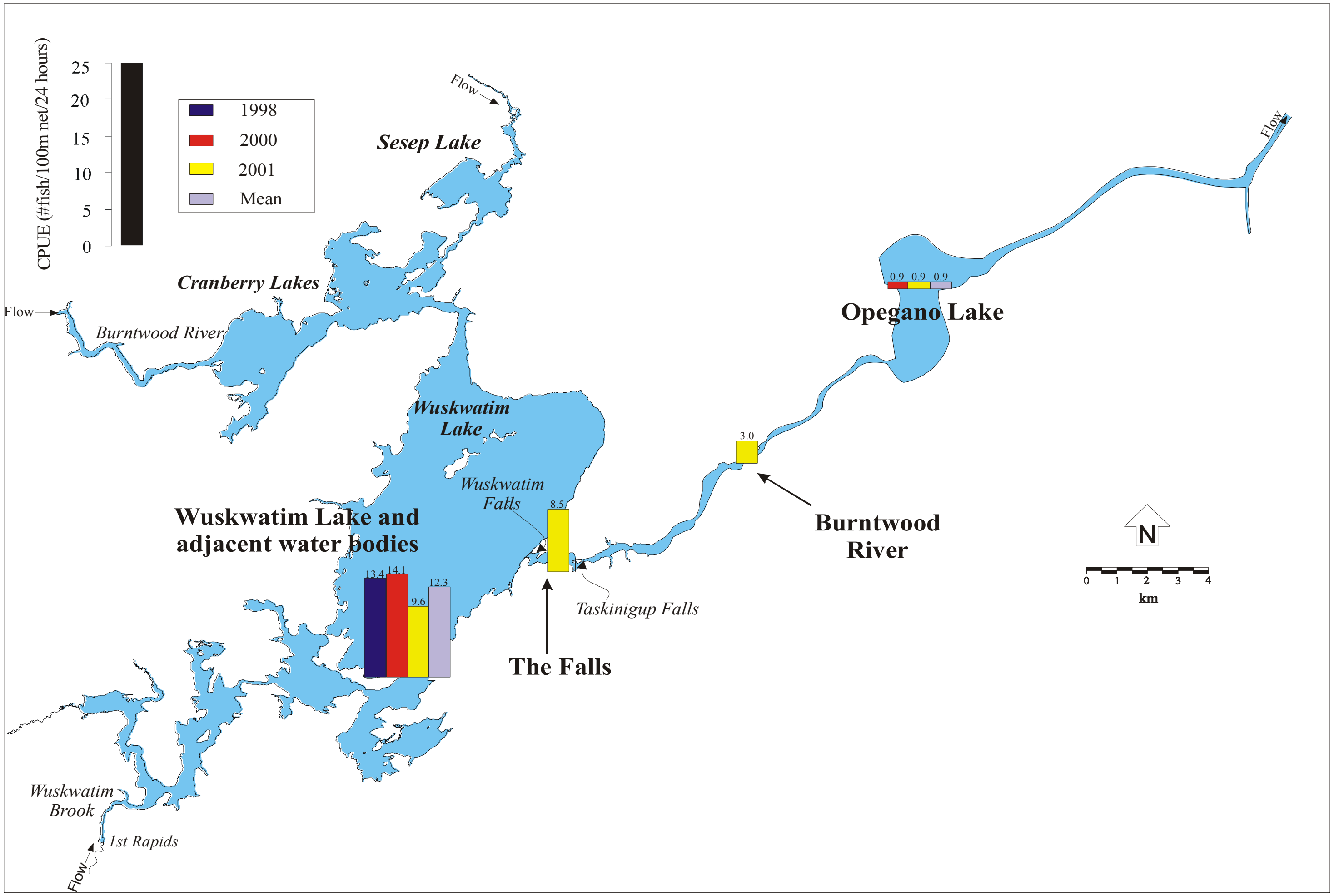


Figure 8-22. Catch-per-unit-effort of lake cisco from index gillnetting programs conducted in the study area, 1998 - 2001.

Prior to CRD, lake cisco spawned in the Burntwood River immediately downstream of Early Morning Rapids (NCN field assistant, pers. comm.). Information collected from tagging studies and neuston tows suggests that lake cisco used Cranberry Lakes and much of the west, south and southeast shores of Wuskwatim Lake main for spawning (Figures 8-23 and 8-24). Larval lake cisco were not collected from either Sesep Lake or Wuskwatim Brook, making these areas unlikely lake cisco spawning habitat. Potential spawning habitat for lake cisco is presented in Figure 8-25, with additional information presented in Appendix 12, Table A12-3.

The mean length of lake cisco captured in index gill nets set in Wuskwatim Lake and adjacent water bodies ranged from a low of 301 mm in 2000 to a high of 345 mm in 2001. Mean lengths of lake cisco caught in the Cranberry Lakes (380 mm), Sesep Lake (396 mm), and Wuskwatim Brook (371 mm) during 2001 were somewhat larger, suggesting that these areas may support a greater proportion of older fish (North/South Consultants Inc. unpublished data). Lake cisco captured in flooded terrestrial habitat in Reach 1 also appeared to be larger (Table A14-3).

Lake cisco captured in Wuskwatim Lake and adjacent water bodies from 1998 to 2001 fed almost exclusively on aquatic invertebrates. Fourteen taxa of invertebrates were identified from stomachs of lake cisco captured in Wuskwatim Lake main, with Ephemeroptera occurring in 69.0% of the stomachs and accounting for 94% of the total biomass. The remainder of the dietary biomass was composed of Bivalvia, Gastropoda, Hemiptera, Oligochaeta, Amphipoda, Ceratopogonidae, Aranea (water spiders), Chironomidae, Conchostraca, Hirudinae, Chaoboridae, Trichoptera, Odonata, and zooplankton.

The Falls

It is expected that much of the habitat present within The Falls would be avoided by lake cisco, due to the medium and high water velocities (>0.5m/s) present within much of the reach (Section 8.3.1). Lake cisco possess swimming speeds comparable to those of walleye and lake whitefish, but critical velocity is unknown. Lake cisco were the third most abundant species captured between Wuskwatim Falls and Taskinigup Falls, accounting for 9.9% of the catch in 2001 and 2002 index gillnetting studies (Table 8.4). Mean catch-per-unit-effort (6.4) was lower than that of Wuskwatim Lake (12.3), but higher than the other two reaches (Table 8-4). However, as discussed in Section 8.3.1, fish abundance is probably over-estimated as gill nets could only be set in low velocity habitat along the channel margins where fish likely congregate and not the areas of

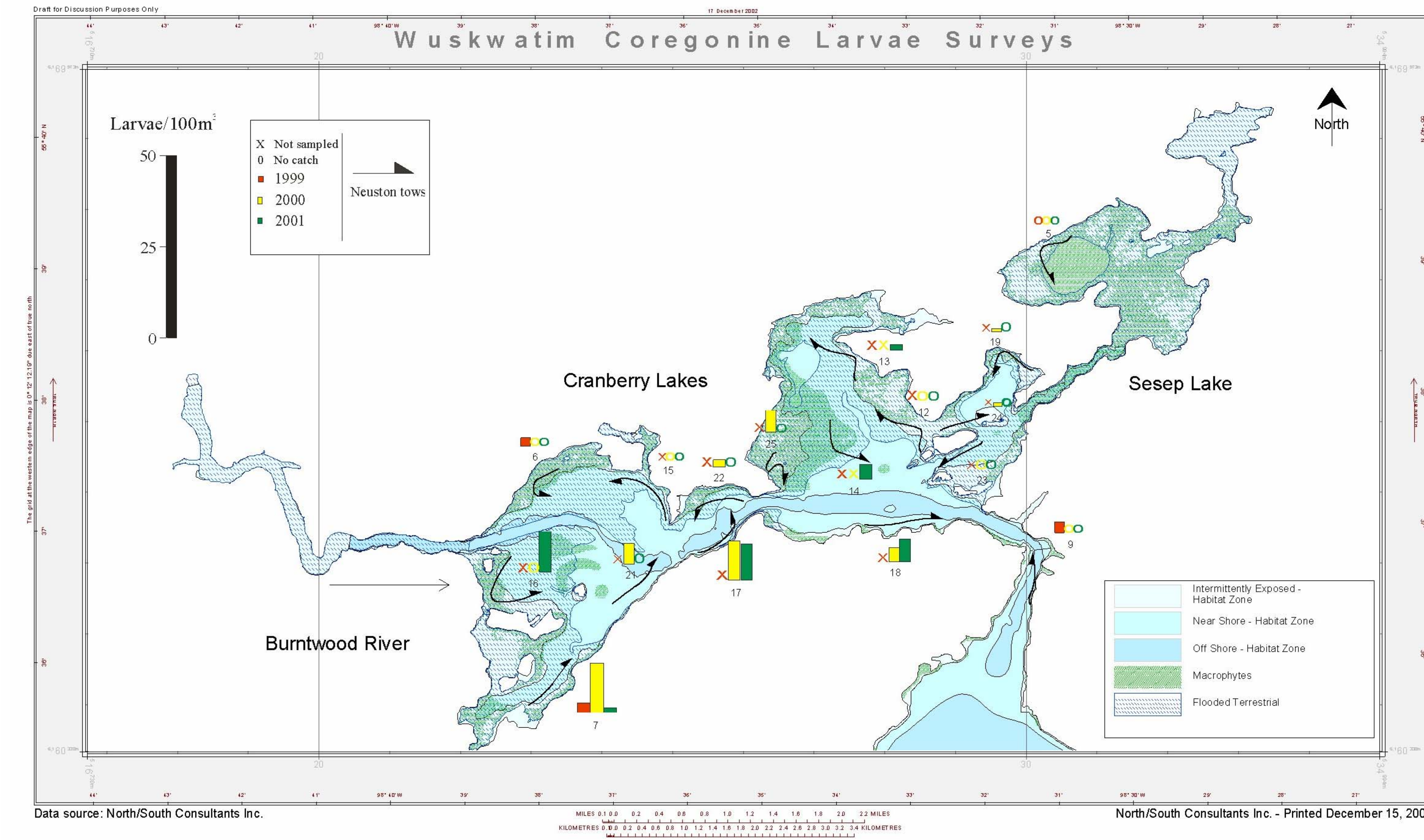


Figure 8-23. Catch-per-unit-effort of larval lake cisco in neuston tows conducted in the Cranberry Lakes and Sesep Lake in 1999, 2000, and 2001.

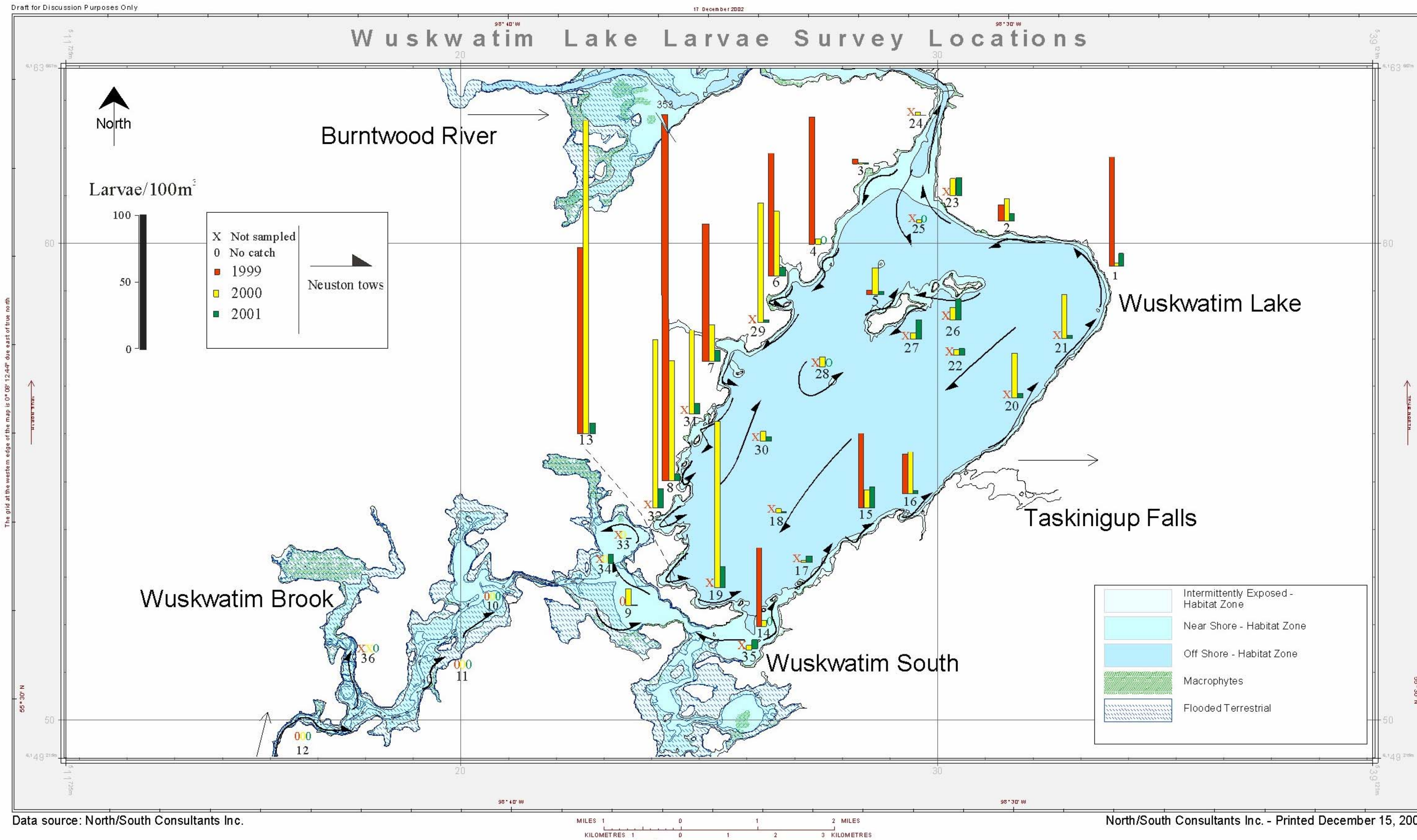


Figure 8-24. Catch-per-unit-effort of larval lake cisco in neuston tows conducted in Wuskwatim Lake and Wuskwatim Brook in 1999, 2000, and 2001.

medium and high water velocity that comprise a large proportion of the reach. Lake cisco captured in this reach showed a preference for soft silt/clay-based substrate (CPUE = 9.4) over hard silt/clay-based substrate (CPUE = 3.4) (Table 8-7). Lake cisco ranged from 146 to 388 mm in length (Table A13-1) and fed on Cladocera, Copepoda, and Hemiptera (North/South Consultants Inc. unpublished data).

Lake cisco in this reach are believed to be transients that have moved downstream from Wuskwatim Lake. The 1999/2000 radio telemetry studies provided evidence of this downstream movement, as one of eight lake cisco tagged in Wuskwatim Lake moved downstream over Wuskwatim Falls and Taskinigup Falls (Section 8.3.4.3). Similar to lake whitefish, it is unlikely that individual lake cisco carry out their entire life cycle within the reach. No larval lake cisco were captured in this reach during 2001 or 2002 and, consequently, no spawning habitat was identified (Figure 8-25). If spawning did occur in this reach, it is expected that larval and juvenile lake cisco would be entrained in the flow and transported downstream over Taskinigup Falls.

It was not possible to assess overwintering habitat in Reach 2 due to unsafe conditions.

Burntwood

Lake cisco comprised 8.6% of the index gillnet catch in this reach (2001-2002) (Table 8-4). Catch-per-unit-effort (2.9) was lower than upstream areas, but higher than Opegano Lake (0.9) (Table 8-4). Lake cisco captured in this reach showed a preference for "wetted, backwater inlets, soft silt/clay-based, no plants, low water velocity" habitat (CPUE = 4.3) over "wetted, mainstem (a composite of three substrate types), no plants, low water velocity" habitat (CPUE = 1.5; Table 8-8). Lake cisco captured were predominantly small, immature fish ranging from 141-403 mm in length (Table A14-3) that fed on Bivalvia and Ephemeroptera (North/South Consultants Inc. unpublished data).

Lake cisco are primarily a pelagic lake species and not commonly found in rivers, except during spawning migrations. Many of the lake cisco captured in this reach were probably migrants from Wuskwatim Lake. It is not likely that individual lake cisco carry out their entire life cycle within Reach 3. No larval lake cisco were captured in this reach during spring 2001 or 2002. Water velocities within much of the reach are likely too fast to provide suitable spawning habitat for lake cisco. However, some adult lake cisco were found during fall. It is suspected that some spawning may occur in low velocity habitat near the base of the north channel of Taskinigup Falls and in the lower 5 km of Reach 3

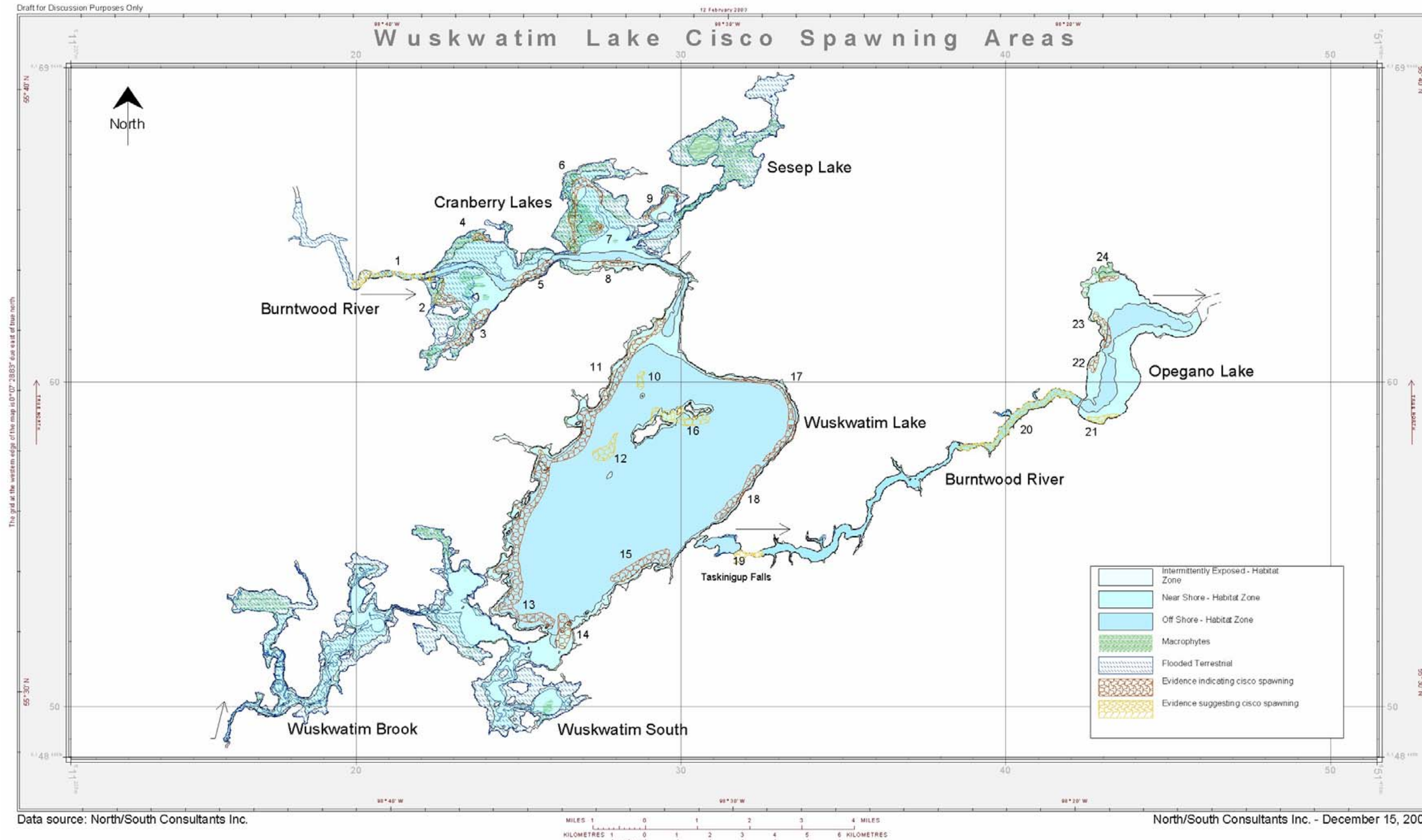


Figure 8-25. Potential lake cisco spawning habitat in the study area.

(Figure 8-25). It is doubtful that much nursery habitat occurs within the reach as any emerging larvae are likely swept downstream in the current. Lake cisco comprised approximately 6.0% of late winter gillnet catches from backwater inlets (Figure 8-4). As discussed for lake whitefish, backwater inlets probably provide less than optimal overwintering habitat for coregonines because of high predator densities. Lake cisco in this reach may move downstream to Opegano Lake to overwinter.

Opegano

Lake cisco comprised just 2.3% of the index gillnet catch from Opegano Lake in 2000 and 2001 (Table 8-4). Catch-per-unit-effort (0.9) was substantially lower than all other reaches (Table 8-4). Due to the small number of lake cisco captured, differences in CPUE among habitat types were inconclusive (Table 8-9). Lake cisco captured in this reach ranged from 199-380 mm in length (Table A14-3).

Lake cisco are generally regarded as pelagic open-water fish that prefer large stratified lakes. The relatively small surface area and flow regime of Opegano Lake provide less than optimal habitat for lake cisco and likely explain the low abundance relative to Wuskwatim Lake. Small numbers of larval lake cisco were found throughout Opegano Lake during spring 2001 and 2002 and provide some evidence of reproductive success in the lake (Figure 8-26). Probable spawning habitat for lake cisco in Opegano Lake includes the northwest shoreline of the lake, the south shoreline of the lake, and low velocity habitat in the lower 5 km of Reach 3 (Figure 8-25).

Four of 13 fish captured in Opegano Lake during March 2002 were lake cisco. Because of the relatively low water velocities, Opegano Lake probably provides the most suitable overwintering habitat for lake cisco between Taskinigup Falls and Jackpine Falls.

Road Crossings

No lake cisco were captured at any of the eight stream crossings and are not expected to be present due to the numerous blockages to fish passage and the absence of suitable habitat.

8.3.4.3 Movements

A total of 361 lake cisco were Floy-tagged in the study area. Most (359) were tagged in Wuskwatim Lake and adjacent water bodies (Table 8-15). Four of the tagged cisco were recaptured in Wuskwatim Lake or Wuskwatim Brook and all four had not moved far from their tagging location.

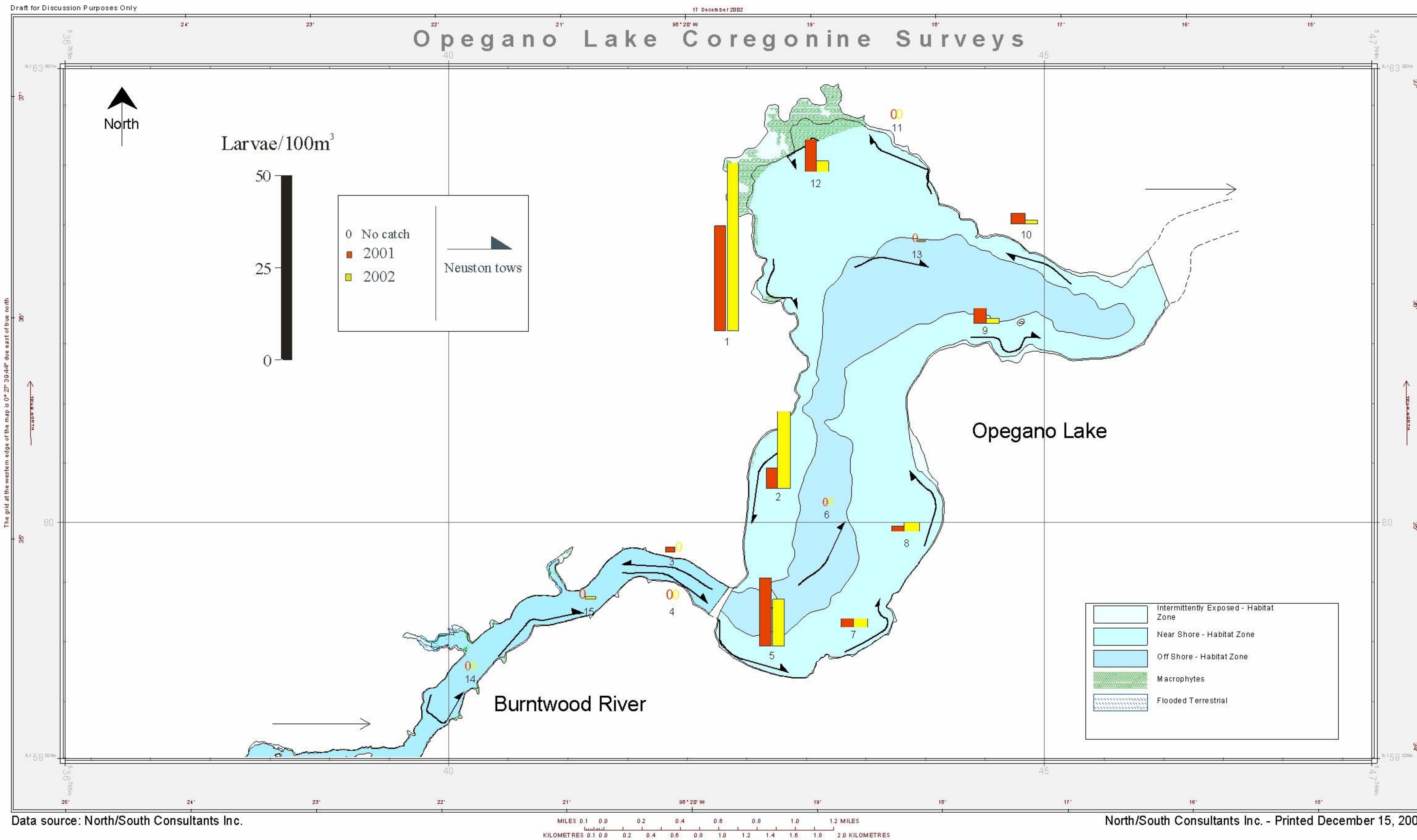


Figure 8-26. Catch-per-unit-effort for larval lake cisco captured in neuston tows conducted in Opegano Lake, 2001 and 2002.

Table 8-15. Number of lake cisco Floy-tagged and recaptured in the study area, 1999-2002.

Tagging Location	Location code	Number Tagged	Number Recaptured/Location 1	2	3	4	5	6	7	Total Number Recaptured	Percent Recaptured
Cranberry Lakes	1	10	-	-	-	-	-	-	-	0	0
Sesep Lake	2	6	-	-	-	-	-	-	-	0	0
Wuskwatim Lake (including (Wuskwatim Brook)	3	343	-	-	4	-	-	-	-	4	1.17
Wuskwatim Falls to Taskinigup Falls	4	0	-	-	-	-	-	-	-	0	-
Taskinigup Falls to Opegano Lake	5	1	-	-	-	-	-	-	-	0	-
Opegano Lake	6	0	-	-	-	-	-	-	-	0	-
Birch Tree Lake	7	1	-	-	-	-	-	-	-	0	-
Total		361	0	0	4	0	0	0	0	4	1.11

The two lake cisco fitted with radio-tags in 1999 were relocated but neither of the two moved, suggesting fish mortality or tag loss. All eight lake cisco fitted with radio-transmitters in the fall of 1999 and in the spring of 2000 in Wuskwatim Lake were relocated at least once (Table 8-16). Two of six lake cisco tagged in 2000 were relocated only once, but both of these fish showed large movements. On 24 September 2000, one fish was relocated upstream into Wuskwatim Brook while another was relocated slightly upstream of Opegano Lake. These fish were not relocated again. The other four fish tagged in 2000 were successfully located on all six tracking flights. None of these four fish moved far from the tagging location, and all remained within Wuskwatim Lake south or just east of the peninsula separating Wuskwatim Lake south from Wuskwatim Lake main (Figures 8-27 and 8-28).

Table 8-16. Summary of movements of lake cisco radio-tagged in Wuskwatim Lake, 1999 and 2000.

Year	Number Tagged	Number relocated at least once	Remained within Wuskwatim Lake	Moved upstream into another part of Reach I[3]	Moved downstream over Wuskwatim Falls only	Moved downstream over Wuskwatim and Taskinigup Falls
1999	2	2	2	0	0	0
2000	6	6	4	1	0	1

[1]Fish were tagged in September/October 1999 and tracked between October 1999 and May 2000.
[2]Fish were tagged from May to September 2000 and tracked between September and Novermber 2000.
[3]No tagged fish were recaptured upstream of Early Morning Rapids. These movements include those fish that moved upstream into Wuskwatim Brook, Cranberry Lakes, or into the Muskeseu River system.

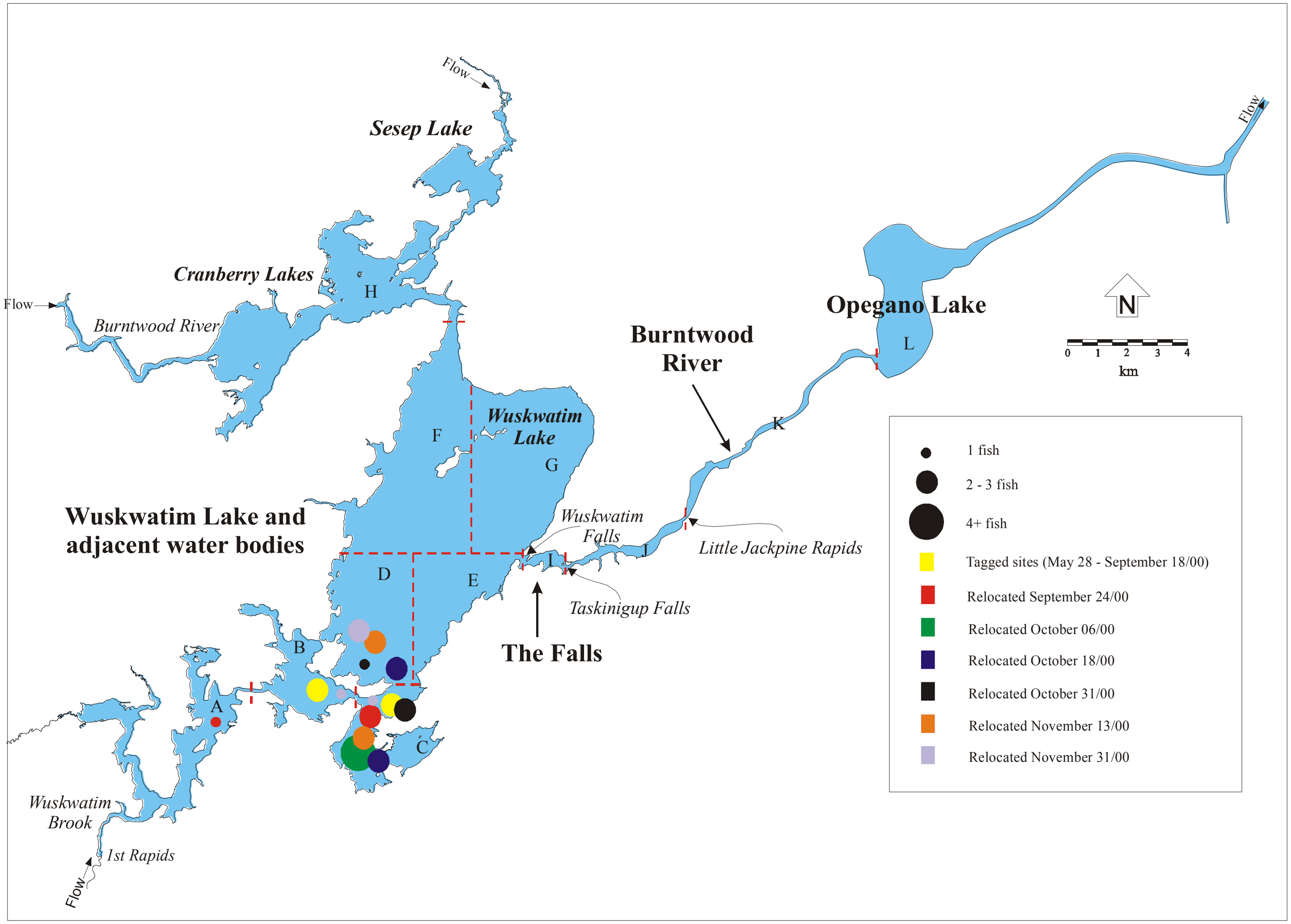


Figure 8-27. Tagging and relocation sites of all six lake cisco radio-tagged in the study area, 2000.

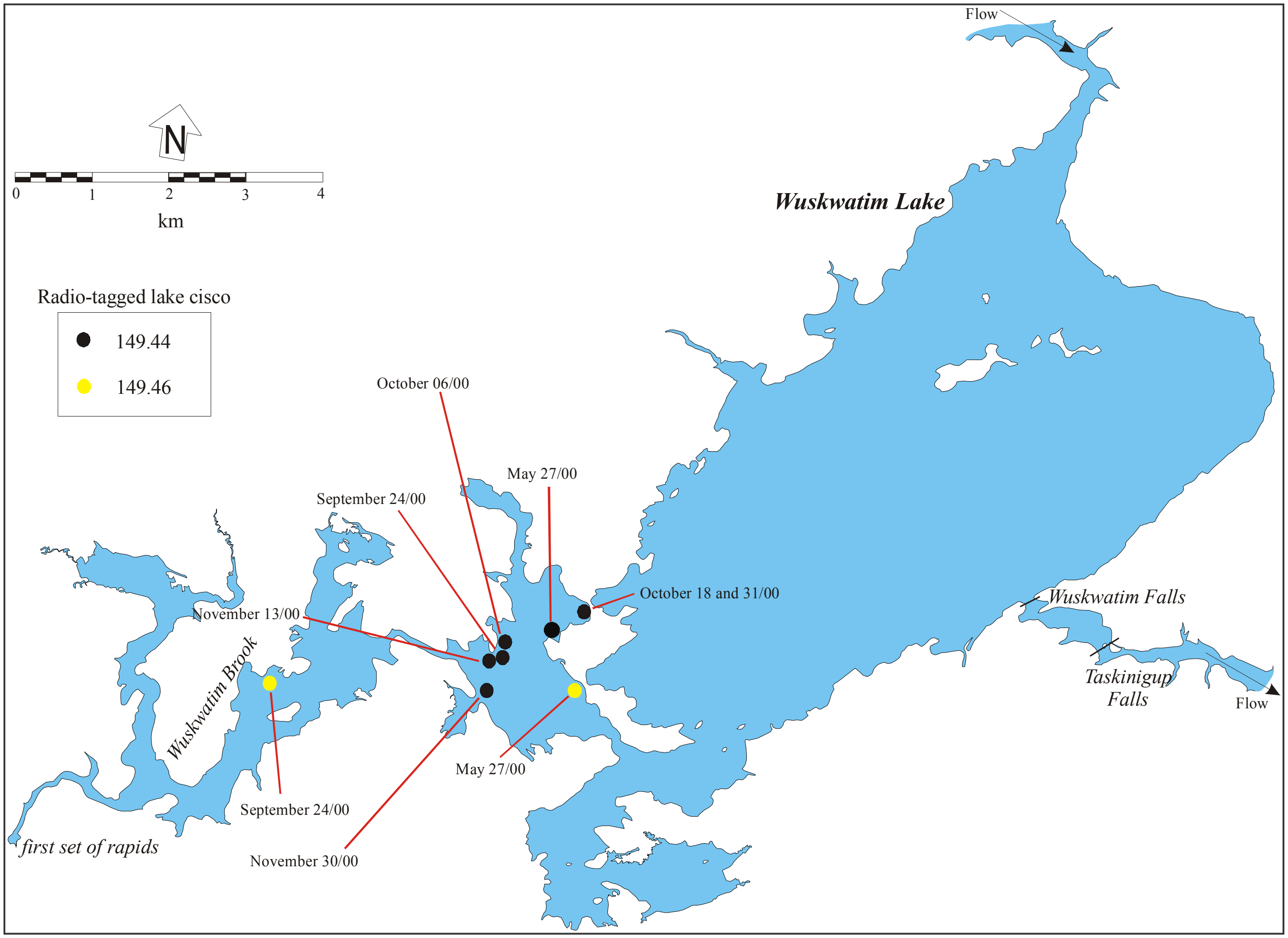


Figure 8-28. Movements of two lake cisco radio-tagged at Wuskwatim Lake, 2000.

The results of radio-tagging studies suggest that most lake cisco move a small amount during fall. As with lake whitefish, there was no apparent migration to one or a few spatially well-defined areas during fall, suggesting that fish were already near or at potential spawning sites. Fish that were successfully tracked over a ten-week period from mid-September to 30 November 2000 generally remained within the area of the peninsula in the southwest corner of the lake (Figure 8-27). Final tracking locations on 30 November 2000 suggested that lake cisco overwintered in the same portion of the lake (west and east of the peninsula in the southwest corner of the lake). These data are supported by the results of winter gillnetting as discussed above (Section 8.3.4.2).

No radio-tagged or Floy-tagged lake cisco moved upstream over Wuskwatim Falls, Taskinigup Falls, or Early Morning Rapids, although one radio-tagged fish did move upstream into Wuskwatim Brook from Wuskwatim Lake main. One lake cisco that was radio-tagged in Wuskwatim Lake moved downstream over Wuskwatim Falls and Taskinigup Falls and was relocated only once a short distance upstream of Opegano Lake.

8.3.5 Northern Pike

8.3.5.1 General Life History and Biology

Northern pike begin to spawn after ice break-up in the spring at water temperatures of 4 to 11°C. Spawning occurs during daylight in shallow (< 0.5 m deep) water over heavily vegetated floodplains of rivers, marshes, and bays of larger lakes (Diana et al. 1977, Casselman and Lewis 1996). In northern populations, age of sexual maturity is reached at five years for males and six years for females, and fish reach sexual maturity at approximately 400 mm in length (Scott and Crossman 1998).

Northern pike inhabit vegetated areas of lakes and slow meandering rivers (McPhail and Lindsey 1970, Scott and Crossman 1998). Adult northern pike prefer areas less than 5 m in depth for most of the year, moving into deeper water to overwinter (Diana et al. 1977, Inskip 1982, Scott and Crossman 1998). They are ambush predators requiring cover (logs, weeds, stumps, boulders) to ambush their prey (Inskip 1982), and are most commonly found in moderately vegetated areas along the interface between vegetation and open water (Inskip 1982, Randall et al. 1996, Casselman and Lewis 1996). Grimm (1989) suggested that a water body must contain more than 25% submerged macrophytes for a northern pike dominated fish community to exist. Northern pike are opportunistic feeders and will feed upon whatever is readily accessible, including aquatic invertebrates, fish, ducklings, mice, and small mammals (Lawler 1965).

Quiet bays with adequate vegetation are the preferred habitats for juvenile northern pike where adequate cover provides both an ambush position and shelter from predators, including larger northern pike (Chapman and Mackay 1990). After hatching, juvenile northern pike generally seek out areas of aquatic vegetation that provide cover from predators. Holland and Huston (1984) found that young northern pike were ten times more abundant in emergent vegetation and three times more abundant in submergent vegetation than in unvegetated areas.

Northern pike locomotion is generally considered somewhere between that of **anguilliform** and sub-carangiform swimmers, and display sustained and prolonged swimming speeds less than those of walleye and lake whitefish (Katopodis and Gervais 1991). Critical velocity is 0.38 m/s (Katopodis and Gervais 1991; Appendix 11).

Given their preference for vegetated habitat, northern pike would be particularly sensitive to any disturbance to aquatic macrophyte beds.

8.3.5.2 Abundance, Habitat Use, and Biological Data

Wuskwatim Lake

Northern pike are a small component of the Wuskwatim Lake commercial fishery. They are not a major component of the fish community in Reach 1, accounting for 5.9% of the open-water index gillnet catches (Table 8-4, Figure 8-29). However, they are more abundant in some of the more inshore areas, including Sesep Lake where northern pike were the most commonly captured species accounting for 37.3% of the gillnet catch. Less turbid waters and greater abundance of preferred habitats (see below) in Wuskwatim Brook and Sesep Lake probably account for larger catches of northern pike in these adjacent water bodies. The CPUE for pike in Wuskwatim Lake and adjacent water bodies was variable between years (2.1 to 5.2), with the mean CPUE (4.0) comparable to that of Opegano Lake (Table 8-4, Figure 8-30).

Similar to habitat preferences reported in the literature (Section 8.3.5.1), northern pike were most abundant in "nearshore, flooded terrestrial, rooted vascular plants" habitat (based on data from the available vegetated habitat), followed by "nearshore, flooded terrestrial, no plants" habitat, and were least abundant in "offshore, soft silt/clay-based, no plants" habitat (Table 8-5). The cover afforded by rooted plants and terrestrial vegetation, for northern pike and their prey, likely explains the greater abundance of northern pike in these habitat types.

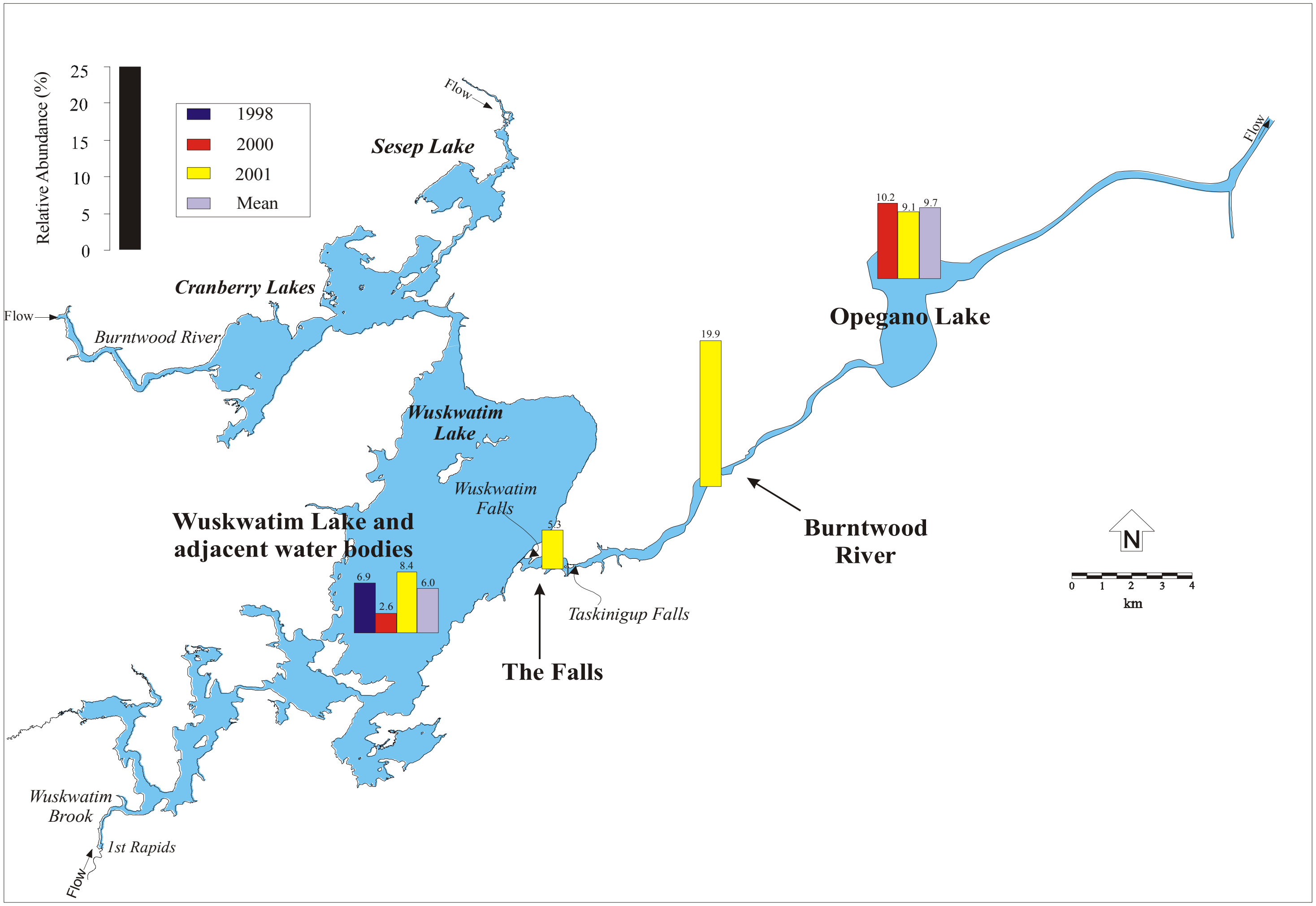


Figure 8-29. Relative abundance of northern pike from index gillnetting programs conducted in the study area, 1998 - 2001.

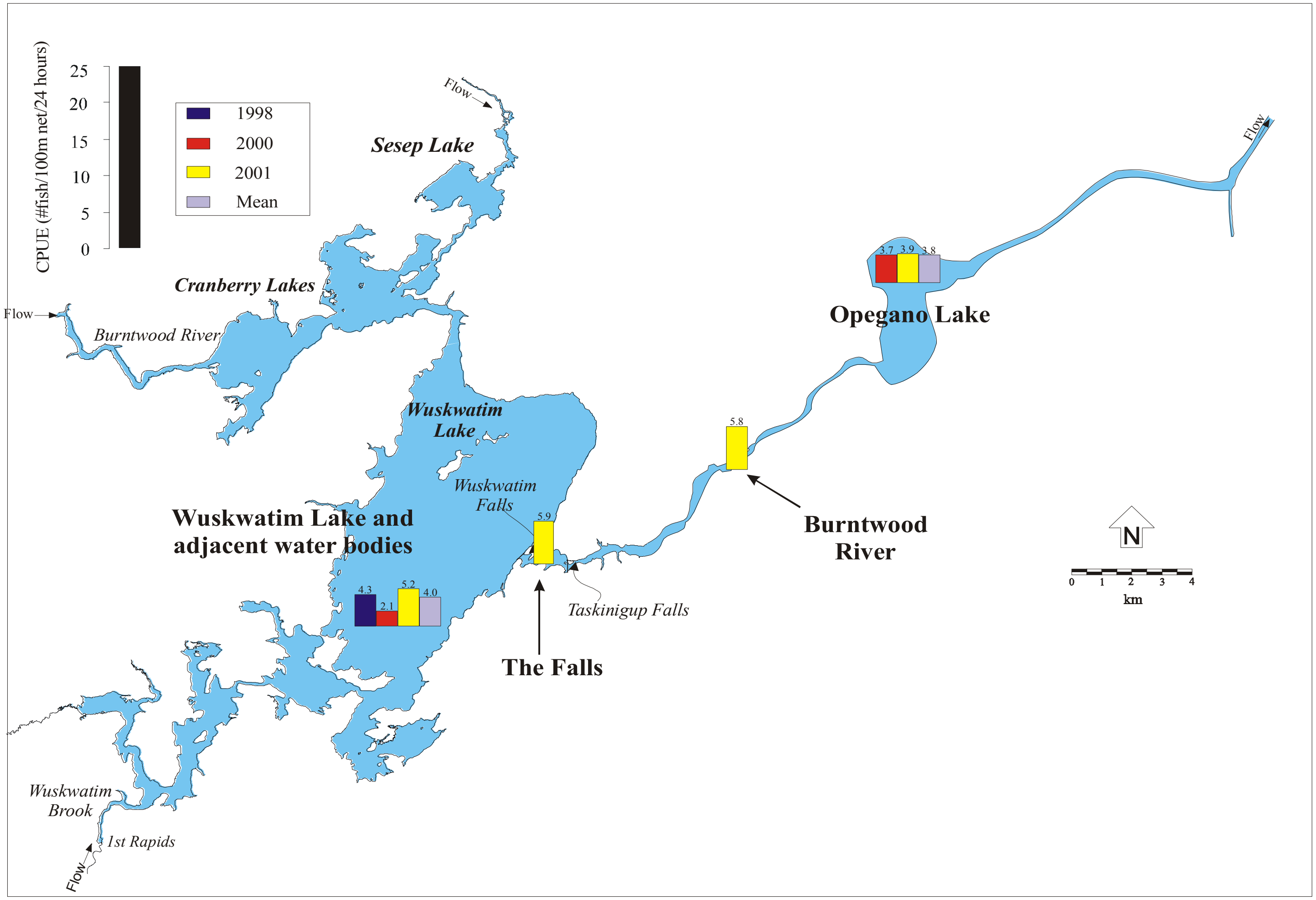


Figure 8-30. Catch-per-unit-effort of northern pike from index gillnetting programs conducted in the study area, 1998 - 2001.

Gill nets were set in Sesep Lake, Wuskwatim Brook, and Wuskwatim Lake south during March 2002 to assess overwintering habitat. Northern pike were captured at all four sites (Figure 8-4), suggesting that northern pike overwinter in much of the adjacent water bodies. Northern pike are also expected to overwinter in Wuskwatim Lake main.

Suitable northern pike spawning habitat (shallow, relatively calm water over inundated vegetation) is abundant in Wuskwatim Lake and adjacent water bodies although no specific spawning sites were identified (Figure 8-31; Table A12-4). Northern pike maturing to spawn later that spring were captured in spring 2001 in Cranberry Lakes, Sesep Lake, Wuskwatim Brook, and in the southwest bay of Wuskwatim Lake, west of the peninsula, suggesting that all these areas, and possibly the Muskeseu River, are being used for spawning. The capture of post-spawn northern pike in Wuskwatim Brook during spring provides strong evidence that northern pike utilize the brook area for spawning. Pike probably also spawn along seasonally inundated shorelines of Wuskwatim Lake main.

Northern pike in Wuskwatim Lake were small, with mean lengths of index gillnet-caught fish ranging from 353 mm in 1998 to 459 mm in 2001 (Table A14-4). Northern pike tended to be somewhat larger in the areas peripheral to Wuskwatim Lake main (Cranberry Lakes, Sesep Lake, and Wuskwatim Brook; Mota 2003), resulting in the larger mean length observed in 2001 data. There appeared to be no substantial differences in the mean lengths of northern pike among the four habitat types fished in Wuskwatim (Table A14-4).

As is common for the species, northern pike fed mainly upon fish. In Wuskwatim Lake main, fish species including walleye, burbot, troutperch, yellow perch, lake cisco, and northern pike were found in 77.0% of the stomachs with contents, and invertebrates including Ephemeroptera, Decapoda, and Odonata were found in the remaining 23.0% of the stomachs. Most of the other water bodies were similar, although in Sesep Lake, Amphipoda were present in 50.0% of the stomachs.

Falls

The reach between Wuskwatim Falls and Taskinigup Falls provides marginal northern pike habitat because of medium and high water velocities in much of the reach and a limited amount of rooted plants (Section 6). Although the peripheral off-channel areas (including the north and south bays) provide some suitable habitat, it is believed that few, if any, northern pike carry out their entire life cycle within the reach.

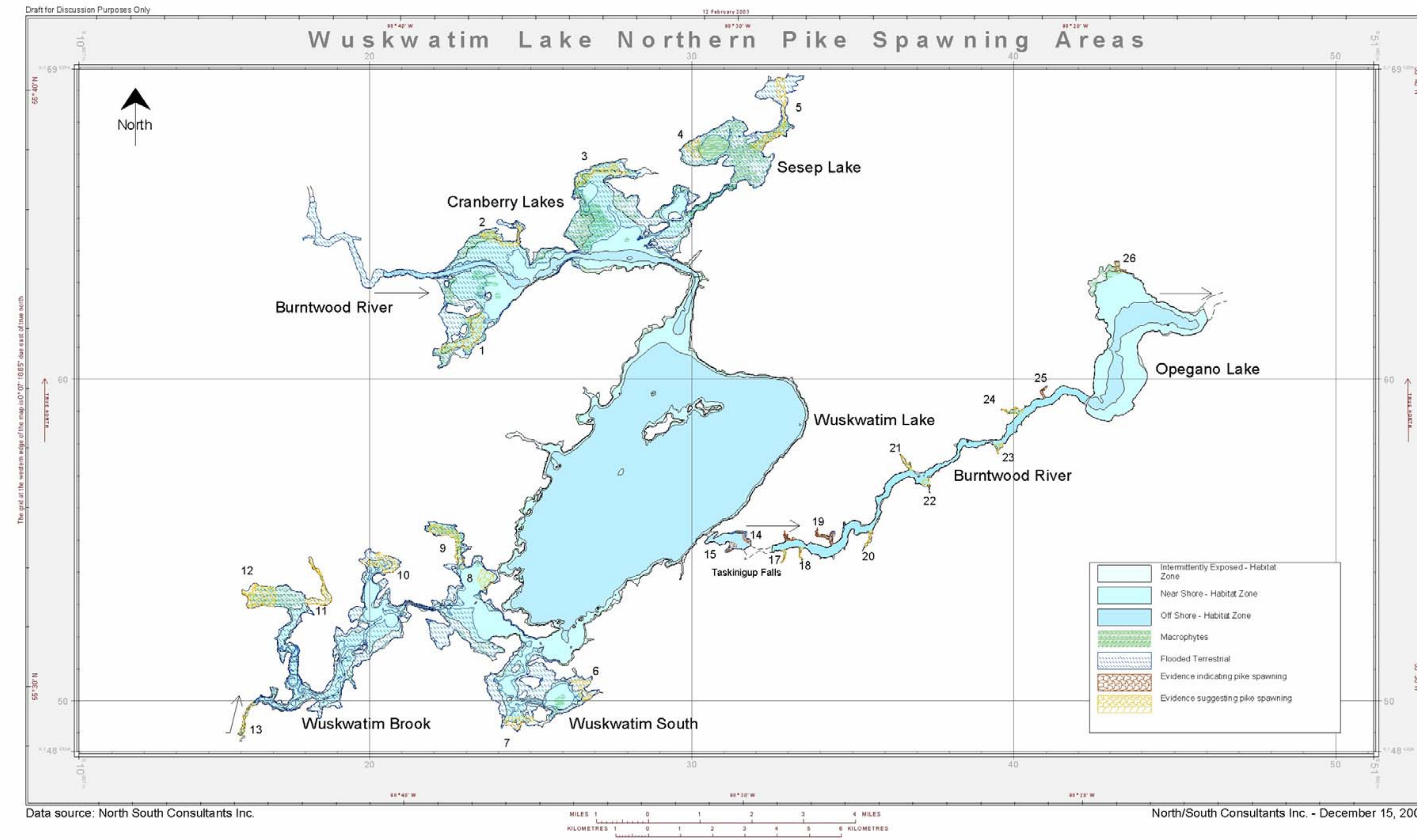


Figure 8-31. Potential northern pike spawning habitat in the study area.

Northern pike were the fifth most abundant species sampled in the reach in 2001 and 2002, comprising on average 7.4% of the index gillnet catch (Table 8-4). Mean northern pike CPUE (4.8) was similar to all other reaches sampled (Table 8-4). However, as discussed for other species, this value is not considered representative of the entire reach and likely overestimates the abundance of northern pike. Northern pike in this reach showed a slight preference for "wetted, mainstem, soft silt/clay-based, no plants" habitat (CPUE = 5.7) over "wetted, mainstem, hard silt/clay-based, no plants" habitat (CPUE = 3.8; Table 8-7).

The northern pike captured in Reach 2 were of moderate size, ranging from 249-665 mm in length (Table A13-1) and fed exclusively on fish, including burbot, spottail shiner, and troutperch.

Although habitat within most of Reach 2 is less than optimal for northern pike spawning, the capture of pike larvae in nearshore areas during spring 2002 indicates that some spawning does occur within the reach (Figure 8-31). It is expected that the majority of northern pike larvae that emerge in this reach drift downstream after hatching.

It was not possible to assess overwintering habitat within Reach 2 due to unsafe conditions.

Burntwood River

Northern pike was the third most abundant fish species captured in this reach, accounting for 14.4% of the overall catch from index gillnetting studies from 2001 and 2002 (Table 8-4). Northern pike CPUE (4.7) was similar to all other reaches sampled (Table 8-4). However, as noted previously, CPUEs from this reach are only indicative of fish abundance in the backwater inlets and in low velocity habitat within the mainstem and not the reach as a whole. Northern pike in this reach displayed a strong preference for "wetted, backwater inlets, soft silt/clay-based, no plants, low water velocity" habitat (CPUE = 8.5) over "wetted, mainstem (a composite of three substrate types), no plants, low water velocity" habitat (CPUE = 1.0) (Table 8-8).

Most northern pike captured were sexually mature, moderately large fish ranging from 212-899 mm in length (Table A14-4). The primary food item consumed was fish, including walleye, northern pike, and forage fish species. Decapoda were the only other food item identified from northern pike stomachs.

Much of this reach of the Burntwood River is unsuitable for northern pike because of water velocities greater than 0.5 m/s and a low occurrence of aquatic vegetation (Section 6.0). Critical velocity for northern pike is 0.38 m/s (Katopodis & Gervais 1991), making prolonged swimming impossible for northern pike in this reach. Northern pike captured during the open-water season were concentrated in backwater inlets, which offer refuge from higher water velocities and provide more suitable habitat in terms of flooded terrestrial and aquatic vegetation. Capture of northern pike in backwater inlets during late winter indicate that these locations also provide overwintering habitat.

Tributaries and backwater inlets likely provide the only suitable spawning habitat for northern pike in this reach. Northern pike found in backwater inlets during late winter may have moved upstream from Opegano Lake in preparation for spawning. Larval pike were captured in backwater inlets 1, 4, and 10 in 2002, indicating that some spawning does occur in the reach. It is suspected that northern pike may spawn in all ten backwater inlets in Reach 3 (Figure 8-31).

Opegano

Northern pike was the fourth most abundant fish species captured in Opegano Lake and comprised 9.6% of the index gillnetting catch (Table 8-4). Average northern pike CPUE from Opegano Lake (4.0) was comparable to the average northern pike CPUE from all reaches in the study area (Table 8-4).

Fish habitat within Opegano Lake is sub-optimal for northern pike because it is characterized by open-water with little aquatic vegetation. Available aquatic vegetation is concentrated at the north end of the lake (Figure 8-6). Among habitat types that were sampled, northern pike preferred “nearshore, flooded terrestrial, no plants” habitat and were absent from “offshore, soft silt/clay-based, no plants” habitat (Table 8-9).

Although there is little typical northern pike spawning habitat in Opegano Lake, larval pike were captured in one bay in the spring of 2002 (Figure 8-31). Flooded backwater inlets located upstream and downstream of the lake probably provide additional spawning habitat for pike. Northern pike were captured in the one gillnet set in Opegano Lake in March 2002. Suitable overwintering habitat, which is characterized by low water velocities, relatively deep water, and sufficient oxygen, does not appear to be limiting in Opegano Lake.

Northern pike captured were relatively large compared to other reaches, with lengths ranging from 249 to 800 mm (Table A14-4). Decapoda and fish comprised most of the diet, with sauger, yellow perch, lake cisco, ninespine stickleback, and northern pike identified from stomachs.

Road Crossings

No northern pike were captured at any of the stream crossings and are not expected to be present due to the presence of numerous beaver dams and other blockages that would impede access to these sites from larger water bodies (Section 6.0).

8.3.5.3 Movements

Radio-tags were not applied to this species as pike generally do not undertake long distance movements. A total of 146 northern pike were Floy-tagged in the study area, of which 105 were applied to fish captured in the southwest bay of Wuskwatim Lake or Wuskwatim Brook (Table 8-17). Six of these pike were recaptured, all within Wuskwatim Lake. No Floy-tagged northern pike were recaptured upstream of Early Morning Rapids or downstream of Wuskwatim Falls or Taskinigup Falls.

Table 8-17. Number of northern pike Floy-tagged and recaptured in the study area, 1999-2002.

Tagging Location	Location code	Number Tagged	Number Recaptured/Location							Total Number Recaptured	Percent Recaptured
			1	2	3	4	5	6	7		
Cranberry Lakes	1	10	-	-	-	-	-	-	-	0	0
Sesep Lake	2	10	-	-	-	-	-	-	-	0	0
Wuskwatim Lake (including Wuskwatim Brook)	3	105	-	-	6	-	-	-	-	6	5.71
Wuskwatim Falls to Taskinigup Falls	4	0	-	-	-	-	-	-	-	0	-
Taskinigup Falls to Opegano Lake	5	10	-	-	-	-	-	-	-	0	-
Opegano Lake	6	11	-	-	-	-	-	-	-	0	-
Birch Tree Lake	7	0	-	-	-	-	-	-	-	0	-
Total		146	0	0	6	0	0	0	0	6	4.11

8.4 IMPACTS AND MITIGATION

The following sections provide a description of the potential effects of construction (Section 8.4.1) and operation (Section 8.4.2) of the Project on the fish community. Operational effects are described in terms of the fish community as a whole (Section 8.4.2.1) and in terms of specific effects to each of the VEC fish species (Section 8.4.2.2).

8.4.1 Construction

Impacts to fish species in general, including VEC species, from most construction-related impacts are similar. Therefore, no distinction is made among fish species in the discussion below unless there are species-specific effects. Disturbances from construction activities and the potential effects on VEC fish species (i.e., walleye, lake whitefish, lake cisco, and northern pike) are considered together and are summarized in Table 8-18 and discussed in detail below.

Table 8-18. Disturbances from construction activities and their potential effects on VEC fish species.

Disturbance	Effect
Changes to Water Quality	
Increased TSS	Short-term, small and local (-)
Introduction of trace elements	Ø
Accidental hydrocarbon spills and releases	Ø
Input of treated sewage effluent	Short-term, small, and site-specific (-)
Construction of stream crossings	Short-term, small, and local (-)
Blasting	Short-term, small, and site-specific (-)
Entrainment and impingement of fish due to water intakes	Ø

Changes to water quality

The following summarizes potential impacts to VEC fish species resulting from changes in water quality due to Project construction. A detailed discussion of potential effects of Project construction on water quality is found in Section 5.

Increases in TSS levels resulting from construction-related activities are described in Section 5. Increased TSS is not expected to have a significant effect on VEC fish species due to the low frequency of impact (a few episodes during construction), relatively short duration of impact (several weeks), and the expected level of increase in TSS (i.e., increases well below lethal limits) in the fully mixed zone of the river. Fish within the immediate construction area may be affected by plumes with higher concentrations of TSS; however, they would be able to avoid these areas. Fish inhabiting most backwater inlets would be exposed to little, if any, increase in TSS. Consequently, increased TSS is expected to have a short-term, small, and local negative effect on VEC fish species.

It is predicted that there will be a negligible to small increase in some metals and/or metalloids due to sediment re-suspension, coffer dam removal, and acid generation from leachate (Section 5). The predicted level of increase is expected to have no effect on VEC fish species.

As discussed in Section 5, no significant impacts due to accidental spills and releases of hydrocarbons and other hazardous materials are expected due to safe handling and spill containment measures outlined in the Project Description (Volume 3). Consequently, accidental hydrocarbon spills and releases are expected to have no effect on VEC fish species.

Treated sewage effluent from the construction camp will be discharged twice a year (five days in spring and 10 days in late fall) into Backwater Inlet 4 (an approximately 9 ha inlet on the Burntwood River in Reach 3). Small, short-term reductions in dissolved oxygen concentrations in Backwater Inlet 4 are predicted during these periods (Section 5). The increase in TSS is not expected to affect the fish community, but the reduction in dissolved oxygen may affect the suitability of Backwater Inlet 4 as fish habitat during spring and late fall, particularly for northern pike. Consequently, input of sewage is expected to have a short-term, small, and site-specific negative effect on VEC fish species.

Access road stream crossings

Although measures will be taken to minimize the input of sediments (Section 5.4.1), small, short-term increases in TSS are expected during and immediately after installation of culverts. Additionally, there is a small potential for accidental spills and releases of hydrocarbons at the stream crossings, but spill containment measures that will be described in the spill response plan will minimize the potential for impacts affecting more than the local area.

At each of the eight stream crossings, there will be a direct loss of aquatic habitat due to the footprint of the road and the culvert. None of the habitat to be affected is considered critical (i.e., spawning or overwintering habitat). Changes to aquatic habitat at each road crossing will include the following:

- some decrease in depth for the length of the culvert at some sites and an increase in depth immediately upstream and downstream of the culvert at most sites;
- some increase in sedimentation downstream of the culvert at most sites;
- loss of rooted submergent aquatic plants in the immediate footprint of the road and culvert at most sites; and
- increase in average velocity for the length of the culvert and a short length immediately upstream and downstream at all sites.

There is not expected to be a reduction in invertebrate or forage fish production at any of the eight crossings. Consequently, the road crossing should not result in a significant change in the amount of food available to the fish community in any of the eight tributaries.

Movement of all fish at the eight proposed crossings is currently limited because of an abundance of beaver dams and obstructions downstream of the crossings. Northern pike were not captured at any of the eight sites surveyed, while white sucker were captured at three of the eight sites. None of the white sucker captured were greater than 200 mm in length, but one fish at Crossing 9 was a sexually mature male. This information suggests that the habitat present at the road crossings is supporting resident populations and not migrants from larger systems such as the Burntwood River or Birch Tree Lake. It is thought that, at present, the movement of all fish within the tributaries, and between the tributaries and larger systems, is limited by natural blockages within the tributaries. With the possible exception of the existing beaver dam at Crossing 4, none of the existing obstructions are likely to be removed. Consequently, operation of the GS access road is unlikely to affect the local abundance of northern pike and larger suckers, or fish movement in general.

Given appropriate sizing and installation of culverts, and strict adherence to the Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat (Fisheries and Oceans Canada and Manitoba Natural Resources 1996), habitat alterations associated with stream crossings are not expected to significantly affect the fish community.

Blasting

Blasting will generally be conducted in accordance with DFO guidelines for the use of explosives in or near Canadian fisheries waters (Wright and Hopky 1998) to ensure compliance with various fish and fish habitat protection provisions of the *Fisheries Act* (including provisions to protect spawning beds during **egg incubation**). The exception will be a set of single blasts conducted for the removal of rock plugs in the **spillway** channel, channel improvement area, and at the station in 2008 and 2009 that may not be able to meet all the criteria in the guidelines. However, each of these single events is not expected to result in the mortality of a large number of fish. Consequently, it is expected that blasting will have a short-term, small, and site-specific negative effect on VEC fish species.

Water intake

During construction of the Project, water will be required for several uses including potable water for the camp and work areas, and water for mixing of concrete. Intake pipes will be screened according to current end-of-pipe fish screening guidelines (DFO 1995) to minimize the **entrainment** and **impingement** of fish. Consequently, it is expected that water intakes will have no effect on VEC fish species.

Increased fishing activity

The potential for increased fishing activity due to the presence of construction workers and increased access during Project construction is discussed fully in Volume 7. To reduce the effects of increased harvesting, NCN and Manitoba Hydro, in consultation with the Nelson House Resource Management Board, will develop an Access Management Plan prior to construction. Measures included in the Access Management Plan will determine the extent of impact related to changes in harvesting activity. It should be noted that Manitoba Conservation is responsible for the management of fisheries in the province, including avoidance of adverse effects related to over-harvest.

Assessment of significance

Mitigation measures (see Project Description: Volume 3) are expected to minimize the duration and magnitude of most construction-related impacts on VEC fish species. However, some effects, such as increased TSS due to releases of coffer dams and rock plugs, and blasting of rock plugs will result in short-term and small negative effects to fish abundance within a given area. Overall, it is expected that construction of the Project will have a **short-term, small, local and, therefore, not significant negative effect on populations of VEC fish species within the study area**.

8.4.2 Operation

8.4.2.1 Overview of Effects of Operation on the Fish Community

The following assessment is based on information related to the Project and direct effects to the physical environment presented in Volumes 3 and 4 and summarized in Section 4 of this volume, as well as assessments of effects to water quality (Section 5), physical attributes of aquatic habitat (Section 6), and lower trophic levels (Section 7).

Reach 1: Wuskwatim

Changes in water quality (Section 5)

Expected changes to water quality in Reach 1 resulting from operation of the Project are as follows:

- no change in overall water quality in Reach 1, but an increase in the amount of TSS in shallow water habitat adjacent to eroding banks in Wuskwatim Lake main and Cranberry Lakes, particularly after storms; and
- in tributary waters (e.g., Wuskwatim Brook, Sesep Lake, and the south bay of Wuskwatim Lake) there may be localized reductions in oxygen concentration in some isolated bays as a result of the leaching of organic substances from terrestrial vegetation and soils in areas that become permanently wetted, in particular in winter (Section 5).

Although fish may avoid some eroding shorelines in Wuskwatim Lake main and Cranberry Lakes in the short-term (5 years), it is not expected that the increase in TSS will have a measurable effect on the fish community. Shorelines that are susceptible to increased erosion are already eroding (though at a lower rate), and much of the most productive nearshore habitat (based on invertebrate abundance) is in off system waters that will not be susceptible to increased erosion. Localized reductions in dissolved oxygen concentrations may reduce the quality of overwintering habitat in off-current areas such as Wuskwatim Brook, Sesep Lake, and the south bay of Wuskwatim Lake. However, because the availability of overwintering habitat is not a limiting factor in Reach 1 (i.e., it is abundant in Wuskwatim Lake main), the reduction is not expected to have any affect on fish populations in the reach.

Changes in the quantity and quality of aquatic habitat (Section 6)

Expected changes to aquatic habitat in Reach 1 resulting from operation of the Project are as follows:

- stabilization of water levels in Reach 1 at the upper end of the existing range will convert 1588 ha of intermittently exposed habitat to wetted nearshore habitat, yielding a post-Project total of 4167 ha of wetted nearshore habitat (approximately 19% of the existing intermittently exposed area is covered by peat islands). The majority of the change in habitat types will occur in the shallow bays of Wuskwatim Brook, Sesep Lake, Cranberry Lakes and Wuskwatim Lake south (Section 6);

- the intermittently exposed zone will be reduced in size from an estimated 2022 ha to 342 ha (most converted to nearshore habitat, with a very small amount [92 ha] becoming permanently dry);

- water levels will normally remain within the top 0.25 m of the reservoir (generally in the top 0.08 m) in comparison to the current 1.3 m typical annual range;

- as water level elevation will fluctuate somewhat during normal operation of the Project, an intermittently exposed zone will exist between 233.75 m and 234.0 m;

- the majority of nearshore and offshore areas will remain predominantly soft silt/clay (i.e., fine sediments);

- in Wuskwatim Lake main and portions of Cranberry Lakes, the nearshore zone adjacent to eroding banks will experience a large increase in sedimentation (for approximately 5 years post-Project and decreasing thereafter) with a much smaller increase in the offshore zone (Volume 4);

- in most areas, increased sedimentation will affect areas of existing soft substrate, but fine sediments may also be deposited on the boulder/cobble that currently exists off of some eroding shorelines;

- areas of coarse substrate in the nearshore environment of Wuskwatim Lake main and Cranberry Lakes that are covered by fine sediments as a result of increased erosion on adjacent banks are expected to return to their current condition after erosion rates on these banks return to present day levels. The slope of the majority of these nearshore areas is sufficient to result in the transport of fine sediments offshore (Section 6).

- the decrease in water level fluctuations will reduce the extent of the area periodically cleansed by wave action, but the most affected areas are shallow backwater bays that currently have fine sediments, and so no change in sediment composition is expected (Section 6);

- as the reservoir ages and on-going erosion alters the slope of the littoral zone, the ultimate composition of substrate in the nearshore environment cannot be predicted as it depends in part on material underlying existing banks (Section 6);

- the spatial extent of the area where rooted submergent aquatic plants occur now is not expected to change; however, the density of plant growth is expected to increase in some areas where growth is currently sparse and patchy;

- no detectable change in the species composition of rooted submergent aquatic plant beds is expected;

- this reach is primarily lacustrine in nature and contains little habitat with discernable water velocity. As the 234 m contour extends up to the first set of rapids on Wuskwatim Brook, and close to Early Morning Rapids on the Burntwood River, there will be small lotic portions of the reach where velocity will be reduced. However, neither Early Morning Rapids nor the first set of rapids on Wuskwatim Brook will be affected; and

- stabilization of water levels at the upper end of the existing range will increase the water level in the mouths of small tributaries entering into Reach 1, particularly during summer and fall.

The conversion of 1588 ha of intermittently exposed habitat to wetted nearshore habitat will create additional aquatic habitat for the fish community. Stabilization of water levels at the upper end of the existing range will create additional spawning habitat (or better access to it) for spring and fall spawners (discussed in more detail in Section 8.4.2.2). It will also reduce the potential for exposure of eggs or larvae, particularly with fall spawners (Table 8-19). Sedimentation of areas of coarse substrate adjacent to eroding shorelines may potentially decrease the quality of spawning habitat for some species, including lake whitefish and lake cisco, in the short term. As rooted submergent aquatic plants provide excellent cover for many species of fish, increases in the abundance of plant beds will benefit the fish community.

Changes in invertebrate production (Section 7)

Expected changes to invertebrate production in Reach 1 resulting from operation of the Project are as follows:

Table 8-19. Calculation of potential spawning area and percentage of spawning area lost on Wuskwatim Lake due to water level regulation.

Year	A	B	C	D	E	F		
	Average Water Level Elevation (m) October 15 to November 1	Maximum Elevation (m) of Spawning Area	Total Spawning Area (m)	Minimum Overwintering Elevation (m) November 1 to May 15	Minimum Overwintering Elevation minus Ice Cover (m)	Amount of Spawning Area Lost (m)	Usable Spawning Area (m)	Percent of Spawning Area Lost
		A - 1.5	B - 229		D - 1.0	B - E	C - F	F / C
Pre-Project								
1978/1979	233.86	232.36	3.36	232.84	231.84	0.52	2.84	15.5%
1979/1980	233.78	232.28	3.28	233.46	232.46	0.00	3.28	0.0%
1980/1981	233.80	232.30	3.30	233.54	232.54	0.00	3.30	0.0%
1981/1982	233.11	231.61	2.61	232.99	231.99	0.00	2.61	0.0%
1982/1983	233.97	232.47	3.47	233.06	232.06	0.41	3.06	11.8%
1983/1984	233.97	232.47	3.47	233.04	232.04	0.43	3.04	12.3%
1985/1986	233.81	232.31	3.31	233.54	232.54	0.00	3.31	0.0%
1986/1987	234.06	232.56	3.56	233.99	232.99	0.00	3.56	0.0%
1988/1989	233.74	232.24	3.24	233.45	232.45	0.00	3.24	0.0%
1990/1991	233.27	231.77	2.77	232.90	231.90	0.00	2.77	0.0%
1992/1993	233.64	232.14	3.14	232.94	231.94	0.19	2.94	6.1%
1995/1996	233.12	231.62	2.62	232.85	231.85	0.00	2.62	0.0%
1996/1997	233.52	232.02	3.02	233.12	232.12	0.00	3.02	0.0%
1997/1998	234.25	232.75	3.75	233.42	232.42	0.33	3.42	8.8%
1998/1999	233.91	232.41	3.41	232.86	231.86	0.55	2.86	16.1%
1999/2000	233.14	231.64	2.64	232.65	231.65	0.00	2.64	0.0%
2000/2001	234.03	232.53	3.53	233.35	232.35	0.19	3.35	5.3%
2001/2002	233.60	232.10	3.10	233.34	232.34	0.00	3.10	0.0%
Based on Average	-	-	-	-	-	-	3.05	4.2%
Post-Project								
	233.93	232.43	3.43	233.75	232.75	0.00	3.43	0.0%
	233.75	232.25	3.25	233.75	232.75	0.00	3.25	0.0%
	233.93	232.43	3.43	233.93	232.93	0.00	3.43	0.0%

- there will be a small increase in zooplankton production in tributary waterbodies (e.g., Sesep Lake, Wuskwatim Lake south, Wuskwatim Brook) though no change is expected for Wuskwatim Lake main or Cranberry Lakes; and

- overall, there is expected to be a small increase in the abundance and distribution of benthic invertebrates in Wuskwatim Lake main, and a moderate increase in the adjacent water bodies, due to the conversion of intermittently exposed to nearshore habitat. Increased exposure to highly turbid waters and an increase in sedimentation during the first five years of Project operation is expected to negatively affect benthic invertebrate production over areas of boulder/cobble or bedrock substrates, particularly in Wuskwatim Lake main. However, the overall proportion of habitat affected is small and the effect is short-term.

Increased production of zooplankton and benthic invertebrates is expected to increase the amount of food available to forage fish and larger members of the fish community in Reach 1.

Changes in forage fish production

Expected changes to forage fish production in Reach 1 resulting from operation of the Project are as follows:

- due to the conversion of 1588 ha of partially exposed habitat into permanently wetted nearshore habitat, aquatic macrophyte, phytoplankton, zooplankton, and benthic invertebrate production in Reach 1 is expected to increase, particularly in the adjacent water bodies; and

- due to the greater production of food and amount of available habitat, forage fish production is expected in increase in Reach 1, particularly in the adjacent water bodies.

Increased production of forage fish is expected to increase the amount of food available to predators in Reach 1.

Changes in fish movements

The majority of NCN members who provided Traditional Knowledge on fish movements felt that fish did not move upstream over Wuskwatim Falls or Taskinigup Falls either before or after CRD. However, there were several Elders who were familiar with the area who thought fish had been able to move upstream over Taskinigup Falls prior to CRD. Based on both Traditional Knowledge and the environmental assessment studies (radio- and Floy-tagging results, and observations of the height of the falls and water velocities), it is felt that fish do not currently move upstream over either Taskinigup Falls or Wuskwatim Falls.

Presently an unknown portion of the Wuskwatim Lake fish community moves downstream over Wuskwatim and, in most cases, Taskinigup Falls. The results of radio- and Floy-tagging data have shown that walleye, lake whitefish, and lake cisco, and likely several other species, move downstream over Wuskwatim Falls from Reach 1 into the downstream reaches. While numbers are not known, larval fish also drift downstream out of Reach 1.

Inundation of Wuskwatim Falls will result in a substantial change in water velocity and depths in the vicinity of the falls. Present water velocities range up to 10 m/s and these will be reduced to the order of 0.5-0.7 m/s (Volume 4). A substantial post-Project reduction in water velocities upstream of the crest is expected to result in lower entrainment of larval fish in downstream flows and will allow most non-larval fish that move downstream over Wuskwatim Falls and into Reach 2 to move back upstream into Reach 1.

Increased fishing activity

Increased access to Wuskwatim Lake is expected to result in an increase in domestic, commercial, and recreational fishing compared to pre-Project levels (Volume 7). The extent of this increase will depend on measures taken in the Access Management Plan (Appendix 3, Volume 3).

To a large extent, the potential increase in commercial fishing depends on the response of the Freshwater Fish Marketing Corporation (FFMC) to information gathered as a result of the EIA studies. The FFMC recently stopped accepting walleye from Wuskwatim Lake due to high mercury levels. Sampling conducted during EIA studies indicated that mercury levels in walleye have declined and are now well below the limit for commercial sale. For the purposes of the EIS, it is assumed that FFMC will review the status of Wuskwatim Lake walleye and it is further assumed that FFMC will resume accepting these fish for commercial sale.

Reach 2: Falls

Changes in water quality (Section 5)

Expected changes to water quality in Reach 2 resulting from operation of the Project are as follows:

- changes in TSS levels in Reach 1 are not expected to generally be detectable downstream, and TSS inputs from erosion in this reach are expected to be minimal; and

- site-specific decreases in dissolved oxygen concentrations (e.g., over small area of flooded peat).

The increased TSS concentrations are expected to have no effect on the fish community. Localized reductions in dissolved oxygen may render some of the off-current habitat created within this reach less suitable, particularly during winter.

Changes in the quantity and quality of aquatic habitat (Section 6)

Expected changes to aquatic habitat in Reach 2 resulting from operation of the Project are as follows:

- there will be a direct gain of 37.2 ha of aquatic habitat in Reach 2. Of this, 3.4 ha will be part of the channel extension adjacent to Wuskwatim Falls, 8.9 ha will be flooded terrestrial habitat overlain by a dyke, and 24.8 ha will be newly flooded undisturbed terrestrial habitat;

- inundation of this reach and stabilization of the water level at approximately 234 m will result in an increase in water elevation of approximately 7 m;

- as water levels will fluctuate somewhat during normal operation of the Project, an intermittently exposed zone will exist between 233.75 m and 234.0 m (water level variations immediately upstream of the station will be larger);

- the intermittently exposed area in Reach 2a (the portion of Reach 2 where safe data collection was possible; refer to Section 6) will be reduced from 9.6% to 0.9%;

- there will be 24.8 ha of newly flooded terrestrial habitat that will be cleared of large trees but not have the surface organic layer removed (i.e., not grubbed);

- substrate over the dyke will consist of coarse material (riprap);

- there is expected to be little deposition of sediments in Reach 2, although some deposition may occur along eroding shorelines;

- existing rooted submergent aquatic plant beds in the north and south bays in Reach 2 (2.2 ha) will die-off due to inundation. It is expected that, over time, a bed comparable to the existing one in the south bay (0.7 ha) will develop. Rooted submergent aquatic plants in the north bay (1.5 ha) will not be replaced as the disturbed newly flooded habitat in this area post-Project will largely consist of the surface of a dyke. This will result in a net loss of 1.5 ha of rooted submergent aquatic plants;

- the south bay plant bed is expected to be recolonized by the same species;

- post-Project water velocities in Reach 2a will be lower than in the pre-Project condition, with most of the reach converted to low velocity habitat;

- water velocities at Wuskwatim Falls will be reduced substantially; and

- water velocities at the GS intake will be reduced relative to those of Taskinigup Falls. Under an operating outflow of about 1100 m^3/s, velocities approximately 1 m upstream of the intake gates will range from 0.75 to 1.0 m/s (medium velocity) (Volume 4). These velocities would be consistent across the entire intake opening, extending from an elevation of 207.2 to 227.1 m. Under the same outflow operation, velocities about 30 m upstream of the intake gates will range from 0.5 to 0.75 m/s (medium velocity) (Volume 4).

There will be a direct gain of 37.2 ha of aquatic habitat available in Reach 2. Due to the stabilization of water levels at 233.75 - 234 m, there will be a reduction in the amount intermittently exposed habitat. The more stable water level will reduce the potential for exposure of eggs or larvae when spring spawning has occurred at a high water level (northern pike spawning has been documented within this reach).

The conversion of Reach 2 into an area of deeper, slower water will enhance physical conditions for overwintering fish. However, depletion of dissolved oxygen levels during winter may make some of the newly flooded areas unsuitable as overwintering habitat. The loss of 1.5 ha of rooted submergent aquatic plants will result in a loss of cover for invertebrates and fish within the reach.

Reduced water velocity in Reach 2 will make more of the reach usable to fish. Lower water velocities at Wuskwatim Falls are expected to result in unrestricted movement between Reach 1 and 2 for most non-larval fish. Fish in Reach 2 will have access to aquatic habitat within all of Wuskwatim Lake and adjacent water bodies for spawning, feeding, and overwintering. However, habitat diversity will be reduced with the loss of fast turbulent water habitat at the base of Wuskwatim Falls. Potential spawning habitat at the base of Wuskwatim Falls is expected to be lost to any fish presently using it.

Changes in invertebrate production

Expected changes to invertebrate production in Reach 2 resulting from operation of the Project are as follows:

- Reach 2 is not expected to experience any notable changes in phytoplankton and zooplankton production; and

- the higher, more stable water level will result in a moderate increase in benthic invertebrate production within the reach. A shift in benthic invertebrate species composition from that typical of river environments (as occurs now) to a community resembling that of Wuskwatim Lake is expected. However, species biodiversity is not expected to be affected. Increased production of benthic invertebrates is expected to increase the amount of food available to forage fish and larger members of the fish community in Reach 2.

Increased production of benthic invertebrates is expected to increase the amount of food available to forage fish and larger members of the fish community in Reach 2.

Changes in forage fish production

Expected changes to forage fish production in Reach 2 resulting from operation of the Project are as follows:

- increased production of benthic invertebrates, combined with the greater amount of available habitat, is expected to increase forage fish production in Reach 2.

Increased production of forage fish is expected to increase the amount of food available to predators.

Changes in fish movements

As discussed for Reach 1, fish do not currently move upstream over Taskinigup Falls. The results of radio- and Floy-tagging data have shown that walleye, lake whitefish, lake cisco, and likely several other species, move downstream over Wuskwatim Falls and Taskinigup Falls from Reach 1 into the downstream reaches. While numbers are not known, larval fish also drift downstream over Taskinigup Falls.

The GS will reroute the flow of the Burntwood River through the station's intake and, when in use (approximately 7% of the time), the spillway. The substantial reduction in post-Project water velocity upstream of the station is expected to reduce the entrainment of larval and non-larval fish, such that fewer will move downstream out of the reach.

Presently, fish residing in Reach 2 are confined to 46.5 ha of usable fish habitat. Construction of the Project will connect fish habitat in Reach 2 to Reach 1, providing fish currently resident in Reach 2 with access to habitat in Reach 1 and potentially further reducing the incidence of downstream movements.

Changes in fishing activity

At present, there is no domestic, commercial, or recreational fishing activity in Reach 2 because of the difficulty and danger associated with accessing the area. No substantial amount of fishing activity is expected to occur in Reach 2 following construction of the Project. However, as fish residing within Reach 2 will have unlimited access to Reach 1, they will be targetted by the Wuskwatim Lake fisheries that have previously been discussed

<u>Reach 3: Burntwood</u>

Changes in water quality (Section 5)

Expected changes to water quality in Reach 3 resulting from operation of the Project are as follows:

- no overall change in TSS;
- localized reductions in dissolved oxygen may occur in the backwater inlets of tributary streams, particularly during winter; and
- accidental spills or releases of hydrocarbons may occur at the GS.

The increased TSS and nutrient concentrations contributed from upstream of the GS are expected to have no effect on the fish community in Reach 3. Localized reductions in dissolved oxygen concentrations may render some of aquatic habitat within the backwater inlets unsuitable for overwintering fish. Control measures discussed in Volume 3 and to be described in the EnvPP are expected to prevent the release of harmful quantities of substances such as hydrocarbons to the aquatic environment and, therefore, no effect on the fish community is expected.

Changes in the quantity and quality of aquatic habitat (Section 6)

Expected changes to aquatic habitat in Reach 3 resulting from operation of the Project are as follows:

- following construction of the GS, about 3 ha of aquatic habitat will be lost from the upper end of Reach 3 due to the concrete footprint of the GS structure (0.4 ha) and the dewatering of Taskinigup Falls (2.7 ha). Immediately downstream of the GS in the tailrace channel, about 0.9 ha will be a channel excavated through former terrestrial habitat and 1.1 ha will become disturbed aquatic habitat. The bay on the south side of the river, immediately downstream of Taskinigup Falls, will become part of the post-Project backwater area (4.2 ha) created downstream of the main dam;

- during operation, water levels in Reach 3 will fluctuate depending on the inflow and the number of units operating;

- the intermittently exposed zone will increase from 44 ha to 64 ha; of this, 17 ha will be a conversion of permanently wetted habitat to intermittently exposed habitat and 3 ha of terrestrial habitat will become intermittently exposed habitat;

- the quality of the post-Project intermittently exposed habitat will be degraded in comparison to the pre-Project condition due to the increased frequency of water level fluctuations;

- the distribution of substrata types will not be noticeably altered with the exception of the small increase in area (3 ha) of flooded terrestrial habitat;

- the altered water regime may result in the loss of a substantial portion of the 3.9 ha of rooted submergent aquatic plant beds (1% of the aquatic habitat in this section);

- the general pattern of post-Project water velocity will be similar to the pre-Project condition. For example, the amount of low velocity (< 0.5 m/s) habitat present within the mainstem of Reach 3 under 3 unit best gate flows (122.1 ha; Section 6) is comparable to the amount of low velocity habitat present under existing 95 percentile conditions (121.9 ha; Section 6). However, daily fluctuations in water velocity at certain points within the reach will change considerably following construction of the GS;

- under existing 95 percentile flow conditions, 19.3 ha of backwater inlet habitat lies within the intermittently exposed zone and 17.2 ha are in the permanently wetted;

- under post-Project 3 unit full-gate flows, 27.8 ha of backwater inlet habitat lies within the intermittently exposed zone and 10.1 ha are permanently wetted; and

- due to the increased amount of intermittently exposed habitat in the backwater inlets, and the increased frequency of water level fluctuations, access to and from tributaries will be more difficult.

The loss of habitat due to the dewatering of Taskinigup Falls and the conversion of a fast-flowing section of the river to a backwater area represents a loss of areas with extremely high water velocities and turbulence and, consequently, negligible capacity as fish habitat. Conversion of permanently wetted to intermittently exposed habitat, in conjunction with the increased frequency of water level fluctuations, is expected to negatively affect the quantity and quality of spawning, feeding, and overwintering habitat available to fish in Reach 3. Habitat will be particularly affected in the backwater inlets, where access to and from spawning and feeding habitat in tributaries entering into these inlets, and in the inlets themselves, may also be reduced. The potential loss of 3.9 ha of rooted submergent aquatic plants would result in a loss of cover for fish within the reach. Overall, there is expected to be little change in the amount and distribution of high, medium, and low water velocity habitat. Under certain flow conditions, water level changes within the day will provide periods of relatively lower flow, which may improve the ability of fish to move through some of the faster portions of Reach 3 (e.g., Little Jackpine Rapids).

Changes in invertebrate production (Section 7)

Expected changes to invertebrate production in Reach 3 resulting from operation of the Project are as follows:

- no change in zooplankton abundance and distribution is expected; and

- benthic invertebrates are expected to noticeably decrease in abundance and distribution as the quality of the intermittently exposed zone and, to a lesser extent, the shallow areas of the permanently wetted zone will be degraded due to the increase in the frequency of water level fluctuations.

Reduced production of benthic invertebrates is expected to decrease the amount of food available to forage fish and larger members of the fish community in Reach 3.

Changes in forage fish production

Expected changes to forage fish production in Reach 3 resulting from operation of the Project are as follows:

- the decreased production of benthic invertebrates, combined with the reduction in the amount of available habitat, is expected to reduce forage fish production in Reach 3.

Reduced production of benthic invertebrates is expected to decrease the amount of food available to forage fish and larger members of the fish community in Reach 3.

Changes in fish movements

As discussed in the previous section, fish do not currently move upstream over Taskinigup Falls. Radio- and Floy-tagging data show that walleye, lake whitefish, lake cisco, and likely several other species, move downstream over Wuskwatim Falls and Taskinigup Falls and into the downstream reaches. While numbers are not known, larval fish also drift downstream over Taskinigup Falls. The reduction of water velocities at and upstream of Wuskwatim Falls and Taskinigup Falls (as discussed for Reach 2) are expected to result in a reduction in the number of fish moving downstream into Reach 3.

Upstream fish passage facilities are not included in the design of the Project for the following reasons:

- upstream fish passage is not required for any important life history functions (i.e., fish do not currently move upstream over Taskinigup Falls); and

- upstream movements are restricted not only by Taskinigup Falls and Wuskwatim Falls but also by three sets of rapids between Taskinigup Falls and Opegano Lake and by two sets of impassable falls between Opegano Lake and Birch Tree Lake.

Downstream fish passage facilities are not included in the design of the Project for the following reasons:

- there is currently no upstream fish passage; therefore, any fish moving downstream are permanently lost to upstream locations that are utilized by domestic, commercial, and recreational fishers;

- fish located downstream of Taskinigup Falls (e.g., Opegano Lake) are not currently utilized by either domestic, commercial, or recreational fishers due to poor access, unsafe travel conditions, and low fish abundance;

- fish moving downstream would move from an area being positively affected by the Project (e.g., stabilized water levels in Wuskwatim Lake) to an area being negatively affected by the Project (e.g., increased water level fluctuations downstream of the GS); and

- as discussed above, the number of downstream migrants during operation of the Project is expected to decrease relative to the present condition.

It should also be noted that high water velocities and poor flow diversity limit the quality of fish habitat currently available between Taskinigup Falls and Opegano Lake.

Turbine Mortality

Although the effects of turbine passage on fish have been studied extensively, the vast majority of this research has focused on anadromous (e.g., *Salmo*, *Oncorhynchus*, *Alosa*) and catadromous (e.g., *Anguilla*) species, particularly on Pacific salmon smolts in the Snake-Columbia River system (e.g., Cada 2001). Limited data exist on turbine mortality for typical boreal species such as walleye, northern pike, lake whitefish, or lake cisco (a few notable exceptions include Barus et al. 1984, Matousek et al. 1994, and Navarro et al. 1996).

Injuries and mortality during turbine passage result from several forces, most notably rapid and extreme pressure changes, cavitation, shear stress, turbulence, strike, and grinding (Cada 2001). The degree to which fish will experience these forces depends on fish species and size, the entrainment depth, and turbine type and efficiency. Generally, mechanical-related injuries are the dominant cause of mortality at low head (< 30 m) dams (Therrien and Bourgeois 2000). Although direct turbine mortality has been shown to be greater for small (0-5 cm long) north temperate fish (Navarro et al. 1996), the probability of mechanical injuries has been shown to increase with fish size in studies involving smallmouth bass (*Micropterus dolomieui*) and a variety of salmonids

(Turnpenny 1998, Therrien and Lemieux 2000). Matousek et al. (1994) found the highest survival rates for north temperate fish between 5 and 30 cm in length, with the smallest (less than 5 cm) and the largest (greater than 30 cm) fish having the lowest survival rates.

The generating station will have approximately 22 m of hydraulic head, with three generation units equipped with fixed blade vertical shaft turbines (Volume 3). Under most operating conditions, all of the flow of the Burntwood River will pass through the turbines; downstream migrants will pass through the turbines with passage over the spillway being restricted to high flow events (7% of the time). The trashracks have been designed with a spacing of 165 mm between vertical bars and 500 mm between horizontal bars (G. Cook, Manitoba Hydro, pers. comm.) and, consequently, no fish will be impinged on the trashracks.

Mortality estimates are variable between fish species, fish lengths, turbine types, and the specific configurations of the generating stations (Matousek et al. 1994; Navarro et al. 1996). However, for fish lengths between 15 and 40 cm, mortality is generally expected to fall between 10 and 20% of the fish moving downstream through the turbines.

As discussed in the previous section, fewer larval and non-larval fish are expected to move downstream out of Reach 2. Some proportion of those fish that do move downstream through the GS will be susceptible to turbine mortality. Consequently, the fish community in Reach 3 is expected to be affected by the smaller number of migrants from upstream of the GS.

During use of the spillway it is expected that relatively more fish will be entrained in the flow and move downstream than during normal GS operation due to high water velocities in the immediate forebay upstream of the spillway. The spillway has been designed with a gradual slope and no abrupt drops, which is expected to reduce the mortality of fish moving downstream.

Changes in fishing activity

At present, Reach 3 receives no domestic, commercial, or recreational fishing activity because of the difficulty and danger associated with accessing the area. The construction of a road connecting PR #391 with the Wuskwatim GS will increase greatly the potential for people to access Wuskwatim Lake. Reach 3 itself is unlikely to be affected by any domestic or commercial fishing activity because boat access will remain difficult and dangerous. Some recreational fishing activity may take place immediately downstream of the GS. The expected level of harvest is expected to have no effect on the fish community of Reach 3.

Reach 4: Opegano

Changes in water quality (Section 5)

Expected changes to water quality in Reach 4 are similar to those described for Reach 3.

Changes in the quantity and quality of aquatic habitat (Section 6)

Expected changes to aquatic habitat in Reach 4 resulting from operation of the Project are as follows:

- during operation, water level elevation in Reach 4 will fluctuate depending on the inflow and the number of units operating;
- the intermittently exposed zone will increase in size from 50 ha to 86 ha; of this, 27.9 ha will be a conversion of permanently wetted to intermittently exposed habitat and 8.5 ha of terrestrial habitat will become intermittently exposed;
- the nearshore zone will decrease in size (due to conversion to intermittently exposed habitat) but the offshore zone will remain the same size;
- the quality of the post-Project intermittently exposed habitat and shallow nearshore habitat will be degraded in comparison to the pre-Project condition due to the increased frequency of water level fluctuations;
- the distribution of substrata types will not be noticeably altered with the exception of the small increase in area (8.5 ha) of flooded terrestrial habitat;
- the altered water regime may result in the loss of a substantial portion of the 45.5 ha of rooted submergent aquatic plants beds (6% of the aquatic habitat in the reach); and
- one unnamed tributary enters into the north end of Opegano Lake. Water depth and velocity within the lower reach of this tributary are not expected to be affected by operation of the GS.

Conversion of permanently wetted to intermittently exposed habitat, in conjunction with the increased frequency of water level fluctuations, is expected to negatively affect the quantity and quality of spawning and feeding habitat available to fish in Reach 4. The potential loss of a substantial proportion of the 45.5 ha of rooted submergent aquatic plants would result in a loss of cover for fish within the reach.

Changes in invertebrate production (Section 7)

Expected changes to invertebrate production in Reach 4 resulting from operation of the Project are as follows:

- as in Reach 3, benthic invertebrates are expected to noticeably decrease in abundance and distribution in Reach 4, as the quality of the intermittently exposed zone will be degraded; and

- reduced production of benthic invertebrates is expected to decrease the amount of food available to forage fish and larger members of the fish community in Reach 4.

Reduced production of benthic invertebrates is expected to decrease the amount of food available to forage fish and larger members of the fish community in Reach 4.

Changes in forage fish production

Expected changes to forage fish production in Reach 4 resulting from operation of the Project are as follows:

- the decreased production of benthic invertebrates, combined with the reduction in the amount of available habitat, is expected to reduce forage fish production in Reach 4; and

- reduced production of forage fish is expected to decrease the amount of food available to predators in Reach 4.

Reduced production of benthic invertebrates is expected to decrease the amount of food available to forage fish and larger members of the fish community in Reach 4.

Changes in fish movements

Expected changes to fish movements in Reach 4 resulting from operation of the Project are as follows:

- fish movements within Opegano Lake itself, and movements downstream below Opegano Lake, will not be affected by operation of the GS;

- fish movements from Opegano Lake upstream into Reach 3 may be affected due to differences in water depth and velocity under some flow scenarios; and
- it is expected that a reduction in the number of fish moving downstream from Reach 2 into Reach 3 will result in fewer fish moving downstream into Reach 4.

Fewer fish are expected to move downstream into Reach 3 and, ultimately, Reach 4.

Changes in fishing activity

Because access to Opegano Lake will remain difficult, no increase in domestic, commercial or recreational fishing is expected as a result of the Project.

Access road stream crossings

Changes in quantity and quality of habitat that are described under construction will continue under operation, as the access road will remain in place for the lifespan of the GS. Regular inspection and maintenance of the stream crossings will ensure that proper water flow and fish passage are maintained, and reduce the chance of erosion and sedimentation (Volume 3).

8.4.2.2 Effects of Operation on Valued Ecosystem Component Species

Walleye

Predicted impacts on the walleye population of the study area resulting from habitat alteration due to operation of the Project are summarized in Table 8-20.

Reach 1: Wuskwatim

Stabilization of water levels in Reach 1 at the upper end of the existing range will convert 1588 ha of intermittently exposed to wetted nearshore habitat (Section 6). Most of the newly created wetted nearshore habitat occurs in the shallow, productive areas of the adjacent water bodies (Sesep Lake, Wuskwatim Brook, and Wuskwatim Lake south; Section 6). This change in water level regime is expected to result in a small, long-term increase in the production of aquatic plants and invertebrates (Section 7), which is expected to result in an increase in the production of forage fish and the amount of food available to walleye. An increase in the amount of spawning (i.e., better access to tributaries such as the Muskeseu River) and feeding habitat available to walleye is also expected.

Table 8-20. Summary of impacts on walleye resulting from habitat alteration due to operation of the Project.[1]

	Changes in water quality	Changes in the quantity and quality of aquatic habitat	Changes in invertebrate production	Changes in forage fish production
Reach 1: Wuskwatim				
Spawning	Ø	+	N/A	N/A
Feeding	Ø	+	+	+
Overwintering	-	Ø	N/A	N/A
Reach 2: The Falls				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	+	+	+
Overwintering	-	+	N/A	N/A
Reach 3: Burntwood				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	-	-	-
Overwintering	-	-	N/A	N/A
Reach 4: Opegano				
Spawning	Ø	Ø	N/A	N/A
Feeding	Ø	-	-	-
Overwintering	Ø	Ø	N/A	N/A

1 Assessments are based on analyses presented in Volume 5, Section 8
\+ The impact is expected to have a positive effect on walleye within the reach
\- The impact is expected to have a negative effect on walleye within the reach
Ø No predicted effect
N/A Not applicable

Fewer larval walleye are expected to drift downstream out of Wuskwatim Lake due to the decrease in water velocity at Wuskwatim Falls. While it is expected that the downstream movement of **juvenile** and **adult** walleye out of Wuskwatim Lake will continue at about the same rate as at present, the reduction of water velocities at Wuskwatim Falls will allow most juvenile and adult walleye the opportunity to move back into Reach 1. The combination of less drift of larval walleye out of Wuskwatim Lake, and the ability of most juvenile and adult walleye to move upstream from Reach 2 into Reach 1, are expected to result in fewer walleye leaving Wuskwatim Lake.

Short-term (5 years) increases in erosion, turbidity, and sedimentation along eroding shorelines within Wuskwatim Lake main and Cranberry Lakes (Section 5.4.1) may reduce the suitability of these areas for invertebrate production and may result in short-term avoidance of these areas by walleye. However, increased erosion, turbidity, and sedimentation in these areas are not expected to adversely affect walleye because: i) the primary walleye spawning areas in Reach 1 (Wuskwatim Brook and the southwest bay of

Wuskwatim Lake) will not be affected; and ii) increased erosion will affect shoreline environments of Wuskwatim Lake main and Cranberry Lakes which are currently not highly productive in terms of **forage**. Although a reduction in the total amount of walleye overwintering habitat in Reach 1 may occur due to reduced oxygen concentrations in off-current areas within some of the adjacent water bodies (Section 5), walleye abundance within this reach is not expected to be affected as overwintering habitat is abundant within the reach (e.g., Wuskwatim Lake main).

Reach 2: Falls

Inundation of Reach 2 due to operation of the Project will produce substantially higher and more stable water levels than under existing conditions. This change in water level regime will increase the amount of aquatic habitat in Reach 2 (Section 6), and is expected to increase the amount of feeding and overwintering habitat available to walleye. The higher, more stable water levels are also expected to increase the amount of invertebrate and forage fish production that is expected to result in an increase in the amount of food available to walleye. Overall, water velocities within Reach 2 will be reduced, making more of the reach usable to walleye.

Presently, walleye residing in Reach 2 are restricted from moving further upstream by Wuskwatim Falls. As discussed above, reduction of water velocities at Wuskwatim Falls will allow most juvenile and adult walleye to move upstream from Reach 2 into Reach 1 and thereby have access to aquatic habitat within all of Wuskwatim Lake and adjacent water bodies for spawning, feeding, and overwintering. Due to non-preferred habitat immediately upstream of the GS (deep and non-productive in terms of forage) and reduction of water velocities at the GS intake (relative to Taskinigup Falls), it is expected that fewer larval, juvenile, and adult walleye will move downstream out of Reach 2 into reaches 3 and 4.

While it is expected that any spawning habitat that walleye presently use within Reach 2 (i.e., downstream of the base of Wuskwatim Falls) will be likely be lost, and no spawning habitat is expected to be created within the reach, walleye within Reach 2 will be able to access spawning habitat in Reach 1. Some of the overwintering habitat created by flooding within off-current areas of Reach 2 may undergo moderate, short-term reductions in dissolved oxygen concentration (Section 5) making this habitat unsuitable for walleye. Flooding of terrestrial habitat in Reach 2 is expected to have no other effects on water quality and, therefore, no impacts on walleye.

Reach 3: Burntwood

During operation of the Project, Reach 3 will undergo a conversion of 17 ha of wetted nearshore habitat to intermittently exposed habitat and a reduction in the quality of intermittently exposed habitat (relative to the pre-Project condition) due to the increased frequency of water level fluctuations (Section 6). Increased water level fluctuations are predicted to negatively affect the quality and quantity of walleye spawning (tributaries draining into backwater inlets 6, 9, and 10), feeding, and overwintering habitat in Reach 3. A further reduction in the quantity and quality of preferred walleye overwintering habitat may occur in Reach 3 due to reduced oxygen concentrations in backwater inlets (Section 5). Increased water level fluctuations also are expected to negatively affect aquatic plant, invertebrate, and forage fish production, and, consequently, result in less food for walleye in Reach 3.

Alterations in water velocity within Reach 3 are not expected to negatively affect walleye. The amount of low velocity (< 0.5 m/s) habitat present within Reach 3 under 3 units best gate flows (122.1 ha; Section 6) is comparable to the amount of low velocity habitat present under existing 95 percentile conditions (121.9 ha; Section 6), and 2 units best gate (139.6 ha) and 1 unit best gate (197.4 ha) flow scenarios result in a gain in low velocity habitat (Section 6). Under existing conditions, walleye likely have difficulty moving upstream through the rapids immediately downstream of Backwater Inlet 3, Little Jackpine Rapids, the second set of rapids, and the third set of rapids. During operation of the Project, more frequent fluctuations in water level and velocity may improve the ability of walleye to move upstream through these rapids.

As discussed above, it is expected that fewer larval, juvenile, and adult walleye will move downstream out of Reach 2 into Reach 3. Additionally, a proportion of those walleye that do move downstream through the GS will be susceptible to turbine mortality. Consequently, due to the reduced number of walleye that move downstream out of Reach 2, and turbine mortality, fewer larval, juvenile, and adult walleye will move into Reach 3 from upstream locations.

Reach 4: Opegano

During operation of the Project, Opegano Lake will undergo a conversion of 27.9 ha of wetted nearshore habitat to intermittently exposed habitat and a reduction in the quality of intermittently exposed habitat (relative to the pre-Project condition) due to the increased frequency of water level fluctuations (Section 6). The increased frequency of water level fluctuations are predicted to negatively affect the quality and quantity of walleye feeding habitat, although the quality and quantity of spawning and overwintering habitat are not expected to be affected. Water level fluctuations also are expected to negatively affect aquatic plant, invertebrate, and forage fish production, and, consequently, result in less food for walleye in Reach 4. As noted above, reduced water velocities at the inlet and outlet of Reach 2 and turbine mortality are expected to result in fewer walleye migrating into Opegano Lake from upstream of the GS.

Assessment of significance

It is expected that operation of the Project will result in more walleye in reaches 1 and 2 due to greater access to spawning and feeding habitat, more invertebrates and forage fish available as food, unrestricted movement between reaches 1 and 2 for most walleye, and fewer walleye moving downstream out of Reach 2.

It is expected that there will be fewer walleye in reaches 3 and 4 due to an increase in the frequency of water level fluctuations that will affect the quantity and quality of spawning, feeding, and overwintering habitat in Reach 3, and feeding habitat in Reach 4, and result in a reduction in the abundance of invertebrates and forage fish available as food. Additionally, fewer walleye are expected to move downstream into reaches 3 and 4 from upstream of the GS. Although the relative contribution of migrants from Wuskwatim Lake to the total number of walleye in reaches 3 and 4 is not known, given the small amount of aquatic habitat in reaches 3 and 4 relative to that of Wuskwatim Lake and adjacent water bodies, migrants from Reach 1 may comprise a measurable proportion of the number of walleye in reaches 3 and 4.

Overall, it is expected that, since the abundance of walleye in the upstream reaches (particularly Reach 1) is greater than in the downstream reaches, the positive effects to walleye in reaches 1 and 2 will outweigh the negative effects to walleye in reaches 3 and 4 and result in a **long-term, small, local and, therefore, not significant positive effect to the walleye population of the study area**.

Lake Whitefish

Predicted impacts on the lake whitefish population of the study area resulting from habitat alteration due to operation of the Project are summarized in Table 8-21.

Reach 1: Wuskwatim

The small, long-term increase in the production of invertebrates in Reach 1 that will result from stabilization of lake levels at the upper end of the existing range will increase

Table 8-21. Summary of impacts on lake whitefish resulting from habitat alteration due to operation of the Project[1]

	Changes in water quality	Changes in the quantity and quality of aquatic habitat	Changes in invertebrate production	Changes in forage fish production
Reach 1: Wuskwatim				
Spawning	Ø	+/-	N/A	N/A
Feeding	Ø	+	+	Ø
Overwintering	Ø	Ø	N/A	N/A
Reach 2: The Falls				
Spawning	Ø	Ø	N/A	N/A
Feeding	Ø	Ø	Ø	Ø
Overwintering	Ø	Ø	N/A	N/A
Reach 3: Burntwood				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	-	-	Ø
Overwintering	Ø	Ø	N/A	N/A
Reach 4: Opegano				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	-	-	Ø
Overwintering	Ø	Ø	N/A	N/A

[1] Assessments are based on analyses presented in Volume 5, Section 8
\+ The impact is expected to have a positive effect on lake whitefish within the reach
\- The impact is expected to have a negative effect on lake whitefish within the reach
Ø No predicted effect
N/A Not applicable

the amount of food available to lake whitefish. The altered water level regime is also expected to increase the quantity of spawning and feeding habitat and eliminate the potential for exposure or **ice-scouring** of eggs and/or larvae due to winter **drawdown** that occurs under existing conditions in years when the water level declines between fall and late winter.

As discussed for walleye, the combination of less drift of larval lake whitefish out of Wuskwatim Lake, and the ability of most juvenile and adult whitefish to move upstream from Reach 2 into Reach 1, are expected to result in fewer lake whitefish leaving Wuskwatim Lake.

Increased erosion and sedimentation in Wuskwatim Lake main and Cranberry Lakes may reduce the quality of lake whitefish spawning habitat along eroding shorelines for the first 5 years of operation of the Project. Lake whitefish overwintering habitat in Reach 1 is not expected to be affected by localized reductions in dissolved oxygen concentrations in off-current areas as whitefish overwintering habitat appears to be limited to Wuskwatim Lake main.

Reach 2: Falls

Presently, the small number of lake whitefish found within Reach 2 are believed to be transients that have moved downstream over Wuskwatim Falls and will likely move further downstream in the near future as they are not able to move back upstream over Wuskwatim Falls. Reduction of water velocities at Wuskwatim Falls will allow most juvenile and adult whitefish found within Reach 2 to move back upstream into Reach 1 and thereby have access to aquatic habitat within all of Wuskwatim Lake and adjacent water bodies for spawning, feeding, and overwintering. Due to less suitable habitat immediately upstream of the GS (deep and non-productive in terms of forage) and reduction of water velocities at the GS intake, it is expected that fewer larval, juvenile, and adult lake whitefish will move downstream out of Reach 2 into reaches 3 and 4.

Reach 3: Burntwood

The increased frequency of water level fluctuations is predicted to negatively affect the quality and quantity of lake whitefish spawning (due to the potential for exposure or ice-scouring of eggs and/or larvae) and feeding (exposure of backwater inlets) habitat. The increased frequency of water level fluctuations is also expected to negatively affect invertebrate production, and, consequently, result in less food for lake whitefish in Reach 3. As whitefish do not extensively use the backwater inlets for overwintering, reduced oxygen concentrations nor fluctuating water levels are expected to negatively affect lake whitefish overwintering habitat. As discussed for walleye, alterations in water velocity within Reach 3 due to operation of the Project are not expected to negatively affect lake whitefish. Reduced water velocities at the inlet and outlet of Reach 2 and turbine mortality are expected to result in fewer lake whitefish migrating into Reach 3 from upstream of the GS.

Reach 4: Opegano

The increased frequency of water level fluctuation and reduction in the quality of intermittently exposed habitat are predicted to negatively affect the quantity and quality of lake whitefish feeding habitat (exposure of productive feeding habitat in the north end of the lake), although overwintering habitat is not expected to be affected. There may be a minor reduction in the quantity and quality of spawning habitat due to exposure or ice scour of eggs and/or larvae. Water level fluctuations also are expected to negatively affect invertebrate production (Section 7) and, consequently, result in less food for lake whitefish in Reach 4. Similar to the above discussion, reduced water velocities at the inlet and outlet of Reach 2 and turbine mortality are expected to result in fewer lake whitefish migrating into Opegano Lake from upstream of the GS.

Assessment of significance

In the short-term (5 years after construction of the Project), it is expected that operation of the Project will have positive (more food and an increase in the quantity of spawning habitat) and negative (a decrease in the quality of spawning habitat due to sedimentation of some areas) effects on lake whitefish in Reach 1. However, in the long-term, it is expected that the number of lake whitefish in Reach 1 will increase due to more spawning and feeding habitat, more food, unrestricted movement between reaches 1 and 2 for most individuals, and fewer whitefish moving downstream out of Reach 2.

It is expected that there will be fewer lake whitefish in reaches 3 and 4 due to an increase in the frequency of water level fluctuations that will affect the quality and quantity of spawning and feeding habitat in reaches 3 and 4, and result in a reduction in the amount of food. Additionally, fewer whitefish are expected to move downstream into reaches 3 and 4 from upstream of the GS. As discussed for walleye, migrants from Reach 1 may comprise a measurable proportion of the number of lake whitefish in reaches 3 and 4.

Overall, it is expected that the positive effects to lake whitefish in Reach 1 will outweigh the negative effects to whitefish in reaches 3 and 4 and result in a **long-term, small, local and, therefore, not significant positive effect to the lake whitefish population of the study area**.

Lake Cisco

Predicted impacts on the lake cisco population of the study area resulting from habitat alteration due to operation of the Project are summarized in Table 8-22.

Reach 1: Wuskwatim

The assessment of impacts on lake cisco in Reach 1 is similar to that of lake whitefish and only the differences will be discussed here. Unlike lake whitefish, lake cisco overwinter in some of the off-current areas of Reach 1 that may be affected by localized reductions in dissolved oxygen concentration (Section 5). However, lake cisco abundance is not expected to be affected as overwintering habitat is abundant within the reach (e.g., Wuskwatim Lake main).

Table 8-22. Summary of impacts on lake cisco resulting from habitat alteration due to operation of the Project.[1]

	Changes in water quality	Changes in the quantity and quality of aquatic habitat	Changes in invertebrate production	Changes in forage fish production
Reach 1: Wuskwatim				
Spawning	Ø	+/-	N/A	N/A
Feeding	Ø	+	+	Ø
Overwintering	-	Ø	N/A	N/A
Reach 2: The Falls				
Spawning	Ø	Ø	N/A	N/A
Feeding	Ø	+	+	Ø
Overwintering	-	+	N/A	N/A
Reach 3: Burntwood				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	-	-	Ø
Overwintering	-	-	N/A	N/A
Reach 4: Opegano				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	-	-	Ø
Overwintering	Ø	Ø	N/A	N/A

1 Assessments are based on analyses presented in Volume 5, Section 8
\+ The impact is expected to have a positive effect on lake cisco within the reach
\- The impact is expected to have a negative effect on lake cisco within the reach
Ø No predicted effect
N/A Not applicable

Reach 2: Falls

Unlike lake whitefish, lake cisco are relatively abundant in Reach 2, although the majority of these fish are also believed to be transients. Substantially higher and more stable water levels are expected to increase the amount of feeding and overwintering habitat that would be available to lake cisco in Reach 2. The higher, more stable water levels are also expected to increase the amount of invertebrate production that will result in an increase in the amount of food. As discussed for lake whitefish, reductions in water velocity at Wuskwatim Falls and the GS intake (relative to Taskinigup Falls) will result in access to Reach 1 for cisco in Reach 2, and fewer larval, juvenile, and adult cisco moving downstream out of Reach 2 into reaches 3 and 4. Some of the overwintering habitat created within off-current areas of Reach 2 may undergo moderate, short-term reductions in dissolved oxygen concentration, making this habitat less suitable for lake cisco.

Reach 3: Burntwood

The assessment of impacts on lake cisco in Reach 3 is similar to that of lake whitefish. Lake cisco appear to make more use of the backwater inlets for overwintering than lake whitefish and, consequently, reduced oxygen concentrations and fluctuating water levels in the backwater inlets will affect lake cisco overwintering habitat in Reach 3. However, it is expected that lake cisco would use other low velocity habitat within Reach 3 or move downstream to Opegano Lake to overwinter. Reduced water velocities at the inlet and outlet of Reach 2 and turbine mortality are expected to result in fewer lake cisco migrating into Reach 3 from upstream of the GS.

Reach 4: Opegano

Impacts of operation of the Project on lake cisco in Reach 4 are identical to those of lake whitefish.

Assessment of significance

In the short-term (5 years after construction of the Project), it is expected that operation of the Project will have both positive (more food and an increase in the quantity of spawning habitat) and negative (a decrease in the quality of spawning habitat due to sedimentation of some areas) effects on lake cisco in Reach 1. However, in the long-term, it is expected that the number of lake cisco in Reach 1 will increase due to more spawning and feeding habitat, more food, unrestricted movement between reaches 1 and 2 for most individuals, and fewer cisco moving downstream out of Reach 2.

It is expected that there will be fewer lake cisco in reaches 3 and 4 due to an increase in the frequency of water level fluctuations that will affect the quality and quantity of spawning and feeding habitat in reaches 3 and 4, and overwintering habitat in Reach 3, and result in less food. Additionally, fewer cisco are expected to migrate into reaches 3 and 4 from upstream of the GS. As discussed for walleye and lake whitefish, migrants from Reach 1 may comprise a measurable proportion of the number of lake cisco in reaches 3 and 4.

Overall, it is expected that the positive effects to lake cisco in Reach 1 will outweigh the negative effects to cisco in reaches 3 and 4 and result in a **long-term, small, local and, therefore, not significant positive effect to the lake cisco population of the study area**.

Northern pike

Predicted impacts on the northern pike population of the study area resulting from habitat alteration due to operation of the Project are summarized in Table 8-23.

Table 8-23. Summary of impacts on northern pike resulting from habitat alteration due to operation of the Project.[1]

	Changes in water quality	Changes in the quantity and quality of aquatic habitat	Changes in invertebrate production	Changes in forage fish production
Reach 1: Wuskwatim				
Spawning	Ø	+	N/A	N/A
Feeding	Ø	+	+	+
Overwintering	-	Ø	N/A	N/A
Reach 2: The Falls				
Spawning	Ø	+/-	N/A	N/A
Feeding	Ø	+/-	+	+
Overwintering	-	+	N/A	N/A
Reach 3: Burntwood				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	-	-	-
Overwintering	-	-	N/A	N/A
Reach 4: Opegano				
Spawning	Ø	-	N/A	N/A
Feeding	Ø	-	-	-
Overwintering	Ø	Ø	N/A	N/A

1 Assessments are based on analyses presented in Volume 5, Section 8
\+ The impact is expected to have a positive effect on northern pike within the reach
\- The impact is expected to have a negative effect on northern pike within the reach
Ø No predicted effect
N/A Not applicable

Reach 1: Wuskwatim

The assessment of impacts on northern pike in Reach 1 is similar to that of walleye and only the differences will be discussed here. In the short-term, there will be a small to moderate increase in the quantity of spawning habitat for northern pike in Reach 1 due to the inundation of emergent vegetation near the mouths of tributaries resulting from higher water levels. However, in the long-term much of this vegetation will decompose due to the stabilization of water levels and northern pike spawning habitat will be restricted to flooded tributary mouths. While northern pike are less effective swimmers than the other three VEC species, it is believed that large pike will be able to move freely between reaches 1 and 2 in the post-Project environment.

Reach 2: Falls

Substantially higher and more stable water levels are expected to increase the amount of feeding and overwintering habitat for northern pike in Reach 2. As in Reach 1, there will be a short-term small increase in the quantity of spawning habitat due to the inundation of terrestrial vegetation near the south shore tributary. However, in the long-term much of this vegetation will decompose and spawning habitat will be restricted to the flooded tributary mouth along the south shore. The loss of the north shore tributary (Section 6) will result in a loss of spawning habitat. The loss of 1.5 ha of rooted submergent aquatic plants habitat (Section 6) will result in a reduction in the quality of feeding habitat. As discussed above, large northern pike will be able to move freely between reaches 1 and 2, thereby expanding the amount of spawning, feeding, and overwintering habitat available to individuals resident in Reach 2. Additionally, fewer larval, juvenile, and adult northern pike are expected to move downstream out of Reach 2 into reaches 3 and 4.

Reach 3: Burntwood

Northern pike use the backwater inlets habitat in Reach 3 for spawning, feeding, and overwintering and, consequently, the periodic loss of a substantial proportion of this habitat due to more frequent water level fluctuations will have a negative effect on northern pike in this reach. Substantial daily water level fluctuations during the spring spawning period could result in some pike eggs being laid during high water periods and subsequently being exposed when water levels decline. Reduced water velocities at the inlet and outlet of Reach 2 and turbine mortality are expected to result in fewer northern pike migrating into Reach 3 from upstream of the GS.

Reach 4: Opegano

The increased frequency of water level fluctuations on Opegano Lake are predicted to negatively affect the quantity and quality of northern pike spawning and feeding habitat, particularly in the vicinity of the tributary flowing into the north shore of the lake. As discussed above, daily water level fluctuations could result in exposure of pike eggs and/or larvae. Similar to previous discussions, reduced water velocities at the inlet and outlet of Reach 2 and turbine mortality are expected to result in fewer northern pike migrating into Opegano Lake from upstream of the GS.

Assessment of significance

It is expected that there will be more northern pike in reaches 1 and 2 due to greater access to spawning and feeding habitat, more food, unrestricted movement between reaches 1 and 2 for larger northern pike, and fewer pike moving downstream out of Reach 2.

It is expected that there will be fewer northern pike in reaches 3 and 4 due to an increase in the frequency of water level fluctuations that will affect the quantity and quality of spawning, feeding, and overwintering habitat in Reach 3, and spawning and feeding habitat in Reach 4, and result in less food available to pike. Additionally, fewer northern pike are expected to migrate into reaches 3 and 4 from upstream of the GS. As discussed for the other three VEC species, migrants from Reach 1 may comprise a measurable proportion of the number of northern pike in reaches 3 and 4.

Overall, the greater abundance of northern pike in reaches 1 and 2 is expected to outweigh the reduced abundance of pike in reaches 3 and 4 and result in a **long-term, small, local and, therefore, not significant positive effect to the northern pike population of the study area**.

Increased fishing activity

Increased access to Wuskwatim Lake is expected to result in a substantial increase in domestic harvest and a moderate increase in the recreational harvest of walleye and northern pike over pre-Project levels (Volume 7). The extent of this increase will depend on measures taken in the Access Management Plan.

To a large extent, the potential increase in commercial fishing depends on the response of the Freshwater Fish Marketing Corporation (FFMC) to information gathered as a result of the EIA studies. The FFMC does not currently accept walleye from Wuskwatim Lake due to recorded high mercury levels. Sampling conducted during EIA studies indicated that mercury levels in walleye have declined and are now well below the limit for commercial sale. For the purposes of the EIS, it is assumed that FFMC will review the status of Wuskwatim Lake walleye and it is further assumed that FFMC will resume accepting these fish for commercial sale.

Because access to Opegano Lake will remain difficult, no domestic, commercial, or recreational fishing activity is expected to occur as a result of operation of the Project.

Although an increase in the abundance of walleye, lake whitefish, lake cisco, and northern pike in the study area is predicted, the presence of active domestic, commercial, and recreational fisheries during operation of the Project will increase fish mortality and may affect the abundance of the four VEC fish species, particularly in Wuskwatim Lake and adjacent water bodies. Manitoba Conservation is responsible for the management of fisheries in the province, including avoidance of adverse effects related to over-harvest.

8.5 RESIDUAL EFFECTS

Expected residual effects to VEC fish species resulting from construction and operation of the Project are summarized in Volume 5, Section 10. Additional detail regarding expected residual effects to VEC fish species are discussed in Section 8.4. **In summary, the residual effects of construction of the Project on populations of VEC fish species are expected to be negative, short-term, small, local and, therefore, not significant**. **The residual effects of operation of the Project on populations of VEC fish species are expected to be positive, long-term, small, local and, therefore, not significant.**

9.0 FISH QUALITY

9.1 INTRODUCTION

Fish are important indicators of ecosystem health, are valuable to NCN as a domestic and commercial resource, and are a regional recreational resource. Changes in fish quality (either directly or indirectly via the food chain) can affect domestic fish consumption and may also affect the livelihood of commercial fishers. Indicators of fish quality being considered in this assessment include trace metals, particularly mercury, internal parasites, and fish palatability. Four important domestic and commercial fish species - walleye, northern pike, lake whitefish, and lake cisco have been selected as VECs for the purpose of assessing the significance of any adverse project-related effects on fish quality.

9.2 MERCURY

This section provides a brief overview of the environmental relevance of mercury and summarizes available information on fish mercury levels in the study area. Between lake comparisons of fish mercury concentrations and the relationships between mercury levels and fish size and age are discussed for Wuskwatim, Opegano, and Birch Tree lakes. Pre and post CRD mercury levels from Wuskwatim Lake and information from Leftrook Lake (a reference lake in the Nelson House RMA that was not affected by CRD) are cited to evaluate the present results in a broader geographical and historical context.

9.2.1 Approach and methods

Mercury in the aquatic environment

Due to the detrimental effects of relatively small amounts of mercury, the frequent consumption of fish with high mercury levels may pose a risk to human health (Clarkson 1997; Weir 2000). Mercury levels in aquatic systems and its bioaccumulation in fish are the result of numerous processes. Mercury can be released directly into aquatic systems through natural weathering of rocks (Derksen 1978) or from deposition of emissions and effluents from anthropogenic sources such as chlor-alkali plants, coal-fired generating stations, smelters, incinerators, and other industries (Brouzes et al. 1977). Human activities can also make mercury more available to the food chain. For example, the inundation of rock, soils and vegetation as a result of the creation of new reservoirs introduces inorganic mercury and organic nutrients to the water column, which in turn, increase microbial methyl mercury production (Ramlal et al. 1987; Kelly et al. 1997). Methyl mercury is primarily taken up via the diet (Harris and Snodgrass 1993; Hall et al.

1997) and accumulates in biota. In fish, 71-95% of the total mercury is present as the organic form methyl mercury (Jackson 1991; Phillips and Gregory 1979; Bloom 1992; Bodaly and Fudge 1999). Skeletal muscle is the principle storage tissue for mercury in fish, concentrations generally increase with increasing age or body size (Phillips and Buhler 1978; Huckabee et al. 1979). Elimination of methyl mercury is slower than the rate of uptake in fish. Similar to many other pollutants, methyl mercury is biomagnified as it moves through the food chain (Jernelöv and Lann 1971; Cox et al. 1979; Hall et al. 1997); the magnitude of bioaccumulation is positively related to food chain length (Harris and Snodgrass 1993; Cabana et al. 1994; Kidd et al. 1995). Other factors such as behaviour, habitat preferences, metabolic rate, age, and size also potentially affect the bioaccumulation of mercury in fish (Jackson 1991).

The numerous reports of abnormally high mercury levels in fish soon after the impoundment of formerly riverine habitats from geographically distinct and environmentally diverse regions of the world (e.g., Cox et al. 1979; Bodaly et al 1984; Surma-Aho et al. 1983; Yingcharoen and Bodaly 1993), suggest that the above processes and patterns of mercury accumulation are a common consequence of reservoir creation. In northern Manitoba reservoirs, mercury concentrations generally show a characteristic pattern of increase and decline over time, with maximum values usually occurring 6-11 years after flooding (Bodaly et al. 1997). Mercury levels in piscivorous fish in northern reservoirs remain elevated over pre-impact levels for approximately 20-30 years (Bodaly et al. 1997).

Maximum mercury concentrations in piscivorous fish in boreal reservoirs usually exceed the recommended level of 0.2 ppm in fish muscle to be consumed by persons eating large quantities of fish (Wheatley 1984), as well as the guideline of 0.5 ppm for fish to be commercially marketed in Canada (Health Canada 2002). Mercury concentrations of piscivorous fish in natural northern lakes can also surpass recommended consumption and marketing thresholds. For example, northern pike of 700 mm standardized length from 59 non-impacted lakes in northern Quebec had mean mercury concentrations ranging from 0.30 to 1.81 $\mu g \cdot g^{-1}$ (Schetagne and Verdon 1999).

Fish sampling

Fish for mercury analyses were captured during index gillnetting programs at Wuskwatim Lake in August 1998 (Bernhardt 1999) and in August 2002, at Opegano Lake in August 2000 (Mota et al. 2001a) and in August 2001 (Mota et al. 2001b), at Birch Tree Lake in July 2000 (Mota et al. 2001b) and in August 2001, and at Leftrook Lake in August of 1999 (Fazakas 2000; Figure 9-1). Muscle samples for mercury analysis were collected from a length-stratified sample of the four VEC fish species: lake whitefish, lake cisco, northern pike, and walleye. Captured fish were measured for fork length (±1 mm) and total weight (±25 g), and bony structures were removed for age analysis. Because fish accumulate mercury over their lifetime, older and larger individuals normally have higher concentrations than younger, smaller fish, mean mercury concentrations (µg mercury·g^{-1} body wet weight; ppm) were standardized by length to facilitate comparisons between samples of fish from the same lake or between samples of fish from different water bodies over time. Standard lengths of 300, 350, 550 and 400 mm were used for lake cisco, lake whitefish, northern pike, and walleye, respectively. These are the same standard lengths used in the Program for Monitoring of Mercury Concentrations in Fish in Northern Manitoba Reservoirs (MMCR; see Strange and Bodaly 1999).

9.2.2 Results

9.2.2.1 Recent mercury levels in fish from Wuskwatim, Opegano and Birch Tree lakes

A total of 676 fish (155 cisco, 170 whitefish, 156 pike, and 195 walleye) taken from in Wuskwatim, Opegano, and Birch Tree lakes between 1998 and 2002 were analyzed for muscle mercury concentrations (Table 9-1). Differences in the number of fish of a given species sampled within in each lake were largely due to differences in the abundance and availability of each of the four fish species, e.g. despite substantial sampling effort, only seven cisco were captured from Opegano Lake in 2000 and 2001 (Table 9-1). Whitefish and pike from Wuskwatim Lake analyzed for mercury in 1998 were significantly smaller and younger than those sampled in Opegano and Birch Tree lakes (Table 9-1). The samples of the same two species collected in 2002, were comprised of significantly older, but not larger, fish than in 1998. In contrast, Wuskwatim Lake walleye sampled in 2002 were significantly smaller, but not younger, than the 1998 sample. Overall, walleye from Wuskwatim Lake were significantly younger than walleye from Opegano and Birch Tree lakes, and whitefish from Birch Tree Lake were significantly older, but not larger, than whitefish from Opegano Lake (Table 9-1).

Standardized mercury concentrations were usually lower than the arithmetic values (Table 9-2), reflecting the fact that in most cases the mean length of the total catch analyzed for mercury was higher than the "standard" length for each species. The following discussions relate only to standardized mean mercury concentrations.

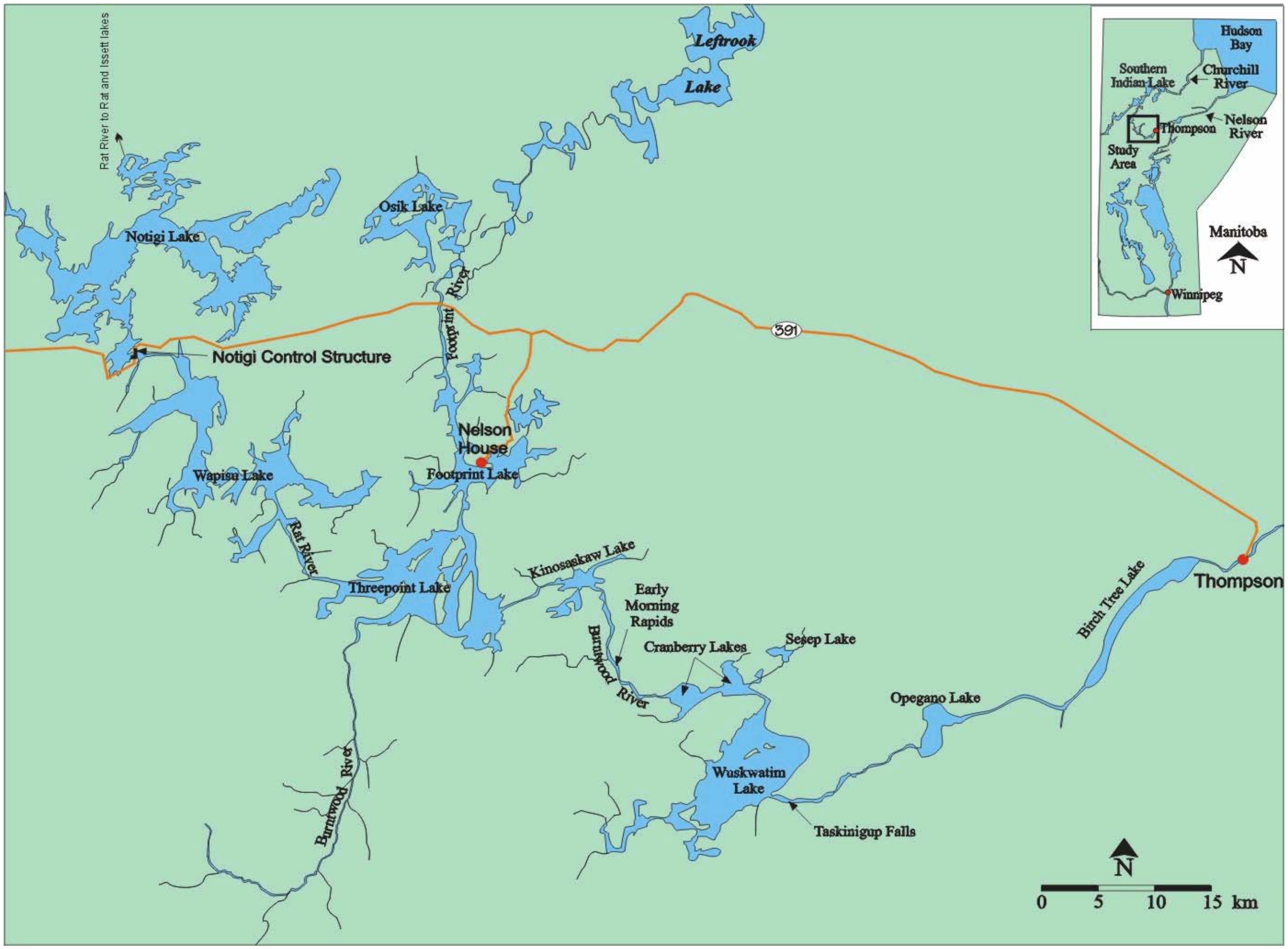


Figure 9-1. Study area for mercury sampling conducted between 1998 and 2002.

Table 9-1. Mean (±SE) fork length, total weight, and age of lake cisco, lake whitefish, northern pike, and walleye from Wuskwatim, Opegano and Birch Tree lakes used for muscle mercury analysis between 1998 and 2002. For Birch Tree Lake, the number of fish for which age was determined is 1 or 2 less than the number for which length and weight was taken. No meaningful mean fish weights could be calculated for Wuskwatim Lake in 2002, because of a lack of data for fish <200 mm length.

Lake	Species	Year	n	Length	Weight	Age [1]
Wuskwatim	Cisco	1998	24	355.9 ± 9.1	772.0 ± 64.6	5.88 ± 0.28
		2002	47	344.0 ± 15.3	-	6.07 ± 0.36 [2]
	Whitefish	1998	30	346.4 ± 14.6	805.8 ± 80.3	5.10 ± 0.44
		2002	60	365.8 ± 12.8	-	8.32 ± 0.70 [3]
	Pike	1998	17	496.6 ± 12.4	864.5 ± 78.3	4.58 ± 0.23 [4]
		2002	75	490.5 ± 19.5	-	6.51 ± 0.42 [5]
	Walleye	1998	44	379.2 ± 15.1	664.6 ±76.9	6.82 ± 0.47 [6]
		2002	44	339.6 ± 12.5	-	6.49 ± 0.36 [7]
Opegano	Cisco	2000	7	302.7 ± 24.7	438.1 ± 92.3	6.29 ± 0.81
		2001	7	342.1 ± 4.7	521.4 ± 19.2	8.14 ± 0.77
	Whitefish	2000	16	399.6 ±11.2	1014.1 ± 91.5	8.88 ± 0.74
		2001	16	402.5 ±7.9	1037.5 ± 65.6	9.88 ± 1.43
	Pike	2000	17	557.4 ± 20.9	1352.9 ±154.2	5.59 ± 0.26
		2001	19	580.2 ± 27.7	1643.4 ± 294.9	6.68 ± 0.56
	Walleye	2000	22	382.1 ± 25.5	767.3 ± 134.5	9.14 ± 1.06
		2001	25	378.0 ± 21.2	710.0 ± 112.8	8.68 ± 0.83
Birch Tree	Cisco	2000	23	367.6 ± 19.9	1077.2 ± 125.6	8.23 ± 0.86
		2001	27	356.5 ± 20.7	920.4 ± 101.2	8.04 ± 0.83
	Whitefish	2000	24	418.4 ± 19.7	1360.4 ± 155.9	14.95 ± 1.75
		2001	24	420.4 ± 22.5	1442.7 ± 191.5	12.29 ± 1.54
	Pike	2000	13	560.0 ± 31.1	1442.3 ± 267.2	5.85 ± 0.46
		2001	15	603.2 ± 33.6	1820.0 ± 288.3	6.93 ± 0.62
	Walleye	2000	31	409.1 ± 21.7	1033.9 ± 161.8	10.20 ± 0.97
		2001	29	385.8 ± 21.5	822.4 ± 129.2	8.69 ± 0.80

[1] - For Birch Tree Lake, the number of fish for which age was determined is 1 or 2 less than the number for which length and weight was taken.

[2] - n=42 [3] - n=57 [4] - n= 21 [5] - n=73 [6] - n=34 [7] - n=43.

Table 9-2. Mean arithmetic (±SE) and standardized (95% C.I.) mercury concentrations ($\mu g \cdot g^{-1}$) of lake cisco, lake whitefish, northern pike, and walleye from Wuskwatim, Opegano, and Birch Tree lakes for 1998-2002. Statistical tests for differences in mercury concentrations between lakes used only data for the years 1998 and 2000; [a] significantly ($p<0.01$) different from Wuskwatim Lake; [b] significantly ($p<0.05$) different from Wuskwatim Lake; [c] significantly ($p<0.01$) different from Opegano Lake; [d] significantly ($p<0.05$) different from Birch Tree Lake in 2000.

Lake	Year	Lake cisco		Lake whitefish		Northern pike		Walleye	
		arithmetic	standard	arithmetic	standard	arithmetic	standard	arithmetic	standard
Wuskwatim	1998	0.13 ±0.01	0.09 (0.07-0.11)	0.11 ±0.01	0.1 (0.09-0.11)	0.36 ±0.03	0.37 (0.28-0.49)	0.31 ±0.04	0.28 (0.24-0.33)
	2002	0.14 ±0.01	0.11 (0.10-0.13)	0.12 ±0.01	0.1 (0.09-0.11)	0.42 ±0.04	0.43 (0.39-0.48)	0.27 ±0.02	0.31 (0.26-0.36)
Opegano	2000	0.11 ±0.01	0.1 (0.07-0.15)	0.15 ±0.02	0.07 (0.05-0.09)	0.68 ±0.09	0.59 [b] (0.50-0.70)	0.43 ±0.06	0.42 (0.36-0.48)
	2001	0.09 ±0.01	0.09 (0.03-0.27)	0.12 ±0.01	0.06 (0.05-0.09)	0.7 ±0.07	0.6 (0.53-0.68)	0.45 ±0.05	0.45 (0.39-0.52)
Birch Tree	2000	0.22 ±0.03	0.15 [a] (0.12-0.19)	0.18 ±0.02	0.11 (0.10-0.13)	0.75 ±0.11	0.67 [a] (0.56-0.80)	0.69 ±0.06	0.64 [a, c] (0.59-0.70)
	2001	0.22 ±0.02	0.18 (0.16-0.22)	0.2 ±0.03	0.13 (0.10-0.16)	0.79 ±0.08	0.65 (0.56-0.76)	0.76 ±0.06	0.76 [d] (0.66-0.86)

Generally, mean mercury concentrations for all lakes and years of cisco (0.09-0.18 $\mu g \cdot g^{-1}$) and whitefish (0.06-0.13 $\mu g \cdot g^{-1}$) were substantially lower than those of pike (0.37-0.67 $\mu g \cdot g^{-1}$) and walleye (0.28-0.76 $\mu g \cdot g^{-1}$). Pike from Opegano and Birch Tree lakes and walleye from Birch Tree Lake exceeded mean mercury concentrations of 0.5 $\mu g \cdot g^{-1}$ (Table 9-2, Figure 9-3), the limit for commercial marketing (Section 9.2.1). All individual pike and walleye from the study area lakes exceeded mercury concentrations of 0.2 $\mu g \cdot g^{-1}$, the level at which regular human consumption of fish is considered problematic (Wheatley 1984).

Mean mercury concentrations of each species were almost identical for the two sampling years in Opegano Lake (Table 9-2; Figures 9-2 and 9-3). Mercury levels in cisco, whitefish, and pike from Birch Tree Lake were also similar in 2000 and 2001. However, Birch Tree Lake walleye had significantly ($p<0.01$) higher mercury concentrations in 2001 than in 2000 (Table 9-2). Mercury levels for cisco, pike, and walleye, increased progressing downstream on the Burntwood River from Wuskwatim Lake to Opegano Lake to Birch Tree Lake (Figures 9-2 and 9-3); concentrations in all three species were significantly higher in Birch Tree Lake samples than those from Wuskwatim Lake. Walleye from Birch Tree Lake had significantly higher mercury levels than walleye from Opegano Lake. Mercury concentrations in pike from Opegano Lake were significantly higher than those in Wuskwatim Lake. The general pattern of higher mercury levels in fish from Birch Tree Lake compared to Opegano Lake and, particularly, Wuskwatim Lake appears to correspond to the proportion of shoreline habitat that was flooded due to CRD (Table 9-3). This correlation is supported by current theories on bioaccumulation of mercury in fishes from flooded reservoirs and a data set of 13 lakes and reservoirs from northern Manitoba (North/South Consultants Inc., unpublished data). However, the correlation becomes weaker if the flooded area of waterbodies contiguous to Wuskwatim Lake is considered, as this would increase the % flooding at Wuskwatim Lake to almost the level observed at Birch Tree Lake.

Table 9-3. Approximate change in relative surface area (Δ area) due to the Churchill River Diversion for the three study area lakes and for Leftrook Lake; data sources: Bodaly et al 1984; CMMA 1987.

Lake	Wuskwatim	Opegano	Birch Tree	Leftrook
Δ area (%)	2-13*	5	38	0

* Δ area (%) becomes approximately 30% if flooding of contiguous waterbodies is included.

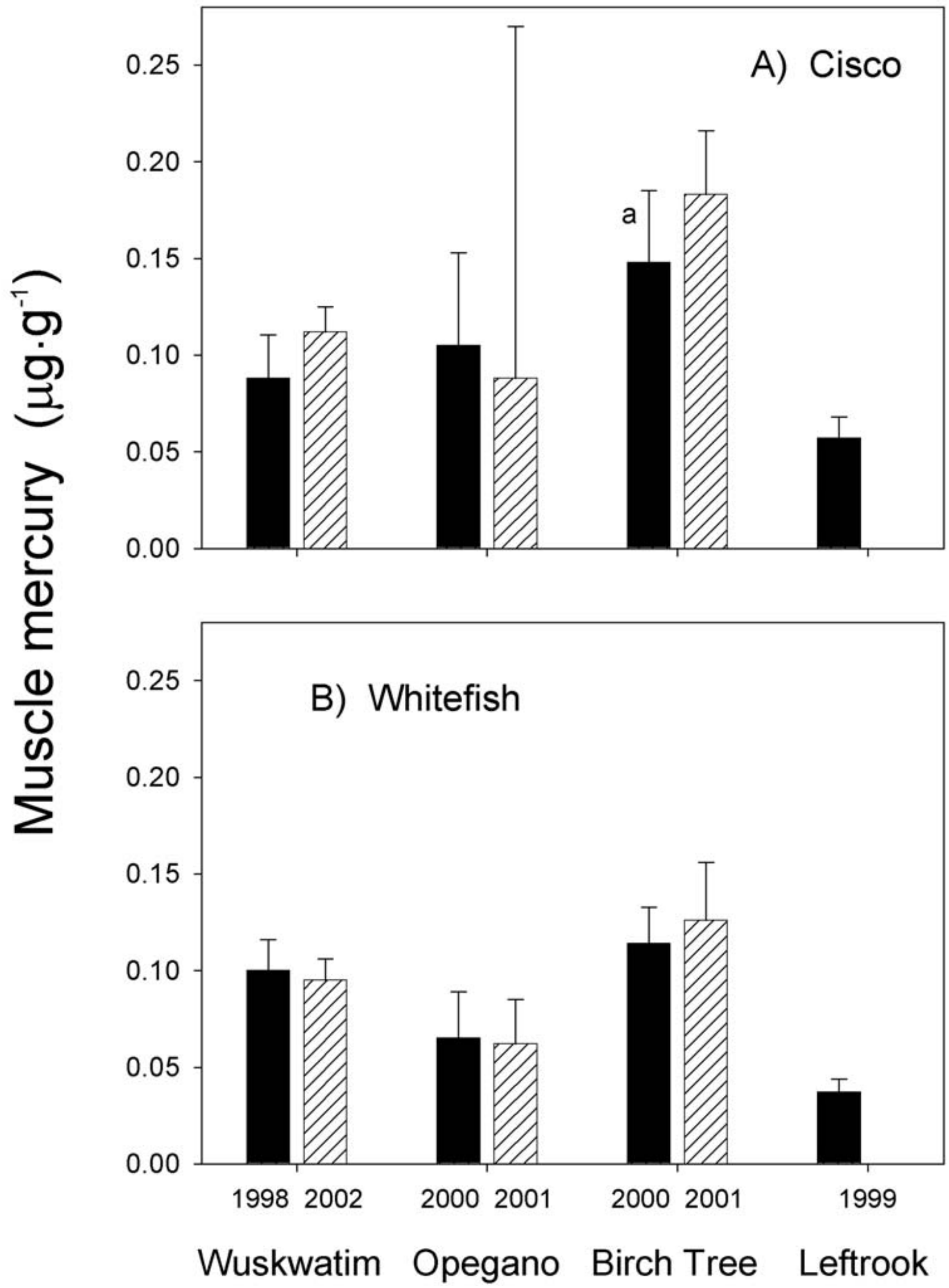


Figure 9-2. Mean and upper 95% confidence limit of standardized muscle mercury concentrations for lake cisco (A) and lake whitefish (B) from Wuskwatim, Opegano, Birch Tree, and Leftrook lakes; a= significantly different from Wuskwatim Lake.

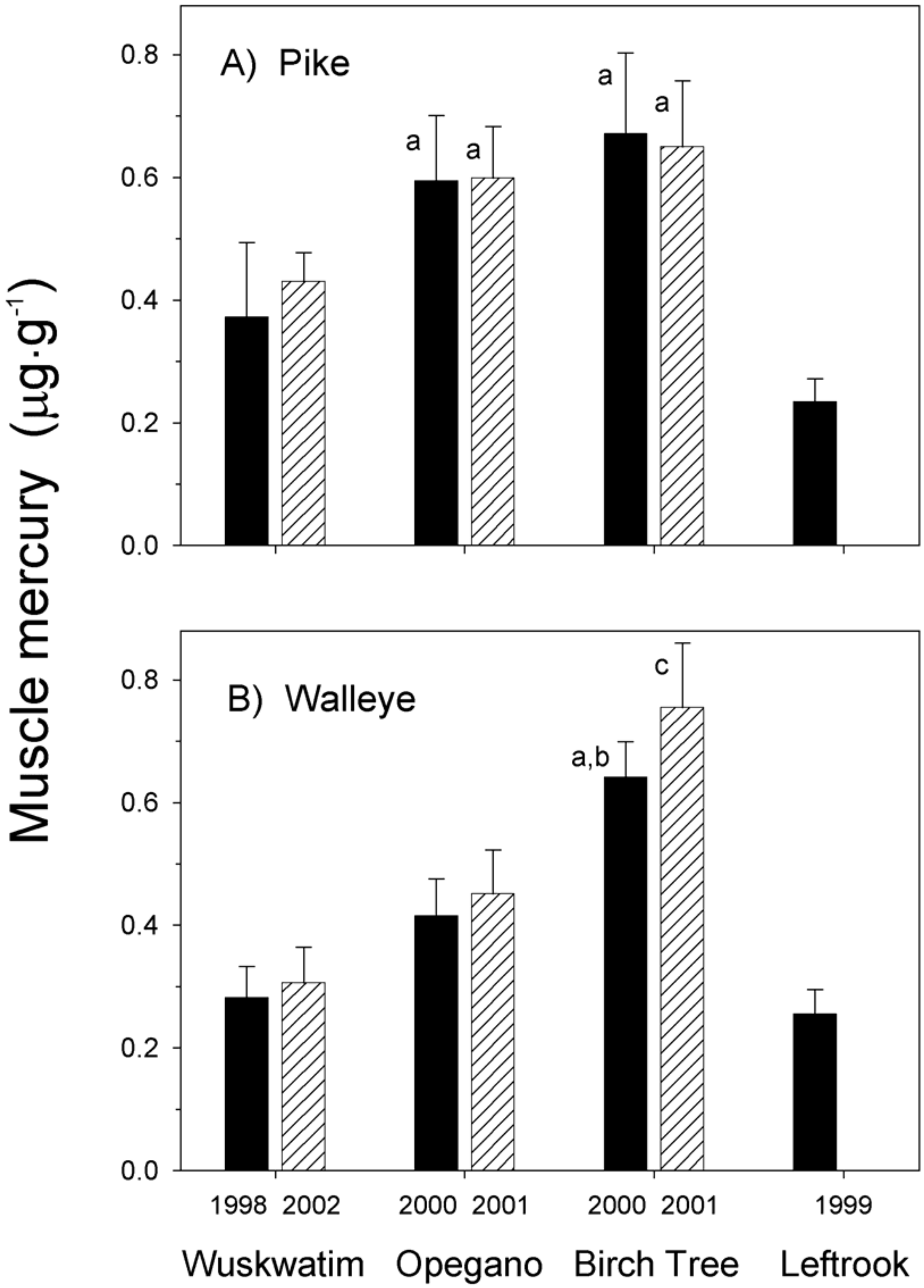


Figure 9-3. Mean and upper 95% confidence limit of standardized muscle mercury concentrations for northern pike (A) and walleye (B) from Wuskwatim, Opegano, Birch Tree, and Leftrook lakes; a= significantly different from Wuskwatim Lake, b= significantly different from Opegano Lake, c= significantly different from year 2000 in Birch Tree Lake.

Mercury levels of all four fish species in Wuskwatim, Opegano, and Birch Tree lakes were higher than those for Leftrook Lake, the reference lake unaffected by CRD (Figures 9-2 and 9-3). These differences were statistically significant except for cisco from Opegano Lake and walleye from Wuskwatim Lake in 1998.

Mercury levels of cisco, whitefish and pike from all Burntwood lakes were between 1.5 and 3.3 times as high as the respective concentrations in the same species from Leftrook Lake. Walleye from Wuskwatim Lake had mean mercury concentrations in 1998 and 2002 that were less than120% of that of their conspecifics from Leftrook Lake,

Generally, mercury concentrations increased significantly with increasing fish length in all three study area lakes. Only the small samples of pike from Wuskwatim Lake (Figure 9-4) and of cisco from Opegano Lake in 2000 and 2001 (Figures 9-5 and 9-6) produced non-significant linear regressions of mercury level against fish length.

The relationship between mercury concentration and fish length was relatively weak for fish from Wuskwatim Lake, as indicated by the relatively large scatter of the data, and the consequent low coefficients of determination. This circumstance was particularly pronounced in walleye, where, in both sampling years, length explained less than 30% of the variability in mercury concentration (Figure 9-4). The large sample of pike collected in 2002 showed the closest relationship between mercury level and fish length of all species collected in Wuskwatim Lake (Figure 9-5).

For fish sampled from Opegano and Birch Tree lakes, the mercury-length relationship was generally stronger than that for fish from Wuskwatim Lake, although some variability existed between the two sampling years and between species. For example, length consistently explained between 58% and 77% of the variability in mercury concentration of pike, whereas whitefish showed the largest variability in r^2- values (Figures 9-6 to 9-9).

Although fork length is commonly used when relating mercury levels to fish size, this independent variable was often not the best descriptor of mercury concentration. In most years, fish age was more closely related to mercury levels; the exceptions being cisco from Wuskwatim Lake and pike from Birch Tree Lake (North/South Consultants Inc. unpublished data).

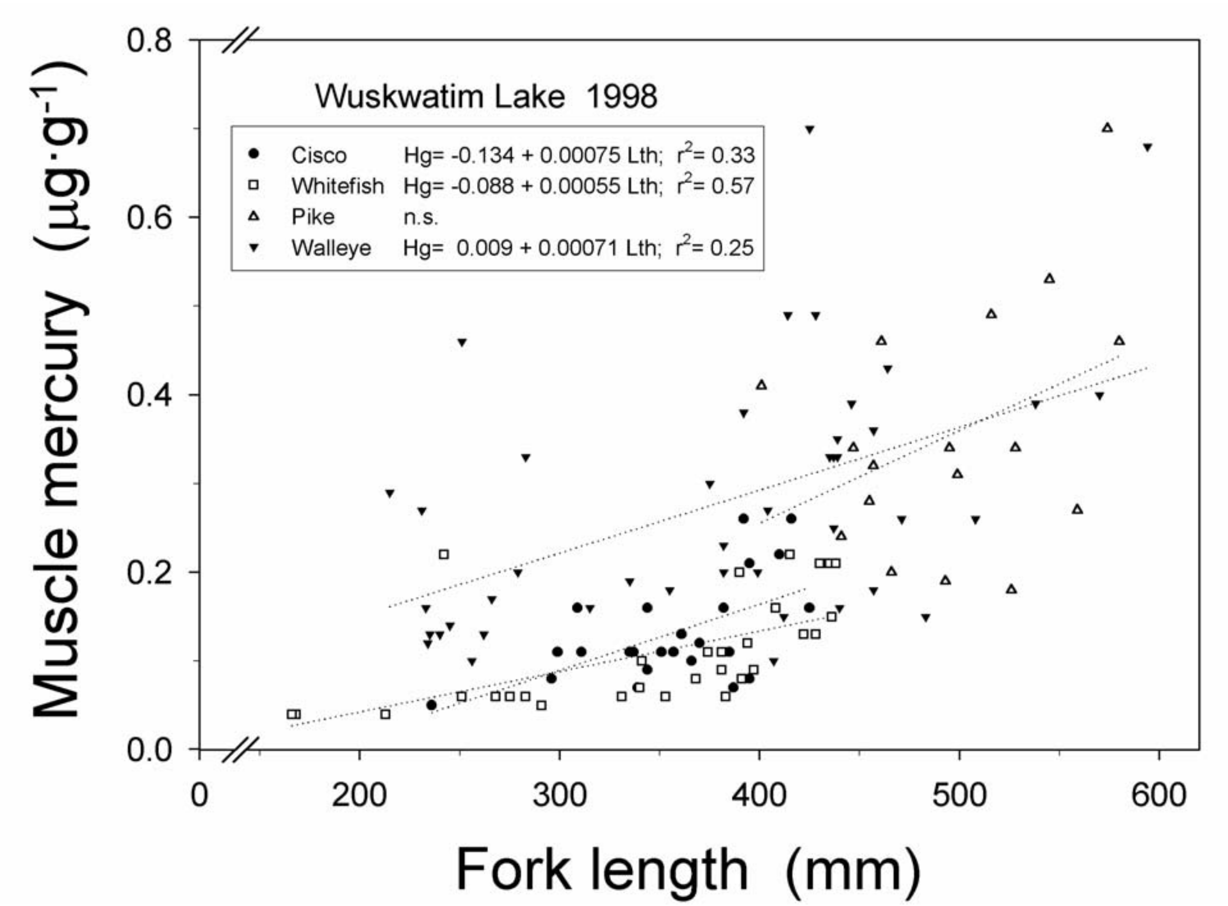


Figure 9-4. Linear relationships between muscle mercury (Hg) concentration and fish length (Lth) for lake cisco, lake whitefish, northern pike, and walleye from Wuskwatim Lake in 1998. Significant regression equations and the coefficient of determination (r^2) are given. One walleye (650 mm length, 1.85 $\mu g \cdot g^{-1}$ mercury) was excluded from the graph and in the calculation of the regression equation; one whitefish (242 mm length, 0.22 $\mu g \cdot g^{-1}$ mercury) was excluded in the calculation of the regression equation; n.s. = not significant.

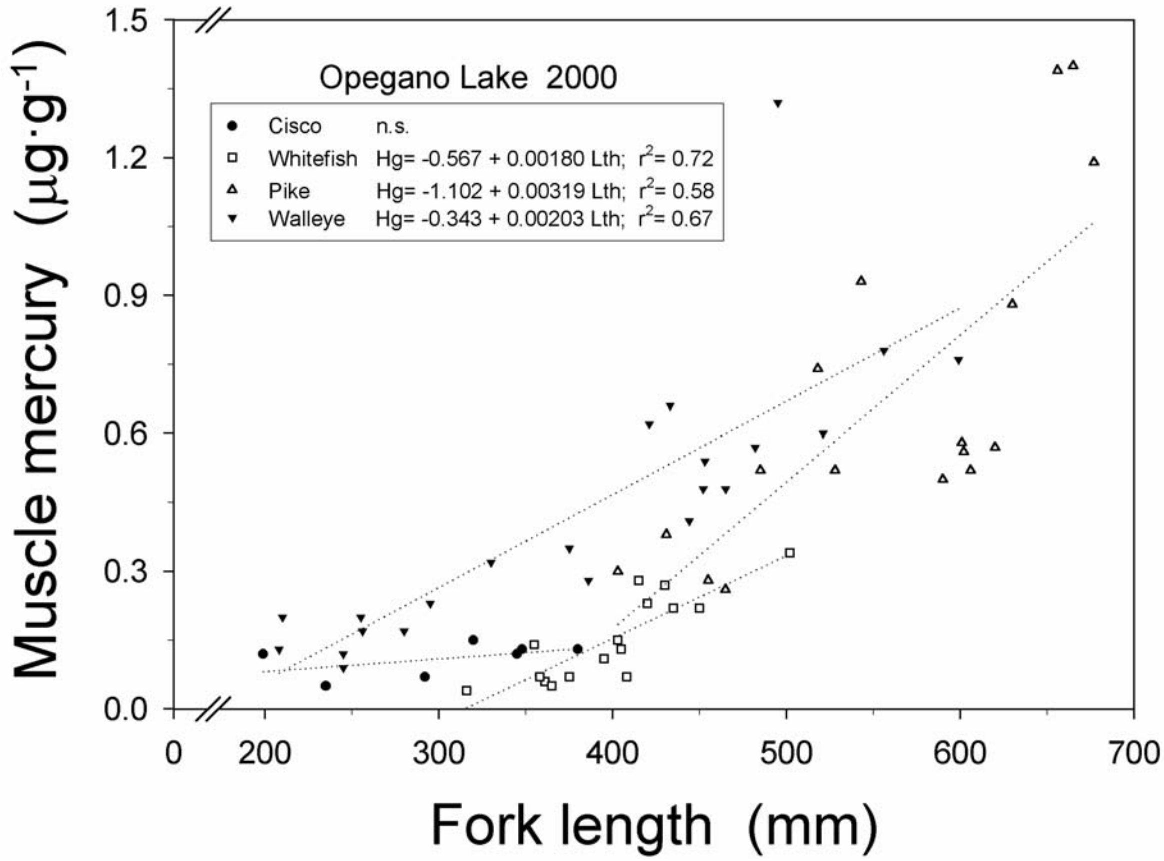


Figure 9-5. Linear relationships between muscle mercury (Hg) concentration and fish fork length (Lth) for lake cisco, lake whitefish, northern pike, and walleye from Wuskwatim Lake in 2002. Significant regression equations and the coefficient of determination (r^2) are given.

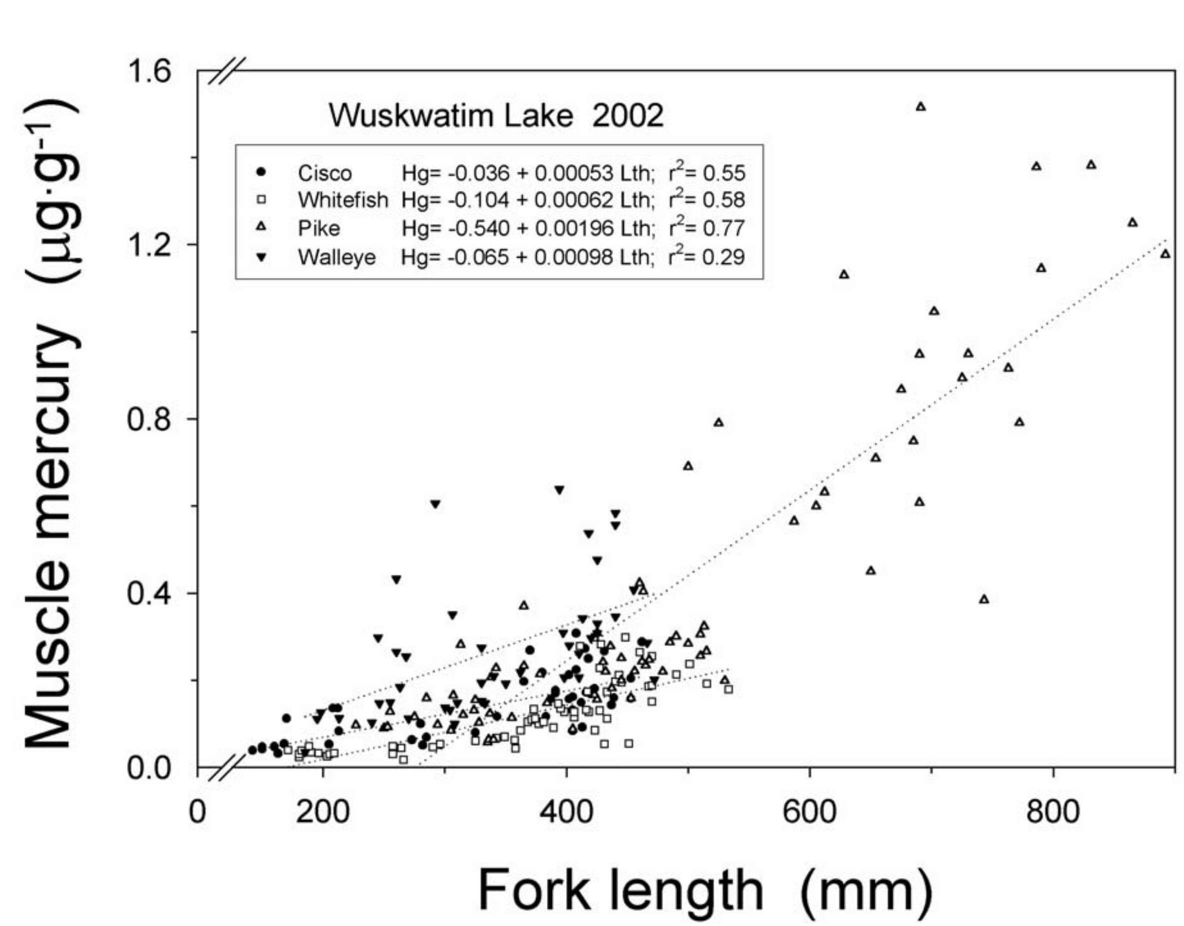


Figure 9-6. Linear relationships between muscle mercury (Hg) concentration and fish fork length (Lth) for lake cisco, lake whitefish, northern pike, and walleye from Opegano Lake in 2000. Significant regression equations and the coefficient of determination (r^2) are given; n.s.= not significant.

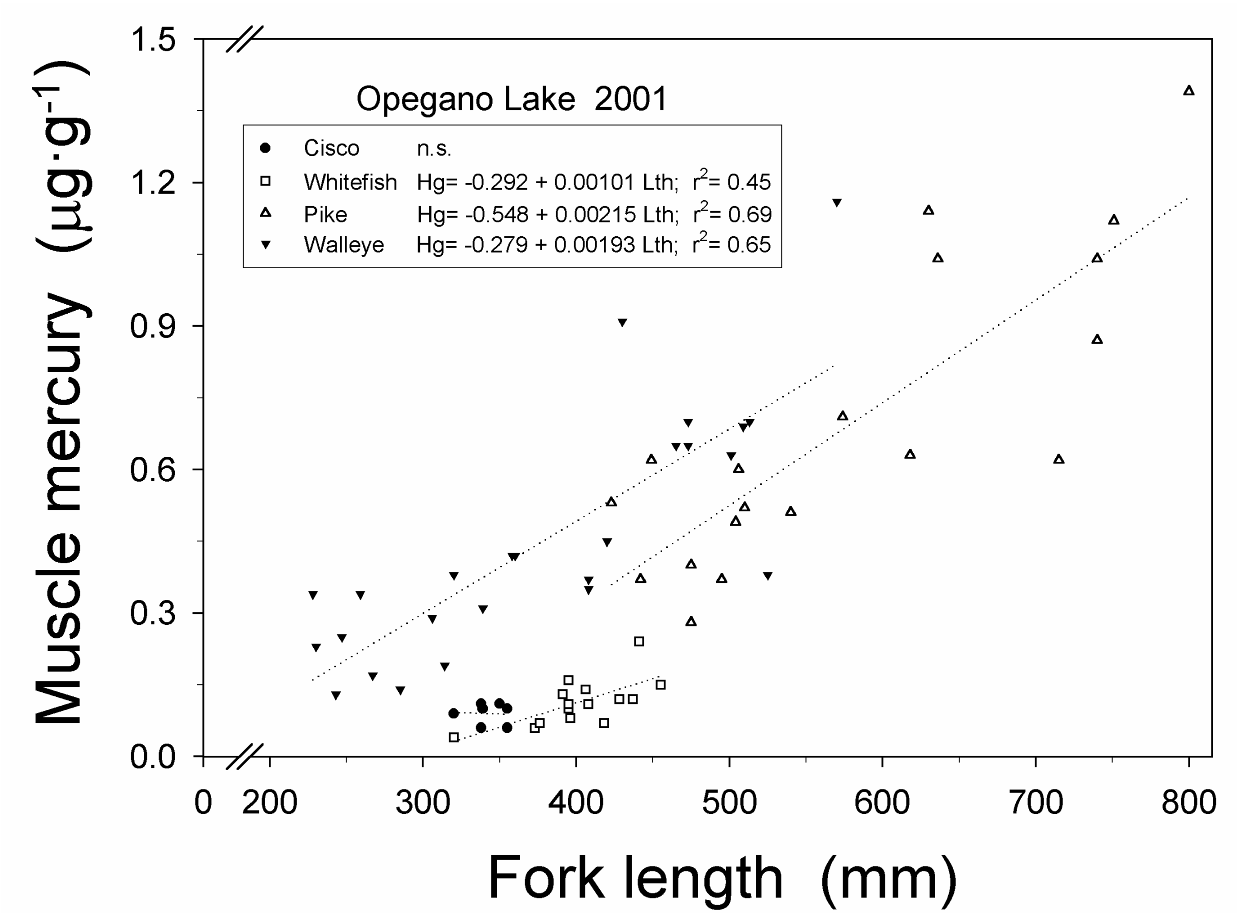


Figure 9-7. Linear relationships between muscle mercury (Hg) concentration and fish fork length (Lth) for lake cisco, lake whitefish, northern pike, and walleye from Opegano Lake in 2001. Significant regression equations and coefficients of determination (r^2) are given; n.s.= not significant.

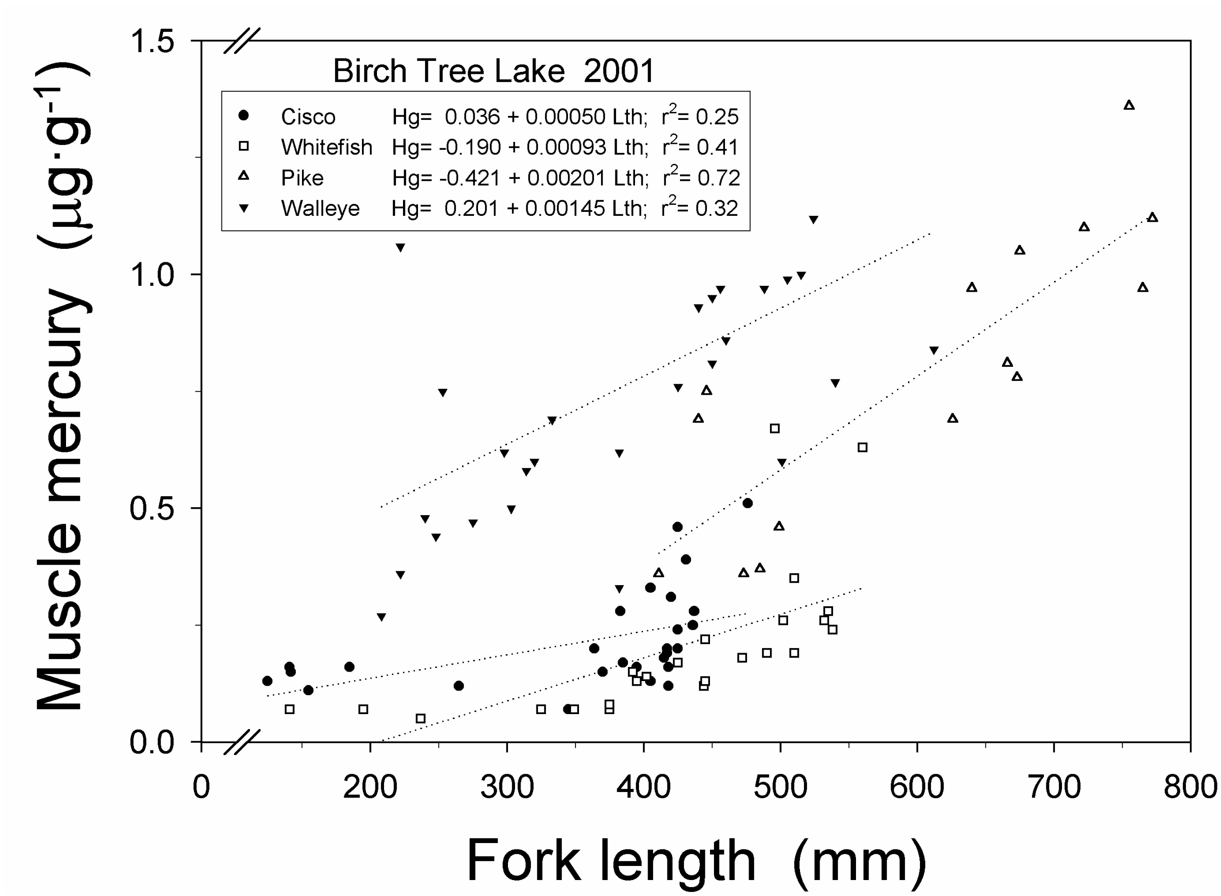


Figure 9-8. Linear relationships between muscle mercury (Hg) concentration and fish fork length (Lth) for lake cisco, lake whitefish, northern pike, and walleye from Birch Tree lakes in 2000. Significant regression equations and coefficients of determination (r^2) are given.

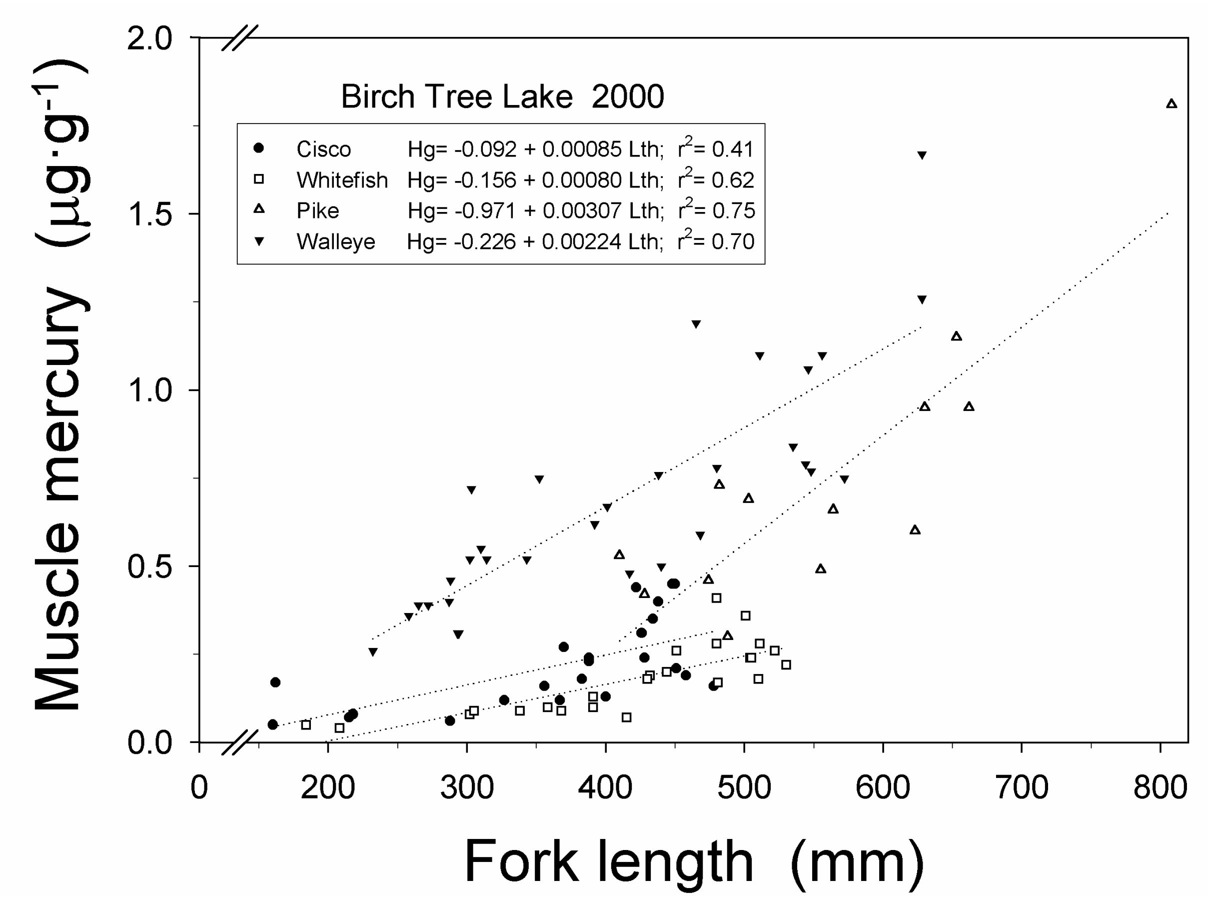


Figure 9-9. Linear relationships between muscle mercury (Hg) concentration and fish fork length (Lth) for lake cisco, lake whitefish, northern pike, and walleye from Birch Tree lakes in 2001. Significant regression equations and coefficients of determination (r^2) are given.

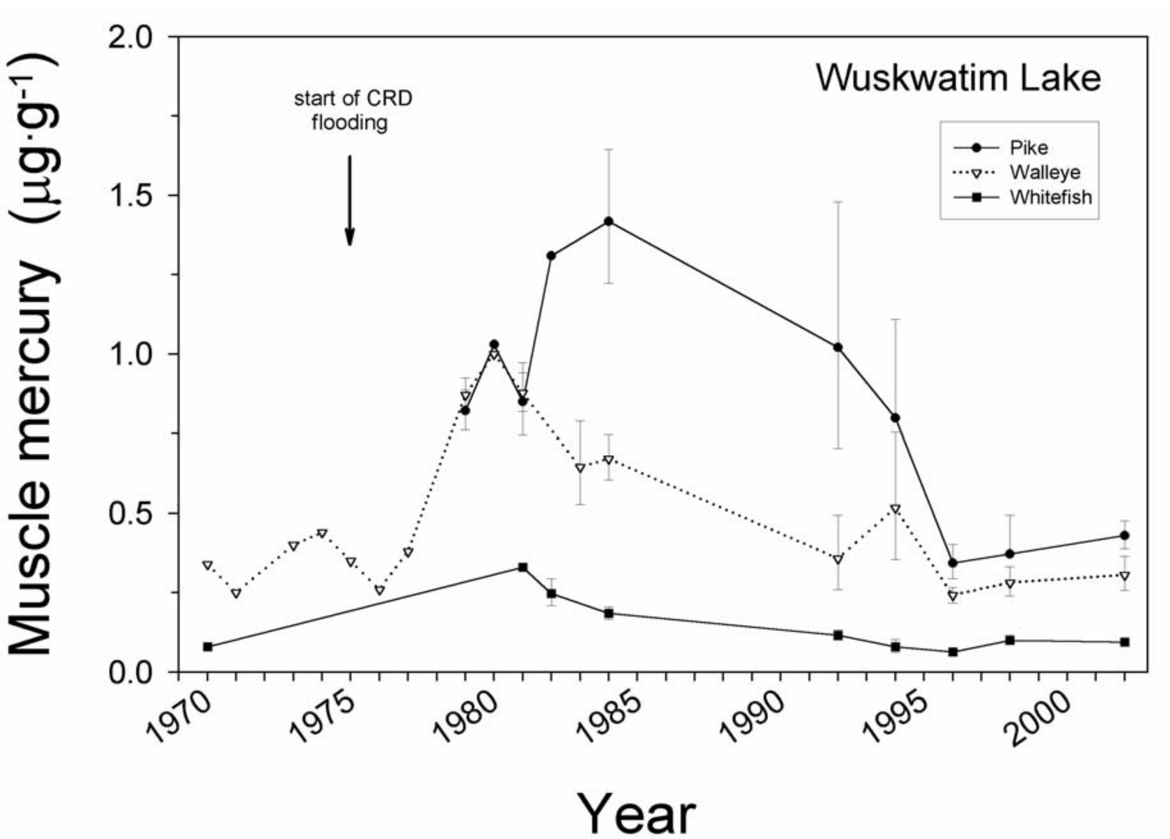


Figure 9-10. Mean muscle mercury concentrations for northern pike, walleye, and lake whitefish for the years 1970-2002 from Wuskwatim Lake. Only means for 1979, 1981, and 1984 onwards could be standardized for fish length.

9.2.2.2 Historic mercury levels in fish from Wuskwatim Lake

While the recent joint studies undertaken by NCN and Manitoba Hydro provided the first set of mercury data for Birch Tree and Opegano lakes, Wuskwatim Lake has been monitored for fish mercury levels since the 1970s, and the data for 1998 can be placed into an historic perspective. It has to be cautioned, however, that the "historic" fish mercury concentrations data have been collected under several programs (e.g., commercial catch monitoring, survey catches, MMCR), which differed in their sampling protocols, fish sample size, and statistical treatment of the data. For these reasons, the mean mercury concentrations of lake whitefish, northern pike, and walleye presented in Figure 9-10 are not directly comparable (e.g., means could not be standardized for fish size in all years). Nevertheless, the temporal pattern shows that mercury levels in fish from Wuskwatim Lake, particularly pike and walleye, increased dramatically after CRD flooded the lake, adjacent waterbodies and upstream habitats on the Rat/Burntwood River system. Maximum mercury concentrations in whitefish and walleye were reached in the early 1980s. However, pike attained maximum levels (1.5 $\mu g \cdot g^{-1}$) several years after mercury concentrations had peaked in the other species (Figure 9-10). Maximum concentrations in walleye (1.0 $\mu g \cdot g^{-1}$) and whitefish (0.33 $\mu g \cdot g^{-1}$) were approximately four times higher than minimum, pre-CRD mercury levels (0.25 and 0.08 $\mu g \cdot g^{-1}$, respectively). Mercury concentrations have decreased substantially over time in all three species, and based on the data for 1996, 1998, and 2002, levels in walleye and pike have returned to, and stabilized at, near pre-CRD concentrations (if it is assumed that pre-flooding mercury levels in pike were similar or slightly higher to those found in walleye).

9.2.3 Impacts

Two models, both based on a relationship between fish mercury content and the percentage of flooded reservoir area (PF), were used to estimate the potential effect of the Project on mercury levels in pike, walleye, and whitefish from the Wuskwatim Lake area. The PF was calculated using the following assumptions about the extent of flooding in the Wuskwatim Lake area, producing two scenarios - a "best case" and a "worst case":

1) The area that potentially promotes the production of methyl mercury is comprised of: i) 37 ha of land that will be permanently flooded immediately upstream of the proposed generating station site; and ii) approximately 403 ha of organic soils (of the total 1100 ha of shoreline between current (233.7 m ASL) and post-Project (234.0 m ASL) water levels along the shorelines of Wuskwatim Lake, Wuskwatim Brook, Sesep Lake, and the Cranberry Lakes that will become more permanently wetted due to regulation of water levels in the reservoir). The shoreline terrestrial environment is described in more detail in Section 6.

2) In 2001, these 403 ha of organic soils were comprised mainly (402 ha) of floating or grounded peat islands and with small areas (1 ha) of shore-anchored peatland, and low gradient areas with sedimentary peat (Section 6). The peat islands are expected to remain structurally intact and "grow up" with the slightly higher, more stable water levels, reversing the current trend of peat island disintegration. Peatlands are known to release/generate substantial amounts of methyl mercury. In the Experimental Lakes Area Reservoir Project, an experimentally flooded wetland including extensive peatlands and peat islands released large amounts of methyl mercury into the water column immediately after flooding and for nine years thereafter (Drew Bodaly, DFO, pers. comm.). If the peat islands in the Wuskwatim reservoir remain intact, the potential for methyl mercury generation from the

peatlands would be relatively small. Conversely, if all the peat islands disintegrated and released their methyl mercury, the worst-case scenario would occur.

3) It has been estimated that annually, an additional 5 ha of mainly forest soils will enter Wuskwatim Lake due to incremental erosion, in each of the five first years after project in-service. Lesser amounts will be eroded thereafter (Section 6). The additional 25 ha of forest soils are included in the newly flooded area total as a potential additional source of methyl mercury; the smaller amounts of eroded materials after year five were not included.

4) The extensive areas of lacustrine clayey material and the associated beach vegetation that comprise almost 90% of the shoreline in the main basin of Wuskwatim Lake and lesser areas of similar materials in the peripheral lakes were not included in the calculations of newly flooded area. These areas are, in general, only sparsely vegetated with emergent macrophytes, which become dead organic matter every fall. Although the Project will likely result in shifts in the plant species composition of these areas in the long-term (Section 6), it was assumed that the total pool of carbon available as a bacterial energy source will remain constant and methyl mercury production will not be measurably affected.

5) The total "pre-Project" area that will be affected by changes/stabilization of water levels is approximately 8970 ha, excluding the few mineral islands in Wuskwatim Lake.

The "best" and "worst" case mercury production scenarios were:

Scenario A (best case): only the 37 ha flooding in the forebay and the 25 ha of eroding forest soils were considered new sources, providing a post-flooded area of 9032 ha, and a PF of 0.69%.

Scenario B (worst case): The newly flooded area was assumed to be the combined total area of the forebay, the eroding forest soils, and the peatlands and peat islands (i.e., 465 ha) providing a PF of 5.15 %. It was further assumed that the area of the peat islands does not increase the post-flooded area.

One model used to estimate post-Project fish mercury levels was a single variable Johnson et al. (1991) model with PF as the independent variable previously used to assess the potential impact of flooding on fish mercury levels (North/South Consultants Inc.

2000; Drew Bodaly, DFO, pers. comm.). The model was more closely adapted to the specific conditions of Wuskwatim Lake as per the advice of one of the co-authors (Drew Bodaly, DFO, pers. comm.): the "generic" intercept of the regression equation was replaced with a value calculated from the mean weight of a fish of "standard" length and the mean standardized mercury concentration for Wuskwatim Lake in 1998. Thus, maximum expected mercury concentrations for the three selected species were derived from the following modified regression equations, and by dividing mean mercury burden (MERC) by the weight of the respective "standard" fish:

- for a 1148 g, 550 mm pike: MERC = 427.1 + 15.70 PF
- for a 710 g, 400 mm walleye: MERC = 200.2 + 10.18 PF
- for a 679 g, 350 mm whitefish: MERC = 65.9 + 1.60 PF

Other independent variables used in the Johnston model, such as change in surface water level or flooded area to lake volume ratio were not considered because of the uncertainties in the estimates of these two variables, and because of their very similar predictive powers compared to PF (Johnston et al. 1991). Upstream effects are not a relevant factor for the Project, and the respective variables for this component of the Johnston model were not considered.

Given the foregoing assumptions, the modified Johnson model predicts that compared to present (1998) levels, "best case" and "worst case" mercury concentrations in pike, walleye and whitefish from Wuskwatim Lake will increase between 2-19%, 5-27%, and 2-12% respectively as a result of the Project (Table 9-6). The 1998 data were used for comparison because mean mercury concentrations were not significantly different for 1996, 1998, and 2002, and the 1998 values are mid range for the three years (Section 9.2.2.2). Under the "worst case" scenario for walleye and pike, levels will remain below the commercial marketing threshold of $0.5 \mu g \cdot g^{-1}$ mercury (pike may reach $0.5 \mu g \cdot g^{-1}$) and whitefish will not exceed the $0.2 \mu g \cdot g^{-1}$ mercury advisory threshold for frequent human consumption (Table 9-4).

Table 9-4. Comparison of predicted mean standard mercury (Hg) concentrations based on the modified Johnson et al. (1991) model in three fish species for a "best" case (Min) and a "worst" case (Max) scenario with actual mean levels in Wuskwatim Lake for 1998 (see section 9.2.2.1).

Species	Predicted Hg ($\mu g \cdot g^{-1}$) Min	Max	Wuskwatim 1998 Hg ($\mu g \cdot g^{-1}$)
Lake whitefish	0.10	0.11	0.10
Northern pike	0.38	0.44	0.37
Walleye	0.30	0.36	0.28

Although the Johnston model is based on empirical data from northern Manitoba reservoirs, and is believed to perform better when applied to local water bodies (Johnston et al. 1991), there remain a number of uncertainties associated with its predictions for Wuskwatim Lake fish. For example, the modified model used for this application accounts for only 38-57% of the variation in MERC (Johnston et al. 1991). Therefore, approximately half of the variability in mercury levels remains unexplained. Furthermore, the Johnston model was developed for predicting maximum mercury levels in fish from water bodies that were considered to be un-impacted before the major flooding event. Approximately 30 % of Wuskwatim Lake's post Project flooded area was flooded in 1976 as part of the Churchill River Diversion Project. It is unknown if the model is appropriate for Wuskwatim Lake, which will experience some additional flooding after previous flooding caused by CRD. Furthermore, post-CRD water levels in Wuskwatim Lake often fluctuated by as much as 0.6 m over extended time periods, whereas under the proposed hydrological regime for the Project, water levels will remain relatively stable. Although there are no supporting empirical data, it could be argued on theoretical grounds that permanently inundated lake sediments probably generate less methyl mercury than periodically wetted areas. The model is based on unstable flooding regimes and may be less useful for predicting the effect of more permanent flooding (i.e., mercury increases may be somewhat less than predicted).

Because of the foregoing limitations of the Johnson model, a second approach was taken to estimate future mercury levels in fish from Wuskwatim Lake. While this method also used the relationship between percent flooded area and fish mercury levels, it calculated the expected increase in mercury concentration per percent flooding based on the empirical data from Wuskwatim Lake (Table 9-5).

Table 9-5. Increase in mercury (Hg) concentrations in fish from Wuskwatim Lake for each percent of flooding (% flood) after CRD. The total flooded area was assumed to be 30% of the pre-flooding area. Hg max= maximum mean mercury concentration observed after 1976; Hg pre= mean mercury concentration observed before 1976 (for pike the same value as for walleye was used).

Species	Hg max ($\mu g \cdot g^{-1}$)	Hg pre ($\mu g \cdot g^{-1}$)	max - pre ($\mu g \cdot g^{-1}$)	(µg Hg / % flood
Whitefish	0.33	0.08	0.25	0.008
Northern pike	1.42	0.35	1.07	0.036
Walleye	1.00	0.35	0.65	0.022

The "best case" and "worst case" scenarios were again applied with regard to the potential for mercury production. The "best case" scenario assumed that upon flooding, all peatlands will rise with the water level and no large-scale decomposition of plant material will occur. Thus, no major pulse of methyl mercury from the peat pore water will be released into the water column and little organic matter will be available as a bacterial energy source. The "worst case" scenario assumed that all peatlands will be source of additional methyl mercury to enter the food chain.

The mercury concentrations calculated based on the historical relationship between PF and Wuskwatim Lake fish mercury levels (i.e., the "Wuskwatim" model; Table 9-8) show a slightly larger range in values between the "best case" and the "worst case" scenarios than those predicted by the modified Johnston model. For pike and walleye, estimated "best case" mercury concentrations were at or marginally higher than current levels, whereas "worst case" concentrations were approximately 50% higher than current levels (Table 9-4 and Table 9-6). One reason why maximal fish mercury levels calculated from the "Wuskwatim" model could be relatively high is that the maximum mercury values in Table 9-5, and thus the increase in mercury concentrations for each percent flooding due to CRD may be partially due to methyl mercury that was generated in flooded water bodies upstream of Wuskwatim Lake. When a large amount of flooding occurs, such an "upstream effect" can be important (Johnston et al. 1991), but it is difficult to quantify. For Wuskwatim Lake, the "upstream effect" is assumed to be small because Threepoint Lake, the closest lake, almost 15 km upstream, had relatively less flooding than many other CRD lakes.

Table 9-6. Predicted mercury (Hg) concentrations in fish from Wuskwatim Lake from flooding caused by the Project assuming that either all (Max) or none (Min) of the 408 ha of peatlands will contribute to methyl mercury production (see text). For the Min scenario only the 37 ha of the forebay area and 25 ha of eroding forest soils were considered. The increase due to flooding was calculated based on the data in Table 9-5. All values are given in $\mu g \cdot g^{-1}$.

Species	Increase due to flooding		Current Hg	Predicted Hg after flooding	
	Min	Max		Min	Max
Whitefish	0.006	0.042	0.097	0.10	0.14
Northern pike	0.025	0.184	0.372	0.40	0.56
Walleye	0.015	0.112	0.282	0.30	0.39

Relatively little is known about the contribution of different types of vegetation in promoting methyl mercury production after flooding. DFO's ELARP studies indicate that peatlands, with their large and relatively available carbon store, seem not only to respond quickly after flooding in promoting increases in fish mercury concentrations, but also continue to do so over time (Drew Bodaly, DFO, pers. comm.). As peat is a major component of flooded material in the Wuskwatim area, fish mercury levels are likely to remain elevated longer than if mainly mineral soils would be flooded.

In calculating expected fish mercury levels, a conservative approach has been taken by including only peatlands and eroding forest soils in the calculation of flooded shoreline area outside of the forebay. It has been predicted that the flooding will not cause substantial vegetation die-off and/or erosion and decomposition of other organic soils (Section 6). If this is the case, future fish mercury concentrations should be close to the "best case" predictions; if not, there could be additional inputs of methyl mercury into the Wuskwatim Lake ecosystem, resulting in fish mercury levels more closely aligned with the "worst case" scenario. Studies on flooded wetlands at the ELA have shown that the time course of the response of peat island materials to flooding can be unpredictable (J. Rudd, DFO, pers. comm.), and only post-Project monitoring will provide more definitive conclusions as to their methyl mercury release and/or production.

Under the most likely scenario (in which the project-induced changes in the abiotic and biotic conditions of the Wuskwatim Lake area are expected to fall slightly below the median of the "best case" and the "worst case" scenario for methyl mercury bioaccumulation), maximum mean standardized mercury concentrations in lake whitefish will likely just exceed 0.10 $\mu g \cdot g^{-1}$, may reach 0.35 $\mu g \cdot g^{-1}$ in walleye, and could increase to slightly below the commercial limit of 0.5 $\mu g \cdot g^{-1}$ mean standardized pike muscle concentrations.

As the predicted increases associated with the Project will be substantially lower than those due to CRD, such maximum mercury levels will not be observed until 3-5 years post-flooding if the time course of mercury concentrations follows the typical pattern for northern reservoirs (Bodaly et al. 1997; Jansen et al. 2002). An additional time period of perhaps up to 10 years will be required for concentrations to return to pre-impact values. It is noted that the predicted values of post-Project mercury levels in the economically three most important fish species in Wuskwatim Lake are only slightly elevated above current concentrations, and, at least for walleye, fall within the upper confidence limit of the most recent data for 2002 (see section 9.2.2.1). The maximum post-Project mercury concentrations may not be statistically significantly different from current levels (depending on the sample size and the variation of values from individual fish around the mean).

There also is the potential for downstream export of mercury from Wuskwatim Lake into Opegano Lake and for some increase in the internal methyl mercury production of Opegano Lake. As indicated by the fish movements observed in the project area (North/South Consultants Inc. unpublished data), the downstream export of mercury may not only be via the Burntwood River water but potentially includes migration of fish into Opegano Lake. However, the contribution of both these processes is expected to be minor. If they should affect the mercury levels of fish from Opegano Lake, the increase is likely to be very small and will be "lost" within the present variability of mean mercury concentrations. The variable water regimes affecting relatively small areas of peatlands in the Opegano Lake reach may contribute to minor temporary local increases in mercury concentrations in Opegano Lake resident fish. It is expected that mercury concentrations downstream of Opegano Lake will not be measurably affected as a result of the Project.

Fish are a major dietary item for people from communities in the study area and the knowledge of safe consumption levels is important. Safe consumption limits for fish from Wuskwatim Lake pre and post Project are based on literature values for the relationship between blood mercury levels in man and dose of methyl mercury (Kershaw et al. 1980) and are provided in Table 9-7. These data show that weekly consumption of walleye and pike could be reduced from current safe levels by approximately 100 g or 19% and 23%, respectively, and 1.6 fewer meals per week of walleye should be eaten. A man weighing 70 kg can safely eat approximately one meal of whitefish a day after the maximum expected post-Project mercury levels has been reached. The safe consumption limits for Wuskwatim Lake walleye and pike, fall between the limits calculated for Leftrook Lake, a lake in a system unaffected by flooding, and Footprint Lake, a water body more severely flooded than Wuskwatim Lake.

Table 9-7. Weight (1st value) and number of meals (2nd value) of walleye (pickerel), pike, and whitefish that can be safely eaten by a 70 kg (154 lb) man in a week[a]. Values are calculated for fish from Wuskwatim, Leftrook and Footprint lakes assuming current (C; 1998-99) muscle mercury concentration for a fish of standard length. For Wuskwatim Lake, consumption values for post-Project (PP) predicted mercury levels also are given (0.12 $\mu g \cdot g^{-1}$ for whitefish, 0.35 $\mu g \cdot g^{-1}$ for walleye, and 0.48 $\mu g \cdot g^{-1}$ for pike).

Source	Walleye	Pike	Whitefish
Wuskwatim (C)	550 g ; 2.8	420 g ; 2.1	1610 g ; 8.1
Wuskwatim (PP)	445 g ; 2.2	325 g ; 1.6	1300 g ; 6.5
Footprint (C)	230 g ; 1.1	260 g ; 1.3	2330 g ; 11.6
Leftrook (C)	610 g ; 3.1	665 g ; 3.3	4215 g ; 21.1

[a] For women age 15-39, it is recommended that mercury levels be maintained at less than one half of the normal acceptable levels to avoid potential harmful effects if the woman becomes pregnant.

9.3 OTHER METALS

9.3.1 Methods

A sample of 20 whitefish and 10 walleye from Wuskwatim Lake captured from 20-23 September 2001 were dressed, sectioned, and frozen for later analysis of 27 trace metals at Envirotest Laboratories (Winnipeg, Manitoba). In 2002, 19 whitefish and 20 walleye from Birch Tree Lake; eight whitefish and five walleye from Opegano Lake; three whitefish, 13 walleye, and four pike from the Burntwood River between Taskinigup Falls and Opegano Lake; and 20 whitefish and 20 walleye from Wuskwatim Lake in August and September, 2002, were treated as in 2001 for analysis of trace metals at PSC Analytical Services (Mississauga, Ontario).

Skin and bones were removed from complete dorsal to ventral sections of muscle taken from just behind the dorsal fin. Acid digested samples (0.5-0.6 g) were analysed by Inductively Coupled Plasma Mass Spectroscopy (ICPMS) for total content of aluminium, antimony, arsenic, barium, beryllium, bismuth, cadmium, chromium, cobalt, copper, iron, lead, manganese, molybdenum, nickel, selenium, silver, strontium, thallium, tellurium, tin, titanium, uranium, vanadium, and zinc. In addition, similarly prepared muscle samples (approximately 1.0 g) were analysed photometrically for total elemental mercury using cold vapour techniques. All concentrations were expressed as mg/kg (ppm) muscle wet weight.

9.3.2 Results

Except for mercury, only data from the more extensive sampling in 2002 will be discussed. Concentrations of many metals were at, or below, the detection limit of the analytical method used (Tables 9-8 and 9-9). These results are for total metals concentrations, which are generally considered to overestimate the bioavailable fractions.

Mean (±SE) concentrations of mercury for whitefish and walleye in 2001 (0.10± 0.01 and 0.38± 0.03 ppm, respectively) and 2002 (Tables 9-8 and 9-9) were similar to the arithmetic means obtained from samples for Wuskwatim Lake in 1998 and 2002 and for Opegano and Birch Tree lakes in 2000 and 2001 from different samples of fish and using a different analytical method (see Table 9-2 in section 9.2.2.1). Mean concentrations of lead and mercury, the only two metals for which Provincial and Federal guideline levels for “Aquatic Life Tissue Residue” exist (Williamson 2002), were below recommended levels (0.5 ppm for both mercury and lead). More detailed information and discussion of fish mercury concentrations are presented in Section 9.2.

9.3.3 Impacts

As a result of increased post-Project erosion, metal concentrations could become elevated in the water and sediment of the Burntwood River downstream of the hydroelectric plant and in near-shore areas during and shortly after construction (Section 5). These potential changes have been assessed within the context of existing conditions in the study area. Concentrations of some metals are naturally elevated in the water and sediments of the Burntwood River and study area lakes (Section 5), e.g. concentrations of aluminum and iron in water are typically at least an order of magnitude above guidelines for the protection of aquatic life, and for some locations, levels of arsenic, chromium, copper, iron, manganese, and nickel in sediment exceeded the guideline value. Although these concentrations are considered potentially harmful to aquatic life (Williamson 2002), none of the tested samples showed evidence of substantive accumulation of these metals in fish muscle (see Section 9.3.2). A linkage between water concentrations and metal levels in fish muscle is not expected, because most metals do not accumulate in fish muscle (ESG International 1999). Based on the available data and referenced literature, it is not expected that the Project will affect trace metal levels (with the exception of mercury as outlined in section 9.2.3), in study area fish.

Table 9-8. Mean (±SE) trace metal concentrations for lake whitefish captured at Wuskwatim, Opegano, and Birch Tree lakes, and the Burntwood River (BWR) in September 2002. All values are expressed as mg/kg muscle wet weight. Missing ±SE indicate that concentration were below the detection limit of the analytical method.

Metal	**Water body**			
	Wuskwatim	**BWR**	**Opegano**	**Birchtree**
Aluminum (Al)	1.7 ±0.1	4.2 ±0.5	3.8 ±0.3	1.5 ±0.2
Antimony (Sb)	0.030	0.030 ±0.000	0.030	0.030
Arsenic (As)	0.13 ±0.01	0.10	0.10	0.10
Barium (Ba)	0.38 ±0.03	0.83 ±0.12	0.70 ±0.10	0.70 ±0.10
Beryllium (Be)	0.05	0.05	0.05	0.65 ±0.07
Bismuth (Bi)	0.05	0.05	0.05	0.05
Cadmium (Cd)	0.005	0.005	0.005	0.019 ±0.012
Chromium (Cr)	0.3	0.3	0.3	0.3 ±0.0
Cobalt (Co)	0.0230 ±0.0020	0.0100 ±0.0020	0.0100 ±0.0009	0.0150 ±0.0010
Copper (Cu)	0.52 ±0.02	0.62 ±0.01	0.67 ±0.09	0.57 ±0.03
Iron (Fe)	9.6 ±0.4	11.3 ±1.7	13.5 ±1.2	11.6 ±0.5
Lead (Pb)	0.040 ±0.010	0.050	0.050 ±0.010	0.370 ±0.270
Manganese (Mn)	1.0 ±0.1	1.3 ±0.2	1.3 ±0.2	1.1 ±0.1
Mercury (Hg)	0.11 ±0.01	0.12 ±0.03	0.13 ±0.01	0.15 ±0.01
Molybdenum (Mo)	0.05	0.05	0.05	0.05
Nickel (Ni)	0.05	0.05	0.05	0.07 ±0.01
Selenium (Se)	0.110 ±0.010	0.100	0.100	0.105 ±0.005
Silver (Ag)	0.005	0.005	0.005	0.005
Strontium (Sr)	5.52 ±0.56	8.63 ±0.42	9.78 ±1.92	9.02 ±1.09
Thallium (Tl)	0.0030	0.0030	0.0030	0.0030
Titanium (Ti)	0.5	0.5	0.5	0.5
Uranium (U)	0.005	0.005	0.007 ±0.001	0.005
Vanadium (V)	0.050 ±0.004	0.087 ±0.003	0.060 ±0.010	0.050 ±0.005
Zinc (Zn)	8.6 ±0.3	8.7 ±0.5	11.4 ±1.6	10.1 ±0.6

Table 9-9. Mean (±SE) trace metal concentrations for pike and walleye captured at Wuskwatim, Opegano, and Birch Tree lakes, and the Burntwood River in September 2002. All values are expressed as mg/kg muscle wet weight. Missing ±SE indicate that concentration were below the detection limit of the analytical method.

Metal	Pike	Walleye			
	BWR	Wuskwati	BWR	Opegano	Birchtree
Aluminum (Al)	3.2 ±0.5	2.0 ±0.3	4.0 ±0.6	4.0 ±0.7	1.7 ±0.1
Antimony (Sb)	0.03	0.03	0.03	0.03	0.03
Arsenic (As)	0.1	0.10	0.1	0.1	0.1
Barium (Ba)	0.33 ±0.03	0.54 ±0.05	0.58 ±0.06	0.80 ±0.10	0.50 ±0.10
Beryllium (Be)	0.050	0.050	0.050	0.050	0.050
Bismuth (Bi)	0.050	0.050	0.050	0.050	0.050
Cadmium (Cd)	0.008 ±0.002	0.005	0.006 ±0.001	0.005	0.009 ±0.002
Chromium (Cr)	0.300	0.300	0.300	0.300	0.300
Cobalt (Co)	0.0068 ±0.0006	0.0050	0.0052 ±0.0002	0.0052 ±0.0002	0.0050 ±0.0001
Copper (Cu)	0.43 ±0.03	0.43 ±0.02	0.47 ±0.03	0.46 ±0.05	0.44 ±0.02
Iron (Fe)	8.5 ±0.3	7.0 ±0.4	8.5 ±0.9	9.4 ±0.5	6.5 ±0.3
Lead (Pb)	0.108 ±0.039	0.035 ±0.004	0.045 ±0.004	0.030	0.140 ±0.040
Manganese (Mn)	1.3 ±0.3	0.9 ±0.1	0.8 ±0.1	1.3 ±0.3	0.9 ±0.1
Mercury (Hg)	0.72 ±0.08	0.32 ±0.02	0.46 ±0.03	0.66 ±0.10	0.65 ±0.04
Molybdenum (Mo)	0.05	0.05	0.05	0.05	0.05
Nickel (Ni)	0.05	0.05	0.05	0.05	0.06 ±0.01
Selenium (Se)	0.100	0.120 ±0.010	0.140 ±0.010	0.140 ±0.020	0.130 ±0.011
Silver (Ag)	0.005	0.005	0.005	0.005	0.005
Strontium (Sr)	2.10 ±0.21	3.98 ±0.21	3.38 ±0.26	4.58 ±1.00	3.99 ±0.42
Thallium (Tl)	0.0030	0.0044 ±0.0002	0.0040	0.0038 ±0.0004	0.0034 ±0.0002
Titanium (Ti)	0.5	0.5	0.5	0.5	0.5
Uranium (U)	0.005	0.005	0.005	0.005	0.005
Vanadium (V)	0.030	0.030	0.030	0.030	0.030
Zinc (Zn)	12.3 ±1.4	9.2 ±0.4	7.8 ±0.2	9.0 ±0.7	8.1 ±0.2

9.4 PARASITES

Several coregonid species, including lake whitefish and lake cisco are second intermediate hosts of the cestode *Triaenophorus crassus* (Hoffman 1999). The plerocercoid (immature worm) forms visible yellowish cysts in the musculature of the host fish, which, depending on the rate of infection, can limit its commercial marketability.

9.4.1 Methods

Lake whitefish from Wuskwatim Lake were inspected for the presence of cysts of *T. crassus* in the body musculature. In 2001, 13 whitefish (317-464 mm fork length; 550-1750 g total weight) captured with gill nets from 20-23 September were immediately frozen for later delivery to the Freshwater Fish Marketing Corporation (FFMC) in Winnipeg for inspection. In 2002, 12 whitefish (386-468 mm fork length; 950-1500 g total weight) gill netted from 3-4 September were sent frozen to the FFMC.

At the FFMC, six whitefish randomly chosen from the 2001 sample and all fish sampled in 2002 were thawed, filleted and inspected according to the "Whitefish Inspection Protocol" (FFMC, unpubl. document). The rate of infection (R.I.) was calculated as [number of cysts/lbs. of fish] x 100. R.I. values of <50 are graded as "export", values of 50-80 are graded as "continental", and values >80 are graded as "cutter" by the FFMC.

9.4.2 Results

The six whitefish sampled in 2001 had a dressed weight of 9.66 lbs (4.38 kg); they were found to have six cysts, resulting in a R.I. value of 62.1 and an infection grade of "continental". The twelve fish sampled in 2002 had a dressed weight of 32.8 lbs (14.88 kg) and had no cysts, resulting in an R.I. value of 0 and an infection grade of "export".

Wuskwatim Lake whitefish have been previously inspected by the FFMC. In 1998, four samples weighing 13-14 pounds each and taken from commercially caught fish in June, September, and October yielded R.I. values ranging between 0 and 46.2 (mean 24.6). Similarly, 13 samples weighing between 13-18 pounds each and taken in August, September, and October of 1999 all resulted in a grade of "export", with R.I. values ranging between 0 and 33.8 (mean 10.1).

Except for the single sample taken in 2001, whitefish from Wuskwatim Lake have always been assigned an "export" grade. It is unknown why the small sample taken in 2001 had a higher number of cysts and, consequently, was of lower grade than the commercial samples taken in 1998 and 1999 and the second sample from 2002 during the current study. It is likely that the higher count in 2001 was a chance event, and could possibly result from a single heavily infected fish (FFMC results are given for the entire sample without discrimination between individual fish).

9.4.3 Impacts

Based on the projections of Project related impacts on the zooplankton and fish communities in the study area, infection rates of lake whitefish with plerocercoids of *T. crassus* could be affected by the Project. Changes in infection can be the result of a number of biological parameters that interact with different stages in the life cycle of *T. crassus*. The predicted increase in the abundance/density of pike (the primary final host of *T. crassus*) and walleye (a secondary final host) in the Wuskwatim Lake area, particularly in Wuskwatim Brook, Sesep Lake and the Cranberry Lakes (see section 8.4) has the potential to increase the number of reproducing individuals of *T. crassus* and, thus the density of infective stages of the parasite in the environment. Parameters that potentially affect whitefish infection levels by increasing the transmission rate of the parasite between first (copepod) and second (whitefish) intermediate hosts, such as zooplankton taxa composition, particularly the relative abundance of copepods (see section 7.4.2), or whitefish diet, are not thought to change in response to the Project.

9.5 FISH PALATABILITY

Palatability is an important component of fish quality since taste directly affects the acceptability of fish as a food source.

9.5.1 Methods

On October 22 and 23, 2002, 49 panellists from the community of Nelson House were recruited to evaluate the taste of walleye (pickerel), northern pike, and lake whitefish from Wuskwatim, Footprint, Leftrook, and Baldock lakes. Baldock Lake is located approximately 80 km north of Thompson completely off the Rat/Burntwood River system. Fish were caught in gill nets from September 29 to October 14, 2002. Fillets of similar sized walleye (1000 g) and pike (2700 g), and dressed and scaled whitefish (2000 g) were immediately frozen until preparation for testing (for details see Ryland and Watts 2002). Samples of 30-40 g of freshly prepared fried filets and boiled pieces (whitefish only) were assigned unique, three digit random numbers and were evaluated by the panellists for acceptability using a seven point category scale (1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = neither like nor dislike, 5 = like slightly, 6 = like moderately, 7 = like very much). Analysis of variance was conducted on number scores (SAS, PC Version 8.2) to determine if significant differences in acceptability were found between lakes for the same species of fish ($p<0.05$).

9.5.2 Results

Insufficient numbers of northern pike and whitefish were collected from Footprint Lake to evaluate and therefore acceptability data for this lake were collected for walleye only. Whitefish and walleye from all locations were liked moderately with mean values of 5.9 to 6.3 with Wuskwatim Lake having the highest acceptability for whitefish and Baldock Lake the highest for walleye (Table 9-10). Northern pike was liked slightly to moderately with mean values of 5.3 for Leftrook and Wuskwatim lakes to 5.9 for Baldock Lake. No significant differences were found among lakes for any species of fish. None of the lakes gave consistently the highest or lowest acceptability mean values. As a potential limitation of this study, it should be noted, that these results might be specific to the season of fish sampling. The fish were caught in the early winter and may not have the same sensory quality as those caught during another time of the year. For detailed results including demographic information on the panellists see Ryland and Watts (2002).

Table 9-10. Mean (±SD) acceptability values for three fish species from Baldock, Leftrook, Wuskwatim, and Footprint lakes. Means are based on 47-49 responses. A mean value of 5 corresponds to “like slightly”, a value of 6 corresponds to “like moderately”.

Lake	**Species**		
	Walleye	**Pike**	**Whitefish**
Baldock	6.3 ±0.9	5.9 ±1.2	5.9 ±1.6
Leftrook	6.2 ±1.1	5.3 ±1.7	6.2 ±1.5
Wuskwatim	6.2 ±1.0	5.3 ±1.9	6.3 ±1.1
Footprint	5.9 ±1.3	-	-

9.5.3 Impacts

It is not expected that during construction and under normal operation of the hydroelectric plant any substances will be released into the aquatic environment that will compromise fish palatability. Should accidental spills of potentially tainting substances occur as result of the Project, the effect on fish palatability will have to be assessed on a case-by-case basis.

10.0 RESIDUAL EFFECTS

10.1 WATER QUALITY

Expected residual effects of the Project on water quality are summarized in Table 10-1. Additional detail regarding expected residual effects to water quality is provided in Volume 5, Section 5.4. **In summary, the expected residual effects of construction of the Project are expected to be local to regional, small to moderate, short-term, and not significant (extent of effects varies among water quality parameters). The expected residual effects of operation of the Project on water quality are expected to be local, small, short-term, and not significant.**

10.2 AQUATIC HABITAT

Aquatic habitat is not a VEC and the expected residual effects of the Project have not been assessed in terms of significance (Volume 5, Section 6.4). However, expected residual effects of the Project on aquatic habitat were assessed and are summarized in Table 10-2. Additional detail regarding expected residual effects to aquatic habitat is provided in Volume 5, Section 6.4.

10.3 LOWER TROPHIC LEVELS

Lower trophic levels are not a VEC and the expected residual effects of the Project have not been assessed in terms of significance (Volume 5, Section 7.4). However, expected residual effects to lower trophic levels were assessed and are summarized in Table 10-3. Additional detail regarding expected residual effects to lower trophic levels is provided in Volume 5, Section 7.4.

10.4 FISH COMMUNITY AND MOVEMENTS

Expected residual effects to VEC fish species resulting from construction and operation of the Project are summarized in Table 10-4. Additional detail regarding expected residual effects to VEC fish species is provided in Volume 5, Section 8.4. **In summary, the residual effects of construction of the Project on populations of VEC fish species are expected to be negative, short-term, small, local and, therefore, not significant**. **The residual effects of operation of the Project on populations of VEC fish species are expected to be positive, long-term, small, local and, therefore, not significant.**

10.5 FISH QUALITY

Expected residual effects to fish quality resulting from construction and operation of the Project are summarized in Table 10-5. Additional detail regarding expected residual effects to fish quality is provided in Volume 5, Section 9.0. **In summary, the expected residual effects of the Project on fish quality are expected to be negative, long-term, small, local and, therefore, not significant.**

Table 10-1. Expected residual effects of the Project on water quality. (Note that the significance of effects is described in terms of exceedence of the applicable MWQSOGs.)

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
	CONSTRUCTION			
REACHES 2, 3, AND 4	Suspended solids and sediment inputs due to discharge from wash water settling ponds, cofferdam placement and removal, removal of rock plugs, and erosion of riverbank and riverbed during river management.	Increases in TSS for several weeks at and downstream of the construction site; magnitude of increase varying among activities. Increase in metals associated with sediment suspended solids.	Measures to minimize inputs with the intent to maintain TSS increase to less than 25 mg/L (daily average in fully mixed zone).	Negative and not significant (short-term, moderate [decreasing to small with distance downstream], and local to regional) effects to suitability for aquatic life.
	Blasting causing release of ammonia and nitrate into Reach 2 and upper Reach 3.	Large increases in ammonia may be toxic to aquatic life.	Unspent charges will be removed from blasts conducted in the dry (large majority of blasting).	Negative and not significant (short-term, negligible to small and site-specific) increases in ammonia affecting the suitability for aquatic life. Negative and not significant (short-term, negligible to small and site-specific) increases in nitrate.
	Discharge of treated sewage effluent into backwater inlet of reach 4.	Increases in nutrients, with subsequent effects to algal and plant growth and oxygen levels. Increases in biochemical oxygen demand and decreases in dissolved oxygen. Minor effects to TSS. Increase in faecal coliform bacteria during and immediately after discharge.	Treated sewage effluent will meet provincial standards.	Negative and not significant (short-term, small to moderate, and site-specific (only detectable within inlet)) effects to suitability for aquatic life.
	Potential for rock used during construction to generate acid leachate.	Acid leachate could decrease pH and/or increase metal concentrations in surface waters.	Measures identified in project description.	No effects predicted that can not be mitigated.

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
	Accidental spills	Release of harmful quantities of various deleterious substances, in particular hydrocarbons, into surface waters.	Spill containment areas, safe handling and storage procedures, and spill response measures minimize the risk that harmful quantities will be released.	Small potential for the release of harmful quantities of deleterious substances, not likely to have a significant adverse effect.
STREAM CROSSINGS	**CONSTRUCTION**			
	Sediment inputs downstream of road crossings during construction of crossings and installation of culverts.	Increase in TSS at and downstream of crossings for short periods during and immediately after construction.	Installation during winter will reduce inputs to the water; will follow guidelines.	Negative and not significant (short-term, small to moderate, and site specific increase in TSS) effects on suitability of water for aquatic life.
	Accidental spills	Release of harmful quantities of various deleterious substances, in particular hydrocarbons, into surface waters.	Safe handling procedures and spill response measures minimize the risk that harmful quantities will be released.	Small potential for the release of harmful quantities of deleterious substances, not likely to have a significant adverse effect.

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
REACH 1	**OPERATION**			
	Increase of sediment inputs from presently eroding shorelines, especially in the first five years of operation.	Measurable TSS increase in Wuskwatim Lake as a whole is not expected; suspended sediment levels will be higher adjacent to eroding shorelines, particularly during and after storms. Increases in metals associated with eroded material (e.g., iron and aluminum).	None.	Negative and not significant (short term (5 years), moderate, and site specific to local) effects to use of water for drinking[1], suitability for aquatic life, navigation, and aesthetics. Larger increase in TSS after storms, but frequency is low.
	Stabilization of water levels near the upper end of the existing range and increased input of organics from erosion on erodible shorelines.	Conversion of intermittently wetted to permanently wetted habitat, in particular in tributary waters (e.g., Sesep Lake, Wuskwatim Brook) may cause measurable increases in nutrients; increased levels of organics would decrease oxygen, particularly in winter.	None.	Negative and not significant (short term (5 years), moderate, and site-specific to local) effects to use of water for drinking, suitability for aquatic life, and aesthetics.
REACH 2	**OPERATION**			
	Flooding of approximately 25 ha of natural terrestrial habitat (remainder of flooded area within GS structures) will result in inputs of nutrients, organics, metals, and sediments. No increase in erosion is expected.	Measurable effects of inputs of nutrients, organics, metals and sediments restricted to the immediate flooded area. Localized reductions in oxygen, particularly during winter, may occur.	None.	Negative and not significant (long-term, small to moderate, and site-specific) effects to suitability of water for aquatic life.
	Change in water quality from upstream (Reach 1).	As discussed for Reach 1, no overall changes in water quality are expected therefore, no significant change.	Not applicable.	None.
REACHES 3 - 6	**OPERATION**			
	Increased erosion of riverbanks and riverbed in response to new flow patterns during initial operation. No long term increases in riverbank erosion are predicted.	Increase in TSS will initially occur during construction phase and may extend to initial period of operation.	None (beyond what is conducted during construction phase)	Negative and not significant (short term, small to moderate, and local to regional) effects to suitability of water for aquatic life.

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
	Die-off of peat in backwater inlets and along north shore of Opegano Lake.	Input of organic material and increase in nutrients may decrease oxygen concentrations, particularly in winter, in proximity of the peat areas.	None.	Negative and not significant (long term, small to moderate, site specific) effects to the suitability of water for aquatic life.
STREAM CROSSINGS	**OPERATION**			
	Inputs of sediments at stream crossings.	Minor (negligible) increases in TSS.	Erosion control measures that will be described in the EnvPP.	Negative, not significant (short to long-term, negligible, site-specific) effects to the suitability of water for aquatic life.

[1] drinking water use refers to use of surface waters by resource users. Note that all surface waters should be sterilized prior to human consumption.

Table 10-2. Expected residual effects of the Project on aquatic habitat. (Note: Description of effect incorporates assessments presented in Table 10-1.)

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
REACHES 2, 3, AND 4	**CONSTRUCTION**			
	Cofferdam placement in Reach 2 and construction of other structures.	The majority of aquatic habitat area disturbed by cofferdam placement will either be occupied by the GS structure or will be modified as part of the intake channel (powerhouse) or the approach channel (spillway).	None	Short-term loss/alteration of aquatic habitat (effect of permanent structures considered under operation), small, site-specific.
STREAM CROSSINGS	**CONSTRUCTION**			
	Footprint of access road (permanent) and installation of culvert(s) at eight stream crossings.	Loss of aquatic habitat; possible changes in water depth and velocity at crossings; introduction of rip-rap; some increase in sedimentation downstream of crossing.	All stream crossings will meet the "Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat".	Long-term (due to construction of permanent structures), small, site-specific.
REACH 1	**OPERATION**			
	Water level will be stabilized near the upper end of the existing range.	The intermittently exposed zone (IEZ) will decrease from 2022 ha to 342 ha and the nearshore zone will increase by 1588 ha. Sedimentation rates will increase.	None	Long-term decrease in IEZ and increase in nearshore zone will be moderate, local. Relatively short-term (first 5 years after construction) increase in sedimentation rates will be small, local.
REACH 2	**OPERATION**			
	Water level will increase (flooding) and stabilize at the same level as that of Reach 1. Habitat loss/alteration at locations of permanent structures.	Aquatic habitat will increase by 37.2 ha. Post-Project water velocities will be lower than existing ones. There will be a net loss of about 1.5 ha of aquatic plant beds.	None.	Long-term increase in aquatic habitat and reduction in water velocities will be moderate, site-specific. Long-term net loss of aquatic plant beds will be moderate, site-specific.

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
REACH 3	**OPERATION**			
	Daily water level fluctuations superimposed on the present fluctuations. Post-Project minimum water level will be lower than existing condition.	The IEZ will increase from 44 ha to 64 ha and habitat quality will decline. The wetted zone will decrease from 253 ha to 236 ha. Most of the existing 3.9 ha of aquatic plant beds may be lost.	None.	Long-term increase in IEZ, degradation of IEZ quality, and decrease in wetted zone will be moderate, local. Long-term potential loss of aquatic plant beds will be moderate, local.
REACH 4	**OPERATION**			
	Daily water level fluctuations superimposed on the present fluctuations. Post-Project minimum water level will be slightly lower than existing condition.	The IEZ will increase from 50 ha to 86 ha and habitat quality will be decline. The nearshore zone will decrease from 498 ha to 470 ha. A substantial portion of the existing 45.5 ha of aquatic plant beds may be lost.	None.	Long-term increase in IEZ, degradation of IEZ quality, and decrease in nearshore zone will be moderate, local. Long-term potential loss of aquatic plant beds will be moderate, local.
STREAM CROSSINGS	**OPERATION**			
	Footprint of access road.	Loss of aquatic habitat.	All stream crossings will meet the "Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat". Impacts related to operation will be minimized due to control measures outlined in the Project Description (Volume 3) and practices that will be described in the EnvPP.	Long-term, small, site-specific.

Table 10-3. Expected residual effects of the Project on lower trophic levels. (Note: Description of effect incorporates assessments presented in Tables 10-1 and 10-2.)

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
REACHES 2, 3, AND 4	**CONSTRUCTION**			
	Cofferdam placement and construction of other structures. Water quality effects in immediate forebay, Burntwood River, and at Backwater Inlet 4, including accidental spills. Blasting.	The majority of aquatic habitat disturbed by cofferdam placement will be occupied by the GS structure, or will be modified as part of the intake channel (powerhouse) or the approach channel (spillway). Short-term changes in water quality will not substantially affect lower trophic communities, although there may be some temporary effects (e.g., downstream movement of invertebrates exposed to a sediment plume). Blasting in or near water may cause some mortality.	Measures to mitigate effects to water quality. Majority of blasting (except single blast removal of rock plugs) will be within guidelines.	Short-term (1-2 years), small decrease in abundance and distribution, local.
STREAM CROSSINGS	**CONSTRUCTION**			
	Footprint of access road (permanent) and installation of culvert(s) at eight stream crossings. Water quality effects, including accidental spills.	Rooted submergent aquatic plants and benthic invertebrates in the footprint of the road and culvert(s) would be lost. Changes in water quality will not substantially affect lower trophic communities.	All stream crossings will meet the "Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat". Measures to mitigate effects to water quality.	Long-term (due to construction of permanent structures), small decrease in abundance and distribution, local.

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
REACH 1	**OPERATION**			
	Water level will be stabilized near the upper end of the existing range.	Small increase in phytoplankton and zooplankton production in tributary waterbodies; small increase in rooted submergent aquatic plants in Wuskwatim Lake and a moderate increase in tributary waterbodies; small increase in abundance and distribution of benthic invertebrates in Wuskwatim Lake, and a moderate increase in tributary waterbodies.	None.	Long-term, small to moderate increase in abundance and distribution, dependant on lower trophic community, local.
REACH 2	**OPERATION**			
	Water level will increase (flooding) and stabilize at the same level as that of Reach 1 . Habitat loss/alteration at locations of permanent structures. Water quality impacts, including accidental spills.	Moderate decrease in abundance and distribution of aquatic plants; and a moderate increase in abundance and distribution, and a change in species composition of benthic invertebrates.	None.	Long-term, moderate decrease in abundance and distribution (aquatic plants) or increase (benthic invertebrates), local.
REACH 3	**OPERATION**			
	Daily water level fluctuations superimposed on the present fluctuations. Post-Project minimum water level will be lower than existing condition. Water quality impacts, including accidental spills.	Potential decrease in abundance and distribution of aquatic plants; and a moderate decrease in abundance and distribution, and a change in species composition of benthic invertebrates.	None.	Long-term, moderate decrease in abundance and distribution, local.
REACH 4	**OPERATION**			
	Daily water level fluctuations superimposed on the present fluctuations. Post-Project minimum water level will be slightly lower than existing condition.	Potential decrease in abundance and distribution of aquatic plants; and a moderate decrease in abundance and distribution of benthic invertebrates.	None.	Long-term, moderate decrease in abundance and distribution, local.

STUDY REACH	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
STREAM CROSSINGS	**OPERATION**			
	Footprint of access road.	Rooted submergent aquatic plants and benthic invertebrates in the footprint of the road and culvert(s) would be lost.	All stream crossings will meet the "Manitoba Stream Crossing Guidelines for the Protection of Fish and Fish Habitat". Impacts related to operation will be minimized due to control measures outlined in the Project Description (Volume 3) and practices that will be described in the EnvPP.	Long-term, small decrease in abundance and distribution, local.

Table 10-4. Expected residual effects of the Project on VEC fish species. (Note: Description of effect incorporates assessments presented in Tables 10-1 to 10-3.)

VEC SPECIES	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
ALL VEC SPECIES	**CONSTRUCTION**			
	Increased TSS, potential for accidental hydrocarbon spills and releases, and input of sewage effluent and trace elements. Blasting	Changes in water quality may affect fish habitat and displace some individuals. Blasting in or near water may cause mortality of some individuals.	Measures to mitigate potential increases in TSS and trace elements, accidental spills and releases of hydrocarbons, and the treatment of sewage effluent are identified in the Project Description. Majority of blasting (except single blast removal of rock plugs) will be within guidelines.	Short-term, small, local and, therefore, not significant negative effect on populations of VEC fish species in the study area.
	Increased domestic, commercial, and recreational fishing activity.	Overharvesting during construction of the GS could affect the abundance of fish in Wuskwatim Lake.	Manitoba Conservation is responsible for the management of fisheries in the province, including avoidance of adverse effects related to over-harvest. NCN and Manitoba Hydro, in consultation with the Nelson House Resource Management Board (NHRMB), will develop an Access Management Plan (AMP) to manage, among other things, access to Wuskwatim Lake for domestic, commercial, and recreational fishers.	Mitigation and management will be used to assure that negative effects will not be significant.

VEC SPECIES	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
WALLEYE	**OPERATION**			
	Reach 1: stabilization of water level at upper end of existing range; Reach 2: inundation and stabilization of water level equal to that of Reach 1; localized increases in TSS and reductions in dissolved oxygen concentrations (DO). Reaches 3 and 4: daily water level fluctuations superimposed upon the present fluctuations; GS/turbine mortality; localized reductions in DO.	More spawning and feeding habitat, more food, unrestricted movement between reaches 1 and 2 for most individuals, and more fish retained upstream due to fewer downstream migrants. Reduction in the quality and quantity of spawning (Reach 3), feeding (Reaches 3 and 4), and overwintering (Reach 3) habitat, less food, and fewer migrants from Reach 2.	None	Long-term, small, local and, therefore, not significant positive effect to the walleye population of the study area.
	Increased domestic, commercial, and recreational fishing activity.	Overharvesting during operation of the GS could affect the abundance of walleye in Wuskwatim Lake.	Manitoba Conservation is responsible for the management of fisheries in the province, including avoidance of adverse effects related to over-harvest. NCN and Manitoba Hydro, in consultation with the NHRMB, will develop an AMP to manage, among other things, access to Wuskwatim Lake for domestic, commercial, and recreational fishers.	Mitigation and management will be used to assure that negative effects will not be significant.

VEC SPECIES	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
	OPERATION			
LAKE WHITEFISH	Reach 1: stabilization of water level at upper end of existing range; Reach 2: inundation and stabilization of water level equal to that of Reach 1; localized increases in TSS and reductions in dissolved oxygen (DO) concentrations. Reaches 3 and 4: daily water level fluctuations superimposed upon the present fluctuations; GS/turbine mortality; localized reductions in DO.	Short-term (5-10 years) negative effect (decrease in the quality of spawning habitat due to sedimentation in some areas) outweighed by a long-term increase in the quantity of spawning and feeding habitat, more food, unrestricted movement between reaches 1 and 2 for most individuals, and more fish retained upstream due to fewer downstream migrants. Reduction in the quality and quantity of spawning and feeding habitat; less food; and fewer migrants from Reach 2.	None	Long-term, small, local and, therefore, not significant positive effect to the lake whitefish population of the study area.
	Increased domestic, commercial, and recreational fishing activity.	Overharvesting during operation of the GS could affect the abundance of lake whitefish in Wuskwatim Lake.	Manitoba Conservation is responsible for the management of fisheries in the province, including avoidance of adverse effects related to over-harvest. NCN and Manitoba Hydro, in consultation with the NHRMB, will develop an AMP to manage, among other things, access to Wuskwatim Lake for domestic, commercial, and recreational fishers.	Mitigation and management will be used to assure that negative effects will not be significant.

VEC SPECIES	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
LAKE CISCO	**OPERATION**			
	Reach 1: stabilization of water level at upper end of existing range; Reach 2: inundation and stabilization of water level equal to that of Reach 1 localized increases in TSS and reductions in dissolved oxygen (DO) concentrations. Reaches 3 and 4: daily water level fluctuations superimposed upon the present fluctuations; GS/turbine mortality; localized reductions in DO.	Short-term (5-10 years) negative effect (decrease in the quality of spawning habitat due to sedimentation in some areas) outweighed by a long-term increase in the quantity of spawning and feeding habitat, more food, unrestricted movement between reaches 1 and 2 for most individuals, and more fish retained upstream due to fewer downstream migrants. Reduction in the quality and quantity of spawning and feeding habitat; less food; and fewer migrants from Reach 2.	None	Long-term, small, local and, therefore, not significant positive effect to the lake cisco population of the study area.
	Increased domestic, commercial, and recreational fishing activity.	Overharvesting during operation of the GS could affect the abundance of lake cisco in Wuskwatim Lake.	Manitoba Conservation is responsible for the management of fisheries in the province, including avoidance of adverse effects related to over-harvest. NCN and Manitoba Hydro, in consultation with the NHRMB, will develop an AMP to manage, among other things, access to Wuskwatim Lake for domestic, commercial, and recreational fishers.	Mitigation and management will be used to assure that negative effects will not be significant.

VEC SPECIES	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
NORTHERN PIKE	**OPERATION**			
	Reach 1: stabilization of water level at upper end of existing range; Reach 2: inundation and stabilization of water level equal to that of Reach 1 localized increases in TSS and reductions in dissolved oxygen (DO) concentrations. Reaches 3 and 4: daily water level fluctuations superimposed upon the present fluctuations; GS/turbine mortality; localized reductions in DO.	More spawning and feeding habitat, more food, unrestricted movement between reaches 1 and 2 for larger pike, and more fish retained upstream due to fewer downstream migrants. Reduction in the quality and quantity of spawning (Reaches 3 and 4), feeding (Reaches 3 and 4), and overwintering (Reach 3) habitat, less food, and fewer migrants from Reach 2.	None	Long-term, small, local and, therefore, not significant positive effect to the northern pike population of the study area.
	Increased domestic, commercial, and recreational fishing activity.	Overharvesting during operation of the GS could affect the abundance of northern pike in Wuskwatim Lake.	Manitoba Conservation is responsible for the management of fisheries in the province, including avoidance of adverse effects related to over-harvest. NCN and Manitoba Hydro, in consultation with the NHRMB, will develop an AMP to manage, among other things, access to Wuskwatim Lake for domestic, commercial, and recreational fishers.	Mitigation and management will be used to assure that negative effects will not be significant.

Table 10-5. Expected residual effects of the Project on fish quality of VEC fish species. (Note: Description of effect incorporates assessments presented in Tables 10-1 to 10-4.)

ISSUE	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
MERCURY	**OPERATION**			
	Reach 1: peat will come into contact with water more frequently as a result of stabilization of water level at the upper end of existing range; Reach 2: inundation of 34 hectares between Wuskwatim Falls and Taskinigup Falls.	Increase in mercury concentration in VEC fish species (lake cisco, lake whitefish, northern pike, walleye).	None.	Negative, long-term, small, local and therefore, not significant effect to VEC species.
	Reaches 3 & 4: die-off of peatlands in backwater inlets of the Burntwood River and the northern shore of Opegano Lake as a result of daily water level fluctuations superimposed upon the present fluctuations.	Increase in mercury concentration in VEC fish species.	None.	Effect is not expected to be measurable due to the large amount of flow in relation to the small area affected.
OTHER METALS	**CONSTRUCTION**			
	Increase in rate or erosion, acid leachate, and sediment loading.	Increase in metal concentrations in VEC fish species.	None.	No effect is expected on VEC species because metals do not typically accumulate in fish muscle.
	OPERATION			
	Increase in erosion and sediment loading upstream and downstream of the Generating Station.	Increase in metal concentrations in VEC fish species.	None.	No effect expected.

ISSUE	SOURCE OF EFFECT	DESCRIPTION OF EFFECT	MITIGATION MEASURE	RESIDUAL EFFECT
PARASITES	**OPERATION**			
	Reach 1 & 2: increase in lake whitefish and northern pike abundance.	Potential increase in *T. crassus* in lake whitefish.	Monitor commercial catches.	Negative, long-term, small, local and therefore, not significant effect.
FISH PALATABILITY	**OPERATION**			
	Project operations (specific source of effect not identified).	Change in fish palatability.	None.	No effect is expected.

11.0 CUMULATIVE EFFECTS ASSESSMENT

This section provides an overview of the potential cumulative effect of impacts of the Wuskwatim Project in conjunction with activities listed in Volume 5, Section 2.2. A description of the approach and scoping of the CEA, as well as information on developments/activities considered in the CEA is provided in Volume 10. Detailed cumulative effects assessments for various components of the aquatic environment are provided in Volume 5.

The CEA considered three phases of the Project:

(i) construction (2004-2009);

(ii) transition (2009-2034) – period when environment is adjusting to new water regime; effects are greatest during the initial part of this period and diminish thereafter; and

(iii) stabilized (2034+) – after the adjustment period and extending for the lifespan of the Project.

The following activities were considered in the CEA for the aquatic environment:

- Wuskwatim Transmission Project;
- Tolko Forestry, including projected future forestry operations with and without the establishment of an ASI at Partridge Crop Hill;
- increased cabin development at Wuskwatim Lake;
- TLE development at Wuskwatim Lake; and
- climate change.

Future hydroelectric development at Notigi, Gull/Keeyask, and Conawapa, and other projects associated with transmission development or maintenance projects such as the Kelsey upgrading, were not considered in this CEA as there was no spatial and temporal overlap with the effects of the Wuskwatim Project. In addition, impacts of two current projects, the CRD and INCO smelter at Thompson, were not included in the CEA as the residual effects of these projects were not expected to change the assessment of significance of residual effects of the Wuskwatim Project. The effect of CRD is incorporated into the description of the existing environment, which is believed to have adjusted to CRD and be relatively stable; in addition, any residual effects that are still changing (e.g., erosion) are expected to become smaller, rather than larger, over time. Aerial emissions from the INCO smelter may be contributing to on-going metal enrichment in the aquatic environment (in particular sediments); however, this impact was not assessed as the study area is in the secondary area of deposition, as the quality of smelter emissions will likely improve over time, and as there is no recent information available (Volume 10).

11.1 CONSTRUCTION

During the construction phase, measurable impacts at the construction site and extending downstream are expected for:

(i) Water Quality – short-term elevations in TSS in the Burntwood River during activities such as coffer dam construction and removal and at stream crossings during road construction, and increases in nutrients, ammonia and other parameters in the backwater inlet 4 during sewage lagoon discharge.

(ii) VEC fish species – may observe a negligible, short-term decrease in fish abundance due to the combined effects of short-term inputs of TSS (e.g., in plumes), excavation, blasting, and degradation of habitat in backwater inlet 4 during sewage lagoon discharge. Harvesting during construction could have an effect on fish populations (depends on management).

Construction of the Wuskwatim transmission line is the only major activity identified during this phase (though limited forestry may occur in 2009). The transmission line extending from the Wuskwatim site to Thompson would cross the Burntwood River and several tributaries on the south side. However, no impacts to water quality or fish and fish habitat are expected due to environmental protection measures during construction (Wuskwatim Transmission Project EIS 2003). Therefore, no cumulative effects are expected. The second line, which connects Wuskwatim GS to the Herblet Lake Transmission station, after crossing the Burntwood River, does not pass through aquatic areas affected by construction of the GS.

11.2 TRANSITION

Following construction of the Project, conditions both upstream and downstream are expected to evolve quite rapidly over the first several years, and then more slowly thereafter. A twenty-five year period has been designated as the transition phase.

During this period, the following measurable impacts to the aquatic VECs are expected:

(i) water quality - local effects as discussed in Volume 5, Section 5.4, including increases in suspended sediment and some metals off of banks experiencing a marked increase in the rate of erosion in Wuskwatim Lake; slight nutrient enrichment and exacerbation of existing low oxygen levels in off-current areas of off-system waters (e.g., Wuskwatim Brook, Sesep Lake); and potentially some depletion of oxygen adjacent to peatlands in backwater inlets and the north shore of Opegano Lake;

(ii) walleye and northern pike – increased production upstream of the GS due to more food and increased access to spawning and feeding habitat on Wuskwatim Lake; a decline in production downstream of the GS up to and including Opegano Lake due to: (i) a general decrease in productivity in this reach, and (ii) a reduction in the downstream movement of fish from Wuskwatim Lake. Overall, a not significant positive increase in the abundance of these species is predicted in the long term for the study area;

(iii) lake whitefish and lake cisco – increased production upstream of the GS due to more food and increased access to spawning and feeding habitat on Wuskwatim Lake counteracted in first years of transition phase by increased sedimentation affecting a portion of the spawning habitat. As with walleye and northern pike, a decline in the abundance of these species is expected in the Burntwood River between the GS up to and including Opegano Lake. Overall, a not significant positive increase in the abundance of these species is predicted in the long term;

(iv) increased mercury levels in northern pike, walleye and, to a lesser extent, lake whitefish and lake cisco; and

(v) increased domestic, commercial, and recreational harvest is predicted. Manitoba Conservation is responsible for the management of fisheries, including avoiding potential adverse effects associated with over-harvest.

The following activities/developments were evaluated for this phase:

Wuskwatim transmission facilities – no impact on aquatic environment.

Forestry – areas to the south of Wuskwatim Lake and the Burntwood River upstream and throughout the reach could be harvested. It should be noted that this is a hypothetical scenario and actual harvesting would be contingent on receiving approvals from Manitoba Conservation. Based on the Environmental Impact Statement for the Repap Manitoba Inc. 1997-2009 Forest Management Plan (assessed harvest in the areas under consideration), timber harvest and the associated development of roads can result in impacts to water quality and fish and fish habitat (e.g., impediment of fish passage at stream crossings, degradation of habitat due to sedimentation), but these impacts can be minimized through the implementation of appropriate measures.

The cumulative impacts to water quality in Wuskwatim Lake and adjoining waters from forestry are expected to be minimal for the following reasons:

- during timber harvest, maintenance of a buffer along Wuskwatim Lake would minimize the inputs of sediments from harvested areas to the nearshore environment, where suspended sediments and sedimentation are increased as a result of the Wuskwatim Project;

- timber harvest and the construction of roads in the upper sections of Wuskwatim Brook could cause minor downstream increases in suspended sediments and nutrients. If these effects occur in the first years after the Wuskwatim Project is built, there would be a cumulative effect to water quality in this area; and,

- no major upstream movements of fish into Wuskwatim Brook or other tributaries where upstream reaches could be impacted by forestry were identified. Therefore, alterations to fish habitat in these tributaries is not expected to affect fish populations in Wuskwatim Lake.

Increased number of cabins and TLE from NCN - the increased number of cabins could lead to localized effects to water quality (e.g., seepage from pit privies, oil and gas from boat motors) and an incremental increase in harvesting of fish.

With respect to the TLE, no plans have been developed, but an increase in human usage of Wuskwatim Lake, in conjunction with possible development of infrastructure (e.g., cabins) would likely occur. Impacts would be similar to increased development of cabins.

Effects of the Project on Wuskwatim Lake would impose few limitations in usage. The primary effect would be to the suitability of surface waters at local sites as a drinking water source: for example, there will be an increase in suspended sediments off of eroding shorelines (e.g., peninsula at south end of lake selected as a TLE is in a high erosion area). Likewise, isolated bays on Wuskwatim Brook and Sesep Lake may experience a greater amount of oxygen depletion during winter, making the water less suitable for drinking. With respect to cabin and other development along the lakeshore, it is recommended that activities not be undertaken which would exacerbate the existing erosion along the shoreline, to avoid incremental effects on whitefish and cisco spawning habitat.

11.3 STABILIZED PHASE

Prediction of potential developments and impacts during the stabilized phase is associated with a high degree of uncertainty due to the interaction of many variables. By 2034, the aquatic environment in the area affected by the Wuskwatim Project is expected to have achieved a new steady state, and the residual effects of the Project would be related to permanent changes in the water regime:

(i) Wuskwatim Lake levels would be generally steady, with a resulting small increase in lake productivity compared to the existing condition;

(ii) daily fluctuation of water levels downstream of the GS up to and including Opegano Lake would have resulted in a generally less productive environment; and

(iii) fewer fish would be moving downstream from Wuskwatim Lake to Opegano Lake than under pre-Project conditions due to the presence of the GS.

During this phase, several activities considered in the transition phase (e.g., transmission facilities, timber harvest within the immediate watershed, NCN activities at Wuskwatim Lake) would continue; however, after the transition phase, cumulative impacts with the Wuskwatim Project would no longer be expected to occur.

In this phase, climate change could also affect the environment. Due to the high level of uncertainty, expected impacts to the aquatic environment are difficult to describe, however an increase in overall temperature is expected (Volume 4). Indirect effects to the aquatic environment, related to the melting of permafrost and an increase in the frequency of fires, may also occur (Volume 10).

The residual impacts of the Project during the stabilized state are not expected to act in a cumulative manner with the impacts of climate change. Although climate change may affect water quality, operation of the Project is not expected to affect water quality during this phase. Likewise, an increase in water temperature could reduce the suitability of the environment for coldwater species such as lake whitefish and lake cisco; however, during this period the station is not expected to cause a measurable impact to these species (population-related effects due to turbine mortality are expected to be negligible).

It should be noted that, in the long term, additional hydroelectric stations may be constructed at sites on the Burntwood River within the Wuskwatim study area; however, plans for these stations have not been developed and, as they would be subject to an environmental review process, are not included in this CEA.

12.0 ENVIRONMENTAL MONITORING AND FOLLOW-UP

This section provides an overview of the aquatic ecosystem environmental monitoring and follow-up activities that will be undertaken during construction and operation of the Project. Detailed descriptions of the programs are presented in Volume 5 of the Project EIS.

The aquatic monitoring and follow-up program is intended to document conditions over time for identified VECs and other parameters to:

- confirm impact predictions;
- identify unexpected effects and impacts;
- monitor effectiveness of mitigation measures;
- identify other mitigation or remedial actions that may be implemented;
- confirm compliance with regulatory requirements including Project approvals; and
- provide baseline data and information for other users.

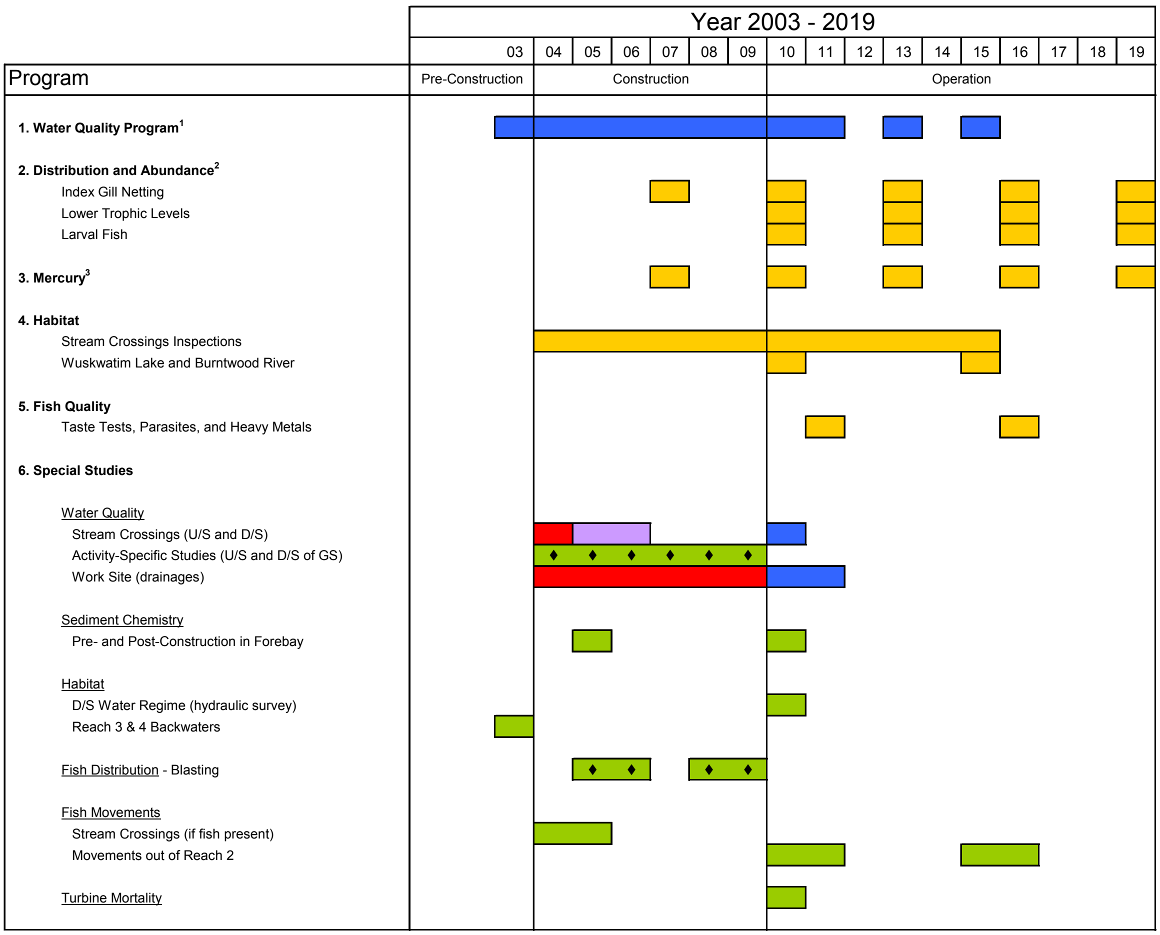
As many aquatic ecosystem components experience wide ranges of seasonal and year-to-year variation, and as some effects of the Project may only be detectable after a period of several years, the monitoring program must be long-term and designed to document the key characteristics of each component. Some monitoring activities will be scheduled within an ongoing program, while others will be conducted on an "as required" basis; some activities will be confined to a specific site, whereas some will be regional in scope. The assessment studies conducted for the EIS have established monitoring sites and sampling protocols that will be maintained through the construction and operation of the Project. Each monitoring program and activity will be described in a work plan supporting the Environmental Protection Plan

As the field studies for the EIS were primarily conducted in the 1998 – 2002 period, and as in many instances only one or two rounds of samples or measurements were taken, and as environmental components often have a wide range of year-to-year natural variability, and as the Project will not cause major changes to water regimes for several years, there is opportunity to carry out additional pre-construction monitoring to strengthen the data base for key aquatic components, such as water quality.

Monitoring activities will be conducted by competent professionals and technicians using accepted methods and appropriate equipment to produce scientifically credible results. Traditional Knowledge will be a major component of the monitoring record and NCN resource users will participate in implementing the monitoring program. Monitoring activities will be reviewed with resource managers and resource users prior to program implementation and results will be made available to all interested parties.

The following outlines the proposed aquatic monitoring activities that are summarized in Table 12-1.

Table 12-1. Aquatic Monitoring Program Activity Schedule.



[1] Water quality sampling at permanent sites on the Burntwood River, including sites upstream and downstream of the GS.
[2] Distribution and abundance as per pre-Project programs.
[3] Standardized sampling as per established protocols.

Legend:
- Once per year
- Monthly (open-water period)
- Bi-monthly (open-water period)
- Four times per year
- Special studies
- ♦ Subject to construction schedule

12.1 PRE-CONSTRUCTION

Prior to flooding of the forebay and changes to the upstream and downstream water regimes the following aquatic monitoring will be conducted:

- collection of water samples at permanent water quality monitoring sites to strengthen the existing data base (including quarterly water quality sampling from sites immediately upstream and downstream of the generating station site) (2003); and
- collection of additional information on aquatic habitat and vegetation communities in backwaters of reaches 3 & 4 (2003).

12.2 CONSTRUCTION

Construction activities, environmental parameters and environmental effects will be closely monitored during the construction period. The Environmental Protection Plan for the Project outlines monitoring requirements and responsibilities arising from the commitments made in the EIS, as well as the Terms and Conditions of Environment Act License, Fisheries Act Authorizations, Work Permits and other approvals granted for the work. This monitoring will include, but not necessarily be limited to:

Access Road Stream Crossings

- water quality sampling upstream and downstream of each crossing will be conducted before and after road construction to assess those parameters most likely to be affected by construction. Monthly water quality analysis during the 2004 open-water season and bi-monthly sampling during the 2005 and 2006 open-water seasons will be conducted. The need for additional sampling will be determined on the basis of the results from the 2004 to 2006 sampling programs; and
- annual visual inspection of aquatic habitat and fish passage conditions upstream and downstream of road crossings (spring of 2004 to 2009) and assessment of fish passage in spring of 2004 and 2005.

Construction Camp and Work Areas

- monthly observations and sampling of basic water quality parameters in drainages from active work sites at the site boundary and at their discharge into the Burntwood River (2004 to 2009). (Discharges from the sewage plant and other operating site facilities will be monitored as required by approvals for those facilities).

Generating Station Site

- site- and activity-specific water quality monitoring as appropriate to assess only those parameters most likely to be affected during construction activities such as coffer dam construction and removal, rock excavation, and flooding of the forebay (2004 to 2009);
- monitoring of fish presence in reaches 1-3 within 1 km of the site pre- and post-blasting (2005 and 2006);
- monitoring of fish mortality following single blasts for removal of rock plugs (2008 and 2009);
- standard gang index gill net survey in reaches 1 – 4 to determine fish distribution and abundance (2007); and
- documentation of sediment chemistry immediately upstream of the station and dam prior to inundation (2005).

Reaches 1- 4

- four times a year water quality monitoring at permanent sites (2004 to 2009); and
- mercury sampling in fish from Wuskwatim Lake and Opegano Lake to strengthen mercury database (2007).

12.3 OPERATION

Access Road Stream Crossings

- four times a year water quality sampling upstream and downstream of each road crossing in 2010 to assess only those parameters most likely to have been affected by construction; and
- annual visual inspection of aquatic habitat and fish passage conditions upstream and downstream of each road crossing (2010 to 2015).

Construction Camp and Work Areas

- four times a year observation and sampling of basic water quality parameters at the drainage site discharging into the Burntwood River for two years after site rehabilitation (2010 and 2011).

Generating Station Site

- fish tagging and recapture study to document fish movements upstream and downstream from the generating station forebay in 2010/11 and 2015/16;

- turbine mortality study in 2010; and
- documentation of post-construction forebay sediment chemistry following construction of the GS (2010).

Reaches 1 - 4

- four times a year water quality monitoring at permanent sites in 2010, 2011, 2013, and 2015;
- hydraulic survey of downstream water regime in 2010;
- standard gang index gill net surveys of reaches 1 – 4 to define fish distribution and abundance in 2010, 2013, 2016, and 2019;
- sampling of fish for mercury content in Wuskwatim and Opegano lakes in 2010, 2013, 2016, and 2019;
- surveys for lower trophic levels and larval fish at all established sampling sites in 2010, 2013, 2016, and 2019;
- survey of lake and river habitat in reaches 1 – 4 in 2010 and 2015; and
- fish quality tests in 2011 and 2016 (taste tests, parasites, and heavy metals).

12.4 REPORTING

Annual reports presenting monitoring activities and results for all parameters will be issued. These reports will be distributed to Manitoba Hydro, NCN Chief and Council, and NCN resource users, federal/provincial regulatory authorities, and resource managers. Presentation of the results will also be provided to NCN community members at meetings in Nelson House. Changes to the monitoring programs will be based on results and only be made with the concurrence of all the involved parties. A meeting between all involved parties is proposed for years 2, 5 and 10 following completion of construction to review monitoring results, environmental changes resulting from the Project and revisions to the monitoring program.

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14.0 GLOSSARY OF TERMS AND ACRONYMS

acid neutralizing capacity – measure of the ability of water (or soil) to resist changes in pH.

acidic (acid) - a pH value of less than 7.0 (pH is a way to measure the acidity or alkalinity of a solution).

adult – sexually mature life history stage of a species

aerobic - refers to the presence of oxygen.

aesthetics - beauty and/or pleasurable nature of something. When used in reference to water quality, it generally refers to the odour, taste, and appearance of water.

algae - a group of simple plant-like aquatic organisms possessing chlorophyll and capable of photosynthesis; they may be attached to surfaces or free-floating; most freshwater species are small or microscopic in size

alkaline (basic) - a pH value of greater than 7.0 (pH is a way to measure the acidity or alkalinity of a solution).

alkalinity - the capacity of water for neutralizing an acid solution, generally expressed in terms of calcium carbonate units (mg/L); alkalinity of natural waters is due largely due to the presence of hydroxides, bicarbonates, and carbonates.

allochthonous - organic material with a terrestrial origin (i.e., organic material that falls into a stream form the surrounding land).

ambient - outside, or surrounding on all sides.

ammonia nitrogen – a compound of nitrogen and hydrogen formed by decay of organic nitrogen and which breaks down to form nitrite. Ammonia is taken up by aquatic plants as a nutrient.

anguilliform locomotion – the type of swimming mode for fish that swim like an eel, and move through the water by undulating most or all of their body

anoxic – absence of oxygen.

anthropogenic – involving the impact of humans on nature; induced, caused, or altered by the presence and activities of man, as in water and air pollution.

aquatic - living or found in water.

aquatic environment - areas that are permanently under water, or that are under water for a sufficient period to support organisms that remain for their entire lives, or a significant portion of their lives, totally immersed in water

aquatic habitat - the place where an aquatic plant or animal lives; often related to a function such as breeding, feeding, etc

aquatic macrophyte - large, rooted plants that live in water (e.g., pond weeds)

areal – adjective describing a particular extent of space or ground

autochthonous - organic material produced in the stream usually through primary production; pertaining to substances, materials, or organisms originating within and remaining in a waterway.

backpack electrofisher – a unit equipped with a power source which makes use of electric currents to capture fish in shallow tributaries

bacteria - microscopic single-celled organisms found in soil, water, organic matter, and the atmosphere

basal pterygiophores – form the base of support for the dorsal and anal fin rays

baseline information – information about an area, over a period of time, that is used as background for detecting and/or comparing potential future changes.

bathymetric survey - a survey to describe the area and water depth of a lake or river

BCMOE - British Columbia Ministry Of Environment

bed - a thick mat of vegetation growing on the bottom of a water body (e.g., seagrass bed, eelgrass bed)

bedrock - solid rock underlying alluvial deposits, etc.

benthic - of, or pertaining to, the bottom of a water body

benthic - of, or pertaining to, the bottom of a water body.

benthic invertebrate - a small animal (without a backbone) that lives on or in the bottom of a waterbody (e.g., insect larvae, clams)

benthos - animals and plants that live on or in the bottom of a water body

bioaccumulate - the uptake and accumulation of a substance in an organism.

bioavailability - a term used to refer to the availability of substances to be accumulated by biota.

biochemical oxygen demand (BOD) - a test used to measure the level of pollution in water by determining how much dissolved oxygen is consumed by microorganisms (e.g., bacteria) as they break down organic matter (e.g., plants).

biodiversity - the existence of a wide range of different species in a given area or during a specific period of time

biota - the animal (fauna) and plant (flora) life of a region.

bog - wetland ecosystem characterized by an accumulation of peat, acid conditions, and a plant community dominated by sphagnum moss

boreal forest - needle-leafed evergreen or coniferous forest bordering sub-polar regions

boulder - the largest of rock particles, having a diameter greater than 256 mm

catch-per-unit-effort - the number or weight of fish caught in a given unit of effort within a given time period (e.g., #fish/100m of net/24hrs)

CCME - Canadian Council of Ministers of the Environment

CFU - Coliform units

chlorophyll - a group of green pigments present in plant cells that are essential in the trapping of light energy during photosynthesis

Cladocera - any minute freshwater crustacean of the Order Cladocera*,* which includes the water fleas

clay - the finest particles in soils, having a particle diameter of less than 0.002 mm

cobble - rocks larger than gravel but smaller than boulders, having a particle diameter between 64 and 256 mm

cofferdam - an enclosure, usually only partially obstructing a river, from which water is pumped to expose the bottom to permit construction

colour - the colour of water is the result of backscattering of light upward from a water body after it is selectively absorbed at various depths.

concentration - the density or amount of a material suspended or dissolved in a fluid (aqueous) or amount of a material in a solid (e.g., sediments).

condition factor (K) – a relationship between length and weight (fork length X 10^5 / weight^3) that can be used to compare the relative condition of a particular species of fish in different bodies of water and within the same water body over time

conductivity - a measure of the ability of a solution to conduct electrical flow; units are measured in microSiemens per centimetre

confluence - the meeting place of two streams

conservation - any various efforts to preserve or restore the earth's natural resources, including such measures as: the protection of wildlife, the maintenance of forest or wilderness areas, the control of air and water pollution, and the prudent use of farmland, mineral deposits, and energy supplies

Copepoda - minute planktonic or parasitic crustaceans of the Order Copepoda

cover - 1) vegetation such as trees or undergrowth that provide shelter for wildlife; 2) also the surface area of a stratum of vegetation as based on the vertical projection on the ground of all aboveground parts of the plant, and, which in the present study corresponds to the following category: closed = >60% cover; open = >25-60% cover; and sparse = 10-25% cover; 3) also the material in or overhanging the wetted area of a lake or stream that provides fish with protection from predators or adverse flow conditions, e.g., boulders, deep pools, logs, vegetation

CRD - Churchill River Diversion

Cryptosporidium - a protozoan parasite found in intestinal tracts of various vertebrates; it has been implicated in human intestinal disease (Cryptosporidiosis).

culvert - a large pipe or covered structure that carries drainage or a watercourse underground

cumulative impacts - the impact on the environment which results from effects of a project when combined with those of other past, existing, and imminent projects and activities

CWQI - Canadian Water Quality Index

demersal - living near, deposited on, or sinking to the bottom of a water body

density - the number of individuals in relation to the space in which they occur

deposition - to settle out of the water column onto the bottom

detritivore - an organism that feeds upon decomposing organic matter

detritus - particulate and dissolved organic matter that is produced by the decomposition of plant and animal matter

dewatering - removing or diverting all or some of the water from a river, lake or stream

DFO - Department of Fisheries and Oceans

DIN - dissolved inorganic nitrogen

discharge - rate of outflow; volume of water flowing down a river, through a pipe or from a hydroelectric dam

DL - detection limits

DO - dissolved oxygen

DOC - dissolved organic carbon

DP - dissolved phosphorus

drawdown - a lowering of a water level (as in a reservoir)

dyke - a long wall or embankment built to prevent flooding, or restrict water flow

ecosystem - all living organisms in an area and the non-living components of the environment upon which they depend, as well as all interactions, both among living and non-living components of the ecosystem

egg incubation – the act or process of maintaining an egg under conditions favourable for hatching and development

EIS – Environmental Impact Statement

Ekman dredge - a box shaped device used to collect organisms living on the soft bottom of a water body

emergent - an aquatic plant having most of its vegetative parts (leaves/stems) above water

entrainment - to draw in and transport fish by the flow of water

environment - 1) the total of all the surrounding natural conditions that affect the existence of living organisms on earth, including air, water, soil, minerals, climate, and the organisms themselves; 2) the local complex of such conditions that affects a particular organism and ultimately determines its physiology and survival

environmental impact assessment - an evaluation of the likely adverse environmental effects of a project.

Environmental Protection Plan (EnvPP) - a document that provides site-specific and detailed information on construction practices that will be followed during project construction so as to avoid or minimize potential environmental effects

ephemeral - existing for only a short time, typically one season or less

erosion – 1) the wearing away of the earth's surface by the action of water, wind, current, etc.

euphotic - of, relating to, or constituting the upper layers of a body of water into which sufficient light penetrates to permit growth of green plants

euphotic zone - area of the water column in which there is light is adequate light to support photosynthesis. It is generally defined as the depth within a minimum of 1% of radiation remains.

eutrophic - a body of water with high concentrations of nutrients, particularly nitrogen and phosphorus, and high productivity.

eutrophication - the process of nutrient enrichment of a body of water that leads to high, often undesirable, levels of productivity.

fecal coliform bacteria - fecal coliform bacteria, which include genera such as *Escherichia* and *Klebsiella*, are indicators of organisms from the intestinal tracts of humans and other animals, used to represent the potential presence of pathogens.

FEMP - Federal Ecological Monitoring Program

fen - a peatland with the water table usually at or just above the surface; often stagnant and alkaline

filamentous - having a long, threadlike structure

first-order stream - stream originating in a seepage zone or spring, with no entering tributaries; the most headward channels in the drainage network

Floy tag - a spaghetti-like marker, possessing an identifying series and number, which is attached between the basal pterygiophores of the dorsal fin of a fish

food chain - sequence of organisms in which each uses the next lower member of the sequence as a food source and is eaten by the one above

food web - a pattern of interconnecting food chains

footprint - the surface area occupied by a structure or activity

forage - to locate, capture and eat food

freshet - the flood of a river from heavy rain or melted snow

Geographic Information System (GIS) - a computerized information system which uses geo-referenced spatial and tabular databases to capture, store, update, manipulate, analyze and display information

Giardia - *Giardia* sp. is a protozoan parasite living in the intestines of mammals that causes the disease giardiasis (i.e., beaver fever) in humans.

glide - areas of swift flowing water without surface waves in a stream or river

gradient - the slope of a stream or land surface

gravel - an accumulation of loose or unconsolidated, rounded rock fragments larger than sand, and between 10 and 100 mm in diameter; rock larger than sand but smaller than cobble having a particle diameter between 2 and 64 mm**herbivore** - an animal that eats plants

ha - hectares

heterogeneous - consisting of dissimilar components

hydraulic - 1) of or relating to liquid in motion; and, 2) of or relating to the pressure created by forcing a liquid through a relatively small orifice, pipe, or other small channel

hydrocarbon - an organic compound that contains only carbon and hydrogen, and no other elements; derived mostly from crude petroleum and also from coal tar and plant sources. Excessive levels may be toxic.

hypoxic - deficiency of oxygen.

ice scouring - removal of material from the banks or bottom of a lake or stream by moving ice

immunocompetency - the predisposition of the immune system of organisms to combat infection or disease.

impingement - to have an effect or to strike or dash especially with a sharp collision

inorganic nitrogen - nitrogen in the form of ammonia and nitrate and nitrite nitrogen. Inorganic nitrogen is readily taken up by aquatic plants and algae.

invertebrate - an animal with no backbone, e.g., an insect

juvenile - the stage in an organism's life before it is able to reproduce

kick net – a fine meshed hand-held dip net used to collect benthic invertebrates, fish eggs and larvae. Samples are collected by moving the net through the water, or placing the net on the substrate and "kicking" the substrate immediately upstream of the net.

km - kilometre

lacustrine – pertaining to a lake

larval drift traps – modified traps placed in the water column (either fixed near the substrate or suspended) which collect organisms drifting downstream

lentic - pertaining to very slow moving or standing water, as in lakes or ponds

life history - the timeline of an organism's life; including development, maturation and reproduction

light extinction coefficient – coefficient that describes the inverse of light penetration in a body of water as a function of depth; the greater the light extinction coefficient, the more rapidly incoming surface radiation is attenuated along the vertical depth.

littoral - shore zone of tidal water between high water and low water marks; also the shallow water zone of a lake or river in which light penetrates to the bottom, permitting plant growth

LOEL - Lowest Effect Level

lotic - pertaining to moving water

lower trophic level - a level in the movement of matter and energy along a food chain or through a food web that supports higher levels of that food chain; generally refers to algae, zooplankton, and benthic invertebrates

macroalgae - algae large enough either as individuals or communities to be readily visible with the naked eye

macrophyte - multi-celled aquatic and terrestrial plants

mainstem - the unimpeded, main channel of a river

major ions – major cations (e.g., Ca^{2+}; Mg^{2+}; Na^{+}; and, K^{+}) and anions (e.g., Cl^{-}; and, SO_4^{2-}) that together comprise the total ionic salinity of water. They typically occur at higher concentrations than other ions in aquatic systems.

marsh - a low-lying wetland with grassy vegetation; differs from a swamp by having more vegetation and few or no trees; and differs from a bog by having soil as a base

meiofauna - Animals whose shortest dimension is less than 0.5 mm but greater than or equal to 0.1 mm

meristic – countable characteristics (e.g., fin rays or lateral line scales)

metalloids – an element with properties of metals and non-metals (e.g., arsenic, selenium, bismuth).

metals – an element yielding positively charged ions in aqueous solutions of its salts.

microorganisms - small plants and animals that are generally not visible, or barely visible, to the naked eye

microscopic - small enough so as to be undetectable with the naked eye

model - a tool used to help visualize something that cannot be directly observed

modified neuston sampler – instrumentation used for collecting larval fish from the neuston (surface) layer of water

monitoring – measurement or collection of information to determine whether change is occurring

morphological – pertaining to the structure and form of an organism

morphometry - the measurement of the physical shape characteristics of a thing; e.g., a lake, a fish

m/s - metres per second (a measurement of velocity)

m^3/s - cubic metres per second (a measurement of discharge)

MSQG - Manitoba Sediment Quality Guideline

MWQSOG - Manitoba Water Quality Standards, Objectives, and Guidelines

NCN – Nisichawayasihk Cree Nation

NTU - Nephelometric Turbidity Units

nursery - an area where an organism spends the early developmental stages of its life

OMOE - Ontario Ministry of the Environment

organic - the compounds formed by living organisms

organic carbon – measure of organic matter (in dissolved or particulate forms in water or in sediments).

organic nitrogen (ON) - nitrogen which is bound to carbon-containing compounds (i.e., organic matter). Organic nitrogen is converted to ammonia via anaerobic bacteria.

organism - an individual living thing

overwintering - remaining through the winter months

PAH - Polycyclic aromatic hydrocarbons

particle size - the size of a mineral particle in sediment

PEL - Probable Effects Level

peat - material consisting of under-composed and only slightly decomposed organic matter found in extremely moist areas

pelagic – pertaining to open water at all depths

percentile - a value on a scale of one hundred that indicates the percent of the distribution that is equal to or below it

periphyton – assemblage of microorganisms (plants and animals) attached to and growing upon solid surfaces (e.g., rocks, logs) on the bottom of aquatic systems. Periphyton is primarily algae but also includes bacteria, fungi, protozoa, rotifers, and other small organisms.

pH - method of expressing acidity or basicity of a solution. pH is the logarithm of the reciprocal of the hydrogen ion concentration, with pH 7.0 indicating neutral conditions.

photic - of, relating to, or involving light especially in relation to organisms

photosynthesis – process by which green plants (and other organisms) convert carbon dioxide and water to carbohydrates (an energy source). Chlorophyll is the typical catalyst for the process.

physico-chemical - physical and chemical processes.

phytoplankton – microscopic floating plants (primarily algae) that live suspended in water bodies.

polycyclic aromatic hydrocarbons (PAHs) – class of highly stable organic molecules comprised of only carbon and hydrogen, found in coal tar, crude oil, creosote, roofing tar, dyes, plastics, and pesticides and may be present in the aquatic environment in association with heavy boat traffic. They are formed from incomplete combustion of coal, oil and gas, garbage and other organic substances (e.g., tobacco).

ponar dredge - a box-like device used to sample benthic organisms and sediment from the bottom of water bodies with a variety of substrates (e.g., mud or sand)

pool - an artificially confined body of water above a dam or weir; a deep, slow moving area of a stream

primary production – measure of algal productivity (rate of growth), which is influenced by amounts of nutrients, solar radiation, temperature, and hydraulic conditions (e.g., water residence times, velocities).

producer - an organism that creates organic matter from inorganic matter; usually refers to primary producers, i.e., plants and algae that use energy from sunlight to combine carbon dioxide and water to form organic matter

productivity - rate of formation of organic matter over a defined period of time; this can include the production of offspring.

radio tag - a small electronic device that is attached to a fish and emits a radio signal at a specific frequency so that its movements can be tracked

radioactivity - energy released when certain radioactive elements (radionuclides) decay or break down. For example, uranium and thorium are two radioactive elements found naturally in the earth's crust. Over billions of years, these two elements slowly change form and produce "decay products" such as radium and radon. During this change process, energy is released. Two forms of this energy alpha and beta radiation.

radionuclides – radioactive elements that emit radiation; radionuclides are either natural (e.g., U-238) or synthetic.

rapids - a section of shallow, fast moving water in a stream made turbulent by totally or partly submerged rocks

rearing - the raising of young

relief - elevations or inequalities of land surface

residence times – the time required for a 'parcel' of water to flow through a lake. It generally describes the relationship between the size (or volume) of a lake and the streams or rivers that flow into it.

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residual impact – a left over impact caused by the alteration of the surrounding environment

riffle - a shallow areas where the water flows swiftly over partially or completely submerged materials to produce surface agitation; generally of lower slope and velocity than rapids

right-of-way - a strip of land obtained and cleared for the purpose of building a road or transmission line

riparian - along the banks of rivers and streams

rip-rap - a light-weight stone covering used to protect soil or surface bedrock from erosion by water or the elements

riverbed - the low-lying alluvial land through which a river flows (also river bottom)

riverine – relating to, formed by, or resembling a river including tributaries, streams, brooks, etc.

runoff - the flow of flood waters out of a drainage basin

sand - **1)** a small, somewhat rounded fragment or particle of rock ranging from 0.05 to 2 mm in diameter, and commonly composed of quartz; **2)** a loose aggregate or more or less unconsolidated deposit, consisting essentially of sand-sized rock particles or medium-grained clastics

scour - erosion along the bottom and sides of water bodies

Secchi depth - the depth to which water is transparent

Secchi disc – circular black and white disc used to measure the transparency/clarity of a water body.

Secchi disc depth – measure of the turbidity/clarity of water. Depth at which it is no longer visible from the water surface.

second-order streams – stream resulting from the joining of two first-order streams

sedges - grass or rush-like plants typically growing in marshy areas

sediment - material, usually soil or organic detritus, which is deposited in the bottom of a waterbody

SEL - Severe Effect Level

shoal - a bank or bar usually composed of sand, mud or organic material on top of which there is a shallow layer of water

shrub - a woody plant with overwintering buds above ground level, smaller than a tree, with a circumference of breast height of less than 10 cm

silt - a very small rock fragment or mineral particle, smaller than a very fine grain of sand and larger than coarse clay; usually having a diameter of 0.002 to 0.06 mm; the smallest soil material that can be seen with the naked eye

slumping - the erosion and partial collapse of a bank due to prolonged exposure to wave action or flowing water.

spatial - relating to space

spawning - the act of reproducing in fish

species - a group of inter-breeding organisms that can produce fertile offspring

species composition - the number of different species that occur in an area

spillway - a series of chutes in a hydroelectric facility that permit the passage of water out of the forebay and is not used to generate power

stage - 1) the height of a water surface, usually above sea level; and, 2) regarding wildlife, the process of stopping over during migration

Standard Error (SE) - standard error of the mean

standard gang index gill net – a gill net comprised of adjoining different sized panels (often six panels consisting of 1.5, 2, 3, 3.75, 4.25, and 5 inch stretched mesh) used to assess fish abundance

stratification – arrangement of a body of water (e.g., a lake) into two or more horizontal layers of differing characteristics (e.g., temperature, pH, dissolved oxygen, density).

sub-carangiform locomotion – the type of swimming mode for fish that swim like trout or salmon, and move through the water by undulating the posterior third to half of their body

submerged - beneath the surface of water

submergents - aquatic plants that live below the surface of the water

substrate - the surface or material on which an organism lives or to which it is attached

surficial – of or relating to a surface. When used in reference to sediments, it refers to the upper layers of sediments, frequently the upper 5 cm.

taxa - a group of any valid taxonomic categories (i.e. plural of taxon) used in taxonomy

taxonomy - the science of the classification of organisms

TCU - true colour units

TEH - total extractable hydrocarbons

terrestrial - living on or in the ground; relating to the ground/earth as opposed to the water

thalweg - deepest part of a channel or waterway

TKN - total Kjeldahl nitrogen

TN - total nitrogen

TOC - total organic carbon

topographic - referring to a map that shows all the surface features of the terrain

total dissolved solids (TDS) – measure of the amount of material dissolved in water (primarily inorganic salts).

total kjeldahl nitrogen (TKN) – total concentration of nitrogen in the form of ammonia and organic nitrogen.

total suspended solids (TSS) - solids present in water that can be removed by filtration, consisting of suspended sediments, phytoplankton, and zooplankton.

TP - total phosphorus

transect - a long continuous sample area usually perpendicular to the shore of a river or stream; a line along which samples are taken at set points

tributary - any secondary stream or river that flows into a larger waterway

trophic level - functional classification of organisms in an ecosystem according to feeding relationships, e.g., herbivores, carnivores; any of a series of steps on a food chain or food pyramid from producers to primary, secondary and tertiary consumers

true colour (TC) - True colour is used as an indicator of dissolved and suspended materials in water.

turbid - water that has a cloudy, murky, or muddy appearance

turbidity – measure of the reduced transparency of water due to suspended materials (e.g., clay, silt, organic matter, plankton), with reference to the interference of these materials on the passage of light through the water column. Turbidity is a measure of the optical properties of water that cause light to be scattered and absorbed; the higher the turbidity, the higher the intensity of scattered light.

ubiquitous - present everywhere, omnipresent.

velocity – a measurement of speed of flow

water hardness - the presence of dissolved minerals, generally expressed as calcium carbonate.

wave action - erosion of the bank of a waterbody, primarily due to prolonged exposure to wave action

WQ - water quality

WQI - Water Quality Index

zooplankton - floating or weakly swimming animals that live in the water column

APPENDIX 1. HISTORICAL WATER QUALITY DATA: MANITOBA CONSERVATION WATER QUALITY MONITORING DATA, LOWER BURNTWOOD RIVER NEAR THOMPSON (WQ0093.00) AND FEDERAL ECOLOGICAL MONITORING PROGRAM (FEMP), 1986-1989.

The following is provided on the enclosed CD:

Table A1-1	Figure A1-11
Table A1-2	Figure A1-12
Table A1-3	Figure A1-13
Table A1-4	Figure A1-14
Table A1-5	Figure A1-15
Figure A1-1	Figure A1-16
Figure A1-2	Figure A1-17
Figure A1-3	Figure A1-18
Figure A1-4	Figure A1-19
Figure A1-5	Figure A1-20
Figure A1-6	Figure A1-21
Figure A1-7	Figure A1-22
Figure A1-8	Figure A1-23
Figure A1-9	Figure A1-24
Figure A1-10	Figure A1-25

Table A1-1. Summary statistics for routine water chemistry parameters measured at the Manitoba Conservation Water Quality Monitoring Station 0093.00 on the lower Burntwood River at the City of Thompson: open-water (June 1980 – August 2000) and ice-cover (January 1980 – February 2000) seasons. Data were provided in raw format by Manitoba Conservation (2001). Abbreviations are defined in the footnotes[1].

Season		Temperature ºC	pH (*in situ*)	pH (Laboratory)	DO mg/L	Conductivity (*in situ*) µS/cm	Conductivity (Laboratory) µS/cm	TDS mg/L	Hardness as $CaCO_3$ mg/L	Chlorophyll *a* µg/L
Open-water Season										
	Mean±SE	15.3±0.5	7.95±0.05	7.97±0.02	10.9±0.2	116±2	114.2±1.2	93±2	59.3±1.0	2.0±0.7
	Range	(8.0 – 20.6)	(7.30 – 8.70)	(7.41 – 8.20)	(7.0 – 13.7)	(60 – 150)	(96.5 – 141)	(71 – 140)	(51.3 – 80.5)	(< 1.0 – 7.0)
	n	50	40	53	53	49	53	40	40	9
Ice-cover Season										
	Mean±SE	0.0±0.0	7.73±0.04	7.78±0.03	14.8±0.3	119±2	118.5±1.7 [2]	95±3	58.3±0.9	-
	Range	(0.0 – 0.1)	(7.50 – 8.20)	(7.30 – 8.10)	(7.1 – 16.6)	(101 – 145)	(95 – 147)	(67 – 130)	(48.3 – 67.9)	-
	n	37	26	41	33	27	40	30	30	-

Season		Water Transparency					Alkalinity		
		Secchi Disc Depth m	Turbidity (*in situ*)	Turbidity (Laboratory)	TSS mg/L	TC TCU	Total mg/L	As Bicarbonate mg/L	Carbonate mg/L
Open-water Season									
	Mean±SE	0.4±0.0	32.5±1.2	25±1	18±2	30±3	53.5±0.5	65.0±0.7	< DL
	Range	(0.2 – 0.6)	(22.8 – 45.0)	(8 – 51)	(< 5 – 124)	(5 – 70)	(46.0 – 64.0)	(52.2 – 79.0)	(< 0.60 - < 20)
	n	8	29	49	52	40	53	53	25
Ice-cover Season									
	Mean±SE	-	31.5±1.6	26±2	12±1 [4]	31±3	54.8±0.8	66.9±1.0	2.7±0.7
	Range	-	(16.0 – 48.0)	(4 – 55)	(< 5 –30)	(< 30 - > 50)	(46.0 – 67.6)	(56.1 – 82.5)	(0 – 10.0)
	n	-	27	36	39	30	39	39	39

Table A1-1. – continued –

Season	Alkalinity	Carbon (C)					
	Hydroxide mg/L	Total C mg/L	Dissolved C mg/L	DOC mg/L	DIC mg/L	TOC mg/L	TIC mg/L
Open-water Season							
Mean±SE	< DL	20.6±0.5	20.5±0.7	7.2±0.4	12.0±0.4	8.4±0.3	12.1±0.2
Range	(< 0.34 - < 10.20)	(11.0 – 24.0)	(17.0 – 23.7)	(< 5.0 – 11.8)	(4.0 – 14.8)	(< 5.0 – 12.5)	(7.0 – 15.0)
n	25	25	12	27	27	48	45
Ice-cover Season							
Mean±SE	< DL	20.6±0.4	19.5±0.2	7.1±0.4	11.6±0.4	8.6±0.3	12.6±0.3
Range	(< 0.34 - < 10.20)	(18.2 – 26.0)	(18.1 – 21.0)	(< 5.0 – 11.3)	(7.0 – 14.2)	(5.0 – 14.0)	(7.8 – 18.5)
n	20	20	12	23	23	39	36

Season	Nitrogen					
	Total Ammonia mg/L	Dissolved Ammonia mg/L	Soluble Ammonia mg/L	Dissolved Nitrate/nitrite mg/L	TKN mg/L	DKN mg/L
Open-water Season						
Mean±SE	0.018±0.001	0.011±0.002	0.020±0.003	0.011±0.002	0.38±0.02	0.29±0.01
Range	(0.009 – 0.031)	(< 0.002 – 0.020)	(0.006 – 0.051)	(< 0.01 – 0.06)	(< 0.20 – 0.90)	(0.20 – 0.40)
n	15	9	16	36	53	30
Ice-cover Season						
Mean±SE	0.013±0.001	0.008±0.002	0.014±0.001	0.13±0.03	0.34±0.01	0.29±0.01
Range	(< 0.020 – 0.017)	(< 0.002 – 0.011)	(0.006 – 0.026)	(0.07 – 0.82)	(0.21 – 0.60)	(< 0.20 – 0.40)
n	10	3	17	25	42	23

Table A1-1. – continued –

Season		Phosphorus (P)			Sulphate		Chloride
		Total P mg/L	Dissolved P mg/L	Particulate P mg/L	Soluble mg/L	Dissolved mg/L	Soluble mg/L
Open-water Season							
	Mean±SE	0.039±0.001	0.010±0.001	0.027±0.001	7.22±1.09	3.4±0.9	2.5±0.3
	Range	(0.016 – 0.060)	(0.002 – 0.020)	(0.008 – 0.050)	(2.25 – 23.0)	(1.7 – 10.0)	(1.1 – 7.0)
	n	53	39	39	31	9	31
Ice-cover Season							
	Mean±SE	0.050±0.005	0.015±0.001	0.022±0.002	10.21±1.45	6.8±2.4	2.94±0.46
	Range	(0.022 – 0.195)	(0.002 – 0.029)	(0.003 – 0.048)	(1.38 – 23.00)	(2.6 – 11.0)	(1.00 – 12.00)
	n	42	28	28	27	3	27

[1] Abbreviations are as follows: DO = dissolved oxygen; TDS = total dissolved solids; TSS = total suspended solids; TC = true colour; DOC = dissolved organic carbon; DIC = dissolved inorganic carbon; TOC = total organic carbon; TIC = total inorganic carbon; TKN = total kjeldahl nitrogen; and, DKN = dissolved kjeldahl nitrogen.

[2] One outlier removed (1235 µS/cm).

[3] Three outliers removed (385, 160, and 83 mg/L).

[4] Where values were reported as less than the analytical detection limits, values of one-half the corresponding detection limit were assigned for the purposes of calculating statistics. Values reported as 'greater than' (e.g., > 50) a given value were assigned that value (e.g., 50) for the purposes of calculating statistics.

[5] Where the mean for a parameter was below all analytical detection limits, but more than one detection limit is reported, the mean is indicated in the above table as < DL (detection limit).

[6] Three outlying values were omitted from the statistical summary: 385 mg/L, 11 February, 1980; 160 mg/L, 13 March, 1980; and, 83 mg/L, 20 January, 1981.

Table A1-2. Summary statistics for inorganic elements (metals and metalloids) measured at the Manitoba Conservation Water Quality Monitoring Station 0093.00 on the lower Burntwood River at the City of Thompson: open-water and ice-cover seasons 1980 – 2001. Data were provided in raw format by Manitoba Conservation (2001). Note that most measurements were taken between 1998 – 2001.

	Aluminum		Antimony		Arsenic		Barium	
Season	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L
Open-water Season								
Mean±SE [1]	0.08±0.01	2.85±0.17	-	< 0.001	< 0.001	0.0005±0.00003	-	0.0338±0.015
Range	(0.05 – 0.11)	(2.39 – 3.12)	-	(< 0.001 – 0.001)	-	(<0.00005 – 0.001)	-	(0.0309 – 0.0357)
n	7	4	-	3	1	27	-	3
Ice-cover Season								
Mean±SE [1]	0.05±0.02	1.85±0.18	-	< 0.001	0.001±0.0003	< 0.001	-	0.0275
Range	(0.03 – 0.08)	(1.50 – 2.06)	-	-	(< 0.001 – 0.001)	(< 0.001 – 0.0008)	-	-
n	3	3	-	1	2	20	-	1

	Beryllium		Boron		Cadmium		Calcium	
Season	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L
Open-water Season								
Mean±SE [1]	-	< 0.001	< 0.05	0.02±0.003	< 0.0005	< 0.0005	14.5	15.8±0.6
Range	-	-	-	(< 0.01 – 0.03)	-	(< 0.0002 - < 0.0005)	-	(13.8 – 17.5)
n	-	3	1	7	1	7	1	7
Ice-cover Season								
Mean±SE [1]	-	<0.001	<0.05	0.02±0.002	< 0.0005	< DL	14.5±0.6	14.8±0.7
Range	-	-	-	(< 0.05 – 0.02)	-	(< 0.0001 - < 0.0005)	(13.9 – 15.1)	(13.5 – 15.8)
n	-	1	2	3	2	3	2	3

Table A1-2. - continued -

Season	Chromium		Cobalt		Copper		Iron	
	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L
Open-water Season								
Mean±SE [1]	-	0.005±0	-	0.0009±0.0001	< 0.005	0.006±0.002	0.04	1.69±0.13
Range	-	-	-	(0.0008 – 0.0010)	-	(0.003 – 0.017)	-	(1.30 – 2.25)
n	-	3		3	1	7	1	7
Ice-cover Season								
Mean±SE [1]	-	0.004	-	0.0006	0.014±0.012	0.004±0.001	0.25±0.21	1.16±0.18
Range	-	-	-	-	(< 0.005 – 0.026)	(< 0.005 – 0.005)	(0.04 – 0.45)	(0.83 – 1.43)
n	-	1	-	1	2	3	2	3

Season	Lead		Manganese		Magnesium		Mercury	
	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L
Open-water Season								
Mean±SE [1]	< 0.001	0.0015±0.0004	< 0.005	0.0331±0.0024	4.27	5.10±0.22	-	-
Range	-	(< 0.0005 – 0.0039)	-	(0.0260 – 0.0408)	-	(4.09 – 5.73)	-	-
n	1	7	1	7	1	7	-	-
Ice-cover Season								
Mean±SE [1]	< 0.001	0.0010±0.00003	0.012±0.005	0.0241±0.0038	4.63±0.06	4.95±0.19	-	-
Range	-	(0.0009 – 0.0010)	(0.007 – 0.016)	(0.0170 – 0.0300)	(4.57 – 4.69)	(4.62 – 5.28)	-	-
n	2	3	2	3	2	3	-	-

Table A1-2. - continued -

Season	Molybdenum		Nickel		Potassium		Selenium	
	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L
Open-water Season	-	0.0002±0.00003	< 0.002	0.004±0.0003	1.2	1.89±0.12	-	< 0.002
Mean±SE [1]	-	(0.0002 – 0.0003)	-	(0.003 – 0.005)	-	(1.42 – 2.42)	-	-
Range	-	3	1	7	1	7	-	3
n								
Ice-cover Season								
Mean±SE [1]	-	0.0002	< 0.002	0.003±0.0003	1.3±0.0	1.70 – 0.10	-	0.002
Range	-	-	-	(0.003 – 0.004)	-	(1.50 – 1.81)	-	-
n	-	1	2	3	2	3	-	1

Season	Silver		Sodium		Strontium		Thallium	
	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L
Open-water Season								
Mean±SE [1]	-	< 0.0004	3.1	3.13±0.15	-	0.0405±0.0026	-	< 0.0001
Range	-	-	-	(2.50 – 3.57)	-	(0.0363 – 0.0453)	-	-
n	-	3	1	7	-	3	-	3
Ice-cover Season								
Mean±SE [1]	-	< 0.0004	3.6±0.2	3.41±0.40	-	0.039	-	< 0.0001
Range	-	-	(3.4 – 3.8)	(2.92 – 4.20)	-	-	-	-
n	-	1	2	3	-	1	-	1

Table A1-2. - continued -

Season	Tin		Uranium		Vanadium		Zinc	
	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L	Total mg/L
Open-water Season								
Mean±SE [1]	-	< 0.0005	-	0.0002±0.0000	-	0.005±0.0003	< 0.01	0.01±0.00
Range	-	(<0.0005 – 0.0006)	-	-	-	(0.004 – 0.005)	-	(< 0.02 – 0.01)
n	-	3	-	3	-	3	1	7
Ice-cover Season								
Mean±SE [1]	-	0.0005	-	0.0002	-	0.003	< 0.01	0.01±0.004
Range	-	-	-	-	-	-	-	(< 0.01 – 0.02)
n	-	1	-	1	-	1	2	3

[1] Where values were reported as less than the analytical detection limits, values of one-half the corresponding detection limit were assigned for the purposes of calculating statistics. Values reported as 'greater than' (e.g., > 50) a given value were assigned that value (e.g., 50) for the purposes of calculating statistics.

Table A1-3. Summary of the frequency that water quality measurements obtained at MB Conservation water quality monitoring station WQ0093.00 on the lower Burntwood River at Thompson, 1980 – 2000, exceeded MWQSOGs. Frequency of exceedences are expressed as a percentage of total measurements (sample size [n] in parantheses). Inorganic elements (metals and metalloids) are compared to MWQSOGs for the total form of the element, for all forms of the element measured.

Measured Parameter		Exceedences: % of measurements (n)				
		MWQSOGs: Aquatic Life		Drinking Water Quality Guideline		
		Chronic Objective or Guideline	Acute Objective	Maximum Acceptable	Interim Maximum Acceptable	Aesthetic
Open-Water Season						
DO		0% (55)	0% (55)	-	-	-
pH	*In situ*	0% (42)	-	-	-	2.4% (42)
	Laboratory	0% (55)	-	-	-	0% (55)
Magnesium	Extractable	-	-	-	-	2.9% (35) [1]
TSS		14.8% (54) [1,2]	-	-	-	-
True Colour		-	-	-	-	90.5% (42) [3]
Ammonia	Total	0% (15)	0% (15)	-	-	-
	Dissolved	0% (9)	0% (9)	-	-	-
	Soluble	0% (18)	0% (18)	-	-	-
Phosphorus	Total	55% (41) [4]	-	-	-	-
Nitrate/nitrite	Dissolved	-	-	0% (36)	-	-
	Soluble	-	-	0% (18)	-	-
Aluminum	Extractable	100% (4)	-	-	-	-
	Dissolved	100% (7)	-	-	-	-
	Total	100% (4)	-	-	-	-
Antimony	Total	-	-	0% (3)	-	-
Arsenic	Extractable	0% (26)	0% (26)	-	0% (26)	-
	Dissolved	0% (1)	0% (1)	-	0% (1)	-
	Total	0% (29)	0% (29)	-	0% (29)	-
Barium	Total	-	-	0% (3)		-

Table A1-3. - continued -

Measured Parameter		Exceedences: % of measurements (n)				
		MWQSOGs: Aquatic Life		Drinking Water Quality Guideline		
		Chronic Objective or Guideline	Acute Objective	Maximum Acceptable	Interim Maximum Acceptable	Aesthetic
Boron	Extractable	-	-	-	0% (7)	-
	Dissolved	-	-	-	0% (1)	-
	Total	-	-	-	0% (7)	-
	Soluble	-	-	-	0% (20)	-
Cadmium	Extractable	4.1% (49)	0% (49)	2.0% (49)	-	-
	Dissolved	0% (1)	0% (1)	0% (1)	-	-
	Total	0% (7)	0% (7)	0% (7)	-	-
Chromium	Total	0% (3)	0% (3)	0% (3)	-	-
Copper	Extractable	20.4% (49) [5]	0% (49)	-	-	0% (49)
	Dissolved	0% (1)	0% (1)	-	-	0% (1)
	Total	42.9% (7)	0% (7)	-	-	0% (7)
Iron	Extractable	100 % (36)	-	-	-	100 % (36)
	Dissolved	0% (1)	-	-	-	0% (1)
	Total	100% (7)	-	-	-	100% (7)
Lead	Extractable	6.1% (49) [6]	0% (49)	2.0% (49)	-	-
	Dissolved	0% (1)	0% (1)	0% (1)	-	-
	Total	14.3% (7)	0% (7)	0% (7)	-	-
Mercury	Extractable	0% (13) [7]	-	0% (13) [7]	-	-
Molybdenum	Total	0% (3)	-	-	-	-
Nickel	Extractable	2.0% (49)	-	-	-	-
	Dissolved	0% (1)	-	-	-	-
	Total	0% (7)	-	-	-	-
Selenium	Total	0% (3) [8]	-	0% (3)	-	-
Silver	Total	0% (3) [8]	-	-	-	-
Thallium	Total	0% (3)	-	-	-	-

Table A1-3. - continued -

Measured Parameter		Exceedences: % of measurements (n)				
		MWQSOGs: Aquatic Life		Drinking Water Quality Guideline		
		Chronic Objective or Guideline	Acute Objective	Maximum Acceptable	Interim Maximum Acceptable	Aesthetic
Uranium	Total	-	-	-	0% (3)	
Zinc	Extractable	0% (46)	-	-	-	0% (46)
	Dissolved	0% (1)	-	-	-	0% (1)
	Total	0% (7)	-	-	-	0% (7)
Chloride	Soluble	-	-	0% (33)	-	-
	Dissolved	-	-	0% (9)	-	-
Sulphate	Soluble	-	-	0% (33)	-	-
	Dissolved	-	-	0% (9)	-	-
Ice-Cover Season						
DO		0% (33)	0% (33)	-	-	-
pH	*In situ*	0% (26)	-	-	-	0% (26)
	Laboratory	0% (41)	-	-	-	0% (41)
Magnesium	Extractable	-	-	-	-	3.4% (29)
TSS		10.3% (39) [9]	-	-	-	-
True Colour		-	-	-	-	100% (30) [10]
Ammonia	Total	0% (9)	0% (9)	-	-	-
	Dissolved	0% (3)	0% (3)	-	-	-
	Soluble	0% (17)	0% (17)	-	-	-
Phosphorus	Total	23.3% (43) [4]	-	-	-	-
Nitrate/nitrite	Dissolved	-	-	0% (25)	-	-
	Soluble	-	-	0% (17)	-	-
Aluminum	Extractable	100% (4)	-	-	-	-
	Dissolved	100% (3)	-	-	-	-
	Total	100% (3)	-	-	-	-

Table A1-3. - continued -

Measured Parameter		Exceedences: % of measurements (n)				
		MWQSOGs: Aquatic Life		Drinking Water Quality Guideline		
		Chronic Objective or Guideline	Acute Objective	Maximum Acceptable	Interim Maximum Acceptable	Aesthetic
Antimony	Total	-	-	0% (1)	-	-
Arsenic	Extractable	0% (22)	0% (22)	-	4.5% (22)	-
	Dissolved	0% (2)	0% (2)	-	0% (2)	-
	Total	0% (20)	0% (20)	-	0% (20)	-
Barium	Total	-	-	0% (1)		-
Boron	Extractable	-	-	-	0% (7)	-
	Dissolved	-	-	-	0% (2)	-
	Total	-	-	-	0% (3)	-
	Soluble	-	-	-	0% (16)	-
Cadmium	Extractable	7.3% (41) [11]	0% (41)	2.4% (41)	-	-
	Dissolved	0% (2)	0% (2)	0% (2)	-	-
	Total	0% (3)	0% (3)	0% (3)	-	-
Chromium	Total	0% (1)	0% (1)	0% (1)	-	-
Copper	Extractable	34.1% (41) [12]	0% (41)	-	-	0% (41)
	Dissolved	0% (2)	0% (2)	-	-	0% (2)
	Total	0% (3)	0% (3)	-	-	0% (3)
Iron	Extractable	100 % (29)	-	-	-	100 % (29)
	Dissolved	50% (2)	-	-	-	50% (2)
	Total	100% (3)	-	-	-	100% (3)
Lead	Extractable	6.1% (49) [13]	0% (49)	2.0% (49)	-	-
	Dissolved	0% (2)	0% (2)	0% (2)	-	-
	Total	0% (3)	0% (3)	0% (3)	-	-
Mercury	Extractable	0% (13) [14]	-	0% (13) [14]	-	-
Molybdenum	Total	0% (1)	-	-	-	-
Nickel	Extractable	0% (41)	-	-	-	-

Table A1-3. - continued -

Measured Parameter		Exceedences: % of measurements (n)				
		MWQSOGs: Aquatic Life		Drinking Water Quality Guideline		
		Chronic Objective or Guideline	Acute Objective	Maximum Acceptable	Interim Maximum Acceptable	Aesthetic
	Dissolved	0% (2)	-	-	-	-
	Total	0% (3)	-	-	-	-
Selenium	Total	100% (1)	-	0% (1)	-	-
Silver	Total	0% (1) [15]	-	-	-	-
Thallium	Total	0% (1)	-	-	-	-
Uranium	Total	-	-	-	0% (1)	-
Zinc	Extractable	0% (41)	-	-	-	0% (41)
	Dissolved	0% (2)	-	-	-	0% (2)
	Total	0% (3)	-	-	-	0% (3)
Chloride	Soluble	-	-	0% (27)	-	-
	Dissolved	-	-	0% (3)	-	-
Sulphate	Soluble	-	-	0% (27)	-	-
	Dissolved	-	-	0% (3)	-	-

[1] One outlying measurement was omitted from the data set.
[2] Compliance was assessed against the previous water quality objective of 25 mg/L (Williamson 1988).
[3] Values reported as one-half the detection limit (DL) were assigned a value equal to one-half of the DL; these values exceeded the MWQSOG for true colour.
[4] Narrative Guideline is provided to prevent nuisance plant growth; guideline for streams is applied here (0.05 mg/L).
[5] 23 measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[6] 40 measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[7] 13 (all) measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[8] 3 (all) measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[9] 3 outlying values were excluded.
[10] 6 measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[11] 34 measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[12] 18 measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[13] 29 measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[14] 23 (all) measurements could not be assessed for compliance because analytical detection limits were higher than the corresponding objectives.
[15] The single measurement could not be assessed for compliance because the analytical detection limit was higher than the corresponding objectives.

Table A1-4. Historical water quality data for the lower Burntwood River collected during the Federal Ecological Monitoring Program (FEMP), reported in Ramsey (1991). Data were collected from the Burntwood River at Thompson from January 1987 to October 1989 and the Burntwood River at Split Lake from September 1986 to October 1989. Abbreviations are defined in the footnotes [1].

Season	pH (*in situ*)	pH (Laboratory) µS/cm	Conductivity (*in situ*) µS/cm	Conductivity (Laboratory) mg/L	TDS mg/L	Hardness as $CaCO_3$ µg/L	Chlorophyll *a* µg/L	Water Clarity: Turbidity (*in situ*) NTU	Water Clarity: Turbidity (Laboratory) NTU
Burntwood River at Thompson									
Mean±SD	7.6±0.3	7.68±0.24	111±10	116±6	60±4	52.8±3.2	2±1	31±9	27±6
Range	(7.1 – 8.2)	(6.80 – 7.96)	(90 - 142)	(104 - 133)	(54 - 68)	(47.6 – 62.7)	(< 1 - 5)	(18 – 65)	(15 – 37)
Burntwood River at Split Lake									
Mean±SD	7.6±0.2	7.76±0.19	120±12	123±6	65±3	56.6±3.1	2±1	34±11	35±10
Range	(7.2 – 8.2)	(7.33 – 8.17)	(86 - 138)	(107 - 138)	(58 - 71)	(48.1 – 62.9)	(< 1 - 5)	(17 - 70)	(20 – 71)

Season	Water Clarity: TSS [2] mg/L	Water Clarity: TC Relative	Alkalinity: Total mg/L	Alkalinity: As Bicarbonate mg/L	Carbon: DOC mg/L	Carbon: TOC mg/L	Carbon: DIC mg/L	Fluoride Dissolved mg/L	Chloride Dissolved mg/L
Burntwood River at Thompson									
Mean±SD	17±5	21±5	53.1±3.1	64.7±3.8	6.49±0.55	6.95±0.64	12.4±1.2	0.09±0.01	1.2±0.2
Range	(7 - 32)	(10 - 30)	(46.4 – 59.9)	(56.6 – 73.0)	(5.58 – 7.60)	(6.02 – 8.54)	(6.7 – 14.4)	(0.07 – 0.14)	(0.8 – 1.8)
Burntwood River at Split Lake									
Mean±SD	24±16	22±6	56.9±3.2	69.4±3.9	6.78±0.76	7.40±0.89	13.4±0.7	0.09±0.02	1.2±0.2
Range	(10 - 107)	(10 - 40)	(49.1 – 64.7)	(59.9 – 78.9)	(5.70 – 9.10)	(6.11 – 9.72)	(11.8 – 14.9)	(0.08 – 0.15)	(0.9 – 1.5)

Table A1-4. - continued -

Season		Sulphate	Nitrogen				Phosphorus		
		Dissolved	Total Ammonia	Nitrate/Nitrite	TN	TDN	Total	Dissolved	Orthophosphate
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
Burntwood River at Thompson									
	Mean±SD	2.6±0.7	0.015±0.011	0.022±0.038	0.30±0.04	0.249±0.047	0.036±0.007	0.012±0.005	0.003±0.005
	Range	(1.7 – 5.1)	(< 0.005 – 0.050)	(< 0.010 – 0.210)	(0.23 – 0.48)	(0.190 – 0.436)	(0.025 – 0.056)	(0.003 – 0.026)	(< 0.003 – 0.027)
Burntwood River at Split Lake									
	Mean±SD	2.9±0.9	0.014±0.007	0.019±0.025	0.31±0.04	0.248±0.039	0.039±0.013	0.012±0.006	0.003±0.003
	Range	(1.5 – 7.1)	(< 0.005 – 0.030)	(< 0.010 – 0.077)	(0.24 – 0.40)	(0.200 – 0.370)	(0.021 – 0.102)	(< 0.003 – 0.029)	(< 0.003 – 0.017)

[1] Abbreviations are as follows: TDS = total dissolved solids; TSS = total suspended solids; TC = true colour; DOC = dissolved organic carbon; DIC = dissolved inorganic carbon; TOC = total organic carbon; TN = total nitrogen; and, TDN = total dissolved nitrogen.
[2] As non-filterable residue.

Table A1-5. Historical water quality data for inorganic elements measured in the lower Burntwood River during the Federal Ecological Monitoring Program (FEMP), January 1987 – October 1989, reported in Ramsey (1991).

Season		Aluminum		Arsenic	Barium	Cadmium	
		Extractable mg/L	Dissolved mg/L	Dissolved mg/L	Total mg/L	Total mg/L	Dissolved mg/L
Burntwood River at Thompson							
	Mean±SD	0.491±0.154	< 0.100+0.043	0.0002±0.0001	< 0.08	< 0.0001±0.0001	0.0001±0.0001
	Range	(0.230 – 0.826)	(< 0.100 – 0.179)	(< 0.0001 – 0.0003)	(< 0.08 - < 0.08)	(< 0.0001 – 0.0002)	(< 0.0001 – 0.0003)
Burntwood River at Split Lake							
	Mean±SD	0.592±0.315	< 0.100±0.058	0.0002±0.0001	< 0.08±0.01	< 0.0001±0.0001	< 0.0001±0.0001
	Range	(0.235 – 2.140)	(< 0.100 – 0.255)	(< 0.0001 – 0.0003)	(< 0.08 – 0.11)	(< 0.0001 – 0.0003)	(< 0.0001 – 0.0003)

Season		Calcium	Cobalt	Copper		Iron	
		Dissolved mg/L	Total mg/L	Total mg/L	Dissolved mg/L	Extractable mg/L	Dissolved mg/L
Burntwood River at Thompson							
	Mean±SD	14.6±1.0	< 0.0005+0.0002	0.0040±0.0051	0.0014±0.0006	0.624±0.189	0.076±0.041
	Range	(12.9 – 17.7)	(< 0.0005 – 0.0011)	(0.0009 – 0.0240)	(0.0008 – 0.0034)	(0.256 – 0.931)	(0.014 – 0.156)
Burntwood River at Split Lake							
	Mean±SD	15.9±0.9	0.0005±0.0004	0.0048±0.0062	0.0014±0.0006	0.774±0.416	0.090±0.053
	Range	(13.0 – 17.6)	(< 0.0005 – 0.0021)	(0.0010 – 0.0278)	(0.0010 – 0.0032)	(0.299 – 2.860)	(< 0.007 – 0.208)

Table A1-5. - continued –

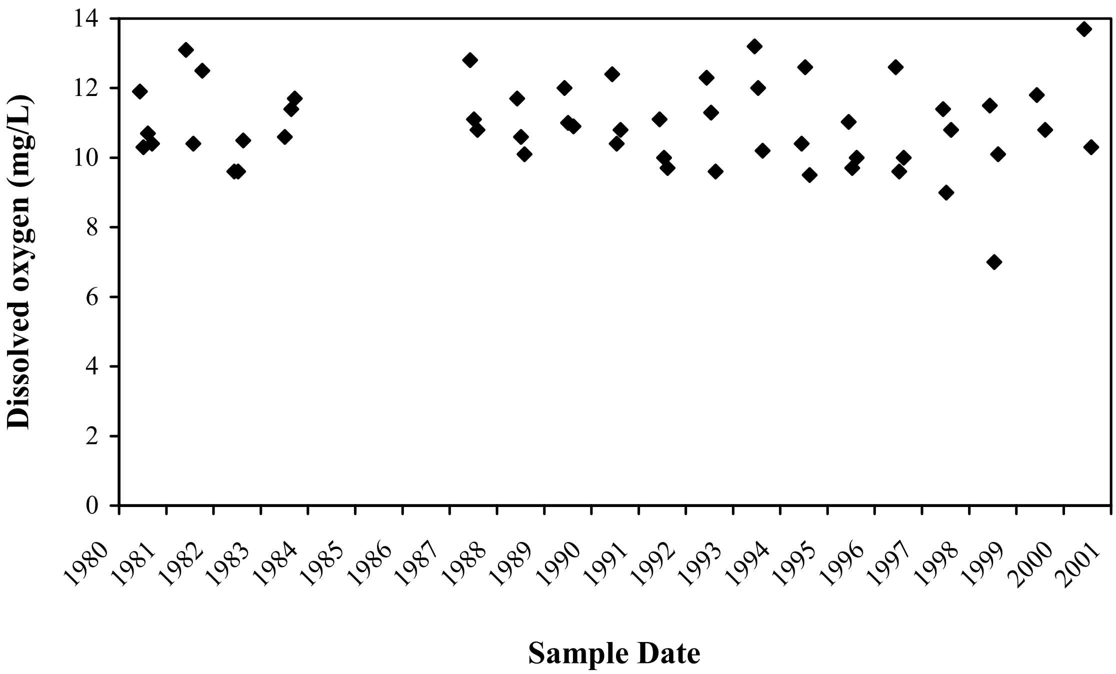
Season	Lead		Magnesium	Manganese		Nickel	
	Total mg/L	Dissolved mg/L	Dissolved mg/L	Extractable mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L
Burntwood River at Thompson							
Mean±SD	0.0009±0.0006	0.0012+0.0016	4.0±0.2	0.021±0.005	0.004±0.003	0.0018±0.0014	0.0007±0.0004
Range	(< 0.0007 – 0.0027)	(< 0.0007 – 0.0057)	(3.6 – 4.6)	(0.005 – 0.030)	(< 0.002 – 0.012)	(0.0007 – 0.0089)	(< 0.0005 – 0.0015)
Burntwood River at Split Lake							
Mean±SD	0.0010±0.0007	0.0007±0.0008	4.1±0.2	0.030±0.027	0.004±0.002	0.0023±0.0011	0.0011±0.0005
Range	(< 0.0007 – 0.0034)	(< 0.0007 – 0.0035)	(3.6 – 4.6)	(0.004 – 0.177)	(< 0.002 – 0.011)	(0.0010 – 0.0077)	(< 0.0005 – 0.0021)

Season	Potassium	Selenium	Silica	Sodium	Vanadium	
	Dissolved mg/L	Dissolved mg/L	Reactive mg/L	Dissolved mg/L	Total mg/L	Dissolved mg/L
Burntwood River at Thompson						
Mean±SD	1.05±0.07	0.0001±0.0001	2.01+0.71	2.7±0.3	0.0013±0.0005	< 0.0005±0.0002
Range	(0.95 – 1.28)	(< 0.0001 – 0.0003)	(0.78 – 3.32)	(2.2 – 3.4)	(< 0.0005 - 0.0025)	(< 0.0005 – 0.0007)
Burntwood River at Split Lake						
Mean±SD	1.05±0.06	0.0001±0.0001	1.96±0.68	2.8±0.3	0.0016±0.0008	< 0.0005±0.0002
Range	(0.96 – 1.21)	(< 0.0001 – 0.0004)	(0.89 – 3.39)	(2.4 – 3.5)	(< 0.0005 – 0.0047)	(< 0.0005 – 0.0009)

Table A1-5. - continued –

Season	Zinc	
	Total mg/L	Dissolved mg/L
Burntwood River at Thompson		
Mean±SD	0.0035±0.0030	0.0012±0.0013
Range	(0.0012 – 0.0172)	(< 0.0003 – 0.0051)
Burntwood River at Split Lake		
Mean±SD	0.0045±0.0033	0.0009±0.0007
Range	(0.0011 – 0.0181)	(< 0.0003 – 0.0021)

(A)



(B)

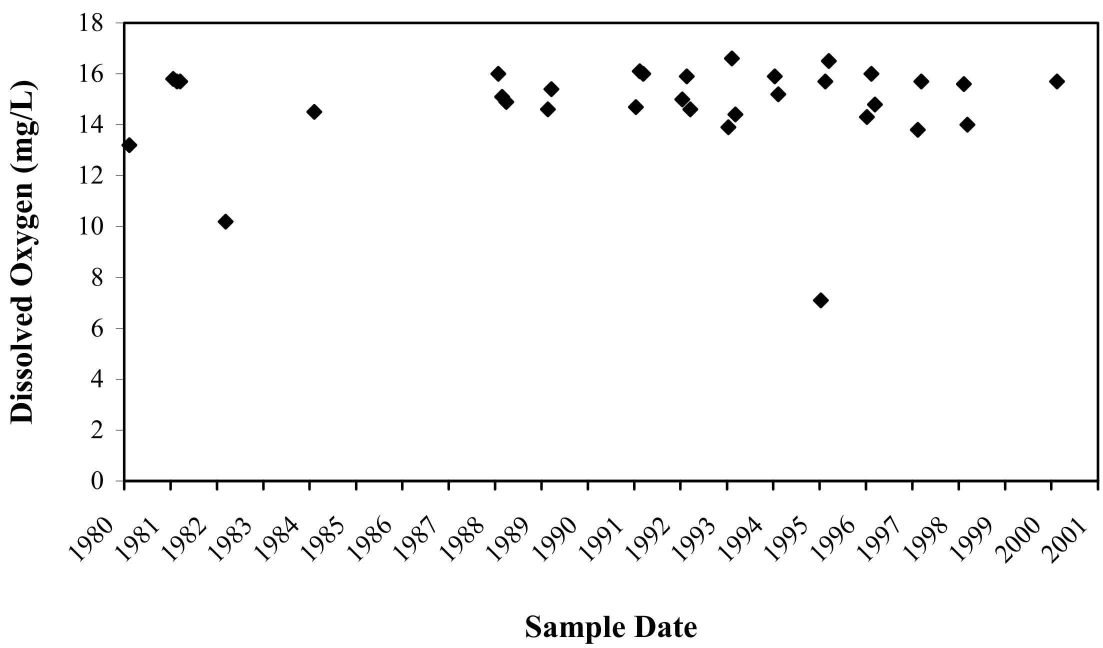
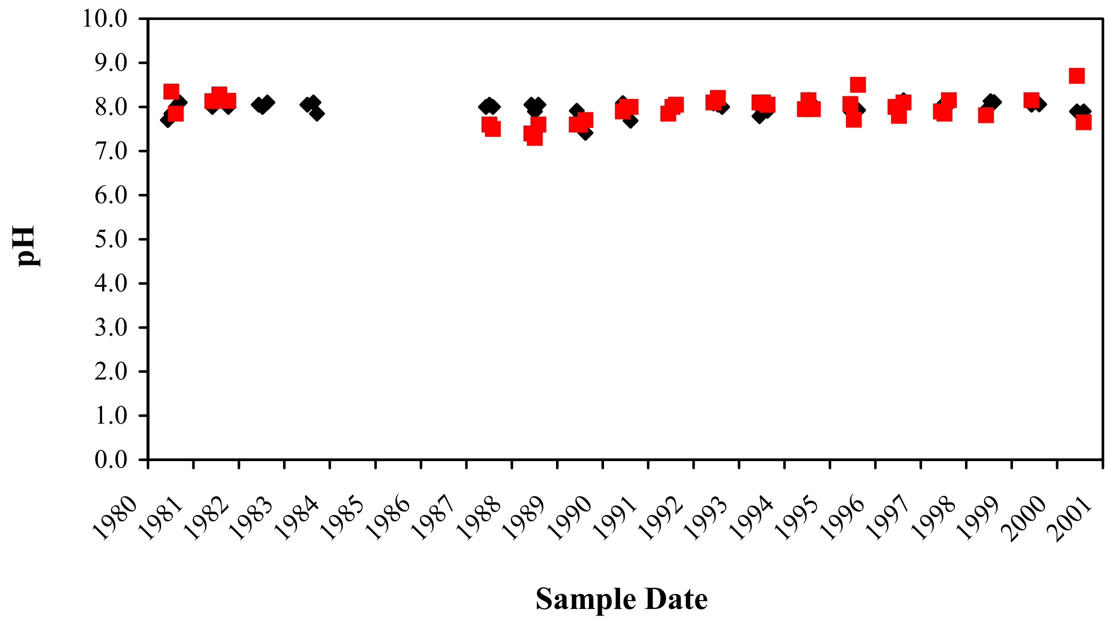


Figure A1-1. Dissolved oxygen (*in situ*) in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

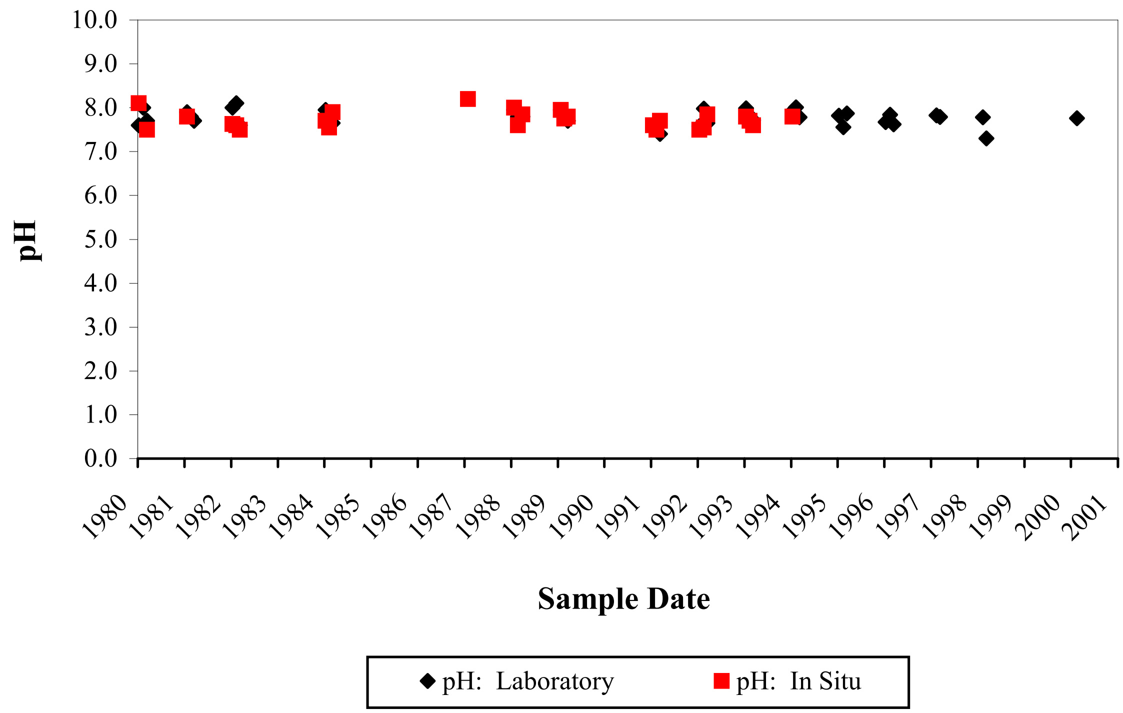
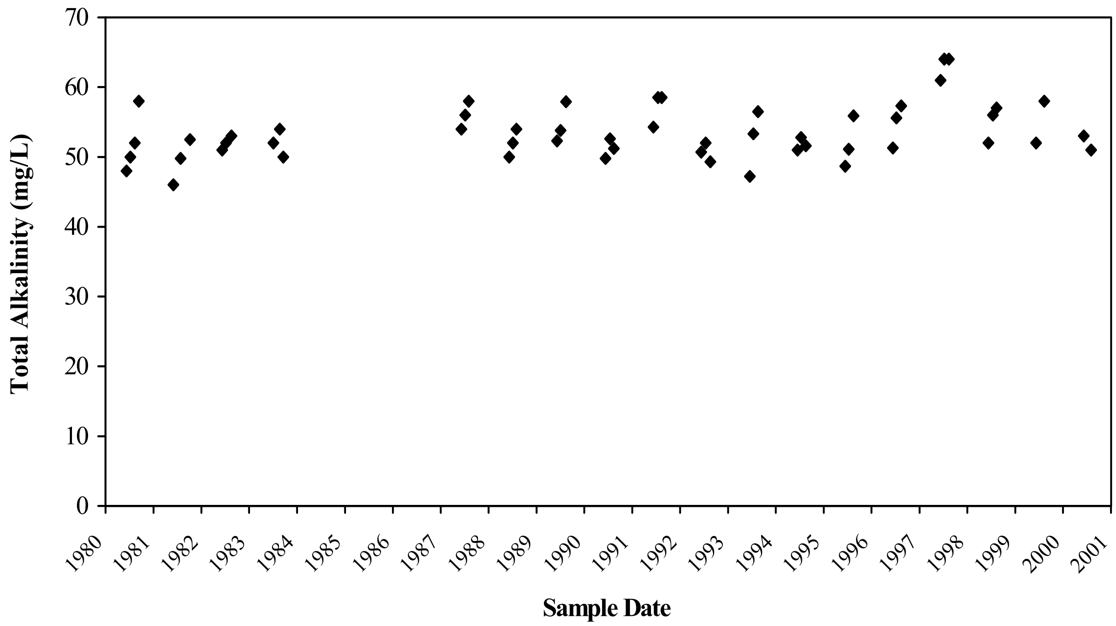


Figure A1-2. pH in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

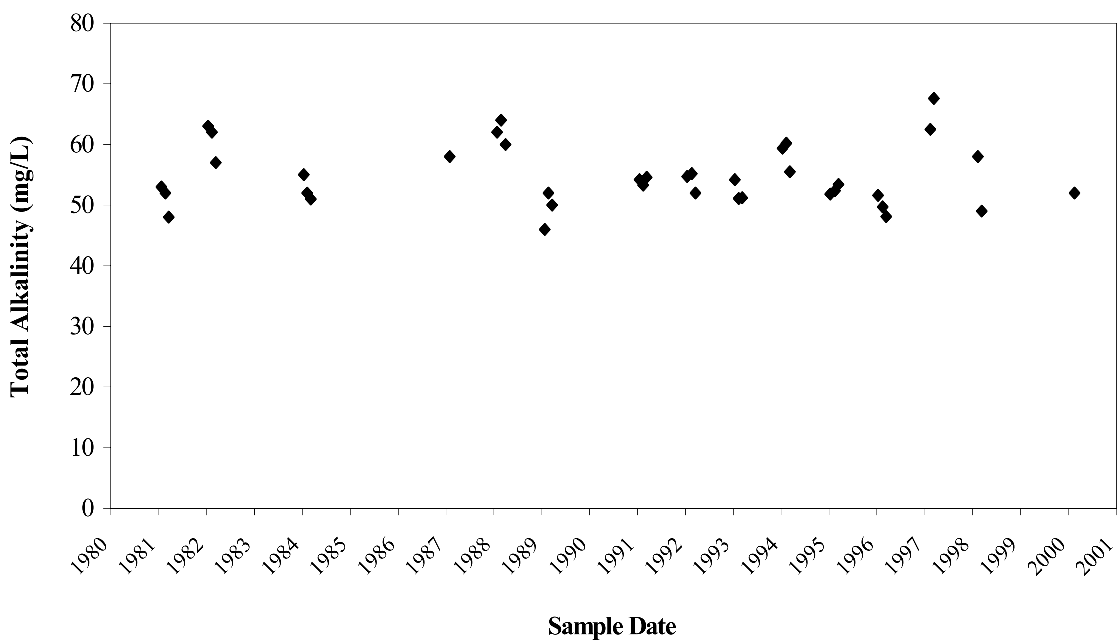


Figure A1-3. Total alkalinity, expressed as calcium carbonate, in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

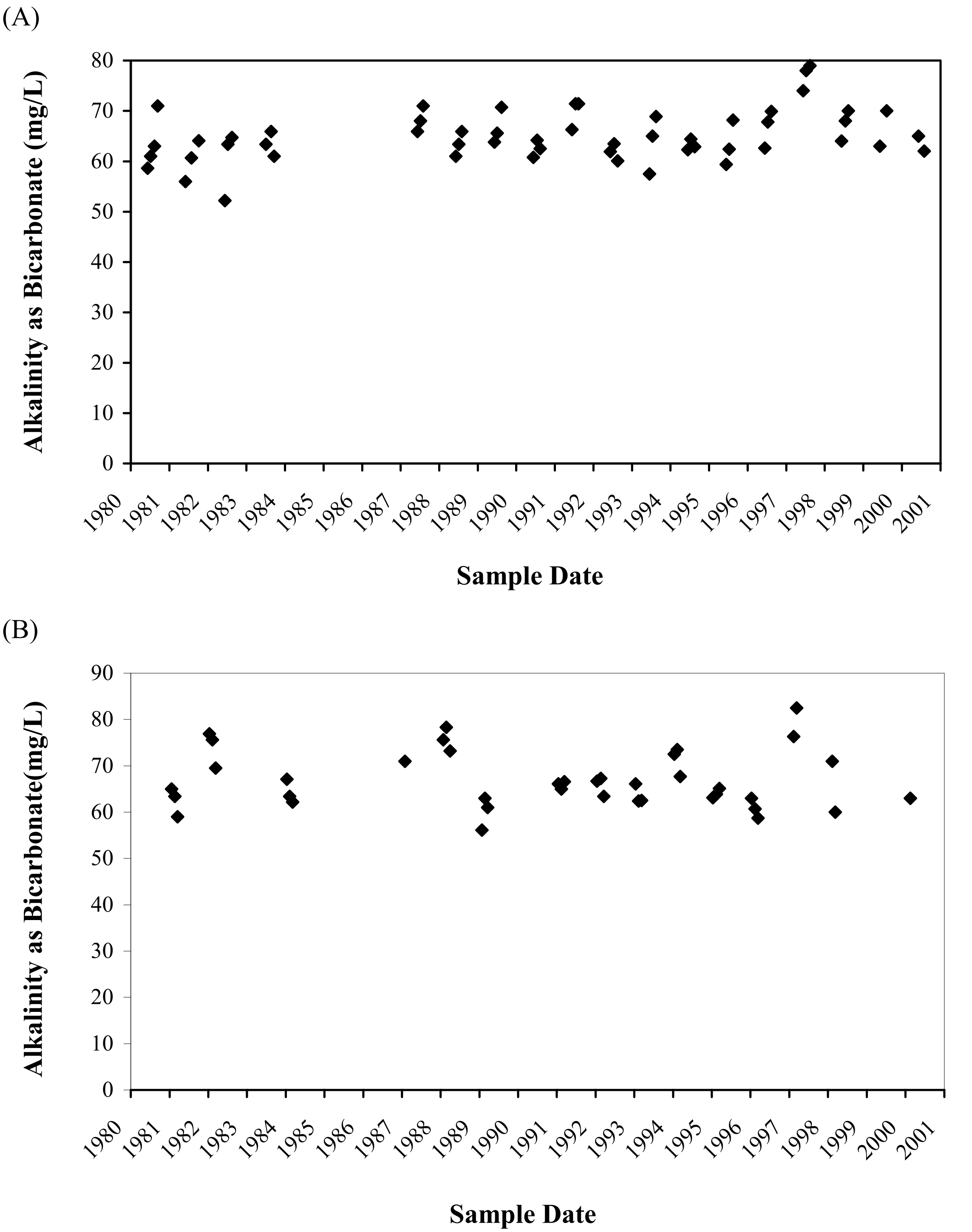
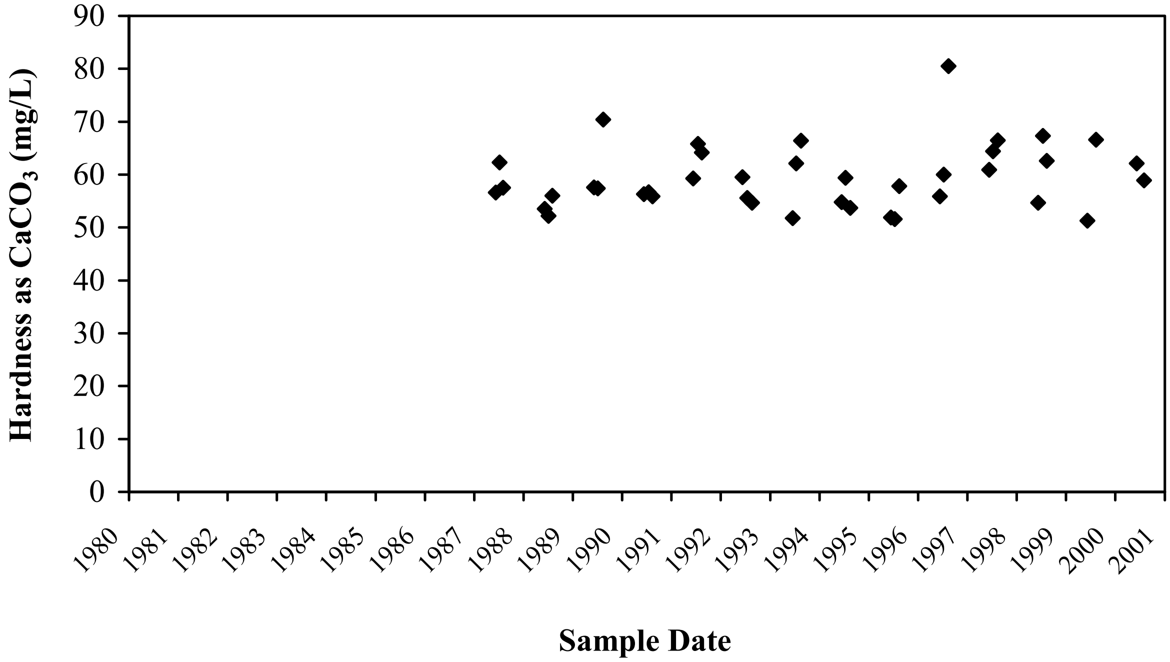


Figure A1-4. Alkalinity as bicarbonate in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

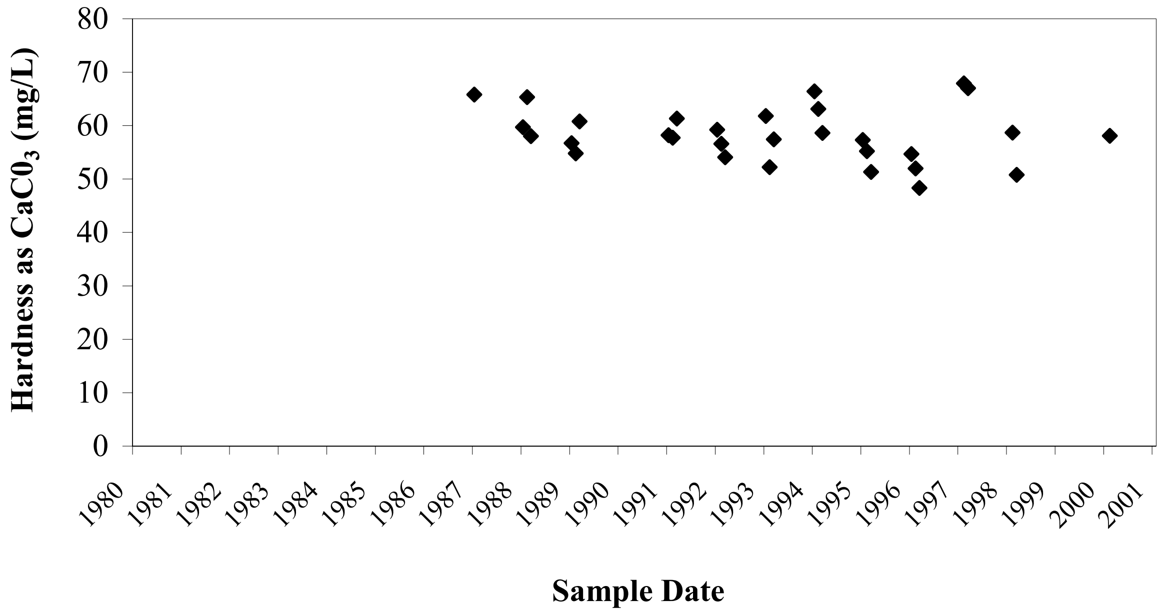
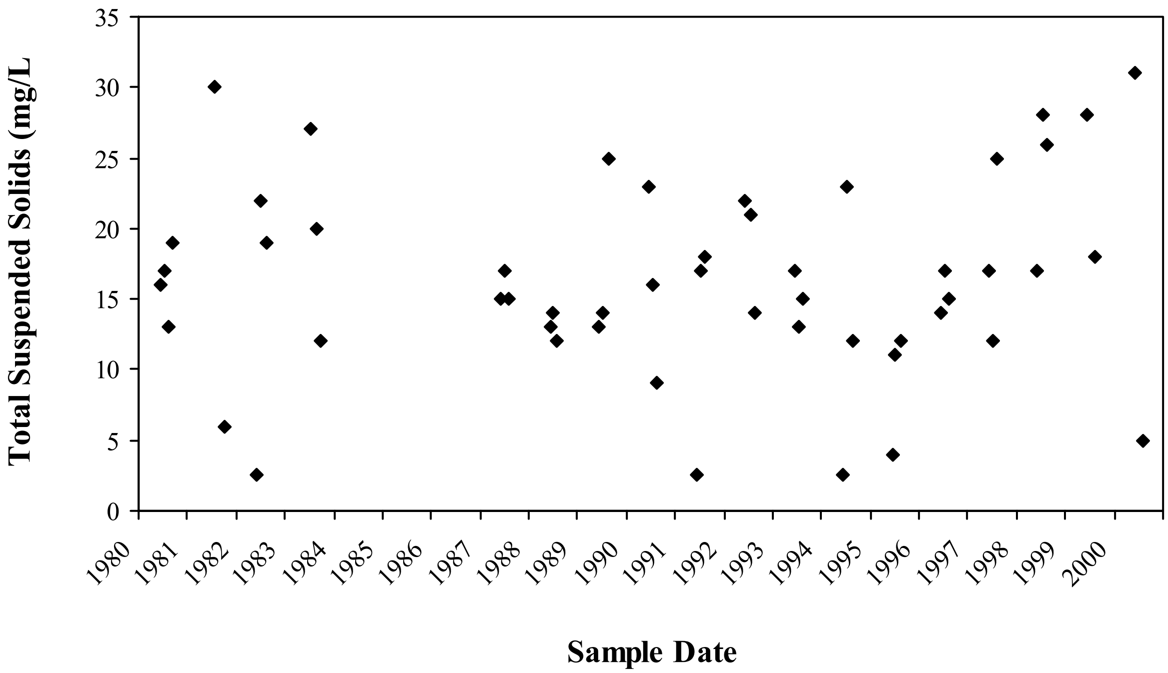


Figure A1-5. Water hardness as calcium carbonate in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

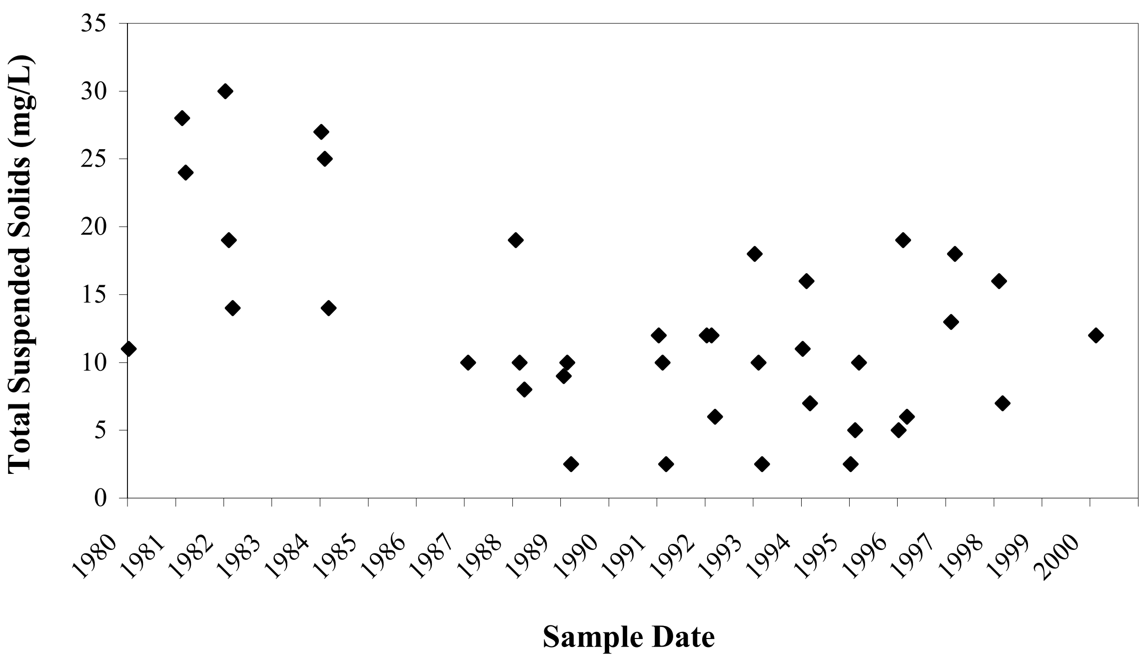
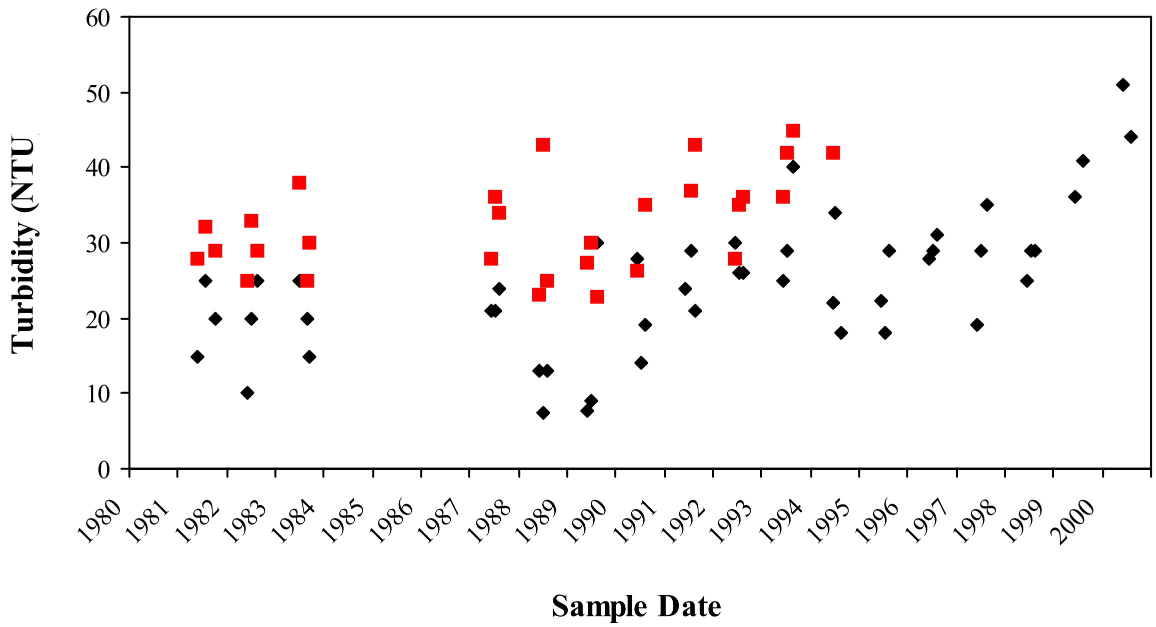


Figure A1-6. Total suspended solids in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

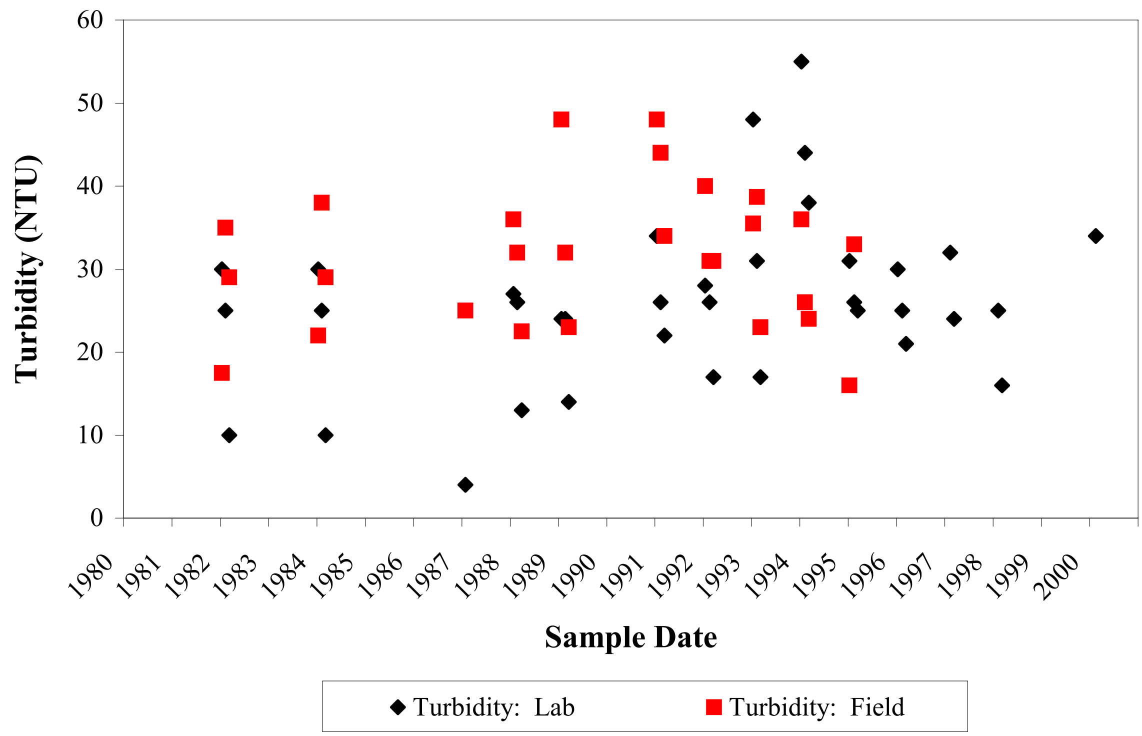
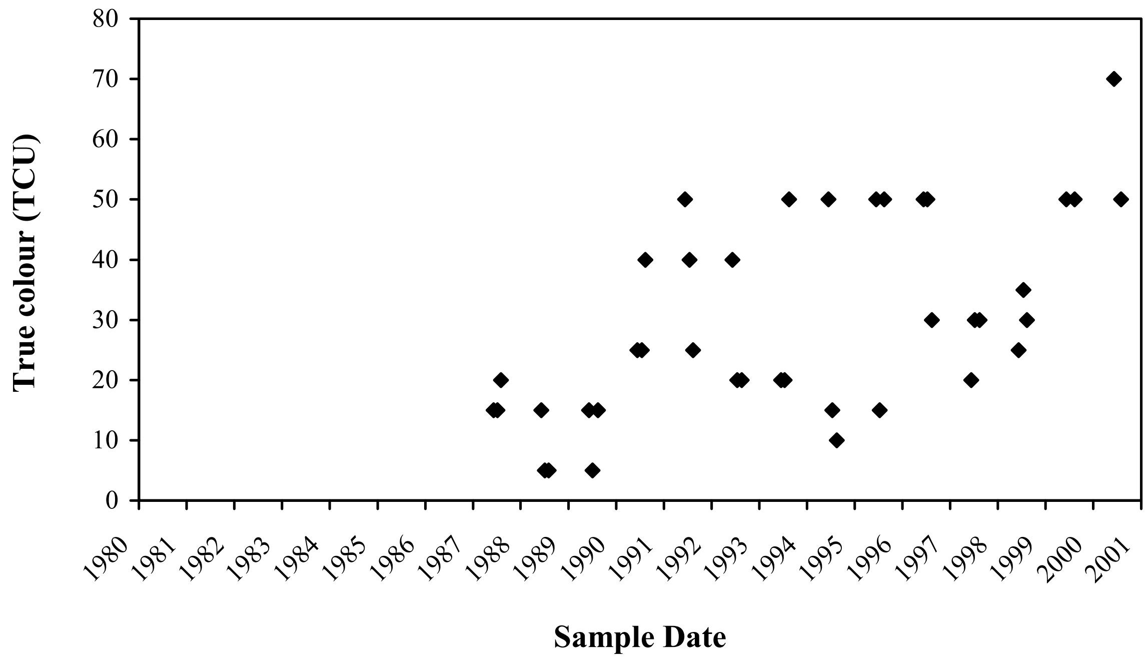


Figure A1-7. Turbidity in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

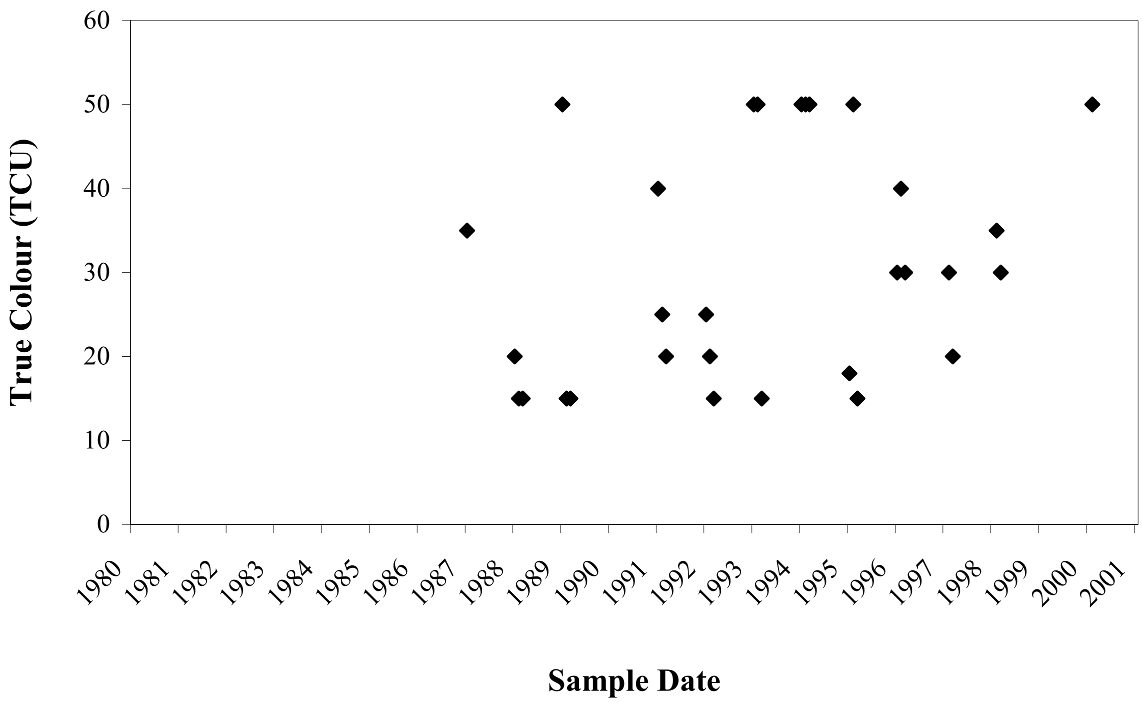
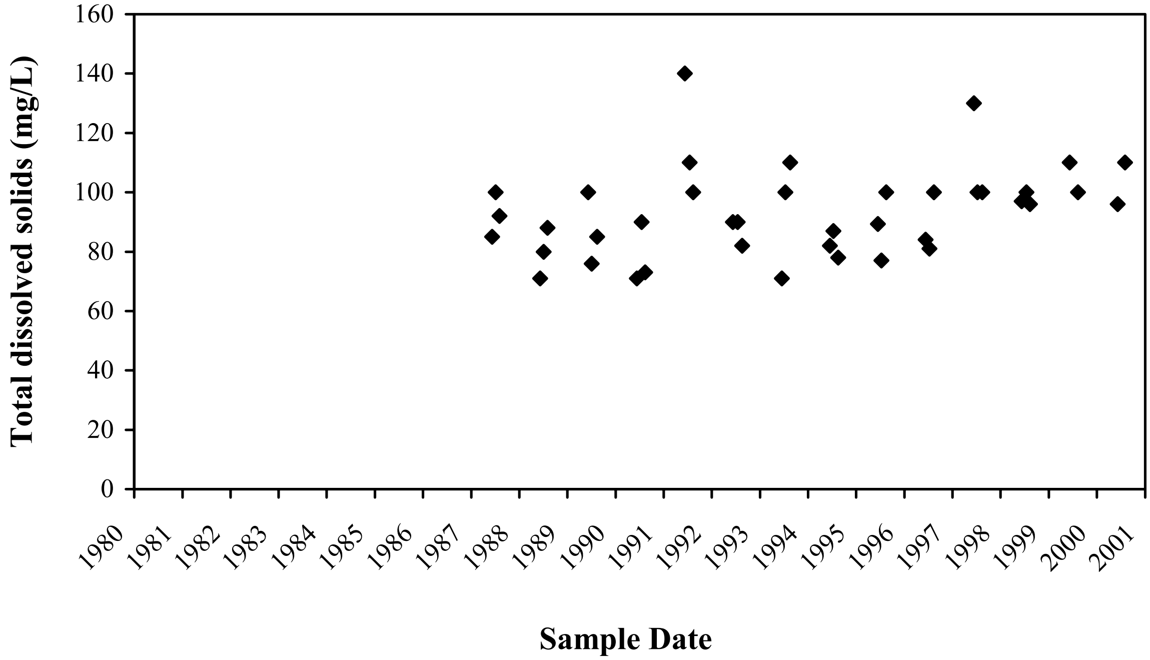


Figure A1-8. True colour in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

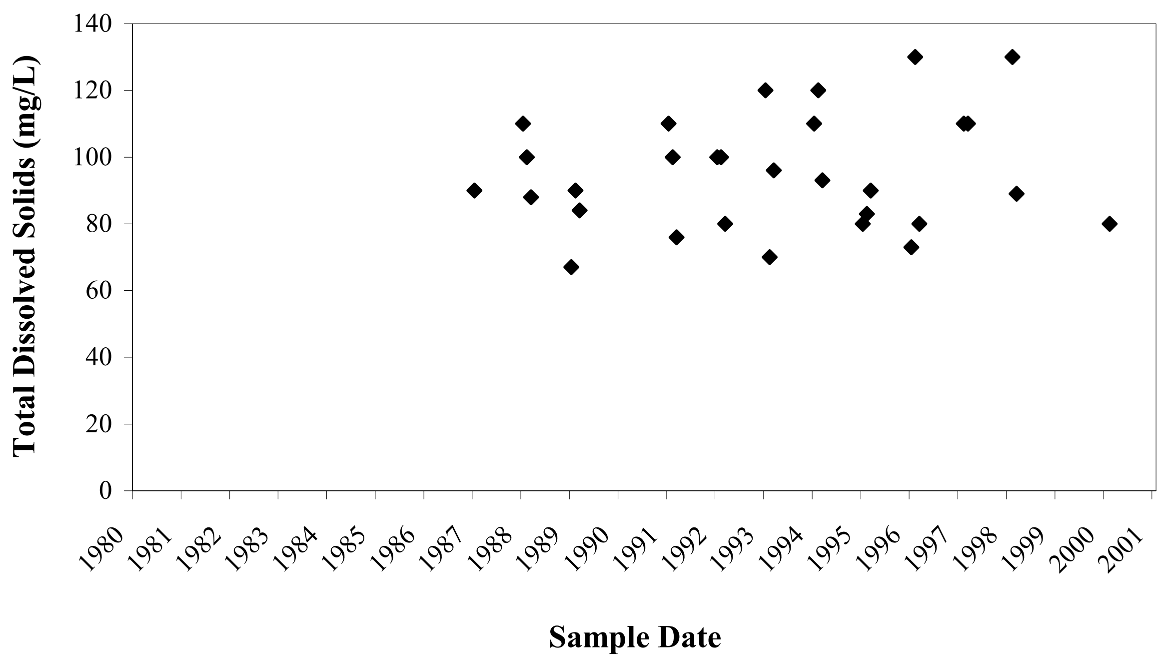
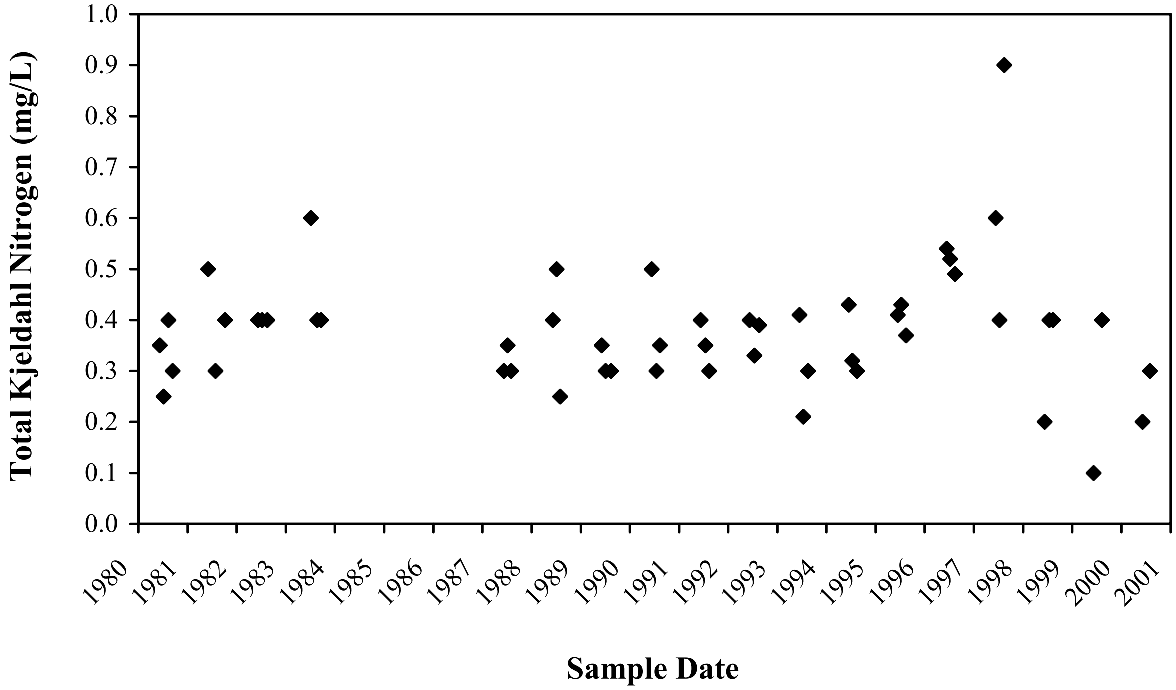


Figure A1-9. Total dissolved solids in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

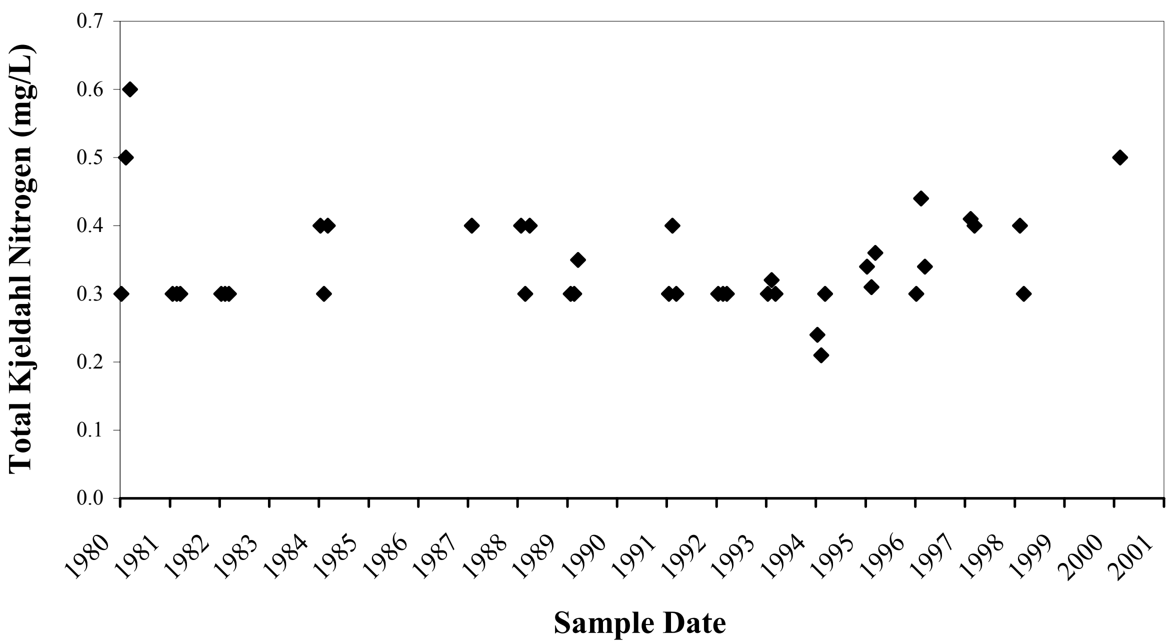
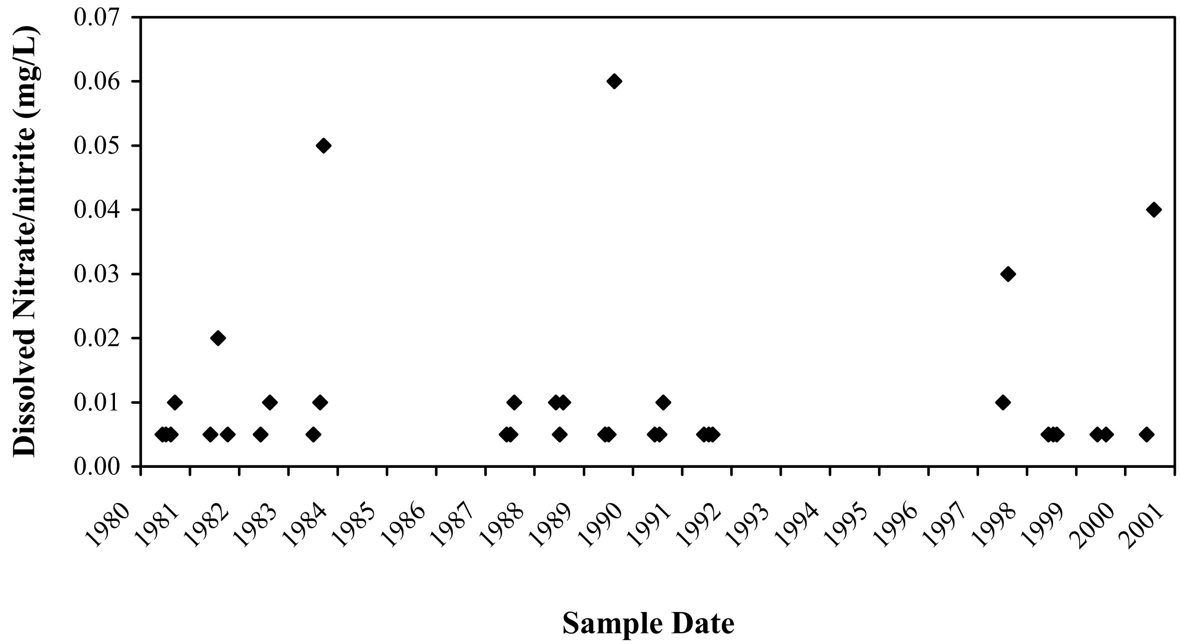


Figure A1-10. Total kjeldahl nitrogen in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

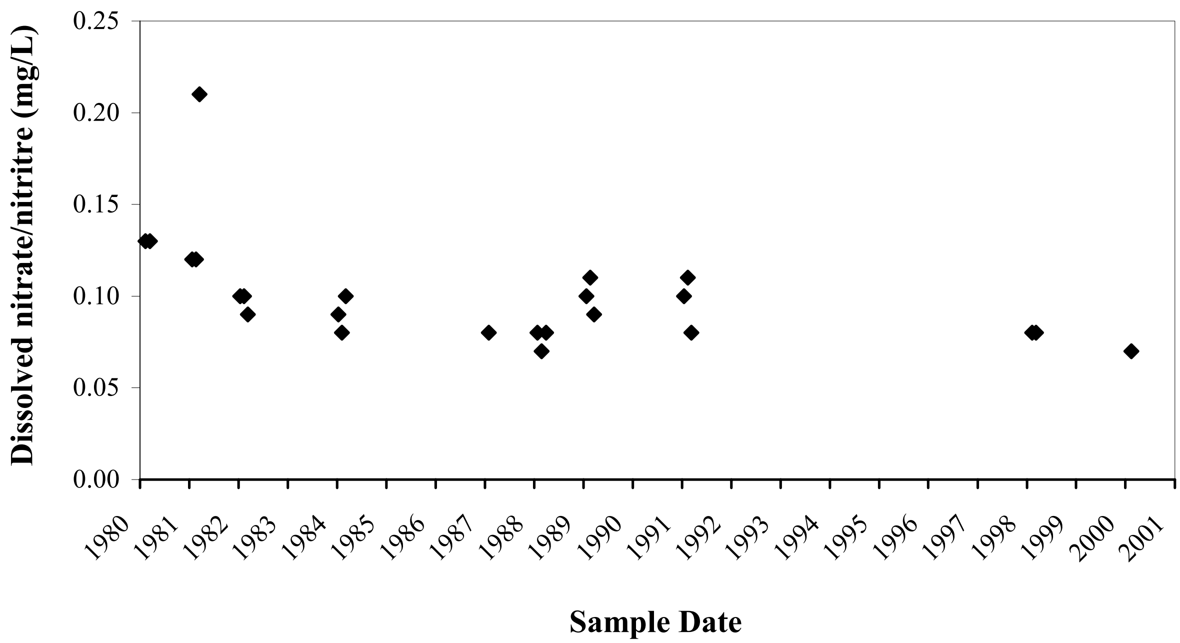
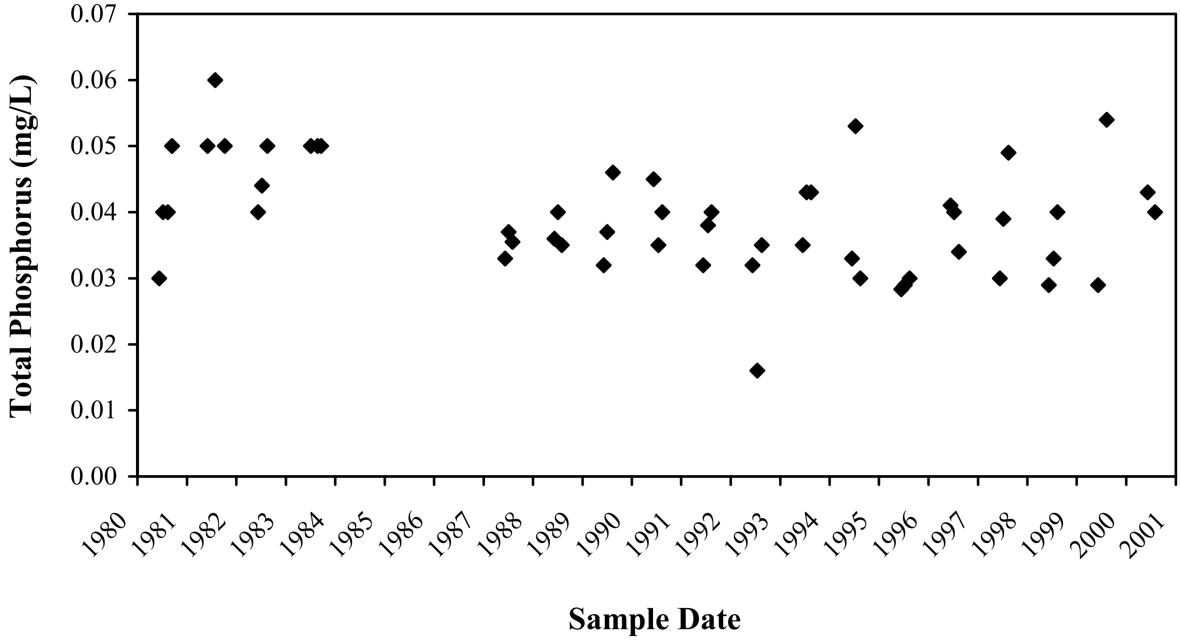


Figure A1-11. Nitrate/nitrite nitrogen in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

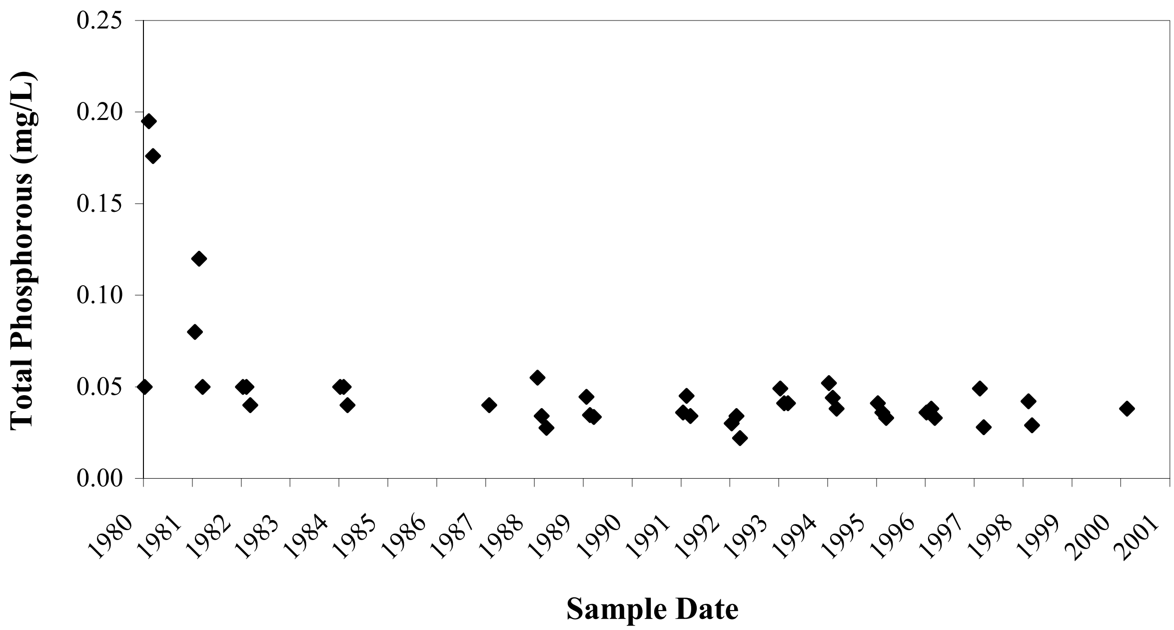
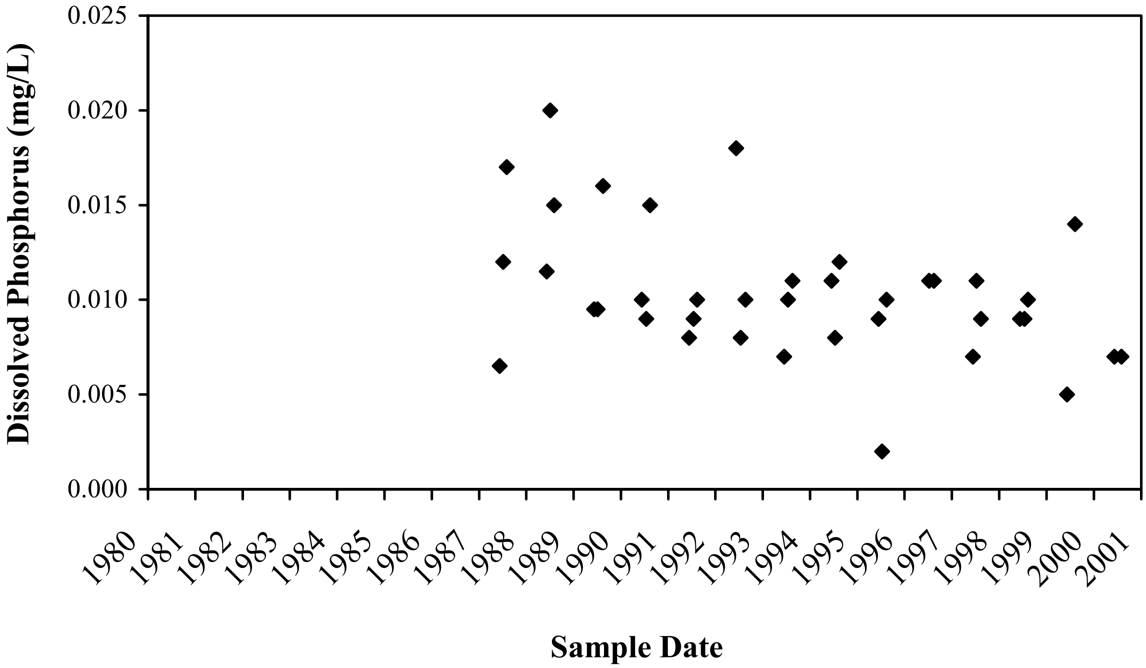


Figure A1-12. Total phosphorus in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

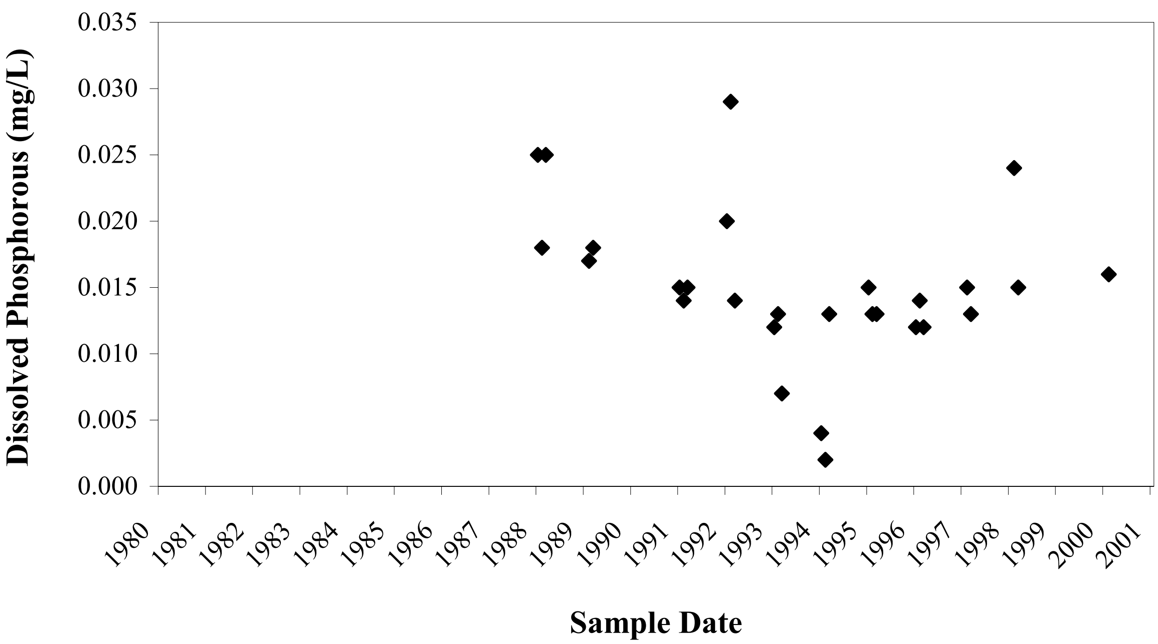
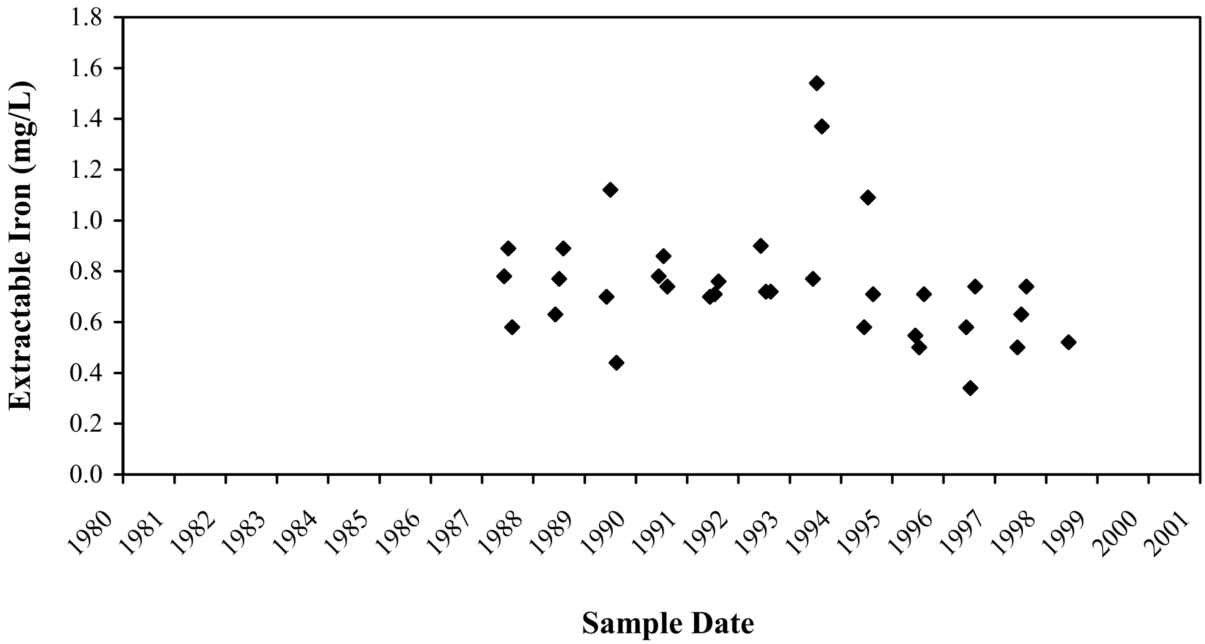


Figure A1-13. Dissolved phosphorus in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

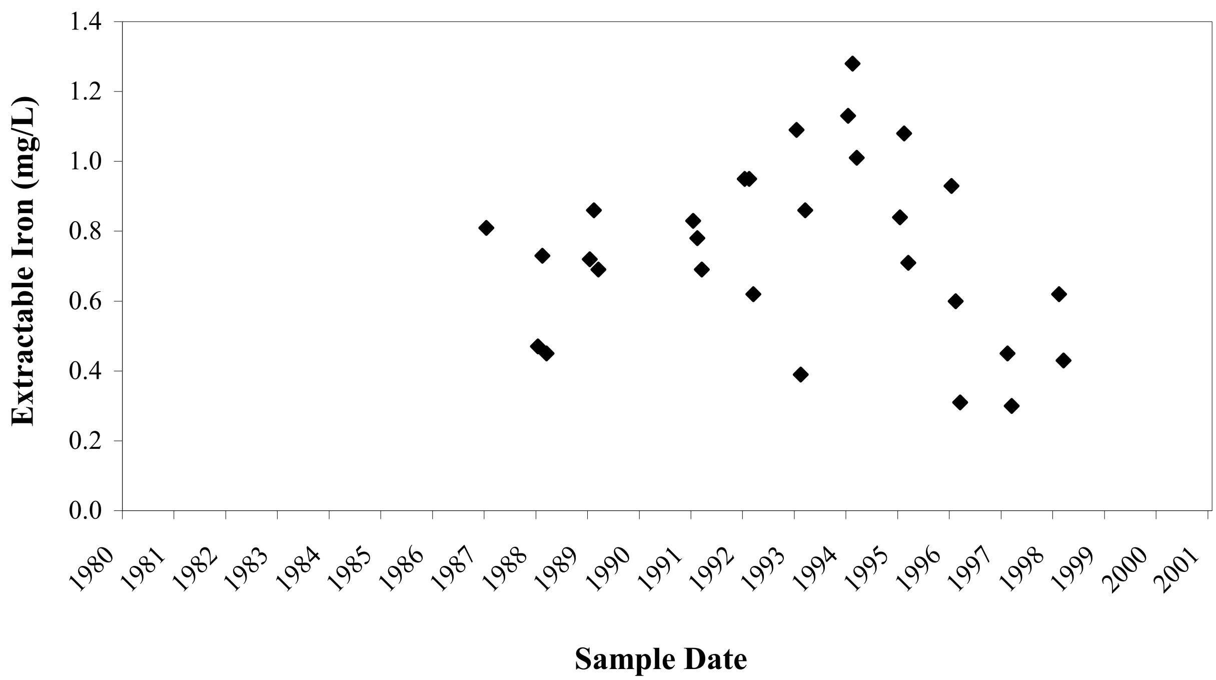
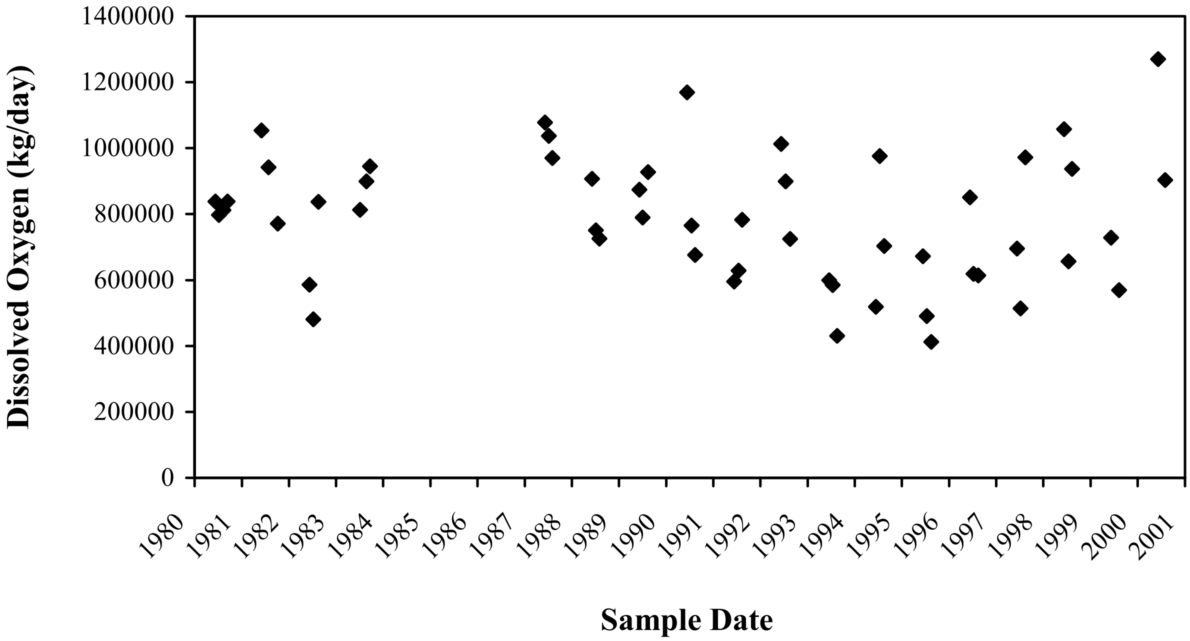


Figure A1-14. Extractable iron in the lower Burntwood River at Thompson: (A) open-water season; and (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

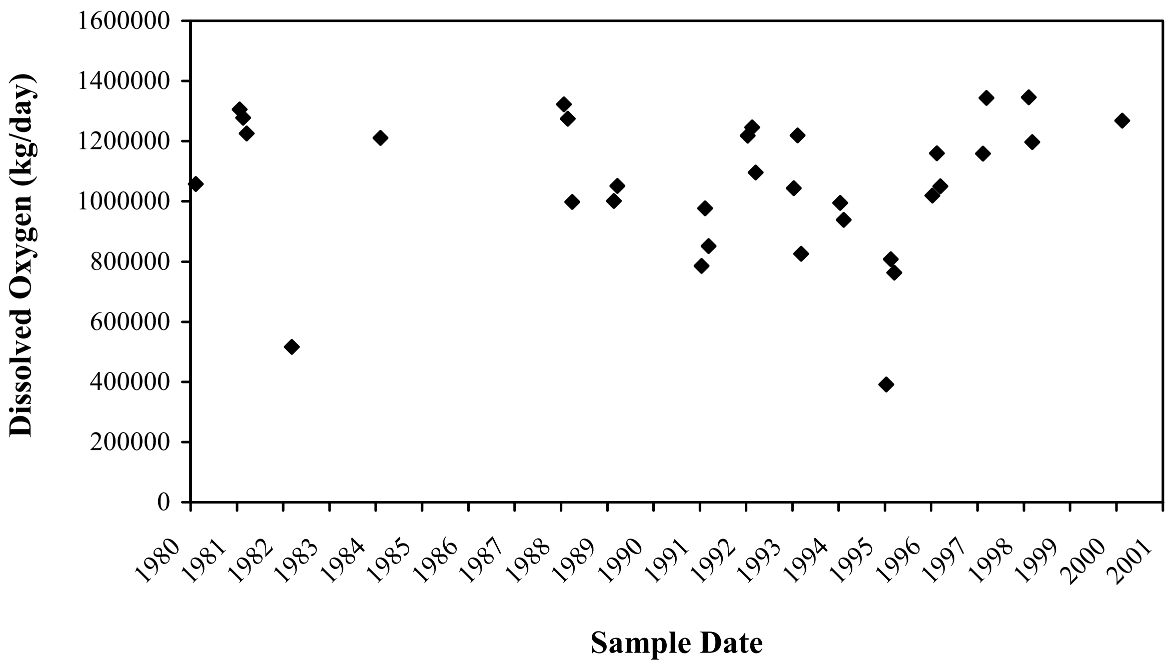
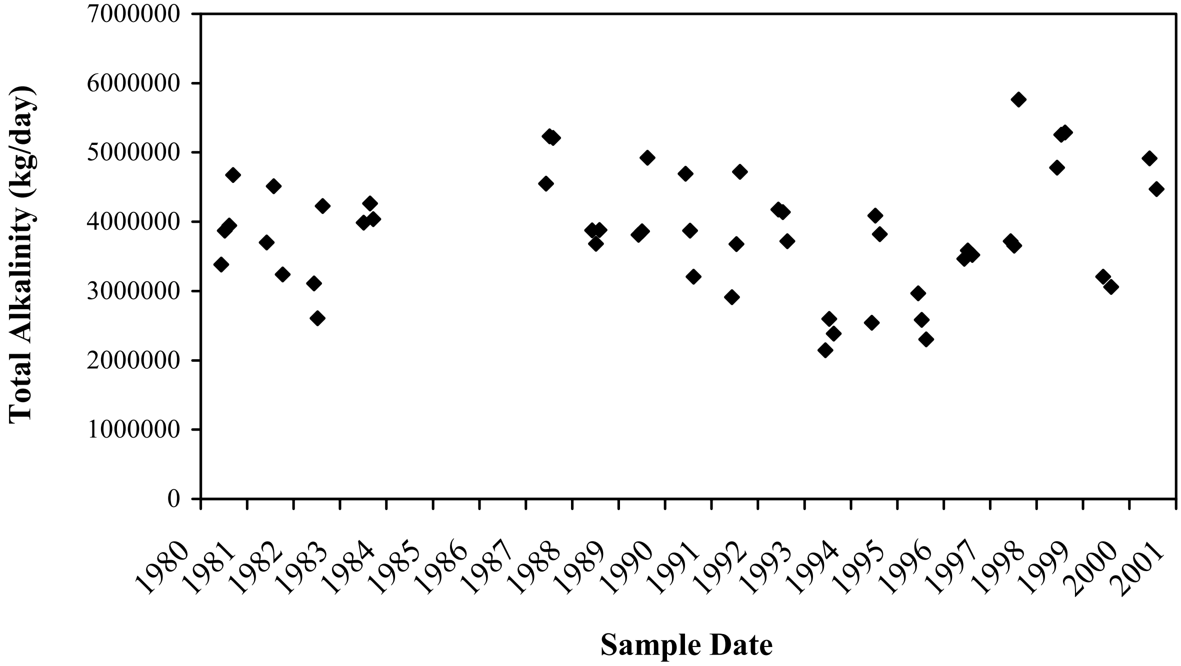


Figure A1-15. Loads of dissolved oxygen measured *in situ* in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

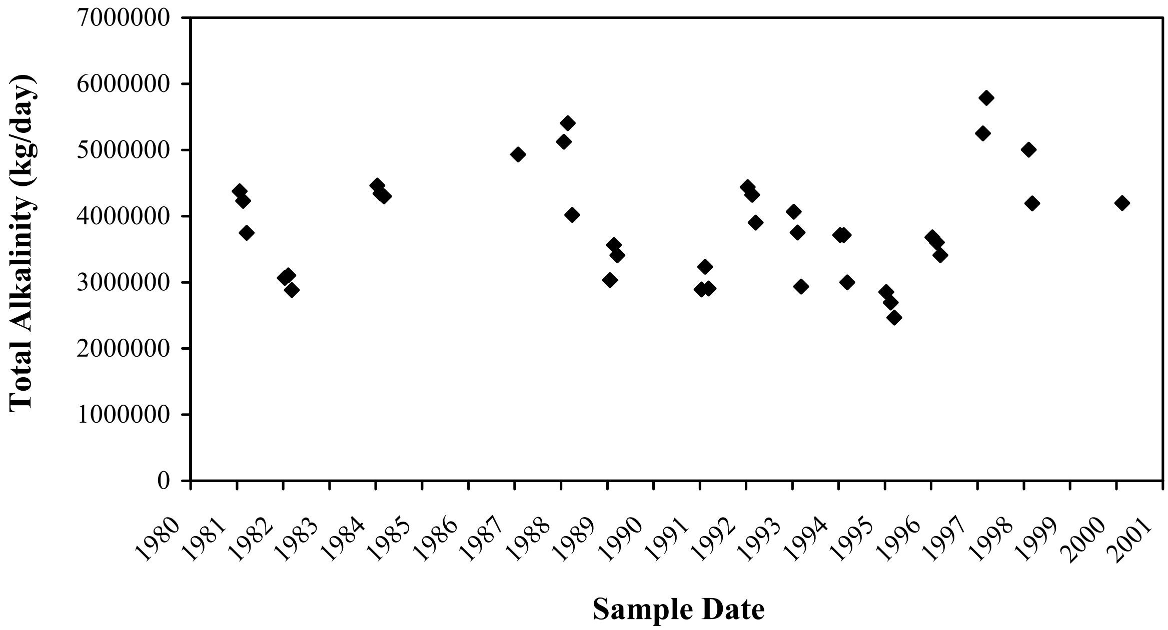
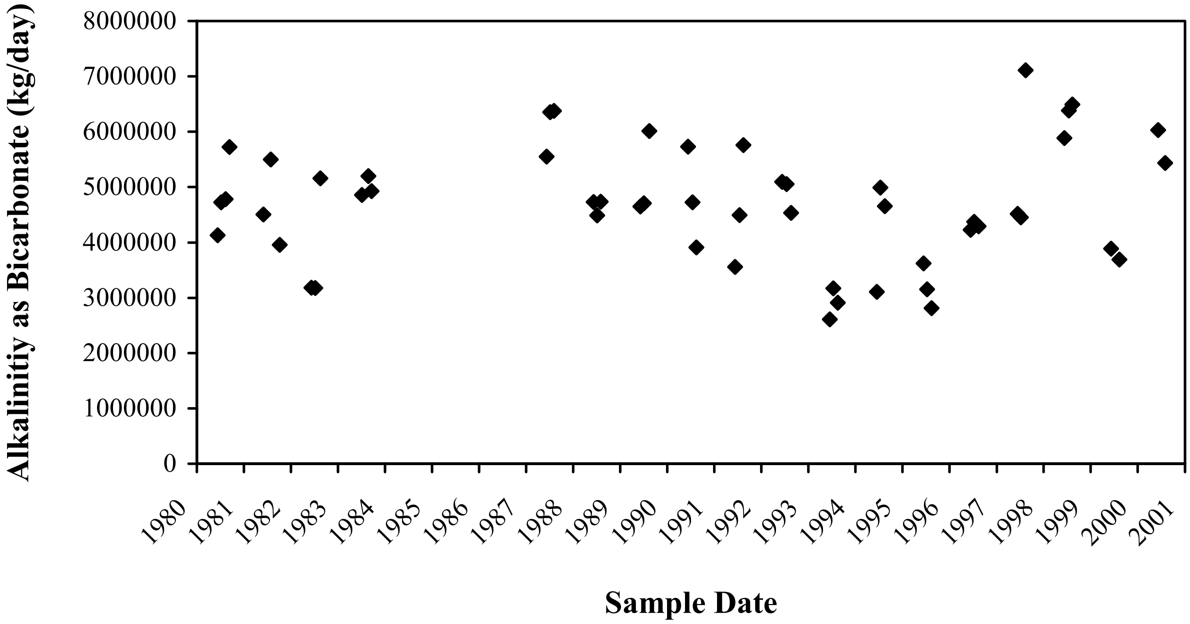


Figure A1-16. Temporal evaluation of loads of total alkalinity, expressed as calcium carbonate, measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

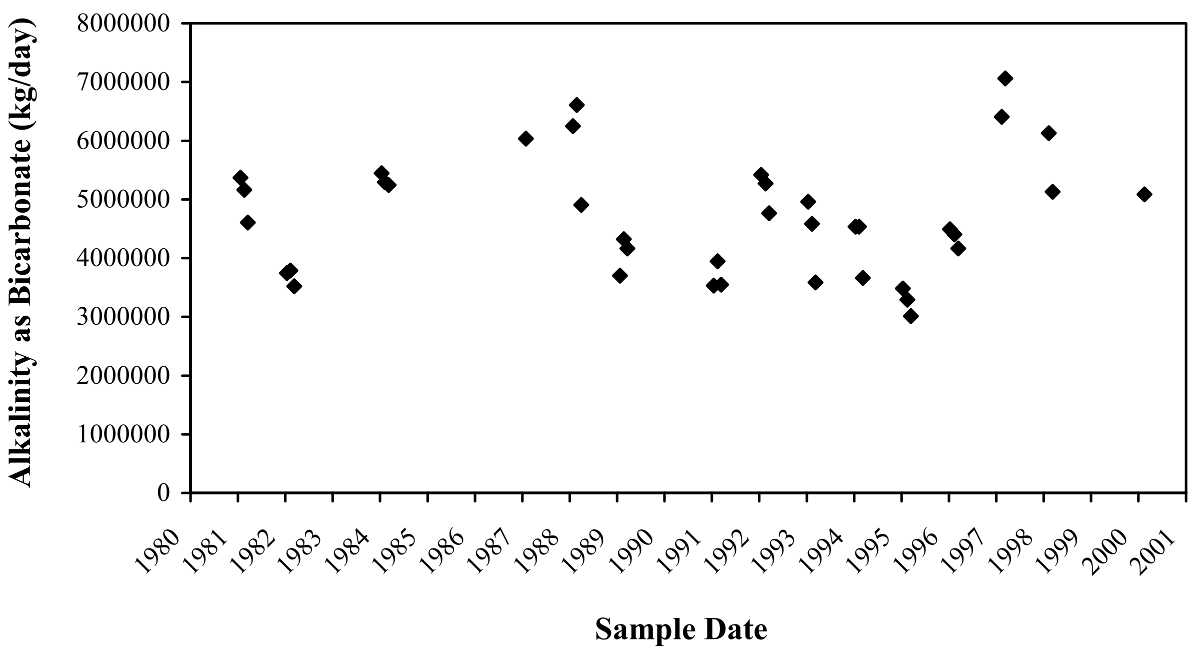
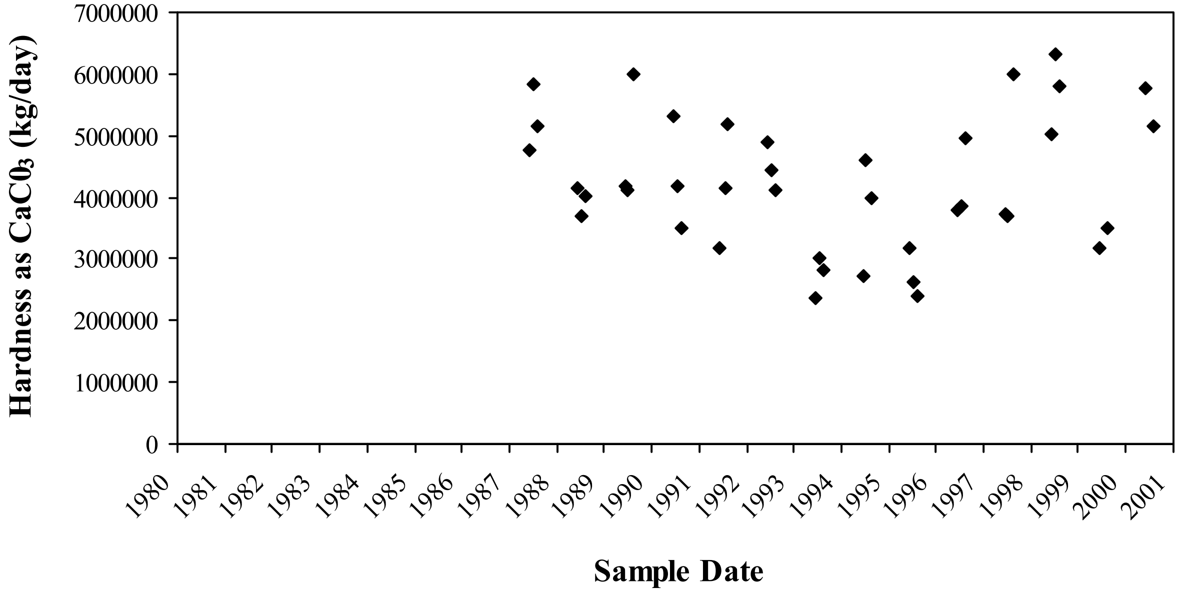


Figure A1-17. Temporal evaluation of loads of bicarbonate alkalinity measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

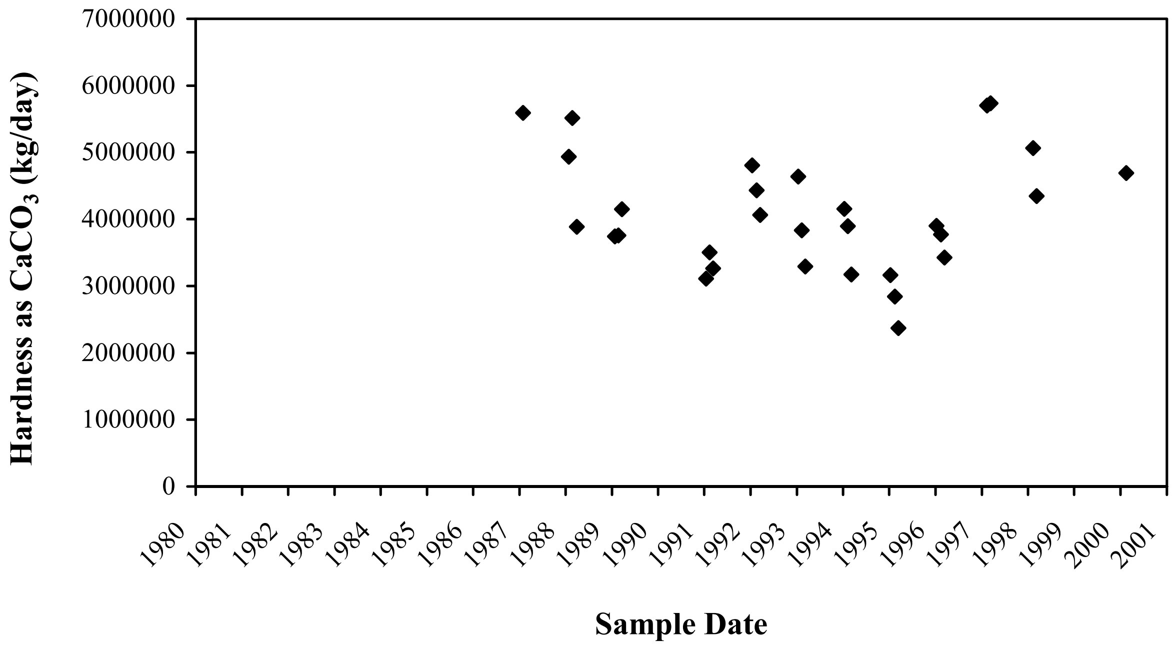
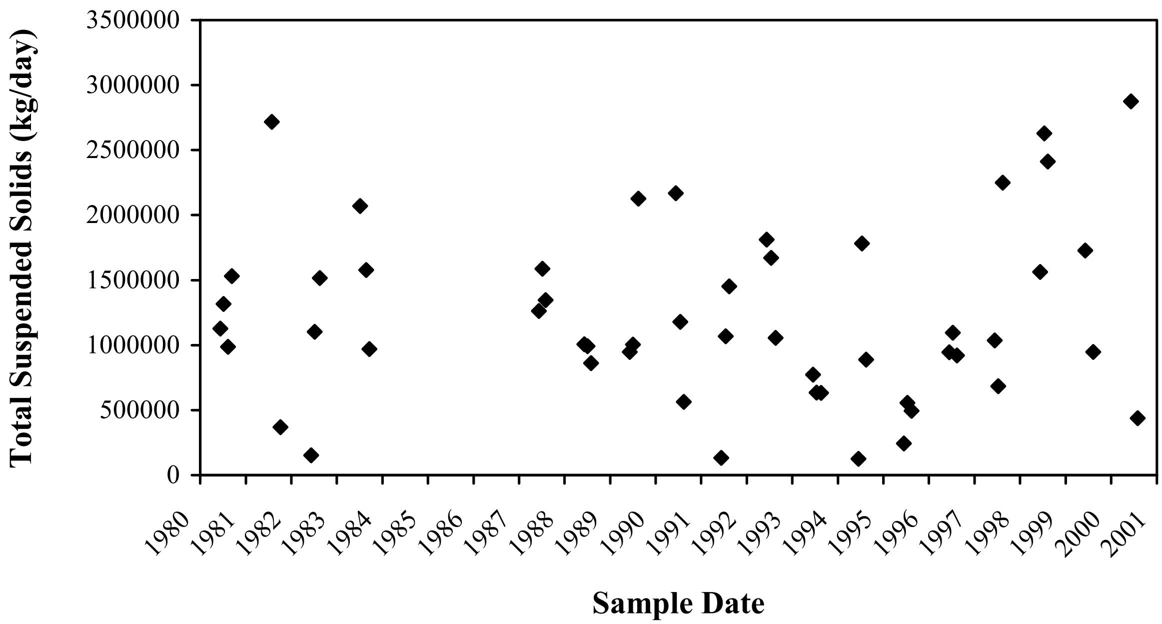


Figure A1-18. Temporal evaluation of loads of water hardness expressed as calcium carbonate measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

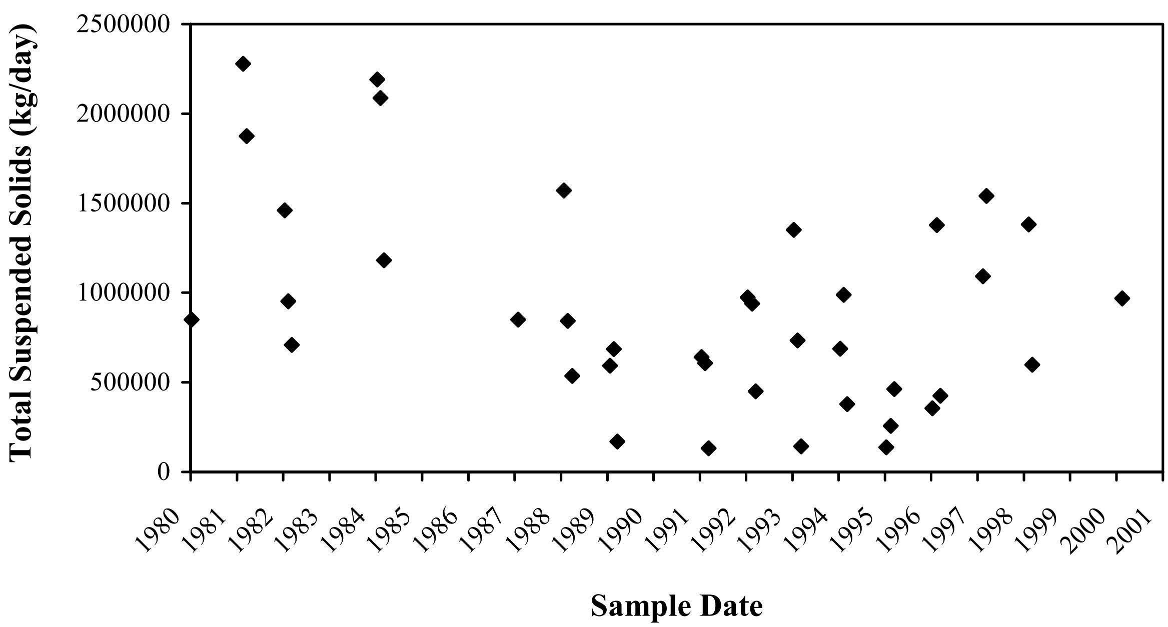
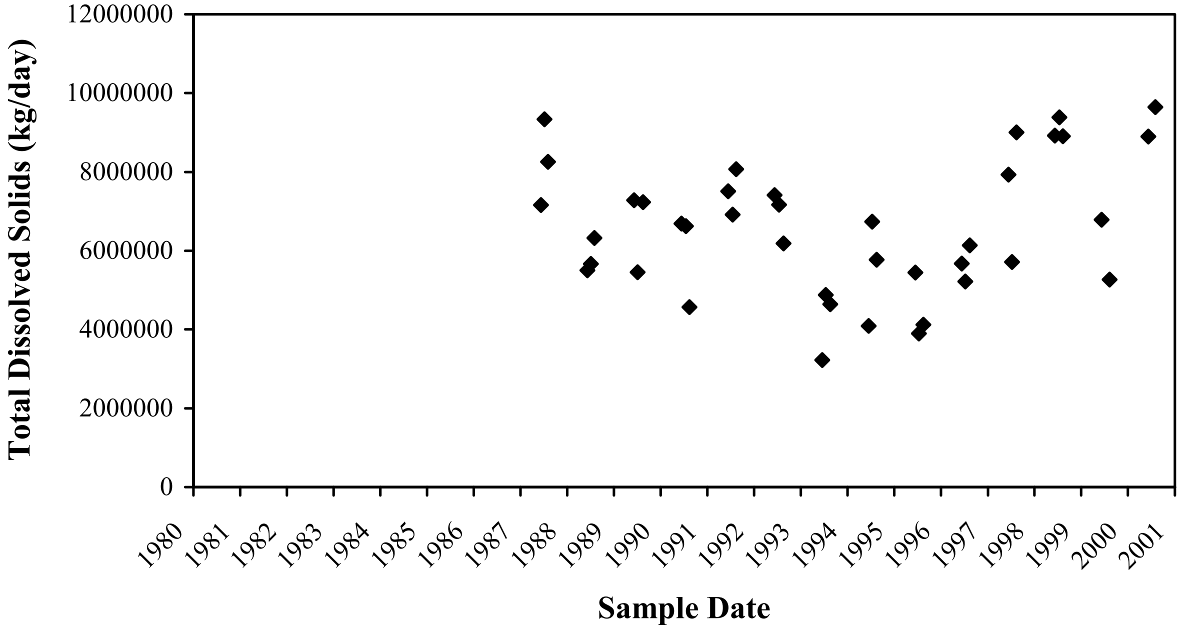


Figure A1-19. Temporal evaluation of loads of total suspended solids measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001). Three outliers (February 11, 1980; March 13, 1980; and, January 20, 1981) were omitted.

(A)



(B)

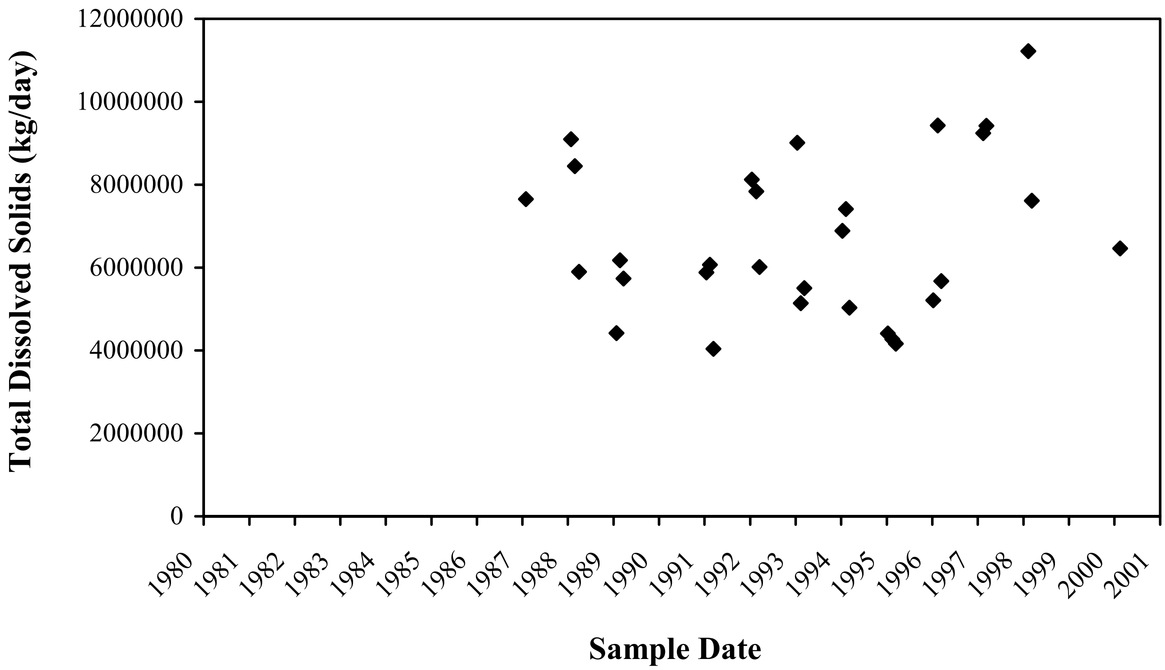
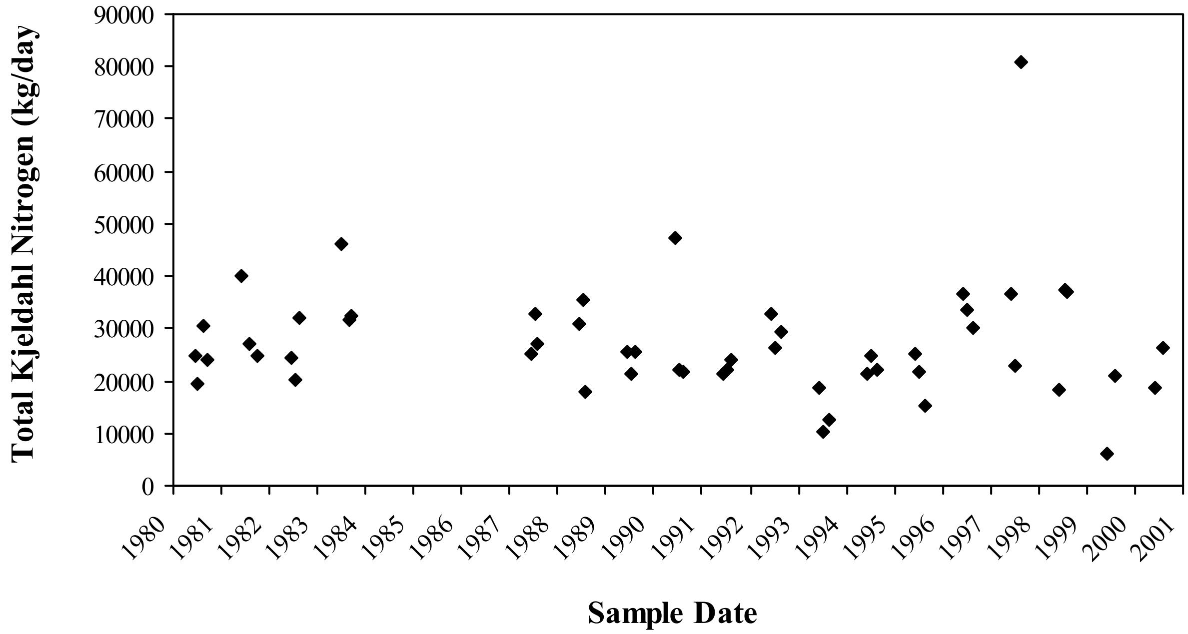


Figure A1-20. Temporal evaluation of loads of total dissolved solids measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

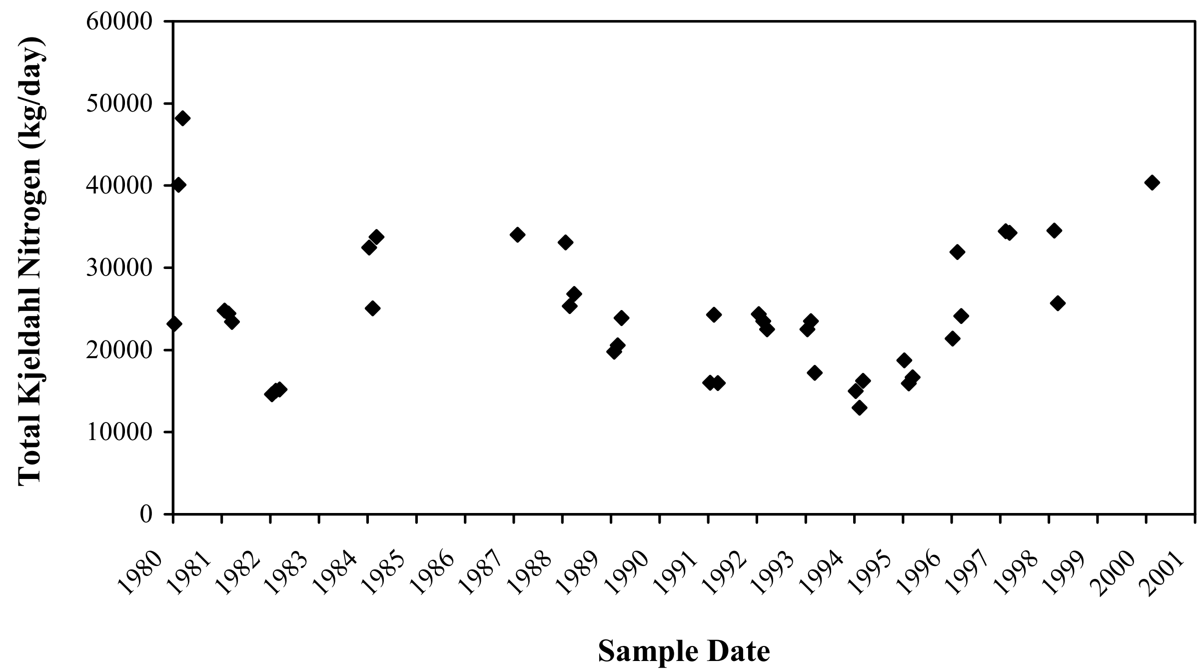
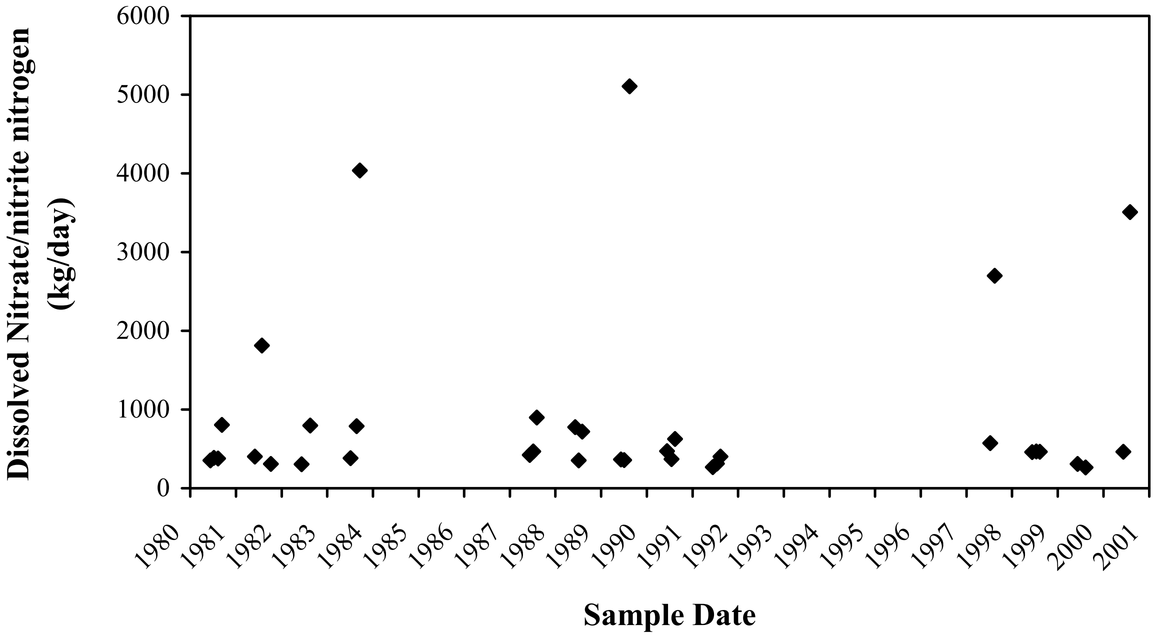


Figure A1-21. Temporal evaluation of loads of total kjeldahl nitrogen measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

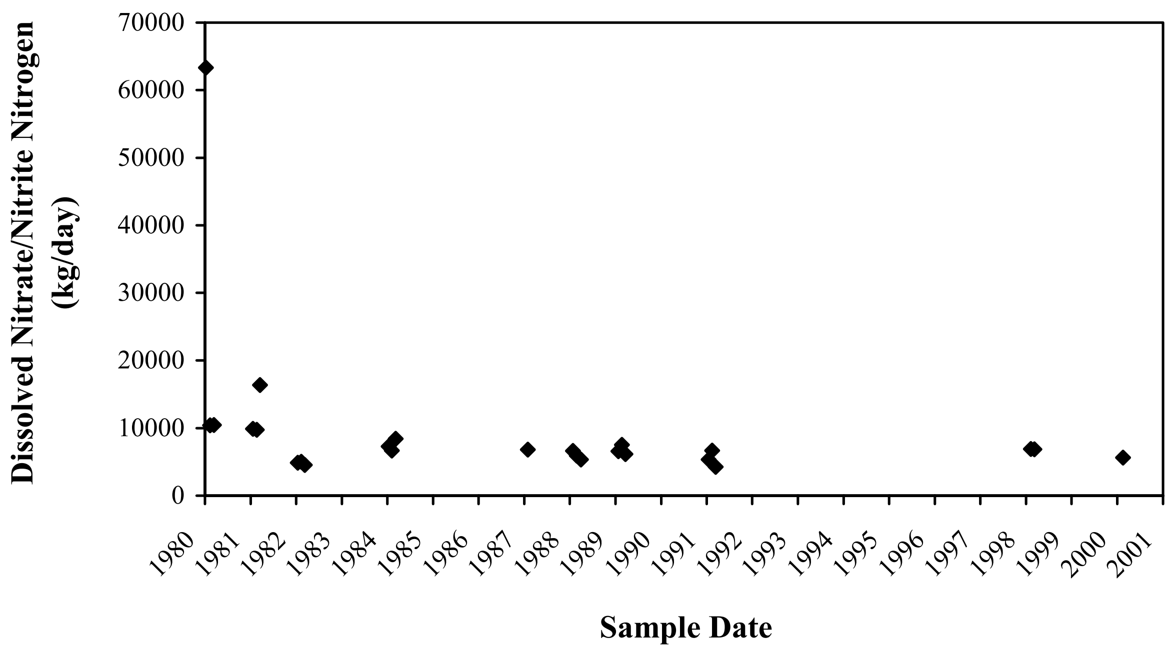
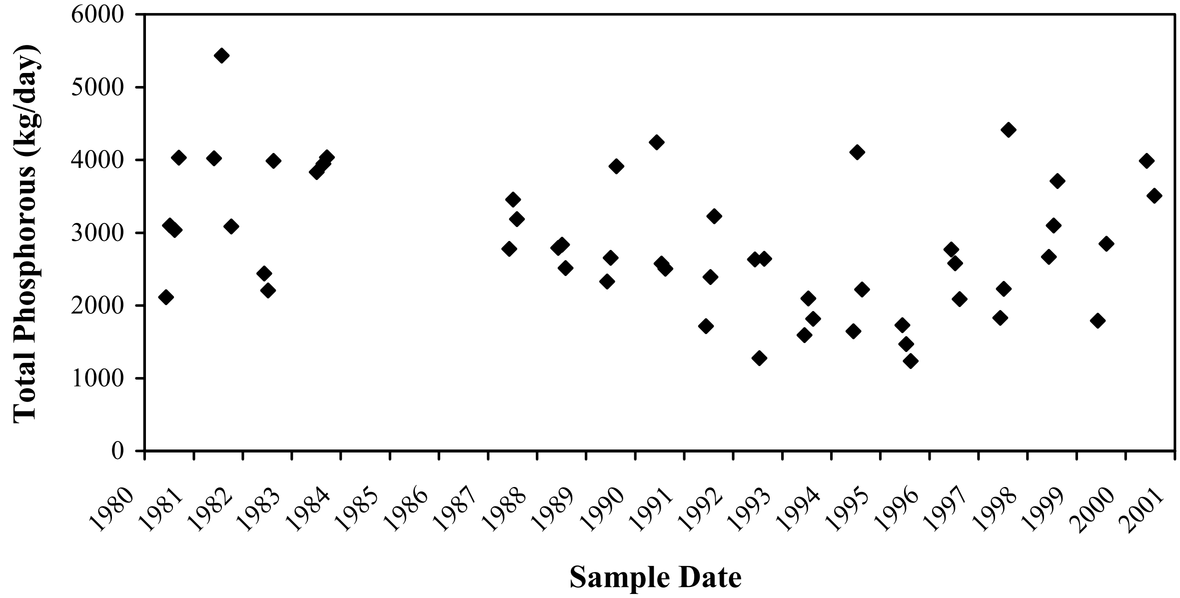


Figure A1-22. Temporal evaluation of loads of dissolved nitrate/nitrite nitrogen measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

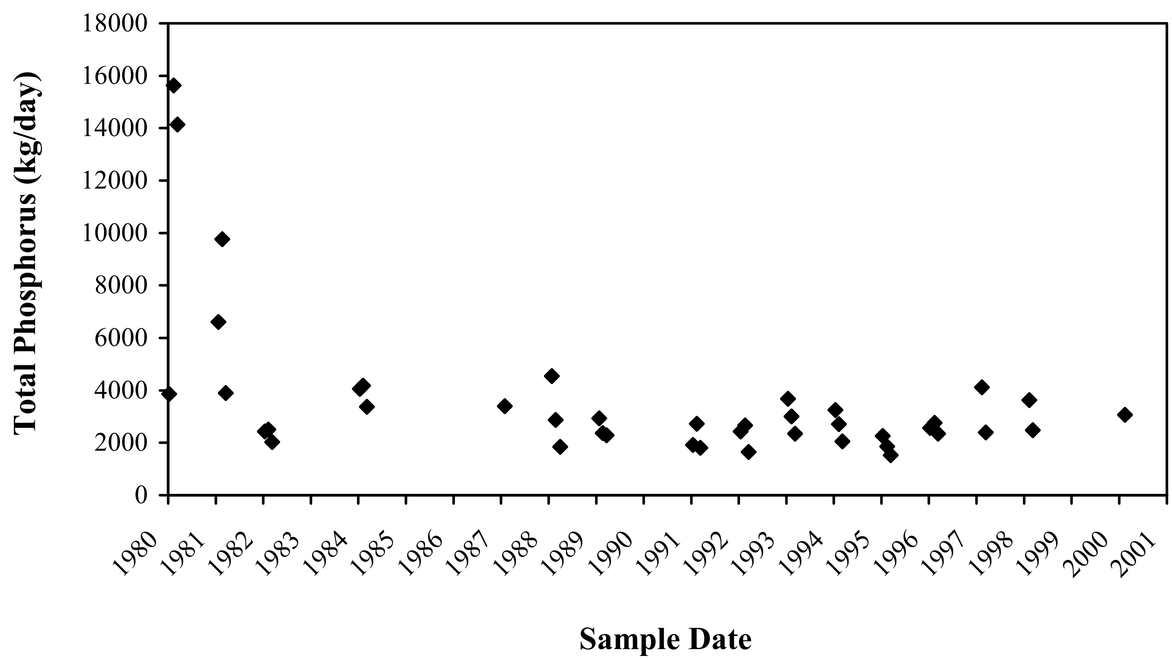
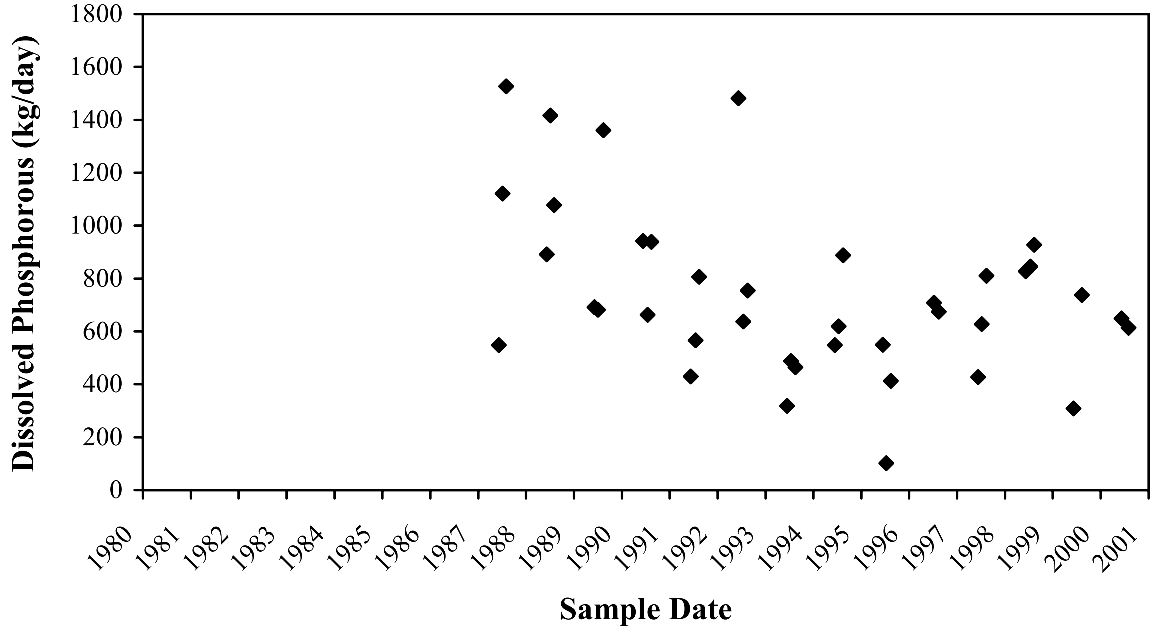


Figure A1-23. Temporal evaluation of loads of total phosphorus measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

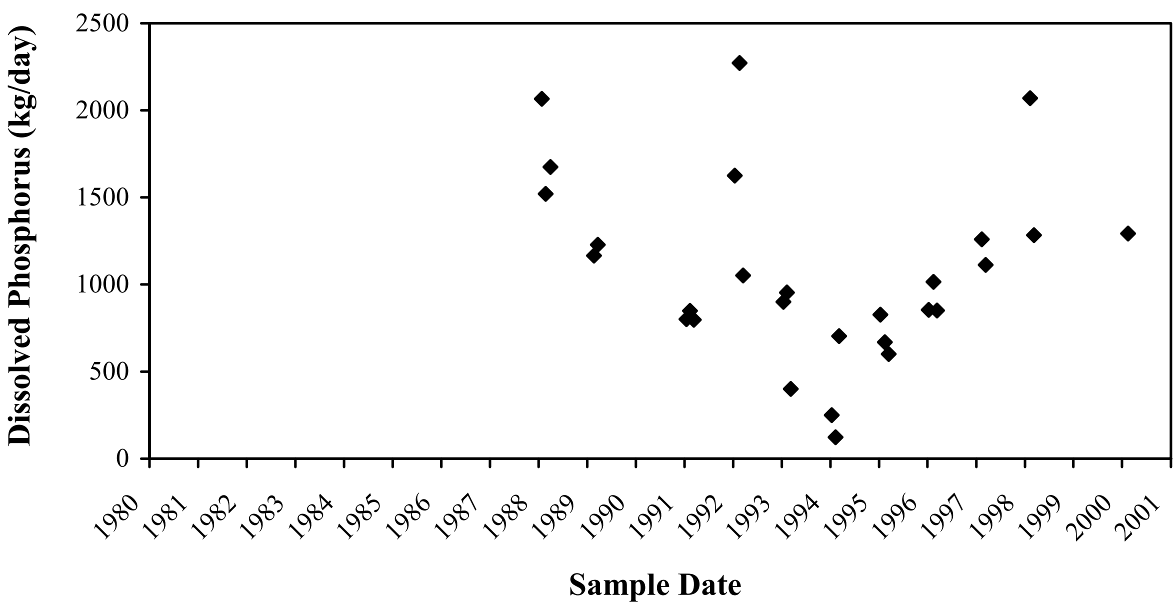
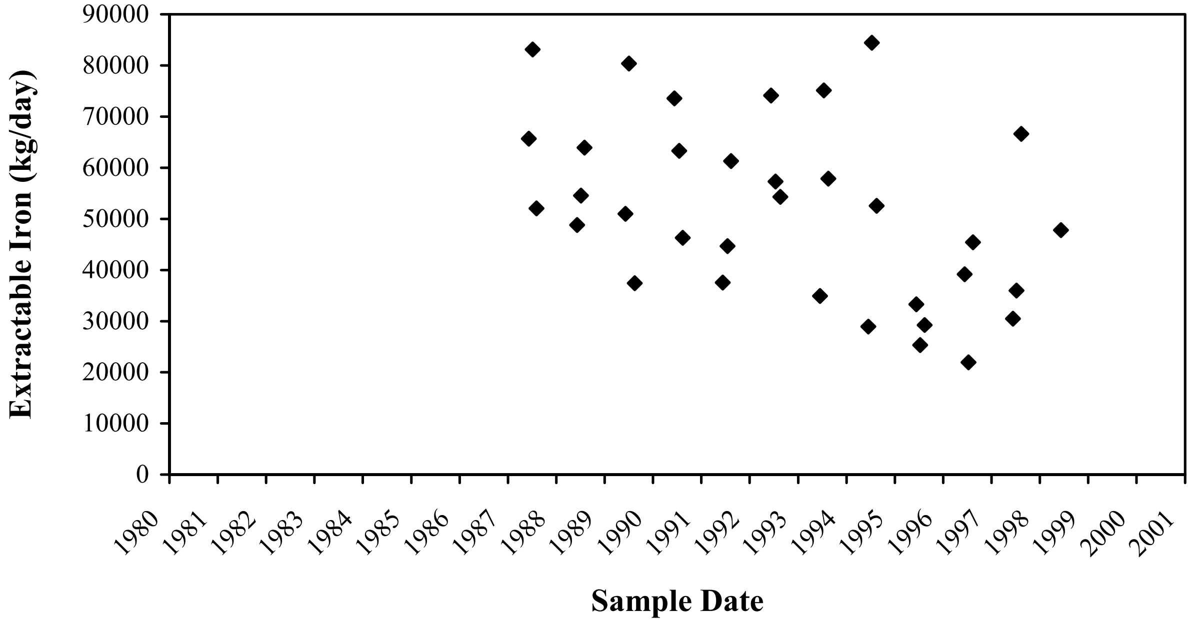


Figure A1-24. Temporal evaluation of loads of dissolved phosphorus measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

(A)



(B)

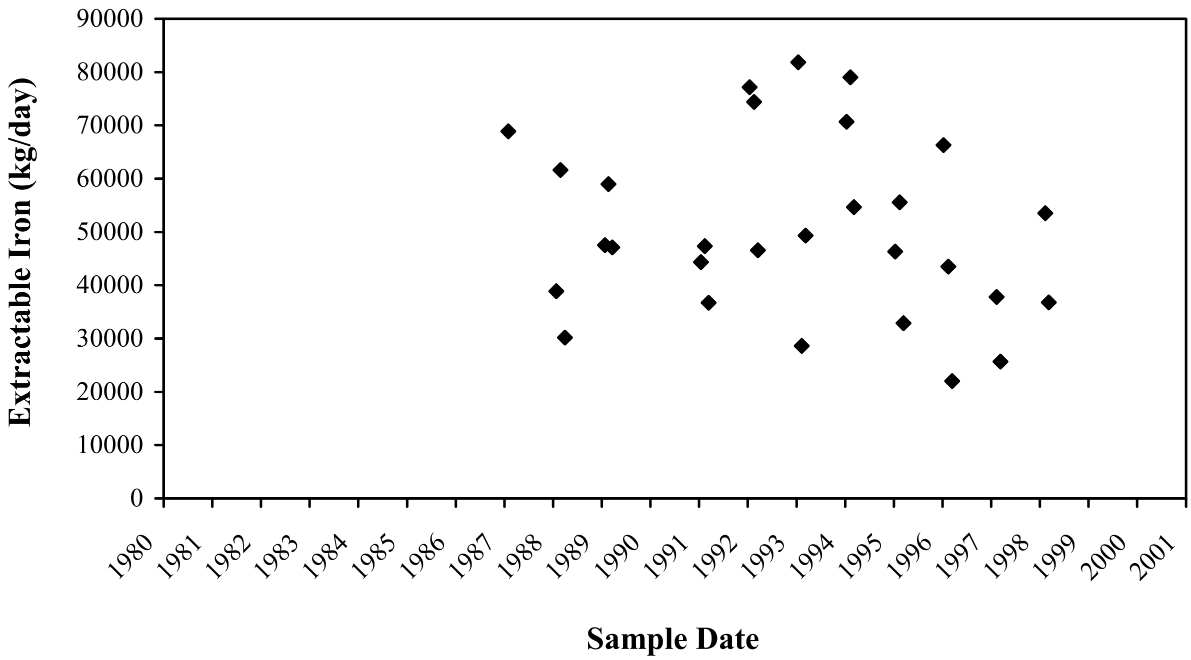


Figure A1-25. Temporal evaluation of loads of dissolved phosphorus measured in the lower Burntwood River at Thompson: (A) open-water season; and, (B) ice-cover season, 1980 - 2000. Water quality data (WQ 0093.00) provided by Manitoba Conservation (2001).

APPENDIX 2. DETAILED RESULTS OF BASELINE WATER CHEMISTRY ANALYSES IN THE WUSKWATIM STUDY AREA, 1999 - 2002.

The following is provided on the enclosed CD:

Table A2-1.
Table A2-2
Table A2-3
Table A2-4
Table A2-5
Table A2-6
Table A2-7
Table A2-8
Table A2-9
Table A2-10
Table A2-11
Table A2-12

Table A2-1. Water chemistry data measured in the laboratory, main study area 1999 – 2002. Abbreviations are defined in the footnotes [1].

Sampling Location	Location ID	Sample Date	Alkalinity: As Bicarbonate (mg/L)	Alkalinity: As $CaCO_3$ (mg/L)	Alkalinity: As Carbonate (mg/L)	Alkalinity: As Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia[2] (mg/L N)	Nitrogen: Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen: TKN (mg/L)	Nitrogen: Organic Nitrogen [3] (mg/L N)	Nitrogen: Total Nitrogen [4] (mg/L)	Nitrogen: Dissolved Inorganic Nitrogen [5] (mg/L N)	Phosphorus: Dissolved (mg/L P)	Phosphorus: Total (mg/L P)	Phosphorus: Dissolved Fraction (%)
Open-water Season 1999															
Lower Burntwood River	LBRB	28-May-99	-	-	-	-	0.02	< 0.01	0.2	0.180	0.205	0.025	0.004	0.027	15
Lower Burntwood River	LBRB	20-Jun-99	-	-	-	-	0.01	< 0.01	0.4	0.390	0.405	0.015	0.006	0.025	24
Lower Burntwood River	LBRB	23-Aug-99	-	-	-	-	0.002	< 0.01	0.4	0.398	0.405	0.007	0.008	0.026	31
Lower Burntwood River	LBRB	23-Sep-99	-	-	-	-	0.01	0.02	0.6	0.590	0.620	0.03	0.024	0.033	73
Lower Burntwood River	LBRC	02-Jun-99	-	-	-	-	< 0.01	< 0.01	< 0.2	0.095	0.105	< 0.01	0.006	0.018	33
Lower Burntwood River	LBRC	26-Jun-99	-	-	-	-	< 0.01	< 0.01	0.3	0.295	0.305	< 0.01	0.007	0.033	21
Lower Burntwood River	LBRC	19-Aug-99	-	-	-	-	< 0.01	< 0.01	0.4	0.395	0.405	< 0.01	0.010	0.023	43
Lower Burntwood River	LBRC	29-Sep-99	-	-	-	-	0.005	<0.01	0.5	0.495	0.505	0.01	0.008	0.036	22
Wuskwatim Lake	WuLA	02-Jun-99	-	-	-	-	< 0.01	< 0.01	0.2	0.195	0.205	< 0.01	0.007	0.024	29
Wuskwatim Lake	WuLA	26-Jun-99	-	-	-	-	0.01	< 0.01	0.4	0.390	0.405	0.015	0.007	0.028	25
Wuskwatim Lake	WuLA	19-Aug-99	-	-	-	-	< 0.01	< 0.01	0.4	0.395	0.405	< 0.01	0.010	0.030	33
Wuskwatim Lake	WuLA	29-Sep-99	-	-	-	-	0.01	<0.01	0.5	0.490	0.505	0.015	0.010	0.038	26
Wuskwatim Lake	WuLB	02-Jun-99	-	-	-	-	< 0.01	< 0.01	0.3	0.295	0.305	< 0.01	0.012	0.018	67
Wuskwatim Lake	WuLB	26-Jun-99	-	-	-	-	< 0.01	< 0.01	0.3	0.295	0.305	< 0.01	0.006	0.031	19
Wuskwatim Lake	WuLB	19-Aug-99	-	-	-	-	< 0.01	< 0.01	0.3	0.295	0.305	< 0.01	0.009	0.033	27
Wuskwatim Lake	WuLB	29-Sep-99	-	-	-	-	0.01	<0.01	0.5	0.490	0.505	0.015	0.010	0.040	25

Table A2-1. - continued –

			Alkalinity				Nitrogen						Phosphorus		
Sampling Location	Location ID	Sample Date	As Bicarbonate (mg/L)	As $CaCO_3$ (mg/L)	As Carbonate (mg/L)	As Hydroxide (mg/L)	Dissolved Ammonia[2] (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [3] (mg/L N)	Total Nitrogen [4] (mg/L)	Dissolved Inorganic Nitrogen [5] (mg/L N)	Dissolved (mg/L P)	Total (mg/L P)	Dissolved Fraction (%)
Open-Water Season 2000															
Lower Burntwood River	LBRB	4-Jun-00	-	-	-	-	0.01	< 0.01	0.5	0.490	0.505	0.015	0.007	0.034	21
Lower Burntwood River	LBRB	17-Jul-00	-	-	-	-	0.02	0.01	0.3	0.280	0.310	0.03	0.005	0.045	11
Lower Burntwood River	LBRB	14-Sep-00	-	-	-	-	0.01	0.02	0.4	0.390	0.420	0.03	0.009	0.036	25
Lower Burntwood River	LBRC	14-Jun-00	-	-	-	-	0.01	0.02	0.4	0.390	0.420	0.03	0.007	0.034	21
Lower Burntwood River	LBRC	24-Jul-00	-	-	-	-	< 0.01	0.02	0.3	0.295	0.320	0.025	0.004	0.024	17
Lower Burntwood River	LBRC	18-Sep-00	-	-	-	-	0.02	0.03	0.6	0.580	0.630	0.05	0.014	0.038	37
Wuskwatim Lake	WuLA	14-Jun-00	-	-	-	-	0.01	0.02	0.4	0.390	0.420	0.03	0.007	0.034	21
Wuskwatim Lake	WuLA	24-Jul-00	-	-	-	-	0.01	0.02	0.3	0.290	0.320	0.03	0.004	0.026	15
Wuskwatim Lake	WuLA	18-Sep-00	-	-	-	-	0.01	0.02	0.5	0.490	0.520	0.03	0.014	0.039	36
Wuskwatim Lake	WuLB	14-Jun-00	-	-	-	-	0.02	0.02	0.6	0.580	0.620	0.04	0.020	0.033	61
Wuskwatim Lake	WuLB	24-Jul-00	-	-	-	-	< 0.01	0.03	0.3	0.295	0.330	0.035	0.004	0.028	14
Wuskwatim Lake	WuLB	18-Sep-00	-	-	-	-	< 0.01	0.02	0.6	0.595	0.620	0.025	0.013	0.040	33
Opegano Lake	OLA	20-Aug-00	-	-	-	-	0.01	0.02	0.4	0.390	0.420	0.03	0.008	0.038	21
Opegano Lake	OLA	24-Sep-00	-	-	-	-	0.004	0.03	0.4	0.396	0.430	0.034	0.013	0.046	28
Opegano Lake	OLB	15-Aug-00	-	-	-	-	0.01	0.02	0.4	0.390	0.420	0.03	0.009	0.037	24
Opegano Lake	OLB	24-Sep-00	-	-	-	-	0.006	0.04	0.4	0.394	0.440	0.046	0.013	0.046	28
Birch Tree Lake	BLA	25-Jul-00	-	-	-	-	< 0.01	0.02	0.3	0.295	0.320	0.025	0.003	0.032	9
Birch Tree Lake	BLA	19-Sep-00	-	-	-	-	0.04	< 0.01	0.5	0.460	0.505	0.045	0.014	0.045	31
Birch Tree Lake	BLB	25-Jul-00	-	-	-	-	< 0.01	0.03	0.3	0.295	0.330	0.03	0.006	0.030	20

Table A2-1. - continued –

Sampling Location	Location ID	Sample Date	Alkalinity: As Bicarbonate (mg/L)	Alkalinity: As $CaCO_3$ (mg/L)	Alkalinity: As Carbonate (mg/L)	Alkalinity: As Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia[2] (mg/L N)	Nitrogen: Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen: TKN (mg/L)	Nitrogen: Organic Nitrogen [3] (mg/L N)	Nitrogen: Total Nitrogen [4] (mg/L)	Nitrogen: Dissolved Inorganic Nitrogen [5] (mg/L N)	Phosphorus: Dissolved (mg/L P)	Phosphorus: Total (mg/L P)	Phosphorus: Dissolved Fraction (%)
Birch Tree Lake	BLB	19-Sep-00	-	-	-	-	0.01	0.02	0.8	0.790	0.820	0.035	0.014	0.045	31
Open-water Season 2001															
Lower Burntwood River	LBRB	29-May-01	-	-	-	-	0.02	0.006	0.5	0.480	0.506	0.026	0.010	0.036	28
Lower Burntwood River	LBRB	15-Jul-01	-	-	-	-	0.009	< 0.005	0.5	0.491	0.503	0.012	0.009	0.024	38
Lower Burntwood River	LBRB	22-Aug-01	-	-	-	-	0.004	0.014	0.4	0.396	0.414	0.018	0.010	0.033	30
Lower Burntwood River	LBRB	26-Sep-01	-	-	-	-	0.01	0.010	0.9	0.890	0.910	0.020	0.009	0.036	25
Lower Burntwood River	LBRB2	30-May-01	61	50	< 20	< 10	0.006	0.005	0.5	0.494	0.505	0.011	0.009	0.035	26
Lower Burntwood River	LBRB2	16-Jul-01	65	53	< 20	< 10	0.01	0.005	0.5	0.490	0.505	0.015	0.007	0.027	26
Lower Burntwood River	LBRB2	23-Aug-01	66	54	< 20	< 10	0.01	0.009	0.4	0.390	0.409	0.019	0.011	0.033	33
Lower Burntwood River	LBRB2	27-Sep-01	64	53	< 20	< 10	0.02	0.019	0.4	0.380	0.419	0.039	0.011	0.035	31
Lower Burntwood River	LBRC	30-May-01	-	-	-	-	0.01	0.008	0.5	0.490	0.508	0.018	0.009	0.037	24
Lower Burntwood River	LBRC	16-Jul-01	-	-	-	-	0.01	< 0.005	0.5	0.490	0.503	0.013	0.007	0.027	26
Lower Burntwood River	LBRC	23-Aug-01	-	-	-	-	0.01	0.005	0.5	0.490	0.505	0.015	0.016	0.035	46
Lower Burntwood River	LBRC	27-Sep-01	-	-	-	-	0.004	0.008	0.5	0.496	0.508	0.012	0.009	0.037	24
Sesep Lake	SLA	30-May-01	-	-	-	-	0.02	0.007	0.5	0.480	0.507	0.027	0.012	0.020	60
Sesep Lake	SLA	16-Jul-01	-	-	-	-	0.02	< 0.005	0.8	0.780	0.803	0.023	0.011	0.030	37
Sesep Lake	SLA	23-Aug-01	-	-	-	-	0.02	< 0.005	0.8	0.780	0.803	0.023	0.013	0.035	37
Sesep Lake	SLA	27-Sep-01	-	-	-	-	0.02	< 0.005	0.9	0.880	0.903	0.023	0.013	0.024	54
Wuskwatim Lake	WuLA	30-May-01	-	-	-	-	<0.002	0.012	0.5	0.499	0.512	0.013	0.010	0.038	26

Table A2-1. - continued -

Sampling Location	Location ID	Sample Date	Alkalinity: As Bicarbonate (mg/L)	Alkalinity: As $CaCO_3$ (mg/L)	Alkalinity: As Carbonate (mg/L)	Alkalinity: As Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia[2] (mg/L N)	Nitrogen: Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen: TKN (mg/L)	Nitrogen: Organic Nitrogen [3] (mg/L N)	Nitrogen: Total Nitrogen [4] (mg/L)	Nitrogen: Dissolved Inorganic Nitrogen [5] (mg/L N)	Phosphorus: Dissolved (mg/L P)	Phosphorus: Total (mg/L P)	Phosphorus: Dissolved Fraction (%)
Wuskwatim Lake	WuLA	16-Jul-01	-	-	-	-	0.02	0.008	0.6	0.580	0.608	0.028	0.008	0.026	31
Wuskwatim Lake	WuLA	23-Aug-01	-	-	-	-	0.02	0.005	0.5	0.480	0.505	0.025	0.012	0.034	35
Wuskwatim Lake	WuLA	27-Sep-01	-	-	-	-	0.01	0.008	0.5	0.490	0.508	0.018	0.010	0.037	27
Wuskwatim Lake	WuLB	30-May-01	63	52	< 20	< 10	<0.002	0.008	0.5	0.499	0.508	0.009	0.009	0.036	25
Wuskwatim Lake	WuLB	16-Jul-01	65	54	< 20	< 10	0.01	< 0.005	0.4	0.390	0.403	0.013	0.007	0.025	28
Wuskwatim Lake	WuLB	23-Aug-01	69	57	< 20	< 10	0.01	< 0.005	0.5	0.490	0.503	0.013	0.011	0.032	34
Wuskwatim Lake	WuLB	27-Sep-01	68	55	< 20	< 10	0.01	0.007	0.4	0.390	0.407	0.017	0.010	0.039	26
Wuskwatim Lake	WuLC	30-May-01	-	-	-	-	0.02	0.008	0.6	0.580	0.608	0.028	0.013	0.024	54
Wuskwatim Lake	WuLC	16-Jul-01	-	-	-	-	0.01	0.006	0.7	0.690	0.706	0.016	0.011	0.026	42
Wuskwatim Lake	WuLC	23-Aug-01	-	-	-	-	0.03	0.005	0.8	0.770	0.805	0.035	0.017	0.048	35
Wuskwatim Lake	WuLC	27-Sep-01	-	-	-	-	0.03	0.010	0.9	0.870	0.910	0.040	0.013	0.036	36
Wuskwatim Brook	WuBA	30-May-01	-	-	-	-	0.01	0.009	0.6	0.590	0.609	0.019	0.010	0.018	56
Wuskwatim Brook	WuBA	16-Jul-01	-	-	-	-	0.02	< 0.005	0.7	0.680	0.703	0.023	0.009	0.017	53
Wuskwatim Brook	WuBA	23-Aug-01	-	-	-	-	0.02	< 0.005	0.8	0.780	0.803	0.023	0.017	0.028	61
Wuskwatim Brook	WuBA	27-Sep-01	-	-	-	-	0.01	< 0.005	0.8	0.790	0.803	0.013	0.010	0.024	42
Taskinigup Falls	TF	30-May-01	62	51	< 20	< 10	0.01	0.011	0.6	0.590	0.611	0.021	0.010	0.039	26
Taskinigup Falls	TF	16-Jul-01	66	54	< 20	< 10	0.02	0.013	0.5	0.480	0.513	0.033	0.009	0.030	30
Taskinigup Falls	TF	23-Aug-01	69	57	< 20	< 10	0.02	0.009	0.4	0.380	0.409	0.029	0.011	0.031	35
Taskinigup Falls	TF	27-Sep-01	69	56	< 20	< 10	0.003	0.007	0.5	0.497	0.507	0.010	0.009	0.035	26
Opegano Lake	OLA	31-May-01	-	-	-	-	0.01	0.007	0.5	0.490	0.507	0.017	0.009	0.039	23

Table A2-1. - continued -

Sampling Location	Location ID	Sample Date	Alkalinity: As Bicarbonate (mg/L)	Alkalinity: As $CaCO_3$ (mg/L)	Alkalinity: As Carbonate (mg/L)	Alkalinity: As Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia[2] (mg/L N)	Nitrogen: Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen: TKN (mg/L)	Nitrogen: Organic Nitrogen [3] (mg/L N)	Nitrogen: Total Nitrogen [4] (mg/L)	Nitrogen: Dissolved Inorganic Nitrogen [5] (mg/L N)	Phosphorus: Dissolved (mg/L P)	Phosphorus: Total (mg/L P)	Phosphorus: Dissolved Fraction (%)
Opegano Lake	OLA	17-Jul-01	-	-	-	-	0.02	0.009	0.5	0.480	0.509	0.029	0.008	0.028	29
Opegano Lake	OLA	26-Aug-01	-	-	-	-	0.02	0.012	0.3	0.280	0.312	0.032	0.011	0.032	34
Opegano Lake	OLA	30-Sep-01	-	-	-	-	0.02	0.008	0.5	0.480	0.508	0.028	0.009	0.033	27
Opegano Lake	OLB	31-May-01	-	-	-	-	0.01	0.008	0.6	0.590	0.608	0.018	0.009	0.041	22
Opegano Lake	OLB	17-Jul-01	-	-	-	-	0.02	0.009	0.5	0.480	0.509	0.029	0.007	0.029	24
Opegano Lake	OLB	26-Aug-01	-	-	-	-	0.02	0.011	0.5	0.480	0.511	0.031	0.011	0.034	32
Opegano Lake	OLB	30-Sep-01	-	-	-	-	0.03	0.008	0.5	0.470	0.508	0.038	0.010	0.033	30
Birch Tree Lake	BLA	31-May-01	-	-	-	-	< 0.002	0.006	0.5	0.499	0.506	0.007	0.007	0.039	18
Birch Tree Lake	BLA	17-Jul-01	-	-	-	-	0.002	0.006	0.4	0.398	0.406	0.008	0.007	0.029	24
Birch Tree Lake	BLA	26-Aug-01	-	-	-	-	0.01	< 0.005	0.3	0.290	0.303	0.013	0.010	0.031	32
Birch Tree Lake	BLA	30-Sep-01	-	-	-	-	0.003	0.011	0.5	0.497	0.511	0.014	0.014	0.031	45
Birch Tree Lake	BLB	31-May-01	70	58	< 20	< 10	0.01	0.006	0.5	0.490	0.506	0.016	0.025	0.039	64
Birch Tree Lake	BLB	17-Jul-01	67	55	< 20	< 10	0.01	0.008	0.5	0.490	0.508	0.018	0.007	0.033	21
Birch Tree Lake	BLB	26-Aug-01	69	57	< 20	< 10	0.02	0.009	0.4	0.380	0.409	0.029	0.010	0.038	26
Birch Tree Lake	BLB	30-Sep-01	68	55	< 20	< 10	0.01	0.014	0.4	0.390	0.414	0.024	0.018	0.031	58
Birch Tree Lake	BLC	26-Aug-01	69	57	< 20	< 10	0.02	0.010	0.4	0.380	0.410	0.030	0.010	0.032	31
Birch Tree Lake	BLC	30-Sep-01	-	-	-	-	0.01	0.014	0.5	0.490	0.514	0.024	0.009	0.032	28
Lower Burntwood River	LBRE1	27-Aug-01	-	-	-	-	0.12	< 0.005	0.3	0.180	0.303	0.122	0.009	0.033	27
Lower Burntwood River	LBRE1	30-Sep-01	68	56	< 20	< 10	0.01	0.112	0.6	0.590	0.712	0.013	0.010	0.032	31
Lower Burntwood River [6]	LBRE	27-Aug-01	70	57	< 20	< 10	0.01	< 0.005	0.4	0.390	0.403	0.123	0.013	0.032	41

Table A2-1. - continued -

Sampling Location	Location ID	Sample Date	Alkalinity: As Bicarbonate (mg/L)	Alkalinity: As $CaCO_3$ (mg/L)	Alkalinity: As Carbonate (mg/L)	Alkalinity: As Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia[2] (mg/L N)	Nitrogen: Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen: TKN (mg/L)	Nitrogen: Organic Nitrogen [3] (mg/L N)	Nitrogen: Total Nitrogen [4] (mg/L)	Nitrogen: Dissolved Inorganic Nitrogen [5] (mg/L N)	Phosphorus: Dissolved (mg/L P)	Phosphorus: Total (mg/L P)	Phosphorus: Dissolved Fraction (%)
Lower Burntwood River	LBRF	27-Aug-01	70	57	< 20	< 10	0.01	0.005	0.4	0.390	0.405	0.015	0.011	0.032	34
Lower Burntwood River	LBRF	1-Oct-01	69	56	< 20	< 10	0.03	0.020	0.8	0.770	0.820	0.050	0.009	0.029	31
Ice-cover Season 2001															
Wuskwatim Falls	WF	28-Mar-01	-	-	-	-	0.01	0.08	0.4	0.390	0.480	0.090	0.015	0.030	50
Taskinigup Falls	TF	28-Mar-01	-	-	-	-	0.01	0.08	0.4	0.390	0.480	0.090	0.015	0.028	54
Opegano Lake	OLB	28-Mar-01	66	54	< 20	< 10	0.01	0.09	0.5	0.490	0.590	0.100	0.016	0.027	59
Ice-cover Season 2002															
Cranberry Lakes	CLA	26-Mar-02	63	52	< 20	< 10	0.006	0.066	0.3	0.294	0.366	0.072	0.014	0.022	64
Sesep Lake	SLB	26-Mar-02	-	-	-	-	0.008	0.192	0.5	0.492	0.692	0.200	0.02	0.024	83
Wuskwatim Lake	WuLA	26-Mar-02	-	-	-	-	0.006	0.074	0.3	0.294	0.374	0.080	0.014	0.026	54
Wuskwatim Lake	WuLB	26-Mar-02	64	52	< 20	< 10	0.006	0.065	0.3	0.294	0.365	0.071	0.014	0.025	56
Wuskwatim Lake	WuLC	26-Mar-02	-	-	-	-	0.009	0.076	0.2	0.191	0.276	0.085	0.015	0.026	58
Wuskwatim Brook	WuBA	26-Mar-02	-	-	-	-	0.007	0.108	0.4	0.393	0.508	0.115	0.018	0.035	51
Opegano Lake	OLA	26-Mar-02	-	-	-	-	0.010	0.078	0.5	0.490	0.578	0.088	0.018	0.034	53
Birch Tree Lake	BLA	26-Mar-02	-	-	-	-	0.005	0.078	0.3	0.295	0.378	0.083	0.014	0.026	54
Birch Tree Lake	BLB	27-Mar-02	62	51	< 20	< 10	0.006	0.104	< 0.2	0.094	0.204	0.110	0.013	0.027	48
Birch Tree Lake	BLC	27-Mar-02	63	51	< 20	< 10	0.005	0.072	0.2	0.195	0.272	0.077	0.012	0.027	44
Lower Burntwood River	LBRF	27-Mar-02	65	54	< 20	< 10	0.005	0.076	0.2	0.195	0.276	0.081	0.014	0.054	26

Table A2-1. - continued –

			Nitrogen:Phosphorus Molar Ratios			Organic Carbon (OC)		OC:N Molar Ratios			Water Clarity								
Sampling Location	Location ID	Sample Date	TotN: TotP	DIN: DP	DIN: TP	Total (mg/L)	Dissolved (mg/L)	TOC: ON	TOC: TN	Dissolved Solids (mg/L)	TSS (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations mEq/L	Total Anions mEq/L	Total Cations - Total Anions mEq/L	Chlorophyll *a* (µg/L)
Open-water Season 1999																			
Lower Burntwood River	LBRB	28-May-99	16.8	13.8	2.0	8	8	52	46	-	< 5	-	-	-	-	-	-	-	2
Lower Burntwood River	LBRB	20-Jun-99	35.8	5.5	1.3	7	7	21	20	-	6	-	-	-	-	-	-	-	< 1
Lower Burntwood River	LBRB	23-Aug-99	34.4	1.9	0.6	6	6	18	17	-	8	-	-	-	-	-	-	-	3
Lower Burntwood River	LBRB	23-Sep-99	41.5	2.8	2.0	7	6	14	13	-	7	-	-	-	-	-	-	-	2
Lower Burntwood River	LBRC	02-Jun-99	-	-	-	8	7	-	-	-	9	-	-	-	-	-	-	-	2
Lower Burntwood River	LBRC	26-Jun-99	20.4	-	-	6	7	24	23	-	17	-	-	-	-	-	-	-	2
Lower Burntwood River	LBRC	19-Aug-99	38.9	-	-	6	6	18	17	-	9	-	-	-	-	-	-	-	3
Lower Burntwood River	LBRC	29-Sep-99	31.0	2.8	0.6	6	7	14	14	-	10	-	-	-	-	-	-	-	10
Wuskwatim Lake	WuLA	02-Jun-99	18.9	-	-	8	9	48	46	-	10	-	-	-	-	-	-	-	2
Wuskwatim Lake	WuLA	26-Jun-99	32.0	4.7	1.2	6	7	18	17	-	7	-	-	-	-	-	-	-	1
Wuskwatim Lake	WuLA	19-Aug-99	29.9	-	-	6	6	18	17	-	3	-	-	-	-	-	-	-	4
Wuskwatim Lake	WuLA	29-Sep-99	29.4	3.3	0.9	7	7	17	16	-	7	-	-	-	-	-	-	-	4
Wuskwatim Lake	WuLB	02-Jun-99	37.5	-	-	8	8	32	31	-	5	-	-	-	-	-	-	-	2
Wuskwatim Lake	WuLB	26-Jun-99	21.8	-	-	7	7	28	27	-	9	-	-	-	-	-	-	-	2
Wuskwatim Lake	WuLB	19-Aug-99	20.4	-	-	6	6	24	23	-	3	-	-	-	-	-	-	-	4
Wuskwatim Lake	WuLB	29-Sep-99	27.9	3.3	0.8	7	7	17	16	-	9	-	-	-	-	-	-	-	4

Table A2-1. - continued -

			Nitrogen:Phosphorus Molar Ratios			Organic Carbon (OC)		OC:N Molar Ratios			Water Clarity								
Sampling Location	Location ID	Sample Date	TotN: TotP	DIN: DP	DIN: TP	Total (mg/L)	Dissolved (mg/L)	TOC: ON	TOC: TN	Dissolved Solids (mg/L)	TSS (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations mEq/L	Total Anions mEq/L	Total Cations - Total Anions mEq/L	Chlorophyll *a* (µg/L)
Open-water Season 2000																			
Lower Burntwood River	LBRB	4-Jun-00	32.8	4.7	1.0	10	10	23	24	-	17	-	-	-	-	-	-	-	3
Lower Burntwood River	LBRB	17-Jul-00	15.2	13.3	1.5	6	7	23	25	-	6	-	-	-	-	-	-	-	2
Lower Burntwood River	LBRB	14-Sep-00	25.8	7.4	1.8	10	10	28	30	-	19	-	-	-	-	-	-	-	5
Lower Burntwood River	LBRC	14-Jun-00	27.3	9.5	2.0	7	7	19	21	-	13	-	-	-	-	-	-	-	4
Lower Burntwood River	LBRC	24-Jul-00	29.5	13.8	2.3	8	8	29	32	-	18	-	-	-	-	-	-	-	4
Lower Burntwood River	LBRC	18-Sep-00	36.7	7.9	2.9	9	7	17	18	-	12	-	-	-	-	-	-	-	4
Wuskwatim Lake	WuLA	14-Jun-00	27.3	9.5	2.0	8	9	22	24	-	13	-	-	-	52.7	-	-	-	4
Wuskwatim Lake	WuLA	24-Jul-00	27.2	16.6	2.6	9	8	33	36	-	7	-	-	-	46.8	-	-	-	2
Wuskwatim Lake	WuLA	18-Sep-00	29.5	4.7	1.7	8	7	18	19	-	8	-	-	-	55.2	-	-	-	5
Wuskwatim Lake	WuLB	14-Jun-00	41.5	4.4	2.7	10	10	19	20	-	19	-	-	-	-	-	-	-	2
Wuskwatim Lake	WuLB	24-Jul-00	26.1	19.3	2.8	8	8	28	32	-	7	-	-	-	-	-	-	-	2
Wuskwatim Lake	WuLB	18-Sep-00	34.3	4.3	1.4	9	8	17	18	-	21	-	-	-	-	-	-	-	5
Opegano Lake	OLA	20-Aug-00	24.4	8.3	1.7	7	7	19	21	-	< 5	-	-	-	-	-	-	-	4
Opegano Lake	OLA	24-Sep-00	20.7	5.8	1.6	8	8	22	24	-	13	-	-	-	-	-	-	-	3
Opegano Lake	OLB	15-Aug-00	25.1	7.4	1.8	8	7	22	24	-	< 5	-	-	-	-	-	-	-	2
Opegano Lake	OLB	24-Sep-00	21.2	7.8	2.2	7	8	19	21	-	15	-	-	-	-	-	-	-	6

Table A2-1. - continued -

			Nitrogen:Phosphorus Molar Ratios			Organic Carbon (OC)		OC:N Molar Ratios			Water Clarity								
Sampling Location	Location ID	Sample Date	TotN: TotP	DIN: DP	DIN: TP	Total	Dissolved	TOC: ON	TOC: TN	Dissolved Solids	TSS	Turbidity	True Colour	pH	Hardness as $CaCO_3$	Total Cations	Total Anions	Total Cations - Total Anions	Chlorophyll *a*
						(mg/L)	(mg/L)			(mg/L)	(mg/L)	(NTU)	(TCU)		(mg/L)	mEq/L	mEq/L	mEq/L	(µg/L)
Birch Tree Lake	BLA	25-Jul-00	22.1	18.4	1.7	9	7	33	36	-	13	-	-	-	-	-	-	-	2
Birch Tree Lake	BLA	19-Sep-00	24.8	7.1	2.2	8	8	18	20	-	12	-	-	-	-	-	-	-	4
Birch Tree Lake	BLB	25-Jul-00	40.3	4.7	1.5	8	8	11	12	-	22	-	-	-	-	-	-	-	2
Birch Tree Lake	BLB	19-Sep-00	24.3	12.9	2.6	8	8	28	32	-	15	-	-	-	-	-	-	-	4
Open-water Season 2001																			
Lower Burntwood River	LBRB	29-May-01	31.1	5.7	1.6	11	12	27	25	-	14	-	-	7.91	-	-	-	-	2
Lower Burntwood River	LBRB	15-Jul-01	46.3	2.8	1.1	8	8	19	19	-	8	-	-	7.67	-	-	-	-	3
Lower Burntwood River	LBRB	22-Aug-01	27.7	4.0	1.2	8	7	24	23	-	12	-	-	7.91	-	-	-	-	4
Lower Burntwood River	LBRB	26-Sep-01	55.9	4.9	1.2	7	6	9	9	-	9	-	-	7.77	-	-	-	-	4
Lower Burntwood River	LBRB2	30-May-01	31.9	2.7	0.7	11	10	26	25	86	20	-	60	7.66	56.2	1.35	1.24	0.11	2
Lower Burntwood River	LBRB2	16-Jul-01	41.4	4.7	1.2	8	8	19	18	110	7	-	30	7.64	56.3	1.30	1.27	0.03	4
Lower Burntwood River	LBRB2	23-Aug-01	27.4	3.8	1.3	8	8	24	23	98	10	-	25	7.71	51.4	1.19	1.31	-0.12	3
Lower Burntwood River	LBRB2	27-Sep-01	26.5	7.8	2.5	8	7	25	22	82	9	-	10	7.84	57.0	1.32	1.05	0.27	6
Lower Burntwood River	LBRC	30-May-01	30.4	4.4	1.1	11	10	26	25	-	16	-	-	7.89	-	-	-	-	2
Lower Burntwood River	LBRC	16-Jul-01	41.2	3.9	1.0	8	8	19	19	-	7	-	-	7.82	-	-	-	-	4
Lower Burntwood River	LBRC	23-Aug-01	31.9	2.1	0.9	8	8	19	18	-	10	-	-	7.73	-	-	-	-	4
Lower Burntwood River	LBRC	27-Sep-01	30.4	2.9	0.7	8	7	19	18	-	9	-	-	7.84	-	-	-	-	2

Table A2-1. - continued -

			Nitrogen:Phosphorus Molar Ratios			Organic Carbon (OC)		OC:N Molar Ratios			Water Clarity								
Sampling Location	Location ID	Sample Date	TotN: TotP	DIN: DP	DIN: TP	Total (mg/L)	Dissolved (mg/L)	TOC: ON	TOC: TN	Dissolved Solids (mg/L)	TSS (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations mEq/L	Total Anions mEq/L	Total Cations - Total Anions mEq/L	Chlorophyll *a* (µg/L)
Sesep Lake	SLA	30-May-01	56.1	5.0	3.0	13	13	32	30	-	< 2	-	-	7.68	-	-	-	-	1
Sesep Lake	SLA	16-Jul-01	59.2	4.5	1.7	15	16	22	22	-	< 2	-	-	7.57	-	-	-	-	11
Sesep Lake	SLA	23-Aug-01	50.7	3.8	1.4	15	16	22	22	-	4	-	-	7.57	-	-	-	-	16
Sesep Lake	SLA	27-Sep-01	83.2	3.8	2.1	15	15	20	19	-	3	-	-	7.84	-	-	-	-	12
Wuskwatim Lake	WuLA	30-May-01	29.8	2.9	0.8	11	11	26	25	-	17	-	-	7.88	-	-	-	-	3
Wuskwatim Lake	WuLA	16-Jul-01	51.7	7.7	2.4	9	9	18	17	-	5	-	-	7.80	-	-	-	-	5
Wuskwatim Lake	WuLA	23-Aug-01	32.8	4.6	1.6	11	9	27	25	-	7	-	-	7.79	-	-	-	-	4
Wuskwatim Lake	WuLA	27-Sep-01	30.4	4.0	1.1	7	7	17	16	-	2	-	-	7.94	-	-	-	-	4
Wuskwatim Lake	WuLB	30-May-01	31.2	2.2	0.6	11	10	26	25	90	24	-	60	7.71	59.3	1.41	1.28	0.13	2
Wuskwatim Lake	WuLB	16-Jul-01	35.6	3.9	1.1	9	8	27	26	100	3	-	40	7.78	55.9	1.29	1.07	0.22	4
Wuskwatim Lake	WuLB	23-Aug-01	34.7	2.5	0.9	10	8	24	23	90	6	-	20	7.86	55.5	1.31	1.36	-0.05	4
Wuskwatim Lake	WuLB	27-Sep-01	23.1	3.8	1.0	8	7	24	23	74	13	-	< 5	7.89	59.2	1.38	1.11	0.27	4
Wuskwatim Lake	WuLC	30-May-01	56.0	4.8	2.6	17	17	34	33	-	4	-	-	7.51	-	-	-	-	3
Wuskwatim Lake	WuLC	16-Jul-01	60.0	3.2	1.4	17	17	29	28	-	4	-	-	7.58	-	-	-	-	6
Wuskwatim Lake	WuLC	23-Aug-01	37.1	4.6	1.6	15	15	23	22	-	8	-	-	7.73	-	-	-	-	12
Wuskwatim Lake	WuLC	27-Sep-01	55.9	6.8	2.5	16	15	21	21	-	7	-	-	7.80	-	-	-	-	11
Wuskwatim Brook	WuBA	30-May-01	74.8	4.2	2.3	18	20	36	34	-	3	-	-	7.38	-	-	-	-	3
Wuskwatim Brook	WuBA	16-Jul-01	91.4	5.5	2.9	20	20	34	33	-	< 2	-	-	7.36	-	-	-	-	4

Table A2-1. - continued -

			Nitrogen:Phosphorus Molar Ratios			Organic Carbon (OC)		OC:N Molar Ratios			Water Clarity								
Sampling Location	Location ID	Sample Date	TotN: TotP	DIN: DP	DIN: TP	Total (mg/L)	Dissolved (mg/L)	TOC: ON	TOC: TN	Dissolved Solids (mg/L)	TSS (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations mEq/L	Total Anions mEq/L	Total Cations - Total Anions mEq/L	Chlorophyll *a* (µg/L)
Wuskwatim Brook	WuBA	23-Aug-01	63.4	2.9	1.8	20	20	30	29	-	< 2	-	-	7.45	-	-	-	-	10
Wuskwatim Brook	WuBA	27-Sep-01	73.9	2.8	1.2	20	19	30	29	-	4	-	-	7.61	-	-	-	-	15
Taskinigup Falls	TF	30-May-01	34.6	4.6	1.2	11	10	22	21	90	24	-	50	7.68	57.7	1.37	1.26	0.11	2
Taskinigup Falls	TF	16-Jul-01	37.8	8.1	2.4	8	8	19	18	100	6	-	30	7.69	58.5	1.37	1.31	0.06	4
Taskinigup Falls	TF	23-Aug-01	29.2	5.8	2.1	7	7	21	20	92	8	-	25	7.84	58.6	1.35	1.36	-0.01	2
Taskinigup Falls	TF	27-Sep-01	32.0	2.5	0.6	7	7	16	16	72	10	-	15	7.89	60.5	1.41	1.13	0.28	4
Opegano Lake	OLA	31-May-01	28.7	4.2	1.0	12	12	29	28	-	14	-	-	7.91	-	-	-	-	3
Opegano Lake	OLA	17-Jul-01	40.2	8.0	2.3	9	10	22	21	-	6	-	-	7.85	-	-	-	-	3
Opegano Lake	OLA	26-Aug-01	21.6	6.4	2.2	6	7	25	22	-	10	-	-	7.88	-	-	-	-	4
Opegano Lake	OLA	30-Sep-01	34.0	6.9	1.9	7	7	17	16	-	8	-	-	7.89	-	-	-	-	4
Opegano Lake	OLB	31-May-01	32.8	4.4	1.0	13	13	26	25	-	14	-	-	7.94	-	-	-	-	5
Opegano Lake	OLB	17-Jul-01	38.8	9.2	2.2	9	8	22	21	-	7	-	-	7.80	-	-	-	-	2
Opegano Lake	OLB	26-Aug-01	33.2	6.2	2.0	7	7	17	16	-	9	-	-	7.84	-	-	-	-	4
Opegano Lake	OLB	30-Sep-01	34.0	8.4	2.5	8	7	20	18	-	9	-	-	7.80	-	-	-	-	5
Birch Tree Lake	BLA	31-May-01	28.7	2.2	0.4	10	10	23	23	-	13	-	-	8.10	-	-	-	-	4
Birch Tree Lake	BLA	17-Jul-01	31.0	2.5	0.6	8	8	23	23	-	5	-	-	7.88	-	-	-	-	4
Birch Tree Lake	BLA	26-Aug-01	21.6	2.8	0.9	8	7	32	31	-	6	-	-	7.88	-	-	-	-	4
Birch Tree Lake	BLA	30-Sep-01	36.5	2.2	1.0	9	9	21	21	-	10	-	-	7.84	-	-	-	-	3

Table A2-1. - continued -

Sampling Location	Location ID	Sample Date	Nitrogen:Phosphorus Molar Ratios TotN: TotP	DIN: DP	DIN: TP	Organic Carbon (OC) Total (mg/L)	Dissolved (mg/L)	OC:N Molar Ratios TOC: ON	TOC: TN	Dissolved Solids (mg/L)	Water Clarity TSS (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations mEq/L	Total Anions mEq/L	Total Cations - Total Anions mEq/L	Chlorophyll *a* (µg/L)
Birch Tree Lake	BLB	31-May-01	28.7	1.4	0.9	12	11	29	28	98	33	-	120	8.07	47.3	1.07	1.39	-0.32	4
Birch Tree Lake	BLB	17-Jul-01	34.0	5.7	1.2	8	7	19	18	110	6	-	35	7.82	58.6	1.32	1.10	0.22	3
Birch Tree Lake	BLB	26-Aug-01	23.8	6.4	1.7	7	7	21	20	92	11	-	40	7.80	57.9	1.30	1.13	0.17	5
Birch Tree Lake	BLB	30-Sep-01	29.5	2.9	1.7	9	9	27	25	70	13	-	25	7.76	58.4	1.30	1.11	0.19	4
Birch Tree Lake	BLC	26-Aug-01	28.3	6.6	2.1	8	9	25	23	94	9	-	25	7.84	58.1	1.34	1.13	0.21	5
Birch Tree Lake	BLC	30-Sep-01	35.5	5.9	1.7	9	9	21	20	-	13	-	-	7.86	-	-	-	-	2
Lower Burntwood River	LBRE1	27-Aug-01	49.2	27.0	8.4	7	7	45	27	-	8	-	-	7.88	-	-	-	-	5
Lower Burntwood River	LBRE1	30-Sep-01	27.8	2.1	0.9	9	9	18	15	80	11	-	30	7.78	60.8	1.41	1.11	0.30	3
Lower Burntwood River [6]	LBRE	27-Aug-01	20.3	30.1	8.2	6	7	18	17	68	10	-	25	7.92	62.9	1.45	1.39	0.06	6
Lower Burntwood River	LBRF	27-Aug-01	28.0	3.0	1.0	8	7	24	23	64	10	-	25	7.88	59.6	1.38	1.15	0.23	5
Lower Burntwood River	LBRF	1-Oct-01	62.5	12.3	3.8	9	8	14	13	92	17	-	20	7.89	60.1	1.40	1.13	0.27	2
Ice-cover Season 2001																			
Wuskwatim Falls	WF	28-Mar-01	35.4	13.3	6.6	9	9	27	22	-	5	-	-	7.42	-	-	-	-	< 1
Taskinigup Falls	TF	28-Mar-01	37.9	13.3	7.1	9	9	27	22	-	8	-	-	7.54	-	-	-	-	< 1
Opegano Lake	OLB	28-Mar-01	48.3	13.8	8.2	9	10	21	18	160	8	-	20	7.56	55.0	1.29	1.33	-0.04	< 1

Table A2-1. - continued -

Sampling Location	Location ID	Sample Date	Nitrogen:Phosphorus Molar Ratios			Organic Carbon (OC)		OC:N Molar Ratios		Dissolved Solids	Water Clarity			pH	Hardness as $CaCO_3$	Total Cations	Total Anions	Total Cations - Total Anions	Chlorophyll *a*
			TotN: TotP	DIN: DP	DIN: TP	Total	Dissolved	TOC: ON	TOC: TN		TSS	Turbidity	True Colour						
						(mg/L)	(mg/L)			(mg/L)	(mg/L)	(NTU)	(TCU)		(mg/L)	mEq/L	mEq/L	mEq/L	(µg/L)
Ice-cover Season 2002																			
Cranberry Lakes	CLA	26-Mar-02	36.8	11.4	7.2	8	8	32	25	82	3	13	20	7.38	49.8	1.19	1.03	0.16	< 1
Sesep Lake	SLB	26-Mar-02	63.8	22.1	18.4	13	14	31	22	-	< 2	4.6	-	7.00	-	-	-	-	1
Wuskwatim Lake	WuLA	26-Mar-02	31.8	12.6	6.8	8	9	32	25	-	5	15	-	7.36	-	-	-	-	3
Wuskwatim Lake	WuLB	26-Mar-02	32.3	11.2	6.3	8	9	32	26	82	3	14	25	7.4	49.4	1.18	1.05	0.13	2
Wuskwatim Lake	WuLC	26-Mar-02	23.5	12.5	7.2	8	9	49	34	-	2	16	-	7.48	-	-	-	-	< 1
Wuskwatim Brook	WuBA	26-Mar-02	32.1	14.1	7.3	9	9	27	21	-	2	18	-	7.17	-	-	-	-	2
Opegano Lake	OLA	26-Mar-02	37.6	10.8	5.7	9	9	21	18	-	9	18	-	7.47	-	-	-	-	< 1
Birch Tree Lake	BLA	26-Mar-02	32.1	13.1	7.1	9	9	36	28	-	5	18	-	7.56	-	-	-	-	2
Birch Tree Lake	BLB	27-Mar-02	16.7	18.7	9.0	8	8	99	46	84	9	20	25	7.46	50.6	1.21	1.02	0.19	1
Birch Tree Lake	BLC	27-Mar-02	22.3	14.2	6.3	8	8	48	34	80	7	20	30	7.48	49.6	1.18	1.03	0.15	< 1
Lower Burntwood River	LBRF	27-Mar-02	11.3	12.8	3.3	8	9	48	34	80	40	36	30	7.57	62.2	1.47	1.07	0.40	< 1

[1] Abbreviations are as follows: TKN = total kjeldahl nitrogen; TOT N = total nitrogen; TOT P = total phosphorus; DIN = dissolved inorganic nitrogen; DP = dissolved phosphorus; OC = organic carbon; TOC = total organic carbon; ON = organic nitrogen; and, TSS = total suspended solids.
[2] Where values are indicated to 2 decimal places, analytical detection limit is 0.01 mg/L; Where values are indicated to 3 decimal places, analytical detection limit is 0.002 mg/L.
[3] Organic nitrogen estimated from: TKN – dissolved ammonia.
[4] Total nitrogen estimated from TKN + dissolved nitrate/nitrite.
[5] Dissolved inorganic nitrogen is the sum of dissolved ammonia and nitrate/nitrite nitrogen.
[6] One sample of water was collected on the lower Burntwood River downstream of the Manasan River in August 2001; due to problems with accessibility, this site was not visited again.

Table A2-2. Water quality parameters measured *in situ* in the main study area 1999 – 2002.

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m-1)	z_1 [3] (m)	pH
Open-water Season 1999												
Lower Burntwood River	LBRB	28-May-99	4.90	10.6	10.05	92.0	100.0	29.0	0.38	3.42	1.25	7.60
Lower Burntwood River	LBRB	20-Jun-99	-	17.2	-	-	105.1	22.2	0.60	2.17	1.98	7.11
Lower Burntwood River	LBRB	23-Aug-99	-	18.2	6.57	70.2	108.8	25.3	0.55	2.36	1.82	-
Lower Burntwood River	LBRB	23-Sep-99	-	11.3	10.30	95.7	115.9	39.0	0.35	3.71	1.16	7.93
Lower Burntwood River	LBRC	2-Jun-99	-	11.5	11.08	103.3	101.0	24.5	0.60	2.17	1.98	-
Lower Burntwood River	LBRC	26-Jun-99	-	15.5	-	-	107.9	35.9	0.30	4.33	0.99	7.16
Lower Burntwood River	LBRC	19-Aug-99	-	18.5	7.39	79.4	110.5	30.3	0.48	2.71	1.58	-
Lower Burntwood River	LBRC	29-Sep-99	-	10.6	10.71	98.1	117.1	37.9	-	-	-	8.12
Wuskwatim Lake	WuLA	2-Jun-99	9.50	13.2	9.53	92.0	103.2	26.1	0.55	2.36	1.82	-
Wuskwatim Lake	WuLA	26-Jun-99	8.00	16.4	-	-	109.8	24.6	0.42	3.10	1.39	7.20
Wuskwatim Lake	WuLA	19-Aug-99	7.50	18.0	7.90	84.1	110.8	25.5	0.40	3.25	1.32	-
Wuskwatim Lake	WuLA	29-Sep-99	8.60	10.2	10.21	92.7	119.3	41.1	0.40	3.25	1.32	8.32
Wuskwatim Lake	WuLB	2-Jun-99	7.75	13.5	9.33	90.6	103.0	23.4	0.60	2.17	1.98	-
Wuskwatim Lake	WuLB	26-Jun-99	7.75	16.7	-	-	110.2	31.1	0.38	3.42	1.25	7.04
Wuskwatim Lake	WuLB	19-Aug-99	7.60	18.2	7.90	84.4	111.4	27.0	0.40	3.25	1.32	-
Wuskwatim Lake	WuLB	29-Sep-99	7.70	10.4	10.43	95.1	118.4	41.9	0.40	3.25	1.32	8.20

Table A2-2. - continued -

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m-1)	z_1 [3] (m)	pH
Open-water Season 2000												
Lower Burntwood River	LBRB	04-Jun-00	-	9.7	12.03	108.2	93.7	30.3	-	-	-	-
Lower Burntwood River	LBRB	17-Jul-00	5.0	15.8	7.81	79.5	103.8	54.3	-	-	-	-
Lower Burntwood River	LBRB	14-Sep-00	-	13.6	8.82	85.8	109.1	37.5	0.4	3.71	1.16	-
Lower Burntwood River	LBRC	14-Jun-00	-	-	-	-	-	-	-	-	-	-
Lower Burntwood River	LBRC	24-Jul-00	-	18.2	9.72	103.9	101.0	28.0	-	-	-	7.64
Lower Burntwood River	LBRC	18-Sep-00	-	12.7	9.02	86.2	110.6	46.7	-	-	-	8.28
Wuskwatim Lake	WuLA	14-Jun-00	-	-	-	-	-	-	-	-	-	-
Wuskwatim Lake	WuLA	24-Jul-00	9.6	18.2	9.33	99.7	102.0	26.9	0.6	2.17	1.98	8.18
Wuskwatim Lake	WuLA	18-Sep-00	-	12.7	9.50	90.8	110.6	40.3	0.3	4.33	0.99	8.30
Wuskwatim Lake	WuLB	14-Jun-00	-	-	-	-	-	-	-	-	-	-
Wuskwatim Lake	WuLB	24-Jul-00	8.5	19.0	9.40	102.1	104.7	31.3	0.5	2.60	1.65	7.61
Wuskwatim Lake	WuLB	18-Sep-00	-	12.6	9.24	88.1	112.5	50.0	0.4	3.71	1.16	7.85
Taskinigup Falls	TF	25-May-00	-	-	-	-	-	-	-	-	-	-
Taskinigup Falls	TF	23-Jul-00	-	-	-	-	-	-	-	-	-	-
Taskinigup Falls	TF	18-Sep-00	-	-	-	-	-	-	-	-	-	-
Opegano Lake	OLA	20-Aug-00	7.8	18.6	9.23	99.3	105.8	42.2	0.4	3.42	1.25	8.17
Opegano Lake	OLA	24-Sep-00	-	10.0	10.72	96.8	112.4	49.2	0.2	6.50	0.66	8.42
Opegano Lake	OLB	15-Aug-00	8.0	18.7	9.40	101.3	105.7	39.6	0.4	3.33	1.29	7.6
Opegano Lake	OLB	24-Sep-00	-	10.1	10.95	99.1	112.6	49.6	0.2	6.50	0.66	8.49

Table A2-2. - continued -

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m-1)	z_1 [3] (m)	pH
Birch Tree Lake	BLA	25-Jul-00	6.9	20.3	8.32	92.6	109.1	32.8	0.4	3.25	1.32	8.29
Birch Tree Lake	BLA	19-Sep-00	7.0	12.1	8.47	79.8	115.4	52.5	0.3	5.20	0.83	8.48
Birch Tree Lake	BLB	25-Jul-00	8.0	18.7	8.91	96.0	107.1	45.5	0.4	3.25	1.32	7.89
Birch Tree Lake	BLB	19-Sep-00	8.0	12.1	8.60	81.1	115.3	54.9	0.3	5.20	0.83	8.61
Open-water Season 2001												
Lower Burntwood River	LBRB	29-May-01	>10	10.7	9.59	88.0	94	56	-	-	-	7.70
Lower Burntwood River	LBRB	15-Jul-01	3.5	18.6	9.50	102.3	103	29	-	-	-	8.01
Lower Burntwood River	LBRB	22-Aug-01	>10	18.0	9.90	105.4	104	36	-	-	-	7.94
Lower Burntwood River	LBRB	26-Sep-01	9.0	11.7	10.40	97.4	100	43	-	-	-	8.29
Lower Burntwood River	LBRB2	30-May-01	>10	11.5	9.88	92.1	92	62	-	-	-	8.39
Lower Burntwood River	LBRB2	16-Jul-01	10.0	19.0	10.70	116.2	103	29	-	-	-	7.81
Lower Burntwood River	LBRB2	23-Aug-01	>10	17.5	10.30	108.5	104	37	-	-	-	7.95
Lower Burntwood River	LBRB2	27-Sep-01	>10	11.9	11.00	103.4	100	42	-	-	-	8.29
Lower Burntwood River	LBRC	30-May-01	>10	11.3	9.73	90.4	93	57	-	-	-	8.13
Lower Burntwood River	LBRC	16-Jul-01	>10	19.3	10.80	118.0	104	28	-	-	-	7.96
Lower Burntwood River	LBRC	23-Aug-01	>10	17.5	10.30	108.5	105	38	-	-	-	7.94
Lower Burntwood River	LBRC	27-Sep-01	>10	11.8	10.80	101.3	95	46	-	-	-	8.30
Sesep Lake	SLA	30-May-01	3.0	15.2	7.66	77.0	113	2	2.7	0.48	8.91	8.04
Sesep Lake	SLA	16-Jul-01	3.0	22.2	8.90	103.1	127	4	1.6	0.81	5.28	7.72
Sesep Lake	SLA	23-Aug-01	3.0	17.5	9.10	95.9	139	5	1.7	0.76	5.61	7.69

Table A2-2. - continued -

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m-1)	z_1 [3] (m)	pH
Sesep Lake	SLA	27-Sep-01	3.0	10.7	11.30	103.7	137	4	1.9	0.68	6.27	8.24
Wuskwatim Lake	WuLA	30-May-01	9.0	11.4	9.38	87.3	96	64	0.4	3.25	1.32	7.93
Wuskwatim Lake	WuLA	16-Jul-01	8.5	19.5	10.10	110.8	101	22	0.6	2.17	1.98	7.85
Wuskwatim Lake	WuLA	23-Aug-01	8.5	17.8	10.10	107.1	107	36	0.6	2.17	1.98	7.44
Wuskwatim Lake	WuLA	27-Sep-01	9.0	11.2	10.60	98.3	101	45	0.5	2.60	1.65	8.24
Wuskwatim Lake	WuLB	30-May-01	8.0	11.6	9.38	87.7	98	53	0.4	3.25	1.32	8.09
Wuskwatim Lake	WuLB	16-Jul-01	7.5	19.8	9.50	104.9	105	20	0.6	2.17	1.98	8.15
Wuskwatim Lake	WuLB	23-Aug-01	7.5	17.5	10.20	107.5	109	30	0.7	1.86	2.31	7.90
Wuskwatim Lake	WuLB	27-Sep-01	8.0	11.1	10.80	99.9	104	49	0.5	2.60	1.65	8.32
Wuskwatim Lake	WuLC	30-May-01	4.0	15.1	7.92	79.5	75	9	1.2	1.08	3.96	7.77
Wuskwatim Lake	WuLC	16-Jul-01	3.0	22.5	9.40	109.6	100	12	1.0	1.30	3.30	7.74
Wuskwatim Lake	WuLC	23-Aug-01	3.0	17.6	10.20	107.7	120	27	0.8	1.63	2.64	7.96
Wuskwatim Lake	WuLC	27-Sep-01	3.0	10.9	10.80	99.5	117	22	0.7	1.86	2.31	8.25
Wuskwatim Brook	WuBA	30-May-01	3.0	15.6	7.61	77.1	74	9	-	-	-	7.51
Wuskwatim Brook	WuBA	16-Jul-01	2.0	23.4	8.70	103.3	93	4	-	-	-	7.55
Wuskwatim Brook	WuBA	23-Aug-01	2.0	18.2	9.40	100.4	113	5	1.3	1.00	4.29	7.64
Wuskwatim Brook	WuBA	27-Sep-01	2.0	11.0	10.90	100.6	118	5	-	-	-	8.04
Taskinigup Falls	TF	30-May-01	shore	11.3	9.87	91.7	97	63	-	-	-	8.36
Taskinigup Falls	TF	16-Jul-01	shore	18.8	10.80	116.8	104	34	-	-	-	8.05
Taskinigup Falls	TF	23-Aug-01	shore	17.5	11.20	118.0	110	29	-	-	-	7.97

Table A2-2. - continued -

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m-1)	z_1 [3] (m)	pH
Taskinigup Falls	TF	27-Sep-01	shore	11.0	12.00	110.8	106	50	-	-	-	8.23
Opegano Lake	OLA	31-May-01	4.0	12.1	9.94	93.7	99	62	0.4	3.25	1.32	8.22
Opegano Lake	OLA	17-Jul-01	4.5	19.2	10.70	116.5	106	36	0.6	2.17	1.98	7.55
Opegano Lake	OLA	26-Aug-01	2.5	17.7	11.10	117.2	109	33	0.5	2.60	1.65	7.78
Opegano Lake	OLA	30-Sep-01	3.5	11.4	11.30	105.0	105	44	0.5	2.60	1.65	8.14
Opegano Lake	OLB	31-May-01	5.0	12.2	9.91	93.6	99	64	0.4	3.25	1.32	8.47
Opegano Lake	OLB	17-Jul-01	3.0	19.1	11.10	120.6	106	33	-	-	-	7.89
Opegano Lake	OLB	26-Aug-01	4.0	17.7	10.90	115.1	109	39	0.5	2.60	1.65	7.89
Opegano Lake	OLB	30-Sep-01	3.5	11.8	11.20	104.9	104	43	0.5	2.60	1.65	7.92
Birch Tree Lake	BLA	31-May-01	6.0	12.6	9.44	89.9	102	60	0.4	3.25	1.32	8.46
Birch Tree Lake	BLA	17-Jul-01	6.0	20.2	10.70	118.9	108	36	0.5	2.60	1.65	8.12
Birch Tree Lake	BLA	26-Aug-01	5.5	18.1	10.40	110.7	111	33	-	-	-	8.14
Birch Tree Lake	BLA	30-Sep-01	6.0	11.4	11.10	103.1	108	43	0.5	2.60	1.65	8.25
Birch Tree Lake	BLB	31-May-01	6.5	12.3	9.81	92.8	100	70	0.4	3.25	1.32	8.44
Birch Tree Lake	BLB	17-Jul-01	7.0	19.8	10.90	120.1	107	48	0.5	2.60	1.65	7.99
Birch Tree Lake	BLB	26-Aug-01	7.0	18.1	10.70	113.9	105	37	0.5	2.60	1.65	7.98
Birch Tree Lake	BLB	30-Sep-01	7.0	11.5	11.50	107.1	106	48	0.5	2.60	1.65	8.30
Birch Tree Lake	BLC	26-Aug-01	12.0	18.0	10.60	112.6	110	36	0.6	2.17	1.98	7.93
Birch Tree Lake	BLC	30-Sep-01	11.0	11.5	11.30	105.2	106	48	0.5	2.60	1.65	8.30
Lower Burntwood River	LBRE1	27-Aug-01	>10	17.6	10.50	110.7	111	36	-	-	-	7.97

Table A2-2. - continued -

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m^{-1})	z_1 [3] (m)	pH
Lower Burntwood River	LBRE1	30-Sep-01	>10	11.5	11.2	104.3	106	51	-	-	-	8.33
Lower Burntwood River [4]	LBRE	27-Aug-01	>10	17.6	11.0	115.9	111	38	-	-	-	8.11
Lower Burntwood River	LBRF	27-Aug-01	4.0	17.7	11.5	121.4	111	38	-	-	-	8.17
Lower Burntwood River	LBRF	01-Oct-01	>10	11.4	11.9	110.6	107	52	-	-	-	8.16
Ice-cover Season 2001												
Wuskwatim Falls	WF	28-Mar-01	3.25	0.2	15.40	114.2	60	18	-	-	-	-
Taskinigup Falls	TF	28-Mar-01	-	0.2	16.90	125.3	61	24	-	-	-	-
Opegano Lake	OLB	28-Mar-01	4.5	0.2	15.96	118.1	60	24	-	-	-	-
Ice-cover Season 2002												
Cranberry Lakes	CLA	26-Mar-02	2.7	0.1	13.08	96.8	58.6	-	0.8	1.63	2.64	-
Sesep Lake	SLB	26-Mar-02	2.3	0.9	8.02	60.3	98.80 [5]	-	0.8	1.63	2.64	-
Wuskwatim Lake	WuLA	26-Mar-02	7.5	0.1	13.52	100.0	58.3	-	0.5	2.60	1.65	-
Wuskwatim Lake	WuLB	26-Mar-02	7.4	0.1	13.60	100.6	58.7	-	0.5	2.60	1.65	-
Wuskwatim Lake	WuLC	26-Mar-02	2.5	0.1	13.24	98.0	57.1	-	0.7	1.86	2.31	-
Wuskwatim Brook	WuBA	26-Mar-02	0.6	0.5	8.51	63.5	71.4	-	-	-	-	-
Opegano Lake	OLA	26-Mar-02	3.2	0.1	13.73	101.4	58.6	-	-	-	-	-
Birch Tree Lake	BLA	26-Mar-02	5.4	0.1	13.61	100.5	57.3	-	-	-	-	-
Birch Tree Lake	BLB	27-Mar-02	4.7	0.1	12.98	95.9	59.4	-	-	-	-	-

Table A2-2. - continued -

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (ºC)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m-1)	z_1 [3] (m)	pH
Birch Tree Lake	BLC	27-Mar-02	6.6	0.1	12.55	92.7	59.4	-	-	-	-	-
Lower Burntwood River	LBRF	27-Mar-02	10.5	0.1	12.72	94.0	59.9	-	-	-	-	-

[1] In ice-cover season refers to the effective depth: Effective depth = Water depth – ice depth.
[2] Ke is the light extinction coefficient, estimated from secchi depths.
[3] z_1 is the depth of the euphotic zone (depth where 1% of surface irradiation still remains), estimated from Secchi depths.
[4] One sample of water was collected on the lower Burntwood River downstream of the Manasan River in August 2001; due to problems with accessibility, this site was not visited
[5] Conductivity varied vertically: surface 98.80 µS/cm; middle 114.2 µS/cm; and bottom 280.0 µS/cm.

Table A2-3. Temperature, conductivity, dissolved oxygen, pH, and turbidity depth profiles for the study area, 1999 – 2002.

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
Open-water Season 1999										
Wuskwatim Lake	WuLA	2-Jun-99	9.50	0	13.2	103.2	9.53	92.21	-	-
				1	12.8	103.1	9.58	91.95	-	-
				2	12.6	102.9	9.57	91.48	-	-
				3	12.2	102.6	9.63	91.31	-	-
				4	12.0	102.2	9.65	91.13	-	-
				5	11.5	102.2	9.68	90.49	-	-
				6	11.2	102.0	9.64	89.57	-	-
				7	11.1	102.4	9.65	89.48	-	-
				8	11.0	102.3	9.65	89.30	-	-
				9	10.9	103.2	9.48	87.54	-	-
Wuskwatim Lake	WuLA	26-Jun-99	8.00	0	16.4	109.8	-	-	-	-
				1	16.4	109.8	-	-	-	-
				2	16.4	109.8	-	-	-	-
				3	16.4	109.8	-	-	-	-
				4	16.4	109.8	-	-	-	-
				5	16.4	109.8	-	-	-	-
				6	16.4	109.8	-	-	-	-
				7	16.4	109.8	-	-	-	-
				8	16.4	109.8	-	-	-	-
Wuskwatim Lake	WuLA	19-Aug-99	7.50	0	18.0	-	7.90	84.26	-	-
				1	17.7	-	7.90	83.75	-	-
				2	17.5	-	7.88	83.20	-	-
				3	17.4	-	7.85	82.72	-	-

Table A2-3. –continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				4	17.2	-	7.80	81.86	-	-
				5	17.1	-	7.60	79.60	-	-
				6	16.8	-	7.18	74.74	-	-
				7	16.1	-	6.68	68.55	-	-
Wuskwatim Lake	WuLA	29-Sep-99	8.60	0	10.2	119.3	10.21	92.95	-	-
				1	10.2	119.3	10.22	93.05	-	-
				2	10.2	119.3	10.16	92.50	-	-
				3	10.2	119.3	10.14	92.32	-	-
				4	10.2	119.3	10.05	91.50	-	-
				5	10.2	119.3	10.03	91.32	-	-
				6	10.2	119.3	10.01	91.13	-	-
				7	10.2	119.3	9.96	90.71	-	-
				8	10.2	119.5	9.94	90.50	-	-
				9	10.2	119.3	9.84	89.59	-	-
Wuskwatim Lake	WuLB	2-Jun-99	7.75	0	13.5	103.0	9.33	90.83	-	-
				1	12.7	103.1	9.36	89.65	-	-
				2	12.6	103.0	9.34	89.28	-	-
				3	11.9	103.3	9.28	87.45	-	-
				4	11.5	103.6	9.21	86.09	-	-
				5	10.9	104.1	9.18	84.77	-	-
				6	10.7	104.6	9.12	83.88	-	-
				7	10.5	105.2	8.93	81.80	-	-
				8	10.2	106.2	8.66	78.84	-	-

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
Wuskwatim Lake	WuLB	26-Jun-99	7.75	0	16.7	110.2	-	-	-	-
				1	16.7	110.2	-	-	-	-
				2	16.7	110.2	-	-	-	-
				3	16.7	110.2	-	-	-	-
				4	16.7	110.2	-	-	-	-
				5	16.7	110.2	-	-	-	-
				6	16.7	110.2	-	-	-	-
				7	16.7	110.2	-	-	-	-
				8	16.7	110.2	-	-	-	-
Wuskwatim Lake	WuLB	19-Aug-99	7.60	0	18.2	-	7.90	84.61	-	-
				1	17.4	-	7.99	84.19	-	-
				2	17.2	-	7.88	82.70	-	-
				3	17.2	-	7.86	82.49	-	-
				4	17.1	-	7.85	82.21	-	-
				5	17.1	-	7.84	82.11	-	-
				6	17.0	-	7.62	79.64	-	-
				7	16.7	-	7.48	77.71	-	-
Wuskwatim Lake	WuLB	29-Sep-99	7.70	0	10.4	118.4	10.43	95.34	-	-
				1	10.4	118.4	10.40	95.07	-	-
				2	10.4	118.4	10.39	94.98	-	-
				3	10.4	118.4	10.33	94.43	-	-
				4	10.4	118.4	10.31	94.25	-	-
				5	10.4	118.3	10.25	93.70	-	-
				6	10.4	118.3	10.21	93.33	-	-

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (^{o}C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				7	10.4	118.3	10.16	92.88	-	-
				8	10.4	118.3	10.13	92.60	-	-
Open-water Season 2000										
Wuskwatim Lake	WuLA	24-Jul-00	9.60	0	18.2	102.0	9.33	99.92	-	-
				1	18.2	102.0	9.18	98.31	-	-
				2	18.2	102.0	9.09	97.35	-	-
				3	18.2	102.1	9.02	96.60	-	-
				4	18.1	102.2	9.30	99.40	-	-
				5	18.1	101.8	9.31	99.50	-	-
				6	18.1	101.7	9.26	98.97	-	-
				7	18.1	101.5	9.29	99.29	-	-
				8	18.1	101.7	9.27	99.08	-	-
				9	18.1	101.7	9.25	98.86	-	-
				10	-	-	-	-	-	-
Wuskwatim Lake	WuLA	18-Sep-00	-	0	12.7	110.6	9.50	90.99	-	-
				1	12.7	110.6	9.38	89.84	-	-
				2	12.7	110.6	9.33	89.37	-	-
				3	12.7	110.6	9.31	89.17	-	-
				4	12.7	110.6	9.29	88.98	-	-
				5	12.7	110.6	9.28	88.89	-	-
				6	12.7	110.6	9.27	88.79	-	-
				7	12.7	110.6	9.27	88.79	-	-
				8	12.7	110.6	9.26	88.69	-	-
				9	12.7	110.6	9.23	88.41	-	-

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				10	12.7	110.6	9.18	87.93	-	-
Wuskwatim Lake	WuLB	24-Jul-00	8.50	0	19.0	104.7	9.40	102.32	-	-
				1	18.8	104.7	9.30	100.82	-	-
				2	18.7	104.6	9.26	100.18	-	-
				3	18.4	104.0	9.26	99.58	-	-
				4	18.2	104.0	9.23	98.85	-	-
				5	18.2	104.3	9.19	98.42	-	-
				6	17.4	103.0	9.08	95.68	-	-
				7	16.3	107.3	8.67	89.34	-	-
				8	16.0	109.9	8.07	82.65	-	-
Wuskwatim Lake	WuLB	18-Sep-00	9.00	0	12.6	112.5	9.24	88.32	-	-
				1	12.6	112.5	9.22	88.13	-	-
				2	12.6	112.5	9.23	88.23	-	-
				3	12.6	112.6	9.15	87.46	-	-
				4	12.6	112.6	9.12	87.18	-	-
				5	12.6	112.6	9.12	87.18	-	-
				6	12.6	112.8	9.09	86.89	-	-
				7	12.6	112.9	9.06	86.60	-	-
				8	12.6	112.9	9.05	86.51	-	-
				9	12.6	112.9	9.04	86.41	-	-
Opegano Lake	OLA	15-Aug-00	7.80	0	18.6	105.8	9.23	99.66	-	-
				1	18.6	105.8	9.23	99.66	-	-

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				2	18.6	105.7	9.23	99.66	-	-
				3	18.6	105.7	9.23	99.66	-	-
				4	18.6	105.7	9.23	99.66	-	-
				5	18.6	105.7	9.23	99.66	-	-
				6	18.6	105.7	9.32	100.63	-	-
				7	18.6	105.7	9.32	100.63	-	-
				7.5	18.6	105.7	9.32	100.63	-	-
Opegano Lake	OLB	15-Aug-00	8.00	0	18.7	105.7	9.40	101.70	-	-
				1	18.7	105.7	9.40	101.70	-	-
				2	18.7	105.7	9.40	101.70	-	-
				3	18.7	105.7	9.40	101.70	-	-
				4	18.7	105.7	9.40	101.70	-	-
				5	18.7	105.7	9.40	101.70	-	-
				6	18.7	105.7	9.40	101.70	-	-
				7	18.7	105.7	9.40	101.70	-	-
				8	18.7	105.7	9.40	101.70	-	-
Birch Tree Lake	BLA	25-Jul-00	6.90	0	20.3	109.1	8.32	92.99	-	-
				1	19.7	108.7	8.27	91.31	-	-
				2	18.9	108.7	8.19	88.97	-	-
				3	18.5	108.0	8.19	88.25	-	-
				4	18.4	107.6	8.19	88.07	-	-
				5	18.3	107.3	8.21	88.11	-	-
				6	18.3	107.2	8.19	87.89	-	-
				6.5	18.2	108.3	8.30	88.89	-	-

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
Birch Tree Lake	BLA	19-Sep-00	7.00	0	12.1	115.4	8.47	80.15	-	-
				1	12.1	115.4	8.52	80.62	-	-
				2	12.2	115.6	8.54	80.97	-	-
				3	12.1	115.7	8.57	81.09	-	-
				4	12.2	115.5	8.62	81.73	-	-
				5	12.2	115.5	8.65	82.02	-	-
				6	12.2	115.7	8.70	82.49	-	-
				7	-	-	-	-		
Birch Tree Lake	BLB	25-Jul-00	8.00	0	18.7	107.1	8.91	96.40	-	-
				1	18.7	107.0	8.81	95.31	-	-
				2	18.3	106.0	8.87	95.19	-	-
				3	18.3	106.0	8.86	95.08	-	-
				4	18.3	106.0	8.85	94.97	-	-
				5	18.3	106.0	8.84	94.87	-	-
				6	18.3	106.0	8.84	94.87	-	-
				7	18.3	106.0	8.84	94.87	-	-
				8	18.3	106.0	8.85	94.97	-	-
Birch Tree Lake	BLB	19-Sep-00	8.00	0	12.1	115.3	8.60	81.38	-	-
				1	12.1	115.3	8.67	82.04	-	-
				2	12.1	115.2	8.69	82.23	-	-
				3	12.1	115.1	8.70	82.32	-	-
				4	12.1	115.2	8.71	82.42	-	-
				5	12.1	115.2	8.74	82.70	-	-
				6	12.1	115.2	8.77	82.98	-	-

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				7	12.1	115.3	8.80	83.27	-	-
				8	-	-	-	-	-	-
Open-Water Season 2001										
Lower Burntwood River	LBRB	29-May-01	>10	0.1	10.7	94	9.59	88.0	7.70	56
				5.0	10.4	88	11.13	101.5	8.33	54
				10.0	10.4	97	11.42	104.2	7.48	54
Lower Burntwood River	LBRB2	30-May-01	>10	0.1	11.5	92	9.88	92.1	8.39	62
				5.0	11.3	96	10.69	99.3	7.83	61
				10.0	11.3	87	11.09	103.0	7.89	60
Lower Burntwood River	LBRC	30-May-01	>10	0.1	11.3	93	9.73	90.4	8.13	57
				5.0	11.2	95	11.02	102.1	7.91	57
				10.0	11.2	93	11.25	104.3	8.44	58
Sesep Lake	SLA	30-May-01	3.0	0.1	15.2	113	7.66	77.0	8.04	2
				1.5	15.1	103	8.04	80.7	8.04	2
				3.0	15.0	103	8.01	80.2	7.59	2
Wuskwatim Lake	WuLA	30-May-01	9.0	0.1	11.4	96	9.38	87.3	7.93	64
				4.5	11.3	88	10.55	98.0	7.56	65
				9.0	11.3	91	11.18	103.8	7.61	67
Wuskwatim Lake	WuLB	30-May-01	8.0	0.1	11.6	98	9.38	87.7	8.09	53
				4.0	10.9	88	10.65	98.1	8.46	50

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				8.0	9.5	89	11.02	98.7	7.53	48
Wuskwatim Lake	WuLC	30-May-01	4.0	0.1	15.1	75	7.92	79.5	7.77	9
				2.0	15.0	69	7.98	79.9	7.95	9
				4.0	15.0	69	8.28	82.9	6.95	9
Wuskwatim Brook	WuBA	30-May-01	3.0	0.1	15.6	74	7.61	77.1	7.51	9
				3.0	15.6	73	7.89	80.0	6.83	9
				1.5	15.6	71	7.77	78.8	7.69	9
Lower Burntwood River	TF	30-May-01	shore	0.1	11.3	97	9.87	91.7	8.36	63
Opegano Lake	OLA	31-May-01	4.0	0.1	12.1	99	9.94	93.8	8.22	62
				2.0	11.9	99	10.15	95.4	8.43	61
				4.0	11.9	99	10.59	99.6	7.56	62
Opegano Lake	OLB	31-May-01	5.0	0.1	12.2	99	9.91	93.7	8.47	64
				2.5	12.0	97	10.61	100.0	8.41	61
				5.0	12.0	97	10.93	103.0	7.73	61
Birch Tree Lake	BLA	31-May-01	6.0	0.1	12.6	102	9.44	90.0	8.46	60
				3.0	12.1	102	10.48	98.9	8.55	60
				6.0	11.6	94	10.81	101.0	7.62	65
Birch Tree Lake	BLB	31-May-01	6.5	0.1	12.3	100	9.81	93.0	8.44	70
				3.0	11.8	91	10.83	101.6	8.48	69

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				6.5	11.7	92	11.15	104.4	7.60	67
Lower Burntwood River	LBRB	15-Jul-01	3.5	0.1	18.6	103	9.5	102.3	8.01	29
				1.8	18.5	97	10.2	109.6	7.97	27
				3.5	18.5	96	10.4	111.8	7.62	27
Lower Burntwood River	LBRB2	16-Jul-01	10.0	0.1	19.0	103	10.7	116.2	7.81	29
				5.0	18.8	92	11.3	122.2	7.36	29
				10.0	18.9	92	11.4	123.5	7.34	28
Lower Burntwood River	LBRC	16-Jul-01	>10	0.1	19.3	104	10.8	118.0	7.96	28
				5.0	19.1	105	10.9	118.6	7.55	28
				10.0	19.1	105	11.2	121.9	7.51	28
Sesep Lake	SLA	16-Jul-01	3.0	0.1	22.2	127	8.9	103.1	7.72	4
				1.5	21.9	114	8.8	101.4	7.86	4
				3.0	21.6	114	8.6	98.5	7.41	4
Wuskwatim Lake	WuLA	16-Jul-01	8.5	0.1	19.5	101	10.1	110.8	7.85	22
				4.2	19.3	101	10.8	118.0	7.42	23
				8.5	19.0	101	11.1	120.5	7.32	29
Wuskwatim Lake	WuLB	16-Jul-01	7.5	0.1	19.8	105	9.5	104.9	8.15	20
				1.0	19.5	106	10.0	109.7	8.26	20
				2.0	19.3	106	9.8	107.1	8.21	20
				3.0	19.2	106	10.3	112.3	8.09	20

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				4.0	19.1	106	10.4	113.2	7.87	20
				5.0	19.0	106	10.6	115.1	7.71	20
				6.0	17.2	107	9.8	102.6	7.49	-
				7.5	15.6	109	9.2	93.2	7.33	-
Wuskwatim Lake	WuLC	16-Jul-01	3.0	0.1	22.5	100	9.4	109.6	7.74	12
				1.5	22.2	101	9.3	107.8	7.89	12
				3.0	20.9	100	8.5	95.9	7.36	14
Wuskwatim Brook	WuBA	16-Jul-01	2.0	0.1	23.4	93	8.7	103.3	7.55	4
				1.0	23.3	94	8.6	101.9	7.61	3
				2.0	21.9	94	8.5	97.9	7.31	3
Lower Burntwood River	TF	16-Jul-01	shore	0.1	18.8	104	10.8	116.8	8.05	34
Opegano Lake	OLA	17-Jul-01	4.5	0.1	19.2	106	10.7	116.4	7.55	36
				2.2	19.1	106	11.2	121.6	7.42	34
				4.5	19.1	106	11.4	123.7	7.27	34
Opegano Lake	OLB	17-Jul-01	3.0	0.1	19.1	106	11.1	120.5	7.89	33
				1.5	19.1	106	11.1	120.5	7.97	33
				3.0	19.0	106	11.4	123.5	7.67	33
Birch Tree Lake	BLA	17-Jul-01	6.0	0.1	20.2	108	10.7	118.8	8.12	36
				3.0	18.9	108	10.8	116.8	7.81	37
				6.0	18.6	108	10.6	113.9	7.55	33

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
Birch Tree Lake	BLB	17-Jul-01	7.0	0.1	19.8	107	10.9	120.0	7.99	48
				3.5	19.7	108	11.2	123.1	7.85	40
				7.0	19.6	108	11.5	126.1	7.65	39
Lower Burntwood River	LBRB	22-Aug-01	>10	0.1	18.0	104	9.9	105.4	7.94	36
				5.0	18.0	104	10.6	112.8	7.29	35
				10.0	18.0	101	10.6	112.8	7.41	35
Lower Burntwood River	LBRB2	23-Aug-01	>10	0.1	17.5	104	10.3	108.5	7.95	37
				5.0	17.6	94	10.9	115.1	7.31	35
				10.0	17.6	94	11.3	119.3	7.37	36
Lower Burntwood River	LBRC	23-Aug-01	>10	0.1	17.5	105	10.3	108.5	7.94	38
				5.0	17.5	94	11.1	116.9	7.34	38
				10.0	17.5	95	11.2	118.0	7.45	38
Sesep Lake	SLA	23-Aug-01	3.0	0.1	17.5	139	9.1	95.9	7.69	5
				1.5	17.6	122	9.4	99.2	7.66	5
				3.0	17.5	136	9.5	100.1	7.34	4
Wuskwatim Lake	WuLA	23-Aug-01	8.5	0.1	17.8	107	10.1	107.1	7.44	36
				4.2	17.9	107	10.7	113.6	7.23	35
				8.5	17.9	106	10.9	115.8	7.21	37
Wuskwatim Lake	WuLB	23-Aug-01	7.5	0.1	17.5	109	10.2	107.5	7.90	30

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				3.8	17.6	110	10.5	110.8	7.33	29
				7.5	17.6	108	10.9	115.1	7.38	29
Wuskwatim Lake	WuLC	23-Aug-01	3.0	0.1	17.6	120	10.2	107.7	7.96	27
				1.5	17.6	120	10.2	107.7	7.98	25
				3.0	17.6	120	10.2	107.7	7.59	27
Wuskwatim Brook	WuBA	23-Aug-01	2.0	0.1	18.2	113	9.4	100.4	7.64	5
				1.0	18.2	112	9.0	96.2	7.71	4
				2.0	18.2	112	9.3	99.4	7.53	5
Lower Burntwood River	TF	23-Aug-01	shore	0.1	17.5	110	11.2	118.0	7.97	29
Opegano Lake	OLA	26-Aug-01	2.5	0.1	17.7	109	11.1	117.2	7.78	33
				1.5	17.7	109	11.3	119.3	8.03	33
				2.5	17.7	109	11.4	120.4	7.47	33
Opegano Lake	OLB	26-Aug-01	4.0	0.1	17.7	109	10.9	115.1	7.89	39
				2.0	17.7	109	11.4	120.4	7.76	34
				4.0	17.7	109	11.4	120.4	7.48	32
Birch Tree Lake	BLA	26-Aug-01	5.5	0.1	18.1	111	10.4	110.6	8.14	33
				2.7	18.1	111	10.9	115.9	7.47	30
				5.5	18.1	110	11.1	118.1	7.62	31
Birch Tree Lake	BLB	26-Aug-01	7.0	0.1	18.1	105	10.7	113.8	7.98	37

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
				3.5	18.1	111	11.2	119.1	7.33	36
				7.0	18.1	111	11.4	121.3	7.34	36
Birch Tree Lake	BLC	26-Aug-01	12.0	0.1	18.0	110	10.6	112.5	7.93	36
				5.0	18.0	111	11.3	120.0	7.55	35
				10.0	18.0	111	11.5	122.1	7.63	35
Lower Burntwood River	LBRE1	27-Aug-01	>10	0.1	17.6	111	10.5	110.6	7.97	36
				5.0	17.6	110	10.9	114.8	7.58	36
				10.0	17.6	110	10.5	110.6	7.67	36
Lower Burntwood River [1]	LBRE	27-Aug-01	>10	0.1	17.6	111	11.0	115.8	8.11	38
				5.0	17.7	109	12.5	131.9	7.57	37
				10.0	17.7	109	12.7	134.0	7.57	37
Lower Burntwood River	LBRF	27-Aug-01	4.0	0.1	17.7	111	11.5	121.3	8.17	38
				2.0	17.7	111	11.4	120.3	8.19	38
				4.0	17.7	111	11.2	118.2	7.70	38
Lower Burntwood River	LBRB	26-Sep-01	9.0	0.1	11.7	100	10.4	97.4	8.29	43
				4.5	11.7	102	11.3	105.8	8.22	44
				9.0	11.7	102	11.1	104.0	8.08	43
Lower Burntwood River	LBRB2	27-Sep-01	>10	0.1	11.9	100	11.0	103.4	8.29	42
				5.0	11.9	90	11.6	109.1	8.18	39
				10.0	11.9	98	11.7	110.0	7.89	38

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
Lower Burntwood River	LBRC	27-Sep-01	>10	0.1	11.8	95	10.8	101.3	8.30	46
				5.0	11.7	96	11.5	107.7	8.19	42
				10.0	11.7	91	11.6	108.6	7.84	42
Sesep Lake	SLA	27-Sep-01	3.0	0.1	10.7	137	11.3	103.7	8.24	4
				1.5	10.7	125	11.1	102.1	8.18	4
				3.0	10.7	126	11.3	103.7	8.06	3
Wuskwatim Lake	WuLA	27-Sep-01	9.0	0.1	11.2	101	10.6	98.3	8.24	45
				4.5	11.2	100	11.6	107.5	8.26	45
				9.0	11.2	105	11.6	107.5	7.97	44
Wuskwatim Lake	WuLB	27-Sep-01	8.0	0.1	11.1	104	10.8	99.9	8.32	49
				4.0	11.0	101	11.1	102.5	8.10	48
				8.0	11.0	102	11.5	106.2	7.87	50
Wuskwatim Lake	WuLC	27-Sep-01	3.0	0.1	10.9	117	10.8	99.5	8.25	22
				1.5	10.8	108	10.9	100.2	8.26	22
				3.0	10.8	108	11.0	101.1	8.12	22
Wuskwatim Brook	WuBA	27-Sep-01	2.0	0.1	11.0	118	10.9	100.6	8.04	5
				1.0	11.0	119	10.9	100.6	8.05	5
				2.0	10.9	119	10.9	100.4	7.93	5
Lower Burntwood River	TF	27-Sep-01	shore	0.1	11.0	106	12.0	110.8	8.23	50

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (µS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity (NTU)
Opegano Lake	OLA	30-Sep-01	3.5	0.1	11.4	105	11.3	105.0	8.14	44
				1.8	11.4	105	11.5	106.9	8.28	44
				3.5	11.4	105	11.4	105.9	7.78	44
Opegano Lake	OLB	30-Sep-01	3.5	0.1	11.8	104	11.2	104.9	7.92	43
				1.8	11.6	104	11.7	109.2	8.05	42
				3.5	11.7	105	11.7	109.4	7.48	43
Birch Tree Lake	BLA	30-Sep-01	6.0	0.1	11.4	108	11.1	103.1	8.25	43
				3.0	11.3	108	11.2	103.8	8.25	43
				6.0	11.3	109	11.3	104.7	7.97	42
Birch Tree Lake	BLB	30-Sep-01	7.0	0.1	11.5	106	11.5	107.0	8.30	48
				3.5	11.5	107	11.9	110.7	8.23	46
				7.0	11.5	107	12.1	112.6	7.97	47
Birch Tree Lake	BLC	30-Sep-01	11.0	0.1	11.5	106	11.3	105.1	8.30	48
				5.0	11.5	107	12.0	111.6	8.21	47
				10.0	11.5	107	12.1	112.6	7.98	47
Lower Burntwood River	LBRE1	30-Sep-01	>10	0.1	11.5	106	11.2	104.2	8.33	51
				5.0	11.5	107	11.8	109.8	8.14	47
				10.0	11.5	107	11.8	109.8	7.97	47

Table A2-3. -continued-

Sampling Location	Location ID	Sample Date	Total Depth (m)	Depth (m)	Temperature (°C)	Conductivity (uS/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	pH	Turbidity NTU
Lower Burntwood River	LBRF	01-Oct-01	>10	0.1	11.4	107	11.9	110.5	8.16	52
				5.0	11.3	108	12.7	117.7	8.26	53
				10.0	11.3	108	12.8	118.6	7.78	52

[1] One sample of water was collected on the lower Burntwood River downstream of the Manasan River in August 2001; due to problems with accessibility, this site was not visited again.

Table A2-4. Major ions, radiation, and inorganic elements measured in water samples collected in the study area 2000 – 2002.

Sampling Location	Location ID	Sample date	Hardness as $CaCO_3$ (mg/L)	Aluminum Dissolved (mg/L)	Aluminum Total (mg/L)	Antimony Dissolved (mg/L)	Antimony Total (mg/L)	Arsenic Dissolved (mg/L)	Arsenic Total (mg/L)	Barium Dissolved (mg/L)	Barium Total (mg/L)	Beryllium Dissolved (mg/L)	Beryllium Total (mg/L)	Boron Dissolved (mg/L)	Boron Total (mg/L)
Open-water Season 2000															
Wuskwatim Lake	WuLA	14-Jun-00	52.7	-	1.87	-	< 0.001	-	0.0017	-	0.0270	-	< 0.001	-	0.01
Wuskwatim Lake	WuLA	24-Jul-00	46.8	-	1.47	-	< 0.001	-	0.0005	-	0.0214	-	< 0.001	-	< 0.01
Wuskwatim Lake	WuLA	18-Sep-00	55.2	-	2.05	-	< 0.001	-	0.0033	-	0.0265	-	< 0.001	-	0.01
Taskinigup Falls	TF	25-May-00	53.3	-	1.74	-	< 0.001	-	< 0.0005	-	0.0241	-	< 0.001	-	0.01
Taskinigup Falls	TF	23-Jul-00	50.9	-	1.67	-	< 0.001	-	0.0070	-	0.0237	-	< 0.001	-	< 0.01
Taskinigup Falls	TF	18-Sep-00	59.2	-	2.78	-	< 0.001	-	0.0030	-	0.0314	-	< 0.001	-	0.01
Open-water Season 2001															
Lower Burntwood River	LBRB2	30-May-01	56.2	-	2.16	-	< 0.001	-		-	0.0274	-	< 0.001	-	< 0.03
Lower Burntwood River	LBRB2	16-Jul-01	56.3	-	0.76	-	< 0.001	-	< 0.0005	-	0.0164	-	< 0.001	-	< 0.03
Lower Burntwood River	LBRB2	23-Aug-01	51.4	-	1.18	-	< 0.001	-		-	0.0178	-	< 0.001	-	< 0.03
Lower Burntwood River	LBRB2	27-Sep-01	57.0	-	1.31	-	< 0.001	-	< 0.0005	-	0.0204	-	< 0.001	-	< 0.03
Wuskwatim Lake	WuLB	30-May-01	59.3	-	1.92	-	< 0.001	-	<0.0005	-	0.0247	-	< 0.001	-	< 0.03
Wuskwatim Lake	WuLB	16-Jul-01	55.9	-	0.86	-	< 0.001	-	< 0.0005	-	0.0167	-	< 0.001	-	< 0.03
Wuskwatim Lake	WuLB	23-Aug-01	55.5	-	1.19	-	< 0.001	-	0.0008	-	0.0187	-	< 0.001	-	< 0.03
Wuskwatim Lake	WuLB	27-Sep-01	59.2	-	1.72	-	< 0.001	-	< 0.0005	-	0.0235	-	< 0.001	-	< 0.03
Taskinigup Falls	TF	30-May-01	57.7	-	2.14	-	< 0.001	-	0.0006	-	0.0273	-	< 0.001	-	< 0.03
Taskinigup Falls	TF	16-Jul-01	58.5	-	1.31	-	< 0.001	-	< 0.0005	-	0.0202	-	< 0.001	-	0.03
Taskinigup Falls	TF	23-Aug-01	58.6	-	1.16	-	< 0.001	-	< 0.0005	-	0.0199	-	< 0.001	-	0.04
Taskinigup Falls	TF	27-Sep-01	60.5	-	1.61	-	< 0.001	-	0.0005	-	0.0233	-	< 0.001	-	< 0.03

Table A2-4. - continued -

Sampling Location	Location ID	Sample date	Hardness as $CaCO_3$ (mg/L)	Aluminum Dissolved (mg/L)	Aluminum Total (mg/L)	Antimony Dissolved (mg/L)	Antimony Total (mg/L)	Arsenic Dissolved (mg/L)	Arsenic Total (mg/L)	Barium Dissolved (mg/L)	Barium Total (mg/L)	Beryllium Dissolved (mg/L)	Beryllium Total (mg/L)	Boron Dissolved (mg/L)	Boron Total (mg/L)
Birch Tree Lake	BLB	31-May-01	47.3	0.06	2.50	< 0.001	< 0.001	< 0.0005	0.0033	0.0078	0.0295	< 0.001	< 0.001	0.014	< 0.03
Birch Tree Lake	BLB	17-Jul-01	58.6	0.10	1.22	< 0.001	< 0.001	0.0008	0.0007	0.0100	0.0227	< 0.001	< 0.001	0.021	< 0.03
Birch Tree Lake	BLB	26-Aug-01	57.9	0.13	1.36	< 0.001	< 0.001	< 0.0005	0.0008	0.0103	0.0211	< 0.001	< 0.001	0.013	< 0.03
Birch Tree Lake	BLB	30-Sep-01	58.4	0.06	1.67	< 0.001	< 0.001	0.0006	< 0.0005	0.0090	0.0225	< 0.001	< 0.001	0.014	< 0.03
Birch Tree Lake	BLC	26-Aug-01	58.1	-	1.28	-	< 0.001	-	0.0007	-	0.0188	-	< 0.001	-	< 0.03
Lower Burntwood River	LBRE1	27-Aug-01	63.5	-	1.77	-	< 0.001	-	0.0007	-	0.0242	-	< 0.001	-	0.03
Lower Burntwood River	LBRE1	30-Sep-01	60.8	-	1.57	-	< 0.001	-	< 0.0005	-	0.0215	-	< 0.001	-	< 0.03
Lower Burntwood River [1]	LBRE	27-Aug-01	62.9	-	1.38	-	< 0.001	-	0.0012	-	0.0208	-	< 0.001	-	< 0.03
Lower Burntwood River	LBRF	27-Aug-01	59.6	-	1.42	-	< 0.001	-	0.0006	-	0.0206	-	< 0.001	-	0.04
Lower Burntwood River	LBRF	1-Oct-01	60.1	-	1.67	-	< 0.001	-	< 0.0005	-	0.0243	-	< 0.001	-	< 0.03
Ice-cover Season 2001															
Opegano Lake	OLB	28-Mar-01	55.3	-	0.88	-	< 0.001	-	< 0.0005	-	0.0177	-	< 0.001	-	< 0.03
Ice-cover Season 2002															
Cranberry Lakes	CLA	26-Mar-02	49.8	-	0.84	-	< 0.001	-	0.0006	-	0.0188	-	< 0.001	-	< 0.03
Wuskwatim Lake	WuLB	26-Mar-02	49.4	-	0.89	-	< 0.001	-	0.0006	-	0.0193	-	< 0.001	-	< 0.03
Birch Tree Lake	BLB	27-Mar-02	50.6	-	1.11	-	< 0.001	-	0.0006	-	0.0207	-	< 0.001	-	< 0.03
Birch Tree Lake	BLC	27-Mar-02	49.6	-	1.06	-	< 0.001	-	< 0.0005	-	0.0201	-	< 0.001	-	< 0.03
Lower Burntwood River	LBRF	27-Mar-02	62.2	-	1.82	-	< 0.001	-	0.0005	-	0.0272	-	< 0.001	-	< 0.03

Table A2-4. - continued -

Sampling Location	Location ID	Sample date	Cadmium Dissolved (mg/L)	Cadmium Total (mg/L)	Calcium Dissolved (mg/L)	Calcium Total (mg/L)	Chloride Dissolved (mg/L)	Chromium Dissolved (mg/L)	Chromium Total (mg/L)	Cobalt Dissolved (mg/L)	Cobalt Total (mg/L)	Copper Dissolved (mg/L)	Copper Total (mg/L)	Flouride Dissolved (mg/L)
Open-water Season 2000														
Wuskwatim Lake	WuLA	14-Jun-00	-	< 0.0002	-	13.7	-	-	0.003	-	0.0007	-	0.004	-
Wuskwatim Lake	WuLA	24-Jul-00	-	< 0.0002	-	12.6	-	-	0.002	-	0.0003	-	0.002	-
Wuskwatim Lake	WuLA	18-Sep-00	-	< 0.0002	-	15.3	-	-	0.003	-	0.0006	-	0.003	-
Taskinigup Falls	TF	25-May-00	-	< 0.0002	-	13.8	-	-	0.003	-	0.0006	-	0.002	-
Taskinigup Falls	TF	23-Jul-00	-	< 0.0002	-	13.6	-	-	0.002	-	0.0004	-	0.002	-
Taskinigup Falls	TF	18-Sep-00	-	< 0.0002	-	16.2	-	-	0.004	-	0.0007	-	0.003	-
Open-water Season 2001														
Lower Burntwood River	LBRB2	30-May-01	-	< 0.0002	-	14.7	< 10	-	0.002	-	0.0006	-	0.003	0.1
Lower Burntwood River	LBRB2	16-Jul-01	-	< 0.0002	-	15.4	< 10	-	< 0.002	-	0.0004	-	0.003	0.1
Lower Burntwood River	LBRB2	23-Aug-01	-	< 0.0002	-	14.1	< 10	-	0.003	-	0.0005	-	0.002	0.1
Lower Burntwood River	LBRB2	27-Sep-01	-	< 0.0002	-	15.5	< 10	-	< 0.002	-	0.0004	-	< 0.001	< 0.1
Wuskwatim Lake	WuLB	30-May-01	-	< 0.0002	-	15.9	< 10	-	0.002	-	0.0007	-	0.002	0.1
Wuskwatim Lake	WuLB	16-Jul-01	-	< 0.0002	-	15.3	< 10	-	< 0.002	-	0.0004	-	0.002	0.2
Wuskwatim Lake	WuLB	23-Aug-01	-	< 0.0002	-	15.3	< 10	-	0.004	-	0.0003	-	0.003	0.1
Wuskwatim Lake	WuLB	27-Sep-01	-	< 0.0002	-	16.1	< 10	-	0.002	-	0.0005	-	0.001	< 0.1
Taskinigup Falls	TF	30-May-01	-	< 0.0002	-	15.4	< 10	-	0.002	-	0.0009	-	0.003	0.2
Taskinigup Falls	TF	16-Jul-01	-	< 0.0002	-	15.9	< 10	-	0.002	-	0.0005	-	0.002	0.2
Taskinigup Falls	TF	23-Aug-01	-	< 0.0002	-	16.3	< 10	-	< 0.002	-	0.0003	-	0.002	< 0.1
Taskinigup Falls	TF	27-Sep-01	-	< 0.0002	-	16.6	< 10	-	0.002	-	0.0005	-	0.005	0.1

Table A2-4. - continued -

Sampling Location	Location ID	Sample date	Cadmium Dissolved (mg/L)	Cadmium Total (mg/L)	Calcium Dissolved (mg/L)	Calcium Total (mg/L)	Chloride Dissolved (mg/L)	Chromium Dissolved (mg/L)	Chromium Total (mg/L)	Cobalt Dissolved (mg/L)	Cobalt Total (mg/L)	Copper Dissolved (mg/L)	Copper Total (mg/L)	Flouride Dissolved (mg/L)
Birch Tree Lake	BLB	31-May-01	< 0.0002	< 0.0002	13.2	16.6	< 10	< 0.001	0.003	< 0.0002	0.0007	0.0015	0.003	-
Birch Tree Lake	BLB	17-Jul-01	< 0.0002	< 0.0002	16.3	16.9	< 10	< 0.001	0.003	< 0.0002	0.0005	0.0010	0.002	< 0.1
Birch Tree Lake	BLB	26-Aug-01	< 0.0002	< 0.0002	16.2	17.3	< 10	< 0.001	< 0.002	< 0.0002	0.0005	0.0014	0.001	< 0.1
Birch Tree Lake	BLB	30-Sep-01	< 0.0002	< 0.0002	16.5	16.4	< 10	< 0.001	0.004	0.0003	0.0005	< 0.0004	0.003	< 0.1
Birch Tree Lake	BLC	26-Aug-01	-	< 0.0002	-	16.1	< 10	-	0.004	-	0.0005	-	0.033	< 0.1
Lower Burntwood River	LBRE1	27-Aug-01	-	< 0.0002	-	17.5		-	0.002	-	0.0005	-	0.002	-
Lower Burntwood River	LBRE1	30-Sep-01	-	< 0.0002	-	16.5	< 10	-	0.003	-	0.0005	-	0.005	< 0.1
Lower Burntwood River [1]	LBRE	27-Aug-01	-	< 0.0002	-	17.3	< 10	-	< 0.002	-	0.0005	-	0.002	0.1
Lower Burntwood River	LBRF	27-Aug-01	-	< 0.0002	-	16.5	< 10	-	0.003	-	0.0004	-	0.002	0.1
Lower Burntwood River	LBRF	1-Oct-01	-	< 0.0002	-	16.2	< 10	-	0.003	-	0.0005	-	< 0.001	0.1
Ice-cover Season 2001														
Opegano Lake	OLB	28-Mar-01	-	< 0.0002	-	14.5	< 10	-	< 0.002	-	0.0003	-	0.011	0.2
Ice-cover Season 2002														
Cranberry Lakes	CLA	26-Mar-02	-	< 0.0002	-	-	< 10	-	< 0.002	-	0.0003	-	0.002	< 0.1
Wuskwatim Lake	WuLB	26-Mar-02	-	< 0.0002	-	12.9	-	-	< 0.002	-	0.0003	-	0.008	-
Birch Tree Lake	BLB	27-Mar-02	-	< 0.0002	-	13.3	< 10	-	< 0.002	-	0.0004	-	0.005	< 0.1
Birch Tree Lake	BLC	27-Mar-02	-	< 0.0002	-	13.0	-	-	< 0.002	-	0.0004	-	0.006	< 0.1
Lower Burntwood River	LBRF	27-Mar-02	-	< 0.0002	-	15.9	< 10	-	0.004	-	0.0008	-	0.005	< 0.1

Table A2-4. - continued –

Sampling Location	Location ID	Sample date	Iron		Lead		Manganese		Magnesium		Mercury		Molybdenum	
			Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Open-water Season 2000														
Wuskwatim Lake	WuLA	14-Jun-00	-	1.50	-	0.0011	-	0.0250	-	4.50	-	-	-	0.0002
Wuskwatim Lake	WuLA	24-Jul-00	-	1.00	-	0.0006	-	0.0154	-	3.73	-	-	-	0.0001
Wuskwatim Lake	WuLA	18-Sep-00	-	1.53	-	0.0009	-	0.0254	-	4.13	-	-	-	0.0008
Taskinigup Falls	TF	25-May-00	-	1.29	-	0.0012	-	0.0247	-	4.57	-	-	-	0.0001
Taskinigup Falls	TF	23-Jul-00	-	1.31	-	0.0007	-	0.0205	-	4.12	-	-	-	0.0001
Taskinigup Falls	TF	18-Sep-00	-	2.02	-	0.0011	-	0.0310	-	4.56	-	-	-	0.0006
Open-water Season 2001														
Lower Burntwood River	LBRB2	30-May-01	-	1.76	-	0.0072	-	0.0297	-	4.73	-	< 0.0003	-	0.0002
Lower Burntwood River	LBRB2	16-Jul-01	-	0.72	-	0.0008	-	0.0139	-	4.33	-	< 0.0003	-	< 0.0002
Lower Burntwood River	LBRB2	23-Aug-01	-	0.96	-	0.0005	-	0.0168	-	3.93	-	< 0.0003	-	0.0005
Lower Burntwood River	LBRB2	27-Sep-01	-	1.07	-	< 0.0005	-	0.0184	-	4.45	-	< 0.0003	-	0.0002
Wuskwatim Lake	WuLB	30-May-01	-	1.67	-	0.0011	-	0.0278	-	4.75	-	< 0.0003	-	0.0002
Wuskwatim Lake	WuLB	16-Jul-01	-	0.71	-	< 0.0005	-	0.0102	-	4.31	-	< 0.0003	-	0.0002
Wuskwatim Lake	WuLB	23-Aug-01	-	1.49	-	< 0.0005	-	0.0199	-	4.20	-	< 0.0003	-	0.0021
Wuskwatim Lake	WuLB	27-Sep-01	-	1.38	-	< 0.0005	-	0.0225	-	4.62	-	< 0.0003	-	0.0002
Taskinigup Falls	TF	30-May-01	-	1.77	-	0.0010	-	0.0304	-	4.68	-	< 0.0003	-	0.0002
Taskinigup Falls	TF	16-Jul-01	-	1.12	-	0.0007	-	0.0179	-	4.56	-	< 0.0003	-	0.0002
Taskinigup Falls	TF	23-Aug-01	-	0.87	-	< 0.0005	-	0.0148	-	4.35	-	< 0.0003	-	0.0002
Taskinigup Falls	TF	27-Sep-01	-	1.26	-	< 0.0005	-	0.0210	-	4.64	-	< 0.0003	-	< 0.0002

Table A2-4. - continued –

Sampling Location	Location ID	Sample date	Iron Dissolved (mg/L)	Iron Total (mg/L)	Lead Dissolved (mg/L)	Lead Total (mg/L)	Manganese Dissolved (mg/L)	Manganese Total (mg/L)	Magnesium Dissolved (mg/L)	Magnesium Total (mg/L)	Mercury Dissolved (mg/L)	Mercury Total (mg/L)	Molybdenum Dissolved (mg/L)	Molybdenum Total (mg/L)
Birch Tree Lake	BLB	31-May-01	0.18	1.82	0.0001	0.002	0.0023	0.0277	3.48	5.03	< 0.0002	< 0.0003	< 0.0001	0.0002
Birch Tree Lake	BLB	17-Jul-01	0.15	1.10	0.0002	0.0006	0.0026	0.0194	4.34	4.57	< 0.0002	< 0.0003	0.0001	0.0002
Birch Tree Lake	BLB	26-Aug-01	0.15	1.02	< 0.0001	0.0005	0.0008	0.0178	4.23	4.73	< 0.0002	< 0.0003	0.0002	0.0002
Birch Tree Lake	BLB	30-Sep-01	0.13	1.31	< 0.0001	0.0019	0.0009	0.0218	4.19	4.64	< 0.0002	< 0.0003	< 0.0001	< 0.0002
Birch Tree Lake	BLC	26-Aug-01	-	1.03	-	< 0.0005	-	0.0177	-	4.35	-	< 0.0003	-	0.0007
Lower Burntwood River	LBRE1	27-Aug-01	-	1.11	-	0.0006	-	0.0182	-	4.80	-	< 0.0003	-	0.0002
Lower Burntwood River	LBRE1	30-Sep-01	-	1.29	-	0.0022	-	0.0218	-	4.77	-	< 0.0003	-	< 0.0002
Lower Burntwood River [1]	LBRE	27-Aug-01	-	1.03	-	0.0007	-	0.0190	-	4.78	-	< 0.0003	-	< 0.0002
Lower Burntwood River	LBRF	27-Aug-01	-	1.07	-	0.0006	-	0.0176	-	4.46	-	< 0.0003	-	0.0006
Lower Burntwood River	LBRF	1-Oct-01	-	1.36	-	< 0.0005	-	0.0229	-	4.77	-	< 0.0003	-	0.0010
Ice-cover Season 2001														
Opegano Lake	OLB	28-Mar-01	-	0.86	-	0.0005	-	0.0158	-	4.65	-	< 0.0003	-	0.0002
Ice-cover Season 2002														
Cranberry Lakes	CLA	26-Mar-02	-	0.61	-	< 0.0005	-	0.0108	-	4.22	-	< 0.00005	-	0.0003
Wuskwatim Lake	WuLB	26-Mar-02	-	0.66	-	< 0.0005	-	0.0119	-	4.18	-	< 0.00005	-	0.0003
Birch Tree Lake	BLB	27-Mar-02	-	0.87	-	< 0.0005	-	0.0167	-	4.22	-	< 0.00005	-	0.0003
Birch Tree Lake	BLC	27-Mar-02	-	0.83	-	< 0.0005	-	0.0170	-	4.16	-	< 0.00005	-	0.0003
Lower Burntwood River	LBRF	27-Mar-02	-	1.58	-	0.0008	-	0.0398	-	5.46	-	< 0.00005	-	0.0003

Table A2-4. - continued –

Sampling Location	Location ID	Sample date	Nickel		Potassium		Selenium		Silicon	Silver		Sodium		Strontium	
			Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Open-water Season 2000															
Wuskwatim Lake	WuLA	14-Jun-00	-	0.003	-	1.68	-	< 0.002	-	-	< 0.0004	-	2.72	-	0.0363
Wuskwatim Lake	WuLA	24-Jul-00	-	< 0.002	-	1.41	-	< 0.002	-	-	< 0.0004	-	2.36	-	0.0325
Wuskwatim Lake	WuLA	18-Sep-00	-	0.003	-	1.67	-	0.004	-	-	< 0.0004	-	2.50	-	0.0335
Taskinigup Falls	TF	25-May-00	-	< 0.002	-	1.67	-	< 0.002	-	-	< 0.0004	-	2.96	-	0.0376
Taskinigup Falls	TF	23-Jul-00	-	< 0.002	-	1.50	-	< 0.002	-	-	< 0.0004	-	2.47	-	0.0347
Taskinigup Falls	TF	18-Sep-00	-	0.003	-	1.97	-	0.002	-	-	< 0.0004	-	2.64	-	0.0365
Open-water Season 2001															
Lower Burntwood River	LBRB2	30-May-01	-	0.002	-	1.8	-	< 0.002	-	-	< 0.0005	-	2.71	-	0.0381
Lower Burntwood River	LBRB2	16-Jul-01	-	< 0.002	-	1.2	-	< 0.002	-	-	< 0.0005	-	2.64	-	0.0371
Lower Burntwood River	LBRB2	23-Aug-01	-	< 0.002	-	1.3	-	< 0.002	-	-	< 0.0005	-	2.27	-	0.0339
Lower Burntwood River	LBRB2	27-Sep-01	-	< 0.002	-	1.3	-	< 0.002	-	-	< 0.0005	-	2.51	-	0.0368
Wuskwatim Lake	WuLB	30-May-01	-	0.002	-	1.8	-	< 0.002	-	-	< 0.0005	-	2.66	-	0.0375
Wuskwatim Lake	WuLB	16-Jul-01	-	< 0.002	-	1.2	-	< 0.002	-	-	< 0.0005	-	2.67	-	0.0376
Wuskwatim Lake	WuLB	23-Aug-01	-	0.003	-	1.4	-	< 0.002	-	-	< 0.0005	-	2.50	-	0.0355
Wuskwatim Lake	WuLB	27-Sep-01	-	< 0.002	-	1.4	-	< 0.002	-	-	< 0.0005	-	2.62	-	0.0381
Taskinigup Falls	TF	30-May-01	-	0.014	-	1.8	-	< 0.002	-	-	< 0.0005	-	2.52	-	0.0369
Taskinigup Falls	TF	16-Jul-01	-	< 0.002	-	1.4	-	< 0.002	-	-	< 0.0005	-	2.78	-	0.0385
Taskinigup Falls	TF	23-Aug-01	-	< 0.002	-	1.4	-	< 0.002	-	-	< 0.0005	-	2.50	-	0.0374
Taskinigup Falls	TF	27-Sep-01	-	0.002	-	1.5	-	< 0.002	-	-	< 0.0005	-	2.63	-	0.0379

Table A2-4. - continued –

Sampling Location	Location ID	Sample date	Nickel		Potassium		Selenium		Silicon	Silver		Sodium		Strontium	
			Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Birch Tree Lake	BLB	31-May-01	0.0006	0.003	0.96	2.0	< 0.002	< 0.002	-	< 0.0002	< 0.0005	2.05	2.83	0.0298	0.0399
Birch Tree Lake	BLB	17-Jul-01	0.0007	< 0.002	1.13	1.5	< 0.002	< 0.002	-	< 0.0002	< 0.0005	2.64	2.68	0.0376	0.0416
Birch Tree Lake	BLB	26-Aug-01	0.0004	< 0.002	1.05	1.6	< 0.002	< 0.002		< 0.0002	< 0.0005	2.46	2.56	0.0346	0.0397
Birch Tree Lake	BLB	30-Sep-01	< 0.0002	< 0.002	0.98	1.4	< 0.002	< 0.002		< 0.0002	< 0.0005	2.44	2.62	0.0355	0.0383
Birch Tree Lake	BLC	26-Aug-01	-	0.048	-	1.5	-	< 0.002	-	-	< 0.0005	-	2.44	-	0.0356
Lower Burntwood River	LBRE1	27-Aug-01	-	0.002	-	1.9	-	< 0.002	-	-	< 0.0005	-	2.81	-	0.0403
Lower Burntwood River	LBRE1	30-Sep-01	-	< 0.002	-	1.4	-	< 0.002	-	-	< 0.0005	-	2.68	-	0.0389
Lower Burntwood River [1]	LBRE	27-Aug-01	-	< 0.002	-	1.5	-	< 0.002	-	-	< 0.0005	-	2.72	-	0.0390
Lower Burntwood River	LBRF	27-Aug-01	-	< 0.002	-	1.5	-	< 0.002	-	-	< 0.0005	-	2.55	-	0.0377
Lower Burntwood River	LBRF	1-Oct-01	-	< 0.002	-	1.4	-	< 0.002	-	-	< 0.0005	-	2.59	-	0.0378
Ice-cover Season 2001															
Opegano Lake	OLB	28-Mar-01	-	< 0.002	-	-	-	< 0.002	-	-	< 0.0005	-	-	-	0.0401
Ice-cover Season 2002															
Cranberry Lakes	CLA	26-Mar-02	-	< 0.002	-	1.4	-	< 0.001	-	-	< 0.0001	-	3.03	-	0.0364
Wuskwatim Lake	WuLB	26-Mar-02	-	< 0.002	-	1.4	-	< 0.001	-	-	< 0.0001	-	3.00	-	0.0377
Birch Tree Lake	BLB	27-Mar-02	-	< 0.002	-	1.4	-	< 0.001	-	-	< 0.0001	-	2.94	-	0.0379
Birch Tree Lake	BLC	27-Mar-02	-	0.002	-	1.4	-	< 0.001	-	-	< 0.0001	-	2.88	-	0.0357
Lower Burntwood River	LBRF	27-Mar-02	-	0.003	-	1.7	-	< 0.001	-	-	< 0.0001	-	2.94	-	0.0393

Table A2-4. - continued –

Sampling Location	Location ID	Sample date	Sulphate	Thallium		Tin		Uranium		Vanadium		Zinc		Gross Radiation	
			Dissolved (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Alpha (Bq/L)	Beta (Bq/L)
Open-water Season 2000															
Wuskwatim Lake	WuLA	14-Jun-00	-	-	< 0.0001	-	< 0.0001	-		-	0.003	-	< 0.02	-	-
Wuskwatim Lake	WuLA	24-Jul-00	-	-	< 0.0001	-	< 0.0001	-		-	0.002	-	< 0.02	-	-
Wuskwatim Lake	WuLA	18-Sep-00	-	-	< 0.0001	-	< 0.0001	-		-	0.003	-	-	-	-
Taskinigup Falls	TF	25-May-00	-	-	< 0.0001	-	< 0.0001	-		-	0.003	-	< 0.02	-	-
Taskinigup Falls	TF	23-Jul-00	-	-	< 0.0001	-	< 0.0001	-		-	0.003	-	< 0.02	-	-
Taskinigup Falls	TF	18-Sep-00	-	-	< 0.0001	-	< 0.0001	-		-	0.004	-	< 0.02	-	-
Open-water Season 2001															
Lower Burntwood River	LBRB2	30-May-01	<10	-	< 0.0001	-	0.0027	-	0.0002	-	0.003	-	< 0.02	0.06	0.13
Lower Burntwood River	LBRB2	16-Jul-01	10	-	< 0.0001	-	0.0046	-	0.0002	-	0.001	-	< 0.02	0.03	0.13
Lower Burntwood River	LBRB2	23-Aug-01	11	-	< 0.0001	-	< 0.0005	-	0.0001	-	0.002	-	< 0.02	0.03	0.14
Lower Burntwood River	LBRB2	27-Sep-01	<10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	0.05	0.15
Wuskwatim Lake	WuLB	30-May-01	<10	-	< 0.0001	-	0.0006	-	0.0002	-	0.003	-	< 0.02	0.05	0.17
Wuskwatim Lake	WuLB	16-Jul-01	<10	-	< 0.0001	-	0.0010	-	0.0002	-	0.001	-	< 0.02	< 0.03	0.14
Wuskwatim Lake	WuLB	23-Aug-01	11	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	0.06	0.15
Wuskwatim Lake	WuLB	27-Sep-01	<10	-	< 0.0001	-	0.0006	-	0.0002	-	0.003	-	< 0.02	0.05	0.15
Taskinigup Falls	TF	30-May-01	<10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.003	-	0.03	0.05	0.17
Taskinigup Falls	TF	16-Jul-01	11	-	< 0.0001	-	0.0022	-	0.0002	-	0.002	-	< 0.02	0.10	0.19
Taskinigup Falls	TF	23-Aug-01	11	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	0.04	0.13
Taskinigup Falls	TF	27-Sep-01	<10	-	< 0.0001	-	0.0010	-	0.0002	-	0.003	-	< 0.02	0.03	0.16

Table A2-4. - continued –

Sampling Location	Location ID	Sample date	Sulphate	Thallium		Tin		Uranium		Vanadium		Zinc		Gross Radiation	
			Dissolved (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Alpha (Bq/L)	Beta (Bq/L)
Birch Tree Lake	BLB	31-May-01	<10	< 0.0001	< 0.0001	< 0.0002	< 0.0005	0.0001	0.0003	0.002	0.004	< 0.005	< 0.02	0.06 [2]	0.16 [2]
Birch Tree Lake	BLB	17-Jul-01	<10	< 0.0001	< 0.0001	< 0.0002	0.0014	0.0002	0.0002	0.001	0.003	0.007	0.03	0.03	0.11
Birch Tree Lake	BLB	26-Aug-01	<10	< 0.0001	< 0.0001	< 0.0002	< 0.0005	0.0001	0.0002	< 0.001	0.002	< 0.005	< 0.02	0.03	0.12
Birch Tree Lake	BLB	30-Sep-01	<10	< 0.0001	< 0.0001	< 0.0002	0.0006	0.0001	0.0002	< 0.001	0.003	< 0.005	< 0.02	0.05	0.14
Birch Tree Lake	BLC	26-Aug-01	<10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	0.04	0.13
Lower Burntwood River	LBRE1	27-Aug-01	-	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	-	-
Lower Burntwood River	LBRE1	30-Sep-01	<10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.003	-	< 0.02	0.07	0.14
Lower Burntwood River [1]	LBRE	27-Aug-01	<10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	0.09	0.18
Lower Burntwood River	LBRF	27-Aug-01	<10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	0.02	0.09	0.16
Lower Burntwood River	LBRF	1-Oct-01	<10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.003	-	< 0.02	0.07	0.14
Ice-cover Season 2001															
Opegano Lake	OLB	28-Mar-01	< 10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	-	-
Ice-cover Season 2002															
Cranberry Lakes	CLA	26-Mar-02	< 10	-	< 0.0001	-	0.0007	-	0.0002	-	0.002	-	< 0.02	< 0.02	0.1
Wuskwatim Lake	WuLB	26-Mar-02	-	-	< 0.0001	-	0.0010	-	0.0002	-	0.002	-	< 0.02	0.02	0.12
Birch Tree Lake	BLB	27-Mar-02	< 10	-	< 0.0001	-	0.0006	-	0.0002	-	0.002	-	< 0.02	0.03	0.15
Birch Tree Lake	BLC	27-Mar-02	< 10	-	< 0.0001	-	< 0.0005	-	0.0002	-	0.002	-	< 0.02	0.03	0.14
Lower Burntwood River	LBRF	27-Mar-02	< 10	-	< 0.0001	-	0.0046	-	0.0002	-	0.004	-	< 0.02	0.05	0.17

[1] One sample of water was collected on the lower Burntwood River downstream of the Manasan River in August 2001; due to problems with accessibility, this site was not visited again.
[2] Samples were not preserved correctly.

Table A2-5. Hydrocarbons and PCP measured in surface water samples collected in the Wuskwatim study area, 2000 – 2002.

Sampling Location	Location ID	Sample Date	Acenaphthene (µg/L)	Acenaphthylene (µg/L)	Acridine (µg/L)	Anthracene (µg/L)	Benzene (µg/L)	Benz(a)anthracene (µg/L)	Benzo(a)pyrene (µg/L)	Benzo(b)fluoranthene (µg/L)	Benzo(g)perylene (µg/L)
Open-water Season 2000											
Taskinigup Falls	TF	24-May-00	-	-	-	-	< 0.5	-	-	-	-
Taskinigup Falls	TF	23-Jul-00	-	-	-	-	< 0.5	-	-	-	-
Taskinigup Falls	TF	18-Sep-00	-	-	-	-	< 0.5	-	-	-	-
Open-water Season 2001											
Lower Burntwood River	LBRB2	30-May-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River	LBRB2	16-Jul-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River	LBRB2	23-Aug-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River	LBRB2	27-Sep-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Wuskwatim Lake	WuLB	30-May-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Wuskwatim Lake	WuLB	16-Jul-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Wuskwatim Lake	WuLB	23-Aug-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Wuskwatim Lake	WuLB	27-Sep-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Taskinigup Falls	TF	30-May-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Taskinigup Falls	TF	16-Jul-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Taskinigup Falls	TF	23-Aug-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Taskinigup Falls	TF	27-Sep-01	< 0.05	< 0.05	< 0.02	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01

Table A2-5. - continued –

Sampling Location	Location ID	Sample Date	Acenaphthene (µg/L)	Acenaphthylene (µg/L)	Acridine (µg/L)	Anthracene (µg/L)	Benzene (µg/L)	Benz(a)anthracene (µg/L)	Benzo(a)pyrene (µg/L)	Benzo(b)fluoranthene (µg/L)	Benzo(g)perylene (µg/L)
Birch Tree Lake	BLB	31-May-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Birch Tree Lake	BLB	17-Jul-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Birch Tree Lake	BLB	26-Aug-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Birch Tree Lake	BLB	30-Sep-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Birch Tree Lake	BLC	26-Aug-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River	LBRE1	30-Sep-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River [1]	LBRE	27-Aug-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River	LBRF	27-Aug-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River	LBRF	01-Oct-01	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	0.04	0.02	0.03	0.03
Ice-cover Season 2001											
Opegano Lake	OLB	28-Mar-01	< 0.05	< 0.05	-	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Ice-cover Season 2002											
Cranberry Lakes	CLA	26-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Wuskwatim Lake	WuLB	26-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Birch Tree Lake	BLB	27-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Birch Tree Lake	BLC	27-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Lower Burntwood River	LBRF	27-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01

Table A2-5. - continued –

Sampling Location	Location ID	Sample Date	Benzo(k)fluoranthene (µg/L)	Chrysene (µg/L)	Dibenz(a,h)anthracene (µg/L)	Ethyl benzene (µg/L)	Extractable HC (C11-C30) (µg/L)	Fluoranthene (µg/L)	Fluorene (µg/L)	Indeno(1,2,3-cd)pyrene (µg/L)
Open-water Season 2000										
Taskinigup Falls	TF	24-May-00	-	-	-	< 0.5	140	-	-	-
Taskinigup Falls	TF	23-Jul-00	-	-	-	< 0.5	< 100	-	-	-
Taskinigup Falls	TF	18-Sep-00	-	-	-	< 0.5	< 100	-	-	-
Open-water Season 2001										
Lower Burntwood River	LBRB2	30-May-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Lower Burntwood River	LBRB2	16-Jul-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Lower Burntwood River	LBRB2	23-Aug-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Lower Burntwood River	LBRB2	27-Sep-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Wuskwatim Lake	WuLB	30-May-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Wuskwatim Lake	WuLB	16-Jul-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Wuskwatim Lake	WuLB	23-Aug-01	< 0.01	< 0.05	< 0.01	< 0.5	360	< 0.05	< 0.05	< 0.01
Wuskwatim Lake	WuLB	27-Sep-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Taskinigup Falls	TF	30-May-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Taskinigup Falls	TF	16-Jul-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Taskinigup Falls	TF	23-Aug-01	< 0.01	< 0.05	< 0.01	< 0.5	250	< 0.05	< 0.05	< 0.01
Taskinigup Falls	TF	27-Sep-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01

Table A2-5. - continued –

Sampling Location	Location ID	Sample Date	Benzo(k)fluoranthene (µg/L)	Chrysene (µg/L)	Dibenz(a,h)anthracene (µg/L)	Ethyl benzene (µg/L)	Extractable HC (C11-C30) (µg/L)	Fluoranthene (µg/L)	Fluorene (µg/L)	Indeno(1,2,3-cd)pyrene (µg/L)
Birch Tree Lake	BLB	31-May-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Birch Tree Lake	BLB	17-Jul-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Birch Tree Lake	BLB	26-Aug-01	< 0.01	< 0.05	< 0.01	< 0.5	110	< 0.05	< 0.05	< 0.01
Birch Tree Lake	BLB	30-Sep-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Birch Tree Lake	BLC	26-Aug-01	< 0.01	< 0.05	< 0.01	< 0.5	130	< 0.05	< 0.05	< 0.01
Lower Burntwood River	LBRE1	30-Sep-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Lower Burntwood River [1]	LBRE	27-Aug-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Lower Burntwood River	LBRF	27-Aug-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Lower Burntwood River	LBRF	01-Oct-01	0.04	< 0.05	0.03	< 0.5	< 100	< 0.05	< 0.05	0.03
Ice-cover Season 2001										
Opegano Lake	OLB	28-Mar-01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Ice-cover Season 2002										
Cranberry Lakes	CLA	26-Mar-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Wuskwatim Lake	WuLB	26-Mar-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Birch Tree Lake	BLB	27-Mar-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Birch Tree Lake	BLC	27-Mar-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01
Lower Burntwood River	LBRF	27-Mar-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01

Table A2-5. - continued –

Sampling Location	Location ID	Sample Date	Napthalene (µg/L)	1-Methylnapthalene (µg/L)	2-Methylnapthalene (µg/L)	Pentachlorophenol (µg/L)	Phenanthrene (µg/L)	Pyrene (µg/L)	Quinoline (µg/L)	Toluene (µg/L)
Open-water Season 2000										
Taskinigup Falls	TF	24-May-00	-	-	-	-	-	-	-	< 0.5
Taskinigup Falls	TF	23-Jul-00	-	-	-	-	-	-	-	< 0.5
Taskinigup Falls	TF	18-Sep-00	-	-	-	-	-	-	-	< 0.5
Open-water Season 2001										
Lower Burntwood River	LBRB2	30-May-01	< 0.05	< 0.05	< 0.05	n/s	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River	LBRB2	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River	LBRB2	23-Aug-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River	LBRB2	27-Sep-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Wuskwatim Lake	WuLB	30-May-01	< 0.05	< 0.05	< 0.05	n/s	< 0.05	< 0.05	< 0.05	< 0.5
Wuskwatim Lake	WuLB	16-Jul-01	< 0.05	< 0.05	< 0.05	n/s	< 0.05	< 0.05	< 0.05	< 0.5
Wuskwatim Lake	WuLB	23-Aug-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Wuskwatim Lake	WuLB	27-Sep-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Taskinigup Falls	TF	30-May-01	< 0.05	< 0.05	< 0.05	n/s	< 0.05	< 0.05	< 0.05	< 0.5
Taskinigup Falls	TF	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	< 0.05	< 0.05	< 0.5
Taskinigup Falls	TF	23-Aug-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Taskinigup Falls	TF	27-Sep-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 1	< 0.5

Table A2-5. - continued –

Sampling Location	Location ID	Sample Date	Napthalene (µg/L)	1-Methylnapthalene (µg/L)	2-Methylnapthalene (µg/L)	Pentachlorophenol (µg/L)	Phenanthrene (µg/L)	Pyrene (µg/L)	Quinoline (µg/L)	Toluene (µg/L)
Birch Tree Lake	BLB	31-May-01	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05	< 0.05	< 0.05	0.6
Birch Tree Lake	BLB	17-Jul-01	< 0.05	< 0.05	< 0.05	n/s	< 0.05	< 0.05	< 0.05	< 0.5
Birch Tree Lake	BLB	26-Aug-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Birch Tree Lake	BLB	30-Sep-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Birch Tree Lake	BLC	26-Aug-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River	LBRE1	30-Sep-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River [1]	LBRE	27-Aug-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River	LBRF	27-Aug-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River	LBRF	01-Oct-01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Ice-cover Season 2001										
Opegano Lake	OLB	28-Mar-01	0.11	< 0.05	0.06	-	< 0.05	< 0.05	< 0.05	< 0.5
Ice-cover Season 2002										
Cranberry Lakes	CLA	26-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Wuskwatim Lake	WuLB	26-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Birch Tree Lake	BLB	27-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Birch Tree Lake	BLC	27-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5
Lower Burntwood River	LBRF	27-Mar-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5

Table A2-5. - continued –

Sampling Location	Location ID	Sample Date	Volatile HC (C5-C10) (µg/L)	Xylene - Total (µg/L)	Xylene - meta and para (µg/L)	Xylene - ortho (µg/L)
Open-water Season 2000						
Taskinigup Falls	TF	24-May-00	< 100	< 0.5	< 0.5	< 0.5
Taskinigup Falls	TF	23-Jul-00	< 100	< 0.5	< 0.5	< 0.5
Taskinigup Falls	TF	18-Sep-00	< 100	< 0.5	< 0.5	< 0.5
Open-water Season 2001						
Lower Burntwood River	LBRB2	30-May-01	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRB2	16-Jul-01	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRB2	23-Aug-01	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRB2	27-Sep-01	< 100	< 0.5	< 0.5	< 0.5
Wuskwatim Lake	WuLB	30-May-01	< 100	< 0.5	< 0.5	< 0.5
Wuskwatim Lake	WuLB	16-Jul-01	< 100	0.7	0.7	< 0.5
Wuskwatim Lake	WuLB	23-Aug-01	< 100	< 0.5	< 0.5	< 0.5
Wuskwatim Lake	WuLB	27-Sep-01	< 100	< 0.5	< 0.5	< 0.5
Taskinigup Falls	TF	30-May-01	< 100	< 0.5	< 0.5	< 0.5
Taskinigup Falls	TF	16-Jul-01	< 100	< 0.5	< 0.5	< 0.5
Taskinigup Falls	TF	23-Aug-01	< 100	< 0.5	< 0.5	< 0.5
Taskinigup Falls	TF	27-Sep-01	< 100	< 0.5	< 0.5	< 0.5

[1] One sample of water was collected on the lower Burntwood River downstream of the Manasan River in August 2001; due to problems with accessibility, this site was not visited again.

Table A2-5. - continued –

Sampling Location	Location ID	Sample Date	Volatile HC (C5-C10) (µg/L)	Xylene - Total (µg/L)	Xylene - meta and para (µg/L)	Xylene - ortho (µg/L)
Birch Tree Lake	BLB	31-May-01	< 100	3.4	2.2	1.2
Birch Tree Lake	BLB	17-Jul-01	< 100	< 0.5	< 0.5	< 0.5
Birch Tree Lake	BLB	26-Aug-01	< 100	< 0.5	< 0.5	< 0.5
Birch Tree Lake	BLB	30-Sep-01	< 100	< 0.5	< 0.5	< 0.5
Birch Tree Lake	BLC	26-Aug-01	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRE1	30-Sep-01	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River [1]	LBRE	27-Aug-01	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRF	27-Aug-01	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRF	01-Oct-01	< 100	< 0.5	< 0.5	< 0.5
Ice-cover Season 2001						
Opegano Lake	OLB	28-Mar-01	< 100	-	< 0.5	< 0.5
Ice-cover Season 2002						
Cranberry Lakes	CLA	26-Mar-02	< 100	< 0.5	< 0.5	< 0.5
Wuskwatim Lake	WuLB	26-Mar-02	< 100	< 0.5	< 0.5	< 0.5
Birch Tree Lake	BLB	27-Mar-02	< 100	< 0.5	< 0.5	< 0.5
Birch Tree Lake	BLC	27-Mar-02	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRF	27-Mar-02	< 100	< 0.5	< 0.5	< 0.5

[1] One sample of water was collected on the lower Burntwood River downstream of the Manasan River in August 2001; due to problems with accessibility, this site was not visited again.

Table A2-6. Water chemistry data for water samples collected at tributary streams in Reaches 2 and 3, September 2002 and analysed in the laboratory. Streams were sampled in the backwater inlets (STR-1 to STR-10 D) and a point upstream of the influence of the lower Burntwood River (STR-1 to STR-10 U). Abbreviations are defined in the footnotes [1].

			Alkalinity				Nitrogen						Phosphorus		
Sampling Location	Location ID	Sample Date	As Bicarbonate (mg/L)	As $CaCO_3$ (mg/L)	As Carbonate (mg/L)	As Hydroxide (mg/L)	Dissolved Ammonia[2] (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [3] (mg/L N)	Total Nitrogen [4] (mg/L)	Dissolved Inorganic Nitrogen [5] (mg/L N)	Dissolved (mg/L P)	Total (mg/L P)	Dissolved Fraction (%)
Stream 1	STR-1-U	23-Sep-02	68	55	< 20	< 10	0.012	0.007	0.7	0.688	0.707	0.019	0.013	0.016	81
Stream 1	STR-1-D	23-Sep-02	61	50	< 20	< 10	0.007	0.016	0.5	0.493	0.516	0.023	0.012	0.033	36
Stream 2	STR-2-U	23-Sep-02	-	-	-	-	0.008	0.009	0.7	0.692	0.709	0.017	0.011	0.043	26
Stream 2	STR-2-D	23-Sep-02	-	-	-	-	0.006	0.019	0.6	0.594	0.619	0.025	0.012	0.054	22
Stream 3	STR-3-U	23-Sep-02	-	-	-	-	0.01	0.011	0.8	0.79	0.811	0.021	0.015	0.072	21
Stream 3	STR-3-D	23-Sep-02	-	-	-	-	0.007	0.018	0.4	0.393	0.418	0.025	0.013	0.04	33
Stream 4	STR-4-U	23-Sep-02	111	91	< 20	< 10	0.009	< 0.005	0.7	0.691	0.703	0.012	0.013	0.048	27
Stream 4	STR-4-D	23-Sep-02	65	54	< 20	< 10	0.008	0.015	0.5	0.492	0.515	0.023	0.012	0.047	26
Stream 5	STR-5-U	23-Sep-02	-	-	-	-	0.006	0.015	0.4	0.394	0.415	0.021	0.01	0.038	26
Stream 5	STR-5-D	23-Sep-02	-	-	-	-	0.008	0.009	0.6	0.592	0.609	0.017	0.011	0.022	50
Stream 6	STR-6-U	23-Sep-02	-	-	-	-	0.01	0.005	0.6	0.59	0.605	0.015	0.014	0.033	42
Stream 6	STR-6-D	23-Sep-02	-	-	-	-	0.007	0.012	0.7	0.693	0.712	0.019	0.014	0.057	25
Stream 7	STR-7-U	23-Sep-02	-	-	-	-	0.009	0.008	0.7	0.691	0.708	0.017	0.013	0.021	62
Stream 7	STR-7-D	23-Sep-02	-	-	-	-	0.006	0.014	0.4	0.394	0.414	0.02	0.012	0.037	32
Stream 8	STR-8-U	23-Sep-02	-	-	-	-	0.01	0.008	0.7	0.69	0.708	0.018	0.017	0.038	45
Stream 8	STR-8-D [6]	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stream 9	STR-9-U	23-Sep-02	-	-	-	-	0.01	0.01	0.7	0.69	0.71	0.02	0.013	0.047	28
Stream 9	STR-9-D	23-Sep-02	-	-	-	-	0.008	0.009	0.7	0.692	0.709	0.017	0.012	0.048	25
Stream 10	STR-10-U	23-Sep-02	-	-	-	-	0.01	0.009	0.7	0.69	0.709	0.019	0.015	0.056	27
Stream 10	STR-10-D	23-Sep-02	-	-	-	-	0.01	0.02	0.5	0.49	0.52	0.03	0.014	0.049	29

Table A2-6. - continued -

			Nitrogen:Phosphorus Molar Ratios			Carbon						OC:N Molar Ratios			Water Clarity		
Sampling Location	Location ID	Sample Date	TotN:TotP	DIN:DP	DIN:TP	Total Organic (mg/L)	Dissolved Organic (mg/L)	Total Inorganic (mg/L)	Dissolved Inorganic (mg/L)	Total Carbon (mg/L)	Total Dissolved Carbon (mg/L)	TOC:ON	TOC:TN	TDS (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colout (TCU)
Stream 1	STR-1-U	23-Sep-02	97.7	3.2	2.6	31	31	13	13	44	44	52.5	51.1	140	3	3.5	140
Stream 1	STR-1-D	23-Sep-02	34.6	4.2	1.5	8	7	12	12	20	19	16.6	18.1	56	11	32	30
Stream 2	STR-2-U	23-Sep-02	36.5	3.4	0.9	28	27	-	-	-	-	45.5	46.1	-	25	46	-
Stream 2	STR-2-D	23-Sep-02	25.3	4.6	1.0	8	8	-	-	-	-	15.7	15.1	-	12	33	-
Stream 3	STR-3-U	23-Sep-02	24.9	3.1	0.6	27	27	-	-	-	-	39.9	38.8	-	120	150	-
Stream 3	STR-3-D	23-Sep-02	23.1	4.3	1.4	8	8	-	-	-	-	23.7	22.3	-	12	35	-
Stream 4	STR-4-U	23-Sep-02	32.4	2.0	0.5	25	25	22	22	47	47	42.2	41.5	160	29	42	120
Stream 4	STR-4-D	23-Sep-02	24.2	4.2	1.1	9	9	13	13	22	22	21.3	20.4	96	13	34	40
Stream 5	STR-5-U	23-Sep-02	24.2	4.6	1.2	7	7	-	-	-	-	20.7	19.7	-	10	14	-
Stream 5	STR-5-D	23-Sep-02	61.2	3.4	1.7	23	22	-	-	-	-	43.3	44.0	-	10	29	-
Stream 6	STR-6-U	23-Sep-02	40.5	2.4	1.0	21	20	-	-	-	-	39.5	40.5	-	11	22	-
Stream 6	STR-6-D	23-Sep-02	27.6	3.0	0.7	18	18	-	-	-	-	30.3	29.5	-	21	35	-
Stream 7	STR-7-U	23-Sep-02	74.6	2.9	1.8	24	24	-	-	-	-	40.5	39.5	-	5	8	-
Stream 7	STR-7-D	23-Sep-02	24.7	3.7	1.2	8	8	-	-	-	-	23.7	22.5	-	10	29	-
Stream 8	STR-8-U	23-Sep-02	41.2	2.3	1.0	26	27	-	-	-	-	45.6	42.8	-	16	31	-
Stream 8	STR-8-D [6]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Stream 9	STR-9-U	23-Sep-02	33.4	3.4	0.9	23	22	-	-	-	-	37.2	37.8	-	18	39	-
Stream 9	STR-9-D	23-Sep-02	32.7	3.1	0.8	23	22	-	-	-	-	37.1	37.8	-	16	40	-
Stream 10	STR-10-U	23-Sep-02	28.0	2.8	0.8	25	24	-	-	-	-	40.6	41.1	-	17	66	-
Stream 10	STR-10-D	23-Sep-02	23.5	4.7	1.4	9	9	-	-	-	-	21.4	20.2	-	13	35	-

Table A2-6. - continued –

Sampling Location	Location ID	Sample Date	pH	Hardness as CaCO3 (mg/L)	Total Anions (mEq/L)	Total Cations (mEq/L)	Tot. Cat. - Tot. Anions (mEq/L)	Chlorophyll *a* (µg/L)	BOD (mg/L)
Stream 1	STR-1-U	23-Sep-02	6.98	73.3	1.49	1.61	0.12	< 1	< 1
Stream 1	STR-1-D	23-Sep-02	7.63	49.8	1	1.19	0.19	4	1
Stream 2	STR-2-U	23-Sep-02	7.56	-	-	-	-	1	-
Stream 2	STR-2-D	23-Sep-02	7.51	-	-	-	-	4	-
Stream 3	STR-3-U	23-Sep-02	7.58	-	-	-	-	< 1	-
Stream 3	STR-3-D	23-Sep-02	7.61	-	-	-	-	5	-
Stream 4	STR-4-U	23-Sep-02	7.56	93.9	2.15	2.14	-0.01	< 1	1
Stream 4	STR-4-D	23-Sep-02	7.62	53.2	1.07	1.27	0.2	7	1
Stream 5	STR-5-U	23-Sep-02	7.48	-	-	-	-	< 1	-
Stream 5	STR-5-D	23-Sep-02	7.60	-	-	-	-	4	-
Stream 6	STR-6-U	23-Sep-02	7.66	-	-	-	-	1	-
Stream 6	STR-6-D	23-Sep-02	7.63	-	-	-	-	2	-
Stream 7	STR-7-U	23-Sep-02	7.37	-	-	-	-	1	-
Stream 7	STR-7-D	23-Sep-02	7.70	-	-	-	-	5	-
Stream 8	STR-8-U	23-Sep-02	7.61	-	-	-	-	1	-
Stream 8	STR-8-D [6]	-	-	-	-	-	-	-	-
Stream 9	STR-9-U	23-Sep-02	7.54	-	-	-	-	< 1	-
Stream 9	STR-9-D	23-Sep-02	7.54	-	-	-	-	< 1	-
Stream 10	STR-10-U	23-Sep-02	7.44	-	-	-	-	< 1	-
Stream 10	STR-10-D	23-Sep-02	7.61	-	-	-	-	3	-

[1] Abbreviations are as follows: TKN = total kjeldahl nitrogen; TOT N = total nitrogen; TOT P = total phosphorus; DIN = dissolved inorganic nitrogen; DP = dissolved phosphorus; OC = organic carbon; TOC = total organic carbon; ON = organic nitrogen; TDS = total dissolved solids; and BOD = biochemical oxygen demand.
[2] Where values are indicated to 2 decimal places, analytical detection limit is 0.01 mg/L; Where values are indicated to 3 decimal places, analytical detection limit is 0.002 mg/L.
[3] Organic nitrogen estimated from: TKN – dissolved ammonia.
[4] Total nitrogen estimated from TKN + dissolved nitrate/nitrite.
[5] Dissolved inorganic nitrogen is the sum of dissolved ammonia and nitrate/nitrite nitrogen.
[6] Site not sampled due to inaccessibility.

Table A2-7. Water quality parameters measured *in situ* at tributary streams in Reaches 2 and 3, September 2002. Streams were sampled in the backwater inlets (STR-1 to STR-10 D) and a point upstream of the influence of the lower Burntwood River (STR-1 to STR-10 U).

Sampling Location	Location ID	Sample Date	Water Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	pH
Stream 1	STR-1-U	23-Sep-02	0.1	5.6	9.32	76.92	139	8	7.23
Stream 1	STR-1-D	23-Sep-02	0.1	10.9	8.53	78.40	112	95	8.33
Stream 2	STR-2-U	25-Sep-02	0.1	4.0	11.12	88.84	182	136	8.17
Stream 2	STR-2-D	25-Sep-02	0.1	7.7	8.64	74.41	120	72	8.26
Stream 3	STR-3-U	23-Sep-02	0.1	5.7	10.24	84.68	176	347	8.05
Stream 3	STR-3-D	23-Sep-02	0.1	10.4	9.04	82.24	115	125	8.28
Stream 4	STR-4-U	23-Sep-02	0.1	5.7	10.40	86.01	195	116	7.99
Stream 4	STR-4-D	23-Sep-02	0.1	9.2	9.88	87.72	120	82	8.14
Stream 5	STR-5-U	25-Sep-02	0.1	4.3	10.79	86.73	159	41	7.95
Stream 5	STR-5-D	25-Sep-02	0.1	8.7	8.54	75.06	114	231	8.28
Stream 6	STR-6-U	25-Sep-02	0.1	4.8	10.89	88.43	190	59	8.20
Stream 6	STR-6-D	25-Sep-02	0.1	6.1	9.42	78.54	180	80	8.17
Stream 7	STR-7-U	25-Sep-02	0.1	4.9	10.73	87.31	145	22	7.90
Stream 7	STR-7-D	25-Sep-02	0.1	9.4	9.55	85.14	115	59	8.27
Stream 8	STR-8-U	25-Sep-02	0.1	4.1	11.16	89.34	163	107	8.16
Stream 8	STR-8-D	-	-	-	-	-	-	-	-
Stream 9	STR-9-U	25-Sep-02	0.1	4.7	10.78	87.36	149	99	8.09
Stream 9	STR-9-D	25-Sep-02	0.1	4.9	10.46	85.11	193	159	8.14
Stream 10	STR-10-U	25-Sep-02	0.1	4.7	10.81	87.60	225	194	7.90
Stream 10	STR-10-D	25-Sep-02	0.1	8.0	8.94	77.47	125	86	8.33

Table A2-8. Dissolved oxygen concentrations measured *in situ* at the backwater inlets of tributary streams in Reaches 2 and 3, March and April 2002. Sites are indicated on Figure 5-21.

Sampling Location	Location ID	Sample Date	Effective Depth (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Saturation) [1]
Backwater Inlet 1	STR-1-MOUTH	25-Mar-02	3.2	0.5	13.30	99.3
Backwater Inlet 4	STR-4-MOUTH	31-Mar-02	2.3	-	10.73	80.1
Backwater Inlet 4	STR-4-UPSTREAM	25-Mar-02	3.25	0.5	13.43	100.3
Backwater Inlet 6	STR-6-MOUTH	31-Mar-02	1.3	-	13.51	100.9
Backwater Inlet 6	STR-6-UPSTREAM	25-Mar-02	2.3	0.5	13.54	101.1
Backwater Inlet 9	STR-9-MOUTH	01-Apr-02	2.0	-	13.49	100.7
Backwater Inlet 9	STR-9-UPSTREAM	25-Mar-02	1.6	0.5	13.99	104.5

[1] Where water temperature was not measured, % saturation was calculated assuming a water temperature of 0.5 °C.

Table A2-9. Major ions and inorganic elements (total) measured in water samples collected in tributary streams in Reaches 2 and 3, September 2002. Streams were sampled in the backwater inlets (STR-1-D and STR-4-D) and a point upstream of the influence of the lower Burntwood River (STR-1-U and STR-4 U).

Sampling Location	Location ID	Sample Date	Hardness as CaCO3 (mg/l)	Aluminum (mg/l)	Arsenic (mg/l)	Antimony (mg/l)	Barium (mg/l)	Beryllium (mg/l)	Boron (mg/l)	Cadmium (mg/l)	Calcium (mg/l)	Chromium (mg/l)	Dissolved Chloride (mg/l)	Cobalt (mg/l)	Copper (mg/l)	Dissolved Fluoride (mg/l)
Stream 1	STR-1-U	23-Sep-02	73.3	0.33	< 0.0005	< 0.001	0.0092	< 0.001	< 0.03	< 0.0002	18	< 0.002	< 10	0.0002	0.003	< 0.1
Stream 1	STR-1-D	23-Sep-02	49.8	1.81	< 0.0005	< 0.001	0.0259	< 0.001	< 0.03	< 0.0002	13.2	0.002	< 10	0.002	0.004	0.1
Stream 4	STR-4-U	23-Sep-02	93.9	3.06	0.0008	< 0.001	0.0393	< 0.001	< 0.03	< 0.0002	24.5	0.004	< 10	0.0013	0.003	< 0.1
Stream 4	STR-4-D	23-Sep-02	53.2	1.89	0.0005	< 0.001	0.0274	< 0.001	< 0.03	< 0.0002	14.1	0.002	< 10	0.0007	0.003	< 0.1

Sampling Location	Location ID	Sample Date	Iron (mg/l)	Lead (mg/l)	Magnesium (mg/l)	Manganese (mg/l)	Mercury (mg/l)	Molybdenum (mg/l)	Nickel (mg/l)	Phosphorus (mg/l)	Potassium (mg/l)	Selenium (mg/l)	Silver (mg/l)	Sodium (mg/l)	Strontium (mg/l)
Stream 1	STR-1-U	23-Sep-02	0.22	< 0.0005	6.88	0.0047	< 0.00005	0.0002	0.002	< 0.2	0.6	< 0.001	< 0.0001	2.9	0.0334
Stream 1	STR-1-D	23-Sep-02	1.39	0.0073	4.09	0.0241	< 0.00005	0.0002	0.002	< 0.2	1.5	< 0.001	< 0.0001	2.54	0.0363
Stream 4	STR-4-U	23-Sep-02	2.6	0.0016	7.96	0.0493	< 0.00005	0.0002	0.004	< 0.2	1.4	< 0.001	< 0.0001	3.14	0.0507
Stream 4	STR-4-D	23-Sep-02	1.45	0.0008	4.36	0.0302	< 0.00005	0.0002	0.002	< 0.2	1.5	< 0.001	0.0004	2.59	0.0377

Sampling Location	Location ID	Sample Date	Dissolved Sulphate (mg/l)	Thallium (mg/l)	Tin (mg/l)	Uranium (mg/l)	Vanadium (mg/l)	Zinc (mg/l)
Stream 1	STR-1-U	23-Sep-02	18	< 0.0001	0.0015	0.0002	< 0.001	< 0.02
Stream 1	STR-1-D	23-Sep-02	< 10	< 0.0001	0.0019	0.0002	0.003	0.1
Stream 4	STR-4-U	23-Sep-02	16	< 0.0001	0.0021	0.0004	0.006	< 0.02
Stream 4	STR-4-D	23-Sep-02	< 10	< 0.0001	0.001	0.0002	0.003	< 0.02

Table A2-10. Hydrocarbons measured in surface water samples collected in tributary streams in Reaches 2 and 3, September 2002. Streams 1 and 4 were sampled in the backwater inlets (STR-1-D and STR-4-D) and a point upstream of the influence of the lower Burntwood River (STR-1-U and STR-4 U).

Sampling Location	Location ID	Sample Date	Acenaphthene (µg/L)	Acenaphthylene (µg/L)	Acridine (µg/L)	Anthracene (µg/L)	Benzene (µg/L)	Benz(a)anthracene (µg/L)	Benzo(a)pyrene (µg/L)	Benzo(b)fluoranthene (µg/L)	Benzo(g)perylene (µg/L)
Stream 1	STR-1-U	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Stream 1	STR-1-D	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01
Stream 4	STR-4-U	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	0.01	< 0.01	0.02	0.01
Stream 4	STR-4-D	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01	< 0.01	< 0.01

Sampling Location	Location ID	Sample Date	Benzo(k)fluoranthene (µg/L)	Chrysene (µg/L)	Dibenz(a,h)anthracene (µg/L)	Ethyl benzene (µg/L)	Extractable HC (C11-C30) (µg/L)	Fluoranthene (µg/L)	Fluorene (µg/L)	Indeno (1,2,3-cd)pyrene (µg/L)	Napthalene (µg/L)	1-Methylnapthalene (µg/L)
Stream 1	STR-1-U	23-Sep-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05
Stream 1	STR-1-D	23-Sep-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05
Stream 4	STR-4-U	23-Sep-02	0.01	< 0.05	0.01	< 0.5	< 100	< 0.05	< 0.05	0.01	< 0.05	< 0.05
Stream 4	STR-4-D	23-Sep-02	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05	< 0.05	< 0.01	< 0.05	< 0.05

Sampling Location	Location ID	Sample Date	2-Methylnapthalene (µg/L)	Pentachlorophenol (µg/L)	Phenanthrene (µg/L)	Pyrene (µg/L)	Quinoline (µg/L)	Toluene (µg/L)	Volatile HC (C5-C10) (µg/L)	Xylene - Total (µg/L)	Xylene - meta and para (µg/L)	Xylene - ortho (µg/L)
Stream 1	STR-1-U	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
Stream 1	STR-1-D	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
Stream 4	STR-4-U	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
Stream 4	STR-4-D	23-Sep-02	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5

Table A2-11. Water chemistry data measured in the laboratory for stream crossings along the proposed Mile 17 Access Road, 2002. Abbreviations are defined in the footnotes [1].

			Alkalinity				Nitrogen						Phosphorus		
Sampling Location	Location ID	Sample Date	As Bicarbonate (mg/L)	As $CaCO_3$ (mg/L)	As Carbonate (mg/L)	As Hydroxide (mg/L)	Dissolved Ammonia (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [2] (mg/L N)	Total Nitrogen [3] (mg/L)	Dissolved Inorganic Nitrogen [4] (mg/L N)	Dissolved (mg/L P)	Total (mg/L P)	Dissolved Fraction (%)
Proposed stream crossing	SC2-2	14-Jun-02	-	-	-	-	0.003	0.041	0.5	0.497	0.541	0.044	0.013	0.026	50
Proposed stream crossing	SC4-2	14-Jun-02	-	-	-	-	0.005	< 0.005	0.5	0.495	0.5025	0.0075	0.009	0.015	60
Proposed stream crossing	SC5-2	14-Jun-02	-	-	-	-	0.003	0.02	0.6	0.597	0.62	0.023	0.014	0.033	42
Proposed stream crossing	SC6-2	14-Jun-02	-	-	-	-	0.003	0.02	0.5	0.497	0.52	0.023	0.011	0.024	46
Proposed stream crossing	SC9-2	14-Jun-02	-	-	-	-	0.003	0.018	0.7	0.697	0.718	0.021	0.014	0.084	17

Table A2-11. - continued –

Sampling Location	Location ID	Sample Date	Nitrogen:Phosphorus Molar Ratios			Organic Carbon (OC)		OC:N Molar Ratios			Water Clarity					
			TotN:TotP	DIN:DP	DIN:TP	Total (mg/L)	Dissolved (mg/L)	TOC:ON	TOC:TN	Dissolved Solids (mg/L)	TSS (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Chlorophyll *a* (µg/L)
Proposed stream crossing	SC2-2	14-Jun-02	46.0	7.5	3.7	19	18	45	41	-	6	8.9	-	7.27	-	2
Proposed stream crossing	SC4-2	14-Jun-02	74.1	1.8	1.1	26	26	61	60	-	2	2.6	-	6.87	-	< 1
Proposed stream crossing	SC5-2	14-Jun-02	41.5	3.6	1.5	17	18	33	32	-	11	16	-	7.5	-	2
Proposed stream crossing	SC6-2	14-Jun-02	47.9	4.6	2.1	19	19	45	43	-	8	11	-	7.41	-	2
Proposed stream crossing	SC9-2	14-Jun-02	18.9	3.3	0.6	22	22	37	36	-	63	84	-	7.83	-	2

[1] Abbreviations are as follows: TKN = total kjeldahl nitrogen; TOT N = total nitrogen; TOT P = total phosphorus; DIN = dissolved inorganic nitrogen; DP = dissolved phosphorus; OC = organic carbon; TOC = total organic carbon; ON = organic nitrogen; and, TSS = total suspended solids.
[2] Organic nitrogen estimated from: TKN – dissolved ammonia.
[3] Total nitrogen estimated from TKN + dissolved nitrate/nitrite.
[4] Dissolved inorganic nitrogen is the sum of dissolved ammonia and nitrate/nitrite nitrogen.

Table A2-12. Water chemistry data measured *in situ* for stream crossings along the proposed Mile 17 Access Road, 2002.

Sampling Location	Location ID	Sample Date	Water Depth [1] (m)	Temperature (°C)	Dissolved Oxygen (mg/L)	Dissolved Oxygen % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke [2] (m^{-1})	z_1 [3] (m)	pH
Ice-Cover Season 2002												
Proposed stream crossing	SC2-2	25-March-02	0.55	0.5	2.68	20.2	-	-	-	-	-	-
Proposed stream crossing	SC5-2	25-March-02	0.4	0.6	7.40	55.4	-	-	-	-	-	-
Proposed stream crossing	SC6-2	25-March-02	0.65	0.8	1.28	9.6	-	-	-	-	-	-
Open-water Season 2002												
Proposed stream crossing	SC2-2	14-Jun-02	-	15.0	8.31	83.3	135	-	-	-	-	-
Proposed stream crossing	SC4-2	14-Jun-02	-	13.1	7.52	72.5	74.5	-	-	-	-	-
Proposed stream crossing	SC5-2	14-Jun-02	-	14.6	8.16	81.1	176.6	-	-	-	-	-
Proposed stream crossing	SC6-2	14-Jun-02	-	15.3	9.67	97.5	131.7	-	-	-	-	-
Proposed stream crossing	SC9-2	14-Jun-02	-	14.3	9.61	95.0	164	-	-	-	-	-

[1] In winter, refers to effective depth (total depth – ice thickness).
[2] Ke is the light extinction coefficient, estimated from Secchi depths.
[3] z_1 is the depth of the euphotic zone (depth where 1% of surface irradiation still remains), estimated from Secchi depths.

APPENDIX 3. STATISTICAL SUMMARIES OF BASELINE WATER CHEMISTRY DATA COLLECTED IN THE WUSKWATIM STUDY AREA, 1999-2002.

The following is provided on the enclosed CD:

Table A3-1
Table A3-2
Table A3-3
Table A3-4

Table A3-1. Summary Statistics for water chemistry data (nutrients, water clarity, pH, water hardness, and total dissolved solids) collected from the Study Area in the open-water and ice-cover seasons. Data are presented as mean ± standard error (SE), range and sample size (n).

				Alkalintity				Nitrogen					
Sampling Location	Location ID	Sample Date		as Bicarbonate (mg/L)	as $CaCO_3$ (mg/L)	as Carbonate (mg/L)	as Hydroxide (mg/L)	Dissolved Ammonia [1] (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [2] (mg/L N)	Total Nitrogen [3] (mg/L)	Dissolved Inorganic Nitrogen [4] (mg/L N)
Open-water Season													
Lower Burntwood River	LBRB	1999	Mean±SE	-	-	-	-	0.01±0.004	<0.01±0.004	0.4±0.1	0.390±0.084	0.409±0.085	(0.019±0.005)
			Range					(0.002 - 0.02)	(<0.01 - 0.02)	(0.2 - 0.6)	(0.180 - 0.590)	(0.205 - 0.620)	(0.007 - 0.03)
			n					4	4	4	4	4	4
Lower Burntwood River	LBRC	1999	Mean±SE	-	-	-	-	<0.01±0.000	<0.01	0.3±0.1	0.320±0.085	0.330±0.085	<0.01±0.00
			Range					(< 0.01 - 0.005)	-	(<0.2 - 0.5)	(0.095 - 0.495)	(0.105 - 0.505)	(<0.01 - 0.01)
			n					4	4	4	4	4	4
Wuskwatim Lake	WuLA	1999	Mean±SE	-	-	-	-	<0.01±0.001	<0.01	0.4±0.1	0.368±0.062	0.380±0.063	0.010±0.003
			Range					(< 0.01 - 0.01)	-	(0.2 - 0.5)	(0.195 - 0.490)	(0.205 - 0.505)	(<0.01 - 0.015)
			n					4	4	4	4	4	4
Wuskwatim Lake	WuLB	1999	Mean±SE	-	-	-	-	<0.01±0.001	<0.01	0.4±0.1	0.344±0.049	0.355±0.050	<0.01±0.003
			Range					(<0.01 - 0.01)	-	(0.3 - 0.5)	(0.295 - 0.490)	(0.305 - 0.505)	(<0.01 - 0.015)
			n					4	4	4	4	4	4
Lower Burntwood River	LBRB	2000	Mean±SE	-	-	-	-	0.01±0.003	0.01±0.004	0.4±0.1	0.387±0.061	0.412±0.056	0.03±0.01
			Range					(0.01 - 0.02)	(<0.01 - 0.02)	(0.3 - 0.5)	(0.280 - 0.490)	(0.310 - 0.505)	(0.015 - 0.03)
			n					3	3	3	3	3	3

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Alkalintity as Bicarbonate (mg/L)	Alkalintity as $CaCO_3$ (mg/L)	Alkalintity as Carbonate (mg/L)	Alkalintity as Hydroxide (mg/L)	Nitrogen Dissolved Ammonia [1] (mg/L N)	Nitrogen Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen TKN (mg/L)	Nitrogen Organic Nitrogen [2] (mg/L N)	Nitrogen Total Nitrogen [3] (mg/L)	Nitrogen Dissolved Inorganic Nitrogen [4] (mg/L N)
Lower Burntwood River	LBRC	2000	Mean±SE	-	-	-	-	0.01±0.004	0.02±0.003	0.4±0.1	0.422±0.084	0.457±0.091	0.04±0.01
			Range					(<0.01 - 0.02)	(0.02 - 0.03)	(0.3 - 0.6)	(0.295 - 0.580)	(0.320 - 0.630)	(0.025 - 0.05)
			n					3	3	3	3	3	3
Wuskwatim Lake	WuLA	2000	Mean±SE	-	-	-	-	0.01±0.00	0.02±0.00	0.4±0.1	0.390±0.058	0.420±0.058	0.03±0
			Range					(0.01 - 0.01)	(0.02 - 0.02)	(0.3 - 0.5)	(0.290 - 0.490)	(0.320 - 0.520)	(0.03 - 0.03)
			n					3	3	3	3	3	3
Wuskwatim Lake	WuLB	2000	Mean±SE	-	-	-	-	0.01±0.01	0.02±0.003	0.5±0.1	0.490±0.098	0.523±0.097	0.03±0.00
			Range					(<0.01 - 0.02)	(0.02 - 0.03)	(0.3 - 0.6)	(0.295 - 0.595)	(0.330 - 0.620)	(0.025 - 0.04)
			n					3	3	3	3	3	3
Opegano Lake	OLA	2000	Mean±SE	-	-	-	-	< 0.01±0.003	0.03±0.005	0.4	0.393±0.003	0.425±0.005	0.03±0.00
			Range					(0.004 - 0.01)	(0.02 - 0.03)	-	(0.390 - 0.396)	(0.420 - 0.430)	(0.03 - 0.034)
			n					2	2	2	2	2	2
Opegano Lake	OLB	2000	Mean±SE	-	-	-	-	0.01±0.002	0.03±0.01	0.4	0.392±0.002	0.430±0.010	0.04±0.01
			Range					(0.006 - 0.01)	(0.02 - 0.04)	-	(0.390 - 0.394)	(0.420 - 0.440)	(0.03 - 0.046)
			n					2	2	2	2	2	2
Birch Tree Lake	BLA	2000	Mean±SE	-	-	-	-	0.02±0.02	0.01±0.01	0.4±0.1	0.378±0.083	0.413±0.093	0.035±0.01
			Range					(<0.01 - 0.04)	(<0.01 - 0.02)	(0.3 - 0.5)	(0.295 - 0.460)	(0.320 - 0.505)	(0.025 - 0.045)
			n					2	2	2	2	2	2

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Alkalintity as Bicarbonate (mg/L)	Alkalintity as $CaCO_3$ (mg/L)	Alkalintity as Carbonate (mg/L)	Alkalintity as Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia [1] (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [2] (mg/L N)	Total Nitrogen [3] (mg/L)	Dissolved Inorganic Nitrogen [4] (mg/L N)
Birch Tree Lake	BLB	2000	Mean±SE	-	-	-	-	<0.01±0.003	0.03±0.005	0.6±0.3	0.543±0.248	0.575±0.245	0.03±0.00
			Range					(<0.01 - 0.01)	(0.02 - 0.03)	(0.3 - 0.8)	(0.295 - 0.790)	(0.330 - 0.820)	(0.03 - 0.035)
			n					2	2	2	2	2	2
Lower Burntwood River	LBRB	2001	Mean±SE	-	-	-	-	0.01±0.003	0.008±0.002	0.6±0.1	0.564±0.111	0.583±0.111	0.019±0.003
			Range					(0.004 - 0.02)	(<0.005 - 0.014)	(0.4 - 0.9)	(0.396 - 0.890)	(0.414 - 0.910)	(0.012 - 0.026)
			n					4	4	4	4	4	4
Lower Burntwood River	LBRB2	2001	Mean±SE	64±1	53±1	<20±0	<10±0	0.01±0.003	0.010±0.003	0.5±0.03	0.439±0.031	0.460±0.026	0.021±0.006
			Range	(61 - 66)	(50 - 54)	(<20 - <20)	(<10 - <10)	(0.006 - 0.02)	(0.005 - 0.019)	(0.4 - 0.5)	(0.380 - 0.494)	(0.409 - 0.505)	(0.011 - 0.039)
			n	4	4	4	4	4	4	4	4	4	4
Lower Burntwood River	LBRC	2001	Mean±SE	-	-	-	-	0.01±0.002	0.006±0.001	0.5	0.492±0.001	0.506±0.001	0.015±0.001
			Range					(0.004 - 0.01)	(<0.005 - 0.008)	-	(0.490 - 0.496)	(0.503 - 0.508)	(0.012 - 0.018)
			n					4	4	4	4	4	4
Sesep Lake	SLA	2001	Mean±SE	-	-	-	-	0.02	<0.005±0.001	0.8±0.1	0.730±0.087	0.754±0.086	0.024±0.001
			Range					-	(<0.005 - 0.007)	(0.5 - 0.9)	(0.480 - 0.880)	(0.507 - 0.903)	(0.023 - 0.027)
			n					4	4	4	4	4	4
Wuskwatim Lake	WuLA	2001	Mean±SE	-	-	-	-	0.01±0.005	0.008±0.001	0.5±0.02	0.512±0.023	0.533±0.025	0.021±0.003
			Range					(<0.002 - 0.02)	(0.005 - 0.012)	(0.5 - 0.6)	(0.480 - 0.580)	(0.505 - 0.608)	(0.013 - 0.028)
			n					4	4	4	4	4	4

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Alkalintity as Bicarbonate (mg/L)	Alkalintity as $CaCO_3$ (mg/L)	Alkalintity as Carbonate (mg/L)	Alkalintity as Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia [1] (mg/L N)	Nitrogen: Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen: TKN (mg/L)	Nitrogen: Organic Nitrogen [2] (mg/L N)	Nitrogen: Total Nitrogen [3] (mg/L)	Nitrogen: Dissolved Inorganic Nitrogen [4] (mg/L N)
Wuskwatim Lake	WuLB	2001	Mean±SE	66±1	55±1	<20±0	<10±0	0.01±0.002	0.005±0.001	0.5±0.03	0.442±0.030	0.455±0.029	0.013±0.002
			Range	(63 - 69)	(52 - 57)	(<20 - <20)	(<10 - <10)	(<0.002 - 0.01)	(<0.005 - 0.008)	(0.4 - 0.5)	(0.390 - 0.499)	(0.403 - 0.508)	(0.009 - 0.017)
			n	4	4	4	4	4	4	4	4	4	4
Wuskwatim Lake	WuLC	2001	Mean±SE	-	-	-	-	0.02±0.005	0.007±0.001	0.8±0.1	0.728±0.061	0.757±0.065	0.030±0.001
			Range					(0.01 - 0.03)	(0.005 - 0.010)	(0.6 - 0.9)	(0.580 - 0.870)	(0.608 - 0.910)	(0.016 - 0.040)
			n					4	4	4	4	4	4
Wuskwatim Brook	WuBA	2001	Mean±SE	-	-	-	-	0.02±0.003	<0.005±0.002	0.7±0.05	0.710±0.047	0.729±0.046	0.020±0.002
			Range					(0.01 - 0.02)	(<0.005 - 0.009)	(0.6 - 0.8)	(0.590 - 0.790)	(0.609 - 0.803)	(0.013 - 0.023)
			n					4	4	4	4	4	4
Taskinigup Falls	TF	2001	Mean±SE	67±2	55±1	<20±0	<10±0	0.01±0.005	0.010±0.001	0.5±0.04	0.487±0.043	0.510±0.041	0.023±0.005
			Range	(62 - 69)	(51 - 57)	(<20 - <20)	(<10 - <10)	(0.003 - 0.02)	(0.007 - 0.013)	(0.4 - 0.6)	(0.380 - 0.590)	(0.409 - 0.611)	(0.010 - 0.033)
			n	4	4	4	4	4	4	4	4	4	4
Opegano Lake	OLA	2001	Mean±SE	-	-	-	-	0.02±0.003	0.009±0.001	0.5±0.05	0.433±0.051	0.459±0.049	0.027±0.003
			Range					(0.01 - 0.02)	(0.007 - 0.012)	(0.3 - 0.5)	(0.280 - 0.490)	(0.312 - 0.509)	(0.017 - 0.032)
			n					4	4	4	4	4	4

Table A3-1. -continued-

				Alkalintity				Nitrogen					
Sampling Location	Location ID	Sample Date		as Bicarbonate (mg/L)	as $CaCO_3$ (mg/L)	as Carbonate (mg/L)	as Hydroxide (mg/L)	Dissolved Ammonia [1] (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [2] (mg/L N)	Total Nitrogen [3] (mg/L)	Dissolved Inorganic Nitrogen [4] (mg/L N)
Opegano Lake	OLB	2001	Mean±SE	-	-	-	-	0.02±0.004	0.009±0.001	0.5±0.02	0.505±0.028	0.534±0.025	0.029±0.004
			Range					(0.01 - 0.03)	(0.008 - 0.011)	(0.5 - 0.6)	(0.470 - 0.590)	(0.508 - 0.608)	(0.018 - 0.038)
			n					4	4	4	4	4	4
Birch Tree Lake	BLA	2001	Mean±SE	-	-	-	-	0.004±0.002	0.006±0.002	0.4±0.05	0.421±0.050	0.431±0.049	0.011±0.002
			Range					(<0.002 - 0.01)	(<0.005 - 0.011)	(0.3 - 0.5)	(0.290 - 0.499)	(0.303 - 0.511)	(0.007 - 0.014)
			n					4	4	4	4	4	4
Birch Tree Lake	BLB	2001	Mean±SE	69±1	56±1	<20±0	<10±0	0.01±0.003	0.009±0.002	0.5±0.03	0.438±0.030	0.459±0.028	0.022±0.003
			Range	(67 - 70)	(55 - 58)	(<20 - <20)	(<10 - <10)	(0.01 - 0.02)	(0.006 - 0.014)	(0.4 - 0.5)	(0.380 - 0.490)	(0.409 - 0.508)	(0.016 - 0.029)
			n	4	4	4	4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001	Mean±SE	69	57	<20	<10	0.02±0.01	0.012±0.002	0.5±0.1	0.435±0.055	0.462±0.052	0.027±0.003
			Range	-	-	-	-	(0.01 - 0.02)	(0.010 - 0.014)	(0.4 - 0.5)	(0.380 - 0.490)	(0.410 - 0.514)	(0.024 - 0.030)
			n	1	1	1	1	2	2	2	2	2	2
Lower Burntwood River	LBRE1	2001	Mean±SE	68	56	<20	<10	0.07±0.06	0.057±0.055	0.5±0.2	0.385±0.205	0.507±0.205	0.068±0.055
			Range	-	-	-	-	(0.01 - 0.12)	(<0.005 - 0.112)	(0.3 - 0.6)	(0.180 - 0.590)	(0.303 - 0.712)	(0.013 - 0.122)
			n	1	1	1	1	2	2	2	2	2	2
Lower Burntwood River	LBRE	2001	Mean±SE	70	57	<20	<10	0.01	<0.005	0.4	0.39	0.403	0.123
			Range	-	-	-	-	-	-	-	-	-	-

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Alkalintity as Bicarbonate (mg/L)	Alkalintity as $CaCO_3$ (mg/L)	Alkalintity as Carbonate (mg/L)	Alkalintity as Hydroxide (mg/L)	Nitrogen: Dissolved Ammonia [1] (mg/L N)	Nitrogen: Dissolved Nitrate/ nitrite (mg/L N)	Nitrogen: TKN (mg/L)	Nitrogen: Organic Nitrogen [2] (mg/L N)	Nitrogen: Total Nitrogen [3] (mg/L)	Nitrogen: Dissolved Inorganic Nitrogen [4] (mg/L N)
			n	1	1	1	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	70±1	57±1	<20±0	<10±0	0.02±0.01	0.013±0.008	0.6±0.2	0.580±0.190	0.613±0.208	0.033±0.018
			Range	(69 - 70)	(56 - 57)	(<20 - <20)	(<10 - <10)	(0.01 - 0.03)	(0.005 - 0.020)	(0.4 - 0.8)	(0.390 - 0.770)	(0.405 - 0.820)	(0.015 - 0.050)
			n	2	2	2	2	2	2	2	2	2	2
Ice-cover Season													
Wuskwatim Falls	WF	2001		-	-	-	-	0.01	0.08	0.4	0.39	0.48	0.09
								1	1	1	1	1	1
Taskinigup Falls	TF	2001		-	-	-	-	0.01	0.08	0.4	0.39	0.48	0.09
								1	1	1	1	1	1
Opegano Lake	OLB	2001		66	54	<20	<10	0.01	0.09	0.5	0.49	0.59	0.1
				1	1	1	1	1	1	1	1	1	1
Cranberry Lakes	CLA	2002		63	52	<20	<10	0.006	0.066	0.3	0.294	0.366	0.072
				1	1	1	1	1	1	1	1	1	1
Sesep Lake	SLB	2002		-	-	-	-	0.008	0.192	0.5	0.492	0.692	0.2
								1	1	1	1	1	1

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date	Alkalintity				Nitrogen					
			as Bicarbonate (mg/L)	as $CaCO_3$ (mg/L)	as Carbonate (mg/L)	as Hydroxide (mg/L)	Dissolved Ammonia [1] (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [2] (mg/L N)	Total Nitrogen [3] (mg/L)	Dissolved Inorganic Nitrogen [4] (mg/L N)
Wuskwatim Lake	WuLA	2002	-	-	-	-	0.006	0.074	0.3	0.294	0.374	0.08
							1	1	1	1	1	1
Wuskwatim Lake	WuLB	2002	64	52	<20	<10	0.006	0.065	0.3	0.294	0.365	0.071
			1	1	1	1	1	1	1	1	1	1
Wuskwatim Lake	WuLC	2002	-	-	-	-	0.009	0.076	0.2	0.191	0.276	0.085
							1	1	1	1	1	1
Wuskwatim Brook	WuBA	2002	-	-	-	-	0.007	0.108	0.4	0.393	0.508	0.155
							1	1	1	1	1	1
Opegano Lake	OLA	2002	-	-	-	-	0.01	0.078	0.5	0.49	0.578	0.088
							1	1	1	1	1	1
Birch Tree Lake	BLA	2002	-	-	-	-	0.005	0.078	0.3	0.295	0.378	0.083
							1	1	1	1	1	1

Table A3-1. -continued-

			Alkalintity				Nitrogen					
Sampling Location	Location ID	Sample Date	as Bicarbonate (mg/L)	as $CaCO_3$ (mg/L)	as Carbonate (mg/L)	as Hydroxide (mg/L)	Dissolved Ammonia [1] (mg/L N)	Dissolved Nitrate/ nitrite (mg/L N)	TKN (mg/L)	Organic Nitrogen [2] (mg/L N)	Total Nitrogen [3] (mg/L)	Dissolved Inorganic Nitrogen [4] (mg/L N)
Birch Tree Lake	BLB	2002	62	51	<20	<10	0.006	0.104	<0.2	0.094	0.204	0.11
			1	1	1	1	1	1	1	1	1	1
Birch Tree Lake	BLC	2002	63	51	<20	<10	0.005	0.072	0.2	0.195	0.272	0.077
			1	1	1	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2002	65	54	<20	<10	0.005	0.076	0.2	0.195	0.276	0.081
			1	1	1	1	1	1	1	1	1	1

[1] Where values are indicated to 2 decimal places, analytical detection limit is 0.01 mg/L; Where values are indicated to 3 decimal places, analytical detection limit is 0.002 mg/L.
[2] Organic nitrogen estimated from: TKN - dissolved ammonia.
[3] Total nitrogen estimated from: TKN + dissolved nitrate/nitrite.
[4] Dissolved inorganic nitrogen is the sum of dissolved ammonia and nitrate/nitrite nitrogen.

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus Dissolved (mg/L P)	Phosphorus Total (mg/L P)	Phosphorus Dissolved Fraction (%)	N:P Molar Ratios TotN:TotP	N:P Molar Ratios DIN:DP	N:P Molar Ratios DIN:TP	Organic Carbon (OC) Total (mg/L)	Organic Carbon (OC) Dissolved (mg/L)
Open-water Season											
Lower Burntwood River	LBRB	1999	Mean±SE	0.011±0.005	0.028±0.002	36±13	32.2±5.3	6.0±2.7	1.5±0.3	7±0.4	7±0.5
			Range	(0.004 - 0.024)	(0.025 - 0.033)	(15 - 73)	(16.8 - 41.5)	(1.9 - 13.8)	(0.6 - 2.0)	(6 - 8)	(6 - 8)
			n	4	4	4	4	4	4	4	4
Lower Burntwood River	LBRC	1999	Mean±SE	0.008±0.001	0.028±0.004	30±5	30.1±5.4	2.8	0.6	7±1	7±0.3
			Range	(0.006 - 0.010)	(0.018 - 0.036)	(21 - 43)	(20.4 - 38.9)	-	-	(6 - 8)	(6- 7)
			n	4	4	4	3	1	1	4	4
Wuskwatim Lake	WuLA	1999	Mean±SE	0.009±0.001	0.030±0.003	28±2	27.5±2.9	4.0±0.7	1.0±0.2	7±0.5	7±1
			Range	(0.007 - 0.010)	(0.024 - 0.038)	(25 - 33)	(18.9 - 32.0)	(3.3 - 4.7)	(0.9 - 1.2)	(6 - 8)	(6 - 9)
			n	4	4	4	4	2	2	4	4
Wuskwatim Lake	WuLB	1999	Mean±SE	0.009±0.001	0.031±0.005	35±11	26.9±3.9	3.3	0.8	7±0.4	7±0.4
			Range	(0.006 - 0.012)	(0.018 - 0.040)	(19 - 67)	(20.4 - 37.5)	-	-	(6 - 8)	(6 - 8)
			n	4	4	4	4	1	1	4	4
Lower Burntwood River	LBRB	2000	Mean±SE	0.007±0.001	0.038±0.003	19±4	24.6±5.1	8.5±2.5	1.4±0.3	9±1	9±1
			Range	(0.005 - 0.009)	(0.034 - 0.045)	(11 - 25)	(15.2 - 32.8)	(4.7 - 13.3)	(1.0 - 0.8)	(6 - 10)	(7 - 10)
			n	3	3	3	3	3	3	3	3

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus Dissolved (mg/L P)	Phosphorus Total (mg/L P)	Phosphorus Dissolved Fraction (%)	Nitrogen Phosphorus Molar Ratios TotN:TotP	Nitrogen Phosphorus Molar Ratios DIN:DP	Nitrogen Phosphorus Molar Ratios DIN:TP	Organic Carbon Total (mg/L)	Organic Carbon Dissolved (mg/L)
Lower Burntwood River	LBRC	2000	Mean±SE	0.018±0.003	0.032±0.004	25±6	31.2±2.8	10.4±1.8	2.4±0.3	8±1	7±0.3
			Range	(0.004 - 0.014)	(0.024 - 0.038)	(17 - 37)	(27.3 - 36.7)	(7.9 - 13.8)	(2.0 - 2.9)	(7 - 9)	(7 - 8)
			n	3	3	3	3	3	3	3	3
Wuskwatim Lake	WuLA	2000	Mean±SE	0.008±0.003	0.033±0.004	24±6	28.0±0.7	10.3±3.4	2.1±0.3	8±0.3	8±1
			Range	(0.004 - 0.014)	(0.026 - 0.039)	(15 - 36)	(27.2 - 29.5)	(4.7 - 16.6)	(1.7 - 2.6)	(8 - 9)	(7 - 9)
			n	3	3	3	3	3	3	3	3
Wuskwatim Lake	WuLB	2000	Mean±SE	0.012±0.005	0.034±0.003	36±13	34.0±4.5	9.3±5.0	2.3±0.4	9±1	9±1
			Range	(0.004 - 0.020)	(0.028 - 0.040)	(14 - 61)	(26.1 - 41.5)	(4.3 - 19.3)	(1.4 - 2.8)	(8 - 10)	(8 - 10)
			n	3	3	3	3	3	3	3	3
Opegano Lake	OLA	2000	Mean±SE	0.011±0.003	0.042±0.004	25±4	22.6±1.9	7.0±1.3	1.7±0.1	8±1	8±1
			Range	(0.008 - 0.013)	(0.038 - 0.046)	(21 - 28)	(20.7 - 24.4)	(5.8 - 8.3)	(1.6 - 1.7)	(7 - 8)	(7 - 8)
			n	2	2	2	2	2	2	2	2
Opegano Lake	OLB	2000	Mean±SE	0.011±0.002	0.042±0.005	26±2	23.1±2.0	7.6±0.2	2.0±0.2	8±1	8±1
			Range	(0.009 - 0.013)	(0.037 - 0.046)	(24 - 28)	(21.2 - 25.1)	(7.4 - 7.8)	(1.8 - 2.2)	(7 - 8)	(7 - 8)
			n	2	2	2	2	2	2	2	2

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus			Nitrogen Phosphorus Molar Ratios			Organic Carbon	
				Dissolved (mg/L P)	Total (mg/L P)	Dissolved Fraction (%)	TotN:TotP	DIN:DP	DIN:TP	Total (mg/L)	Dissolved (mg/L)
Birch Tree Lake	BLA	2000	Mean±SE	0.009±0.006	0.039±0.006	20±11	23.5±1.4	12.8±5.7	2.0±0.2	9±1	8±1
			Range	(0.003 - 0.014)	(0.032 - 0.045)	(9 - 31)	(22.1 - 24.8)	(7.1 - 18.4)	(1.7 - 2.2)	(8 - 9)	(7 - 8)
			n	2	2	2	2	2	2	2	2

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus			Nitrogen Phosphorus Molar Ratios			Organic Carbon	
				Dissolved (mg/L P)	Total (mg/L P)	Dissolved Fraction (%)	TotN:TotP	DIN:DP	DIN:TP	Total (mg/L)	Dissolved (mg/L)
Birch Tree Lake	BLB	2000	Mean±SE	0.010±0.004	0.038±0.007	26±6	32.3±8.0	8.8±4.1	2.0±0.6	8	8
			Range	(0.006 - 0.014)	(0.030 - 0.045)	(20 - 31)	(24.3 - 40.3)	(4.7 - 12.9)	(1.5 - 2.6)	-	-
			n	2	2	2	2	2	2	2	2
Lower Burntwood River	LBRB	2001	Mean±SE	0.010±0.000	0.032±0.003	30±3	40.3±6.6	4.4±0.6	1.3±0.1	9±1	8±1
			Range	(0.009 - 0.010)	(0.024 - 0.036)	(25 - 38)	(27.7 - 55.9)	(2.8 - 5.7)	(1.1 - 1.6)	(7 - 11)	(6 - 12)
			n	4	4	4	4	4	4	4	4
Lower Burntwood River	LBRB2	2001	Mean±SE	0.010±0.001	0.033±0.002	29±2	31.8±3.4	4.8±1.1	1.4±0.4	9±1	8±1
			Range	(0.007 - 0.011)	(0.027 - 0.035)	(26 - 33)	(26.5 - 41.4)	(2.7 - 7.8)	(0.7 - 2.5)	(8 - 11)	(7 - 10)
			n	4	4	4	4	4	4	4	4
Lower Burntwood River	LBRC	2001	Mean±SE	0.010±0.002	0.034±0.002	30±5	33.4±2.6	3.3±0.5	0.9±0.1	9±1	8±1
			Range	(0.007 - 0.016)	(0.027 - 0.037)	(24 - 46)	(30.4 - 41.2)	(2.1 - 4.4)	(0.7 - 1.1)	(8 - 11)	(7 - 10)
			n	4	4	4	4	4	4	4	4
Sesep Lake	SLA	2001	Mean±SE	0.012±0.000	0.027±0.003	47±6	62.3±7.2	4.3±0.3	2.0±0.3	15±1	15±1
			Range	(0.011 - 0.013)	(0.020 - 0.035)	(37 - 60)	(50.7 - 83.2)	(3.8 - 5.0)	(1.4 - 3.0)	(13 - 15)	(13 - 16)
			n	4	4	4	4	4	4	4	4
Wuskwatim Lake	WuLA	2001	Mean±SE	0.010±0.001	0.034±0.003	30±2	36.2±5.2	4.8±1.0	1.5±0.4	10±1	9±1
			Range	(0.008 - 0.012)	(0.026 - 0.038)	(26 - 35)	(29.8 - 51.7)	(2.9 - 7.7)	(0.8 - 2.4)	(7 - 11)	(7 - 11)
			n	4	4	4	4	4	4	4	4

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus Dissolved (mg/L P)	Phosphorus Total (mg/L P)	Phosphorus Dissolved Fraction (%)	Nitrogen Phosphorus Molar Ratios TotN:TotP	Nitrogen Phosphorus Molar Ratios DIN:DP	Nitrogen Phosphorus Molar Ratios DIN:TP	Organic Carbon Total (mg/L)	Organic Carbon Dissolved (mg/L)
Wuskwatim Lake	WuLB	2001	Mean±SE	0.009±0.001	0.033±0.003	28±2	31.2±2.9	3.1±0.4	0.9±0.1	10±1	8±1
			Range	(0.007 - 0.011)	(0.025 - 0.039)	(25 - 34)	(23.1 - 35.6)	(2.2 - 3.9)	(0.6 - 1.1)	(8 - 11)	(7 - 10)
			n	4	4	4	4	4	4	4	4
Wuskwatim Lake	WuLC	2001	Mean±SE	0.014±0.001	0.034±0.006	42±4	52.3±5.1	4.8±0.7	2.0±0.3	16±0.5	16±1
			Range	(0.011 - 0.017)	(0.024 - 0.048)	(35 - 54)	(37.1 - 60.0)	(3.2 - 6.8)	(1.4 - 2.6)	(15 - 17)	(15 - 17)
			n	4	4	4	4	4	4	4	4
Wuskwatim Brook	WuBA	2001	Mean±SE	0.012±0.002	0.022±0.003	53±4	75.9±5.8	3.9±0.6	2.0±0.4	20±1	20±0.3
			Range	(0.009 - 0.017)	(0.017 - 0.028)	(42 - 61)	(63.4 - 91.4)	(2.8 - 5.5)	(1.2 - 2.9)	(18 - 20)	(19 - 20)
			n	4	4	4	4	4	4	4	4
Taskinigup Falls	TF	2001	Mean±SE	0.010±0.000	0.034±0.002	29±2	33.4±1.8	5.3±1.2	1.6±0.4	8±1	8±1
			Range	(0.009 - 0.011)	(0.030 - 0.039)	(26 - 35)	(29.2 - 37.8)	(2.5 - 8.1)	(0.6 - 2.4)	(7 - 11)	(7 - 10)
			n	4	4	4	4	4	4	4	4
Opegano Lake	OLA	2001	Mean±SE	0.009±0.001	0.033±0.002	28±2	31.1±4.0	6.4±0.8	1.8±0.3	9±1	9±1
			Range	(0.008 - 0.011)	(0.028 - 0.039)	(23 - 34)	(21.6 - 40.2)	(4.2 - 8.0)	(1.0 - 2.3)	(6 - 12)	(7 - 12)
			n	4	4	4	4	4	4	4	4
Opegano Lake	OLB	2001	Mean±SE	0.009±0.001	0.034±0.002	27±2	34.7±1.4	7.1±1.1	1.9±0.3	9±1	9±1
			Range	(0.007 - 0.011)	(0.029 - 0.041)	(22 - 32)	(32.8 - 38.8)	(4.4 - 9.2)	(1.0 - 2.5)	(7 - 13)	(7 - 13)
			n	4	4	4	4	4	4	4	4

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus: Dissolved (mg/L P)	Phosphorus: Total (mg/L P)	Phosphorus: Dissolved Fraction (%)	Nitrogen Phosphorus Molar Ratios: TotN:TotP	Nitrogen Phosphorus Molar Ratios: DIN:DP	Nitrogen Phosphorus Molar Ratios: DIN:TP	Organic Carbon: Total (mg/L)	Organic Carbon: Dissolved (mg/L)
Birch Tree Lake	BLA	2001	Mean±SE	0.010±0.002	0.033±0.002	30±6	29.4±3.1	2.4±0.1	0.7±0.1	9±0.5	9±1
			Range	(0.007 - 0.014)	(0.029 - 0.039)	(18 - 45)	(21.6 - 36.5)	(2.2 - 2.8)	(0.4 - 1.0)	(8 - 10)	(7 - 10)
			n	4	4	4	4	4	4	4	4
Birch Tree Lake	BLB	2001	Mean±SE	0.015±0.004	0.035±0.002	42±11	29.0±2.1	4.1±1.2	1.4±0.2	9±1	9±1
			Range	(0.007 - 0.025)	(0.031 - 0.039)	(21 - 64)	(23.8 - 34.0)	(1.4 - 6.4)	(0.9 - 1.7)	(7 - 12)	(7 - 11)
			n	4	4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001	Mean±SE	0.010±0.001	0.032±0	30±2	31.9±3.6	6.3±0.4	1.9±0.2	9±1	9
			Range	(0.009 - 0.010)	(0.032 - 0.032)	(28 - 31)	(28.3 - 35.5)	(5.9 - 6.6)	(1.7 - 2.1)	(8 - 9)	-
			n	2	2	2	2	2	2	2	2
Lower Burntwood River	LBRE1	2001	Mean±SE	0.010±0.001	0.033±0.001	29±2	38.5±10.7	14.6±12.4	4.6±3.8	8±1	8±1
			Range	(0.009 - 0.010)	(0.032 - 0.033)	(27 - 31)	(27.8 - 49.2)	(2.1 - 27.0)	(0.9 - 8.4)	(7 - 9)	(7 - 9)
			n	2	2	2	2	2	2	2	2
Lower Burntwood River	LBRE	2001	Mean±SE	0.013	0.032	41	20.3	30.1	8.2	6	7
			Range	-	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	0.010±0.001	0.031±0.001	33±2	45.3±17.3	7.7±4.6	2.4±1.4	9±1	8±1
			Range	(0.009 - 0.011)	(0.029 - 0.032)	(31 - 34)	(28.0 - 62.5)	(3.0 - 12.3)	(1.0 - 3.8)	(8 - 9)	(7 - 8)
			n	2	2	2	2	2	2	2	2

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus			Nitrogen Phosphorus Molar Ratios			Organic Carbon	
				Dissolved (mg/L P)	Total (mg/L P)	Dissolved Fraction (%)	TotN:TotP	DIN:DP	DIN:TP	Total (mg/L)	Dissolved (mg/L)
Ice-cover Season											
Wuskwatim Falls	WF	2001	Mean±SE	0.015	0.03	50	35.4	13.3	6.6	9	9
			n	1	1	1	1	1	1	1	1
Taskinigup Falls	TF	2001	Mean±SE	0.015	0.028	54	37.9	13.3	7.1	9	9
			n	1	1	1	1	1	1	1	1
Opegano Lake	OLB	2001	Mean±SE	0.016	0.027	59	48.3	13.8	8.2	9	10
			n	1	1	1	1	1	1	1	1
Cranberry Lakes	CLA	2002	Mean±SE	0.014	0.022	64	36.8	11.4	7.2	8	8
			n	1	1	1	1	1	1	1	1
Sesep Lake	SLB	2002	Mean±SE	0.02	0.024	83	63.8	22.1	18.4	13	14
			n	1	1	1	1	1	1	1	1
Wuskwatim Lake	WuLA	2002	Mean±SE	0.014	0.026	54	31.8	12.6	6.8	8	9
			n	1	1	1	1	1	1	1	1
Wuskwatim Lake	WuLB	2002	Mean±SE	0.014	0.025	56	32.3	11.2	6.3	8	9
			n	1	1	1	1	1	1	1	1

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		Phosphorus Dissolved (mg/L P)	Phosphorus Total (mg/L P)	Phosphorus Dissolved Fraction (%)	Nitrogen Phosphorus Molar Ratios TotN:TotP	Nitrogen Phosphorus Molar Ratios DIN:DP	Nitrogen Phosphorus Molar Ratios DIN:TP	Organic Carbon Total (mg/L)	Organic Carbon Dissolved (mg/L)
Wuskwatim Lake	WuLC	2002	Mean±SE	0.015	0.026	58	23.5	12.5	7.2	8	9
			n	1	1	1	1	1	1	1	1
Wuskwatim Brook	WuBA	2002	Mean±SE	0.018	0.035	51	32.1	14.1	7.3	9	9
			n	1	1	1	1	1	1	1	1
Opegano Lake	OLA	2002	Mean±SE	0.018	0.034	53	37.6	10.8	5.7	9	9
			n	1	1	1	1	1	1	1	1
Birch Tree Lake	BLA	2002	Mean±SE	0.014	0.026	54	32.1	13.1	7.1	9	9
			n	1	1	1	1	1	1	1	1
Birch Tree Lake	BLB	2002	Mean±SE	0.013	0.027	48	16.7	18.7	9	8	8
			n	1	1	1	1	1	1	1	1
Birch Tree Lake	BLC	2002	Mean±SE	0.012	0.027	44	22.3	14.2	6.3	8	8
			n	1	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2002	Mean±SE	0.014	0.054	26	11.3	12.8	3.3	8	9
			n	1	1	1	1	1	1	1	1

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios TOC:ON	TOC:TN	Dissolved Solids (mg/L)	Water Clarity Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (µg/L)
Open-water Season															
Lower Burntwood River	LBRB	1999	Mean±SE	26±9	24±7	-	6±1	-	-	-	-	-	-	-	2±1
			Range	(14 - 52)	(13 - 46)		(<5 - 8)								(<1 - 3)
			n	4	4		4								4
Lower Burntwood River	LBRC	1999	Mean±SE	19±3	18±3	-	11±2	-	-	-	-	-	-	-	4±2
			Range	(14 - 24)	(14 - 23)		(9 - 17)								(2 - 10)
			n	3	3		4								4
Wuskwatim Lake	WuLA	1999	Mean±SE	25±8	24±7	-	7±1	-	-	-	-	-	-	-	3±1
			Range	(17 - 48)	(16 - 46)		(3 - 10)								(1 - 4)
			n	4	4		4								4
Wuskwatim Lake	WuLB	1999	Mean±SE	25±3	24±3	-	7±2	-	-	-	-	-	-	-	3±1
			Range	(17 - 32)	(16 - 31)		(3 - 9)								(2 - 4)
			n	4	4		4								4
Lower Burntwood River	LBRB	2000	Mean±SE	24±2	26±2	-	14±4	-	-	-	-	-	-	-	3±1
			Range	(23 - 28)	(24 - 30)		(6 - 19)								(2 - 5)
			n	3	3		3								3

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios TOC:ON	OC:N Molar Ratios TOC:TN	Dissolved Solids (mg/L)	Water Clarity Total Suspended Solids (mg/L)	Water Clarity Turbidity (NTU)	Water Clarity True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (µg/L)
Lower Burntwood River	LBRC	2000	Mean±SE	22±4	24±4	-	14±2	-	-	-	-	-	-	-	4±0
			Range	(17 - 29)	(18 - 32)		(12 - 18)								(4 -4)
			n	3	3		3								3
Wuskwatim Lake	WuLA	2000	Mean±SE	24±4	26±5	-	9±2	-	-	-	51.6±2.5	-	-	-	4±1
			Range	(18 - 33)	(19 - 36)		(7 - 13)				(46.8 - 55.2)				(2 - 5)
			n	3	3		3				3				3
Wuskwatim Lake	WuLB	2000	Mean±SE	21±4	23±4	-	16±4	-	-	-	-	-	-	-	3±1
			Range	(17 - 28)	(18 - 32)		(7 - 21)								(2 - 5)
			n	3	3		3								3
Opegano Lake	OLA	2000	Mean±SE	21±1	22±1	-	8±5	-	-	-	-	-	-	-	4±1
			Range	(19 - 22)	(21 - 24)		(<5 - 13)								(3 - 4)
			n	2	2		2								2
Opegano Lake	OLB	2000	Mean±SE	20±2	22±2	-	9±6	-	-	-	-	-	-	-	4±2
			Range	(19 - 22)	(21 - 24)		(<5 - 15)								(2 - 6)
			n	2	2		2								2
Birch Tree Lake	BLA	2000	Mean±SE	26±7	28±8	-	13±1	-	-	-	-	-	-	-	3±1
			Range	(18 - 33)	(20 - 36)		(12 - 13)								(2 - 4)
			n	2	2		2								2

Table A3-1 -continued-

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios TOC:ON	TOC:TN	Dissolved Solids (mg/L)	Water Clarity Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (μg/L)
Birch Tree Lake	BLB	2000	Mean±SE	20±8	22±10	-	19±4	-	-	-	-	-	-	-	3±1
			Range	(11 - 28)	(12 - 32)		(15 - 22)								(2 - 4)
			n	2	2		2								2
Lower Burntwood River	LBRB	2001	Mean±SE	20±4	19±4	-	11±1	-	-	7.82±0.06	-	-	-	-	3±0
			Range	(9 - 27)	(9 - 25)		(8 - 14)			(7.67 - 7.91)					(2 - 4)
			n	4	4		4			4					4
Lower Burntwood River	LBRB2	2001	Mean±SE	23±2	22±1	94±6	12±3	-	31±10	7.71±0.04	55.2±1.3	1.29±0.03	1.22±0.06	0.07±0.08	4±1
			Range	(19 - 26)	(18 - 25)	(82 - 110)	(7 - 20)		(10 - 60)	(7.64 - 7.84)	(51.4 - 57.0)	(1.19 - 1.35)	(1.05 - 1.31)	(-0.12 - 0.27)	(2 - 6)
			n	4	4	4	4		4	4	4	4	4	4	4
Lower Burntwood River	LBRC	2001	Mean±SE	21±2	20±2	-	11±2	-	-	7.82±0.03	-	-	-	-	3±1
			Range	(19 - 26)	(18 - 25)		(7 - 16)			(7.73 - 7.89)					(2 - 4)
			n	4	4		4			4					4
Sesep Lake	SLA	2001	Mean±SE	24±3	23±2	-	2±1	-	-	7.67±0.06	-	-	-	-	10±3
			Range	(20 - 32)	(19 - 30)		(<2 - 4)			(7.57 - 7.84)					(1 - 16)
			n	4	4		4			4					4
Wuskwatim Lake	WuLA	2001	Mean±SE	22±3	21±2	-	8±3	-	-	7.85±0.04	-	-	-	-	4±0
			Range	(17 - 27)	(16 - 25)		(2 - 17)			(7.79 - 7.94)					(3 - 5)
			n	4	4		4			4					4

Table A3-1 -continued-

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios TOC:ON	TOC:TN	Dissolved Solids (mg/L)	Water Clarity Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (µg/L)
Wuskwatim Lake	WuLB	2001	Mean±SE	25±1	24±1	89±5	12±5	-	31±12	7.81±0.04	57.5±1.0	1.35±0.03	1.21±0.07	0.14±0.07	4±1
			Range	(24 - 27)	(23 - 26)	(74 - 100)	(3 - 24)		(<5 - 60)	(7.71 - 7.89)	(55.5 - 59.3)	(1.29 - 1.41)	(1.07 - 1.36)	(-0.05 - 0.27)	(2 - 4)
			n	4	4	4	4		4	4	4	4	4	4	4
Wuskwatim Lake	WuLC	2001	Mean±SE	27±3	26±3	-	6±1	-	-	7.66±0.07	-	-	-	-	8±2
			Range	(21 - 34)	(21 - 33)		(4 - 8)			(7.51 - 7.80)					(3 - 12)
			n	4	4		4			4					4
Wuskwatim Brook	WuBA	2001	Mean±SE	32±2	31±1	-	2±1	-	-	7.45±0.06	-	-	-	-	8±3
			Range	(30 - 36)	(29 - 34)		(<2 - 4)			(7.36 - 7.61)					(3 - 15)
			n	4	4		4			4					4
Taskinigup Falls	TF	2001	Mean±SE	20±1	19±1	89±6	12±4	-	30±7	7.78±0.05	58.8±0.6	1.38±0.01	1.27±0.05	0.11±0.06	3±1
			Range	(16 - 22)	(16 - 21)	(72 - 100)	(6 - 24)		(15 - 50)	(7.68 - 7.89)	(57.7 - 60.5)	(1.35 - 1.41)	(1.13 - 1.36)	(-0.01 - 0.28)	(2 - 4)
			n	4	4	4	4		4	4	4	4	4	4	4
Opegano Lake	OLA	2001	Mean±SE	23±2	22±2	-	10±2	-	-	7.88±0.01	-	-	-	-	4±0
			Range	(17 - 29)	(16 - 28)		(6 - 14)			(7.85 - 7.91)					(3 - 4)
			n	4	4		4			4					4

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios TOC:ON	TOC:TN	Dissolved Solids (mg/L)	Water Clarity Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (µg/L)
Opegano Lake	OLB	2001	Mean±SE	21±2	20±2	-	10±1	-	-	7.85±0.03	-	-	-	-	4±1
			Range	(17 - 26)	(16 - 25)		(7 - 14)			(7.80 - 7.94)					(2 - 5)
			n	4	4		4			4					4
Birch Tree Lake	BLA	2001	Mean±SE	25±2	24±2	-	9±2	-	-	7.93±0.06	-	-	-	-	4±0
			Range	(21 - 32)	(21 - 31)		(5 - 13)			(7.84 - 8.10)					(3 - 4)
			n	4	4		4			4					4
Birch Tree Lake	BLB	2001	Mean±SE	24±2	23±2	93±8	16±6	-	55±22	7.86±0.06	55.6±2.8	1.25±0.06	1.18±0.07	0.07±0.13	4±0
			Range	(19 - 29)	(18 - 28)	(70 - 110)	(6 - 33)		(25 - 120)	(7.76 - 8.07)	(47.3 - 58.6)	(1.07 - 1.32)	(1.10 - 1.39)	(-0.32 - 0.22)	(3 - 5)
			n	4	4	4	4		4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001	Mean±SE	23±2	22±1	94	11±2	-	25	7.85±0.01	58.1	1.34	1.13	0.21	4±2
			Range	(21 - 25)	(20 - 23)	-	(9 - 13)		-	(7.84 - 7.86)	-	-	-	-	(2 - 5)
			n	2	2	1	2		1	2	1	1	1	1	2
Lower Burntwood River	LBRE1	2001	Mean±SE	32±14	21±6	80	10±2	-	30	7.83±0.05	62.2±1.9	1.41	1.11	0.30	4±1
			Range	(18 - 45)	(15 - 27)	-	(8 - 11)		-	(7.78 - 7.88)	(60.8- 63.5)	-	-	-	(3 - 5)
			n	2	2	1	2		1	2	2	1	1	1	2

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios TOC:ON	TOC:TN	Dissolved Solids (mg/L)	Water Clarity Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (µg/L)
Lower Burntwood River	LBRE	2001	Mean±SE	18	17	68	10	-	25	7.92	62.9	1.45	1.39	0.06	6
			Range	-	-	-	-		-	-	-	-	-	-	-
			n	1	1	1	1		1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	19±5	18±5	78±14	14±4	-	23±3	7.89±0.01	59.9±0.3	1.39±0.01	1.14±0.01	0.25±0.02	4±2
			Range	(14 - 24)	(13 - 23)	(64 - 92)	(10 - 17)		(20 - 25)	(7.88 - 7.89)	(59.6 - 60.1)	(1.38 - 1.40)	(1.13 - 1.15)	(0.23 - 0.27)	(2 - 5)
			n	2	2	2	2		2	2	2	2	2	2	2
Ice-cover Season															
Wuskwatim Falls	WF	2001	Mean±SE	27	22	-	5	-	-	7.42	-	-	-	-	<1
			n	1	1		1			1					1
Taskinigup Falls	TF	2001	Mean±SE	27	22	-	8	-	-	7.54	-	-	-	-	<1
			n	1	1		1			1					1
Opegano Lake	OLB	2001	Mean±SE	21	18	160	8	-	20	7.56	55.0	1.29	1.33	-0.04	<1
			n	1	1	1	1		1	1	1	1	1	1	1
Cranberry Lakes	CLA	2002	Mean±SE	32	25	82	3	13	20	7.38	49.8	1.19	1.03	0.16	<1
			n	1	1	1	1	1	1	1	1	1	1	1	1

Table A3-1. -continued-

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios TOC:ON	TOC:TN	Dissolved Solids (mg/L)	Water Clarity Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (µg/L)
Sesep Lake	SLB	2002	Mean±SE	31	22	-	<2	4.6	-	7	-	-	-	-	1
			n	1	1		1	1		1					1
Wuskwatim Lake	WuLA	2002	Mean±SE	32	25	-	5	15	-	7.36	-	-	-	-	3
			n	1	1		1	1		1					1
Wuskwatim Lake	WuLB	2002	Mean±SE	32	26	82	3	14	25	7.4	49.4	1.18	1.05	0.13	2
			n	1	1	1	1	1	1	1	1	1	1	1	1
Wuskwatim Lake	WuLC	2002	Mean±SE	49	34	-	2	16	-	7.48	-	-	-	-	<1
			n	1	1		1	1		1					1
Wuskwatim Brook	WuBA	2002	Mean±SE	27	21	-	2	18	-	7.17	-	-	-	-	2
			n	1	1		1	1		1					1
Opegano Lake	OLA	2002	Mean±SE	21	18	-	9	18	-	7.47	-	-	-	-	<1
			n	1	1		1	1		1					1
Birch Tree Lake	BLA	2002	Mean±SE	36	28	-	5	18	-	7.56	-	-	-	-	2
			n	1	1		1	1		1					1
Birch Tree Lake	BLB	2002	Mean±SE	99	46	84	9	20	25	7.46	50.6	1.21	1.02	0.19	1
			n	1	1	1	1	1	1	1	1	1	1	1	1

Table A3-1.

Sampling Location	Location ID	Sample Date		OC:N Molar Ratios			Water Clarity								
				TOC:ON	TOC:TN	Dissolved Solids (mg/L)	Total Suspended Solids (mg/L)	Turbidity (NTU)	True Colour (TCU)	pH	Hardness as $CaCO_3$ (mg/L)	Total Cations (mEq/L)	Total Anions (mEq/L)	Total Cations - Total Anions (mEq/L)	Chlorophyll *a* (µg/L)
Birch Tree Lake	BLC	2002	Mean±SE	48	34	80	7	20	30	7.48	49.6	1.18	1.03	0.15	<1
			n	1	1	1	1	1	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2002	Mean±SE	48	34	80	40	36	30	7.57	62.2	1.47	1.07	0.40	<1
			n	1	1	1	1	1	1	1	1	1	1	1	1

Table A3-2. Summary statistics for water quality parameters measured *in situ*, open-water and ice-cover seasons, 1999 - 2002.

Sampling Location	Location ID	Sample Date		Water Depth [1] (m)	Temperature (°C)	DO (mg/L)	DO % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke (m^{-1})	z_1 (m)	pH
Open-water Season													
Lower Burntwood River	LBRB	1999	Mean±SE	4.9	14.3±2.0	8.97±1.20	86.0±8.0	107.5±3.3	28.9±3.6	0.47±0.06	2.92±0.38	1.55±0.20	7.55±0.24
			Range	-	(10.6 - 18.2)	(6.57 - 10.30)	(70.2 - 95.7)	(100.0 - 115.9)	(22.2 - 39.0)	(0.35 - 0.60)	(2.17 - 3.71)	(1.16 - 1.98)	(7.11 - 7.93)
			n	1	4	3	3	4	4	4	4	4	3
Lower Burntwood River	LBRC	1999	Mean±SE	-	14.0±1.8	9.73±1.17	93.6±7.2	109.1±3.3	32.2±3.0	0.46±0.09	3.07±0.65	1.52±0.29	7.64±0.48
			Range		(10.6 - 18.5)	(7.39 - 11.08)	(79.4 - 103.3)	(101.0 - 117.1)	(24.5 - 37.9)	(0.30 - 0.60)	(2.17 - 4.33)	(0.99 - 1.98)	(7.16 - 8.12)
			n		4	3	3	4	4	3	3	3	2
Wuskwatim Lake	WuLA	1999	Mean±SE	8.40±0.43	14.5±1.7	9.21±0.69	89.6±2.8	110.8±3.3	29.3±3.9	0.44±0.04	2.99±0.21	1.46±0.12	7.76±0.56
			Range	(7.50 - 9.50)	(10.2 - 18.0)	(7.90 - 10.21)	(84.1 - 92.7)	(103.2 - 119.3)	(24.6 - 41.1)	(0.40 - 0.55)	(2.36 - 3.25)	(1.32 - 1.82)	(7.20 - 8.32)
			n	4	4	3	3	4	4	4	4	4	2
Wuskwatim Lake	WuLB	1999	Mean±SE	7.70±0.04	14.7±1.7	9.22±0.73	90.1±3.1	110.8±3.2	30.9±4.0	0.45±0.05	3.02±0.29	1.47±0.17	7.62±0.58
			Range	(7.60 - 7.75)	(10.4 - 18.2)	(7.90 - 10.43)	(84.4 - 95.1)	(103.0 - 118.4)	(23.4 - 41.9)	(0.38 - 0.60)	(2.17 - 3.42)	(1.25 - 1.98)	(7.04 - 8.20)
			n	4	4	3	3	4	4	4	4	4	2
Lower Burntwood River	LBRB	2000	Mean±SE	5	13.0±1.8	9.55±1.27	91.2±8.7	102.2±4.5	40.7±7.1	0.4	3.71	1.16	-
			Range	-	(9.7 - 15.8)	(7.81 - 12.03)	(79.5 - 108.2)	(93.7 - 109.1)	(30.3 - 54.3)	-	-	-	
			n	1	3	3	3	3	3	1	1	1	

Table A3-2. -continued-

Sampling Location	Location ID	Sample Date		Water Depth [1] (m)	Temperature (°C)	DO (mg/L)	DO % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke (m^{-1})	z_1 (m)	pH
Lower Burntwood River	LBRC	2000	Mean±SE	-	15.5±2.8	9.37±0.35	95.0±8.8	105.8±4.8	37.4±9.4	-	-	-	7.96±0.32
			Range		(12.7 - 18.2)	(9.02 - 9.72)	(86.2 - 103.9)	(101.0 - 110.6)	(28.0 - 46.7)				(7.64 - 8.28)
			n		2	2	2	2	2				2
Wuskwatim Lake	WuLA	2000	Mean±SE	9.6	15.5±2.8	9.42±0.09	95.2±4.5	106.3±4.3	33.6±6.7	0.5±0.2	3.25±1.08	1.49±0.50	8.24±0.06
			Range	-	(12.7 - 18.2)	(9.33 - 9.50)	(90.8 - 99.7)	(102.0 - 110.6)	(26.9 - 40.3)	(0.3 - 0.6)	(2.17 - 4.33)	(0.99 - 1.98)	(8.18 - 8.30)
			n	1	2	2	2	2	2	2	2	2	2
Wuskwatim Lake	WuLB	2000	Mean±SE	8.5	15.8±3.2	9.3±0.1	95.1±7.0	108.6±3.9	40.7±9.4	0.4±0.1	3.16±0.56	1.40±0.25	7.73±0.12
			Range	-	(12.6 - 19.0)	(9.24 - 9.4)	(88.1 - 102.1)	(104.7 - 112.5)	(31.3 - 50.0)	(0.4 - 0.5)	(2.60 - 3.71)	(1.16 - 1.65)	(7.61 - 7.85)
			n	1	2	2	2	2	2	2	2	2	2
Taskinigup Falls	TF	2000	Mean±SE	-	-	-	-	-	-	-	-	-	-
			Range										
			n										
Opegano Lake	OLA	2000	Mean±SE	7.8	14.3±4.3	9.98±0.74	98.0±1.2	109.1±3.3	45.7±3.5	0.3±0.1	4.96±1.54	0.96±0.30	8.30±0.13
			Range	-	(10.0 - 18.6)	(9.23 - 10.72)	(96.8 - 99.3)	(105.8 - 112.4)	(42.2 - 49.2)	(0.2 - 0.4)	(3.42 - 6.50)	(0.66 - 1.25)	(8.17 - 8.42)
			n	1	2	2	2	2	2	2	2	2	2
Opegano Lake	OLB	2000	Mean±SE	8	14.4±4.3	10.2±0.8	100.2±1.1	109.2±3.4	44.6±5.0	0.3±0.1	4.92±1.58	0.97±0.31	8.05±0.45
			Range	-	(10.1 - 18.7)	(9.4 - 10.95)	(99.1 - 101.3)	(105.7 - 112.6)	(39.6 - 49.6)	(0.2 - 0.4)	(3.33 - 6.50)	(0.66 - 1.29)	(7.60 - 8.49)
			n	1	2	2	2	2	2	2	2	2	2

Table A3-2. -continued-

Sampling Location	Location ID	Sample Date		Water Depth [1] (m)	Temperature (°C)	DO (mg/L)	DO % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke (m^{-1})	z_1 (m)	pH
Birch Tree Lake	BLA	2000	Mean±SE	7.0±0.1	16.2±4.1	8.40±0.08	86.2±6.4	112.3±3.2	42.7±9.9	0.3±0.1	4.23±0.98	1.07±0.25	8.39±0.10
			Range	(6.9 - 7.0)	(12.1 - 20.3)	(8.32 - 8.47)	(79.8 - 92.6)	(109.1 - 115.4)	(32.8 - 52.5)	(0.3 - 0.4)	(3.25 - 5.20)	(0.83 - 1.32)	(8.29 - 8.48)
			n	2	2	2	2	2	2	2	2	2	2
Birch Tree Lake	BLB	2000	Mean±SE	8.0±0.0	15.4±3.3	8.8±0.2	88.5±7.5	111.2±4.1	50.2±4.7	0.3±0.1	4.23±0.98	1.07±0.25	8.25±0.36
			Range	(8.0 - 8.0)	(12.1 - 18.7)	(8.6 - 8.91)	(81.1 - 96.0)	(107.1 - 115.3)	(45.5 - 54.9)	(0.3 - 0.4)	(3.25 - 5.20)	(0.83 - 1.32)	(7.89 - 8.61)
			n	2	2	2	2	2	2	2	2	2	2
Lower Burntwood River	LBRB	2001	Mean±SE	5.6±1.2	14.8±2.1	9.8±0.2	98.3±3.8	100±2	41±6	-	-	-	7.99±0.12
			Range	(3.5 - >10)	(10.7 - 18.6)	(9.59 - 10.4)	(88.0 - 105.4)	(94 - 104)	(29 - 56)				(7.70 - 8.29)
			n	4	4	4	4	4	4				4
Lower Burntwood River	LBRB2	2001	Mean±SE	6.3±1.3	15.0±1.9	10.5±0.2	105.1±5.0	100±3	43±7	-	-	-	8.11±0.14
			Range	(10 - >10)	(11.5 - 19.0)	(9.88 - 11.0)	(92.1 - 116.2)	(92 - 104)	(29 - 62)				(7.81 - 8.39)
			n	4	4	4	4	4	4				4
Lower Burntwood River	LBRC	2001	Mean±SE	>10±0	15.0±2.0	10.4±0.3	104.6±5.8	99±3	42±6	-	-	-	8.08±0.08
			Range	(>10 - >10)	(11.3 - 19.3)	(9.73 - 10.8)	(90.4 - 118.0)	(93 - 105)	(28 - 57)				(7.94 - 8.30)
			n	4	4	4	4	4	4				4
Sesep Lake	SLA	2001	Mean±SE	3.0±0	16.4±2.4	9.2±0.8	94.9±6.2	129±6	4±1	2.0±0.2	0.69±0.07	6.52±0.82	7.92±0.13
			Range	(3.0 - 3.0)	(10.7 - 22.2)	(7.66 - 11.3)	(77.0 - 103.7)	(113 - 139)	(2 - 5)	(1.6 - 2.7)	(0.48 - 0.81)	(5.28 - 8.91)	(7.69 - 8.24)
			n	4	4	4	4	4	4	4	4	4	4
Wuskwatim Lake	WuLA	2001	Mean±SE	8.8±.01	15.0±2.2	10.0±0.3	100.9±5.2	101±2	42±9	0.5±0.0	2.55±0.26	1.73±0.16	7.87±0.16
			Range	(8.5 - 9.0)	(11.2 - 19.5)	(9.38 - 10.6)	(87.3 - 110.8)	(96 - 107)	(22 - 64)	(0.4 - 0.6)	(2.17 - 3.25)	(1.32 - 1.98)	(7.44 - 8.24)
			n	4	4	4	4	4	4	4	4	4	4

Table A3-2. -continued-

Sampling Location	Location ID	Sample Date		Water Depth [1] (m)	Temperature (°C)	DO (mg/L)	DO % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke (m^{-1})	z_1 (m)	pH
Wuskwatim Lake	WuLB	2001	Mean±SE	7.8±0.1	15.0±2.2	10.0±0.3	100.0±4.4	104±2	38±8	0.6±0.1	2.47±0.30	1.82±0.21	8.12±0.09
			Range	(7.5 - 8.0)	(11.1 - 19.8)	(9.38 - 10.8)	(87.7 - 107.5)	(98 - 109)	(20 - 53)	(0.4 - 0.7)	(1.86 - 3.25)	(1.32 - 2.31)	(7.90 - 8.32)
			n	4	4	4	4	4	4	4	4	4	4
Wuskwatim Lake	WuLC	2001	Mean±SE	3.3±0.3	16.5±2.4	9.6±0.6	99.1±6.9	103±10	18±4	0.9±0.1	1.47±0.17	3.05±0.37	7.93±0.12
			Range	(3.0 - 4.0)	(10.9 - 22.5)	(7.92 - 10.8)	(79.5 - 109.6)	(75 - 120)	(9 - 27)	(0.7 - 1.2)	(1.08 - 1.86)	(2.31 - 3.96)	(7.74 - 8.25)
			n	4	4	4	4	4	4	4	4	4	4
Wuskwatim Brook	WuBA	2001	Mean±SE	2.3±0.3	17.1±2.6	9.2±0.7	95.4±6.1	100±10	6±1	1.3	1	4.29	7.69±0.12
			Range	(2.0 – 3.0)	(11.0 – 23.4)	(7.61 – 10.9)	(77.1 – 103.3)	(74 – 118)	(4 – 9)	-	-	-	(7.51 – 8.04)
			n	4	4	4	4	4	4	1	1	1	4
Taskinigup Falls	TF	2001	Mean±SE	shore	14.7±2.0	11.0±0.4	109.3±6.1	104±3	44±8	-	-	-	8.15±0.09
			Range	shore	(11.0 – 18.8)	(9.87 – 12.0)	(91.7 – 118.0)	(97 – 110)	(29 – 63)				(7.97 – 8.36)
			n	shore	4	4	4	4	4				4
Opegano Lake	OLA	2001	Mean±SE	3.6±0.4	15.1±2.0	10.8±0.3	108.1±5.6	105±2	44±7	0.5±0.0	2.65±0.22	1.65±0.13	7.92±0.16
			Range	(2.5 – 4.5)	(11.4 – 19.2)	(9.94 – 11.3)	(93.7 – 117.2)	(99 – 109)	(33 – 62)	(0.1 – 0.6)	(2.17 – 3.25)	(1.32 – 1.98)	(7.55 – 8.22)
			n	4	4	4	4	4	4	4	4	4	4
Opegano Lake	OLB	2001	Mean±SE	3.9±0.4	15.2±1.9	10.8±0.3	108.6±6.0	105±2	45±7	0.5±0.0	2.82±0.22	1.54±0.11	8.04±0.14
			Range	(3.0 – 5.0)	(11.8 – 19.1)	(9.91 – 11.2)	(93.6 – 120.6)	(99 – 109)	(33 – 64)	(0.4 – 0.5)	(2.60 – 3.25)	(1.32 – 1.65)	(7.89 – 8.47)
			n	4	4	4	4	4	4	3	3	3	4

Table A3-2. -continued-

Sampling Location	Location ID	Sample Date		Water Depth [1] (m)	Temperature (°C)	DO (mg/L)	DO % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke (m^{-1})	z_1 (m)	pH
Birch Tree Lake	BLA	2001	Mean±SE	5.9±0.1	15.6±2.1	10.4±0.4	105.7±6.2	107±2	43±6	0.5±0.0	2.82±0.22	1.54±0.11	8.24±0.08
			Range	(5.5 – 6.0)	(11.4 – 20.2)	(9.44 – 11.1)	(89.9 – 118.9)	(102 – 111)	(33 – 60)	(0.4 – 0.5)	(2.60 – 3.25)	(1.32 – 1.65)	(8.12 – 8.46)
			n	4	4	4	4	4	4	3	3	3	4
Birch Tree Lake	BLB	2001	Mean±SE	6.9±0.1	15.4±2.1	10.7±0.3	108.5±5.9	105±2	51±7	0.5±0.0	2.76±0.16	1.57±0.08	8.18±0.11
			Range	(6.5 – 7.0)	(11.5 – 19.8)	(9.81 – 11.5)	(92.8 – 120.1)	(100 – 107)	(37 – 70)	(0.4 – 0.5)	(2.60 – 3.25)	(1.32 – 1.65)	(7.98 – 8.44)
			n	4	4	4	4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001	Mean±SE	11.5±0.5	14.8±3.3	11.0±0.4	108.9±3.7	108±2	42±6	0.6±0.0	2.38±0.22	1.82±0.16	8.12±0.18
			Range	(11.0 - 12.0)	(11.5 - 18.0)	(10.6 - 11.3)	(105.2 - 112.6)	(106 - 110)	(36 - 48)	(0.5 - 0.6)	(2.17 - 2.60)	(1.65 - 1.98)	(7.93 - 8.30)
			n	2	2	2	2	2	2	2	2	2	2
Lower Burntwood River	LBRE1	2001	Mean±SE	>10±0	14.6±3.1	10.9±0.4	107.5±3.2	109±3	44±8	-	-	-	8.15±0.18
			Range	(>10 - >10)	(11.5 - 17.6)	(10.5 - 11.2)	(104.3 - 110.7)	(106 - 111)	(36 - 51)				(7.97 - 8.33)
			n	2	2	2	2	2	2				2
Lower Burntwood River	LBRE	2001	Mean±SE	>10	17.6	11.0	115.9	111	38	-	-	-	8.11
			Range	-	-	-	-	-	-				-
			n	1	1	1	1	1	1				1
Lower Burntwood River	LBRF	2001	Mean±SE	4.7±0.3	15.6±2.1	11.5±0.3	116.0±3.1	110±1	43±5	-	-	-	8.15±0.02
			Range	(4 - >10)	(11.4 - 17.7)	(11.0 - 11.9)	(110.6 - 121.4)	(107 - 111)	(38 - 52)				(8.11 - 8.17)
			n	3	3	3	3	3	3				3

Table A3-2. -continued-

Sampling Location	Location ID	Sample Date		Water Depth [1] (m)	Temperature (°C)	DO (mg/L)	DO % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke (m^{-1})	z_1 (m)	pH
Ice-cover Season													
Wuskwatim Falls	WF	2001	Mean±SE	3.25	0.2	15.4	114.2	60	18	-	-	-	-
			n	1	1	1	1	1	1				
Taskinigup Falls	TF	2001	Mean±SE	-	0.2	16.9	125.3	61	24	-	-	-	-
			n		1	1	1	1	1				
Opegano Lake	OLB	2001	Mean±SE	4.5	0.2	15.96	118.1	60	24	-	-	-	-
			n	1	1	1	1	1	1				
Cranberry Lakes	CLA	2002	Mean±SE	2.7	0.1	13.08	96.8	58.6	-	0.8	1.63	2.64	-
			n	1	1	1	1	1		1	1	1	
Sesep Lake	SLB	2002	Mean±SE	2.3	0.9	8.02	60.3	98.8	-	0.8	1.63	2.64	-
			n	1	1	1	1	1		1	1	1	
Wuskwatim Lake	WuLA	2002	Mean±SE	7.5	0.1	13.52	100	58.3	-	0.5	2.6	1.65	-
			n	1	1	1	1	1		1	1	1	
Wuskwatim Lake	WuLB	2002	Mean±SE	7.4	0.1	13.6	100.6	58.7	-	0.5	2.6	1.65	-
			n	1	1	1	1	1		1	1	1	
Wuskwatim Lake	WuLC	2002	Mean±SE	2.5	0.1	13.24	98	57.1	-	0.7	1.86	2.31	-
			n	1	1	1	1	1		1	1	1	

Table A3-2. -continued-

Sampling Location	Location ID	Sample Date		Water Depth [1] (m)	Temperature (°C)	DO (mg/L)	DO % Saturation	Conductivity (µS/cm)	Turbidity (NTU)	Secchi Depth (m)	Ke (m^{-1})	z_1 (m)	pH
Wuskwatim Brook	WuBA	2002	Mean±SE	0.6	0.5	8.51	63.5	71.4	-	-	-	-	-
			n	1	1	1	1	1					
Opegano Lake	OLA	2002	Mean±SE	3.2	0.1	13.73	101.4	58.6	-	-	-	-	-
			n	1	1	1	1	1					
Birch Tree Lake	BLA	2002	Mean±SE	5.4	0.1	13.61	100.5	57.3	-	-	-	-	-
			n	1	1	1	1	1					
Birch Tree Lake	BLB	2002	Mean±SE	4.7	0.1	12.98	95.9	59.4	-	-	-	-	-
			n	1	1	1	1	1					
Birch Tree Lake	BLC	2002	Mean±SE	6.6	0.1	12.55	92.7	59.4	-	-	-	-	-
			n	1	1	1	1	1					
Lower Burntwood River	LBRF	2002	Mean±SE	10.5	0.1	12.72	94	59.9	-	-	-	-	-
			n	1	1	1	1	1					

[1] In the ice-cover season depth refers to the effective depth = Total depth – ice depth.

Table A3-3. Summary statistics for complex ions, radiation, and trace and macro-elements measured in water samples collected in the study area in the open-water seasons 2000 and 2001.

Sampling Location	Location ID	Sample Date		Hardness as $CaCO_3$ (mg/L)	Aluminum Dissolved (mg/L)	Aluminum Total (mg/L)	Antimony Dissolved (mg/L)	Antimony Total (mg/L)	Arsenic Dissolved (mg/L)	Arsenic Total (mg/L)	Barium Dissolved (mg/L)	Barium Total (mg/L)
Lower Burntwood River	LBRB2	2001	Mean±SE	55.2±1.3	-	1.35±0.29	-	<0.001	-	<0.0005	-	0.0205±0.0024
			Range	(51.4 - 57.0)		(0.76 - 2.16)		-		-		(0.0164 - 0.0274)
			n	4		4		4		2		4
Wuskwatim Lake	WuLA	2000	Mean±SE	51.6±2.5	-	1.80±0.17	-	<0.001	-	0.0018±0.0008	-	0.025±0.0018
			Range	(46.8 - 55.2)		(1.47 - 2.05)		-		(0.0005 - 0.0033)		(0.0214 - 0.0270)
			n	3		3		4		3		3
Taskinigup Falls	TF	2000	Mean±SE	54.5±2.5	-	2.06±0.36	-	<0.001	-	0.0034±0.0020	-	0.0264±0.0025
			Range	(50.9 - 59.2)		(1.67 - 2.78)		-		(<0.0005 - 0.0070)		(0.0237 - 0.0314)
			n	3		3		3		3		3
Wuskwatim Lake	WuLB	2001	Mean±SE	57.5±1.0	-	1.42±0.24	-	<0.001	-	<0.0005±0.0001	-	0.0209±0.0019
			Range	(55.5 - 59.3)		(0.86 - 1.92)		-		(<0.0005 - 0.0008)		(0.0167 - 0.0247)
			n	4		4		4		4		4
Taskinigup Falls	TF	2001	Mean±SE	58.8±0.6	-	1.56±0.22	-	<0.001	-	<0.0005±0.0001	-	0.0227±0.0017
			Range	(57.7 - 60.5)		(1.16 - 2.14)		-		(<0.0005 - 0.0006)		(0.0199 - 0.0273)
			n	4		4		4		4		4

Table A3-3. - continued -

Sampling Location	Location ID	Sample Date		Hardness as $CaCO_3$ (mg/L)	Aluminum Dissolved (mg/L)	Aluminum Total (mg/L)	Antimony Dissolved (mg/L)	Antimony Total (mg/L)	Arsenic Dissolved (mg/L)	Arsenic Total (mg/L)	Barium Dissolved (mg/L)	Barium Total (mg/L)
Birch Tree Lake	BLB	2001	Mean±SE	55.6±2.8	0.09±0.02	1.69±0.29	<0.001	<0.001	<0.0005±0.0001	0.0013±0.0007	0.0093±0.0006	0.0240±0.0019
			Range	(47.3 - 58.6)	(0.06 - 0.13)	(1.22 - 2.50)	-	-	(<0.0005 - 0.0008)	(<0.0005 - 0.0033)	(0.0078 - 0.0103)	(0.0211 - 0.0295)
			n	4	4	4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001		58.1	-	1.28	-	<0.001	-	0.0007	-	0.0188
			n	1		1		1		1		1
Lower Burntwood River	LBRE1	2001	Mean±SE	62.2±1.9	-	1.67	-	<0.001	-	<0.0005±0.0002	-	0.0229±0.0014
			Range	(60.8- 63.5)		(1.57 - 1.27)		-		(<0.0005 - 0.0007)		(0.0215 - 0.0242)
			n	2		2		2		2		2
Lower Burntwood River	LBRE1	2001	Mean±SE	62.9	-	1.38	-	<0.001	-	0.0012	-	0.0208
			n	1		1		1		1		1
Lower Burntwood River	LBRF	2001	Mean±SE	59.9±0.3	-	1.55±0.13	-	<0.001	-	<0.0005±0.0002	-	0.0225±0.0019
			Range	(59.6 - 60.1)		(1.42 - 1.67)		-		(<0.0005 - 0.0006)		(0.0206 - 0.0243)
			n	2		2		2		2		2
Ice-cover Season												
Opegano Lake	OLB	2001	Mean±SE	55.3	-	0.88	-	<0.001±0	-	<0.0005	-	0.0177
			n	1		1		1		1		1

Table A3-3. - continued -

Sampling Location	Location ID	Sample Date		Hardness	Aluminum		Antimony		Arsenic		Barium	
				as $CaCO_3$	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
				(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Cranberry Lakes	CLA	2002	Mean±SE	49.8	-	0.84	-	<0.001±0	-	0.0006	-	0.0188
			n	1		1		1		1		1
Wuskwatim Lake	WuLB	2002	Mean±SE	49.4	-	0.89	-	<0.001±0	-	0.0006	-	0.0193
			n	1		1		1		1		1
Birch Tree Lake	BLB	2002	Mean±SE	50.6	-	1.11	-	<0.001±0	-	0.0006	-	0.0207
			n	1		1		1		1		1
Birch Tree Lake	BLC	2002	Mean±SE	49.6	-	1.06	-	<0.001±0	-	<0.0005	-	0.0201
			n	1		1		1		1		1
Lower Burntwood River	LBRF	2002	Mean±SE	62.2	-	1.82	-	<0.001±0	-	0.0005	-	0.0272
			n	1		1		1		1		1

Table A3-3. - continued -

Sampling Location	Location ID	Sample Date		Beryllium Dissolved (mg/L)	Beryllium Total (mg/L)	Boron Dissolved (mg/L)	Boron Total (mg/L)	Cadmium Dissolved (mg/L)	Cadmium Total (mg/L)	Calcium Dissolved (mg/L)	Calcium Total (mg/L)	Chloride Dissolved (mg/L)
Lower Burntwood River	LBRB2	2001	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	14.9±0.3	<10
			Range		-		-		-		(14.1 - 15.5)	-
			n		4		4		4		4	4
Wuskwatim Lake	WuLA	2000	Mean±SE	-	<0.001	-	<0.01	-	<0.0002	-	13.9±0.8	-
			Range		-		-		-		(12.6 - 15.3)	
			n		3		3		3		3	
Taskinigup Falls	TF	2000	Mean±SE	-	<0.001	-	<0.001	-	<0.0002	-	14.5 ±0.8	-
			Range		-		-		-		(13.6 - 16.2)	
			n		3		3		3		3	
Wuskwatim Lake	WuLB	2001	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	15.7±0.2	<10
			Range		-		-		-		(15.3 - 16.1)	-
			n		4		4		4		4	4
Taskinigup Falls	TF	2001	Mean±SE	-	<0.001	-	<0.030±0.006	-	<0.0002	-	16.1±0.3	<10
			Range		-		(<0.030 - 0.040)		-		(15.4 - 16.6)	-
			n		4		4		4		4	4
Birch Tree Lake	BLB	2001	Mean±SE	<0.001	<0.001	0.016±0.002	<0.03	<0.0002	<0.0002	15.6±0.8	16.8±0.2	<10
			Range	-	-	(0.013 - 0.021)	-	-	-	(13.2 - 16.5)	(16.4 - 17.3)	-
			n	4	4	4	4	4	4	4	4	4

Table A3-3. - continued -

Sampling Location	Location ID	Sample Date		Beryllium Dissolved (mg/L)	Beryllium Total (mg/L)	Boron Dissolved (mg/L)	Boron Total (mg/L)	Cadmium Dissolved (mg/L)	Cadmium Total (mg/L)	Calcium Dissolved (mg/L)	Calcium Total (mg/L)	Chloride Dissolved (mg/L)
Birch Tree Lake	BLC	2001	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	16.1	<10
			n		1		1		1		1	1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.001	-	<0.03±0.01	-	<0.0002	-	17.0±0.5	<10
			Range		-		(<0.03 - 0.03)		-		(16.5 - 17.5)	-
			n		2		2		2		2	1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	17.3	<10
			n		1		1		1		1	1
Lower Burntwood River	LBRF	2001	Mean±SE	-	<0.001	-	<0.03±0.013	-	<0.0002	-	16.4±0.1	<10
			Range		-		(<0.03 - 0.04)		-		(16.2 - 16.5)	-
			n		2		2		2		2	2
Ice-cover Season												
Opegano Lake	OLB	2001	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	14.5	<10
			n		1		1		1		1	1
Cranberry Lakes	CLA	2002	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	-	<10
			n		1		1		1			1
Wuskwatim Lake	WuLB	2002	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	12.9	-
			n		1		1		1		1	

Table A3-3. - continued -

Sampling Location	Location ID	Sample Date		Beryllium Dissolved (mg/L)	Beryllium Total (mg/L)	Boron Dissolved (mg/L)	Boron Total (mg/L)	Cadmium Dissolved (mg/L)	Cadmium Total (mg/L)	Calcium Dissolved (mg/L)	Calcium Total (mg/L)	Chloride Dissolved (mg/L)
Birch Tree Lake	BLB	2002	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	13.3	<10
			n		1		1		1		1	1
Birch Tree Lake	BLC	2002	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	13	-
			n		1		1		1		1	
Lower Burntwood River	LBRF	2002	Mean±SE	-	<0.001	-	<0.03	-	<0.0002	-	15.9	<10
			n		1		1		1		1	1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Chromium Dissolved (mg/L)	Chromium Total (mg/L)	Cobalt Dissolved (mg/L)	Cobalt Total (mg/L)	Copper Dissolved (mg/L)	Copper Total (mg/L)	Flouride Dissolved (mg/L)	Iron Dissolved (mg/L)	Iron Total (mg/L)
Lower Burntwood River	LBRB2	2001	Mean±SE	-	<0.002±0.0005	-	0.0005±0.00005	-	0.002±0.001	<0.1±0.01	-	1.13±0.22
			Range		(<0.002 - 0.003)		(0.0004 - 0.0006)		(<0.001 - 0.003)	(<0.1 - 0.1)		(0.72 - 1.76)
			n		4		4		4	4		4
Wuskwatim Lake	WuLA	2000	Mean±SE	-	0.003±0.0003	-	0.0005±0.0001	-	0.003±0.001	-	-	1.34±0.17
			Range		(0.002 - 0.003)		(0.0003 - 0.0007)		(0.002 - 0.004)			(1.00 - 1.53)
			n		3		3		3			3
Taskinigup Falls	TF	2000	Mean±SE	-	0.003±0.001	-	0.0006±0.0001	-	0.002±0.000	-	-	1.54±0.24
			Range		(0.002 - 0.004)		(0.0004 - 0.0007)		(0.002 - 0.003)			(1.29 - 2.02)
			n		3		3		3			3
Wuskwatim Lake	WuLB	2001	Mean±SE	-	0.002±0.001	-	0.0005±0.0001	-	0.002±0.0004	0.1±0.03	-	1.31±0.21
			Range		(<0.002 - 0.004)		(0.0003 - 0.0007)		(0.001 - 0.003)	(<0.1 - 0.2)		(0.71 - 1.67)
			n		4		4		4	4		4
Taskinigup Falls	TF	2001	Mean±SE	-	<0.002±0.0003	-	0.0006±0.0001	-	0.003±0.001	0.14±0.04	-	1.26±0.19
			Range		(<0.002 - 0.002)		(0.0003 - 0.0009)		(0.002 - 0.005)	(<0.1 - 0.2)		(0.87 - 1.77)
			n		4		4		4	4		4
Birch Tree Lake	BLB	2001	Mean±SE	<0.001	0.003±0.001	<0.0002±0.0001	0.0006±0.00005	0.0010±0.0003	0.002±0.0005	<0.1	0.15±0.01	1.31±0.18
			Range	-	(<0.002 - 0.004)	(<0.0002 - 0.0003)	(0.0005 - 0.0007)	(<0.0004 - 0.0015)	(0.001 - 0.003)	-	(0.13 - 0.18)	(1.02 - 1.82)
			n	4	4	4	4	4	4	3	4	4

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Chromium Dissolved (mg/L)	Chromium Total (mg/L)	Cobalt Dissolved (mg/L)	Cobalt Total (mg/L)	Copper Dissolved (mg/L)	Copper Total (mg/L)	Flouride Dissolved (mg/L)	Iron Dissolved (mg/L)	Iron Total (mg/L)
Birch Tree Lake	BLC	2001	Mean±SE	-	0.004	-	0.0005	-	0.033	<0.1	-	1.03
			n		1		1		1	1		1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	0.003±0.001	-	0.0005	-	0.004±0.002	<0.1	-	1.20±0.09
			Range		(0.002 - 0.003)		-		(0.002 - 0.005)	-		(1.11 - 1.29)
			n		2		2		2	1		2
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.002	-	0.0005	-	0.002	0.1	-	1.03
			n		1		1		1	1		1
Lower Burntwood River	LBRF	2001	Mean±SE	-	0.003	-	0.0005±0.0001	-	0.001±0.001	0.1	-	1.22±0.15
			Range		-		(0.0004 - 0.0005)		(<0.001 - 0.002)	-		(1.07 - 1.36)
			n		2		2		2	2		2
Ice-cover Season												
Opegano Lake	OLB	2001	Mean±SE	-	<0.002	-	0.0003	-	0.011	0.2	-	0.86
			n		1		1		1	1		1
Cranberry Lakes	CLA	2002	Mean±SE	-	<0.002	-	0.0003	-	0.002	<0.1	-	0.61
			n		1		1		1	1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Chromium Dissolved (mg/L)	Chromium Total (mg/L)	Cobalt Dissolved (mg/L)	Cobalt Total (mg/L)	Copper Dissolved (mg/L)	Copper Total (mg/L)	Flouride Dissolved (mg/L)	Iron Dissolved (mg/L)	Iron Total (mg/L)
Wuskwatim Lake	WuLB	2002	Mean±SE	-	<0.002	-	0.0003	-	0.008	-	-	0.66
			n		1		1		1			1
Birch Tree Lake	BLB	2002	Mean±SE	-	<0.002	-	0.0004	-	0.005	<0.1	-	0.87
			n		1		1		1	1		1
Birch Tree Lake	BLC	2002	Mean±SE	-	<0.002	-	0.0004	-	0.006	<0.1	-	0.83
			n		1		1		1	1		1
Lower Burntwood River	LBRF	2002	Mean±SE	-	0.004	-	0.0008	-	0.005	<0.1	-	1.58
			n		1		1		1	1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Lead		Manganese		Magnesium		Mercury	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Lower Burntwood River	LBRB2	2001	Mean±SE	-	0.0022±0.0017	-	0.0197±0.0035	-	4.36±0.17	-	<0.0003
			Range		(0.0003 - 0.0072)		(0.0139 - 0.0297)		(3.93 - 4.73)		-
			n		4		4		4		4
Wuskwatim Lake	WuLA	2000	Mean±SE	-	0.0009±0.0001	-	0.0219±0.0033	-	4.12±0.22	-	-
			Range		(0.0006 - 0.0011)		(0.0154 - 0.0254)		(3.73 - 4.50)		
			n		3		3		3		
Taskinigup Falls	TF	2000	Mean±SE	-	0.0010±0.0002	-	0.0254±0.0031	-	4.42±0.15	-	-
			Range		(0.0007 - 0.0012)		(0.0205 - 0.0310)		(4.12 - 4.57)		
			n		3		3		3		
Wuskwatim Lake	WuLB	2001	Mean±SE	-	<0.0005±0.0002	-	0.0201±0.0037	-	4.47±0.13	-	<0.0003
			Range		(<0.0005 - 0.0011)		(0.0102 - 0.0278)		(4.20 - 4.75)		-
			n		4		4		4		4
Taskinigup Falls	TF	2001	Mean±SE	-	0.0006±0.0002	-	0.0210±0.0034	-	4.56±0.07	-	< 0.0003
			Range		(0.0003 - 0.0010)		(0.0148 - 0.0304)		(4.35 - 4.68)		-
			n		4		4		4		4
Birch Tree Lake	BLB	2001	Mean±SE	0.0001±0.00004	0.0013±0.0004	0.0017±0.0005	0.0217±0.0022	4.06±0.20	4.74±0.10	<0.0002	< 0.0003
			Range	(<0.0001 - 0.0002)	(0.0005 - 0.0020)	(0.0008 - 0.0026)	(0.0178 - 0.0277)	(3.48 - 4.34)	(4.57 - 5.03)	-	-
			n	4	4	4	4	4	4	4	4

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Lead		Manganese		Magnesium		Mercury	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Birch Tree Lake	BLC	2001	Mean±SE	-	<0.0005	-	0.0177	-	4.35	-	<0.0003
			n		1		1		1		1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	0.0014±0.0008	-	0.0200±0.0018	-	4.79±0.01	-	< 0.0003
			Range		(0.0006 - 0.0022)		(0.0182 - 0.0218)		(4.77 - 4.80)		-
			n		2		2		2		2
Lower Burntwood River	LBRE1	2001	Mean±SE	-	0.0007	-	0.0190	-	4.78	-	<0.0003
			n		1		1		1		1
Lower Burntwood River	LBRF	2001	Mean±SE	-	<0.0005±0.0002	-	0.0203±0.0027	-	4.62±0.15	-	< 0.0003
			Range		(<0.0005 - 0.0006)		(0.0176 - 0.0229)		(4.46 - 4.77)		-
			n		2		2		2		2
Ice-cover Season											
Opegano Lake	OLB	2001	Mean±SE	-	0.0005	-	0.0158	-	4.65	-	<0.0003
			n		1		1		1		1
Cranberry Lakes	CLA	2002	Mean±SE	-	<0.0005	-	0.0108	-	4.22	-	<0.00005
			n		1		1		1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Lead Dissolved (mg/L)	Lead Total (mg/L)	Manganese Dissolved (mg/L)	Manganese Total (mg/L)	Magnesium Dissolved (mg/L)	Magnesium Total (mg/L)	Mercury Dissolved (mg/L)	Mercury Total (mg/L)
Wuskwatim Lake	WuLB	2002	Mean±SE	-	<0.0005	-	0.0119	-	4.18	-	<0.00005
			n		1		1		1		1
Birch Tree Lake	BLB	2002	Mean±SE	-	<0.0005	-	0.0167	-	4.22	-	<0.00005
			n		1		1		1		1
Birch Tree Lake	BLC	2002	Mean±SE	-	<0.0005	-	0.017	-	4.16	-	<0.00005
			n		1		1		1		1
Lower Burntwood River	LBRF	2002	Mean±SE	-	0.0008	-	0.0398	-	5.46	-	<0.00005
			n		1		1		1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Molybdenum		Nickel		Potassium		Selenium	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Lower Burntwood River	LBRB2	2001	Mean±SE	-	0.0003±0.0001	-	<0.002±0.0003	-	1.4±0.1	-	<0.002
			Range		(<0.0002 - 0.0005)		(<0.002 - 0.002)		(1.2 - 1.8)		-
			n		4		4		4		4
Wuskwatim Lake	WuLA	2000	Mean±SE	-	0.0004±0.0002	-	0.002±0.001	-	1.59±0.09	-	0.002±0.001
			Range		(0.0001 - 0.0008)		(<0.002 - 0.003)		(1.41 - 1.68)		(<0.002 - 0.004)
			n		3		3		3		3
Taskinigup Falls	TF	2000	Mean±SE	-	0.0003±0.0002	-	<0.002±0.001	-	1.71±0.14	-	<0.002±0.0003
			Range		(0.0001 - 0.0006)		(<0.002 - 0.003)		(1.50 - 1.97)		(<0.002 - 0.002)
			n		3		3		3		3
Wuskwatim Lake	WuLB	2001	Mean±SE	-	0.0007±0.0005	-	<0.002±0.0005	-	1.5±0.1	-	<0.002
			Range		(0.0002 - 0.0021)		(<0.002 - 0.003)		(1.2 - 1.8)		-
			n		4		4		4		4
Taskinigup Falls	TF	2001	Mean±SE	-	<0.0002±0.00003	-	0.005±0.003	-	1.5±0.1	-	<0.002
			Range		(<0.0002 - 0.0002)		(<0.002 - 0.014)		(1.4 - 1.8)		-
			n		4		4		4		4
Birch Tree Lake	BLB	2001	Mean±SE	0.0001±0.00004	<0.0002±0.00003	0.0005±0.0001	<0.002±0.001	1.03±0.04	1.6±0.1	<0.002	<0.002
			Range	(<0.0001 - 0.0002)	(<0.0002 - 0.0002)	(<0.0002 - 0.0007)	(<0.002 - 0.003)	(0.96 - 1.13)	(1.4 - 2.0)	-	-
			n	4	4	4	4	4	4	4	4

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Molybdenum		Nickel		Potassium		Selenium	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Birch Tree Lake	BLC	2001	Mean±SE	-	0.0007	-	0.048	-	1.5	-	<0.002
			n		1		1		1		1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.0002±0.0001	-	<0.002±0.001	-	1.7±0.3	-	<0.002
			Range		(<0.0002 - 0.0002)		(<0.002 - 0.002)		(1.4 - 1.9)		-
			n		2		2		2		2
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.0002	-	<0.002	-	1.5	-	<0.002
			n		1		1		1		1
Lower Burntwood River	LBRF	2001	Mean±SE	-	0.0008±0.0002	-	<0.002	-	1.5±0.05	-	<0.002
			Range		(0.0006 - 0.0010)		-		(1.4 - 1.5)		-
			n		2		2		2		2
Ice-cover Season											
Opegano Lake	OLB	2001	Mean±SE	-	0.0002	-	<0.002	-	-	-	<0.002
			n		1		1				1
Cranberry Lakes	CLA	2002	Mean±SE	-	0.0003	-	<0.002	-	1.4	-	<0.001
			n		1		1		1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Molybdenum		Nickel		Potassium		Selenium	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)
Wuskwatim Lake	WuLB	2002	Mean±SE	-	0.0003	-	<0.002	-	1.4	-	<0.001
			n		1		1		1		1
Birch Tree Lake	BLB	2002	Mean±SE	-	0.0003	-	<0.002	-	1.4	-	<0.001
			n		1		1		1		1
Birch Tree Lake	BLC	2002	Mean±SE	-	0.0003	-	0.002	-	1.4	-	<0.001
			n		1		1		1		1
Lower Burntwood River	LBRF	2002	Mean±SE	-	0.0003	-	0.003	-	1.7	-	<0.001
			n		1		1		1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Silver		Sodium		Strontium		Sulphate	Thallium	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Dissolved (mg/L)	Total (mg/L)
Lower Burntwood River	LBRB2	2001	Mean±SE	-	<0.0005	-	2.53±0.10	-	0.0365±0.0009	<10±2	-	<0.0001
			Range		-		(2.27 - 2.71)		(0.0339 - 0.0381)	(<10 - 11)		-
			n		4		4		4	4		4
Wuskwatim Lake	WuLA	2000	Mean±SE	-	<0.0004	-	2.53±0.10	-	0.0335±0.0020	-	-	<0.0001
			Range		-		(2.36 - 2.72)		(0.0325 - 0.0011)			-
			n		3		3		3			3
Taskinigup Falls	TF	2000	Mean±SE	-	<0.0004	-	2.69±0.14	-	0.0365±0.0009	-	-	<0.0001
			Range		-		(2.47 - 2.96)		(0.0347 - 0.0376)			-
			n		3		3		3			3
Wuskwatim Lake	WuLB	2001	Mean±SE	-	<0.0005	-	2.61±0.04	-	0.0372±0.0006	<10±2	-	<0.0001
			Range		-		(2.50 - 2.67)		(0.0355 - 0.0381)	(<10 - 11)		-
			n		4		4		4	4		4
Taskinigup Falls	TF	2001	Mean±SE	-	<0.0005	-	2.61±0.06	-	0.0377±0.0003	<10±2	-	<0.0001
			Range		-		(2.50 - 2.78)		(0.0369 - 0.0385)	(<10 - 11)		-
			n		4		4		4	4		4
Birch Tree Lake	BLB	2001	Mean±SE	<0.0002	<0.0005	2.40±0.12	2.67±0.06	0.0344±0.0016	0.0399±0.0007	<10	<0.0001	<0.0001
			Range	-	-	(2.05 - 2.64)	(2.56 - 2.83)	(0.0298 - 0.0376)	(0.0383 - 0.0416)	-	-	-
			n	4	4	4	4	4	4	4	4	4

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Silver		Sodium		Strontium		Sulphate	Thallium	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Dissolved (mg/L)	Total (mg/L)
Birch Tree Lake	BLC	2001	Mean±SE	-	<0.0005	-	2.44	-	0.0356	<10	-	<0.0001
			n		1		1		1	1		1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.0005	-	2.75±0.06	-	0.0396±0.0007	<10	-	<0.0001
			Range		-		(2.68 - 2.81)			-		-
			n		2		2		2	1		2
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.0005	-	2.72	-	0.039	<10	-	<0.0001
			n		1		1		1	1		1
Lower Burntwood River	LBRF	2001	Mean±SE	-	<0.0005	-	2.57±0.02	-	0.0378±0.00005	<10	-	<0.0001
			Range		-		(2.55 - 2.59)		(0.0377 - 0.0378)	-		-
			n		2		2		2	2		2
Ice-cover Season												
Opegano Lake	OLB	2001	Mean±SE	-	<0.0005	-	-	-	0.0401	<10	-	<0.0001
			n		1				1	1		1
Cranberry Lakes	CLA	2002	Mean±SE	-	<0.0001	-	3.03	-	0.0364	<10	-	<0.0001
			n		1		1		1	1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Silver		Sodium		Strontium		Sulphate	Thallium	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Dissolved (mg/L)	Total (mg/L)
Wuskwatim Lake	WuLB	2002	Mean±SE	-	<0.0001	-	3	-	0.0377	-	-	<0.0001
			n		1		1		1			1
Birch Tree Lake	BLB	2002	Mean±SE	-	<0.0001	-	2.94	-	0.0379	<10	-	<0.0001
			n		1		1		1	1		1
Birch Tree Lake	BLC	2002	Mean±SE	-	<0.0001	-	2.88	-	0.0357	<10	-	<0.0001
			n		1		1		1	1		1
Lower Burntwood River	LBRF	2002	Mean±SE	-	<0.0001	-	2.94	-	0.0393	<10	-	<0.0001
			n		1		1		1	1		1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Tin Dissolved (mg/L)	Tin Total (mg/L)	Uranium Dissolved (mg/L)	Uranium Total (mg/L)	Vanadium Dissolved (mg/L)	Vanadium Total (mg/L)	Zinc Dissolved (mg/L)	Zinc Total (mg/L)	Gross Radiation Gross alpha (Bq/L)	Gross Radiation Gross Beta (Bq/L)
Lower Burntwood River	LBRB2	2001	Mean±SE	-	0.0020±0.0011	-	0.0002±0.00003	-	0.002±0.0004	-	<0.02	0.04±0.01	0.14±0.00
			Range		(<0.0005 - 0.0046)		(0.0001 - 0.0002)		(0.001 - 0.003)		-	(0.03 - 0.06)	(0.13 - 0.15)
			n		4		4		4		4	4	4
Wuskwatim Lake	WuLA	2000	Mean±SE	-	<0.0001	-	-	-	0.003±0.0003	-	<0.02	-	-
			Range		-				(0.002 - 0.003)		-		
			n		3				3		2		
Taskinigup Falls	TF	2000	Mean±SE	-	<0.0001	-	-	-	0.003±0.000	-	<0.02±0	-	-
			Range		-				(0.003 - 0.004)		(<0.02 - <0.02)		
			n		3				3		3		
Wuskwatim Lake	WuLB	2001	Mean±SE	-	0.0006±0.0002	-	0.0002	-	0.002±0.0005	-	<0.02	0.04±0.01	0.15±0.01
			Range		(<0.0005 - 0.0010)		-		(0.001 - 0.003)		-	(0.02 - 0.06)	(0.14 - 0.17)
			n		4		4		4		4	4	4
Taskinigup Falls	TF	2001	Mean±SE	-	0.0009±0.0005	-	0.0002	-	0.003±0.000	-	<0.02±0.01	0.06±0.02	0.16±0.01
			Range		(<0.0005 - 0.0022)		-		(0.002 - 0.003)		(<0.02 - 0.03)	(0.03 - 0.10)	(0.13 - 0.19)
			n		4		4		4		4	4	4
Birch Tree Lake	BLB	2001	Mean±SE	<0.0002	0.0006±0.0003	0.0001±0.00003	0.0002±0.00002	0.001±0.0004	0.003±0.0004	<0.005±0.0011	<0.02±0.01	0.04±0.01	0.13±0.01
			Range	-	(<0.0005 - 0.0014)	(0.0001 - 0.0002)	(0.0002 - 0.0003)	(<0.001 - 0.002)	(0.002 - 0.004)	(<0.005 - 0.007)	(<0.02 - 0.03)	(0.03 - 0.06)	(0.11 - 0.16)
			n	4	4	4	4	4	4	4	4	4	4

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Tin		Uranium		Vanadium		Zinc		Gross Radiation	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Gross alpha (Bq/L)	Gross Beta (Bq/L)
Birch Tree Lake	BLC	2001		-	<0.0005	-	0.0002	-	0.002	-	<0.02	0.04	0.13
			n		1		1		1		1	1	1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.0005	-	0.0002	-	0.003±0.001	-	<0.02	0.07	0.14
			Range		-		-		(0.002 - 0.003)		-	-	-
			n		2		2		2		2	1	1
Lower Burntwood River	LBRE1	2001	Mean±SE	-	<0.0005	-	0.0002	-	0.002	-	<0.02	0.09	0.18
			n		1		1		1		1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	-	<0.0005	-	0.0002	-	0.003±0.001	-	<0.02±0.01	0.08±0.01	0.15±0.01
			Range		-		-		(0.002 - 0.003)		(<0.02 - 0.02)	(0.07 - 0.09)	(0.14 - 0.16)
			n		2		2		2		2	2	2
Ice-cover Season													
Opegano Lake	OLB	2001	Mean±SE	-	<0.0005	-	0.0002	-	0.002	-	<0.02	-	-
			n		1		1		1		1		
Cranberry Lakes	CLA	2002	Mean±SE	-	0.0007	-	0.0002	-	0.002	-	<0.02	<0.02	0.1
			n		1		1		1		1	1	1

Table A3-3. - continued –

Sampling Location	Location ID	Sample Date		Tin		Uranium		Vanadium		Zinc		Gross Radiation	
				Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Dissolved (mg/L)	Total (mg/L)	Gross alpha (Bq/L)	Gross Beta (Bq/L)
Wuskwatim Lake	WuLB	2002	Mean±SE	-	0.001	-	0.0002	-	0.002	-	<0.02	0.02	0.12
			n		1		1		1		1	1	1
Birch Tree Lake	BLB	2002	Mean±SE	-	0.0006	-	0.0002	-	0.002	-	<0.02	0.03	0.15
			n		1		1		1		1	1	1
Birch Tree Lake	BLC	2002	Mean±SE	-	<0.0005	-	0.0002	-	0.002	-	<0.02	0.03	0.14
			n		1		1		1		1	1	1
Lower Burntwood River	LBRF	2002	Mean±SE	-	0.0046	-	0.0002	-	0.004	-	<0.02	0.05	0.17
			n		1		1		1		1	1	1

Table A3-4. Summary statistics for hydrocarbons and PCP measured in surface water samples collected in the Wuskwatim study area, open-water seasons 2000 and 2001 and ice-cover seasons 2001 and 2002.

Sampling Location	Location ID	Sample Date		Acenaphthene (µg/L)	Acenaphthylene (µg/L)	Acridine (µg/L)	Anthracene (µg/L)	Benzene (µg/L)	Benz(a)anthracene (µg/L)	Benzo(a)pyrene (µg/L)
Taskinigup Falls	TF	2000	Mean±SE	-	-	-	-	< 0.5	-	-
			Range					-		
			n					3		
Lower Burntwood River	LBRB2	2001	Mean±SE	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01
			Range	-	-	-	-	-	-	-
			n	4	4	4	4	4	4	4
Wuskwatim Lake	WuLB	2001	Mean±SE	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01
			Range	-	-		-	-	-	-
			n	4	4	4	4	4	4	4
Taskinigup Falls	TF	2001	Mean±SE	< 0.05	< 0.05	< 0.02±0.001	< 0.05	< 0.5	< 0.01	< 0.01
			Range	-	-	(< 0.01 - < 0.02)	-	-	-	-
			n	4	4	4	4	4	4	4
Birch Tree Lake	BLB	2001	Mean±SE	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01
			Range	-	-		-	-	-	-
			n	4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001	Mean±SE	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1

Table A3-4. -continued-

Sampling Location	Location ID	Sample Date		Acenaphthene (µg/L)	Acenaphthylene (µg/L)	Acridine (µg/L)	Anthracene (µg/L)	Benzene (µg/L)	Benz(a)anthracene (µg/L)	Benzo(a)pyrene (µg/L)
Lower Burntwood River	LBRE1	2001	Mean±SE	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1
Lower Burntwood River	LBRE	2001	Mean±SE	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	< 0.01	< 0.01
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	< 0.05	< 0.05	< 0.01	< 0.05	< 0.5	0.02±0.02	0.01±0.01
			Range	-	-	-	-	-	(< 0.01 - 0.04)	(< 0.01 - 0.02)
			n	2	2	2	2	2	2	2
Ice-over Season										
Cranberry Lakes	CLA	2002		< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01
Wuskwatim Lake	WuLB	2002		< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01
Opegano Lake	OLB	2001		< 0.05	< 0.05	-	< 0.05	< 0.5	< 0.01	< 0.01
Birch Tree Lake	BLB	2002		< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01
Birch Tree Lake	BLC	2002		< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01
Lower Burntwood River	LBRF	2002		< 0.05	< 0.05	< 0.05	< 0.05	< 0.5	< 0.01	< 0.01

Table A3-4. -continued-

Sampling Location	Location ID	Sample Date		Benzo(b)fluoranthene (µg/L)	Benzo(g)perylene (µg/L)	Benzo(k)fluoranthene (µg/L)	Chrysene (µg/L)	Dibenz(a,h)anthracene (µg/L)	Ethyl benzene (µg/L)	Extractable HC (C11-C30) (µg/L)	Fluoranthene (µg/L)
Taskinigup Falls	TF	2000	Mean±SE	-	-	-	-	-	< 0.5	80±30	-
			Range						-	(< 100 - 140)	
			n						3	3	
Lower Burntwood River	LBRB2	2001	Mean±SE	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
			Range	-	-	-	-	-	-	-	-
			n	4	4	4	4	4	4	4	4
Wuskwatim Lake	WuLB	2001	Mean±SE	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	128±78	< 0.05
			Range	-	-	-	-	-	-	(< 100 - 360)	-
			n	4	4	4	4	4	4	4	4
Taskinigup Falls	TF	2001	Mean±SE	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	100±50	< 0.05
			Range	-	-	-	-	-	-	(< 100 - 250)	-
			n	4	4	4	4	4	4	4	4
Birch Tree Lake	BLB	2001	Mean±SE	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	65±15	< 0.05
			Range	-	-	-	-	-	-	(< 100 - 110)	-
			n	4	4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001	Mean±SE	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	130	< 0.05
			Range	-	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1	1

Table A3-4. -continued-

Sampling Location	Location ID	Sample Date		Benzo(b)fluoranthene (µg/L)	Benzo(g)perylene (µg/L)	Benzo(k)fluoranthene (µg/L)	Chrysene (µg/L)	Dibenz(a,h)anthracene (µg/L)	Ethyl benzene (µg/L)	Extractable HC (C11-C30) (µg/L)	Fluoranthene (µg/L)
Lower Burntwood River	LBRE1	2001	Mean±SE	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
			Range	-	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1	1
Lower Burntwood River	LBRE	2001	Mean±SE	< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
			Range	-	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	0.02±0.01	0.02±0.01	0.02±0.02	< 0.05	0.02±0.01	< 0.5	< 100	< 0.05
			Range	(< 0.01 - 0.03)	(< 0.01 - 0.03)	(< 0.01 - 0.04)	-	(< 0.01 - 0.03)	-	-	-
			n	2	2	2	2	2	2	2	2
Ice-cover Season											
Cranberry Lakes	CLA	2002		< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
Wuskwatim Lake	WuLB	2002		< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
Opegano Lake	OLB	2001		< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
Birch Tree Lake	BLB	2002		< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
Birch Tree Lake	BLC	2002		< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05
Lower Burntwood River	LBRF	2002		< 0.01	< 0.01	< 0.01	< 0.05	< 0.01	< 0.5	< 100	< 0.05

Table A3-4. -continued-

Sampling Location	Location ID	Sample Date		Fluorene (µg/L)	Indeno(1,2,3-cd)pyrene (µg/L)	Napthalene (µg/L)	1-Methylnapthalene (µg/L)	2-Methylnapthalene (µg/L)	Pentachlorophenol (µg/L)	Phenanthrene (µg/L)
Taskinigup Falls	TF	2000	Mean±SE	-	-	-	-	-	-	-
			Range							
			n							
Lower Burntwood River	LBRB2	2001	Mean±SE	< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05
			Range	-	-	-	-	-	(< 0.05 - < 0.25)	-
			n	4	4	4	4	4	3	4
Wuskwatim Lake	WuLB	2001	Mean±SE	< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
			Range	-	-	-	-	-	-	-
			n	4	4	4	4	4	2	4
Taskinigup Falls	TF	2001	Mean±SE	< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05
			Range	-	-	-	-	-	(< 0.05 - < 0.25)	-
			n	4	4	4	4	4	3	4
Birch Tree Lake	BLB	2001	Mean±SE	< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.25	< 0.05
			Range	-	-	-	-	-	(< 0.05 - < 0.25)	-
			n	4	4	4	4	4	3	4
Birch Tree Lake	BLC	2001	Mean±SE	< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1

Table A3-4. -continued-

Sampling Location	Location ID	Sample Date		Fluorene (µg/L)	Indeno(1,2,3-cd)pyrene (µg/L)	Napthalene (µg/L)	1-Methylnapthalene (µg/L)	2-Methylnapthalene (µg/L)	Pentachlorophenol (µg/L)	Phenanthrene (µg/L)
Lower Burntwood River	LBRE1	2001	Mean±SE	< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1
Lower Burntwood River	LBRE	2001	Mean±SE	< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	< 0.05	0.02±0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
			Range	-	(< 0.01 - 0.03)	-	-	-	-	-
			n	2	2	2	2	2	2	2
Ice-cover Season										
Cranberry Lakes	CLA	2002		< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Wuskwatim Lake	WuLB	2002		< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Opegano Lake	OLB	2001		< 0.05	< 0.01	0.11	< 0.05	0.06	-	< 0.05
Birch Tree Lake	BLB	2002		< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Birch Tree Lake	BLC	2002		< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Lower Burntwood River	LBRF	2002		< 0.05	< 0.01	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Table A3-4. -continued-

Sampling Location	Location ID	Sample Date		Pyrene (µg/L)	Quinoline (µg/L)	Toluene (µg/L)	Volatile HC (C5-C10) (µg/L)	Xylene Total (µg/L)	Xylene Meta and Para (µg/L)	Xylene Ortho (µg/L)
Taskinigup Falls	TF	2000	Mean±SE	-	-	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range			-	-	-	-	-
			n			3	3	3	3	3
Lower Burntwood River	LBRB2	2001	Mean±SE	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range	-	-	-	-	-	-	-
			n	4	4	4	4	4	4	4
Wuskwatim Lake	WuLB	2001	Mean±SE	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range	-	-	-	-	(< 0.5 - 0.7)	(< 0.5 - 0.7)	-
			n	4	4	4	4	4	4	4
Taskinigup Falls	TF	2001	Mean±SE	< 0.05	< 1±0.12	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range	-	(< 0.05 - < 1)	-	-	-	-	-
			n	4	4	4	4	4	4	4
Birch Tree Lake	BLB	2001	Mean±SE	< 0.05	< 0.05	< 0.5	< 100	1.04±0.79	0.74±0.49	< 0.5
			Range	-	-	(< 0.5 - 0.6)	-	(< 0.5 - 3.4)	(< 0.5 - 2.2)	(< 0.5 - 1.2)
			n	4	4	4	4	4	4	4
Birch Tree Lake	BLC	2001	Mean±SE	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1

Table A3-4. -continued-

Sampling Location	Location ID	Sample Date		Pyrene (µg/L)	Quinoline (µg/L)	Toluene (µg/L)	Volatile HC (C5-C10) (µg/L)	Xylene Total (µg/L)	Xylene Meta and Para (µg/L)	Xylene Ortho (µg/L)
Lower Burntwood River	LBRE1	2001	Mean±SE	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1
Lower Burntwood River	LBRE	2001	Mean±SE	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range	-	-	-	-	-	-	-
			n	1	1	1	1	1	1	1
Lower Burntwood River	LBRF	2001	Mean±SE	< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
			Range	-	-	-	-	-	-	-
			n	2	2	2	2	2	2	2
Ice-cover Season										
Cranberry Lakes	CLA	2002		< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
Wuskwatim Lake	WuLB	2002		< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
Opegano Lake	OLB	2001		< 0.05	< 0.05	< 0.5	< 100	-	< 0.5	< 0.5
Birch Tree Lake	BLB	2002		< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
Birch Tree Lake	BLC	2002		< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5
Lower Burntwood River	LBRF	2002		< 0.05	< 0.05	< 0.5	< 100	< 0.5	< 0.5	< 0.5

APPENDIX 4. RESULTS OF FECAL COLIFORM BACTERIA AND *CRYPTOSPORIDIUM* AND *GIARDIA* ANALYSES CONDUCTED ON WATER SAMPLES COLLECTED IN THE WUSKWATIM STUDY AREA, 2000-2002.

The following is provided on the enclosed CD:

Table A4-1
Table A4-2

Table A4-1. Results of microbiological analyses (fecal coliform bacteria, *Cryptosporidium*, and *Giardia*) in surface water samples collected in the Wuskwatim study area, 2000-2002.

Sampling Location	Location ID	Sample Date	Coliform Fecal MF (CFU/100 mL)	*Cryptosporidium* (Oocysts/10 L) Total	Viable Oocysts	Nonviable (empty)	Amorphous	*Giardia* (Cysts/10 L) Total	Viable Cysts	Nonviable (empty)	Amorphous
Open-water Season 2000											
Wuskwatim Lake	WuLA	14-Jun-00	< 1	0	0	0	0	0	0	0	0
Wuskwatim Lake	WuLA	24-Jul-00	< 1	0	0	0	0	0	0	0	0
Wuskwatim Lake	WuLA	18-Sep-00	< 10	0	0	0	0	0	0	0	0
Open-water Season 2001											
Lower Burntwood River	LBRB2	30-May-01	< 10	1	0	0	1	1	0	1	0
Lower Burntwood River	LBRB2	16-Jul-01	< 10	0	0	0	0	0	0	0	0
Lower Burntwood River	LBRB2	23-Aug-01	< 10	0	0	0	0	0	0	0	0
Lower Burntwood River	LBRB2	27-Sep-01	< 10	0	0	0	0	0	0	0	0
Wuskwatim Lake	WuLB	30-May-01	< 10	0	0	0	0	0	0	0	0
Wuskwatim Lake	WuLB	16-Jul-01	< 10	0	0	0	0	0	0	0	0
Wuskwatim Lake	WuLB	23-Aug-01	< 10	0	0	0	0	0	0	0	0
Wuskwatim Lake	WuLB	27-Sep-01	< 10	0	0	0	0	0	0	0	0
Taskinigup Falls	TF	30-May-01	< 10	0	0	0	0	1	1	0	0
Taskinigup Falls	TF	16-Jul-01	< 10	0	0	0	0	0	0	0	0
Taskinigup Falls	TF	23-Aug-01	< 10	0	0	0	0	0	0	0	0

Table A4-1. - continued -

Sampling Location	Location ID	Sample Date	Coliform Fecal MF (CFU/100 mL)	*Cryptosporidium* Total (Oocysts/10 L)	*Cryptosporidium* Viable Oocysts	*Cryptosporidium* Nonviable (empty)	*Cryptosporidium* Amorphous	*Giardia* Total (Cysts/10 L)	*Giardia* Viable Cysts	*Giardia* Nonviable (empty)	*Giardia* Amorphous
Taskinigup Falls	TF	27-Sep-01	< 10	0	0	0	0	0	0	0	0
Birch Tree Lake	BLB	31-May-01	< 10	0	0	0	0	0	0	0	0
Birch Tree Lake	BLB	17-Jul-01	< 10	0	0	0	0	0	0	0	0
Birch Tree Lake	BLB	26-Aug-01	< 10	0	0	0	0	0	0	0	0
Birch Tree Lake	BLB	30-Sep-01	< 10	0	0	0	0	0	0	0	0
Birch Tree Lake	BLC	26-Aug-01	< 10	0	0	0	0	0	0	0	0
Lower Burntwood River	LBRE1	30-Sep-01	< 10	0	0	0	0	0	0	0	0
Lower Burntwood River [1]	LBRE	27-Aug-01	< 10	0	0	0	0	0	0	0	0
Lower Burntwood River	LBRF	27-Aug-01	< 10	0	0	0	0	0	0	0	0
Lower Burntwood River	LBRF	01-Oct-01	< 10	0	0	0	0	0	0	0	0
Ice-cover Season 2001											
Opegano Lake	OLB	28-Mar-01	< 1	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]	0 [2]
Ice-cover Season 2002											
Cranberry Lakes	CLA	26-Mar-02	< 10	0	0	0	0	0	0	0	0
Wuskwatim Lake	WuLB	26-Mar-02	< 10	0	0	0	0	0	0	0	0
Birch Tree Lake	BLB	27-Mar-02	< 10	0	0	0	0	0	0	0	0
Birch Tree Lake	BLC	27-Mar-02	< 10	0	0	0	0	0	0	0	0
Lower Burntwood River	LBRF	27-Mar-02	< 10	0	0	0	0	0	0	0	0

[1] One sample of water was collected on the lower Burntwood River downstream of the Manasan River in August 2001; due to problems with accessibility, this site was not visited again.
[2] Total volume of water filtered 9 L.

Table A4-2. Results of microbiological analyses (fecal coliform bacteria, *Cryptosporidium*, and *Giardia*) in surface water samples collected in tributary streams in Reach 3, September 2002. Streams 1 and 4 were sampled in the backwater inlets (STR-1-D and STR-4-D) and a point upstream of the influence of the lower Burntwood River (STR-1-U and STR-4 U).

			Coliform	*Cryptosporidium*				*Giardia*			
Sampling Location	Location ID	Sample Date	Fecal MF (CFU/100 mL)	Total (Oocysts/10 L)	Viable Oocysts	Nonviable (empty)	Amorphous	Total (Cysts/10 L)	Viable Cysts	Nonviable (empty)	Amorphous
Stream 1	STR-1-U		20	0	0	0	0	0	0	0	0
Stream 1	STR-1-D		< 10	0	0	0	0	0	0	0	0
Stream 4	STR-4-U		< 10	0	0	0	0	0	0	0	0
Stream 4	STR-4-D		10	0	0	0	0	0	0	0	0

APPENDIX 5. RESULTS OF SEDIMENT CHEMISTRY ANALYSES CONDUCTED FOR THE WUSKWATIM STUDY AREA, 2001.

The following is provided on the enclosed CD:

Table A5-1
Table A5-2
Table A5-3
Table A5-4
Table A5-5
Table A5-6

Table A5-1. Results of analyses for inorganic constituents in surficial sediments (upper 5 cm) collected in Wuskwatim Lake (WuLB), the lower Burntwood River at Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in 2001 and 2002.

Sampling Location	Location ID	Sample Date	Aluminum (µg/g)	Arsenic (µg/g)	Barium (µg/g)	Beryllium (µg/g)	Boron (µg/g)	Bismuth (µg/g)	Cadmium (µg/g)	Calcium (µg/g)	Chromium (µg/g)	Cobalt (µg/g)	Copper (µg/g)	Iron (µg/g)
2001														
Wuskwatim Lake	WuLB 1	16-Jul-01	16600	2.52	143	0.73	6.8	0.25	0.18	31700	48.5	13.5	24.2	29300
Wuskwatim Lake	WuLB 2	16-Jul-01	15300	2.64	140	0.73	7.5	0.25	0.17	26000	52.1	13.8	29.7	29200
Wuskwatim Lake	WuLB 3	16-Jul-01	16200	2.54	147	0.73	7.6	0.27	0.18	26500	50.9	14	24.5	28400
Opegano Lake	OLB 1	17-Jul-01	14300	2.68	105	0.57	9.3	0.18	0.11	75100	36.9	10.6	23.7	23700
Opegano Lake	OLB 2	17-Jul-01	10800	2.3	98.8	0.63	6.9	0.19	0.23	14200	37.7	11.8	27.2	18300
Opegano Lake	OLB 3	17-Jul-01	19200	4.08	144	0.95	9	0.25	0.14	31200	57.8	15.7	42.3	37000
2002														
Wuskwatim Lake	WuLB 1	19-Aug-02	20300	5.22	160	0.85	0.29	6.5	0.18	19400	56.3	15.2	25.4	33100
Wuskwatim Lake	WuLB 2	19-Aug-02	20300	2.77	177	0.90	0.32	6.8	0.22	16200	63.1	17.1	27.4	33200
Wuskwatim Lake	WuLB 3	19-Aug-02	18400	3.34	223	0.89	0.31	5.9	0.25	14000	57.6	17.1	25.7	30900
Taskinigup Falls	TF 1	18-Aug-02	16800	29.2	117	0.71	6.4	0.22	0.19	12500	42.3	11.7	28.5	25100
Taskinigup Falls	TF 2	18-Aug-02	16700	6.05	115	0.71	4.3	0.22	0.16	11400	42.3	11.7	25.2	25200
Taskinigup Falls	TF 3	18-Aug-02	17400	3.12	116	0.71	4.8	0.22	0.16	11100	43.4	11.7	26.3	25800
Opegano Lake	OLB 1	18-Aug-02	15000	10.1	1750	0.67	4.5	0.21	0.42	31100	36.8	27.7	26.2	38900
Opegano Lake	OLB 2	18-Aug-02	18400	4.10	266	0.80	6.2	0.26	0.17	42200	44.6	15.4	29.0	30800
Opegano Lake	OLB 3	18-Aug-02	17000	7.02	171	0.68	5.9	0.22	0.13	37300	43.3	13.6	28.9	29300
Birch Tree Lake	BLB 1	20-Aug-02	13800	2.87	107	0.59	0.17	5.6	0.11	19800	42.5	12.5	23.6	22400
Birch Tree Lake	BLB 2	20-Aug-02	10400	2.68	79.1	0.45	0.13	4.5	0.09	16700	34.9	9.92	17.3	16700
Birch Tree Lake	BLB 3	20-Aug-02	11200	2.86	87.1	0.49	0.14	4.9	0.1	18700	37.3	10.6	18.9	17900

Table A5-1. – continued -

Sampling Location	Location ID	Sample Date	Lead (µg/g)	Magnesium (µg/g)	Manganese (µg/g)	Mercury (µg/g)	Molybdenum (µg/g)	Nickel (µg/g)	Potassium (µg/g)	Selenium (µg/g)	Silver (µg/g)	Sodium (µg/g)	Strontium (µg/g)	Thallium (µg/g)
2001														
Wuskwatim Lake	WuLB Sed1	16-Jul-01	11.6	21300	1410	0.03	0.30	38.2	3850	< 0.1	< 1	203	31.4	0.3
Wuskwatim Lake	WuLB Sed2	16-Jul-01	11.4	21500	1270	0.02	0.82	42.5	3810	0.1	< 1	208	28.6	0.3
Wuskwatim Lake	WuLB Sed3	16-Jul-01	11.6	21400	1380	0.03	0.26	39.6	3930	< 0.1	< 1	210	29.3	0.3
Opegano Lake	OLBSed 1	17-Jul-01	8.77	17200	632	< 0.02	0.42	29.5	2940	< 0.1	< 1	186	56.3	0.2
Opegano Lake	OLBSed 2	17-Jul-01	10.9	10600	509	< 0.02	0.7	33.9	2570	0.2	< 1	166	22.8	0.2
Opegano Lake	OLBSed 3	17-Jul-01	12.4	15300	851	< 0.02	1.17	49.3	4390	0.2	< 1	263	38.2	0.3
2002														
Wuskwatim Lake	WuLB Sed1	19-Aug-02	13.9	19800	1090	0.04	0.28	42.0	4640	<0.1	<1	226	28.1	0.4
Wuskwatim Lake	WuLB Sed2	19-Aug-02	14.7	19600	1090	0.04	0.29	46.6	5080	<0.1	<1	245	30.4	0.4
Wuskwatim Lake	WuLB Sed3	19-Aug-02	14.6	17600	1680	0.04	0.28	44.1	4620	<0.1	<1	221	28.4	0.4
Taskinigup Falls	TF Sed 1	18-Aug-02	14.7	12300	398	0.04	0.28	34.9	3410	< 0.1	< 1	207	26	0.3
Taskinigup Falls	TF Sed 2	18-Aug-02	11.3	12000	393	0.02	0.30	34.6	3410	< 0.1	< 1	193	22.8	0.3
Taskinigup Falls	TF Sed 3	18-Aug-02	11.0	11800	376	0.03	0.31	35.7	3550	< 0.1	< 1	234	24.0	0.3
Opegano Lake	OLB Sed 1	18-Aug-02	10.6	17400	18967 [1]	< 0.02	0.80	41.7	3440	< 0.1	< 1	208	62.9	0.5
Opegano Lake	OLB Sed 2	18-Aug-02	11.5	21100	3140	< 0.02	0.34	37.3	4320	< 0.1	< 1	254	44.9	0.3
Opegano Lake	OLB Sed 3	18-Aug-02	10.5	19400	1620	< 0.02	0.43	36.8	3870	< 0.1	< 1	250	37.6	0.3
Birch Tree Lake	BLB Sed 1	20-Aug-02	9.05	15700	706	< 0.02	0.16	41.7	3090	< 0.1	< 1	195	25.2	0.2
Birch Tree Lake	BLB Sed 2	20-Aug-02	7.09	14400	517	< 0.02	0.33	37.4	2330	< 0.1	< 1	158	20.2	< 0.2
Birch Tree Lake	BLB Sed 3	20-Aug-02	7.6	15100	608	< 0.02	0.22	39.7	2530	< 0.1	< 1	166	21.8	< 0.2

[1] Sample was re-analysed for verification in duplicate. Number reported here is the mean of three measurements (19,200, 19, 000, and 18,700 µg/g).

Table A5-1. – continued -

Sampling Location	Location ID	Sample Date	Tin (µg/g)	Titanium (µg/g)	Uranium (µg/g)	Vanadium (µg/g)	Zinc (µg/g)
2001							
Wuskwatim Lake	WuLB Sed1	16-Jul-01	< 4	1400	1.07	41.9	70
Wuskwatim Lake	WuLB Sed2	16-Jul-01	< 4	1310	1.05	42.2	67
Wuskwatim Lake	WuLB Sed3	16-Jul-01	< 4	1360	1.06	43.7	70
Opegano Lake	OLBSed 1	17-Jul-01	< 4	996	1.04	32.6	49
Opegano Lake	OLBSed 2	17-Jul-01	< 4	796	1.43	31.4	78
Opegano Lake	OLBSed 3	17-Jul-01	< 4	1170	1.12	43.8	74
2002							
Wuskwatim Lake	WuLB Sed1	19-Aug-02	< 4	1520	1.30	47.0	80
Wuskwatim Lake	WuLB Sed2	19-Aug-02	< 4	1480	1.55	52.9	88
Wuskwatim Lake	WuLB Sed3	19-Aug-02	<4	1420	1.48	49.7	82
Taskinigup Falls	TF Sed 1	18-Aug-02	< 4	1170	1.68	34.0	65
Taskinigup Falls	TF Sed 2	18-Aug-02	< 4	1140	1.62	33.2	64
Taskinigup Falls	TF Sed 3	18-Aug-02	< 4	1150	1.58	34.6	64
Opegano Lake	OLB Sed 1	18-Aug-02	< 4	984	1.52	38.5	57
Opegano Lake	OLB Sed 2	18-Aug-02	< 4	1130	1.57	38.9	67
Opegano Lake	OLB Sed 3	18-Aug-02	< 4	1100	1.39	35.8	62
Birch Tree Lake	BLB Sed 1	20-Aug-02	< 4	944	0.936	31.9	51
Birch Tree Lake	BLB Sed 2	20-Aug-02	< 4	734	0.805	25.9	38
Birch Tree Lake	BLB Sed 3	20-Aug-02	< 4	787	0.809	27.3	41

Table A5-2. Statistical summaries of analyses for inorganic constituents in surficial sediments (upper 5 cm) collected in Wuskwatim Lake (WuLB), the lower Burntwood River at Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in 2001 and 2002. Data presented are the mean±SE.

Parameter	Concentration (µg/g d.w.)					
	2001		2002			
	Wuskwatim Lake (WuLB)	Opegano Lake (OLB)	Wuskwatim Lake (WuLB)	Taskinigup Falls (TF)	Opegano Lake (OLB)	Birch Tree Lake (BLB)
Aluminum	16,033 (±384)	19,200 (±2436)	19,667 (±633)	16,967 (±219)	16,800 (±987)	11,800 (±1026)
Arsenic	2.57 (±0.04)	3.02 (±0.54)	3.78 (±0.74)	21.79 (±8.25)	7.07 (±1.73)	2.80 (±0.06)
Barium	143 (±2)	116 (±14)	187 (±19)	116 (±1)	729 (±511)	91 (±8)
Beryllium	0.73 (±0)	0.72 (±0.12)	0.88 (±0.02)	0.71 (±0.00)	0.72 (±0.04)	0.51 (±0.04)
Boron	7.30 (±0.25)	8.40 (±0.76)	0.31 (±0.01)	5.2 (±0.6)	5.5 (±0.5)	0.15 (±0.01)
Bismuth	0.26 (±0.01)	0.21 (±0.02)	6.40 (±0.26)	0.22 (±0.00)	0.23 (±0.02)	5.00 (±0.32)
Cadmium	0.18 (±0.00)	0.16 (±0.04)	0.22 (±0.02)	0.17 (±0.01)	0.24 (±0.09)	0.10 (±0.01)
Calcium	28,067 (±1,822)	40,167 (±18,143)	16,533 (±1568)	11,667 (±426)	36,867 (±3212)	18,400 (±907)
Chromium	50.5 (±1.1)	44.1 (±6.8)	59.0 (±2.1)	42.7 (±0.4)	41.6 (±2.4)	38.2 (±2.2)
Cobalt	13.8 (±0.1)	12.7 (±1.5)	16.5 (±0.6)	11.7 (±0.0)	18.9 (±4.4)	11.0 (±0.8)
Copper	26.1 (±1.8)	31.1 (±5.7)	26.2 (±0.6)	26.7 (±1.0)	28.0 (±0.9)	19.9 (±1.9)
Iron	28,967 (±285)	26,333 (±5,556)	32,400 (±751)	25,367 (±219)	33,000 (±2982)	19,000 (±1735)
Lead	11.5 (±0.1)	10.7 (±1.1)	14.4 (±0.3)	12.3 (±1.2)	10.9 (±0.3)	7.9 (±0.6)
Magnesium	21,400 (±58)	14,367 (±1,962)	19,000 (±702)	12,033 (±145)	19,300 (±1069)	15,067 (±376)
Manganese	1,353 (±43)	664 (±100)	1,287 (±197)	389 (±7)	7,909 (±5546)	610 (±55)
Mercury	0.03 (±0.00)	< 0.02	0.04(±0)	0.04(±0.01)	< 0.02	< 0.02
Molybdenum	0.46 (±0.18)	0.76 (±0.22)	0.28 (±0.00)	0.30 (±0.01)	0.52 (±0.14)	0.24 (±0.05)

Table A5-2. – continued -

Parameter	Concentration (µg/g d.w.)					
	2001		2002			
	Wuskwatim Lake (WuLB)	Opegano Lake (OLB)	Wuskwatim Lake (WuLB)	Taskinigup Falls (TF)	Opegano Lake (OLB)	Birch Tree Lake (BLB)
Nickel	40.1 (±1.3)	37.6 (±6.0)	44.2 (±1.3)	35.1 (±0.3)	38.6 (±1.6)	39.6 (±1.2)
Potassium	3,863 (±35)	4,390 (±555)	4,780 (±150)	3,457 (±47)	3,877 (±254)	2,650 (±227)
Selenium	< 0.1	0.2 (±0.1)	<0.1 (±0.0)	<0.1 (±0.0)	<0.1 (±0.0)	<0.1 (±0.0)
Silver	< 1	< 1	<1	<1	<1	<1
Sodium	207 (±2)	205 (±30)	231 (±7)	211 (±12)	237 (±15)	173 (±11)
Strontium	30.0 (±0.8)	39.1 (±9.7)	29 (±1)	24 (±1)	48 (±8)	22 (±1)
Thallium	0.3 (±0.0)	0.3 (±0.0)	0.4 (±0.0)	0.3 (±0.0)	0.4 (±0.1)	<0.2 (±0.0)
Tin	< 4	< 4	<4	<4	<4	<4
Titanium	1,357 (±26)	987 (±108)	1,473 (±29)	1153 (±9)	1071 (±45)	822 (±63)
Uranium	1.06 (±0.01)	1.20 (±0.12)	1.44(±0.07)	1.63 (±0.03)	1.49 (±0.05)	0.85 (±0.04)
Vanadium	42.6 (±0.6)	35.9 (±3.9)	49.9 (±1.7)	33.9 (±0.4)	37.7 (±1.0)	28.4 (±1.8)
Zinc	69 (±1)	67 (±9)	83 (±2)	64 (±0)	62 (±3)	43 (±4)

Table A5-3. Concentrations of organic constituents in surficial sediments (upper 5 cm) collected in Wuskwatim Lake (WuLB), the lower Burntwood River at Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in 2001 and 2002.

Sampling Location	Location ID	Date	Acenaphthene (µg/g)	Acenaphthylene (µg/g)	Anthracene (µg/g)	Benzene (µg/g)	Benzo(a)anthracene (µg/g)	Benzo(a)pyrene (µg/g)
2001								
Wuskwatim Lake	WuLB Sed1	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Wuskwatim Lake	WuLB Sed2	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Wuskwatim Lake	WuLB Sed3	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Opegano Lake	OLBSed 1	17-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Opegano Lake	OLBSed 2	17-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Opegano Lake	OLBSed 3	17-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
2002								
Wuskwatim Lake	WULB Sed1	19-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Wuskwatim Lake	WULB Sed 2	19-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Wuskwatim Lake	WULB Sed 3	19-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Taskinigup Falls	TF Sed 1	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Taskinigup Falls	TF Sed 2	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Taskinigup Falls	TF Sed 3	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Opegano Lake	OLB Sed 1	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Opegano Lake	OLB Sed 2	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Opegano Lake	OLB Sed 3	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Birch Tree Lake	BLB Sed 1	20-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Birch Tree Lake	BLB Sed 2	20-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05
Birch Tree Lake	BLB Sed 3	20-Aug-02	< 0.05	< 0.05	< 0.05	< 0.02	< 0.05	< 0.05

Table A5-3. - continued –

Sampling Location	Location ID	Date	Benzo(b)fluoranthene (µg/g)	Benzo(g,h,i)perylene (µg/g)	Benzo(k)fluoranthene (µg/g)	Chrysene (µg/g)	Dibenzo(a,h)anthracene (µg/g)
2001							
Wuskwatim Lake	WuLB Sed1	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Wuskwatim Lake	WuLB Sed2	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Wuskwatim Lake	WuLB Sed3	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Opegano Lake	OLBSed 1	17-Jul-01	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Opegano Lake	OLBSed 2	17-Jul-01	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Opegano Lake	OLBSed 3	17-Jul-01	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
2002							
Wuskwatim Lake	WULB Sed1	19-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Wuskwatim Lake	WULB Sed 2	19-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Wuskwatim Lake	WULB Sed 3	19-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Taskinigup Falls	TF Sed 1	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Taskinigup Falls	TF Sed 2	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Taskinigup Falls	TF Sed 3	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Opegano Lake	OLB Sed 1	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Opegano Lake	OLB Sed 2	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Opegano Lake	OLB Sed 3	18-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Birch Tree Lake	BLB Sed 1	20-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Birch Tree Lake	BLB Sed 2	20-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05
Birch Tree Lake	BLB Sed 3	20-Aug-02	< 0.05	< 0.05	< 0.05	< 0.1	< 0.05

Table A5-3. - continued –

Sampling Location	Location ID	Date	Ethyl Benzene (µg/g)	Extractable HC (C11-C30) (µg/g)	Fluoranthene (µg/g)	Fluorene (µg/g)	Indeno(1,2,3-cd) pyrene (µg/g)	Moisture Content Organics %	Napthalene (µg/g)	Napthalene - Methyl (µg/g)
2001										
Wuskwatim Lake	WuLB Sed1	16-Jul-01	< 0.03	< 5	< 0.05	< 0.05	< 0.05	59.3	< 0.05	< 0.05
Wuskwatim Lake	WuLB Sed2	16-Jul-01	< 0.03	< 5	< 0.05	< 0.05	< 0.05	55.8	< 0.05	< 0.05
Wuskwatim Lake	WuLB Sed3	16-Jul-01	< 0.03	< 5	< 0.05	< 0.05	< 0.05	52.8	< 0.05	< 0.05
Opegano Lake	OLBSed 1	17-Jul-01	< 0.03	< 5	< 0.05	< 0.05	< 0.05	37.8	< 0.05	< 0.05
Opegano Lake	OLBSed 2	17-Jul-01	< 0.03	< 5	< 0.05	< 0.05	< 0.05	46.4	< 0.05	< 0.05
Opegano Lake	OLBSed 3	17-Jul-01	< 0.03	< 5	< 0.05	< 0.05	< 0.05	40.3	< 0.05	< 0.05
2002										
Wuskwatim Lake	WuLB Sed1	19-Aug-02	< 0.03	<5	< 0.05	< 0.05	< 0.05	59.1	< 0.05	< 0.05
Wuskwatim Lake	WuLB Sed 2	19-Aug-02	< 0.03	<5	< 0.05	< 0.05	< 0.05	66.4	< 0.05	< 0.05
Wuskwatim Lake	WuLB Sed 3	19-Aug-02	< 0.03	<5	< 0.05	< 0.05	< 0.05	55.9	< 0.05	< 0.05
Taskinigup Falls	TF Sed 1	18-Aug-02	< 0.03	< 5	< 0.05	< 0.05	< 0.05	51.5	< 0.05	< 0.05
Taskinigup Falls	TF Sed 2	18-Aug-02	< 0.03	< 5	< 0.05	< 0.05	< 0.05	47.3	< 0.05	< 0.05
Taskinigup Falls	TF Sed 3	18-Aug-02	< 0.03	< 5	< 0.05	< 0.05	< 0.05	47.5	< 0.05	< 0.05
Opegano Lake	OLB Sed 1	18-Aug-02	< 0.03	< 5	< 0.05	< 0.05	< 0.05	28.3	< 0.05	< 0.05
Opegano Lake	OLB Sed 2	18-Aug-02	< 0.03	< 5	< 0.05	< 0.05	< 0.05	27.7	< 0.05	< 0.05
Opegano Lake	OLB Sed 3	18-Aug-02	< 0.03	< 5	< 0.05	< 0.05	< 0.05	24.5	< 0.05	< 0.05
Birch Tree Lake	BLB Sed 1	20-Aug-02	< 0.03	< 5	< 0.05	< 0.05	< 0.05	37.5	< 0.05	< 0.05
Birch Tree Lake	BLB Sed 2	20-Aug-02	< 0.03	9	< 0.05	< 0.05	< 0.05	33	< 0.05	< 0.05
Birch Tree Lake	BLB Sed 3	20-Aug-02	< 0.03	34	< 0.05	< 0.05	< 0.05	34.9	< 0.05	< 0.05

Table A5-3. - continued –

Sampling Location	Location ID	Date	Pentachlorophenol	Phenanthrene	Pyrene	Toluene	Volatile HC (C5-C10)	Xylene Total	Xylene Meta and Para	Xylene Ortho	TPH (C5-C30)
			(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)	(µg/g)
2001											
Wuskwatim Lake	WuLB Sed1	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	11	< 0.02	< 0.01	< 0.01	-
Wuskwatim Lake	WuLB Sed2	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	15	< 0.02	< 0.01	< 0.01	-
Wuskwatim Lake	WuLB Sed3	16-Jul-01	< 0.05	< 0.05	< 0.05	< 0.02	14	< 0.02	< 0.01	< 0.01	-
Opegano Lake	OLBSed 1	17-Jul-01		< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	-
Opegano Lake	OLBSed 2	17-Jul-01		< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	-
Opegano Lake	OLBSed 3	17-Jul-01		< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	-
2002											
Wuskwatim Lake	WULB Sed1	19-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	<5
Wuskwatim Lake	WULB Sed 2	19-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	<5
Wuskwatim Lake	WULB Sed 3	19-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	<5
Taskinigup Falls	TF Sed 1	18-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	< 5
Taskinigup Falls	TF Sed 2	18-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	< 5
Taskinigup Falls	TF Sed 3	18-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	< 5
Opegano Lake	OLB Sed 1	18-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	< 5
Opegano Lake	OLB Sed 2	18-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	< 5
Opegano Lake	OLB Sed 3	18-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	< 5
Birch Tree Lake	BLB Sed 1	20-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	< 5
Birch Tree Lake	BLB Sed 2	20-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	9
Birch Tree Lake	BLB Sed 3	20-Aug-02	-	< 0.05	< 0.05	< 0.02	< 5	< 0.02	< 0.01	< 0.01	34

Table A5-4. Statistical summaries of analyses for organic constituents in surficial sediments (upper 5 cm) collected in Wuskwatim Lake (WuLB), the lower Burntwood River at Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in 2001 and 2002. Data presented are the mean±SE.

Parameter	Concentration (µg/g d.w.)					
	2001		2002			
	Wuskwatim Lake (WuLB)	Opegano Lake (OLB)	Wuskwatim Lake (WuLB)	Taskinigup Falls (TF)	Opegano Lake (OLB)	Birch Tree Lake (BLB)
Acenaphthene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Acenaphthylene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Anthracene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Benzene	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Benz(a)anthracene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Benzo(a)pyrene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Benzo(b)fluoranthene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Benzo(g,h,i)perylene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Benzo(k)fluoranthene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Chrysene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Dibenz(a,h)anthracene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Ethyl Benzene	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03	< 0.03
Extractable HC (C11-C30)	< 5	< 5	15.2 (±9.6)	< 5	< 5	< 5
Fluoranthene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Fluorene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Indeno(1,2,3-cd)pyrene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Naphthalene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Naphthalene-methyl	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05

Table A5-4. - continued –

Parameter	Concentration (µg/g d.w.)					
	2001		2002			
	Wuskwatim Lake (WuLB)	Opegano Lake (OLB)	Wuskwatim Lake (WuLB)	Taskinigup Falls (TF)	Opegano Lake (OLB)	Birch Tree Lake (BLB)
Pentachlorophenol	< 0.05	-	< 0.05	< 0.05	< 0.05	< 0.05
Phenanthrene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Pyrene	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05	< 0.05
Toluene	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Volatile HC (C5-C10)	15 (±1)	< 5	< 5	< 5	< 5	< 5
Xylene (Total)	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02	< 0.02
Xylene (Meta and Para)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Xylene (Ortho)	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01	< 0.01
Moisture Content (%)	56.0 (±1.9)	41.5 (±2.6)	60.5 (±3.1)	48.8 (±1.4)	26.8 (±1.2)	35.1 (±1.3)

Table A5-5. Results for particle size and organic matter content analyses in surficial sediments (upper 5 cm) collected in Wuskwatim Lake (WuLB), the lower Burntwood River at Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in 2001 and 2002.

Sampling Location	Location ID	Particle Size Composition (%)			Organic Matter Composition
		Sand	Silt	Clay	(%)
2001					
Wuskwatim Lake	WuLB 1	18	41	41	2.6
Wuskwatim Lake	WuLB 2	0	51	49	2.4
Wuskwatim Lake	WuLB 3	2	50	48	2.5
Opegano Lake	OLB 1	9	29	62	1.7
Opegano Lake	OLB 2	19	20	60	1.9
Opegano Lake	OLB 3	12	14	74	1.9
2002					
Wuskwatim Lake	WuLB 1	<1	42	58	5
Wuskwatim Lake	WuLB 2	<1	47	53	5
Wuskwatim Lake	WuLB 3	<1	52	48	4
Taskinigup Falls	TF 1	16	46	37	11
Taskinigup Falls	TF 2	15	46	39	9
Taskinigup Falls	TF 3	-	-	-	-
Opegano Lake	OLB 1	56	14	31	3
Opegano Lake	OLB 2	28	26	46	4
Opegano Lake	OLB 3	21	26	53	4
Birch Tree Lake	BLB 1	34	31	35	5
Birch Tree Lake	BLB 2	49	20	31	5
Birch Tree Lake	BLB 3	46	22	32	5

Table A5-6. Statistical summaries of analyses for particle size and organic matter in surficial sediments (upper 5 cm) collected in Wuskwatim Lake (WuLB), the lower Burntwood River at Taskinigup Falls (TF), Opegano Lake (OLB), and Birch Tree Lake (BLB) in 2001 and 2002. Data presented are the mean±SE.

Parameter	Particle Size and Organic Matter Analysis (%)					
	2001		2002			
	Wuskwatim Lake (WuLB)	Opegano Lake (OLB)	Wuskwatim Lake (WuLB)	Taskinigup Falls (TF)	Opegano Lake (OLB)	Birch Tree Lake (BLB)
% Sand	7 (±6)	13 (±3)	<1 (±0)	16 (±1)	35 (±11)	43 (±5)
% Silt	47 (±3)	21 (±4)	47 (±3)	46 (±0)	22 (±4)	24 (±3)
% Clay	46 (±3)	65 (±4)	53 (±3)	38 (±1)	43 (±6)	33 (±1)
% Organic Matter [1]	2.5 (±0.1)	1.8 (±0.1)	5 (±0)	10 (±1)	4 (±0)	5 (±0)

[1]Loss on ignition.

APPENDIX 6. WATER AND SEDIMENT QUALITY OBJECTIVES AND GUIDELINES.

MWQSOGs for Water

Ammonia

Proposed MWQSOGs for ammonia are dependent upon water temperature and pH and the presence of cool- or cold-water aquatic life. A representative range of Manitoba water quality objectives for ammonia appropriate for the range of pH and temperature measured in the study area (i.e., site-specific objectives) during water quality sampling is presented in Table A6-1.

Table A6-1. Range of applicable Manitoba Water Quality Objectives for ammonia, for the protection of cold-water aquatic life and wildlife. Values calculated from algorithms provided in Williamson (2001) and the range of pH and water temperature measured in the study area during time of water sample collection.

pH	Temperature (^oC)	Ammonia Objective (mg/L)		
		Averaging Period		
		30-day	4-day	1-hour
7.04	0	5.82	14.54	23.25
	10	7.78	19.46	23.25
	15	5.64	14.10	23.25
	20	4.09	10.21	23.25
	25	2.96	7.40	23.25
8.25	0	1.65	4.14	3.47
	10	2.21	5.53	3.47
	15	1.60	4.01	3.47
	20	1.16	2.90	3.47
	25	0.84	2.10	3.47
8.61	0	0.90	2.26	1.74
	10	1.21	3.03	1.74
	15	0.88	2.19	1.74
	20	0.64	1.59	1.74
	25	0.46	1.15	1.74

Dissolved Oxygen

Proposed objectives for dissolved oxygen are dependent upon water temperature, the presence of early life stages, and the presence of sensitive fish species (e.g., cool-water fish such as pike and walleye or cold-water fish species such as whitefish and trout) (Williamson 2001). Objectives are generally more stringent in environments inhabited by cold-water fish species, as is true of the Wuskwatim study area. Objectives are specific for early life stages and mature life stages and vary according to the averaging duration are presented in Table A5-6.2.

Table A6-2. Manitoba Water Quality Objectives for dissolved oxygen (Williamson 2001).

Conditions	Dissolved Oxygen Objective (mg/L)			
	Averaging Duration			
	Instantaneous Minimum	7 Day Minimum	7 Days	30 Days
Cold-Water Aquatic Life and Wildlife				
When Water Temperature ≤ 5 ^{o}C and Early Life Stages Present	8.0	-	9.5	-
When Water Temperature > 5 ^{o}C and Mature Life Stages Present	4.0	5.0	-	6.5
Cool-Water Aquatic Life and Wildlife				
When Water Temperature ≤ 5 ^{o}C and Mature Life Stages Present	3.0	4.0	-	5.5
When Water Temperature > 5 ^{o}C and Early Life Stages Present	5.0	-	6.0	-

Therefore, in winter when water temperature is less than or equal to 5 ^{o}C and early life stages of fall spawning cold-water fish species (e.g., lake whitefish and lake cisco) may be present in the study area, the first two objectives apply (9.5 mg/L chronic objective and 8.0 mg/L instantaneous minimum objective) to ensure the protection of these early life stages. Less stringent objectives apply in winter for cool-water fish species that are spring spawners (3.0, 4.0, and 5.5 mg/L).

In the open-water season, when water temperature is greater than 5 ^{o}C and early life stages of cold-water fish species are not present, objectives are less stringent (objectives range from 4.0 to 6.5 mg/L). However, early life stages of spring spawning fish species (e.g., walleye) may be present in the study area at this time, thus requiring application of appropriate guidelines to ensure their protection (i.e., early life stages are present for cool water species). Of the two, objectives for the protection of mature life stages of cold-water fish species and early life stages of cool-water fish species (i.e., when water temperature is greater than 5 ^{o}C) are similar, with one major exception. The instantaneous minimum for the protection of early life stages of cool-water fish species in the ice-free season (5.0 mg/L) is more stringent than the instantaneous minimum objective for the protection of mature life stages of cold-water fish species (4.0 mg/L); chronic objectives are similar for both (5.0 to 6.5 mg/L).

Total Suspended Solids (TSS) and Turbidity

MWQSOGs for TSS and turbidity vary according to the environment; the applicable objective for the study area is an allowable increase in TSS of 5 mg/L (applies to aquatic environments where ‘background’ TSS is ≤ 25 mg/L) (Williamson 2001). Current objectives indicate that non-filterable residue should not exceed 25 mg/L for the protection of aquatic life (Willamson 1988).

Other Physico-chemical Parameters

Guidelines for other relevant water chemistry parameters (i.e., fecal coliform bacteria, nitrate/nitrite, are presented in Table A6.3.

Table A6-3. Proposed MWQSOGs for chemical and physical parameters of surface waters and groundwaters.

Parameter	Water Use	Objectives or guidelines	Comments
Fecal Coliform Bacteria	Primary Recreation	200 CFU/100 mL	1 day averaging duration; 7Q10 design flow
	Groundwater: Drinking water	0 CFU/100 mL	
Nitrate/nitrite-nitrogen	Groundwater: Drinking water	10 mg/L	
TDS	Drinking Water: Aesthetic	≤ 500 mg/L	

Parameter	Water Use	Objectives or guidelines	Comments
	Livestock	≤ 3,000 mg/L	
Total phosphorus	Narrative: To prevent nuisance growth and reproduction of aquatic rooted, attached and floating plants, fungi, or bacteria or to otherwise render the water unsuitable for other beneficial uses.	0.025 mg/L	In reservoirs, lakes, ponds, or tributary at the point of entry to these bodies of water
		0.05 mg/L	All other streams
Colour	Drinking Water: Aesthetic	≤15 TCU	
pH	Drinking Water: Aesthetic	6.5-8.5	
	Freshwater Aquatic Life	6.5-9.0	
	Recreation	5.0-9.0	
Turbidity	Drinking Water: Maximum Acceptable Concentration	1 NTU	
	Drinking Water: Aesthetic	≤ 5 NTU	At the point of consumption

Although there are no MWQSOGs for alkalinity, it is known that levels less than 30 mg/L may cause corrosion of water lines and those in excess of 500 mg/L may cause surface deposits and impair taste of water (Williamson and Ralley 1993).

Inorganic substances

Table A6-4. Proposed MWQSOGs (chronic) for select elements (Williamson 2001). The most stringent criteria are indicated in bold.

Element	Freshwater Aquatic Life	Drinking Water	
	Objectives or Guidelines (µg/L)	Maximum Acceptable Concentration (µg/L)	Aesthetic Objective (µg/L)
Al	**5 - 100**	100 [1]	-
An	-	**6** [2]	-
As	150 [3]	**25** [2]	-
Ba	-	**1,000**	-

Element	Freshwater Aquatic Life	Drinking Water	
	Objectives or Guidelines (µg/L)	Maximum Acceptable Concentration (µg/L)	Aesthetic Objective (µg/L)
Be	-	-	-
B	-	**5,000** [2]	-
Ca	-	-	-
Cd	**1.4 – 1.7** [4]	5	-
Chloride	-	-	**≤ 250,000**
Cr (III)	46 – 59 [4]	50 [5]	-
Co	-	-	-
Cu	**5 - 6**	-	≤ 1,000
Flouride	-	**1,500**	-
Fe	**300**	-	**≤ 300**
Pb	**1.2 – 1.8** [4]	10	-
Mn	-	-	**≤ 50**
Hg	**0.1**	1	-
Mo	**73**	-	-
Ni	**27 – 36** [4]	-	-
Se	**1.0**	10	-
Ag	**0.1**	-	-
Na	-	-	**≤ 200,000**
Sulphate	-	-	**≤ 500,000**
Tl	**0.8**	-	-
U	-	**20** [2,6]	-
V	-	-	-
Zn	**63 – 82** [4]	-	≤ 5,000

1 "A health based guideline for aluminum in drinking water has not been established…Operational guidance values of less than 100 µg/L total aluminum for conventional treatment plants and less than 200 µg/L total aluminum for other types of treatment systems are recommended." (CCME 2001b)

2 Interim maximum acceptable concentration.

3 Dissolved arsenic objective (Williamson 2001).

4 Ranges calculated from the range of water hardness values (46.8-63.5 mg $CaCO_3$/L) measured in the study area in the open-water seasons of 2000 and 2001 and March 2001; values represent the chronic (4-day averaging duration objective) objectives.

5 Total chromium (i.e., Cr (III) + Cr (VI)).

6 Revised 1999 CCME guideline (CCME 2001b).

Polycyclic Aromatic Hydrocarbons

Table A6-5. Proposed MWQSOGs for polycyclic aromatic hydrocarbons (Williamson 2001).

Polycyclic Aromatic Hydrocarbon	Drinking Water Quality Objective: Maximum Acceptable Concentration (µg/L)	Guidelines for the Protection of Freshwater Aquatic Life (µg/L)
Acenaphthene	-	5.8
Acridine	-	4.4
Anthracene	-	0.012
Benz*(a)*anthracene	-	0.018
Benzo*(a)*pyrene	0.01	0.015
Fluoranthene	-	0.04
Fluorene	-	3.0
Naphthalene	-	1.1
Phenanthrene	-	0.4
Pyrene	-	0.025
Quinoline		3.4

Radionuclides

There are currently no guidelines (federal or provincial) for radiation for the protection of aquatic life. However, federal drinking water quality guidelines for the protection of human health have been established for radionuclides, based on maximum acceptable doses (CCME 2001b). Water samples can be evaluated (i.e., screened) for radioactivity of all constituent radionuclides by measuring gross alpha and beta activity. Guidelines are 0.1 Bq/L for gross alpha activity and 1 Bq/L for gross beta activity.

Manitoba and Ontario Criteria for Sediments

Inorganic Substances

Manitoba Sediment Quality Guidelines (MSQGs) and associated 'Probable Effects Levels' (PELs) have been proposed for: arsenic; cadmium; chromium; copper; lead; and, mercury (Williamson 2001); levels are in accordance with federal CCME guidelines (CCME 1999). Additional guidelines are available for Ontario for manganese, nickel, and iron (Persaud et al. 1993). Ontario also provides open-water disposal guidelines for silver and cobalt (Persaud et al. 1993). MSQGs and Ontario sediment quality guidelines are presented in Table A6-6. As neither Manitoba or Ontario have adopted a guideline for selenium, the working guideline of 5 µg/g for selenium adopted by the B.C. Ministry of the Environment (BCMOE 2001) was used for interpretation of data collected in this study. For context and interpretation, ‘background’ concentrations of select trace elements in freshwater sediments in Canada are presented in Table A6-7.

Table A6-6. Ontario Open Water Disposal Guidelines and Ontario (Persaud et al. 1993) and Manitoba (Williamson 2001) sediment quality guidelines for inorganic substances.

Substance	Manitoba Sediment Quality Guidelines (Williamson 2001) (µg/g d.w.)		Ontario Sediment Quality Guidelines (Persaud et al. 1993) (µg/g d.w.)			
	Guideline	PEL [1]	NOEL[2]	LOEL[3]	SEL[4]	Ontario Open Water Disposal Guidelines
As	5.9	17	-	6	33	-
Cd	0.6	3.5	-	0.6	10	-
Co	-	-	-	-	-	50
Cr	37.3	90	-	26	110	-
Cu	35.7	197	-	16	110	-
Fe (%)[5]	-	-	-	2	4	-
Pb	35	91.3	-	31	250	-
Mn	-	-	-	460	1,100	-
Hg	0.17	0.486	-	0.2	2	-
Ni	-	-	-	16	75	-
Ag	-	-	-	-	-	0.5
Zn	123	315	-	120	820	-
TOC[5,6]	-	-	-	1	10	-
TKN[7]	-	-	-	550	4,800	-
TP[8]	-	-	-	600	2,000	-
Ammonia	-	-	-	-	-	100

1 PEL = Probable Effect Level
2 NOEL = No Effect Level
3 LOEL = Lowest Effect Level
4 SEL = Severe Effect Level
5 Expressed as a percentage.
6 TOC = Total Organic Carbon
7 TKN = Total Kjeldahl Nitrogen
8 TP = Total Phosphorus

Table A6-7. Background concentrations of select elements in freshwater sediments in Canada.

Substance	Geological Survey of Canada Background concentration (µg/g d.w.)[1] Lake	Geological Survey of Canada Background concentration (µg/g d.w.)[1] Stream	Great Lakes Background concentration [2] (µg/g d.w.)
As	2.5	10.7	4.2
Cd	0.32	0.63	1.1
Cr	47	81	31
Cu	31	32	25
Fe (%)	-	-	3.12
Hg	0.074	0.075	0.1
Mn	-	-	400
Ni	-	-	31
Pb	6	12.7	23
Zn	104	107	65

[1] Mean background concentrations in the National Geochemical Reconaissance program database, Geological Survey of Canada (CCME 1999).
[2] Values were based on analyses of Great Lakes pre-colonial sediment horizon (Persaud et al. 1993).

Organic Substances

Manitoba (and Ontario) sediment quality guidelines for organic substances relevant to baseline analyses conducted for the Wuskwatim study area are summarized in Table A6-8.

Table A6-8. Manitoba (Williamson 2001) and Ontario (Persaud et al. 1993) sediment quality guidelines for polycyclic aromatic hydrocarbons (PAHs).

Substance	Manitoba Sediment Quality Guidelines (Williamson 2001) (µg/kg d.w.) Guideline	PEL [1]	Ontario Sediment Quality Guidelines (Persaud et al. 1993) LOEL[2] (µg/kg d.w.)	SEL[3] (µg/kg)
PAHs				
Acenaphthene	6.71	88.9	-	-
Acenaphthylene	5.87	128	-	-
Anthracene	46.9	245	220	370
Benz(a)anthracene	31.7	385	320	1,480
Benzo(k)fluoranthene	-	-	240	1,340

Substance	Manitoba Sediment Quality Guidelines (Williamson 2001) (µg/kg d.w.)		Ontario Sediment Quality Guidelines (Persaud et al. 1993)	
	Guideline	PEL [1]	LOEL[2] (µg/kg d.w.)	SEL[3] (µg/kg)
Benzo(g,h,i)perylene	-	-	170	320
Benzo(a)pyrene	31.9	782	370	1,440
Chrysene	57.1	862	340	460
Dibenz(a,h)anthracene	6.22	135	60	130
Fluoranthene	111	2,355	750	1,020
Fluorene	21.2	144	190	160
Indeno(1,2,3-cd)pyrene	-	-	200	320
2-Methylnaphthalene	20.2	201	-	-
Naphthalene	34.6	391	-	-
Phenanthrene	41.9	515	560	950
Pyrene	53.0	875	490	850
PAH (Total)[4]	-	-	4,000	10,000

[1] PEL = Probable Effect Level

[2] LOEL = Lowest Observed Effect Level

[3] SEL = Severe Effect Level; the SEL for a PAH is derived by standardizing the values presented in the SEL column to the measured total organic carbon concentration in the sediment sample.

[4] PAH (Total) is the sum of 16 PAH compounds: acenaphthene; acenaphthylene; anthracene; benzo(k)fluoranthene; benzo(b)fluorine; benzo(a)anthracene; benzo(a)pyrene; benzo(g,h,I)perylene; chrysene; dibenzo(a,h)anthracene; fluoranthene; fluorine; indeno(1,2,3-cd)pyrene; naphthalene; phenanthrene; and, pyrene.

APPENDIX 7. SUMMARY OF APPROACH AND METHODOLOGY USED FOR LOWER TROPHIC LEVELS STUDIES CONDUCTED FOR THE GENERATION PROJECT EIS

Table A7-1. Summary of approach and methodology used for lower trophic levels studies conducted for the Generation Project EIS in Reach 1.

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Phytoplankton	To provide a semi-quantitative description of the phytoplankton community in terms of biomass, composition, and chlorophyll *a* concentration within study area waterbodies.	a) laboratory supplied bottle	a) chlorophyll *a* (µg/L) and phytoplankton species identification, enumeration, and biomass (mg/m^3) determined in surface water sample (at 0.10 m depth)	a) late May-late Sep., 1999 (4 sample times), 2000 (3 sample times), and 2001 (4 sample times)	a) late May-late Sep., 1999 (3), 2000 (3), and 2001 (7)	a) 1 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
Attached Algae and Rooted Aquatic Plants	To provide a description of attached algae and rooted aquatic plants in terms of relative abundance, composition, and distribution within study area waterbodies.	a) video recorder, 35 mm camera, and aquatic habitat survey equipment	a) aerial video-taping surveys to better delineate aquatic plant distribution, and recording and mapping all aquatic plant occurrences as they were observed during the course of aquatic habitat and fisheries surveys	a) aerial video-taping conducted 24 and 27 Aug., and 17 Sep., 2001; aquatic habitat surveys conducted Aug., 1998, 1999, and 2000; fisheries surveys conducted 1998, 2000, 2001, and 2002	a) -	a) -	a) North/South Consultants Inc. unpublished data; Volume 5, Section 6.0; Volume 5, Section 7.0; Volume 5, Section 8.0
		b) multi-pronged hook	b) ground-truth surveys to provide aquatic plant species composition and distribution from representative locations	b) 20-24 Sep., 2001	b) 63	b) 3 per site	b) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
Zooplankton	To provide a semi-quantitative description of the zooplankton community in terms of abundance, composition, and distribution within study area waterbodies.	a) 63 µm mesh, 0.25 m diameter, conical net	a) zooplankton species identification and enumeration (individuals/m^3) determined in depth-integrated water sample	a) late May-late Sep., 1999 (4 sample times), 2000 (3 sample times), and 2001 (4 sample times)	a) late May-late Sep., 1999 (2), 2000 (2), and 2001 (4)	a) 1 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0

Table A7-1. (continued)

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Benthic Invertebrates	a) To provide a replicable, habitat-based quantitative description of benthic invertebrate community abundance, composition, and distribution within study area waterbodies.	a) Ekman dredge (0.023 m^2 opening)	a) benthic invertebrate identification and enumeration (individuals/m^2) determined in the lacustrine soft silt/clay-based and flooded terrestrial substrate classes	a) early Oct., 1998; mid Sep.-early Oct., 1999; late Sep., 2000 and 2001	a) early Oct., 1998 (10); mid Sep.-early Oct., 1999 (17); late Sep., 2000 (17) and 2001 (47)	a) 4-5 per site (1998); 4 per site (1999); 3-4 per site (2000); 4 per site (2001)	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
	b) To provide a qualitative description of the benthic invertebrate community.	b) drift trap (0.023 m^2 opening with 500 µm mesh collecting net)	b) the collection of drifting invertebrates to provide a qualitative description of the benthic invertebrate community in terms of presence/absence of taxa	b) 22-25 Jun., 2001	b) 1	b) 1 per site	b) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0

Table A7-2. Summary of approach and methodology used for lower trophic levels studies conducted for the Generation Project EIS in Reach 2.

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Phytoplankton	Data were not collected in this reach as the water residence time is extremely short and the water tends to be very turbulent. These conditions reduce the potential for notable increases in phytoplankton populations.						
Attached Algae and Rooted Aquatic Plants	To provide a description of attached algae and rooted aquatic plants in terms of relative abundance, composition, and distribution within study area waterbodies.	a) video recorder, 35 mm camera, and aquatic habitat survey equipment	a) aerial video-taping surveys to better delineate aquatic plant distribution, and recording and mapping all aquatic plant occurrences as they were observed during the course of aquatic habitat and fisheries surveys	a) aerial video-taping conducted 24 and 27 Aug., and 17 Sep., 2001; aquatic habitat surveys conducted Sep., 2001; fisheries surveys conducted 2001 and 2002	a) -	a) -	a) North/South Consultants Inc. unpublished data; Volume 5, Section 6.0; Volume 5, Section 7.0; Volume 5, Section 8.0
Zooplankton	Data were not collected in this reach as the water residence time is extremely short and the water tends to be very turbulent. These conditions reduce the potential for notable increases in zooplankton populations.						

Table A7-2. (continued)

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Benthic Invertebrates	a) To provide a replicable, habitat-based quantitative description of benthic invertebrate community abundance, composition, and distribution within study area waterbodies.	a) Ponar dredge (0.023 m^2 opening)	a) benthic invertebrate identification and enumeration (individuals/m^2) determined in the riverine boulder/cobble, and hard silt/clay- and soft silt/clay-based substrate classes	a) late Sep., 2001	a) 9	a) 4 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
	b) To provide a qualitative description of the benthic invertebrate community.	b) drift trap (0.023 m^2 opening with 500 µm mesh collecting net)	b) the collection of drifting invertebrates to provide a qualitative description of the benthic invertebrate community in terms of presence/absence of taxa	b) 22-25 Jun. and 21-27 Jul., 2001	b) 22-25 Jun. (1) and 21-27 Jul. (2), 2001	b) 1 per site	b) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0

Table A7-3. Summary of approach and methodology used for lower trophic levels studies conducted for the Generation Project EIS in Reach 3.

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Phytoplankton	To provide a semi-quantitative description of the phytoplankton community in terms of abundance, composition, and distribution within study area waterbodies.	a) laboratory supplied bottle	a) chlorophyll *a* (µg/L) determined in surface water sample (at 0.10 m depth)	a) late May-late Sep., 2001 (4 sample times)	a) 1	a) 1 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
Attached Algae and Rooted Aquatic Plants	To provide a description of attached algae and rooted aquatic plants in terms of relative abundance, composition, and distribution within study area waterbodies.	a) video recorder, 35 mm camera, and aquatic habitat survey equipment	a) aerial video-taping surveys to better delineate aquatic plant distribution, and recording and mapping all aquatic plant occurrences as they were observed during the course of aquatic habitat and fisheries surveys	a) aerial video-taping conducted 24 and 27 Aug., and 17 Sep., 2001; aquatic habitat surveys conducted Sep., 2001; fisheries surveys conducted 2001 and 2002	a) -	a) -	a) North/South Consultants Inc. unpublished data; Volume 5, Section 6.0; Volume 5, Section 7.0; Volume 5, Section 8.0
Zooplankton	Data were not collected in this reach as the water residence time is extremely short and the water tends to be very turbulent. These conditions reduce the potential for notable increases in zooplankton populations.						

Table A7-3. (continued)

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Benthic Invertebrates	a) b) To provide a replicable, habitat-based quantitative description of benthic invertebrate community abundance, composition, and distribution within study area waterbodies.	a) Ponar dredge (0.023 m^2 opening)	a) benthic invertebrate identification and enumeration (individuals/m^2) determined in the riverine hard silt/clay- and soft silt/clay-based substrate classes	a) late Sep., 2001	a) 44	a) 4 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
		b) Air-lift sampler (0.032 m^2 opening)	b) benthic invertebrate identification and enumeration (individuals/m^2) determined in the riverine bedrock, and boulder/cobble substrate classes	b) late Sep., 2001	b) 15	b) 4 per site	b) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
	c) To provide a qualitative description of the benthic invertebrate community	c) drift trap (0.023 m^2 opening with 500 µm mesh collecting net)	c) the collection of drifting invertebrates to provide a qualitative description of the benthic invertebrate community in terms of presence/absence of taxa	c) 22-25 Jun. and 21-27 Jul., 2001	c) 1	c) 1 per site	c) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0

Table A7-4. Summary of approach and methodology used for lower trophic levels studies conducted for the Generation Project EIS in Reach 4.

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Phytoplankton	To provide a semi-quantitative description of the phytoplankton community in terms of abundance, composition, and distribution within study area waterbodies.	a) laboratory supplied bottle	a) chlorophyll *a* (µg/L) and phytoplankton species identification, enumeration, and biomass (mg/m^3) determined in surface water sample (at 0.10 m depth)	a) mid Aug.-late Sep., 2000 (2 sample times); late May-late Sep., 2001 (4 sample times); March, 2001 (1 sample time)	a) mid Aug.-late Sep., 2000 (2); late May-late Sep., 2001 (2); March, 2001 (1)	a) 1 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
Attached Algae and Rooted Aquatic Plants	To provide a description of attached algae and rooted aquatic plants in terms of relative abundance, composition, and distribution within study area waterbodies.	a) video recorder, 35 mm camera, and aquatic habitat survey equipment	a) aerial video-taping surveys to better delineate aquatic plant distribution, and recording and mapping all aquatic plant occurrences as they were observed during the course of aquatic habitat and fisheries surveys	a) aerial video-taping conducted 24 and 27 Aug., and 17 Sep., 2001; aquatic habitat surveys conducted Aug., 2000; fisheries surveys conducted 2000, 2001, and 2002	a) -	a) -	a) North/South Consultants Inc. unpublished data; Volume 5, Section 6.0; Volume 5, Section 7.0; Volume 5, Section 8.0
Zooplankton	To provide a semi-quantitative description of the zooplankton community in terms of abundance, composition, and distribution within study area waterbodies.	a) 63 µm mesh, 0.25 m diameter, conical net	a) zooplankton species identification and enumeration (individuals/m^3) determined in depth-integrated water sample	a) mid Aug.-late Sep., 2000 (2 sample times); late May-late Sep., 2001 (4 sample times)	a) mid Aug.-late Sep., 2000 (2); late May-late Sep., 2001 (2)	a) 1 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0

Table A7-4. (continued)

Study	Objectives	Primary Equipment	Method	Time Period	No. of Sites	No. of Replicates	References
Benthic Invertebrates	To provide a replicable habitat-based quantitative description of benthic invertebrate community abundance, composition, and distribution within study area waterbodies.	a) Ekman dredge (0.023 m^2 opening)	a) benthic invertebrate identification and enumeration (individuals/m^2) determined in the lacustrine hard silt/clay- and soft silt/clay-based, and flooded terrestrial substrate classes	a) late Sep. 2000 and 2001	a) late Sep. 2000 (12) and 2001 (11)	a) 4 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0

Table A7-5. Summary of approach and methodology used for lower trophic levels studies conducted for the Generation Project EIS at Stream Crossings.

Study	Objectives	Equipment	Method	Time Period	No. of Sites	No. of Replicates	Reference
Phytoplankton	To provide a semi-quantitative description of the phytoplankton community in terms of abundance, composition, and distribution within study area waterbodies.	a) laboratory supplied bottle	a) chlorophyll *a* (µg/L) determined in surface water sample (at 0.10 m depth)	a) mid Jun., 2002 (1 sample time)	a) 1 per crossing	a) 1 per site	a) North/South Consultants Inc. unpublished data; Volume 5, Section 7.0
Attached Algae and Rooted Aquatic Plants	To provide a description of attached algae and rooted aquatic plants in terms of relative abundance, composition, and distribution within study area waterbodies.	a) video recorder, 35 mm camera, and aquatic habitat survey equipment	a) aerial video-taping surveys to better delineate aquatic plant distribution, and recording and mapping all aquatic plant occurrences as they were observed during the course of aquatic habitat and fisheries surveys	a) aerial video-taping conducted 24 and 27 Aug., and 17 Sep., 2001; aquatic habitat surveys conducted Sep., 2001 and Jun., 2002; fisheries surveys conducted 2001 and 2002	a) -	a) -	a) North/South Consultants Inc. unpublished data; Volume 5, Section 6.0; Volume 5, Section 7.0; Volume 5, Section 8.0
Zooplankton	Data were not collected at the stream crossings.						
Benthic Invertebrates	Data were not collected at the stream crossings.						

APPENDIX 8. BENTHIC INVERTEBRATE TAXA

Table A8-1. Benthic invertebrate taxa identified in reaches 1, 2, and 3, 2001.

Phylum Cnidaria		
Class Hydrozoa		
		Hydra spp.
Phylum Platyhelminthes		
Class Turbellaria		
Order Tricladida		
	Family Planariidae	
Phylum Nematoda		
Phylum Annelida		
Class Clitellata		
Subclass Oligochaeta		
	Family Lumbriculidae	
	Family Naididae	
	Family Tubificidae	
Subclass Hirudinea		
	Family Glossiphoniidae	
		Glossophonia complanata (Linnaeus)
		Helobdella spp.
		Placobdella spp.
	Family Erpobdellidae	
		Mooreobdella spp.
Phylum Mollusca		
Class Gastropoda		
Subclass Pulmonata		
	Family Ancylidae	
	Family Lymnaeidae	
		Fossaria spp.
	Family Physidae	
		Physa jennessi skinneri Taylor
	Family Planorbidae	
		Helisoma trivolvis subcrenatum (Carpenter)
Subclass Prosobranchia		
	Family Hydrobiidae	
		Amnicola limosa (Say)
		Probythinella lacustris (Baker)
	Family Valvatidae	
		Valvata sincera sincera Say
		Valvata tricarinata (Say)
Class Bivalvia		
	Family Unionidae	
		Anodonta grandis Say
		Lampsilis radiata siliquoidea (Barnes)
	Family Sphaeriidae	
		Pisidium casertanum (Poli)
		Pisidium compressum Prime
		Pisidium lilljeborgi Clessin
		Sphaerium lacustre (Muller)
		Sphaerium simile (Say)
		Sphaerium striatinum (Lamarck)
		Sphaerium transversum (Say)
Phylum Arthropoda		
Class Arachnida		
Subclass Acari		
Suborder Hydracarina		

Table A8-1. (continued)

Phylum Arthropoda
Class Crustacea
Subclass Branchipoda
Order Conchostraca
Family Cyzicidae
Caenestheriella setosa (Pearse)
Subclass Ostracoda
Subclass Malacostraca
Superorder Pericarida
Order Amphipoda
Diporeia brevicornis (Serg.)
Hyalella azteca (Saussure)
Gammarus lacustris Sars
Class Insecta
Order Ephemeroptera
Family Baetidae
Callibaetis spp.
Family Baetiscidae
Baetisca obesa (Say)
Family Caenidae
Caenis amica Hagen
Caenis latipennis Banks
Family Ephemeridae
Ephemera simulans Walker
Hexagenia limbata Serville
Hexagenia rigida McDunnough
Family Heptageniidae
Heptagenia flavascens (Walsh)
Stenacron interpunctatum (Say)
Stenonema integrum (McDunnough)
Stenonema tripunctatum (Banks)
Family Leptophlebiidae
Leptophlebia spp.
Order Odonata
Suborder Anisoptera
Family Aeshnidae
Aeshna spp.
Family Gomphidae
Ophiogomphus spp.
Suborder Zygoptera
Family Lestidae
Lestes spp.
Order Plecoptera
Family Chloroperlidae
Haploperla brevis (Banks)
Family Perlodidae
Isoperla transmarina (Newman)
Order Hemiptera
Family Corixidae
Hesperocorixa spp.
Order Megaloptera
Family Sialidae
Sialis spp.

Table A8-1. (continued)

Phylum Arthropoda
- Class Insecta
  - Order Trichoptera
    - Family Hydropsychidae
      - *Cheumatopsyche* spp.
      - *Hydropsyche alternans* (Walker) **NOTE:** synonomy with *H. recurvata* Banks
      - *Hydropsyche slossonae* Banks
      - *Potamyia flava* (Hagen)
    - Family Lepidostomatidae
      - *Lepidostoma* spp.
    - Family Leptoceridae
      - *Ceraclea* spp.
      - *Mystacides* spp.
      - *Oecetis* spp.
      - *Trianodes* spp.
    - Family Limnephilidae
      - *Hydatophylax argus* Harris
      - *Limnephilus* spp.
    - Family Molannidae
      - *Molanna flavicornis* Banks
      - *Molannodes tinctus* Zetterstedt
    - Family Phryganeidae
      - *Agrypnia* spp.
      - *Phryganea* spp.
      - *Ptilostomis* spp.
    - Family Polycentropodidae
      - *Neureclipsis* spp.
      - *Phylocentropus placidus* (Banks)
      - *Polycentropus* spp.
  - Order Coleoptera
    - Family Elmidae
  - Order Diptera
    - Suborder Nematocera
      - Family Ceratopogonidae
        - *Bezzia* spp.
      - Family Chaoboridae
        - *Chaoborus* spp.
      - Family Chironomidae
      - Subfamily Chironominae
      - Subfamily Orthocladiinae
      - Subfamily Tanypodinae
    - Suborder Brachycera
      - Division Orthorrhapha
        - Family Empididae
        - Family Tabanidae
          - *Tabanus* spp.
      - Division Cyclorrhapha
        - Family Anthomyiidae
        - Family Sciomyzidae

APPENDIX 9 APPROACH AND METHODOLOGY USED FOR FISH COMMUNITY AND MOVEMENT STUDIES

TableA9-1. Summary of approach and methodology used for fish community and movement studies.

Study Name	Study Objectives	Method	Equipment	Location	Period of time	Number of Sites
Habitat-Based Fish Community Assessment	To provide a replicable habitat-based description of the fish community of study area water bodies	Standard gang index gillnetting	6 – 22.8m (25yd) panels of 38, 51, 76, 95, 108, and 127mm stretched twisted nylon mesh	Reach 1 Reach 2 Reach 3 Reach 4	1998 – 2002 2001 and 2002 2001 and 2002 2000 - 2002	82 4 6 18
Spring-Spawning Habitat	To identify habitat used for spawning by walleye and northern pike	a) Drift traps b) Gillnetting	a) 10 cm X 10 cm opening with 500 :m mesh collecting net b) 3 –22.8m panels of 95, 108, and 127mm stretched nylon mesh	Reach 1 Reach 2 Reach 3 Reach 4	May – July 1999 – 2002 June – July 2002 June – July 2002 June – July 2002	1 a) 6 b) 48 2a) 4 b) 27 3a) 9 b) 19 4a) 0 b) 18
Fall-Spawning Habitat	To identify habitat used for spawning by lake cisco and lake whitefish	a) Neuston sampler b) Drift traps c) Radio-telemetry d) Gillnetting	a) see Mota et al 1999 b) see above c) see Section 8.2.3 d) 3 –22.8m panels of 95, 108, and 127mm stretched nylon mesh	Reach 1 Reach 2 Reach 3 Reach 4	May – July1999 – 2002; Sept – Oct 1999 - 2001	1a) 121 b) 6 c) 28 d) 32 2a) 0 b) 4 c) 0 d) 0 3a) 7 b) 8 c) 0 d) 0 4a) 26 b) 0 c) 0 d) 0
Overwintering Habitat	To identify habitat used for overwintering by fish	Gillnetting	3 – 22.8m panels of 38, 95, 108, and 127mm stretched nylon mesh	Reach 1 Reach 2 Reach 3 Reach 4	March 2002 Not possible March 2002 March 2002	4 0 3 1
Tributary Streams	To assess fish use of streams flowing into Reach 3 and streams crossed by the Mile 17 Access Road	a) Gillnetting b)Electrofishing c) Drift-traps	a) 3 – 22.8m panels of 95, 108, and 127mm stretched nylon mesh b) Smith Root backpack unit Model 15-C POW c) as described above	Reach 3 Reach 5	June – July 2002	3a) 19 b) 17 c) 9 5a) 0 b) 7 c) 0
Fish Movements	To assess general movement patterns of VEC fish species	a) Radio-tags; b) Floy-tags	a) as described above b) An individually numbered spaghetti tag attached between the dorsal fin membranes of a fish .	Reach 1 Reach 2 Reach 3 Reach 4	1. a) Sept 99 –March 00; Sept 00 – Dec 01 2., 3, & 4 – no radio tagging program b) May 99- July 2002	1a) 34 b) 937 2a) 0 b) 57 3a) 0 b) 3 4a) 0 b) 3

APPENDIX 10 MERISTIC AND MORPHOLOGIC ANALYSIS OF LAKE CISCO FROM WUSKWATIM LAKE TO DETERMINE THE PRESENCE/ABSENCE OF SHORTJAW CISCO.

Table A10-1. Meristic and morphological data from lake cisco captured at Wuskwatim Lake.

Date	Species	Fish #	Length	Weight	UGR	LGR	TGR	DRC	ARC	PCRC	PLRC
June 10/02	LKCS	1	397	1246	16	32	48	10	13	16	11
June 10/02	LKCS	2	392	1121	17	30	47	10	13	15	10
June 10/02	LKCS	3	397	1304	17	33	50	11	12	17	11
June 10/02	LKCS	4	252	286	16	30	46	11	12	16	12
June 10/02	LKCS	5	226	180	16	31	47	11	13	16	10
June 10/02	LKCS	6	218	139	16	29	45	10	12	16	10
June 10/02	LKCS	7	160	46	-	-	-	11	12	16	11
June 15/02	LKCS	8	342	755	16	30	46	11	13	15	11
June 15/02	LKCS	9	379	890	15	30	45	10	12	16	11
June 15/02	LKCS	10	336	625	17	30	47	11	12	17	11
June 15/02	LKCS	11	350	800	18	31	49	10	12	16	11
June 15/02	LKCS	12	347	909	15	32	47	11	13	16	11
June 15/02	LKCS	13	341	684	16	31	47	11	12	15	10
June 15/02	LKCS	14	274	270	16	32	48	11	12	15	11
June 15/02	LKCS	15	184	84	15	27	42	11	13	14	10
June 15/02	LKCS	16	179	72	15	27	42	10	12	14	11
June 15/02	LKCS	17	147	42	15	27	42	10	12	15	11
June 15/02	LKCS	18	136	28	16	29	45	11	13	16	10
June 17/02	LKCS	19	271	347	17	31	48	11	13	17	11
June 17/02	LKCS	20	208	145	16	31	47	10	12	15	11
June 17/02	LKCS	21	216	137	16	30	46	11	12	15	11
June 17/02	LKCS	22	173	68	15	29	43	11	13	17	11
June 17/02	LKCS	23	196	97	15	29	43	10	13	16	11
June 14/02	LKCS	24	354	834	17	29	10	13	13	16	11
June 14/02	LKCS	25	373	964	17	31	11	12	12	15	11
June 14/02	LKCS	26	324	589	16	30	10	13	13	15	10
June 14/02	LKCS	27	324	561	17	31	11	12	12	17	11
June 14/02	LKCS	28	332	669	16	30	10	12	12	15	11
June 14/02	LKCS	29	343	657	15	31	11	12	12	17	10
June 14/02	LKCS	30	291	397	16	30	10	13	13	16	11
June 14/02	LKCS	31	332	757	16	29	10	12	12	15	10
June 14/02	LKCS	32	379	995	16	31	10	11	11	14	10
June 14/02	LKCS	33	347	666	17	30	11	11	11	14	11
June 14/02	LKCS	34	292	427	17	32	11	12	12	17	11
June 14/02	LKCS	35	417	1126	17	31	11	13	13	15	2
June 14/02	LKCS	36	355	786	16	32	10	12	12	16	11
June 14/02	LKCS	37	148	40	16	30	10	12	12	15	11
June 14/02	LKCS	38	184	85	14	28	11	13	13	16	10
June 14/02	LKCS	39	178	81	15	29	10	12	12	15	11
June 14/02	LKCS	40	188	85	16	29	10	13	13	15	10
June 14/02	LKCS	41	127	27	15	29	11	12	12	15	10
June 14/02	LKCS	42	318	561	16	30	46	11	12	15	11
June 14/02	LKCS	43	375	905	17	30	47	12	12	15	11
June 14/02	LKCS	44	411	1148	17	31	48	10	12	15	11
June 14/02	LKCS	45	392	813	17	31	48	10	12	15	11
June 14/02	LKCS	46	298	444	16	31	47	11	13	16	10
June 14/02	LKCS	47	386	981	16	30	46	11	13	15	11
June 14/02	LKCS	48	299	476	15	30	45	10	12	15	10
June 14/02	LKCS	49	274	357	15	29	44	12	13	16	11
June 14/02	LKCS	50	293	415	18	31	49	11	12	15	10
June 14/02	LKCS	51	393	1106	17	30	47	10	12	15	10
June 14/02	LKCS	52	389	1046	17	32	49	12	13	16	11
June 14/02	LKCS	53	279	366	16	30	46	10	12	15	11
June 14/02	LKCS	54	227	180	17	31	47	12	13	17	11
June 14/02	LKCS	55	174	74	15	28	43	10	12	15	10
June 14/02	LKCS	56	159	52	15	28	43	11	13	16	10

UGR - Upper Gill Raker Count *LGR - Lower Gill Raker Count* *TGR - Total Gill Raker Count*
DRC - Dorsal Ray Count *ARC - Anal Ray Count* *PCRC - Pectoral Ray Count*
PLRC - Pelvic Ray Count

APPENDIX 11. CLASSIFICATION AND QUANTIFICATION OF WATER VELOCITY IN REACHES 2 AND 3 AND ITS EFFECT ON FISH SWIMMING CAPABILITIES.

Aquatic habitat in the Burntwood River between Wuskwatim Falls and Taskinigup Falls (Reach 2) and between Taskinigup Falls and Opegano Lake (Reach 3) was classified and quantified using the following categories: water level (defined by elevation [intermittently exposed or wetted]); subsystem (backwater inlets or mainstem); substrata type; presence/absence of rooted submergent aquatic plants; and water velocity (Section 6.2). The following presents the methodology and rationale used to classify and quantify water velocity in reaches 2 and 3.

Modelling and Mapping Water Velocity

Water velocity in portions of reaches 2 and 3 where data could be collected safely was measured during September 2001 by Manitoba Hydro (Volume 4). Two hydraulic models were selected to estimate pre- and post-Project water velocity distributions in the Burntwood River between Wuskwatim Falls and Opegano Lake. Flow-3D was used for Reach 2 and River 2D was used for Reach 3 (Volume 4).

Velocity point data from the models was received from Manitoba Hydro. Where data were collected, horizontal velocity grids were interpolated from the point data and plotted for each reach. Each grid was divided into cells that contain values for water velocity, with each cell representing an area of 6.25 m^2 (2.5 m spacing) in Reach 3 and 1 m^2 (1 m spacing) in Reach 2. In the case of Reach 3, each cell value represents the average velocity for the water column of that cell, or the depth-averaged velocity. In Reach 2, each cell value represents a location on a horizontal velocity grid at one elevation: 226.6 m ASL for pre-Project conditions and 233.5 m ASL for post-Project conditions. These two elevations approximate surface water velocities. Though three horizontal velocity grids were plotted at elevations of 225.5, 226.5, and 232.5 m ASL (Figure A11-1) for pre-Project, only the 226.5 m ASL was used for quantification of water velocity.

Figure A11-1 illustrates the velocity grid and the values for each cell. For Reach 3, the water surface value at the top of the blue water column represents the average velocity within that column (depth-averaged velocity). For Reach 2, the values within the blue column represent the velocity of the column at that elevation.

Fish Swimming Performance

In order to take the velocity data generated from the models and classify it into groupings relevant to fish use, it was necessary to obtain information on fish swimming performance. Fish swimming performance is generally described using three basic modes: sustained; prolonged; and burst. Sustained swimming is used to achieve

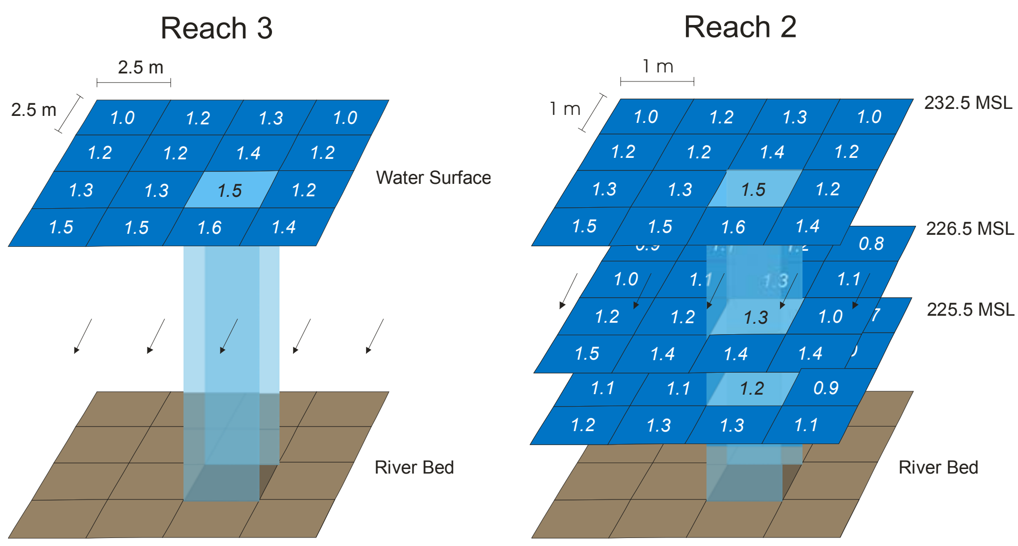


Figure A11-1. Example of horizontal water velocity grids for reaches 2 and 3

relatively slow speeds for long time periods and is generated by aerobic metabolism (Beamish 1978). Burst swimming produces fairly high speeds for short time periods and is fuelled by energy from anaerobic processes (Beamish 1978). Prolonged swimming uses both aerobic and anaerobic energy sources to produce speeds intermediate between sustained and burst (Peake et al. 2000). Critical swimming velocity ($Ucrit_x$) has been defined as the maximum velocity a fish can swim against for time x (in minutes). $Ucrit_{60}$ is defined as the highest swimming speed that a fish can maintain indefinitely, or its maximum sustained speed (Beamish 1978).

Critical swimming velocity has been used to infer the ability of fish to swim against velocity in sustained, prolonged or burst modes of swimming. The ability of a fish to maintain position or traverse areas of a river is dependent on several physical and biological factors, including water velocity, mode of swimming (e.g., subcarangiform vs. anguliform), water temperature, and fish length (Katopodis 1993). Studies on Ucrit by Katopodis (1993) demonstrate that for temperate fishes Ucrit can vary among fish species (Table A11-1).

Classification of the swimming modes of fish is based on the nature of body movements. Fishes found in the study area represent approximate angulliform and subcarangiform swimming modes (Lindsey 1978). Angulliform swimming represents undulatory locomotion where the whole length of the body flexes into lateral waves. In comparison, other fishes, like the subcarangiform, are stronger swimmers as they swim by moving mostly the caudal fin and the posterior half of the body.

Table A11-1. Mean Ucrit values for select species found in the study area (except least cisco) derived using all length classes from a fish swimming performance database provided by C. Katopodis, DFO, 2002.

Common Name	Scientific Name	Ucrit mean (m/s)	Standard Deviation	Max	Min	n
Whitefish	Coregonus clupeaformis	0.545	0.173	0.905	0.151	166
Least cisco	Coregonus autumnalis	0.600	0.000	0.600	0.600	1
Longnose sucker	Catostomus catostomus	0.568	0.212	1.081	0.150	150
Walleye	Stizostedion vitreum	0.559	0.214	0.912	0.138	54
White sucker	Catostomus commersoni	0.553	0.126	0.800	0.326	20
Yellow perch	Perca flavescens	0.434	0.055	0.537	0.313	115
Burbot*	Lota lota	0.396	0.081	0.525	0.201	52
Northern pike*	Esox lucius	0.382	0.150	0.773	0.105	187

subcarangiform except *

Subcarangiform

Most average Ucrit values for subcarangiform fish species in the DFO database (all length classes pooled) with satisfactory sample sizes are similar, and have Ucrit values of about 0.55 m/s. Burst, prolonged, and sustained swimming speeds for fish using subcarangiform swimming mode are presented in Figure A11-2.

Anguilliform

In laboratory conditions, the anguilliform swimmers listed in Table A11-1 demonstrate a lower aerobic metabolic scope when compared to subcarangiform fishes, and thus are expected to tire more readily. While listed as an angulliform swimmer by DFO, northern pike are not always considered to represent well the undulatory angulliform swimming mode like that exhibited by eels (Webb 1998). Due to their lie-and-wait method of predation, northern pike tend to either move little or, as shown in Figure A11-3 below, swim slowly or rapidly. Critical swimming velocity for angulliform fish is lower than that of subcarangiform fish (Table A11-1). Burst/prolonged and sustained swimming speeds for fish using anguilliform swimming mode are presented in Figure A11-3.

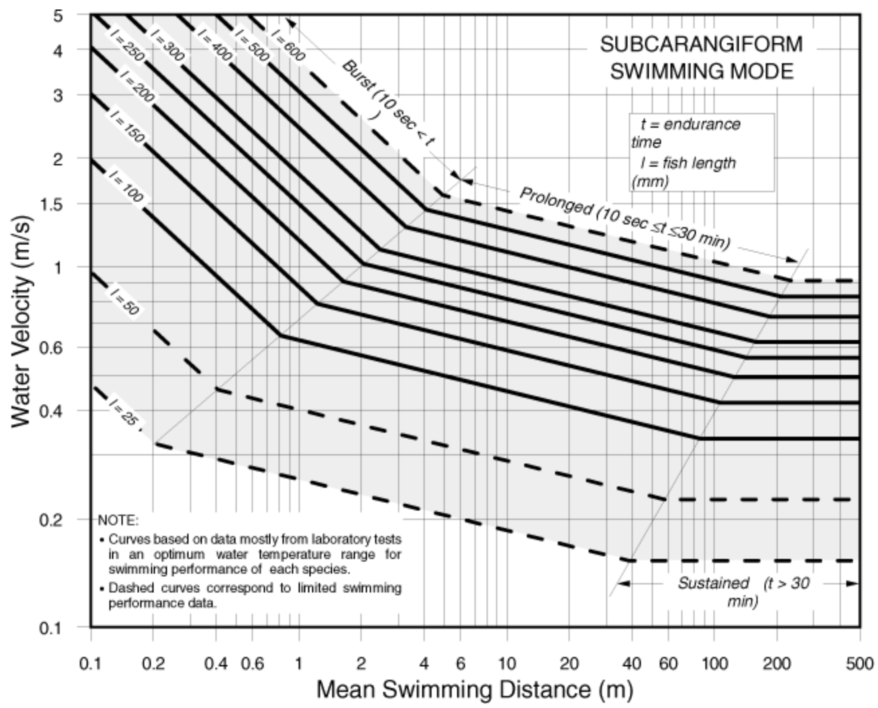


Figure A11-2. Sustained, prolonged, and burst swimming for fish utilizing sub-carangiform locomotion (after Katopodis 1993).

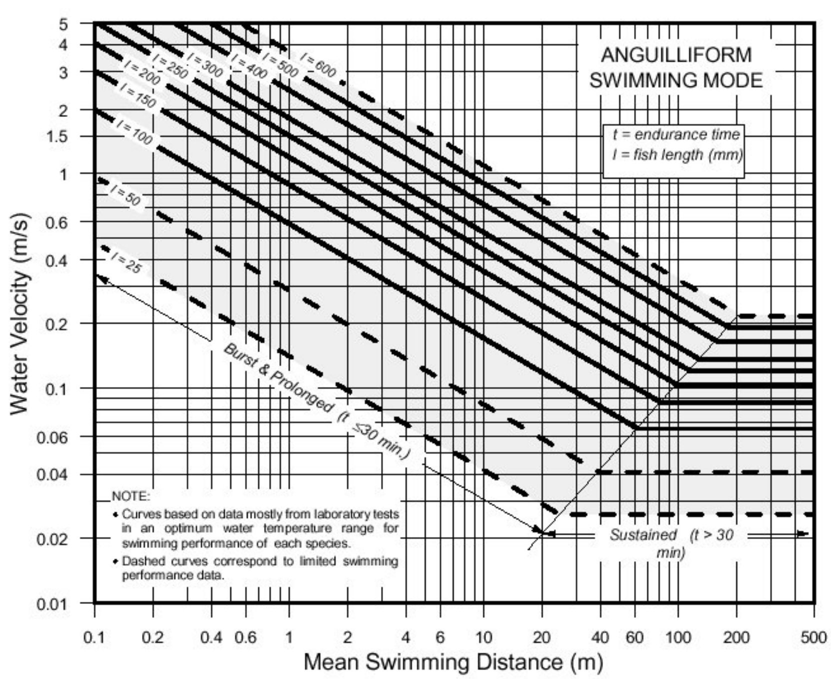


Figure A11-3. Angulliform swimming mode water velocities equating to sustained, prolonged, and burst swimming (after Katopodis 1993).

Classification of Water Velocity

Based on the modelled water velocities and the material presented in Table A11-1 and figures A11-2 and A11-3, water velocity was classified into the following three groupings.

Low (0 – 0.5 m/s)

Sub-carangiform - all fish greater than 200 mm in length can use sustained swimming. Sub-carangiform fish 200 and 500 mm in length would shift from sustained to prolonged swimming at water velocities of 0.5 and 0.8 m/s, respectively.

Anguilliform – 200 and 500 mm long northern pike will shift from sustained to prolonged/burst swimming at water velocities of 0.1 and 0.2 m/s, respectively.

Medium (0.5 – 1.5 m/s)

Sub-carangiform – 200 and 500 mm long sub-carangiform fish will shift from prolonged to burst speed at velocities of 0.9 and 1.5 m/s, respectively.

Anguilliform – as water velocities increase from 0.5 to 1.5 m/s, northern pike would shift to more use of burst swimming as opposed to prolonged swimming, and the distance they could swim would decrease.

High (>1.5 m/s)

Sub-carangiform – at water velocities greater than 1.5 m/s, sub-carangiform fish of all lengths would employ burst swimming. Endurance would be limited to ten seconds or less and 200 and 500 mm long fish would be restricted to distances of approximately 0.7 and 4.0 m/s.

Anguilliform – at water velocities greater than 1.5 m/s, northern pike of all lengths would employ burst swimming. As with sub-carangiform fish, endurance would be limited to ten seconds or less and 200 and 500 mm long fish would be restricted to distances of approximately 0.7 and 4.0 m/s.

Quantification of Areas of Low, Medium, and High Water Velocity

Pre-Project

Aquatic habitat was classified into low, medium, and high water velocity for reaches 2 and 3 under 95 percentile flows. The velocities were taken at 226.5 m ASL for reach 2; for reach 3 velocities were depth-averaged (Figure A11-1). Areas were calculated by multiplying the number of cells in a category by the cell size (1 m² for Reach 2, 6.25 m² for Reach 3). The cells were then grouped by category and plotted. In Reach 3, the velocity values were mapped as a gradient of cell values but were quantified as low, medium, or high.

Post-Project

Aquatic habitat was classified into low, medium, and high water velocity under 1, 2, and 3 units best-gate and 3 units full-gate flow conditions. For Reach 2, 3 units best-gate data was unavailable. The velocities were taken at 233.5 m ASL for reach 2; for reach 3 velocities were depth-averaged (Figure A11-1). Areas were calculated as for pre-Project conditions.

APPENDIX 12 INFORMATION ON POTENTIAL VEC FISH SPECIES SPAWNING LOCATIONS.

Table A12-1. Information on potential walleye spawning areas.

Red polygons indicate walleye spawning areas (i.e., large numbers of ripe and running male and female walleye and/or the presence of larval walleye in small tributaries). Yellow polygons represent areas where evidence suggests that walleye may spawn (i.e., the presence of sexually mature adult walleye and/or the presence of larval walleye) and the presence of suitable spawning habitat (Section 8.3.2.1).

Four areas have been identified as walleye spawning habitat and eleven areas have been identified as potential spawning habitat (Figure 8-9).

1 This area has gravel to boulder-sized rocks, which are preferred walleye spawning habitat (McPhail and Lindsey 1970, Scott and Crossman 1998). However, this reach of the Burntwood River is deep, with moderate to high water velocities and spawning would, therefore, be confined to the shorelines, particularly the south shore.

2 This reach of the Muskeseu River has suitable substrate and velocities to support spawning walleye. Sexually mature walleye were captured in ripe condition but larvae were not observed.

3 This reach of the Muskeseu River has suitable habitat and sexually mature walleye have been captured in near running condition. Larvae were not captured.

4 This area contains several islands and reefs. The substrate is hardpan with gravel to boulder-sized rock. Current from Wuskwatim Brook flows through the islands creating wave action that would aerate maturing eggs. Large numbers of sexually mature walleye were captured. Larvae were not captured.

5 Large numbers of ripe and running walleye were captured in this area.

6 Large numbers of ripe and running walleye were captured in this area.

7 Large numbers of ripe and running walleye (as well as larvae) were captured in this area. Traditional Knowledge indicates that walleye have been spawning here for many generations. TK also indicates that pre-CRD walleye were also spawning upstream of the first set of rapids. However, during EIA field studies, neither larvae or ripe and running walleye were collected upstream of the first set of rapids.

8 This long section of shoreline consists of a 2 m to 4 m wide band of gravel to boulder-sized rock. A small number of eggs and larvae were captured at the downstream end of this band as well as in area # 9. Post-spawn walleye have been captured along this stretch.

9 Much of the reach between Wuskwatim Falls and Taskinigup Falls contains water velocities that are greater than those suitable for walleye spawning. However, large numbers of larval walleye were captured downstream of Wuskwatim Falls as compared to upstream of Wuskwatim Falls. One male walleye in ripe and running condition was captured in the area.

10 Although velocities probably exceed those suitable for walleye spawning, a small number of larvae were captured at this location. It is unknown whether these larvae hatched at this site, or originated from Wuskwatim Lake or Reach 2 and drifted downstream.

11 Water velocities are slower than at polygons 9 and 10, but may still be above those suitable for walleye spawning. Moderate numbers (relative to polygon 9) of larval walleye were captured at this site.

12 This area contains suitable spawning habitat (riffles and gravel to boulder-sized rock substrate) approximately one kilometre upstream of the mouth. During spring 2002, ripe and running walleye were captured at this site and one larvae was captured in a drift trap set in the tributary.

13 Sexually mature walleye were captured in this area but larva were not captured. The substrate consists mainly of soft mud and flooded forest, which has been identified as useable walleye spawning habitat (T. Smith, Manitoba Conservation, pers. comm.).

14 Sexually mature walleye were captured in the area but larvae were not captured. The substrate is similar to that observed in Backwater Inlet 9.

15 This area contains suitable spawning substrate (gravel and rock) and larval walleye were captured in this area.

Table A12-2. Information on potential lake whitefish spawning areas.

Red polygons indicate lake whitefish spawning areas (i.e., large numbers of ripe and running male and female lake whitefish and/or the presence of larval lake whitefish immediately following ice-out). Yellow polygons represent areas where evidence suggests that lake whitefish may spawn (i.e., the presence of sexually mature adult lake whitefish and/or the presence of larval lake whitefish) and the presence of suitable spawning habitat (Section 8.3.3.1).

Eight areas were identified as spawning habitat and eleven areas were identified as potential spawning habitat (Figure 8-16).

1 This was a spawning area pre-CRD and large runs of spawning lake whitefish had been observed (TK from NCN commercial fishers). This area has gravel to boulder-

sized rocks which provide suitable spawning substrate for lake whitefish (Lawrence and Davies 1978, Fudge and Bodaly 1984, Anras et al. 1999). However, this reach of the Burntwood River is deep and contains moderate to high velocities. Spawning, therefore, would likely be confined to lower velocity habitat along the shorelines, particularly the south shore.

2 Larval lake whitefish were captured just after ice-out in 1999, 2000, and 2001. Habitat associated with this spot is not typical spawning habitat, but since CRD lake whitefish may have changed their spawning behaviour from actively seeking shallow riverine, gravel bottom locations, to becoming broadcast spawners, dumping eggs in areas with less than optimal habitat but with enough wave action to aerate their eggs.

3 Same as #2 above.

4 Same as #2 above.

5 Larval lake whitefish were captured in the spring. The area provides suitable whitefish spawning habitat.

6 Same as #2 above.

7 Same as #2 above.

8 This area provides suitable spawning habitat (gravel to boulder-sized rock). Large numbers of adult lake whitefish were captured at this site during the fall.

9 This area (the entire west shoreline of Wuskwatim Lake) had the largest catches of larval lake whitefish in the study area. The majority of habitat along this shore consists of soft silt/clay material which is not typical lake whitefish spawning habitat. Numerous large reefs occur along this shoreline where lake cisco and lake whitefish are traditionally fished by commercial fishers. However, this area was not identified by TK as a spawning area for whitefish.

10 This area provides suitable spawning habitat (boulder-sized rock substrates). Sexually mature lake whitefish were captured here in the fall, suggesting that the reefs may be used for spawning.

11 Similar to # 9, this area also had large catches of larval lake whitefish. The area contains more bedrock and gravel substrates and may provide more typical spawning habitat than # 9.

12 This area has several islands and reefs and provides suitable spawning habitat (gravel to boulder-sized rock).

13 Large numbers of larval lake whitefish were captured at this site. Substrates are similar to those on the west shoreline (composed of soft silt/clay material).

14 This area provides suitable spawning habitat (gravel to boulder-sized rock). Larval lake whitefish were captured in the area.

15 This area contains a band of rock along the shoreline approximately 2 m to 4 m wide. Larval lake whitefish were captured in the area.

16 This area provides suitable spawning habitat. Larval lake whitefish were not captured at this site but were captured further downstream (Area 17).

17 This area provides suitable spawning habitat. Small numbers of larval lake whitefish were captured at this site.

18 This area provides some suitable spawning habitat (gravel to hardpan substrate). A small number of larval whitefish were captured but they may have drifted into the area from upstream spawning sites.

19 The west shoreline of Opegano Lake has numerous reefs overlaid by mud from slumping shorelines. A small number of larval lake whitefish were captured at this site.

Table A12-3. Information on potential lake cisco spawning areas.

Red polygons indicate lake cisco spawning areas (i.e., large numbers of ripe and running male and female lake cisco and/or the presence of larval lake cisco immediately following ice-out). Yellow polygons represent areas where evidence suggests that lake cisco may spawn (i.e., the presence of sexually mature adult lake cisco and/or the presence of larval lake cisco) and the presence of suitable spawning habitat (Section 8.3.4.1).

Thirteen areas have been identified as spawning habitat and twelve areas have been identified as potential spawning habitat (Figure 8-25).

1 This area provides spawning (gravel to boulder-sized rocks). However, this reach of the Burntwood River is deep and contains moderate to high water velocities. Spawning, therefore, would likely be confined to the shorelines, particularly the south shore.

2 Larval lake cisco were captured in this area in the early springs of 1999, 2000, and 2001. Habitat is not typical spawning habitat (soft silt/clay substrate).

3 Same as #2 above.

4 Same as #2 above.

5 Larval lake cisco were captured in this area during spring. The area contains some spawning habitat.

6 Same as #2 above.

7 Same as #2 above.

8 Same as #5 above.

9 Same as #2 above.

10 This area provides spawning habitat (gravel to boulder-sized rock). Large numbers of adult lake cisco have been captured at this site during the fall.

11 This area (the entire west shoreline of Wuskwatim Lake) had the largest catches of larval lake cisco in the study area. The majority of the habitat along this shore is composed of soft silt/clay material, which is not typical lake cisco spawning habitat. There are numerous large reefs along the shoreline where lake cisco and lake whitefish are traditionally fished by commercial fishers. However, this area was not identified by TK as a spawning area for lake cisco.

12 This area provides spawning habitat (gravel to boulder-sized rock). Sexually mature lake cisco were captured here in the fall, suggesting that the reefs may be used for spawning.

13 Large numbers of larval lake cisco were captured in this area. The area provides suitable spawning habitat (bedrock and gravel substrates).

14 This area provides suitable spawning habitat (gravel to boulder-sized rock).

15 Large numbers of larval lake cisco were captured in this area. Substrates are similar to those on the west shoreline (soft silt/clay material).

16 This area provides suitable spawning habitat (gravel to boulder-sized rock). Larval lake cisco were captured in the area (the Burntwood River current flows directly through this area and the larvae may have come from upstream areas).

17 This area contains a band of rock along the shoreline approximately 2 m to 4 m wide. Larval lake cisco were captured in this area.

18 See explanation #17.

19 This area provides suitable spawning habitat. Larval lake cisco have not been captured at this site, however, they have been captured further downstream (Area 20).

20 Small numbers of larval lake cisco were captured in this area. The area has several substrate types including soft silt/clay, gravel, and boulder-sized rock.

21 The area provides suitable spawning habitat. A small number of larval cisco were captured in this area.

22 A small number of larval cisco were captured in this area. The west shoreline of Opegano Lake has numerous reefs overlaid by mud from slumping shorelines.

23 Same as #22 above.

24 Same as #22 above.

Table A12-4. Information on potential northern pike spawning areas.

Red polygons indicate northern pike spawning areas (i.e., large numbers of ripe and running male and female northern pike and/or the presence of larval northern pike in small tributaries). Yellow polygons represent areas where evidence suggests that northern pike may spawn (i.e., the presence of sexually mature adult northern pike and/or the presence of larval northern pike) and the presence of suitable spawning habitat (Section 8.3.5.1).

Six areas were identified as spawning habitat and twenty areas were identified as potential spawning habitat (Figure 8-31).

1 This area has a large section of flooded terrestrial habitat with depths, velocities, and rooted vascular plants suitable for northern pike spawning (Diana et al. 1977). This site is fed by a small tributary at the south end of the bay which also provides suitable spawning habitat.

2 This area has a large section of flooded terrestrial habitat with depths, velocities, and rooted vascular plants suitable for northern pike spawning (Diana et al. 1977).

3 Same as #2 above.

4 This area has a large section of flooded terrestrial habitat with depths, velocities, and rooted vascular plants suitable for northern pike spawning (Diana et al. 1977). A small tributary located at the northwest corner also provides suitable spawning habitat (abundant emergent vegetation).

5 Same as #2 above.

6 This area provides suitable spawning habitat (emergent vegetation).

7 Same as #6 above.

8 This area provides suitable spawning habitat (flooded terrestrial habitat, aquatic rooted vascular plants as well as shoreline bulrushes, cattails, and grasses).

9 This area provides suitable spawning habitat (flooded terrestrial habitat and aquatic rooted vascular plants). This area is fed by a small ephemeral tributary.

10 Same as # 9 above.

11 Same as # 9 above.

12 Same as #9 above.

13 This area provides spawning habitat. Several adult northern pike were captured in post-spawn condition.

14 Larval northern pike were captured immediately after hatch in spring 2002. This area has low velocities, aquatic rooted vascular plants, and depths suitable for northern pike spawning.

15 Same as #14 above.

16 Same as #14 above.

17-25 Sites 17 through 25 are backwater inlets on the Burntwood River downstream of Taskinigup Falls. All are suspected to be potential northern pike spawning areas. Larval northern pike were captured during the spring of 2002 at sites 17, 20, and 26.

26 This site provides suitable spawning habitat (abundant aquatic rooted vascular plants, shallow water, and some flow from a small tributary). Adult and larval northern pike were captured at this site.

APPENDIX 13 MEAN LENGTH, WEIGHT, AND CONDITION FACTOR FOR SPECIES CAPTURED DURING INDEX GILLNETTING STUDIES IN THE STUDY AREA, 1998 – 2002.

Table A13-1. Mean length, weight, and relative condition factor, by species, reach, and year, for fish captured in index gillnets, 1998 - 2002.

			Length (mm)				Weight (g)				Condition Factor (K)		
Species	Reach	Year	n	Mean	Std[1]	Range	n	Mean	Std[1]	Range	n	Mean	Range
Northern pike	1	1998	97	353	83	191 - 580	97	342	294	49 - 1550	97	0.65	0.32 - 1.51
	1	2000	42	396	79	252 - 535	42	447	271	102 - 1200	42	0.65	0.44 - 0.83
	1	2001	128	459	137	201 - 801	127	916	925	54 - 4750	127	0.72	0.41 - 1.45
	2	2001	16	353	113	249 - 665	16	430	557	104 - 2300	16	0.70	0.60 - 0.79
	2	2002	10	355	71	260 - 490	10	277	139	121 - 625	10	0.61	0.33 - 0.69
	3	2001	56	142	486	238 - 758	56	1081	967	78 - 3800	56	0.70	0.48 - 1.00
	3	2002	39	446	153	212 - 899	39	974	1356	64 - 5900	39	0.72	0.57 - 0.98
	4	2000	29	471	128	255 - 677	29	915	721	150 - 2400	29	0.71	0.46 - 1.34
	4	2001	29	497	155	249 - 800	29	-	1230	75 - 4725	29	0.66	0.49 - 0.92
Lake cisco	1	1998	301	312	85	124 - 442	301	608	406	18 - 1700	301	1.53	0.66 - 2.34
	1	2000	287	301	85	129 - 488	287	581	421	15 - 1850	284	1.60	0.56 - 2.47
	1	2001	234	345	79	131 - 461	232	805	427	18 - 1800	232	1.63	0.78 - 2.25
	2	2001	23	271	62	146 - 372	23	305	210	36 - 700	23	1.28	0.91 - 1.88
	2	2002	12	321	41	261 - 388	12	483	212	229 - 900	12	1.39	1.07 - 2.21
	3	2001	29	303	68	164 - 400	29	429	265	48 - 950	29	1.29	0.83 - 1.68
	3	2002	28	314	66	141 - 403	28	478	242	34 - 925	28	1.35	1.03 - 1.81
	4	2000	7	303	65	199 - 380	7	438	244	92 - 825	7	1.41	1.17 - 1.61
	4	2001	7	342	12	320 - 355	7	521	51	450 - 600	7	1.30	1.17 - 1.37
Lake whitefish	1	1998	78	361	93	135 - 495	78	934	541	22 - 2175	78	1.60	0.89 - 1.98
	1	2000	73	361	74	198 - 505	73	912	499	100 - 2400	73	1.72	1.27 - 2.10
	1	2001	80	405	64	152 - 571	80	1243	608	36 - 3650	80	1.72	1.03 - 2.21
	2	2001	3	322	26	300 - 350	3	529	133	413 - 675	3	1.56	1.53 - 1.58
	2	2002	-	-	-	0	-	-	-	0	-	-	-
	3	2001	14	401	31	314 - 437	13	1008	217	750 - 1450	13	1.48	1.18 - 1.92
	3	2002	24	412	30	347 - 476	24	1051	252	650 - 1675	24	1.48	1.19 - 1.81
	4	2000	27	400	36	316 - 502	27	994	295	425 - 1650	27	1.52	1.28 - 1.79
	4	2001	28	412	28	320 - 455	28	1092	234	500 - 1500	28	1.54	1.22 - 1.78
Longnose sucker	1	1998	20	361	62	234 - 462	20	724	381	175 - 1450	20	1.40	1.21 - 1.61
	1	2000	66	420	32	312 - 511	65	1130	237	500 - 1900	65	1.50	1.18 - 2.00
	1	2001	0	0	0	0	0	0	0	0	0	0	0
	2	2001	83	419	30	344 - 475	83	1102	247	600 - 1625	83	1.47	1.28 - 1.74
	2	2002	26	388	49	212 - 465	26	871	334	124 - 1650	26	1.44	1.13 - 1.64
	3	2001	19	382	37	302 - 430	19	732	228	275 - 1100	19	1.27	0.92 - 1.46
	3	2002	44	377	47	236 - 449	44	730	254	153 - 1325	44	1.30	1.12 - 1.97
	4	2000	5	429	62	360 - 502	5	1220	480	650 - 1800	5	1.48	1.39 - 1.61
	4	2001	2	446	57	405 - 486	2	1313	442	1000 - 1625	2	1.46	1.42 - 1.51

Table A13-1. Continued

			Length (mm)				Weight (g)				Condition Factor (K)		
Species	Reach	Year	n	Mean	Std[1]	Range	n	Mean	Std[1]	Range	n	Mean	Range
White sucker	1	1998	416	364	55	154 - 463	416	724	283	40 - 1400	416	1.40	0.96 - 1.98
	1	2000	472	368	54	210 - 480	471	770	318	122 - 1800	471	1.45	0.32 - 1.85
	1	2001	263	393	44	153 - 486	262	893	262	48 - 1700	262	1.42	0.97 - 2.06
	2	2001	2	399	37	372 - 425	2	1038	301	825 - 1250	2	1.62	1.60 - 1.63
	2	2002	1	410	-	-	1	1150	-	-	1	1.67	-
	3	2001	42	418	38	306 - 489	42	1167	297	400 - 1800	42	1.57	1.23 - 1.92
	3	2002	55	420	38	261 - 481	55	1152	303	225 - 1700	55	1.52	1.27 - 1.85
	4	2000	68	414	60	145 - 503	68	1149	365	41 - 1850	68	1.53	1.19 - 1.88
	4	2001	97	426	52	168 - 500	97	1243	386	50 - 2000	97	1.53	1.05 - 1.79
Shorthead redhorse	1	1998	0	-	-	-	0	-	-	-	0	-	-
	1	2000	0	-	-	-	0	-	-	-	0	-	-
	1	2001	1	233	-	-	1	168	-	-	1	1.33	-
	2	2001	0	-	-	-	0	-	-	-	0	-	-
	2	2002	0	-	-	-	0	-	-	-	0	-	-
	3	2001	9	415	20	382 - 446	9	1203	209	950 - 1475	9	1.68	1.45 - 1.99
	3	2002	13	387	73	277 - 455	13	1025	553	325 - 1800	13	1.59	1.17 - 1.94
	4	2000	7	376	77	223 - 442	7	925	432	200 - 1400	7	1.61	1.25 - 1.80
	4	2001	3	313	110	228 - 438	3	625	697	150 - 1425	3	1.47	1.27 - 1.70
Burbot	1	1998	9	462	121	182 - 592	9	688	393	42 - 1250	9	0.61	0.55 - 0.70
	1	2000	22	443	67	211 - 526	22	669	232	61 - 1100	22	0.73	0.57 - 0.94
	1	2001	6	554	38	510 - 611	6	950	228	700 - 1350	6	0.55	0.53 - 0.59
	2	2001	5	376	124	242 - 562	5	452	414	84 - 1125	5	0.67	0.59 - 0.81
	2	2002	2	285	1	284 - 286	2	158	16	146 - 169	2	0.68	0.62 0.74
	3	2001	3	429	14	420 - 446	3	417	29	400 - 450	3	0.53	0.45 - 0.60
	3	2002	4	360	60	294 - 428	4	335	195	157 - 550	4	0.65	0.52 - 0.76
	4	2000	-	-	-	0	-	-	-	0	0	-	-
	4	2001	-	-	-	0	-	-	-	0	0	-	-
Yellow perch	1	1998	62	259	26	168 - 304	62	312	94	60 - 500	62	1.74	1.27 - 2.25
	1	2000	104	259	32	160 - 330	103	334	105	30 - 497	103	1.83	0.73 - 2.20
	1	2001	154	239	44	124 - 333	154	257	133	26 - 600	154	1.67	1.03 - 2.62
	2	2001	1	251	-	-	1	300	-	-	1	1.90	-
	2	2002	2	246	1	245 - 247	2	266	3	264 - 268	2	1.79	1.78 - 1.80
	3	2001	4	216	51	168 - 287	4	179	151	75 - 400	4	1.52	1.16 - 1.69
	3	2002	4	240	45	177 - 282	4	257	134	79 - 400	4	1.67	1.42 - 1.79
	4	2000	9	189	52	126 - 267	9	142	122	31 - 350	9	1.65	1.26 - 1.87
	4	2001	15	183	37	134 - 248	15	98	69	25 - 225	15	1.35	0.91 - 1.85

Table A13-1. Continued

Species	Reach	Year	Length (mm) n	Length (mm) Mean	Length (mm) Std[1]	Length (mm) Range	Weight (g) n	Weight (g) Mean	Weight (g) Std[1]	Weight (g) Range	Condition Factor (K) n	Condition Factor (K) Mean	Condition Factor (K) Range
Sauger	1	1998	323	248	45	114 - 377	323	135	87	12 - 500	323	0.78	0.54 - 1.26
	1	2000	443	230	35	120 - 361	437	117	55	25 - 303	436	0.89	0.51 - 1.88
	1	2001	224	248	32	114 - 374	221	142	64	13 - 500	221	0.88	0.57 - 1.48
	2	2001	15	274	42	194 - 345	15	210	107	50 - 450	15	0.98	0.21 - 1.40
	2	2002	19	262	51	173 - 367	19	185	115	48 - 500	19	0.92	0.71 - 1.20
	3	2001	6	269	18	242 - 292	6	180	38	138 - 223	6	0.91	0.73 - 1.01
	3	2002	33	250	31	184 - 317	33	145	55	57 - 300	33	0.89	0.63 - 1.09
	4	2000	83	235	42	161 - 355	81	122	73	30 - 450	81	0.85	0.54 - 1.21
	4	2001	51	255	35	194 - 326	51	145	67	50 - 300	51	0.82	0.52 - 1.11
Walleye	1	1998	88	310	108	161 - 570	88	405	421	28 - 2050	88	0.89	0.54 - 1.17
	1	2000	106	268	83	151 - 488	106	269	277	25 - 1400	106	1.03	0.56 - 1.70
	1	2001	437	378	59	162 - 512	435	629	246	38 - 1450	435	1.09	0.64 - 1.76
	2	2001	77	361	51	247 - 512	77	596	270	197 - 1600	77	1.19	0.94 - 1.50
	2	2002	55	338	63	176 - 457	55	453	239	48 - 1225	55	1.06	0.88 - 1.32
	3	2001	99	374	83	161 - 601	99	646	463	36 - 3150	99	1.05	0.79 - 1.45
	3	2002	137	344	68	184 - 515	137	483	294	56 - 1700	137	1.05	0.83 - 1.35
	4	2000	47	313	123	171 - 599	47	490	575	37 - 2250	47	0.99	0.60 - 1.59
	4	2001	88	323	101	172 - 570	88	454	449	25 - 2100	88	0.96	0.44 - 1.28

Reach 1 - Wuskwatim Lake and adjacent water bodies
Reach 2 - Burntwood River between Wuskwatim and Taskinigup Falls
Reach 3 - Burntwood River between Taskinigup Falls and Opegano Lake
Reach 4 - Opegano Lake
[1] - Standard Deviation

APPENDIX 14 COMPARISON OF MEAN SIZE AND CONDITION FACTOR, BY HABITAT FOR THE FOUR VEC FISH SPECIES CAPTURED DURING INDEX GILLNETTING PROGRAMS IN THE STUDY AREA, 1998 – 2002.

Table A14-1. Comparison of mean size and condition factor, by habitat type, for walleye captured in index gillnets in the study area, 1998-2002.

Reach	Habitat Type	Length (mm) n	Mean	Std[1]	Range	Weight (g) n	Mean	Std[1]	Range	Condition Factor (K) n	Mean	Range
Wuskwatim Lake and adjacent waterbodies	OS-SC-NP[2]	77	259	94	151-508	77	243	293	25-1200	77	0.93	0.54-1.70
Wuskwatim Lake and adjacent waterbodies	NS-SC-NP[3]	390	351	77	155-570	389	529	292	25-2050	389	1.06	0.56-1.76
Wuskwatim Lake and adjacent waterbodies	NS-FT-RV[4]	15	401	20	366-436	15	740	100	600-1000	15	1.15	0.95-1.23
Wuskwatim Lake and adjacent waterbodies	NS-FT-NP[5]	149	388	63	175-538	148	689	287	49-1700	148	1.09	0.71-1.45
The Falls	W-M-Hc-NP-L[6]	33	347	59	234-457	33	511	284	127-1225	33	1.10	0.88-1.34
The Falls	W-M-Sc-NP-L[7]	99	352	57	176-512	99	545	261	48-1600	99	1.15	0.88-1.50
Burntwood d/s of Taskinigup	W-C-Sc-Sc-L[8]	161	356	74	161-601	161	553	402	36-3150	161	1.05	0.83-1.45
Burntwood d/s of Taskinigup	W-M-Sc-Sc-L[9]	75	357	81	184-513	75	548	339	56-1400	75	1.03	0.79-1.45
Opegano Lake	OS-SC-NP[2]	13	313	135	171-525	13	513	644	43-1775	13	0.95	0.71-1.23
Opegano Lake	NS-SC-NP[3]	92	302	104	172-599	92	390	477	25-2250	92	0.95	0.44-1.28
Opegano Lake	NS-FT-NP[5]	30	376	95	190-509	30	683	423	50-1500	30	1.05	0.73-1.59

[1] - standard deviation
[2] - offshore habitat with silt/clay-based substrate and no vegetation
[3] - nearshore habitat with silt/clay-based substrate and no vegetation
[4] - nearshore flooded terrestrial habitat and rooted vegetation
[5] - nearshore flooded terrestrial habitat and no vegetation
[6] - wetted mainstem hard silt/clay-based habitat with no plants and low water velocity
[7] - wetted mainstem soft silt/clay-based habitat with no plants and low water velocity
[8] - wetted backwater inlets with soft silt/clay-based substrate no plants and low water velocity
[9] - wetted mainstem habitat with lkow water velocity and substrates ranging from soft silt/clay to boulders

Table A14-2. Comparison of mean size and condition factor, by habitat type, for lake whitefish captured in index gillnets in the study area, 1998-2002.

Reach	Habitat Type	Length (mm)				Weight (g)				Condition Factor (K)		
		n	Mean	Std[1]	Range	n	Mean	Std[1]	Range	n	Mean	Range
Wuskwatim Lake and adjacent waterbodies	OS-SC-NP[2]	155	369	71	166-505	155	945	470	58-2175	155	1.68	1.10-2.15
Wuskwatim Lake and adjacent waterbodies	NS-SC-NP[3]	35	363	125	135-571	35	1113	863	22-3650	35	1.6	0.89-2.07
Wuskwatim Lake and adjacent waterbodies	NS-FT-RV[4]	18	439	35	374-525	18	1647	453	900-2600	18	1.9	1.52-2.21
Wuskwatim Lake and adjacent waterbodies	NS-FT-NP[5]	23	395	50	318-510	23	1038	423	500-2150	23	1.6	1.33-1.82
The Falls	W-M-Hc-NP-L[6]	0	0	0	0	0	0	0	0	0	0	0
The Falls	W-M-Sc-NP-L[7]	3	322	26	300-350	3	529	133	413-675	3	1.56	1.53-1.58
Burntwood d/s of Taskinigup	W-C-Sc-Sc-L[8]	29	414	26	347-476	28	1049	239	650-1675	28	1.47	1.18-1.81
Burntwood d/s of Taskinigup	W-M-Sc-Sc-L[9]	8	388	41	314-427	7	929	201	725-1300	7	1.46	1.19-1.67
Opegano Lake	OS-SC-NP[2]	7	402	15	373-421	7	957	114	775-1100	7	1.48	1.27-1.62
Opegano Lake	NS-SC-NP[3]	37	399	35	316-502	37	993	279	425-1650	37	1.52	1.22-1.79
Opegano Lake	NS-FT-NP[5]	11	431	18	395-455	11	1273	167	1000-1500	11	1.58	1.39-1.75

[1] - standard deviation
[2] - offshore habitat with silt/clay-based substrate and no vegetation
[3] - nearshore habitat with silt/clay-based substrate and no vegetation
[4] - nearshore flooded terrestrial habitat and rooted vegetation
[5] - nearshore flooded terrestrial habitat and no vegetation
[6] - wetted mainstem hard silt/clay-based habitat with no plants and low water velocity
[7] - wetted mainstem soft silt/clay-based habitat with no plants and low water velocity
[8] - wetted backwater inlets with soft silt/clay-based substrate no plants and low water velocity
[9] - wetted mainstem habitat with lkow water velocity and substrates ranging from soft silt/clay to boulders

Table A14-3. Comparison of mean size and condition factor, by habitat type, for lake cisco captured in index gillnets in the study area, 1998-2002.

Reach	Habitat Type	Length (mm) n	Mean	Std[1]	Range	Weight (g) n	Mean	Std[1]	Range	Condition Factor (K) n	Mean	Range
Wuskwatim Lake and adjacent waterbodies	OS-SC-NP[2]	172	298	94	124-476	172	548	435	18-1850	172	1.46	0.56-2.18
Wuskwatim Lake and adjacent waterbodies	NS-SC-NP[3]	517	309	83	129-488	515	603	404	15-1700	512	1.57	0.65-2.47
Wuskwatim Lake and adjacent waterbodies	NS-FT-RV[4]	14	379	69	154-434	14	1101	398	43-1600	14	1.83	1.18-2.25
Wuskwatim Lake and adjacent waterbodies	NS-FT-NP[5]	119	375	43	222-461	119	978	328	150-1800	119	1.76	1.11-2.25
The Falls	W-M-Hc-NP-L[6]	9	289	67	195-388	9	354	259	94-900	9	1.26	1.07-1.54
The Falls	W-M-Sc-NP-L[7]	26	288	59	146-372	26	370	217	36-725	26	1.34	0.91-2.21
Burntwood d/s of Taskinigup	W-C-Sc-Sc-L[8]	28	311	72	141-400	28	467	259	34-950	28	1.32	1.06-1.68
Burntwood d/s of Taskinigup	W-M-Sc-Sc-L[9]	16	274	60	194-357	16	307	217	66-700	16	1.23	0.83-1.54
Opegano Lake	OS-SC-NP[2]	1	320	-	-	1	450	-	-	1	1.37	-
Opegano Lake	NS-SC-NP[3]	11	314	52	199-355	11	440	157	92-600	11	1.34	1.17-1.61
Opegano Lake	NS-FT-NP[5]	2	368	18	355-380	2	713	159	600-825	2	1.42	1.34-1.50

[1] - standard deviation
[2] - offshore habitat with silt/clay-based substrate and no vegetation
[3] - nearshore habitat with silt/clay-based substrate and no vegetation
[4] - nearshore flooded terrestrial habitat and rooted vegetation
[5] - nearshore flooded terrestrial habitat and no vegetation
[6] - wetted mainstem hard silt/clay-based habitat with no plants and low water velocity
[7] - wetted mainstem soft silt/clay-based habitat with no plants and low water velocity
[8] - wetted backwater inlets with soft silt/clay-based substrate no plants and low water velocity
[9] - wetted mainstem habitat with lkow water velocity and substrates ranging from soft silt/clay to boulders

Table A14-4. Comparison of mean size and condition factor, by habitat type, for northern pike captured in index gillnets in the study area, 1998-2002.

Reach	Habitat Type	Length (mm)				Weight (g)				Condition Factor (K)		
		n	Mean	Std[1]	Range	n	Mean	Std[1]	Range	n	Mean	Range
Wuskwatim Lake and adjacent waterbodies	OS-SC-NP[2]	13	431	111	262-580	13	652	496	106-1550	13	0.64	0.54-0.79
Wuskwatim Lake and adjacent waterbodies	NS-SC-NP[3]	147	386	110	201-767	146	493	576	52-3725	146	0.66	0.32-1.37
Wuskwatim Lake and adjacent waterbodies	NS-FT-RV[4]	31	465	84	246-680	31	796	422	93-2200	49	0.73	0.60-1.45
Wuskwatim Lake and adjacent waterbodies	NS-FT-NP[5]	76	430	146	191-801	76	832	1006	49-4750	76	0.73	0.41-1.51
The Falls	W-M-Hc-NP-L[6]	10	368	84	260-493	10	340	255	121-950	10	0.61	0.33-0.79
The Falls	W-M-Sc-NP-L[7]	16	345	107	249-665	16	391	540	104-2300	16	0.69	0.60-0.78
Burntwood d/s of Taskinigup	W-C-Sc-Sc-L[8]	75	469	141	212-815	75	989	975	64-4800	75	0.71	0.48-1.00
Burntwood d/s of Taskinigup	W-M-Sc-Sc-L[9]	20	474	174	277-899	20	1215	1630	138-5900	20	0.71	0.57-0.98
Opegano Lake	OS-SC-NP[2]	0	0	0	0	0	0	0	0	0	0	0
Opegano Lake	NS-SC-NP[3]	40	454	121	249-740	40	796	721	75-2850	40	0.66	0.49-1.34
Opegano Lake	NS-FT-NP[5]	18	549	164	255-800	18	1596	1320	150-4725	18	0.73	0.46-1.18

[1] - standard deviation
[2] - offshore habitat with silt/clay-based substrate and no vegetation
[3] - nearshore habitat with silt/clay-based substrate and no vegetation
[4] - nearshore flooded terrestrial habitat and rooted vegetation
[5] - nearshore flooded terrestrial habitat and no vegetation
[6] - wetted mainstem hard silt/clay-based habitat with no plants and low water velocity
[7] - wetted mainstem soft silt/clay-based habitat with no plants and low water velocity
[8] - wetted backwater inlets with soft silt/clay-based substrate no plants and low water velocity
[9] - wetted mainstem habitat with lkow water velocity and substrates ranging from soft silt/clay to boulders