

# A Long-Term Strategic Plan for the Improvement of Water Quality in the Charlie Lake Watershed

By

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For

Charlie Lake Conservation Society  
c/o Box 720, Charlie Lake, BC, Canada, VOC 1H0



(March, 2004)



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The viewpoints, information, data interpretations and recommendations provided in this document reflect the opinions and analyses of the authors and may not, necessarily, be in agreement with those of the Charlie Lake Conservation Society or partner organisations. All maps included in this document are for illustrational purposes only, and should not be used for navigation, as unmarked hazards and inaccuracies do exist.

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## Acknowledgements

We thank the Charlie Lake Conservation Society for giving us the opportunity to assist them with the development of their long-term strategic plan to improve water quality conditions in the Charlie Lake watershed. In particular, we are grateful for the leadership, direction, continual support and encouragement provided by Society Directors Allan Blair, Bruce Kosugi, Jim Krauss and Edward Stanford. Through our work with the Charlie Lake Conservation Society, we had the opportunity to learn about the multitude of landscape-level and within-lake factors that affect water quality in the Peace Region of British Columbia, and the opportunity to meet and work with several dedicated volunteers, university students, professional consultants and government representatives.

Chris Siddle (a retired Fort St. John School teacher and naturalist) inventoried (species-specific counts) the birds he observed on and around Charlie Lake over an eight-year period. He graciously provided us with these data, and assisted us with the writing of Supplement 2 of the strategic plan: *The Birds of Charlie Lake: Results of an Eight-Year Systematic Survey of Lake and Shoreline Regions*. To the best of our knowledge, this document provides the most comprehensive account of Charlie Lake's bird populations to date. Bruce Carmichael (BC Ministry of Water, Land and Air Protection, Prince George) assisted with the writing of Supplement 1 of the strategic plan, which is a comparative analysis of limnological factors that control algal bloom dynamics in three interior British Columbia lakes: *Factors Controlling Algal Biomass in Three Shallow Eutrophic Lakes in Northern British Columbia, Canada: Charlie, Nulki and Tachick Lakes*.

Nick Baccante (BC Ministry of Water, Land and Air Protection, Fort St. John) gave us access to maps of the Charlie Lake watershed, recently published reports and existing fish and fish habitat data. Bryndell Fell and Bob Barradell (Co-operative Education Students, University of Northern BC) provided administrative and technical support, and worked with the Charlie Lake Conservation Society's Board of Directors to undertake the groundwork necessary to implement start-up components of the draft strategic plan. We are also grateful to the BC Lake Stewardship Society (Kelowna) for including the Charlie Lake Conservation Society in their Volunteer Lake Monitoring Program. Limnological data collected through the Program will be critical for the implementation and evaluation phases of the projects described in the strategic plan.

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Sincerely,

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The chapters and supplements are separated from one another with tabs, and each has its own detailed table of contents. One benefit of the way in which this report is compartmentalised is that the Charlie Lake Conservation Society will be able to provide readers, and partners, with chapters/supplements specific to their interests; rather than having to print off the entire document each time information from the strategic plan is requested.

## Specific Recommendations (Cross Referencing)

For recommendations specific to.....

Stream Crossings (Culverts and Bridges)	Go To... →	Chapter 2 (pages 73-75)
Agricultural Land	Go To... →	Chapter 3 (pages 33-37)
Oil & Gas Wellheads	Go To... →	Chapter 3 (page 37)
Direct Lake Treatments & Lakeshore Living	Go To... →	Chapter 4 (pages 10-14)
Birds	Go To... →	Supplement 2 (pages 12-13)

Readers who wish to skip directly to project-specific recommendations can do so by following the cross-referencing shown above.

## Executive Summary

Charlie Lake is located in northeastern British Columbia, approximately 9 km northwest of the City of Fort St. John, with the centre point of the lake having the coordinates 55°20'00"N/120°59'25"W. The Charlie Lake watershed is valued for its natural beauty and residential suitability, its angling (mostly walleye (*Stizostedion vitreum*), northern pike (*Esox lucius*), burbot (*Lota lota*) and, to a more limited extent, yellow perch (*Perca flavescens*)), hunting and boating opportunities, its fertile soils that support a thriving agricultural industry, and its substantial oil and gas reserves. In addition to supporting a wide range of recreational and industrial endeavours, Charlie Lake is the backup water supply for the City of Fort St. John and its surrounding areas (about 17,500 people). According to French & Carmichael (1999), there are 15 licensed water withdrawals in the Charlie Lake watershed that have a combined permitted withdrawal of 8,124 dam<sup>3</sup>yr<sup>-1</sup>. Of the 15 licenses, six are held by the City of Fort St. John, two by Lake Point Golf & Country Club Inc., and seven by single-license users. With the exception of license C034416 which permits a withdrawal from Fish Creek (Charlie Lake's outlet), all withdrawals are taken from either the lake itself or from tributaries (French & Carmichael, 1999). To ensure sufficient water supplies for the various users, a weir was constructed at the lake outlet in the early 1980s that elevated water levels by about 1 m and, thereby, increased the effective storage capacity of the lake.

Charlie Lake has a watershed area of approximately 281 km<sup>2</sup> (surface area of the lake not included). Having a length of 15 km, a shoreline perimeter of 38 km, a surface area of 19 km<sup>2</sup> and a base volume of about 136,800 dam<sup>3</sup>, Charlie Lake is considered to be a medium-sized lake. As are most naturally eutrophic lakes (i.e., lakes characterised by high biological productivity, particularly in terms of algae) of glacial-scour origin (Rawson, 1955; Hutchinson, 1957), Charlie Lake is comparatively shallow, having mean and maximum depths of 7 and 15 m. As indicated on 1:20,000 NTS maps, Charlie Lake has 21 direct tributaries. The results of ground surveys undertaken by the author (T.D. French) and others indicate that most of these tributaries are ephemeral and typically only carry flows during spring melt and rainy periods. The two largest tributaries to Charlie Lake (Stoddart Creek that drains 171 km<sup>2</sup>, and Coffee Creek that drains 25 km<sup>2</sup>) enter from the north and, together, drain nearly 80% of the watershed area. Charlie Lake is drained at its southern-most tip by Fish Creek (a.k.a. Lower Stoddart Creek). After leaving Charlie Lake, Fish Creek flows for about 20 km to where it joins the Beatton River. The Beatton River drains into the Peace River, which flows northeastwardly across northern Alberta to where it drains into the Slave River which ultimately empties into the Beaufort Sea/Arctic Ocean via the Mackenzie River.

The land draining into Charlie Lake lies entirely within the Boreal-White-and-Black-Spruce biogeoclimatic zone (BC Ministry of Forests, 1992). Perhaps due to the frequency of historical fires and historical land-management practices, forests in the Charlie Lake watershed are dominated by early seral species, with the most-dominant tree species being trembling aspen (*Populus tremuloides*). With the exception of the northeastern shoreline of Charlie Lake which is steeply faced (sheer cliffs), the relief of the watershed is, in general, very low to moderately rolling (Lord & Green, 1986). To the best of our knowledge, land utilisation patterns in the Charlie Lake watershed have not been quantifiably described in the recent past. However, an unpublished report commissioned by the Peace-Liard Regional District in 1980 concluded the following about land utilisation in the watershed from ground surveys and air photos taken in the mid-1970s:

1. private land accounts for > 80% of the watershed,
2. vacant Crown land accounts for 16% of the watershed,
3. 2-3% of the land is reserved as parkland (e.g., Charlie Lake Provincial Park located on the south-west

- shore, and Beatton Park located on the south-east shore),
4. of the total shoreline length, 22 km are privately owned, 2.5 km are reserved as parkland and 10.5 km are vacant Crown land,
  5. approximately 40% of the watershed has been cleared for agricultural or other reasons,
  6. the shorelines of Coffee and East and West Stoddart creeks have been cleared for much of their lengths, and
  7. there is evidence of substantial sediment erosion in the Stoddart Creek valley.

Based on more-recent approximations, there are about 900 cattle and bison, 100 sheep and 100 horses in the watershed (Mr. Allan Blair, BC Ministry of Agriculture, Food and Fisheries, Fort St. John, Pers. Comm.). Given that the Peace-Liard Regional District's land-use analyses were based on surveys undertaken more than 20 years ago, the statistics noted in the points above may no longer be completely accurate, such that land-use practices and landscape conditions may be somewhat different now than they were 20 years ago. Charlie Lake presently has a shoreline community consisting of 1,500 to 2,000 individuals. Although there are several well-dispersed residences in the watershed, residential development is concentrated along the shorelines, with one residential corridor extending from the area surrounding Lake Point Golf & Country Club to the south end of the lake, and another from the south edge of Beatton Park to the south end of the lake.

The Charlie Lake Conservation Society and its Technical Advisory Committee are in the process of developing a restoration plan for the improvement and conservation of water quality the Charlie Lake watershed. Of particular interest to the Society and the broader community is the growing perception that tributary and lake water quality is deteriorating as a result of sediment, nutrient (e.g., phosphorus and nitrogen) and bacterial (from domestic and livestock wastes) pollution. Sediment pollution to the tributaries appears to be generated at unstable stream crossings (culverts and bridges), at oil and gas wellhead site, in regions of the watershed where cattle are permitted graze in and around riparian zones (i.e., the vegetated areas along streams and lakes), and in regions, including the lake foreshore, where riparian vegetation has been disturbed or completely removed as a result of shoreline development.

Although the sources of nutrient pollution have not been clearly identified, it is widely believed that poor riparian function and residential development have decreased the land's ability to buffer nutrient transfer to lake and tributary waters. Anecdotal information and paleolimnological data collected from sediment cores (e.g., Reavie *et al.*, 1995) suggest that increases in nutrient loading rates over the past century have increased the intensity of green and blue-green (cyanobacteria) algal blooms, such that algal biomass can now reach maxima in excess of  $400 \mu\text{g L}^{-1}$  chl *a* (hypereutrophic conditions). While there is little, if any, quantitative evidence that algal production in the lake is at levels where fish populations are at risk, there is some concern that further eutrophication could affect fish production, survivorship (particularly over the winter months when the lake is frozen over) and trophic stability. Of equal significance, the City of Fort St. John still uses Charlie Lake as a backup water supply and, this being the case, there are concerns that further eutrophication could put the municipal water supply in jeopardy and increase costs associated with water treatment.

As suggested above, excessively high fecal coliform densities have been observed in all surveyed tributaries to Charlie Lake, such that the geometric mean coliform density ranged from 9 CFU cL<sup>-1</sup> (East Stoddart Creek) to 42 CFU cL<sup>-1</sup> (Residential Ditch #3 and 281<sup>st</sup> Road Creek) (French & Carmichael, 1999). The 90<sup>th</sup> percentile coliform density ranged from 109 (a control stream located just outside the Charlie Lake watershed) to 8,790 CFU cL<sup>-1</sup> (281<sup>st</sup> Road Creek). While the sources of bacterial contamination have not been identified, it is highly

likely that bacteria enter surface waters in the Charlie Lake watershed from areas where livestock are permitted to access tributaries and from drainage off septic fields in residential corridors, which leak via ditches into the lake.

The primary objective of this project was to develop a strategic plan that will direct future actions of the Charlie Lake Conservation Society to improve water quality and habitat in the Charlie Lake watershed. While the watershed has many intrinsic and human-health related values that warrant restorative action, it is also clear that environmental maintenance is a critical factor determining economic sustainability and growth. In terms of economics, improvements in watershed conditions will help maintain, or even enhance, property values and facilitate growth in industries that cater to people who use the lake for recreational purposes (e.g., for fishing, birding, boating, skiing and sledding, etc.). Given the natural beauty of the area, its history and location along the Alaska Highway, it is foreseeable that watershed improvements could also create growth in tourism opportunities which, over time, could bring substantial revenue to the region. The various components of our strategic plan to improve water quality conditions in the Charlie Lake watershed were developed based on the results of a limnological assessment undertaken by French & Carmichael (1999) that described the environmental factors that control algal bloom dynamics in Charlie Lake (a major water quality concern), and broad-based watershed surveys undertaken by the ourselves during the development of the plan.

Based on the results of the limnological assessment and watershed surveys, we have determined that there are seven major factors related to human activities that are contributing to the degradation of water quality in the Charlie Lake watershed (see listing below). Comprehensive descriptions of these factors, with specific recommendations, are given in chapters 2 through 4 of this report (see listing below for page references to project-specific recommendations). The objective of Supplement 1 of this report is to provide readers with the results of the scientific work that has been undertaken to identify the environmental factors that control algal blooms in Charlie Lake. Every effort has been made to describe these results within the context of the most-current knowledge available in the primary literature. We are hoping that the analysis and information provided in Supplement 1 will provide a solid basis for future limnological research on Charlie Lake, and other interior British Columbia lakes that are experiencing similar changes in water quality.

<b>Major Factors Affecting Water Quality</b>	<b>Primary Effects</b>	<b>Report Chapter Reference</b>	<b>Page Reference to Recommendations (within chapter)</b>
Poorly constructed/functioning stream crossings (culverts/bridges)	Increased sediment (and nutrient) export from watershed to lake; habitat fragmentation (perched culverts); reduced thermal buffer (water temperature)	Chapter 2	73-75
Riparian land clearing	Increased sediment (an nutrient) export from watershed to lake; decreased channel stability (increased channel meandering), reduced thermal buffering (water temperature); reduced organic carbon loading to streams from native vegetation	Chapter 3	33-37
Livestock access to stream channels	Increased sediment (an nutrient) export from watershed to lake; increased nutrient loading from animal wastes; bacterial and parasite contamination to tributary waters	Chapter 3	33-37
Poor water management practices on oil and gas wellhead sites and roads	Increased sediment (an nutrient) export from watershed to lake	Chapter 3	37
Inappropriately designed water withdrawals	Concentration of low quality water (nutrient rich) water within Charlie Lake; extraction of high quality water (relatively low nutrient concentrations) from lake	Chapter 4	10
Domestic wastes	Increased nutrient loading to lake; bacterial and parasite contamination	Chapter 4	11
Foreshore residential development	Sediment (an nutrient loading); reduction in riparian function; contaminant loading (household chemicals like herbicides, pesticides, fertilisers, detergents, cleaners, oil and gas, etc.)	Chapter 4	12

The matrix on the following pages proposes a generalised timeline for the implementation of the strategic plan to improve water quality in the Charlie Lake watershed. The proposed timeline is “adaptive” in the sense that that the timing of specific projects can be adjusted to address the schedules and requirements of the Charlie Lake Conservation Society and their project partners. In regards to prioritising watershed improvement projects, it must be understood that none of the projects we have recommended will, on their own, result in noticeable improvements in water quality, such that the degradation of water quality is a response to many watershed-level impacts that cannot be addressed by any single project. Thus, it is critical that the Charlie Lake Conservation Society do their very best to develop a diversity of partnership so that all elements of the strategic plan can be implemented progressively and concurrently.

Readers interested in learning more about the Charlie Lake watershed are encouraged to read the following documents, most of which are available from the BC Ministry of Water, Land and Air Protection office in Fort St. John:

- de Laronde, J. & N. Baccante, 1999. Charlie Lake Wetland Restoration and Enhancement (1999 Final Report). Prepared for Habitat Conservation Trust Fund and BC Ministry of Environment (Fort St. John). 14 pp. (+ Appendices)
- French, T.D. & N.B. Carmichael, 1999. Limnological Aspects of Charlie Lake (Peace River Drainage, British Columbia): A Summary of Data Collected Between 1974 and 1995. 115 pp.
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- Shuman, K. & B. Anderson, 2001. Fish Passage Assessments: Identification of Unnatural Barriers to Fish Migration in the Fort St. John and Dawson Creek Forest Districts. 15 pp. (+ Appendices)

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- Lord, T.M. & A.J. Green, 1986. Soils of the Fort St. John – Dawson Creek Area, British Columbia. Agriculture Canada, Research Branch, Land Resource Research Centre Contribution No. 85-27 (Map Sheets 94/SW (Hudson’s Hope) and 94 A/SE (Fort St. John)).
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Strategic Objectives	Timeline				
	Year 1	Year 2	Year 3	Year 4	Year 5
<b>I. Capacity Building &amp; Communications/Extension</b>					
Develop a written communications strategy					
Update website and post strategic plan (keep website current and comprehensive)					
Establish a regular (bi-annual) newsletter to publish news on activities relevant to Charlie Lake watershed (print and post on website)					
Develop a resource centre (with library) for educational material, and mobile displays for conferences					
Develop and construct all-weather informational signage for placement at boat launches and parks					
Organise periodic training courses, and regional public forums on watershed-related issues (forums could include training sessions, poster sessions and verbal presentations)					
Develop a media kit, and continue with media campaign to promote watershed information					
Send a copy of the strategic plan and project objectives to potential partners with cover letter encouraging their support, and follow up with phone calls to determine whether any financial or in-kind support could become available					
Construct educational modules in website that are relevant to watershed conservation and promote usage in local schools					
Continue promoting community participation in Annual General Meeting/Conference, and continue with lake cleanup events					
Initiate an annual community-based Riparian Planting weekend, to promote community participation and education					
Promote Society project results, challenges and information through written submissions to informational publications like BCLSS Newsletter, StreamLine Watershed Management Bulletin, Lake and Reservoir Management					
<b>II. Stream Crossing Restoration (Refer to Chapter 2)</b>					
Determine who is responsible for maintaining roads and stream crossings surveyed during the development of strategic plan					
Negotiate with responsible organisations (Oil and Gas Commission, provincial Ministry of Transportation and Highways) to see that structural improvements to stream crossings are made with the objective of reducing sediment erosion					
Assess stream crossings that were not surveyed during the development of strategic plan					

Strategic Objectives	Timeline				
	Year 1	Year 2	Year 3	Year 4	Year 5
<b>III. Improve Water Management at Oil and Gas Wellhead Sites (Refer to Chapter 3)</b>					
Consult with Oil and Gas Commission and relevant oil and gas companies to assess water management practices on all oil and gas wellhead sites in the Charlie Lake watershed – water accumulation and piped runoff from some wellhead sites is resulting in substantial sediment erosion					
Determine whether Oil and Gas Commission and relevant oil and gas companies are willing to voluntarily modify their water management practices, and stabilise soils that have been subject to erosion - if so, proceed with program implementation					
If Oil and Gas Commission and relevant oil and gas companies are not willing to undertake site assessments and modify, when necessary, their water management practices consult with responsible government ministries that may be able to enforce changes through the Fisheries Act or Waste Management Act					
<b>IV. Riparian Restoration in Agricultural Reaches (Refer to Chapter 3)</b>					
Organise a landowner working group as a sub-committee within the Charlie Lake Conservation Society that will focus on agriculture-related issues					
Determine the applicability of conservation covenants to the Charlie Lake watershed (as a means to offset restoration costs to landowners)					
Undertake research to identify agencies/organisations that can provide funding for riparian restoration projects on agricultural land					
Negotiate with watershed landowners to gauge the level of support for riparian restoration work on agricultural land and to explain the possible application of conservation covenants					
Work with supporting landowners to undertake demonstration riparian restoration projects and off-channel livestock watering facilities (if successful, other landowners may come on board in the future)					
<b>V. Direct Lake Treatments (Refer to Chapter 4)</b>					
Negotiate with Devon Canada Corporation to determine whether it would be feasible for them to convert their epilimnetic withdrawal to a hypolimnetic withdrawal to increase phosphorus export from Charlie Lake					
If Devon Canada Corporation is willing to consider the construction of a hypolimnetic withdrawal, determine whether the BC Ministry of Water, Land and Air Protection will allow for a change in the water extraction permit (they likely will, as Devon Canada Corporation currently hold a license, and the change in license will be beneficial)					
Obtain schematic of sewage trunk system to determine which foreshore homes are not presently connected; investigate possibility of getting federal or provincial infrastructure grants to offset the costs of connecting these homes to the trunk system					
If the Charlie Lake Conservation Society is interested in further investigating the benefits and risks of bottom sediment extraction, they should discuss the possibility with responsible government ministries to determine whether it is worth undertaking a preliminary impact assessment and feasibility study					
Undertake research to determine the feasibility of a bottom sediment removal project, and determine whether any extracted sediment can be mixed with agricultural soils (i.e., determine whether nutrient-rich lake sediments would promote agricultural production)					

Strategic Objectives	Timeline				
	Year 1	Year 2	Year 3	Year 4	Year 5
<b>VI. Lakeshore Living (Refer to Chapter 4)</b>					
Investigate the applicability of conservation covenants to private lakeshore properties, and determine if these covenants would offset the costs (if any) of riparian conservation					
Promote the conservation of native shoreline vegetation in view of reducing nutrient and sediment erosion					
Promote the vision of the Charlie Lake Conservation Society through homesite assessments and educational materials on water-friendly household products					
<b>VII. Monitoring Programs</b>					
To evaluate projects undertaken to improve water quality conditions, continue sampling Charlie Lake through the BC Lake Stewardship Society's Volunteer Lake Monitoring Program (VLMP)					
To evaluate the water quality of tributaries draining into Charlie Lake, the VLMP should be expanded to include tributary surveys - the Charlie Lake Conservation Society could involve landowners in any tributary monitoring programs					

Disclaimer: This illustration is for information only. The illustration should not be used for navigation as unmarked hazards and some inaccuracies do exist.

LEGEND

-  Rail
-  Lakes and Streams
-  Major Highway
-  Secondary Road
-  Watershed Boundary

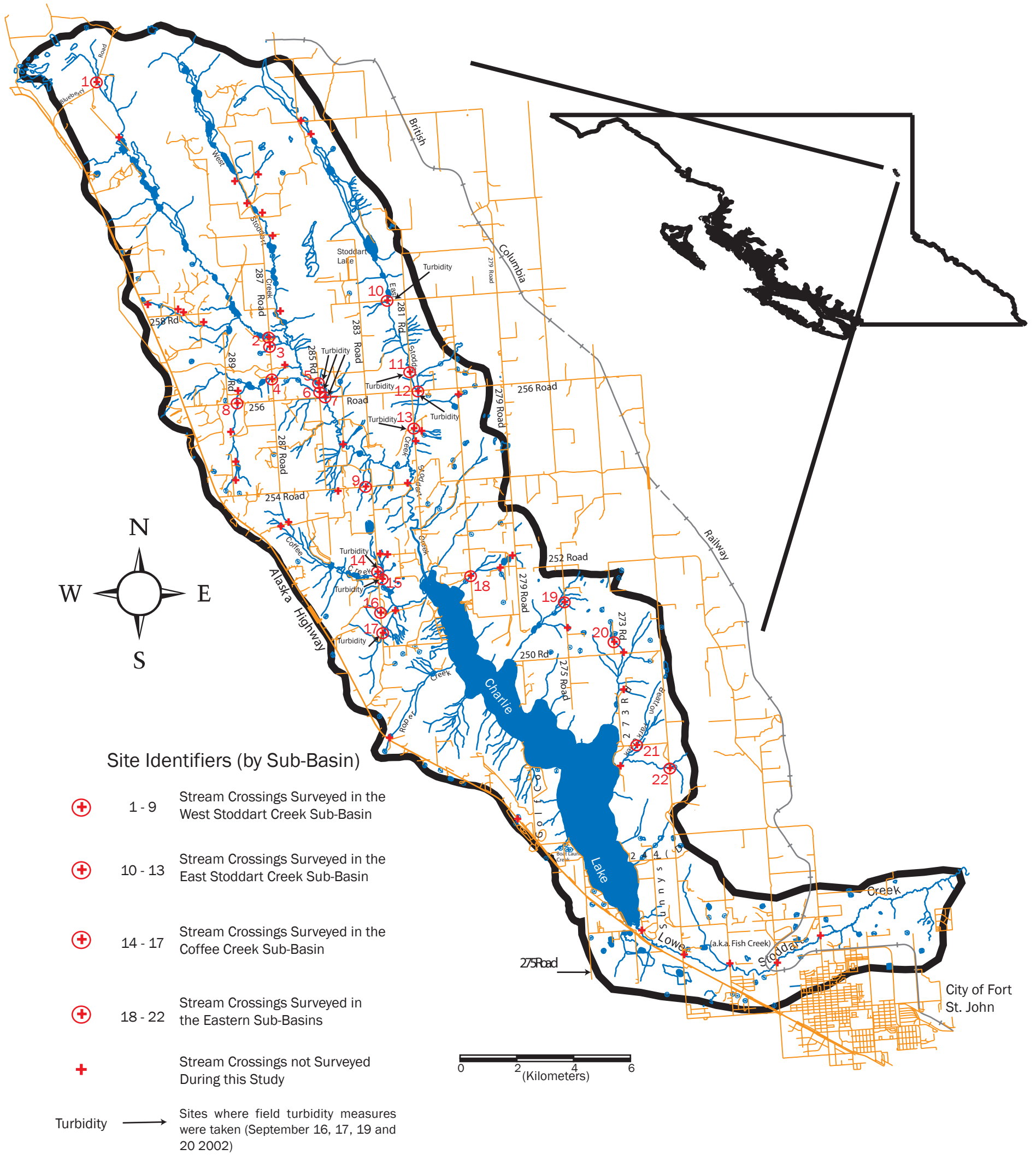


Figure 1. Stream Crossings (mostly culverts, and some bridges) in the Charlie Lake Watershed Surveyed over the period September to November 2002 (full-scale map in associated map tube).

# The Condition of Stream-Crossings (Culvert and Bridges) in the Charlie Lake Watershed with Reference to Water Quality (September to November 2002)<sup>1</sup>

Todd D. French<sup>2</sup> and Barry P. Booth<sup>3</sup>

(March 2004)

**Abstract:** The Charlie Lake Conservation Society is in the process of developing long-term strategic concepts for projects to improve water quality and habitat in Charlie Lake and in tributaries to the lake. In this section of the strategic planning processes we examine the current conditions of culvert- and bridge-type stream crossings in the East and West Stoddart creeks, Coffee Creek and Eastern sub-basins and how these conditions may be affecting water quality in view of sediment transport and factors that are known to be associated with sediment movement. In all, we systematically assessed 22 representative stream crossings over the period September 16 to November 12, 2002 with the objective of describing how road crossings over tributaries to Charlie Lake may be affecting water quality. As indicated on the road crossing map, 17 stream crossings in the West Stoddart Creek sub-basins, six in the East Stoddart Creek sub-basins, five in the Coffee Creek sub-basins, and six in the Eastern sub-basins were not surveyed during this study. Many of the crossings that were not assessed were on private land and, thus, were not readily accessible.

The results of our surveys of representative crossings identified eight crossings that are having little, if any, affect on water quality and eight and six crossings that are having moderate and more severe affects, respectively. Given that several crossings showed evidence of having adverse affects on water quality and habitat, we strongly recommend that similar surveys of the 34 crossings not surveyed during this study be visited and assessed in future years. In the final sections of this report, we describe, in a general sense, an approach that the Charlie Lake Conservation Society may want to consider in view of reducing the adverse water quality affects of priority stream crossings.

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The Charlie Lake Conservation Society is in the process of developing long-term strategic concepts for projects to improve water quality and habitat in Charlie Lake (Fort St. John area, British Columbia) and in tributaries to the lake, and to improve the aesthetic and recreational potential of the watershed as a whole. As discussed in French & Carmichael (1999), the major watershed concerns identified to date are the severity of late-summer and autumn cyanobacteria (blue-green algae) blooms, which are known to occur in response to

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seasonal internal nutrient loads (see Supplement 1: *Factors Controlling Algal Biomass in Three Eutrophic Lakes in Northern British Columbia, Canada: Charlie, Nulki and Tachick Lakes*), sediment inputs from tributaries and the lake shore, and the input of domestic wastes from extensive shoreline sub-divisions. Through their strategic planning process, the Charlie Lake

Conservation Society is hoping to design specific projects and community-level initiatives that will address the watershed-level factors that are thought to be affecting the perceived deterioration in water quality. Ultimately, the Charlie Lake Conservation Society needs these projects and initiatives to be both cost effective and *doable* in a practical sense so that local industries, relevant funding agencies and the public will buy-in to the recommended programs and have the ability to get involved, and believe that their financial and personal commitments are having positive outcomes in terms of improvements to water quality and the watershed as a whole. Charlie Lake is located just off the Alaska Highway and, with this location and its scenic landscape, watershed-level improvements will undoubtedly enhance the region's ability to attract stop-over tourists and help maintain property and recreational values and, perhaps, through reductions in diffuse pollution loads reduce risks to human health.

In this section of the strategic plan we examine the current conditions of culvert- and bridge-type stream crossings in the East and West Stoddart creeks, Coffee Creek and eastern (those streams that drain into the eastern side of Charlie Lake) sub-basins (Figure 1). Our rationale for investigating stream crossings as part of the strategic planning process was that similar studies undertaken in other watersheds have shown that sediment movement (i.e., erosion and slumping resulting from water saturation) at sub-standard crossings can adversely affect water quality, and preliminary observations have indicated similar trends in the Charlie Lake watershed. Through our investigation of stream crossings in the Charlie Lake watershed, we have ranked crossings in terms of their affects to channel morphology and, thus, to water quality as: high, medium and low. Those crossings ranked as having "high" affects are those that the Charlie Lake Conservation Society should prioritise in terms of future restoration projects. The work to be done at priority crossings would largely be accomplished by public and/or private-sector road engineering professionals.

Our primary concern with respect to stream crossings in the Charlie Lake watershed is that there was evidence of considerable sediment movement at many of the crossings that we assessed, in particular those over major mainstems that carry sufficient flow to transport substantial sediment loads to Charlie Lake (e.g., Coffee Creek, East and West Stoddart creeks). It is well documented in the scientific literature that sediment loads in excess of base-line (i.e., natural state) levels can have a multitude of effects on freshwater systems, including:

1. Fine sediments, particularly silts and clays, have surficial exchange sites (i.e., electrostatic charges) that can attract and bind nutrient ions (e.g.,  $PO_4^-$ ) and chemical contaminants such as herbicides, pesticides and metals. Thus, sediments carried in tributary flows transport nutrient ions and, possibly, other chemicals to Charlie Lake. Results on within-lake storage rates presented in French & Carmichael (1999) indicate that much of the sediment-bound nutrient loads to Charlie Lake are stored within the lake (i.e., flushing rates are very low).
2. Suspended sediments reduce water clarity and, thus, increases light attenuation (the rate at which light is absorbed in the water column). Increases in light attenuation resulting from elevated sediment loads can reduce benthic production rates (i.e., biological production on the bottom of streams depends on the photosynthetic rates of attached algae – the base of the food chain).
3. Predatory fish are, in general, visual hunters. Reductions in water clarity resulting from elevated sediment loads have been show to reduce the hunting success of predatory fish.

4. In low-energy reaches (including Charlie Lake), sediment deposition can result in the over-covering of important fish spawning substrates.
5. Sediment transport to slow-flushing lakes tends to make them shallower over time via complex in-filling processes. As lakes shallow, they tend to become more turbid and more susceptible to algae-bloom related problems. This is generally a very slow process, but the process is accelerated by increases in upstream erosion and sediment transport.
6. Sediment transport from regions of the landscape that are susceptible to the erosional forces of water ultimately results in a loss of valuable land.
7. Sediment transport from riparian areas is generally indicative of insufficient vegetation cover (e.g., herbs, grasses, shrubs and trees) that stabilise soils. Riparian vegetation provides thermal buffering to streams (i.e., protects them from rapid and excessive changes in temperature) and provides streams with organic matter that can be used in biological production, and with physical structures that contribute to habitat complexity and diversity.

This report summarises the methods we used to assess stream crossings in the Charlie Lake watershed and the results of the crossing assessments in view of their affects to water quality. We use the results to provide restoration options to the Charlie Lake Conservation Society that will help them address their objective of improving water quality in the Charlie Lake watershed.

## Materials & Methods

Twenty-two stream crossings in the West Stoddart Creek (9 crossings surveyed), East Stoddart Creek (four surveyed), Coffee Creek (four surveyed) and Eastern (small streams draining into Charlie Lake from the east; five surveyed) sub-basins were surveyed in view of their potential affects to water quality over the period September 16 to November 12, 2002 (Figure 1). Of the crossings surveyed, 16 were single culverts, four were dual culverts (i.e., two side-by-side culverts running parallel to one another beneath a road) and two were bridges. Stream crossings surveyed as part of this study were assigned numeric identifiers and plotted on Figure 1 with the Avenza MapPublisher® 5.0 plug-in to Adobe Illustrator® 10.03 (layers exportable to ArcInfo™, ArcView®, Microstation® and other common formats). The simple numeric identifiers were assigned in sub-basin groupings as follows (Figure 1): 1-9 identify crossings that were surveyed in West Stoddart Creek sub-basins, 10-13 identify those surveyed in East Stoddart Creek sub-basins, 14-17 identify those surveyed in Coffee Creek sub-basins, and 18-22 identify those surveyed in Eastern sub-basins.

The information and data collected during the stream-crossing surveys were systematically collected with the objective of describing how crossings over tributaries to Charlie Lake may be affecting water quality in both the tributaries themselves and, thereby, the lake. The parameters assessed during site visits were selected to enable us to qualitatively characterise affects to water quality in terms of sediment transport/erosion and channel/bank stability, bottom substrate characteristics, and culvert/bridge conditions. The parameters collected during site visits were compiled in to a “form” format and laser printed on water proof paper for use in the field (Appendix A). The parameters with rationale and collection methods were as follows:

## GENERAL SITE DESCRIPTORS

Date of Inspection: *Month/Day/Year*

Crossing Type: *Crossing identified as being road, rail line, pipeline, etc.*

Time of Inspection: *To the nearest ¼ hour*

Name of Sampler: *Initials of individual(s) who surveyed the crossing (T. French and/or B. Booth)*

GPS Coordinates: *Latitude and longitude of crossing measured by a Garmin 12 GPS (coordinates used to plot crossing location on Figure 1); all crossings surveyed were on 1:50,000 NTS map sheets 94 A/11 (Murdale), 94 A/6 (Bear Flat) and 94 A/7 (North Pine).*

Location Description: *A short description of the crossing location (e.g., name of road and nearest landmark)*

Structure Description: *Crossing structure identified as being a bridge, culvert, dual culvert, half culvert or other type*

Stream Name: *Gazetted or local name of stream*

Channel Slope (%): *All surveyed streams had a channel slope of <1% (watershed is a generally flat to gently rolling landscape)*

Channel Widths (meters): *Approximately five channel widths were measured upstream and downstream of the crossing at intervals equal to the width of the first channel measurement. Upstream and downstream measurements were not necessarily initiated directly at the upstream/downstream ends of the structure – they were initiated at a the nearest location not directly influenced by the crossing; i.e., where scour holes were present downstream of culverts measurements were started immediately downstream of the scour hole where “average” channel widths were represented. The distance from the downstream/upstream end of the structure where measurements started was recorded. The rationale for collecting channel widths was to allow a comparison of channel widths upstream and downstream of crossing structures; channel widening is indicative of sediment scour and erosion. All measurements were taken with a fibre glass tape calibrated in centimetres.*

Substrate Description: *When possible, bottom sediment grain size distributions were qualitatively (visual inspections) estimated upstream and downstream of the crossing in terms of % contribution to total visible bottom sediment. The following qualitative scale was used: % fines (ladybug sized sediment and smaller), % gravels (lady bug sized to tennis ball sized), % cobbles (tennis ball sized to basketball sized) and % boulders (larger than basketball sized). As with channel widths (see above) bottom sediment inspections were undertaken outside of the zone directly affected by the crossing.*

Sample of Fine Sediment Collected (Y/N): *In some instances, samples of fine bottom sediment were collected (Eckman dredge) for future analyses of exchangeable nitrogen and phosphorus, metals and organics, standardised to sediment grain-size distribution and total organic carbon. The premise for collecting sediments was to quantify the exchangeable chemical capacity of sediments transported by tributaries to Charlie Lake. These sediments are being stored for future analyses at the TDF Watershed Solutions, Research & Management office in Prince George, BC. It is hoped that we will be awarded Provincial funding in fiscal 2003/04 to have these sediments analysed.*

## CROSSING DESCRIPTORS

Length of Crossing (meters): *The total length of the crossing (e.g., culvert) from the upstream end to the downstream end, as measured with a fibreglass tape calibrated in centimetres. With respect to culverts, the measured lengths are approximations as the tape was most-often stretched across the road from one end of the culvert to the other (could not always walk through culverts).*

Diameter of Culvert (meters): *The inside-diameter of the culvert measured to the nearest centimetre either a fibreglass tape or a flip-out meter stick.*

Condition of Culvert: *Whether culvert was in original/intact condition or crushed/compressed.*

Position of Culvert: *The upstream and downstream ends of each culvert were inspected to determine whether they were perched. Two measurements were taken: measurement a was the distance (m) from the bottom of the culvert to the channel bottom and measurement b was the distance (m) from the bottom of the culvert to the surface of the water or ice.*

Crossing Material: *The type of material that the crossing was constructed from (typically corrugated steel and/or wood in the Charlie Lake watershed).*

Turbidity (NTU): *In some instances, water turbidity (HACH 2100P Portable Turbidimeter) was measured upstream and downstream of the crossing.*

## CROSSING FUNCTION

Road Bed Condition: *Whether there was significant sediment (e.g., gravels and sands) on bridge decks. There is evidence that indicates that such sediment is, at least sometimes, washed off bridge decks into stream channels. Sediment build-up on bridges was rated as low, medium or high.*

Ditchline Condition: *Ditches running parallel to roads adjacent to a crossing were qualitatively described as to whether they were eroding or slumping and contributing sediment directly to the channel. Ditches on the upstream and downstream sides of the crossing were examined.*

Conditions of Bridge Pylons: *Condition of bridge pylons were described as being poor, fair or good.*

Bridge Pylon Treatment: *Whether bridge pylons were treated and, if they were, with what.*

Debris Clogging: *Whether there was evidence that debris was, or has potential to, clog and disrupt flow through culvert or under bridge. Debris clogging can cause upstream flooding and reduced*

downstream flows. When material creating the clog is breached, substantial downstream erosion can result when channel bank material and dimensions cannot support unusually high and sudden discharge volumes.

Evidence of Pooling: Whether there was evidence of water pooling immediately upstream and downstream of the crossing. Pools upstream of culverts usually develop when stream discharges cannot be supported by the culvert (i.e., culvert size is too small in relation to channel size). Water pooling upstream of a crossing can backflow in-line with the channel direction, or it can pool up in ditches running parallel to the road. This can result in bank/ditch saturation and slumping and erosion and increase sediment loads carried by the stream. Pools downstream of crossing are most often formed when the crossing structure increases the power of the flowing water, particularly during freshet flows and following severe rain events. Power typically increases when culverts are too small to support large flows (i.e., water is compressed in culvert, resulting in an increase in velocity) and/or when culvert is perched above channel (i.e., the fall of water from the culvert to the channel creates energy). Scour pools and increased channel widths downstream of crossings is evidence of sediment transport. The length and width of upstream and downstream pools were measured with a fibreglass tape calibrated in centimetres. Culverts were also assessed as to whether water was flowing through or pooling within the structure.

Downstream Scour Hole: Whether there was a scour hole formed downstream of crossing. Scour holes are indicative of bank or bed movement. The length and width of downstream scour holes were measured with a fibreglass tape calibrated in centimetres.

Other Forms of Erosion: Whether there was evidence that either backflooding (i.e., upstream of crossing) and/or downstream erosion has resulted in slumping or other forms of sediment erosion.

Human and Animal Disturbances: A description of any activities by humans and/or animals at the crossing that has potential to affect water quality.

Bank/Channel Stabilisation: Whether any efforts have been made to stabilise stream bed or banks at crossing (e.g., rip rap).

## RIPARIAN CONDITION

Description of Riparian Cover: A qualitative description of the riparian plant community. The types of plants that the riparian community was composed of: 1 = grasses, 2 = herbs, 3 = shrubs and 4 = trees (and combinations of 1 through 4). This was examined upstream and downstream of road.

Stabilisation Capacity of Riparian Cover: Whether the riparian plant community has sufficient density and species composition to provide protection from erosion by moving water. This was examined upstream and downstream of road.

Exposed Ground/Soil: A qualitative assessment of the surface area of exposed soil in the vicinity of the crossing.

## PHOTO DOCUMENTATION

Photographic Records: *Photographs were taken of the channel and channel conditions upstream and downstream of the crossing to supplement descriptions. Features in the vicinity of the crossing that may be affecting water quality were also photographed.*

Field measures of turbidity were taken at selected sites in the East Stoddart (four sites), West Stoddart (three sites) and Coffee Creek (three sites) sub-basins on September 16, 17, 19 and 20 2002. The sites in the East Stoddart sub-basin where turbidity measures were taken correspond to site #1 through #4, with those in the West Stoddart and Coffee Creek sub-basins corresponding to sites #5 and #6 and sites #14, #15 and #17, respectively (see Figure 1 for site distributions). The distribution of bottom sediment sampling sites is discussed in Chapter 7 of this series.

## Results

The results of the September through November 2002 stream crossing assessments are reported on below in sub-basin groupings, in the following order:

- PART 1. West Stoddart Creek sub-basins (crossings #1 to #9),
- PART 2. East Stoddart Creek sub-basins (crossings #10 to #13),
- PART 3. Coffee Creek sub-basins (crossings #14 to #17) and, lastly
- PART 4. Eastern tributary sub-basins (crossings #18 to #22).

Readers should refer to Figure 1 to spatially identify each crossings being referred to in the text. A series of photographs is provided with each crossing description to highlight the observed crossing conditions.

## **CROSSING NO. 1 (DESCRIPTION)**

PART 1. WEST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 1  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 33.054'N 121° 13.500'W  
Assessment Date: November 11/2002  
Assessment Time: 15:15hrs

### **Crossing Description:**

Crossing Type: Dual corrugated steel culvert  
Culvert Length: 15 m  
Culvert Diameter: 0.90 m  
Perching: Upstream end flush to channel bottom; downstream end perched 0.65 m above ice surface  
Note: Metal grates have been fitted to the upstream ends of both culverts to minimise debris inflow

### **Channel Conditions:**

The average channel width downstream of the road was 0.76 m. There was a scour hole 15.5 m long by 5.3 m wide at the culvert outlet. Upstream of the road, the channel was only apparent for about 20 m; upstream area was mostly water-filled depressions that supply downstream flows (headwaters of West Stoddart Creek).

### **Riparian Vegetation:**

The riparian community for the first 25 m immediately downstream of the culvert was composed of a thin mixture of grasses, herbs and shrubs with virtually no over-channel cover. The sparse riparian vegetation near the road was not contributing much to bank stability. The channel enters a spruce/pine/alder forest about 25 m downstream of the road. This forested reach was providing both over-channel cover and channel stability.

The riparian community for the first 20 m immediately upstream of the culvert was composed of a thin mixture of grasses, herbs and shrubs that were not providing over-channel cover or much stability to the channel. As indicated above, the channel was not well defined past a distance of 20 m upstream of the road, at which point there was a series of wet depressions which did have substantial tree and shrub cover (these depressions appeared to be the upstream extent of West Stoddart Creek and contribute to downstream flows during wet periods).

### **Water Quality Concerns:**

There were water quality concerns both upstream and downstream of the crossing. Upstream, flows enter the culverts from an extreme angle that has resulted in water backflooding parallel to the road for an extent of about 100 m. This backflooding has, in places, resulted in bank saturation and soil slumping. Over time, this soil is likely carried downslope towards the lake.

The primary culvert was substantially perched at the downstream end. As evidenced by the scour hole, this perching has increased stream power and the rate of downstream sediment transport. The thin riparian community immediately downstream of the road does not provide sufficient protection to the channel during runoff events.

### **Priority:**

High Priority – This reach represents the headwaters of West Stoddart Creek, which is one of the largest tributaries to Charlie Lake. The large scour hole immediately downstream of the road and upstream/downstream slumping resulting from saturation indicates that this crossing is contributing to the downstream movement of sediment. Channel stability could be increased by armouring the channel immediately upstream and downstream of the road (preferably with natural vegetation which will also create cover) and decreasing water energy at culvert outlet by lowering the culvert so that its bottom is flush to the bottom of the channel. An alternative to lowering the culvert could be to backfill downstream of the culvert so as to decrease the gradient immediately downstream of the road. This site would be suitable for a pilot restoration project.



Plate 1. Substantial back flooding upstream of road (channel approaches road from a steep angle). This backflooding resulting from poor drainage is resulting in soil saturation and slumping (November 11/2002).



Plate 2. Channel undercutting downstream of road. Note that riparian grasses and shrubs are not of sufficient density to provide much in the way of channel protection (November 11/2002).

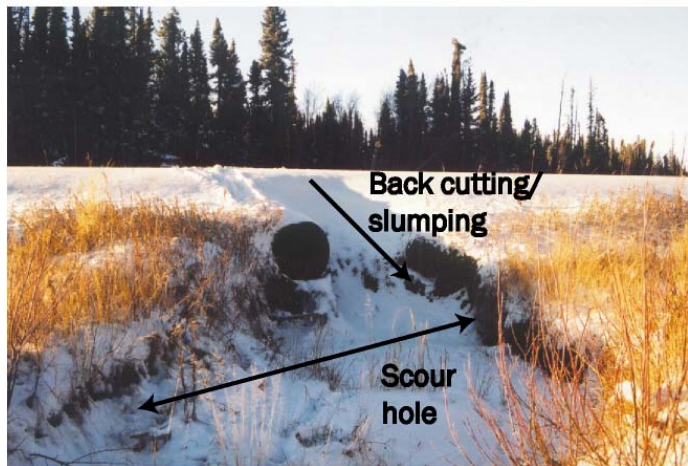


Plate 3. View of culvert downstream of road. Note that the culvert is perched and that there is a substantial scour hole (evidence of sediment movement) (November 11/2002).

## **CROSSING NO. 2 (DESCRIPTION)**

PART 1. WEST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 2 (western fork of West Stoddart Creek)  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 28.206'N 121° 08.225'W  
Assessment Date: November 11/2002  
Assessment Time: 11:30 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 19 m  
Culvert Diameter: 2.5 m  
Perching: Upstream end of culvert was perched 0.05 m above ice surface; downstream end of culvert was perched 0.80 m above ice surface

### **Channel Conditions:**

Beavers have constructed a dam across the upstream end of the culvert. Channel upstream of the road has been flooded into an extensive series of beaver ponds. The average channel width downstream of the road was 3.4 m. There was a scour hole immediately downstream of the culvert outlet that had a maximum length of 22 m and a maximum width of 13 m. Channel approximately 50 m downstream of road showed evidence of substantial widening and slumping resulting from saturation (channel runs through a field with only grasses providing riparian stability).

### **Riparian Vegetation:**

Thin riparian community of grasses, herbs and shrubs was not providing over-channel cover or much in the way of channel armoring (as evidenced by undercutting downstream of the road). The ditches on both sides of the road were lined with grasses.

### **Water Quality Concerns:**

An extensive series of beaver ponds was present upstream of the road. If these dams were to breach, downstream flooding would result in considerable erosion and downstream sediment movement. Presently, these ponds are storing sediment.

The culvert downstream of the road was severely perched above the channel bottom and this has resulted in a substantial increase in stream power during runoff events. The very large scour hole downstream of the culvert indicates that the crossing is contributing substantially to downstream sediment movement and that the thin riparian vegetation is not providing sufficient protection from erosion. Energy from the crossing is causing the channel to widen downstream of the road, particularly from sediment slumping on the outside banks of meanders. A 20-m x 20-m patch of exposed soil near the left bank about 50 m downstream of road is contributing sediment to the channel.

### **Priority:**

High Priority – West Stoddart Creek is one of Charlie Lake's largest tributaries and has potential to transport high sediment loads during runoff periods. The culvert downstream of the road is excessively perched, and this is increasing the power of flows and the rate of downstream erosion (see large scour hole immediately downstream of culvert). If the upstream beaver dams were to breach in the future, downstream erosional rates will be substantial. Downstream channel stability could be increased by armoring the banks with shrubs and trees and by decreasing water energy at the culvert outlet (reducing gradient by backfilling/extension or by lowering the culvert). This site would be a suitable location for a high-profile pilot restoration project.

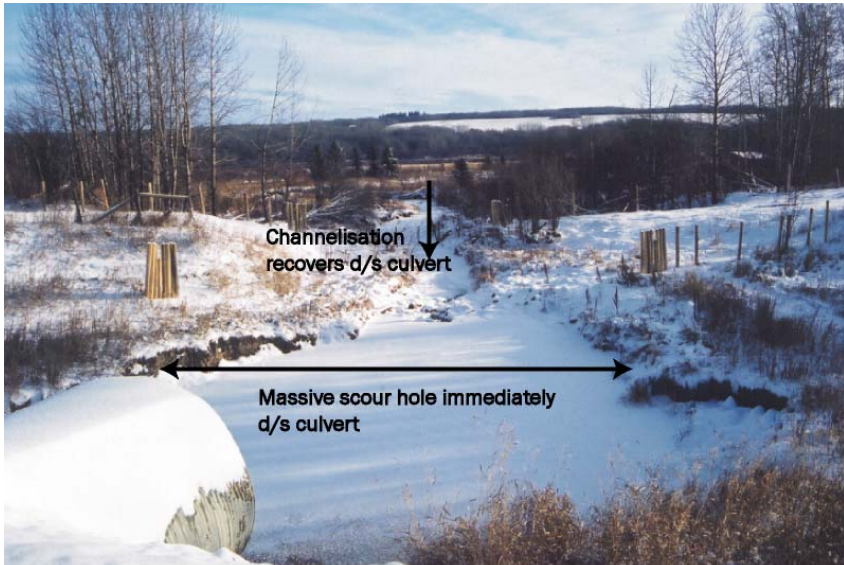


Plate 4. Scour hole downstream of culvert. Note in that the channel reforms downstream of the immediate impacts of the culvert (November 11/2002).



Plate 5. View of culvert outlet downstream of road. Note extremely large scour hole downstream of culvert. If upstream beaver dams were to breach, further downstream scouring would be severe. Note that the culvert is substantially perched (and this increases the power of flows) (November 11/2002).



Plate 6. View of channel approximately 50 m downstream of road. Note that there is evidence of severe slumping on outside bend of the channel (riparian grasses are not sufficient to protect channel from erosion) (November 11/2002).



Plate 7. Series of beaver ponds upstream of road. Note beaver dam in forefront of photo (built in the culvert inlet). The ponds are extensive and if breached could result in torrential downstream flows and erosion (November 11/2002).

## **CROSSING NO. 3 (DESCRIPTION)**

PART 1. WEST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 3  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 28.043'N 121° 08.238'W  
Assessment Date: November 11/2002  
Assessment Time: 10:54 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 10 m  
Culvert Diameter: 0.45 m  
Perching: Upstream end of culvert is perched 0.10 above ground level; downstream end is perched 0.23 m above ground level

### **Channel Conditions:**

The crossing appears to be only draining runoff carried by road ditches. The channel was not clearly defined upstream of the road; however, there may have been a channel in the distant past (possible that the channel has de-watered and in-filled over time). There was some slumping resulting from saturation immediately at the culvert opening. While the channel was not defined upstream of the road, the channel was clearly visible downstream of the road as it runs through a field. We believe that the ditch runoff and culvert provide sufficient energy to maintain the downstream channel during periods of high runoff. There was some exposed soil and saturation-related slumping immediately downstream of the culvert. For the first 15 m downstream of the culvert, channel width ranged from 0.5 to 1.0 m; however, the channel widened to an average width of about 1.5 m in the field downstream of the road (virtually no riparian armouring or over-channel cover).

### **Riparian Vegetation:**

The riparian community upstream and downstream of the road consisted of only grasses and herbs that do not provide over-channel cover or much in the way of channel armouring. There were substantial amounts of exposed soil in riparian area.

### **Water Quality Concerns:**

Current conditions at this crossing are not likely having much of an influence on the water quality of Charlie Lake or major tributaries as the channel will only carry flows during extreme runoff periods. As suggested above, the channel upstream of the road may have de-watered in the distant past as a result of changing hydrologic conditions.

### **Priority:**

Low Priority – This is a relatively small channel and, as such, has little potential to move sediment downstream. It is also apparent that the channel only provides drainage during high runoff events.

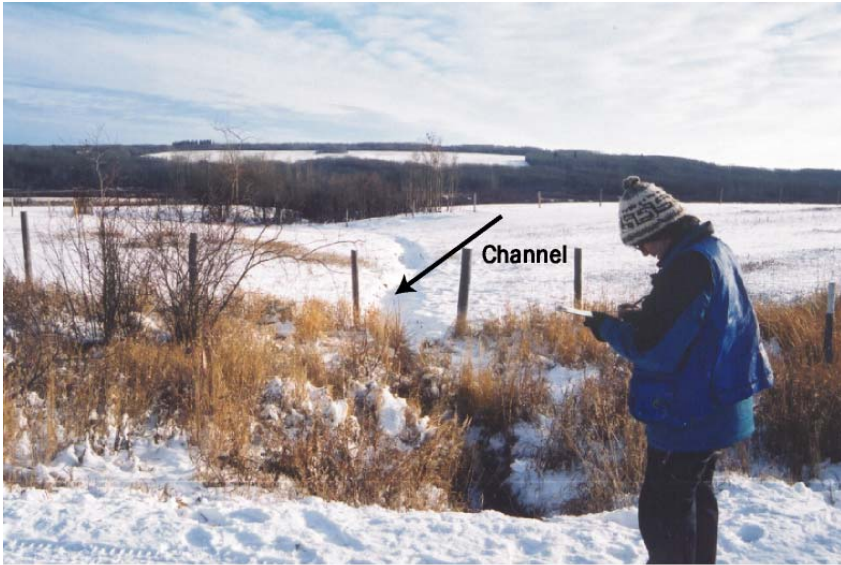


Plate 8. View of channel downstream of road. Note that the channel is not as well defined upstream of the road. Road runoff in combination with lack of riparian vegetation seems to carry enough energy to maintain channel during freshet and rainy periods (November 11/2002).



Plate 9. View of culvert outlet downstream of road. Note that channel is deeply entrenched immediately downstream of road (indicating that there is periodically scouring flows) (November 11/2002).



Plate 10. Culvert inlet upstream of road (November 11/2002).



Plate 11. View upstream of road. Note that channel is not clearly defined. Remnant downstream channel likely just carries melt and rain waters and ditch runoff. Note erosion in ditchline (November 11/2002).

## **CROSSING NO. 4 (DESCRIPTION)**

PART 1. WEST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 4  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 27.410'N 121° 08.238'W  
Assessment Date: November 11/2002  
Assessment Time: 09:32 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 18.5 m  
Culvert Diameter: 2 m  
Perching: Culvert not perched at upstream end, but perched very slightly at downstream end

### **Channel Conditions:**

The average channel width was 1.47 m upstream of the road and 2.73 m downstream of the road. There was a scour hole immediately downstream of the culvert with a maximum length of 16 m and a maximum width of 5.6 m, indicating that there has been substantial downstream sediment movement during runoff events. There was fencing wire running across the upstream end of the culvert with flood debris hanging off of it, indicating that there are considerable amounts of water in the channel seasonally. There was slumping resulting from scour and/or saturation in behind the upstream end of the culvert. There was exposed soil in ditchlines, suggesting that ditches may be contributing sediment to the channel during runoff events. There were several areas downstream of the road that were deeply undercut and providing sediment to the channel as a result of scouring and slumping.

### **Riparian Vegetation:**

The channel immediately upstream of the road had a riparian community of grasses, herbs and shrubs that were dense enough to contribute to channel stability, but were providing little in the way of over-channel cover. Trees increased over-channel cover and channel stability upstream of the immediate influence of the road and ditchline (tree line began about 20-m upstream of road). Similarly, the riparian vegetation was not providing sufficient rooting mass immediately downstream of the road to prevent the formation of a large scour hole.

### **Water Quality Concerns:**

The presence of a large scour hole immediately downstream of the channel and the observed pattern of channel widening downstream of road suggests that the crossing is contributing to downstream sediment movement towards the lake. The riparian vegetation immediately upstream and downstream of the road was not providing sufficient armouring against soil erosion and slumping.

### **Priority:**

High Priority – This is a major tributary to Charlie Lake and there is evidence of substantial sediment movement downstream of the road (see channel undercutting, scour hole and slump zones downstream of road). Culvert perching does not appear to be the primary cause of downstream erosion, but it is possible that the culvert diameter is too small to carry stream flows effectively during periods of high runoff. This site has excellent restoration potential.



Plate 12. View of culvert inlet upstream of road. Note the flood debris hanging on the fence wire that crosses the culvert (indicates periodic high flows). Also note the slumping behind the culvert (evidence that accumulating water is saturating banks) (November 11/2002).



Plate 13. Right-of-way that runs parallel with the main road; photo taken approximately 75 m downstream of the main road (November 11/2002).



Plate 14. View of culvert outlet downstream of road. Note the large scour hole immediately downstream of the culvert (evidence of sediment movement) (November 11/2002).



Plate 15. Large bank slumping approximately 40 m downstream of road (November 11/2002).



Plate 16. Bank undercutting in scour hole immediately downstream of culvert (November 11/2002).

## **CROSSING NO. 5 (DESCRIPTION)**

PART 1. WEST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 5  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 27.268'N 121° 06.649'W  
Assessment Date: September 17/2002  
Assessment Time: 16:15 hrs

### **Crossing Description:**

Crossing Type: Wooden bridge (creosote treated pylons)  
Bridge Width: 7.3 m  
Sediment on Bridge Deck: Low  
Turbidity Upstream Crossing: 32 NTU  
Turbidity Downstream Crossing: 32 NTU

### **Channel Conditions:**

The average channel width upstream of the bridge was 7.5 m, with the average downstream width being the same. A beaver dam has been constructed upstream of the bridge relatively recently, resulting in the formation of an upstream beaver pond. There was some channel slumping downstream of the bridge, but this slumping was more likely the result of bank saturation and lack of riparian vegetation than the bridge itself. In general, bridges in the Charlie Lake watershed appear to have relatively little impact on stream morphology in comparison to culvert-type crossings.

### **Riparian Vegetation:**

The riparian community on the right bank upstream and on the left bank downstream of the bridge consisted of grasses, herbs and shrubs. However, the community was primarily composed of just grasses and herbs on the left bank upstream of the bridge and on the right bank downstream of the bridge. The riparian vegetation was providing very little in the way of over-channel cover and only minimally to channel stability in the immediate vicinity of the road.

It appears that the riparian vegetation in the vicinity of the bridge may be more affected by livestock than by the bridge itself. This area may be a good site for a pilot planting/fencing project to increase riparian function – it is easily accessible and we believe there would be a high probability of success.

### **Water Quality Concerns:**

The bridge itself is probably having minimal affects on water quality. However, as indicated above, riparian function could be improved through a combination of planting and fencing. A potential site for a pilot restoration project.

### **Priority:**

Moderate Priority – The crossing is having minimal affects on water quality; however, riparian function immediately upstream and downstream of the road is not ideal in terms providing over-channel cover or channel stability. The lack of over-channel riparian cover may make the stream susceptible to changes in temperature and decrease the amount of organic material reaching the stream (e.g., leaf and insect fall). As indicated, this would be a great site for a community-based pilot restoration project.

**CROSSING NO. 5 (PHOTODOCUMENTATION)**

*PART 1. WEST STODDART CREEK SUB-BASINS*



Plate 17. Beaver dam upstream of road. Beaver dams can reduce sediment loads by creating depositional zones, but scour can be enhanced when dams are breached (September 17/2002).

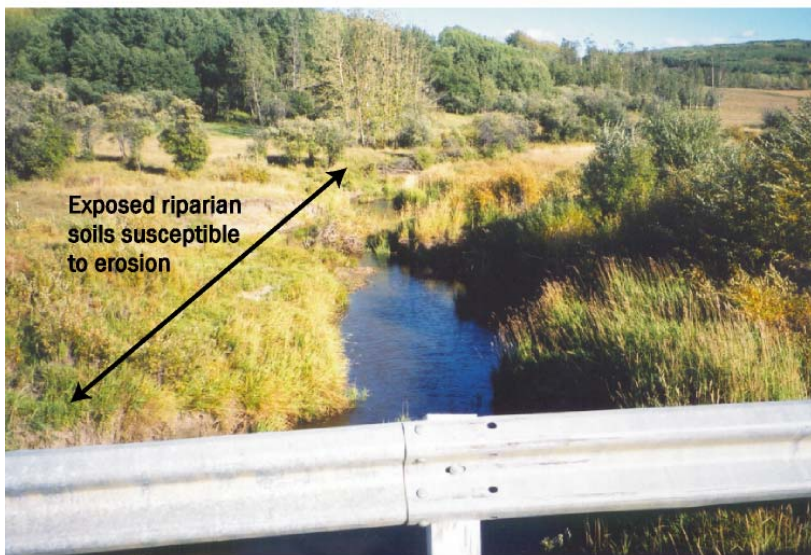


Plate 18. View of channel downstream of bridge. Note that riparian shrubs and grasses are helping to stabilise the channel, but that there are still areas where soils are exposed and slumping (September 17/2002).

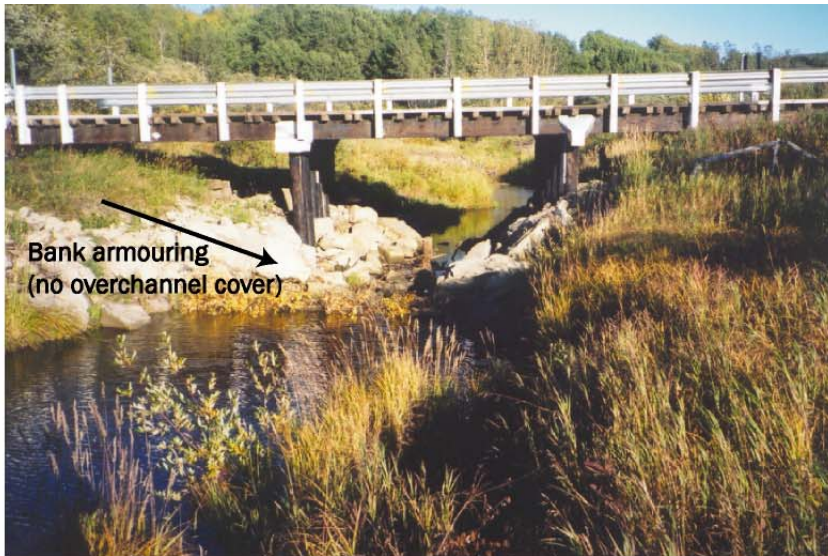


Plate 19. View of channel looking downstream. Note that rock has been used to reduce soil erosion (September 17/2002).



Plate 20. Grasses downstream of road are helping to reduced erosion, but rooting systems are not deep enough to completely eliminate slumping caused by soil saturation. Ideally, the riparian community would be composed of a community of both shrubs and grasses (September 17/2002).



Plate 21. View downstream of road looking upstream (September 17/2002).

## **CROSSING NO. 6 (DESCRIPTION)**

*PART 1. WEST STODDART CREEK SUB-BASINS*

### **Crossing Location:**

Crossing Identification No.: 6  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 27.127'N 121° 06.657'W  
Assessment Date: September 17/2002  
Assessment Time: 17:20 hrs

### **Crossing Description:**

Crossing Type: Steel culvert  
Culvert Length: 9.3 m  
Culvert Diameter: 1.2 m  
Perching: The culvert was not perched at the upstream end or at the downstream end  
Turbidity Upstream Crossing: 17.4 NTU

### **Channel Conditions:**

The average channel width was 1.9 m downstream of the road. There was a small beaver pond upstream of the road that is about 5 m wide. There was no evidence of significant channel erosion.

### **Riparian Vegetation:**

As shown in the photographs, the channel had substantial over-channel riparian cover in the vicinity of the road (dense shrub growth). The riparian vegetation was also providing stability against sediment movement. The dense over-channel shrub growth shows the potential for good riparian function in the Charlie Lake watershed.

### **Water Quality Concerns:**

There was no notable water quality concerns at this crossing.

### **Priority:**

Low Priority – As indicated above, this crossing shows that there is potential for substantial riparian cover and function in the Charlie Lake watershed.



Plate 22. Stream channel immediately downstream of road. Note heavy growths of riparian shrubs and grasses that provide protection against erosion and over channel cover (September 17/2002).



Plate 23. View of channel upstream of road. Note dense overchannel shrub coverage that contributes to channel stability (September 17/2002).



Plate 24. View of culvert outlet downstream of road. Note that the culvert outlet is compressed to channel bottom, i.e., it is not perched (September 17/2002).



Plate 25. Culvert inlet upstream of road. Note that the bottom of the culvert is flush with the bottom of the channel. Also note the leaf litter floating in the stream; leaf litter is an important source of energy to stream ecosystems and is largely contributed by riparian vegetation.

## **CROSSING NO. 7 (DESCRIPTION)**

PART 1. WEST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 7  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 27.005'N 121° 06.478'W  
Assessment Date: September 17/2002  
Assessment Time: 14:36 hrs

### **Crossing Description:**

Crossing Type: Wooden bridge (creosote treated pylons)  
Bridge Width: 7 m  
Sediment on Bridge Deck: Low  
Turbidity Upstream Crossing: 25 NTU  
Turbidity Downstream Crossing: 26

### **Channel Conditions:**

Channel widths ranged from 5 to 9 m upstream and downstream of the bridge. The ditchline on the left side of the channel downstream of the bridge was contributing sediment to the channel. There was little or no evidence that the bridge itself is having an affect on water quality.

### **Riparian Vegetation:**

The riparian community upstream of the road was composed primarily of grasses and herbs, whereas the downstream community in the vicinity of the road was a mixture of grasses, herbs, shrubs and trees. The riparian community downstream of the crossing was providing moderate levels of over-channel cover, where the upstream riparian vegetation was providing little in the way of over-channel cover.

While there was little evidence that the stream crossing itself was having an affect on water quality or riparian function, there was evidence that livestock have caused substantial damage to riparian function both upstream and downstream of the bridge (see photodocumentation). This site would be a good candidate location for a riparian restoration project to improve function by planting and fencing. There is easy access and a high probability of success.

### **Water Quality Concerns:**

There were no substantial water quality concerns regarding the bridge itself. However, there has been considerable damage to the riparian zone by livestock both upstream and downstream of the bridge such that riparian vegetation has been either flattened or completely removed, leaving behind easily-eroded exposed soils.

### **Priority:**

Moderate Priority – While the crossing itself was likely having a negligible effect on water quality, exposed soils upstream and downstream of the bridge resulting from livestock access to the channel have potential to contribute sediment, nutrient and bacterial loads to the stream, particularly during rain and snow-melt events. As indicated above, this site would be a candidate location for a pilot community-based restoration project.

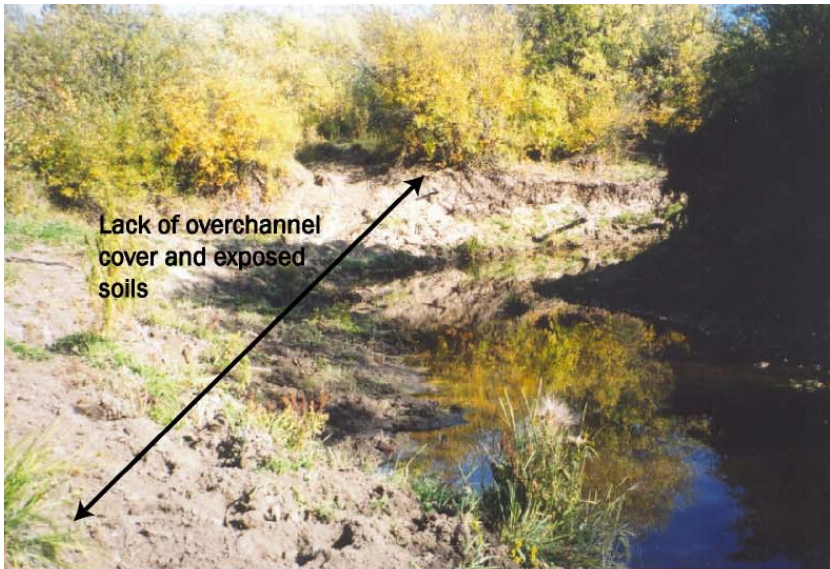


Plate 26. Exposed riparian soils upstream of road that are contributing sediment to the stream. Evidence indicates that the riparian damage was done by livestock; good potential for restoration (September 17/2002).

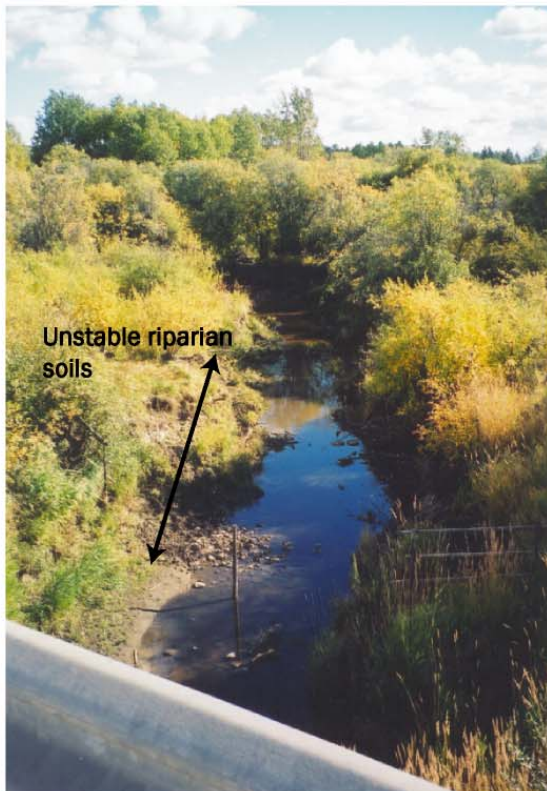


Plate 27. View of channel downstream of bridge. Note that riparian shrubs and grasses are providing protection against soil erosion and substantial over channel cover (September 17/2002).



Plate 28. View of channel upstream of road. Note that riparian grasses are providing some protection against soil erosion, but little in the way of over channel cover and the hayfield encroachment on left bank (September 17/2002).



Plate 29. View downstream of bridge. Note the presence of large boulders used to protect channel from erosion (September 17/2002).

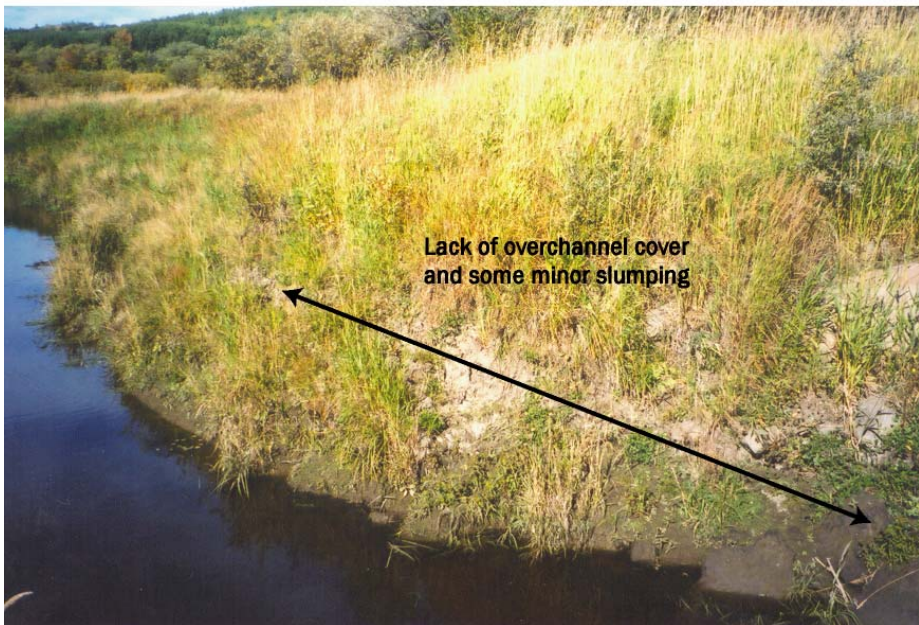


Plate 30. Bank slumping immediately upstream of road. The riparian grasses appear to be controlling much of the potential erosion; however, a mixture of shrubs and grasses would enhance the riparian areas ability to slow sediment transport (September 17/2002).

## **CROSSING NO. 8 (DESCRIPTION)**

PART 1. WEST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 8  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 26.989'N 121° 09.568'W  
Assessment Date: November 11/2002  
Assessment Time: 14:11 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert (slightly crushed/compressed)  
Culvert Length: 12.5 m  
Culvert Diameter: 1.3 m  
Perching: The bottom of the upstream end of the culvert was flush to the bottom of the channel (not perched); however, the downstream end of the culvert was perched 0.91 m above the ice surface

### **Channel Conditions:**

The channel was not well defined upstream of the road. Upstream of the road was characterised by low-lying depressions that hold water during snowmelt and rainy periods. These depressions likely contribute to downstream flows only during wet periods. The average channel width downstream of the road was 2.08 m. As indicated, the channel likely carries water only during seasonal rainy or snowmelt period when upstream depressions are saturated and when ditches are transporting runoff waters.

The scour hole downstream of the road (see photodocumentation) had a maximum length of 6 m and a maximum width of 4 m. The presence of the scour hold indicates that there is sufficient flows and sufficient energy (resulting from perched culvert) to result in downstream sediment movement.

### **Riparian Vegetation:**

The riparian community downstream of the road was composed of a dense mixture of grasses, herbs, shrubs and trees that were providing substantial over-channel cover and was of sufficient density to minimise channel bank erosion (very little in the way of exposed soil). As indicated above, the channel was poorly defined upstream of the road, but there was substantial growths of grasses and shrubs growing between depressions.

### **Water Quality Concerns:**

As suggested above, the only observed crossing-related erosion was taking place immediately downstream of the culvert, in the scour hole. Downstream of the scour hole, the channel had a dense protective riparian zone composed of grasses, herbs, shrubs and trees and was thus not particularly susceptible to the erosional forces of water.

### **Priority:**

Low to Moderate Priority – As viewed from the crossing, the channel had a well-functioning riparian zone that was contributing both stability and woody debris to the channel. The only notable problem at the crossing was that the downstream end of the culvert was severely perched above the bottom of the channel. But, given the rooting density of the downstream riparian zone, erosion appears to have been limited to the area directly below the culvert outlet.



Plate 31. View downstream of road. Note that there is a scour hole directly downstream of the perched culvert but the channel has substantial riparian tree and shrub cover downstream of the immediate road impact (November 11/2002).

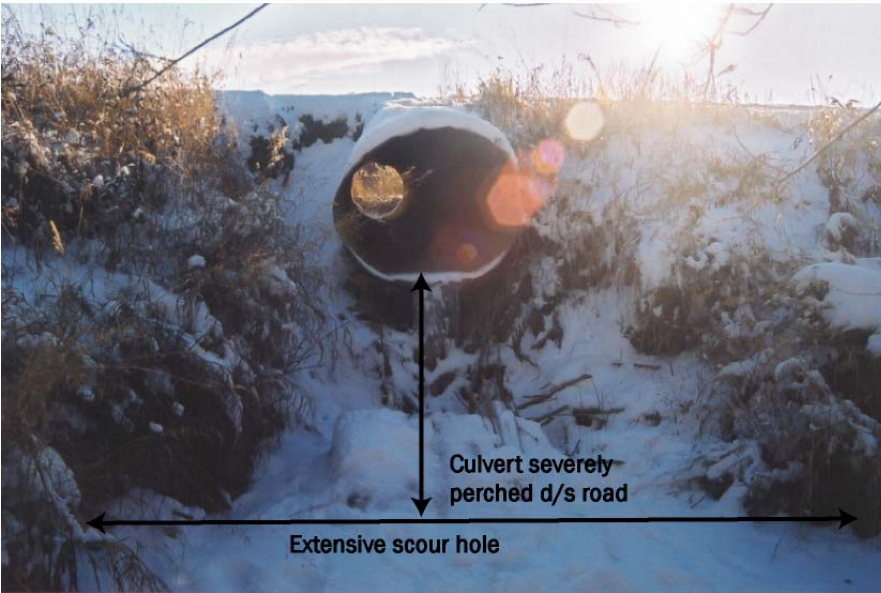


Plate 32. View of culvert outlet downstream of road. Note that the culvert is severely perched and that there is a wide scour hole (November 11/2002).



Plate 33. View of culvert upstream of road (November 11/2002).



Plate 34. The channel is poorly defined upstream of the road. The upstream area is characterised by many small depressions that likely hold water during spring melt and rainy periods. These depressions supply water to downstream flows (November 11/2002).

**CROSSING NO. 9 (DESCRIPTION)***PART 1. WEST STODDART CREEK SUB-BASINS***Crossing Location:**

Crossing Identification No.: 9  
Sub-Basin: West Stoddart Creek  
Site Co-ordinates: 56° 25.270'N 121° 05.489'W  
Assessment Date: November 11/2002  
Assessment Time: 10:21 hrs

**Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 17 m  
Culvert Diameter: 0.6 m  
Perching: The culvert was not perched at the upstream end, but was perched 0.28 m at the downstream end

**Channel Conditions:**

The channel was not clearly defined upstream or downstream of the road. It appears that the primary function of the culvert was to drain the road ditches, as opposed to draining a stream channel.

**Riparian Vegetation:**

As indicated above, there was not a defined channel at this location.

**Water Quality Concerns:**

Given that there does not appear to be a defined channel at this location, the crossing likely has negligible affects on water quality. There was evidence that water pools and accumulates in the ditches parallel to the road during runoff events and that this pooling was resulting in soil saturation and slumping in the ditches; however, given the lack of a definite channel, this slumping is more of a road issue than a water quality issue.

**Priority:**

Low Priority – Any sediment movement resulting from this crossing is likely having negligible effects on water quality.



Plate 35. Downstream view of channel (November 12/2002).



Plate 36. View of culvert inlet immediately upstream of road (November 12/2002).



Plate 37. Downstream right-of-way road that runs parallel to the main road. The road is about 10 m wide (November 12/2002).



Plate 38. Ditchline on both upstream and downstream sides of the road are susceptible to saturation and slumping (poorly drained) (November 12/2002).

## **CROSSING NO. 10 (DESCRIPTION)**

PART 2. EAST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 10  
Sub-Basin: East Stoddart Creek  
Site Co-ordinates: 56° 28.746'N 121° 04.087'W  
Assessment Date: September 16/2002  
Assessment Time: 16:00 hrs

### **Crossing Description:**

Crossing Type: Dual corrugated steel culverts (one large diameter/one small diameter)  
Culvert Length: 12.4 m  
Culvert Diameter: 1.5 m  
Perching: Neither culvert was perched at the downstream end; small diameter culvert was perched 0.15 m above the channel bottom at its upstream end; large culvert was perched 0.20 above the channel bottom at its upstream end

### **Channel Conditions:**

The average channel widths upstream and downstream of the road were 19 m and 18 m, respectively (wide, low-gradient channel).

### **Riparian Vegetation:**

The riparian community upstream of the road was primarily composed of herbs and grasses and was providing little in the way of over-channel cover, but it did seem to be providing sufficient rooting mass to protect the channel from erosion. The riparian community downstream of the road was composed mainly of grasses and shrubs intermixed with trees. The downstream riparian community was providing moderate amounts of over-channel cover and appeared to be protecting the channel from erosion. However, there were patches of exposed soil immediately downstream of the road that were visibly contributing sediment to the water.

### **Water Quality Concerns:**

The perching of the culverts on the upstream side of the road may be causing water to backup and pool upstream of the road. Given that there was little over-channel cover upslope of the road, such pooling may effectively increase evaporation rates and decrease downstream flows. Reductions in downstream flows may have some affect on flushing rates in East Stoddart Creek and in Charlie Lake; however, this is hypothesis is speculative.

### **Priority:**

Low to Moderate – the upstream ends of the culverts should be lowered so that their bases are flush with the bottom of the channel (will decrease any upstream pooling and improve downstream flushing).



Plate 39. Channel downstream of road. Channel has fairly substantial riparian cover downstream of immediate crossing impacts (September 16/2002).



Plate 40. View upstream of road. Grasses appear to be providing protection from erosion (September 16/2002).



Plate 41. View of culvert downstream of road. Note highly turbid water (evidence of sediment transport) (September 16/2002).

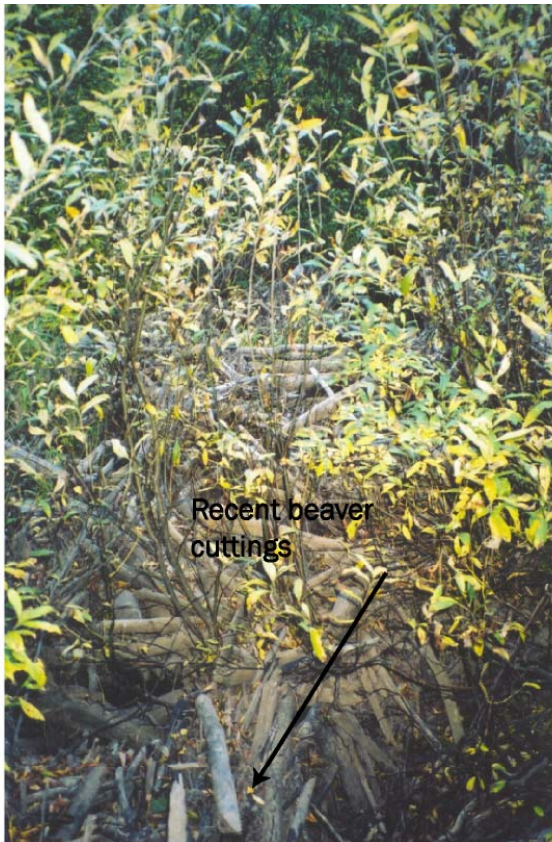
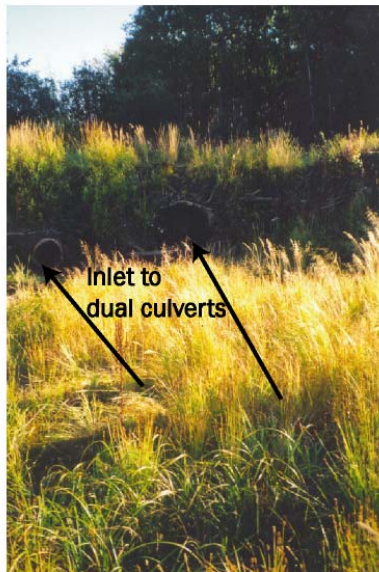


Plate 42. Channel downstream of crossing. Note that overchannel riparian cover is significant downstream of immediate road impact (September 16/2002).



Plate 43. Extreme turbidity downstream of road. Note channel bank erosion (September 16/2002).

Plate 44. Dual culverts upstream of road. Note that dense grass growth is providing protection from erosion (very little bare soil observed) (September 16/2002).



## **CROSSING NO. 11 (DESCRIPTION)**

PART 2. EAST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 11  
Sub-Basin: East Stoddart Creek  
Site Co-ordinates: 56° 27.336'N 121° 03.798'W  
Assessment Date: September 17/2002  
Assessment Time: 10:06 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 19 m  
Culvert Diameter: 1.5 m  
Perching: Culvert was not perched at the downstream end; culvert perched 0.05 m above the channel bottom at the upstream end  
Turbidity Upstream Crossing: 22 NTU  
Turbidity Downstream Crossing: 20 NTU

### **Channel Conditions:**

The average channel widths upstream and downstream of the culvert were 11.8 m and 10.0 m, respectively. Ditch on upstream east side appears to backflood with water causing bank saturation and slumping. There was evidence that soil had been excavated from channel and piled on banks. There was a large scour hole immediately downstream of road.

### **Riparian Vegetation:**

The riparian vegetation on both sides of the road has been severely damaged from the combined affects of human and livestock activities. There were stream segments on both side of the road that had excellent over-channel shrub cover and good bank stability, indicating that this site has very good restoration potential. As can be seen clearly in the photodocumentation, there was excessive amounts of exposed soil at this crossing. Given the easy access to this site, the location has excellent potential for a community-based restoration project.

### **Water Quality Concerns:**

As suggested above, the excessive amounts of exposed soils at this crossing are clearly supplying sediment to the stream and, eventually, to Charlie Lake. This site has excellent potential to be successfully restored through planting and fencing – a potential community-based restoration project that has a high probability of success.

### **Priority:**

High Priority – The excessive amounts of exposed soil at this location are undoubtedly contributing to downstream sediment loads, particularly during rainy periods (excellent restoration potential).



Plate 45. View of culvert outlet downstream of road (September 17/2002).



Plate 46. Saturated and exposed soils downstream of road are highly erodable and contribute sediment loads to stream (September 17/2002).



Plate 47. Exposed riparian soils upstream of road where introducing shrubs and grasses will reduce sediment loading to stream (September 17/2002).

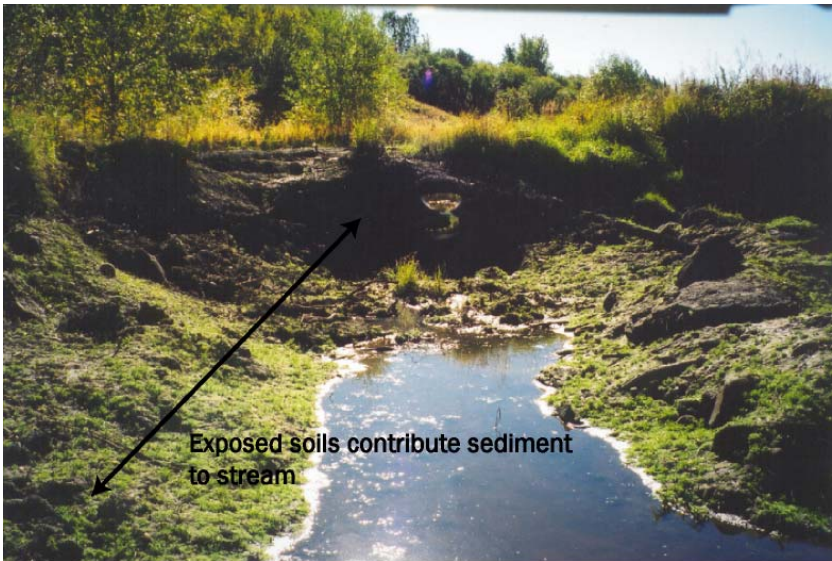


Plate 48. View of channel immediately upstream of road showing lack of riparian protection and exposed soils. Planting shrubs in this reach will stabilise soils and provide over channel cover (September 17/2002).

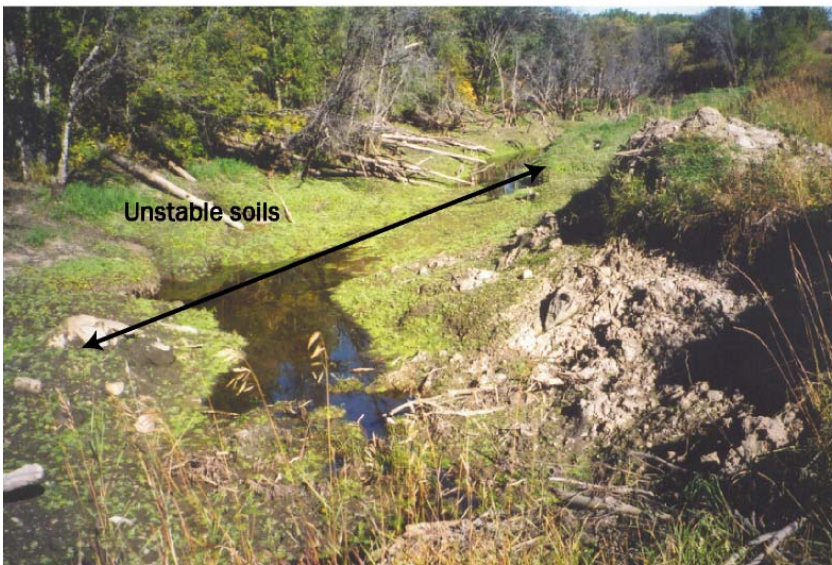


Plate 49. View of channel immediately upstream of road. Note exposed soils in riparian area and general lack of over channel vegetation (very little protection against erosion) (September 17/2002).

## **CROSSING NO. 12 (DESCRIPTION)**

PART 2. EAST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 12  
Sub-Basin: East Stoddart Creek  
Site Co-ordinates: 56° 27.005'N 121° 03.296'W  
Assessment Date: September 17/2002  
Assessment Time: 12:11 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 21 m  
Culvert Diameter: 2.4 m  
Perching: The culvert was flush to channel on both sides of the road (i.e., not perched)  
Turbidity Upstream Crossing: 7 NTU  
Turbidity Downstream Crossing: 21 NTU

### **Channel Conditions:**

The average culvert width was 5.0 m upstream of the road and 5.5 m downstream of the road. Although the channel was slightly widened immediately downstream of the road, there was not an obvious scour hole created by the crossing.

### **Riparian Vegetation:**

The riparian communities upstream and downstream of the road were composed of a fairly dense mixture of grasses, herbs and shrubs that, in places, provided moderate levels of over-channel cover. There was a small area immediately downstream of the road where the riparian vegetation was thin, and this may be a suitable test site for riparian planting.

### **Water Quality Concerns:**

Although there was evidence of some sediment instability at this crossing (i.e., immediately downstream of the road), there appears to be sufficient riparian cover to buffer affects of road.

### **Priority:**

Moderate Priority – The site immediately downstream of the road may provide a suitable test location for riparian planting.



Plate 50. View of channel downstream of road. Note that water is highly turbid (evidence of sediment transport) (September 17/2002).



Plate 51. View of channel upstream of road. Note that there is some exposed riparian soil, but riparian shrubs and grasses are of sufficient density to provide substantial cover and soil stability (September 17/2002).

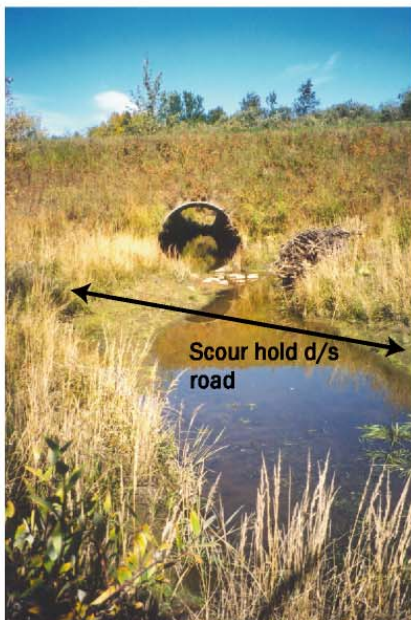


Plate 52. View of culvert downstream of road. Exposed soils immediately downstream of culvert will contribute sediment to stream (restoration opportunity) (September 17/2002).



Plate 53. Inlet of culvert upstream of road. Note that bottom of culvert is flush with the bottom of the channel (not perched) and that large rocks have been used to stabilise soils at the road (September 17/2002).



Plate 54. Channel immediately downstream of road is protected from erosion by a dense mixture of grasses, shrubs and dead woody debris (September 17/2002).

## **CROSSING NO. 13 (DESCRIPTION)**

PART 2. EAST STODDART CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 13  
Sub-Basin: East Stoddart Creek  
Site Co-ordinates: 56° 26.296'N 121° 03.293'W  
Assessment Date: September 17/2002  
Assessment Time: 13:20 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 12 m  
Culvert Diameter: 2.5 m  
Perching: Culvert was not perched at either of the upstream or downstream ends  
Turbidity Upstream Crossing: 17 NTU  
Turbidity Downstream Crossing: 17 NTU

### **Channel Conditions:**

The average channel width downstream of the culvert was 5.5 m, with the average upstream channel width being 4.5 m. There was not a major scour hole downstream of the culvert.

### **Riparian Vegetation:**

The upstream and downstream riparian communities were composed of a mixture of grasses, herbs and shrubs. The riparian community was not providing much in the way of over-channel cover upstream of the road; however, over-channel cover was moderate downstream of the road. Overall, the riparian community appears to be of sufficient density to provide good levels of channel stability; with the exception of the upstream left bank where an ancillary road has encroached into the riparian zone. A pilot project to re-establish riparian vegetation along the ancillary road could be undertaken and should have a relatively high probability of success.

### **Water Quality Concerns:**

The crossing itself was not likely having significant affects on water quality. The riparian belt running parallel to the upstream ancillary road was intermittent (i.e., some exposed soils) and thin in terms of vegetation density. The road itself is likely contributing sediment to the stream during wet periods. As indicated above, a pilot project could be undertaken here to re-establish the riparian vegetation along the ancillary road.

### **Priority:**

Low to Moderate – As indicated, the road crossing itself is probably not relevant in terms of water quality affects. However, the site is a good location for a pilot project to re-vegetate the riparian belt that runs parallel to the ancillary road. Good restoration potential in terms of access and public demonstration.



Plate 55. View of channel immediately downstream of road. Note that grasses and shrubs are stabilising riparian soils and, thereby, reducing potential sediment load (September 17/2002).



Plate 56. View of channel upstream of road. Riparian shrubs and grasses are providing some protection from erosion (September 17/2002).



Plate 57. Culvert downstream of road showing upstream fields and riparian shrubs (September 17/2002).



Plate 58. Downstream view of channel showing side road. The riparian protection running parallel to the road is providing some bank protection; however, the riparian belt is intermittent and not providing much in the way of over channel cover (September 17/2002).

## **CROSSING NO. 14 (DESCRIPTION)**

PART 3. COFFEE CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 14  
Sub-Basin: Coffee Creek  
Site Co-ordinates: 56° 23.626'N 121° 05.075'W  
Assessment Date: September 19/2002  
Assessment Time: 18:09 hrs

### **Crossing Description:**

Crossing Type: Dual corrugated steel culverts  
Culvert Length: Both are 30 m  
Culvert Diameter: One was 0.9 m and the other was 0.6 m  
Perching: Only one of the culverts was visible upstream of the road, and it was perched 0.2 m above the channel bottom; large diameter culvert was perched 0.68 m above the channel at the downstream end; small diameter culvert was perched 0.90 m above the channel bottom at the downstream end  
Turbidity Upstream Crossing: 10 NTU  
Turbidity Downstream Crossing: 16 NTU

### **Channel Conditions:**

The average channel width downstream of the culverts was 6 m, with the average channel width upstream of the culverts being 7.9 m. There was a relatively small scour hole immediately downstream of the culverts. There was substantial amounts of small woody debris (beaver cuttings) in the channel upstream of the road. Debris may have accumulated upstream of the road as a result of one of the culverts being blocked at the upstream end and the other being perched (i.e., insufficient drainage).

### **Riparian Vegetation:**

The riparian community upstream of the road was composed primarily of grasses and herbs, and was not providing much in the way of over-channel cover and it was not of sufficient density to provide protection against channel erosion (i.e., substantial amounts of exposed soil was observed). There was evidence that livestock have access to the channel upstream of the road, as shown by the flattened and sparse riparian vegetation. There was comparatively more over-channel shrub coverage downstream of the road and was contributing to channel stability. It appears that the riparian community upstream of the road may be periodically flooded, probably a result of upstream culvert blocking and perching.

### **Water Quality Concerns:**

Exposed soils in heavy-machinery tracks were likely contributing sediment to the stream during wet periods. Upstream culvert perching and blockage may result in upstream ponding during wet periods and this may increase evaporation rates and slow downstream flushing. Livestock have clearly had access to the channel upstream of the road, as evidenced by damaged riparian community. This site would be an ideal location for a pilot restoration project (riparian planting, fencing and culvert repair).

### **Priority:**

Moderate Priority – Riparian planting, fencing and culvert repairs would improve channel flushing at this location (a good place for a pilot project).

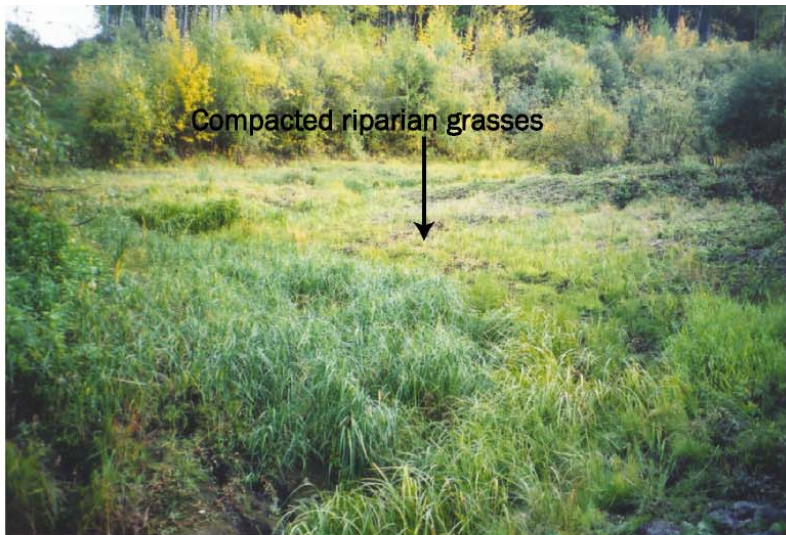


Plate 59. Area immediately upstream of road where livestock have compacted riparian vegetation. Although there is evidence of compaction, the remaining grasses appear to be protecting soils from erosion (very little exposed soil) (September 19/2002).

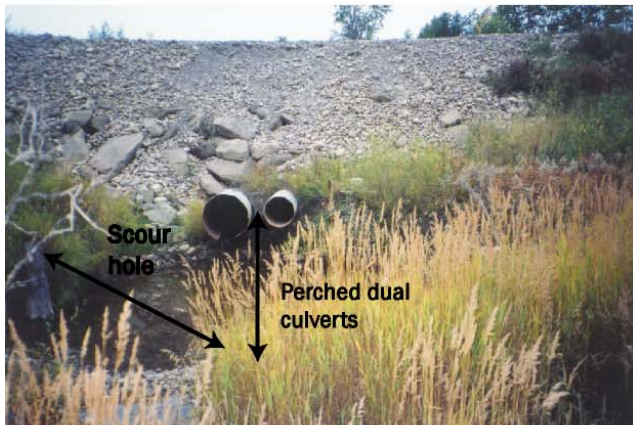


Plate 60. Downstream ends of dual culverts. Note that they are perched well-above the channel; however, riparian grasses and shrubs appear to be minimising the extent of downstream scouring.

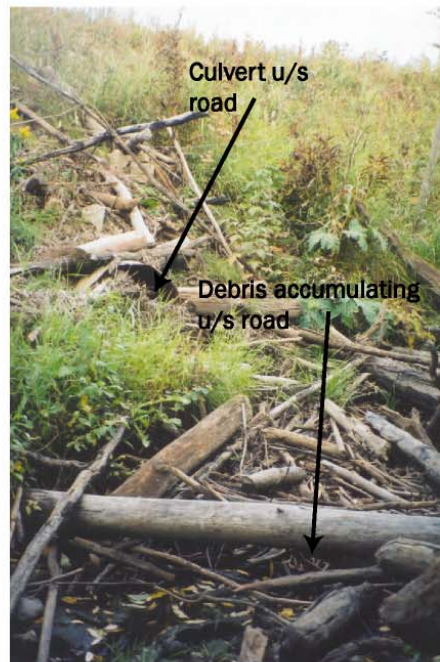


Plate 61. Culvert upstream of road. Note that debris has accumulated upstream of culvert (September 19/2002).



Plate 62. Downstream view of channel. Note that riparian shrubs and trees are providing stability to channel banks (September 19/2002).



Plate 63. Channel immediately downstream of road. Note that riparian shrubs and grasses are contributing to channel bank stability (September 19/2002).

## **CROSSING NO. 15 (DESCRIPTION)**

PART 3. COFFEE CREEK SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 15  
Sub-Basin: Coffee Creek  
Site Co-ordinates: 56° 23.536'N 121° 4.947'W  
Assessment Date: September 20/2002  
Assessment Time: 16:35 hrs

### **Crossing Description:**

Crossing Type: Dual culverts – one corrugated steel, and the other smooth steel  
Culvert Length: Both were 35 m  
Culvert Diameter: Corrugate steel was 0.8 m; smooth was 0.65 m  
Perching: Both culverts were flush to the soil at the upstream end; the corrugated steel culvert was perched 0.53 m above the channel bottom at the downstream end; the smooth steel culvert was perched 0.8 m above the channel bottom at the downstream end  
Turbidity Upstream Crossing: 21 NTU  
Turbidity Downstream Crossing: 17 NTU

### **Channel Conditions:**

The average channel widths upstream and downstream of the road were 2.5 m. There was a substantial scour hole immediately downstream of the culvert outlets, indicating that the crossing is resulting in downstream sediment movement.

### **Riparian Vegetation:**

The upstream and downstream communities were composed of a fairly dense mixture of grasses, herbs and shrubs and appear to be providing reasonable protection from erosion and sediment transport. However, the riparian communities were not providing much in the way of over-channel cover. There was substantial amounts of eroding exposed soil immediately upslope of the scour hole (see photodocumentation). Water tracks in these exposed soils are evidence that sediment was moving during wet periods. Increases in water energy resulting from downstream culvert perching has contributed to sediment transport. This would be an excellent restoration opportunity in terms of demonstrating how riparian stability can be enhanced at road crossings affected by culverts.

### **Water Quality Concerns:**

Sediment movement downstream of the road resulting from culvert perching and lack of protective vegetation is resulting in downstream sediment movement.

### **Priority:**

High Priority – work needs to be done at this site to reduce the effects of culvert perching and exposed soils. A great restoration demonstration site.

**CROSSING NO. 15 (PHOTODOCUMENTATION)**

*PART 3. COFFEE CREEK SUB-BASINS*



Plate 64. Channel upstream of road. Shrubs and grasses appear to be protecting the channel from erosion upstream of immediate impacts of road (September 20/2002).



Plate 65. Culvert opening upstream of road. Note that grasses are providing stability to the soil relative to downstream of the road (September 20/2002).



Plate 66. Dual Culverts downstream of road. Note extensive erosion and culvert perching (September 20/2002).



Plate 67. Channel downstream of road showing extensive and severe erosion. Note that the water downstream of the culvert outlet appears to have high turbidity; evidence of sediment transport (September 20/2002).

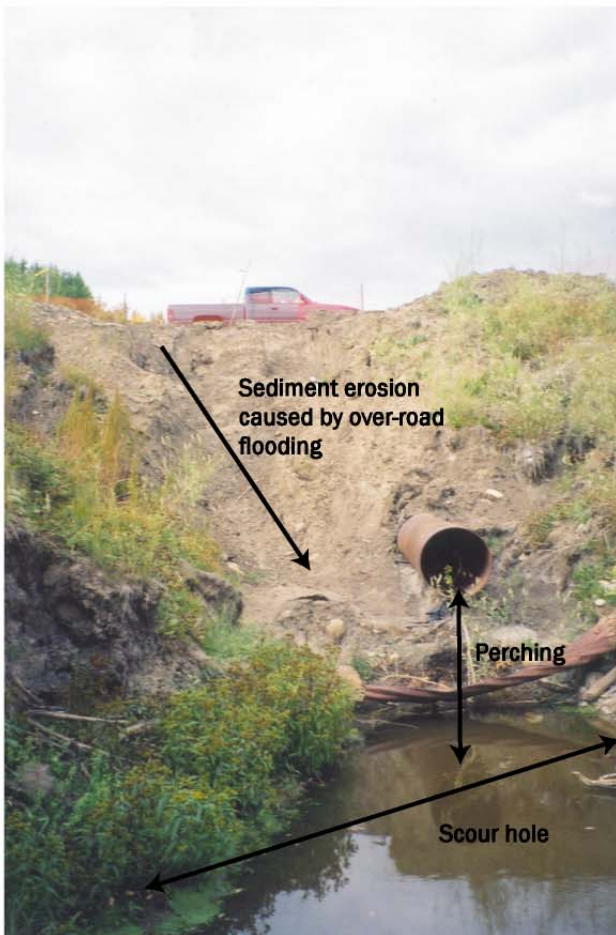


Plate 68. View of culvert downstream of road showing extensive sediment erosion (September 20/2002).

## **CROSSING NO. 16 (DESCRIPTION)**

*PART 3. COFFEE CREEK SUB-BASINS*

### **Crossing Location:**

Crossing Identification No.: 16  
Sub-Basin: Coffee Creek  
Site Co-ordinates: 56° 22.884'N 121° 05.087'W  
Assessment Date: November 12/2002  
Assessment Time: 09:15 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 19 m  
Culvert Diameter: 0.9 m  
Perching: The upstream end of the culvert was perched 0.21 m above the channel bottom; the downstream end was perched 1.3 m above the channel bottom

### **Channel Conditions:**

The channel was not clearly defined upstream of the road. The culvert appears to be primarily moving drainage from road ditches, as opposed to draining a stream channel. There was some channelisation extending for about 50 m downstream of the road; however, the channel was likely formed from road drainage that was provided energy from the perched culvert. The channel was not defined further past 50 m downstream of the road. As shown in the photodocumentation, there was evidence of some backflooding in ditchlines and soil saturation resulting in slumping. However, this is more of a road stability issue than a water quality issue.

### **Riparian Vegetation:**

As indicated above, there was not a true stream channel at this location. The area was characterised by dense shrub and tree coverage.

### **Water Quality Concerns:**

While there was evidence of soil saturation and slumping in ditchlines, we do not feel that this crossing has any influence on downstream water quality.

### **Priority:**

Low Priority – The issues at this crossing were only relevant to road stability, not to water quality.



Plate 69. Back flooding upslope of road is resulting in soil saturation and slumping (November 12/2002).



Plate 70. View of culvert downstream of road. Note that the culvert is perched (November 12/2002).

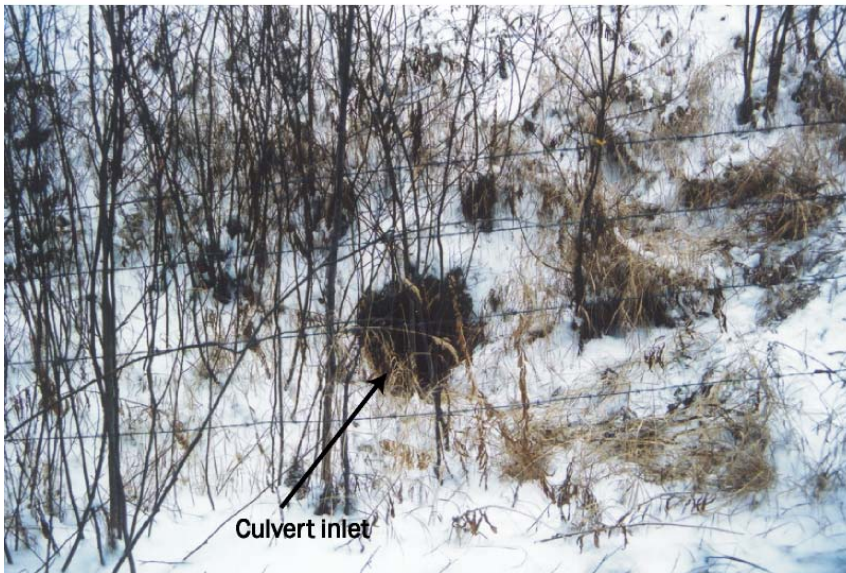


Plate 71. Ditchline is unstable on downstream side of road (resulting from poor drainage and soil saturation (November 12/2002).



Ditchline made unstable by soil saturation

Plate 72. Ditchline is unstable on upslope side of road (slumping is a result of backflooding and soil saturation) (November 12/2002).



Culvert inlet

Plate 73. View of culvert inlet upstream of road (November 12/2002).

## **CROSSING NO. 17 (DESCRIPTION)**

*PART 3. COFFEE CREEK SUB-BASINS*

### **Crossing Location:**

Crossing Identification No.: 17  
Sub-Basin: Coffee Creek  
Site Co-ordinates: 56° 22.471'N 121° 05.067'W  
Assessment Date: September 19/2002  
Assessment Time: 17:28 hrs

### **Crossing Description:**

Crossing Type: Dual corrugated steel culverts  
Culvert Length: Both were 13 m  
Culvert Diameter: Both were 0.60 m  
Perching: The culverts were not perched at their upstream or downstream ends  
Turbidity Upstream Crossing: 13 NTU  
Turbidity Downstream Crossing: 11 NTU

### **Channel Conditions:**

The average channel widths upstream and downstream of the culvert were 1.5 m. The ditchlines did not appear to be contributing sediment to the stream. There was some minor ponding resulting from beaver upstream of the road.

### **Riparian Vegetation:**

The riparian community upstream and downstream of the road was composed of dense growths of shrubs and trees that appeared to be contributing to both over-channel cover and to channel stability. There were some very small patches of saturated exposed soil and some undercutting immediately downstream of the road, but they were not having any major affects on water quality.

### **Water Quality Concerns:**

Overall, the crossing appeared to have little influence on water quality. There were some small areas of exposed soil that could be planted; however, these areas will likely grow over through natural processes.

### **Priority:**

Low Priority – Sediment transport from this location appeared to be minimal and the riparian communities were well established.



Plate 74. Channel downstream of road. Note that riparian shrubs and grasses are protecting the channel from erosion and providing substantial over channel cover (September 19/2002).



Plate 75. View of channel upstream of road. Note that riparian grasses and shrubs are providing stability to channel and substantial over channel cover (September 19/2002).



Plate 76. View of culvert outlet downstream of road. Note that there is some channel undercutting, but that riparian grasses and shrubs are providing some resistance to erosion. Bottom of culvert is flush to bottom of channel, i.e., not perched (September 19/2002).



Plate 77. Culvert inlets upstream of road. Note that riparian shrubs and grasses are providing stability to soils (very little exposed soil) (September 19/2002).



Plate 78. Some exposed soil upstream of the road (September 19/2002).

## **CROSSING NO. 18 (DESCRIPTION)**

PART 4. EASTERN SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 18  
Sub-Basin: Eastern Sub-Basins  
Site Co-ordinates: 56° 23.444'N 121° 01.880'W  
Assessment Date: November 12/2002  
Assessment Time: 11:45 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 13 m  
Culvert Diameter: 1.2 m  
Perching: The culvert bottom was flush to the channel at the upstream end; the downstream end was perched 0.35 m above the channel bottom

### **Channel Conditions:**

The average channel width upstream of the road was 1.9 m, with the average width downstream of the road being 2.8 m. The road ditches leading down to the crossing were severely eroding as the result of the relatively steep gradient, exposed soils and water saturation. Through erosional processes, the ditches were contributing sediment to the stream, which is a major tributary to Charlie Lake. On the sampling date, we observed an excavator and CAT working approximately 200 m upstream of the crossing. The excavator and CAT were working in a right-of-way that had substantial amounts of exposed soil that would have moved towards the channel during wet periods (see photodocumentation). There was also a right-of-way immediately upstream of the road that was oriented perpendicular to the channel. Water running off this right-of-way and ditches has likely contributed to the erosion of the pool located at the upstream of the road. There was a substantial scour hole eroded directly downstream of the culvert, with saturation and slumping in behind the downstream end of the culvert. We observed some bank undercutting directly downstream of the culvert outlet.

### **Riparian Vegetation:**

The riparian community downstream of the road was comprised of a dense mixture of grasses, herbs, shrubs and trees that appeared to be providing substantial over-channel cover and bank stability. However, the riparian community upstream of the road has been severely damaged by two right-of-ways that run parallel to the road. These right-of-ways in combination with the poorly armoured ditches were clearly contributing sediment to the channel. Given that this is a major tributary to Charlie Lake, the Charlie Lake Conservation Society should consider undertaking a riparian stabilisation and culvert improvement project at this site.

### **Water Quality Concerns:**

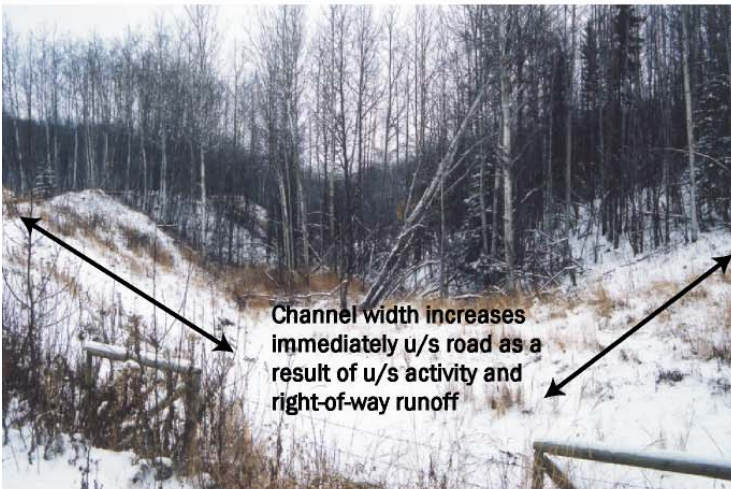
The ditches draining the road were on a relatively steep slope and were not armoured enough to resist erosion by water. These ditches were contributing sediment to the channel. We observed evidence of substantial sediment movement immediately downstream of the road that was likely the result of culvert perching. We were concerned that exposed soils in the right-of-way located approximately 200 m upstream of the road were contributing sediment to the stream.

### **Priority:**

High Priority – Effort should be undertaken to reduce the effects of culvert perching and to re-establishing riparian function upstream of the road. This site would be an excellent location for a pilot restoration project.



Plate 79. View of channel downstream of road. Note that the channel has a dense growth of riparian shrubs that provide both bank stability and over channel cover (November 12/2002).



**Channel width increases immediately u/s road as a result of u/s activity and right-of-way runoff**

Plate 80. View of channel immediately upstream of culvert. Note that the channel has increased in width immediately upstream of the road. Also note that the channel re-establishes its typical width 25 m upstream of the road where the channel is protected by shrubs, grasses and aspen trees (November 12/2002).



**Channel width increases u/s of road (riparian instability)**

Plate 81. Substantial channel widening (evidence of sediment movement) immediately upstream of road. This is evidence that water is accumulating upstream of the road during high flow events (some of this water clearly comes via the upstream channel; however, there is evidence that substantial amounts of water enters from upslope ditchlines) (November 12/2002).



Plate 82. View of culvert outlet downstream of road. Note that there is a substantial scour hole and undercutting behind the culvert (November 12/2002).



Plate 83. Severely eroding ditchline upslope of channel. The ditchlines on both sides of the road are contributing sediment loads to the stream (November 12/2002).

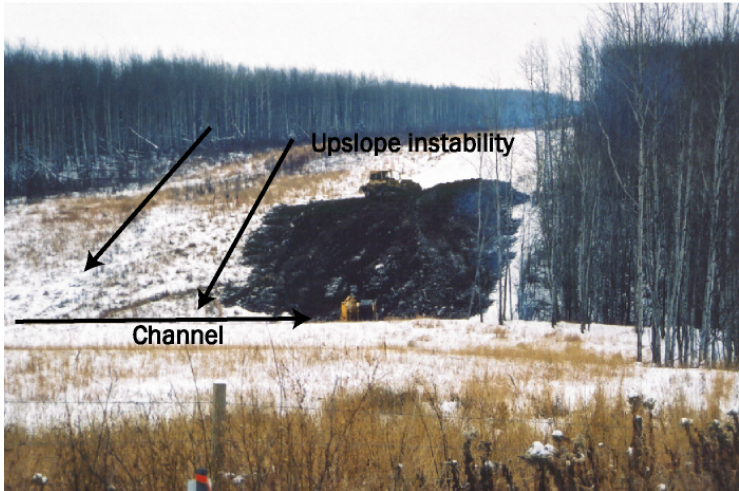


Plate 84. Sloped right-of-way immediately upstream of road has substantial amounts of exposed soils (November 12/2002).

## **CROSSING NO. 19 (DESCRIPTION)**

PART 4. EASTERN SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 19  
Sub-Basin: Eastern Sub-Basins  
Site Co-ordinates: 56° 22.984'N 121° 'W  
Assessment Date: November 12/2002  
Assessment Time: 13:20 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 11 m  
Culvert Diameter: 0.60 m  
Perching: The bottom of the culvert was flush to the ground at both the upstream and downstream ends

### **Channel Conditions:**

There may have been a stream channel at this site in the distant past, but it appears that, if one did exist, that it has de-watered. At the time of the survey, there was not a defined channel upslope of the road or downslope of the road. The crossing appears to only transport drainage from the road. There was some scouring/intermittent channelisation downslope of the road, but this appeared to have been created by road runoff.

### **Riparian Vegetation:**

As indicated above, this crossing does not appear to be associated with a stream channel.

### **Water Quality Concerns:**

There may be minor sediment movements during wet periods, but there would be insufficient energy to move sediment to a stream channel.

### **Priority:**

Low Priority – No issues relevant to water quality observed at this crossing



Plate 85. View downstream of the road. Note that the channel is poorly defined (November 12/2003).



Plate 86. Culvert outlet downstream of road. Note slight backscouring (November 12/2002).



Plate 87. View upslope of road. At this time, the culvert probably just drains the ditchline (no apparent channel). The old channel can be seen in the far distance (November 12/2002).

## **CROSSING NO. 20 (DESCRIPTION)**

PART 4. EASTERN SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 20  
Sub-Basin: Eastern Sub-Basins  
Site Co-ordinates: 56° 22.001'N 121° 57.171'W  
Assessment Date: November 12/2002  
Assessment Time: 14:00 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 17 m  
Culvert Diameter: 0.6 m  
Perching: The bottom of the culvert was flush to the soil at the upstream end; the culvert was perched 0.13 m above the soil at the downstream end

### **Channel Conditions:**

There was not a clearly defined channel upstream or downstream of the road. It appears that the area was just an ephemeral drainage swale (not a channel). There was a small scour hole immediately downstream of the road that had a maximum length of 1.5 m, a maximum width of 0.6 m and a maximum bank depth of 0.20 m (very minor). The crossing only appears to drain the road ditches and does not appear to have any influence on water quality.

### **Riparian Vegetation:**

As indicated above, there was not a defined channel upstream or downstream of the road.

### **Water Quality Concerns:**

Some evidence of saturation-related soil instability was noticed, but we do not feel that this is having any notable affect on water quality (insufficient energy to move sediment to a stream channel).

### **Priority:**

Low Priority – No issues relevant to water quality observed at this crossing



Plate 88. Upstream view of channel. At present, the culvert is draining primarily the ditchline; however, there may be a remnant channel running parallel to treeline in background (November 12/2002).



Plate 89. Upslope end of culvert. This culvert is mainly draining the ditchline. The ditchline is fairly well grassed; thus, crossing is probably contributing little if any to sediment load (November 12/2002).



Plate 90. Upstream view of channel. Note that channel is poorly defined (little if any contribution to sediment load) (November 12/2002).

## **CROSSING NO. 21 (DESCRIPTION)**

PART 4. EASTERN SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 21  
Sub-Basin: Eastern Sub-Basins  
Site Co-ordinates: 56° 20.026'N 121° 56.629'W  
Assessment Date: November 12/2002  
Assessment Time: 14:30 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 32 m  
Culvert Diameter: 0.9 m  
Perching: The culvert was perched 0.9 m above the channel bottom at the upstream end, and 0.5 m above the channel bottom at the downstream end

### **Channel Conditions:**

The average channel width downstream of the road was 0.7 m, with the average channel width upstream of the road being 1.0 m. There was a scour hole immediately downstream of the culvert that had a maximum length of 6 m and a maximum width of 1.5 m. There was also a small pool formed upstream of the road that had a maximum length of 5 m and a maximum width of 2.4 m. The pool was likely created from water running down the ditchline and saturating the channel banks. The ditch on the downslope side of the road appears to have been somewhat unstable and likely carries sediment to the channel during wet periods. The channel was substantially incised immediately upstream of the road, suggesting that the channel substrates are highly erodible.

### **Riparian Vegetation:**

The riparian community upstream and downstream of the road was composed of a dense growths of grasses, herbs, shrubs and trees that were providing substantial over-channel cover and doing a good job of protecting the channel from erosion. Most of the channel erosion was occurring immediately upstream and downstream of the road where the riparian community was not as dense. Some work could be undertaken to stabilise the channel immediately upstream and downstream of the road.

### **Water Quality Concerns:**

There was some evidence of downstream sediment movement immediately upstream and downstream of the road, and some movement in ditchlines. However, the riparian community outside of the immediate influence of the road is providing substantial protection to the channel.

### **Priority:**

Moderate-High Priority - As indicated, there was evidence of sediment movement immediately upstream and downstream of the road; however, we do not feel that this is having a significant influence on water quality. Some work could be done to stabilise the channel immediately upstream and downstream of the road.

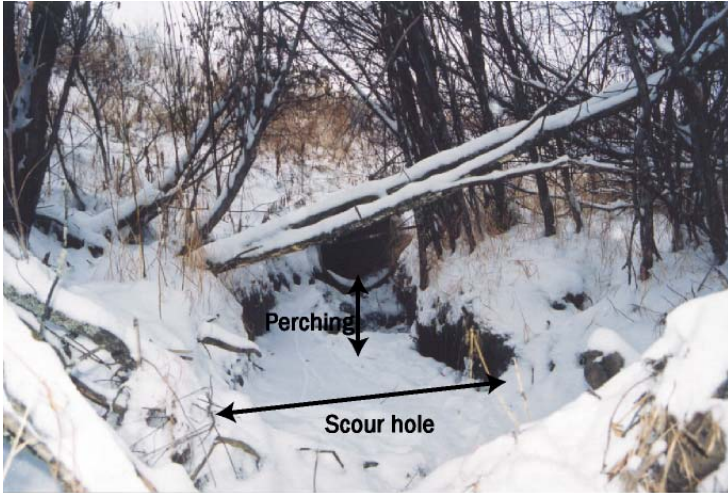


Plate 91. View of culvert outlet downstream of road. Note large scour hole immediately downstream of culvert (November 12/2002).



Plate 92. View of culvert inlet upstream of road. Note the flood debris hanging off the woody debris that is crossing the culvert and slumping behind the culvert (November 12/2002).



Plate 93. Channel is incised immediately downstream of road (November 12/2002).

## **CROSSING NO. 22 (DESCRIPTION)**

PART 4. EASTERN SUB-BASINS

### **Crossing Location:**

Crossing Identification No.: 22  
Sub-Basin: Eastern Sub-Basins  
Site Co-ordinates: 56° 19.554'N 121° 55.588'W  
Assessment Date: November 12/2002  
Assessment Time: 15:15 hrs

### **Crossing Description:**

Crossing Type: Single corrugated steel culvert  
Culvert Length: 15 m  
Culvert Diameter: 0.6 m  
Perching: The bottom of the culvert was flush to the ground at both the upstream and downstream ends

### **Channel Conditions:**

The average channel width upstream and downstream of the road was 0.5 m and 0.7 m, respectively. However, the channel dissipated after it entered the downslope forest (approximately 25 m downstream of the road). It is likely that the crossing's primary function was to drain the road ditches. The channel was more clearly defined upstream of the road, but likely does not carry much water except during extreme runoff events. There was a scour hole with a maximum length of 3 m and a maximum width of 2 m immediately downstream of the road, indicating that the channel does carry runoff during wet periods.

### **Riparian Vegetation:**

As indicated above, the channel dissipated shortly after it enters the forest on the downslope side of the road. Upstream of the immediate influence the road on the upslope side of the road, it appears that the land owner has left a riparian buffer of shrubs and trees and this appeared to have been providing some stabilisation to the channel.

### **Water Quality Concerns:**

While there was some minor evidence of soil instability, it is unlikely that there would ever be sufficient energy in this channel to transport sediment loads of any consequence to Charlie Lake.

### **Priority:**

Low Priority – This crossing likely has negligible effects on water quality.



Plate 94. View of culvert outlet downstream of road (November 12/2002).



Plate 95. Culvert inlet upstream of road (November 12/2002).



Plate 96. Grasses and shrubs lining ditchline upslope of the road (November 12/2002).



Plate 97. Riparian buffer strip of shrubs and grasses upslope of road (November 12/2002).

## Discussion

The results of our stream crossing surveys show that the degree to which crossings affect water quality in the Charlie Lake watershed is highly variable. Thus, the results show that some road crossings are having very little, if any, adverse effects on water quality, while others are having moderate and more severe effects. In general, bridges across the larger channels appear to have less adverse effects than culvert-type crossings. The crossings we identified as having little or no effect on water quality, grouped by sub-basin, were (see Figure 1 and full-size map in associated map tube):

- Crossings #3, #6 and #9 in the West Stoddart Creek sub-basin,
- Crossings #16 and #17 in the Coffee Creek sub-basin, and
- Crossings #19, #20 and #22 in the Eastern sub-basins.

By comparison, our results suggest that the following crossings are having, particularly in terms of sediment-related stability and riparian function, potentially severe effects on water quality in the Charlie Lake watershed:

- Crossings #1, #2 and #4 in the West Stoddart Creek sub-basin,
- Crossing #11 in the East Stoddart Creek sub-basin,
- Crossing #15 in the Coffee Creek sub-basin, and
- Crossing #18 in the Eastern sub-basins.

Crossings classified as having moderate to moderate-high effects on water quality were:

- Crossings #5, #7 and #8 in the West Stoddart Creek sub-basin,
- Crossings #10, #12 and #13 in the East Stoddart Creek sub-basin,
- Crossing #14 in the Coffee Creek sub-basin, and
- Crossing #21 in the Eastern sub-basins.

Table 1 lists the stream crossings we surveyed over the period September to November 2002 with their priority rating described as low, moderate and high with respect to effects to water quality.

Our qualitative assessments show that primary causes of water quality effects at stream crossings in the Charlie Lake watershed were:

1. Culvert perching on either or both ends is the most-commonly observed problem in terms of water quality. A drop on the downstream end of a culvert increases the energy of flowing water (because of the drop) and results in downstream erosion and, in many cases, channel widening. Scour holes, channel widening and bank undercutting are visual indications that downstream sediment movement is occurring. Perching on the upstream end can result in backflooding, reduced flushing, upstream debris accumulation, and soil slumping due to saturation.
2. At least two of the culverts we assessed were put across the road perpendicular to the direction of the road while the stream channel approached the upstream side of the road at a steep angle (i.e., channel direction at the road was not perpendicular to the direction of the road). This has resulted in backflooding, or the formation of "ponds", that fill the ditches parallel to the road. The problem in terms of water quality is that the ponded water saturates soils in the ditchlines and this results in soil slumping. This soil is then carried to the stream channel during wet periods.

Table 1. Stream crossings in the Charlie Lake Watershed (with page reference) and their priority for restoration in view of improving water quality.

Crossing Identifier (Page Ref.)	Sub-Basin	Priority	Comment
#1 (8)	West Stoddart	High	Excellent potential for pilot restoration project. Culvert needs to be replaced and soils stabilised/armoured to minimise perching and scour. Channel should be dredged and armoured upstream of road to reduce backflooding parallel to road (which is resulting in soil saturation and slumping). Plant with shrubs and trees to increase over-channel cover and soil stability.
#2 (10)	West Stoddart	High	Excellent potential for a pilot restoration project. Culvert is excessively perched and needs to be repositioned or taken out and replaced with a bridge. After fixing the culvert, bank armouring and planting should protect from further erosion. Channel downstream of the road runs through a field with minimal riparian function: project should be undertaken to replant the riparian zone on both sides of the channel. Culvert susceptible to clogging with beaver dam debris should the upstream dams breach (another reason to replace culvert with a bridge).
#3 (13)	West Stoddart	Low	-
#4 (16)	West Stoddart	Low	-
#5 (19)	West Stoddart	Moderate	Excellent potential for a pilot restoration project. Bridge crossing itself does not appear to be problematic in terms of water quality, but the fields upstream and downstream of the road could be replanted with shrubs and trees to increase over channel cover and fenced to protect from livestock. Excellent potential for success.
#6 (22)	West Stoddart	Low	-
#7 (25)	West Stoddart	Moderate	Excellent potential for a pilot restoration project. Bridge itself does not appear to be problematic in terms of water quality, but there is excessive amounts of bare soil downstream of the road and poor riparian function upstream and downstream of the road. Excellent potential for planting shrubs and trees and for riparian fencing.
#8 (28)	West Stoddart	Low-Moderate	Culvert is severely perched. Could reposition culvert, or replace with a bridge. Or, could try to slope drop at downstream end of culvert to dissipate energy more slowly.
#9 (31)	West Stoddart	Low	-
#10 (34)	East Stoddart	Low-Moderate	Lowering upstream ends of culverts may improve flushing and increase ability of water to move downstream (i.e., reduce upstream backflooding and reduce build up of potential energy).
#11 (37)	East Stoddart	High	Excellent potential for a pilot restoration project. There was excessive amounts of exposed soil along the channel both upstream and downstream of the road resulting from livestock, human activities and flooding. A bridge may be more suitable for this site. A restoration project could include fencing and planting of shrubs and trees in riparian areas.
#12 (40)	East Stoddart	Moderate	Good site to try some test planting of shrubs and trees immediately downstream of road.
#13 (43)	East Stoddart	Low-Moderate	Good site to undertake test planting of riparian shrubs and trees.
#14 (46)	Coffee Creek	Moderate	Riparian planting, fencing and culvert repairs would increase over-channel cover and channel stability, and backflooding upstream of the road.
#15 (49)	Coffee Creek	High	Excellent potential for a culvert restoration project. Excessive downstream perching is resulting in erosion.
#16 (52)	Coffee Creek	Low	-
#17 (55)	Coffee Creek	Low	-
#18 (58)	Eastern	High	Excellent potential for a pilot restoration project. Road running down to stream is fairly steep and the ditchline is unstable and contributes sediment to the channel. Site could be improved by replacing culvert with a bridge. Culvert is severely perched on downstream end. Exposed soils on the upstream right-of-way is a concern in terms of sediment movement.
#19 (61)	Eastern	Low	-
#20 (63)	Eastern	Low	-
#21 (65)	Eastern	Moderate-High	Some work could be undertaken to stabilise the channel immediately upstream and downstream of road.
#22 (67)	Eastern	Low	-

3. In areas where crossings were located in gullies, ditchline erosion commonly contributes sediment to stream channels. Our observations indicate that erosion and soil slumping resulting from saturation tends to occur most-often in regions of the watershed where there is topographic relief (i.e., sloped landscapes). We found several instances where saturated soils in sloped ditchlines were contributing sediment to stream channels.
4. Our observations indicate that the culverts used to direct water across roads were often too small to adequately support the flows carried in stream channels during high-flow events (i.e., culverts too small relative to channel size and flow volumes). In these instances, substantial flows are compressed through the culvert causing water velocities to increase and, with this additional power, the flowing water has greater potential to erode downstream channel sediments. What can also happen is that water can backflow upstream of the road during high-flow events as a result of inadequate flushing capacity. This backflooding, as was observed in several instances, can saturate soils upstream of the road and cause them to slump into the channel or ditches that drain into the channel, thereby increasing sediment loads.

While the rate at which sediments eroded at stream crossings moves downstream towards the lake would be difficult, but not impossible, to quantify, and depend on a multitude of factors such as channel gradient, soil morphology and density, and discharge, it is fairly certain that sediments moving in channels upstream of Charlie Lake will, over time, deposit in the lake where they will accelerate eutrophication and lake shallowing rates, and decrease water clarity.

Observations made at some stream crossings provided some insights into the basic hydrology of the Charlie Lake watershed. It appeared that many of the stream channels only carried substantial flows during spring runoff and during severe rain events, and were nearly completely dry during other periods. Wide channel widths and elevated flood debris (e.g., see Plates 12 and 92) suggest to us that flows in Charlie Lake tributaries can be quite torrential during runoff events, but water would appear to flush through the tributaries very rapidly with channels becoming dry shortly after such events. The “flashy” nature of tributary flows in the Charlie Lake watershed combined with the fine-textured soils makes stream channels, particularly in reaches affected by culvert-type road crossings and in those having inadequate riparian function, highly susceptible to erosion. The high potential for erosion caused by moving water was clearly shown at Crossing #18 in the Eastern Sub-Basins (see Plate 83) where just a slight increase in topographic gradient has resulted in severe sediment erosion in ditchlines draining into a major channel. Although a detailed hydrologic assessment of the Charlie Lake watershed was beyond the scope of this study, we have speculated that the “flashy” characteristics of tributary flows may be indicative of relatively high rates of overland flow (i.e., water flowing over the landscape directly into stream channels) and low groundwater re-charge rates (i.e., water flowing into stream channels from sub-surface aquifers), which are conditions characteristic of watersheds where a high proportion of the natural forest cover has been removed. In watersheds where natural forest cover has been preserved, streamflows tend to increase in the spring during snowmelt periods, as occurs in the Charlie Lake watershed, with basal flows being maintained through the summer and autumn months via groundwater infiltration to channels. In comparison, much of the water that comes into contact with the landscape in watersheds where there has been substantial amounts of forest clearing drains rapidly via overland flow directly into channels with relatively small volumes of water draining into sub-surface aquifers; thus, with aquifers not being sufficiently re-charged, streams channels tend to become dry after freshet and will only carry water during rain events as seems to happen in the Charlie Lake watershed. Wetzel (2001) provides an excellent drawing that illustrates this process (Figure 2):

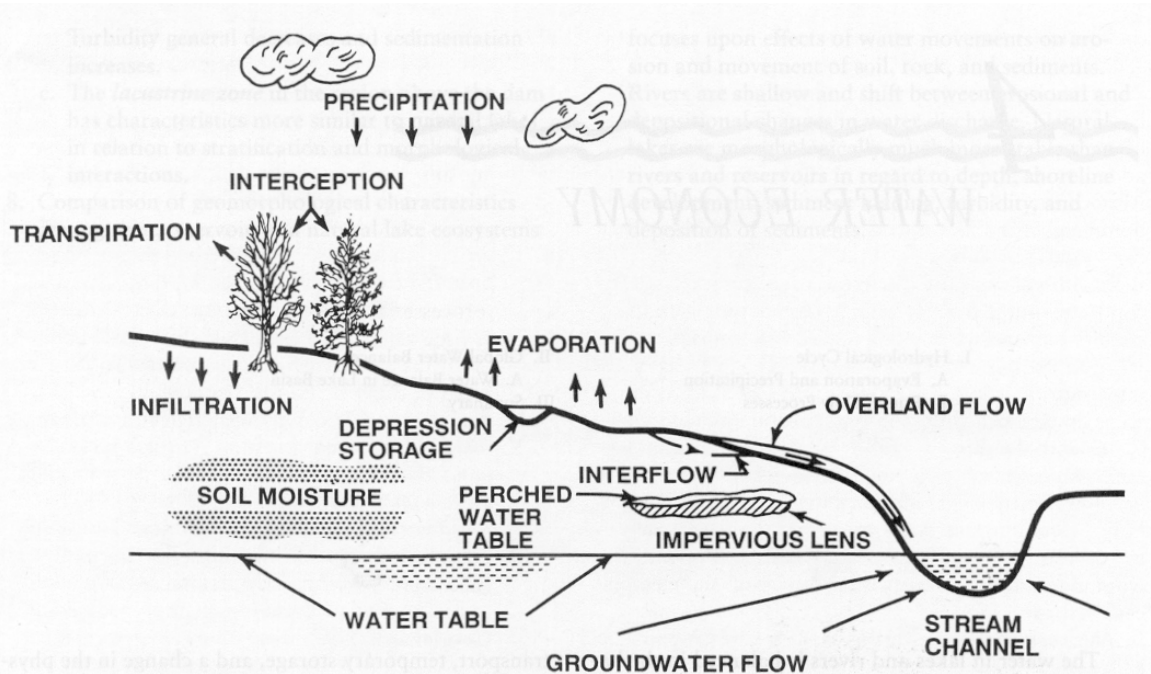


Figure 2. In watersheds where a high proportion of the landscape has been cleared of natural vegetation, water coming into contact with the land tends to move rapidly via overland flow into stream channels, and relatively small volumes recharge sub-surface aquifers (which feed channels with water during summer months in more natural systems (taken directly from Wetzel (2001).

Our limited turbidity data showed that turbidity ranged from 17 to 32 NTU ( $n = 5$ ; Average = 26 NTU) in the West Stoddart Creek sub-basin, from 7 to 22 NTU ( $n = 6$ ; Average = 17 NTU) in the East Stoddart Creek sub-basin, and from 10 to 21 NTU ( $n = 6$ ; Average = 15 NTU). Thus, based on our observed averages, water in the West Stoddart Creek sub-basins was the most turbid during the sampling visits, with Coffee Creek's water being the least turbid (comparisons are not statistically significant).

## Recommendations

In general, stream crossings in the Charlie Lake were causing problems because they are either too small and/or because they are improperly placed. There are effectively four ways to repair problematic stream crossings (D. Craig, pers. comm.):

1. By replacing culverts that are too small relative to channel width/discharge with an appropriately-sized culvert,
2. By re-aligning culverts so that they more closely follows the path of the water course,
3. By replacing culverts, particularly those draining large channels, with a bridge, or
4. By removing the crossing altogether.

From discussions that we have had with engineering companies, repairs of crossings in the Charlie Lake watershed could be as low as \$8,000 or as high as \$55,000 to \$65,000 per crossing. These estimates include repair from start to finish and would cover both replacing culverts, and/or building bridges (D. Ticeric, D. Craig, Pers. Comm.). Culverts that are mis-aligned would likely be more expensive than this cost range because the length of culvert required would be significantly longer and considerably more earth would have to be moved. The overall objective of any work at stream crossings should be to reduced sediment loads to stream channels and to increase overchannel vegetation cover. To initiate work at priority stream crossings, the Charlie Lake

Conservation Society will first need to determine who is responsible for the various crossings (e.g., BC Ministry of Transportation, private land owners, oil and gas companies, forest companies, etc.), then quantify the extent of the problem, develop practical solutions/prescriptions and do what they can to compel those responsible, through community-based partnerships or through legal means, to undertake the required work. Figure 3 shows a schematic for an “approach” to dealing with poorly-functioning stream crossings.

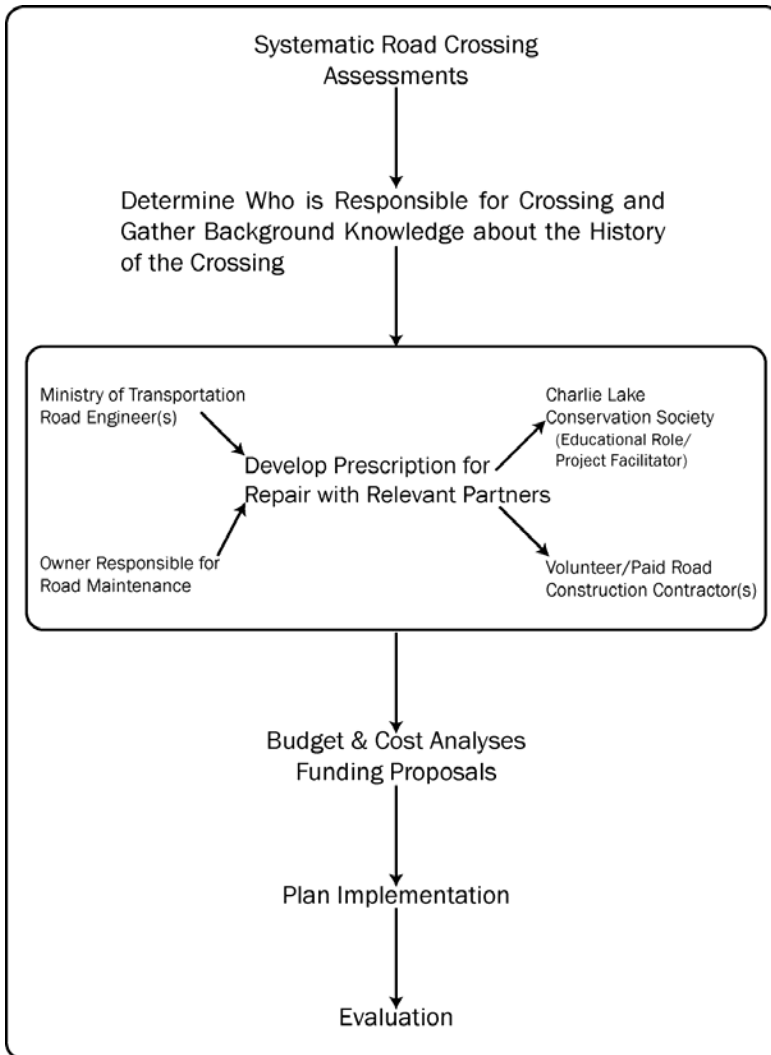


Figure 3. A flow chart for dealing with problematic stream crossings in the Charlie Lake watershed.

Over the course of this study, we had the opportunity to assess and describe the water-quality affects of 22 stream crossings in the West Stoddart Creek, East Stoddart Creek, Coffee Creek and Eastern sub-basins. We estimate that there are an additional 34 crossings that could be assessed by the Charlie Lake Conservation Society using the methods and data forms that we have developed (see Appendix). Several of these crossings are located on private land, so the Society will be required to get permission from relevant landowners prior to any assessments.

There are a wide variety of techniques that can be employed to minimise problems associated with sediment erosion in ditches. Listed below are sections from Chapter 4: Road Drainage Construction (BC Ministry of Forests, 2002) that provide solutions to the current problems, which appear to be most-prevalent in areas of

the watershed where there are topographic gradients greater than about 5% (i.e., slope gives flowing water in ditches sufficient energy to disturb soils). The ditch stabilisation methods described in BC Ministry of Forests (2002) can be summarised as follows:

1. Using cross drains that employ erosion resistant ditch blocks,
2. Installing erosion-resistant aprons at the inlet and outlet of culverts,
3. Armouring ditches using angular shot rock, or lining ditches with geotextiles,
4. Using anti-wash vegetation fabric for low-velocity flow conditions and on soils that are erodable,
5. Building silt fences, blocks or traps,
6. Revegetating exposed soils,
7. Consider using wider ditches with more gently sloped sides in erodable soils,
8. Avoiding abrupt water flow changes along ditch lines (sharp angles in the ditch alignment, or flow obstructions in the ditch, such as boulders or rock outcrops that can potentially deflect water into the subgrade or cut banks, can result in erosion of the subgrade or undermining of the cut bank),
9. Take off or lateral ditches can be used to carry water away from a culvert in order to deposit sediment in places other than in the culvert (lateral ditches need to be designed such that the flow from them is in keeping with existing drainage patterns),
10. Where sediment transport is anticipated and it is neither practical nor environmentally sound to disperse ditch-water immediately before the ditch reaches a stream channel, a sediment settling pond, silt fence, slash filter windrow, or other sediment trapping device may be used (if used, these catchment facilities will require routine maintenance).

Repair work at stream crossings is a complicated matter. There are many jurisdictional and administrative issues that need to be addressed (e.g., who is ultimately responsible for the crossing, what agencies need to be consulted should the repair of a crossing be attempted). In addition, there are technical and professional standards that have to be met than will make the repair of any one crossing extremely expensive. Both of these issues make stream-crossing repair challenging. If repairs of stream crossings are a priority item for the Charlie Lake Conservation Society, then careful consideration will have to be given to the choice of which crossings to repair. The choices will be contingent largely upon cost, but also on jurisdictional issues.

The main barriers to the repair of any stream crossing and/or ditchline are expected to be financial (i.e., work can be very expensive) and administrative (e.g., obtaining required permits, finding a suitable contractor or volunteers). Many of the road crossings that are causing problems are under the jurisdiction of the Ministry of Transportation and Highways. Shrinking government budgets and competing priorities may prohibit the procurement of funding from government for the repair of these crossings. As a result, the repair of many of these crossings will likely require in-kind contributions from product and service suppliers (e.g., culverts and heavy machinery) as well as engineering expertise. Administrative issues may further delay or impede any repair of any crossing. Strong connections between the Charlie Lake Conservation Society and the affected agencies will be paramount. Having outlined some of the challenges associated with restoration projects at stream crossings, there is little doubt that such projects will have positive affects on water quality in the Charlie Lake watershed and the lake itself, and that such improvements to water quality could have positive economic spin offs over the long term.

## References

- BC Ministry of Forests, 2002. Forest road engineering guidebook (2<sup>nd</sup> Edition, June 2002). For. Prac. Br., BC Min. For., Victoria, BC. Forest Practices Code of British Columbia. 218 pp. (available on the internet at <http://www.for.gov.bc.ca/tasb/legsregs/fpc/fpcguide/guidetoc.htm>)
- French, T.D. & N.B. Carmichael, 1999. Limnological aspects of Charlie Lake (Peace River drainage, British Columbia): a summary of data collected between 1974 and 1995. BC Ministry of Environment, Lands, and Parks, 1011-4<sup>th</sup> Avenue (3<sup>rd</sup> Floor), Prince George, BC, Canada, V2L 3H9. 113 pp.
- Wetzel, R.G., 2001. Limnology: lake and river ecosystems (3<sup>rd</sup> Edition). Academic Press, New York. 1006 pp.

# Appendix

## Stream Crossing Survey Forms

## STREAM CROSSING ASSESSMENT FORM

### PART 1: SITE DESCRIPTORS

**Date of inspection** \_\_\_\_\_ **Crossing Type** \_\_\_\_\_ **Time of inspection** \_\_\_\_\_  
 (e.g., Road, rail, pipeline etc)  
**Name of Sampler** \_\_\_\_\_ **GPS Coordinates** \_\_\_\_\_ **GPS Type** Garmon GPS 12 NTS Mapsheet  
 (Lat/Long)  
**Location description** \_\_\_\_\_  
 (e.g., name of road and location of crossing) \_\_\_\_\_  
**Structure Description** (e.g., bridge, culvert, dual culvert, half culverts, etc) \_\_\_\_\_  
**StreamName** \_\_\_\_\_ **Watershed Code** \_\_\_\_\_ **Channel Slope** (<1%, 1-3, 3-5, 5+)

**Channel Widths:**

UPSTREAM Side of Crossing		DOWNSTREAM Side of Crossing	
Distance upstream (m)	Channel Width (m)	Distance downstream (m)	Channel width (m)

**Substrate Description (Visual Estimates):**

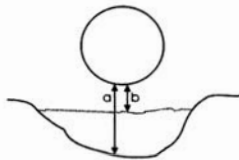
UPSTREAM Side of Crossing	DOWNSTREAM Side of Crossing
% Fines (ladybug sized and smaller) =	% Fines (ladybug sized and smaller) =
% Gravels (ladybug sized to tennis ball) =	% Gravels (ladybug sized to tennis ball) =
% Cobbles (tennis ball sized to basket ball) =	% Cobbles (tennis ball sized to basket ball) =
% Boulders (> basket ball sized) =	% Boulders (> basket ball sized) =

Sample of fine sediment collected? Yes/No \_\_\_\_\_

### PART 2: CROSSING DESCRIPTORS **Position of Culvert (is there evidence of perching?)**

**Length of crossing (m)** \_\_\_\_\_ **Diameter of culvert** \_\_\_\_\_ **Condition of culvert** original/intact crushed/compressed

**Position of Culvert** (is there evidence of perching, or water running under culvert?)



**UPSTREAM**  
Distance

**DOWN STREAM**  
Distance

a \_\_\_\_\_

a \_\_\_\_\_

b \_\_\_\_\_

b \_\_\_\_\_

**Culvert Slope (%)** \_\_\_\_\_ **Culvert Material** (steel corrugated, wood, smooth steel,...) \_\_\_\_\_

**Physical parameters** **Air temp** \_\_\_\_\_ **Water temp** \_\_\_\_\_ **Turbidity** Upstream \_\_\_\_\_ Downstream \_\_\_\_\_

### CULVERT/CROSSING FUNCTION

**1. Road bed condition:** (amount of sediment on deck)      Low    Medium    High      **Photo:**

2. Ditchline Condition: Are the ditchlines eroding and delivering sediment directly to the stream? Yes No

Comments \_\_\_\_\_

3. Condition of the bridge pylons Poor Fair Good Are pylons treated Yes No if yes, then with what?

4. Is there evidence that culvert experiences problem with clogging by debris? Yes No

Comments \_\_\_\_\_

5. Is there standing water upstream and downstream of the culvert? Yes No  
(e.g., is water filling the bottom of the culvert, or is it dry or just puddled inside?)

Comments \_\_\_\_\_

6. Is there evidence that sediment is accumulating on the bottom downstream of the crossing relative to upstream? Yes No

Comments \_\_\_\_\_

7.a Is there evidence of the presence of a large scour hole immediately d/s of the crossing? Yes No

b. is there evidence of other slumps or erosion areas have obviously been created by the crossing? Yes No

Comments \_\_\_\_\_

8. Is there evidence of human disturbance, animal disturbance at road crossing? Human Yes No Animal Yes No  
Comments \_\_\_\_\_

9. Is rip rap being used in vicinity of crossing? Yes No if yes length \_\_\_\_\_ width \_\_\_\_\_ and size \_\_\_\_\_

**PART 3. RIPARIAN CONDITION IN VICINITY OF CROSSING**

**Presence of vegetative buffer**

	Upstream		Downstream	
	Right	Left	Right	Left
Type of cover*				
Is the riparian vegetation providing significant overchannel cover? Yes No				
Is the riparian vegetation providing significant bank stabilisation? Yes No				
Amount of exposed ground/soil**				

\* 1 = grasses, 2 = herbs, 3 = shrubs, 4 = trees Amount of Exposed soil: low, medium, high (high is much exposed soil)

**Photos taken**

Roll #	Detail	Photo #	Detail
	Stream view u/s of crossing		
	Stream view d/s of crossing		
	Crossing outlet(s) looking upstream		
	Crossing inlet(s) looking downstream		

Additional comments \_\_\_\_\_  
 \_\_\_\_\_  
 \_\_\_\_\_

Is there an additional sheet of notes associated with this form? Yes/No

# Water Quality in the Charlie Lake Watershed: Affects of Agricultural- and Oil & Gas-Related Land Clearing<sup>1</sup>

Barry P. Booth<sup>2</sup> and Todd D. French<sup>3</sup>

(March 2004)

**Abstract:** The Charlie Lake Conservation Society is in the process of developing long-term strategic concepts for projects to improve water quality and habitat in Charlie Lake and in tributaries to the lake. In this section of the proposed strategic planning process, we examine the current conditions of riparian habitats, particularly in view of potential for sediment erosion, in agricultural sub-basins of the Charlie Lake watersheds from cursory ground surveys, and from the analysis of 1997 orthophoto coverages. In addition to assessing riparian conditions in agricultural reaches of the Charlie Lake watershed, we use observational accounts to give insights into how road and water management practices on oil and gas industry wellhead sites are affecting water quality.

Our road- and orthophoto-based assessments of riparian conditions in the Charlie Lake watershed showed that there is generally very poor riparian function in the major sub-basins that drain into Charlie Lake, such that large portions of the total lengths of major tributaries have been cleared to, or almost to, the banks. Examinations of orthophotos identified about 136 wellhead sites in the Charlie Lake watershed, the vast majority of which are located in the northern sub-basins. Ground surveys showed that wellhead sites typically had considerable areas of exposed soils and that water management practice, at least at some sites, is further contributing to sediment loading to stream channels. In this report, we provide several management options to improve riparian function in agricultural reaches, and to reduce sediment transport from oil and gas wellhead sites.

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The Charlie Lake Conservation Society is in the process of developing long-term strategic concepts for projects to improve water quality and habitat in Charlie Lake (Fort St. John area, British Columbia) and in tributaries to the lake, and to improve the aesthetic and recreational potential of the watershed as a whole. As

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discussed in French & Carmichael (1999), the major watershed concerns identified to date are the severity of late-summer and autumn cyanobacteria (blue-green algae) blooms, which are known to occur in response to seasonal internal nutrient loads, sediment inputs from tributaries and the lake shore, and the input of domestic wastes from extensive shoreline sub-divisions. Through their strategic

Disclaimer: This illustration is for information only. The illustration should not be used for navigation as unmarked hazards and some inaccuracies do exist.

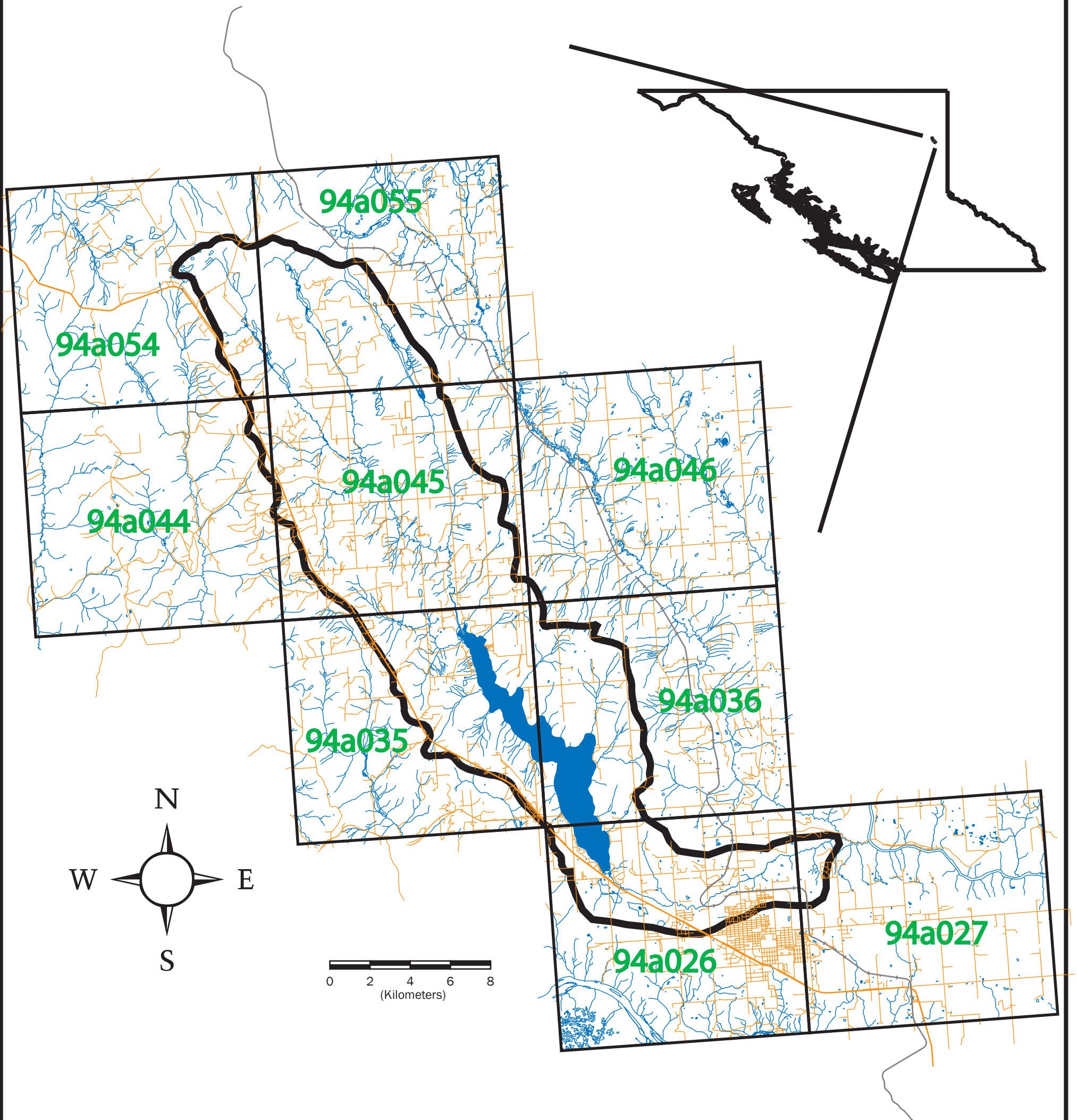


Figure 1. Charlie Lake watershed showing position of orthophoto grids referred to in subsequent figures. Orthophoto grids 94a046 and 94a027 are not represented in subsequent figures because they lie outside of the Charlie Lake watershed.

planning process, the Charlie Lake Conservation Society is hoping to design specific projects and community-level initiatives that will address the watershed-level factors that are thought to be affecting the perceived deterioration in water quality. Ultimately, the Charlie Lake Conservation Society needs these projects and initiatives to be both cost effective and *doable* in a practical sense so that local industries, relevant funding agencies and the public will buy-in to the recommended programs and have the ability to get involved, and believe that their financial and personal commitments are having positive outcomes in terms of improvements to water quality. Charlie Lake is located just off the Alaska Highway and, with this location and its scenic landscape, watershed-level improvements will undoubtedly enhance the region's ability to attract stop-over tourists and help maintain property and recreational values and, perhaps, through reductions in diffuse pollution loads reduce risks to human health.

In this section of the strategic plan we use the results of ground and orthophotos surveys to examine the current condition of riparian habitat in the Charlie Lake watershed. Our rationale for investigating riparian condition as part of the strategic planning process was that it is well documented that poor riparian function (i.e., low vegetation/rooting density and overchannel cover) can result in increased sediment transport rates to stream channels and decreased thermal and chemical (e.g., nutrients) buffering. With regards to sediment, it is well documented in the scientific literature that sediment loads in excess of base-line (i.e., natural state) levels can have a multitude of affects on freshwater systems, including:

1. Fine sediments, particularly silts and clays, have surficial exchange sites (i.e., electrostatic charges) that can attract and bind nutrient ions (e.g.,  $PO_4^-$ ) and chemical contaminants such as herbicides, pesticides and metals. Thus, sediments carried in tributary flows transport nutrient ions and, possibly, other chemicals to Charlie Lake. Results on within-lake storage rates presented in French and Carmichael (1999) indicate that much of the sediment-bound nutrient loads to Charlie Lake are stored within the lake (i.e., flushing rates are very low).
2. Suspended sediments reduce water clarity and, thus, increases light attenuation (the rate at which light is absorbed in the water column). Increases in light attenuation resulting from elevated sediment loads can reduce benthic production rates (i.e., biological production on the bottom of streams depends on the photosynthetic rates of attached algae – the base of the food chain).
3. Predatory fish are, in general, visual hunters. Reductions in water clarity resulting from elevated sediment loads have been show to reduce the hunting success of predatory fish.
4. In low-energy reaches (including Charlie Lake), sediment deposition can result in the over-covering of important fish spawning substrates.
5. Sediment transport to slow-flushing lakes tends to make them shallower over time via complex in-filling processes. As lakes shallow, they tend to become more turbid and more susceptible to algae-bloom related problems. This is generally a very slow process, but the process is accelerated by increases in upstream erosion and sediment transport.
6. Sediment transport from regions of the landscape that are susceptible to the erosional forces of water ultimately results in a loss of valuable land.

7. Sediment transport from riparian areas is generally indicative of insufficient vegetation cover (e.g., herbs, grasses, shrubs and trees) that stabilise soils. Riparian vegetation provides thermal buffering to streams (i.e., protects them from rapid and excessive changes in temperature) and provides streams with organic matter that can be used in biological production, and with physical structures that contribute to habitat complexity and diversity.

This report summarises the methods we used to assess riparian conditions in the Charlie Lake watershed in view of agricultural and oil and gas development. We use the results to recommend management and restoration options to the Charlie Lake Conservation Society that will help them address their objective of improving water quality in the Charlie Lake watershed.

## Materials & Methods

### *Agricultural Lands*

Overview assessments to determine the extent to which agricultural and ranch lands encroach into riparian zones were undertaken over the period September 16 to November 12, 2002, in conjunction with our stream-crossing assessments (see *The Condition of Stream-Crossings (Culverts and Bridges) in the Charlie Lake Watershed with Reference to Water Quality (September to November 2002)*). To avoid trespassing on private properties, the general conditions of riparian habitats were primarily described from observations taken from public roads running adjacent to agricultural lands. During these preliminary roadside assessments, riparian conditions were described with reference to the following:

1. The presence/absence of natural riparian vegetation (non-crop herbs, shrubs and trees), and whether such vegetation was of sufficient density to provide stream channel stability and over-channel cover.
2. The degree of sediment erosion in reaches where agricultural lands extended into riparian habitats, as evidenced by exposed soils.
3. Whether there was evidence of livestock access to stream channels, and if such livestock access was having negative affects on riparian function.

Since more than 80% of the surface water flows to Charlie Lake enter from the north via the Stoddart Creek and Coffee Creek sub-basins (French & Carmichael, 1999), our road surveys of agricultural lands focussed on northern sub-basins; however, the riparian conditions of some major channels that drain into Charlie Lake from the east were assessed during our stream-crossing assessments. On a couple of occasions during our ground surveys of agricultural lands, we had the opportunity to meet with major landowners to discuss water quality issues and to gauge their interest in participating in future riparian conservation and restoration projects.

As indicated, our ground surveys of agricultural impacts to water quality were very cursory, such that stream channels were not walked at length and described in great detail; they were largely undertaken to obtain a “snapshot” of riparian issues in areas of the watershed under high agricultural production. More broad-scaled analyses of riparian conditions in the Charlie Lake watershed were undertaken through the analysis of 1:50,000 orthophotos (compiled from 1:20,000 airphoto tiles taken in 1997) provided by the BC Ministry of Sustainable Resource Management (Fort St. John) for NTS mapsheets 94a054, 94a055, 94a044, 94a045,

94a035, 94a036 and 94a026 (Figure 1). Orthophotos were uploaded with the Avenza MapPublisher® plug-in to Adobe Illustrator® 10.03, and major roads, railroads, stream channels and well-head sites highlighted. To view riparian conditions in agricultural lands, Adobe Illustrator's® zoom-in function was used to increase resolution by up to 1200%. The orthophotos were in high-quality TIFF format; thus, image quality was maintained even under high zoom levels. To assess riparian conditions, stream channels were identified on the orthophotos and traced in blue while describing the presence/absence and width of riparian channel buffers. Reaches having sparse or no identifiable riparian buffer were highlighted in yellow on the orthophotos. We also identified reaches having good riparian function to provide the Charlie Lake Conservation Society with existing "baseline" examples of riparian habitats that appear to be protecting streams from further water quality degradation. Reaches having sufficient riparian buffer zones were highlighted on the orthophotos in green, and represent restoration targets/goals for reaches having sparse riparian zones (those highlighted in yellow).

### *Oil & Gas Wells*

A survey of oil and gas wellhead sites to identify potential impacts to water quality was not initially envisioned as being a component of our strategic planning project. However, a couple of wellhead sites were visited during the agricultural land assessments, and the results of these visits indicated that at least some wellhead sites are adversely affecting water quality in the Charlie Lake watershed. From our preliminary survey of wellhead sites, we described common conditions that have potential to affect water quality. Wellhead sites were highlighted with black squares on 1:50,000 airphotos (see above) for further investigation by the Charlie Lake Conservation Society.

## **Results & Discussion**

### *Agricultural Lands*

Our road-based surveys of near-channel habitats showed that there is generally very poor riparian function in the major sub-basins that drain into Charlie Lake. As illustrated in Plates 1-4, large proportions of the total lengths of major tributaries (e.g., Stoddart and Coffee creeks) have been cleared to, or almost to, the banks. Such clearing has undoubtedly decreased channel stability, resulting in increased sediment transport rates, decreased in-channel habitat complexity by reducing sustainable inputs of large woody debris, reduced thermal buffering capacity (i.e., very sparse over-channel cover) and decreased the potential for nutrient/chemical riparian buffering. In reaches where there have been attempts to maintain riparian buffers, they have been far too thin to provide sustainable channel armouring, cover and nutrient buffering (Plates 5 and 6). Although livestock are not densely populated in the Charlie Lake watershed, when present they often have direct access to stream channels (Plates 7-9). Our observations indicate that the presence of livestock in riparian areas causes physical damage through soil disturbance and grazing on vegetation and, moreover, many studies have shown that livestock faeces can contribute bacteria (e.g., *Escherichia coli*) and protozoan parasites (e.g., *Giardia* and *Cryptosporidium*) to surface waters that can cause health problems in humans if ingested.

While the results of our road-based surveys indicate that agricultural practices in the Charlie Lake watershed have had considerable effects on water quality (see Plate 10), our conversations with major landowners have been very positive and give us reason to believe that there is the regional capability and desire to undertake restoration projects. For example, Mr. Stubbs (major landowner in Stoddart Creek watershed) informed us that

he is partnering with his neighbour to the south, Mr. Gardener, to build a fence parallel to Stoddart Creek to reduce livestock access. Mr. Stubbs also showed us a groundwater spring that he found on his property that he plans to use as a water source for his livestock, reducing the need for his livestock to access stream channels to drink.

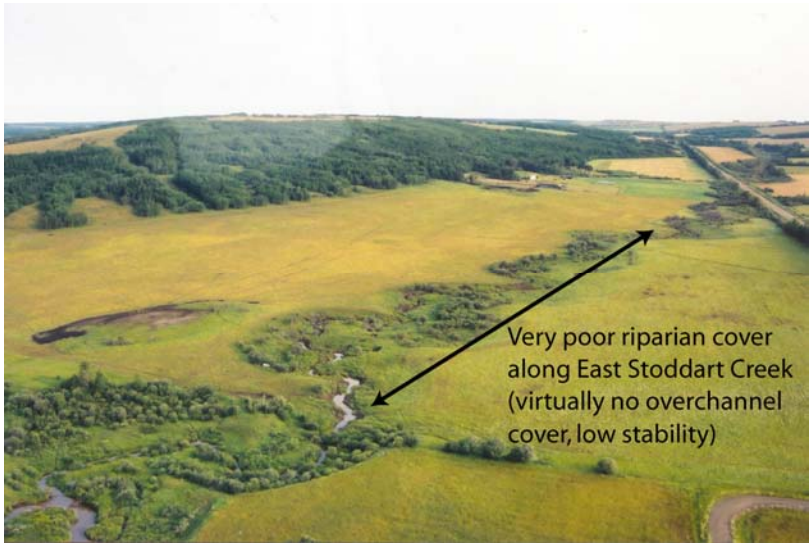


Plate 1. Aerial view of East Stoddart Creek showing reach with poor riparian condition and encroachment of agricultural field.

Very poor riparian cover along East Stoddart Creek (virtually no overchannel cover, low stability)

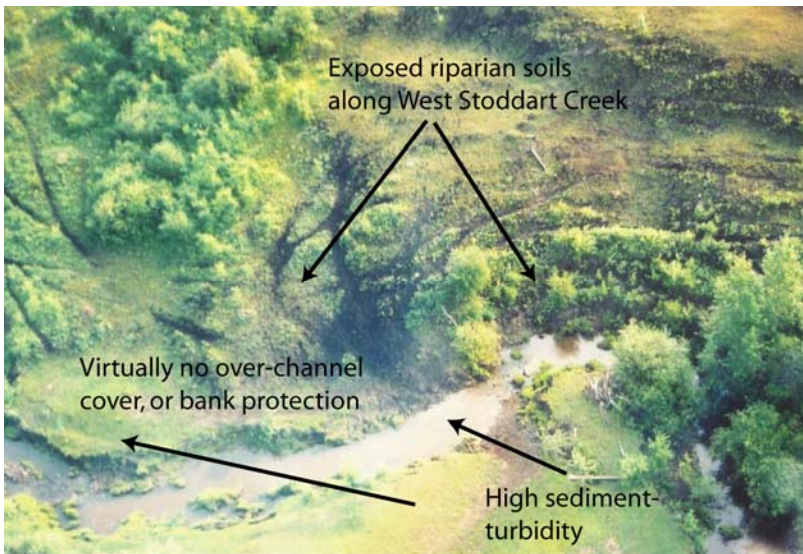


Plate 2. Aerial view of West Stoddart Creek showing poor riparian function and highly erodible exposed soils.

Exposed riparian soils along West Stoddart Creek

Virtually no over-channel cover, or bank protection

High sediment-turbidity

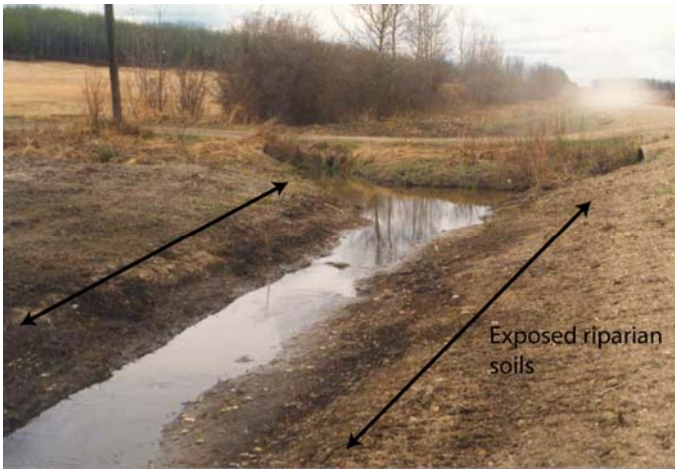


Plate 3. Exposed riparian soils in the Stoddart Creek sub-basin undoubtedly hasten sediment transport rates to Charlie Lake.



Plate 4. Remnant channel in the Stoddart Creek sub-basin. Note complete lack of riparian cover.

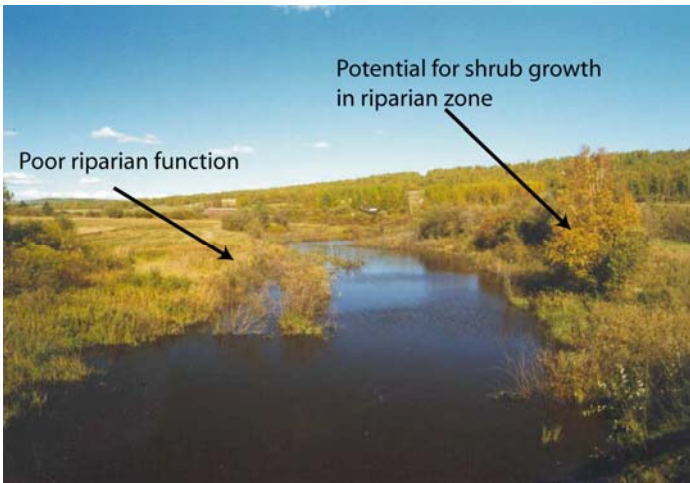


Plate 5. Crop field encroachment into riparian zone in Stoddart Creek sub-basin.



Plate 6. Thin riparian strip along remnant channel in Stoddart Creek sub-basin.

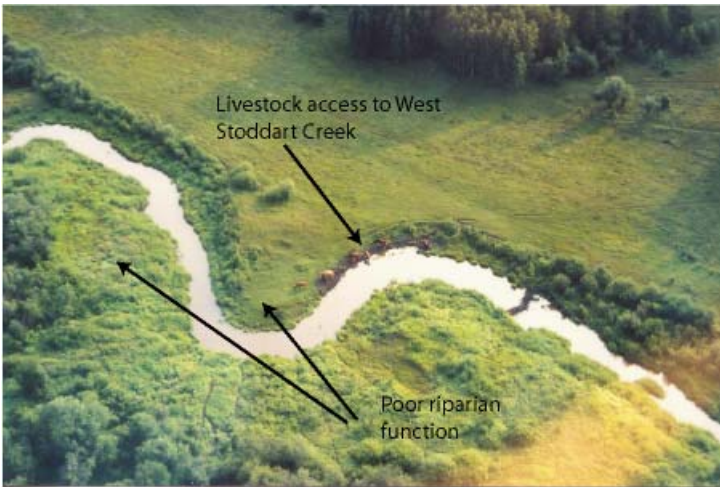


Plate 7. Aerial view of West Stoddart Creek showing cattle access to reach with poor riparian function.

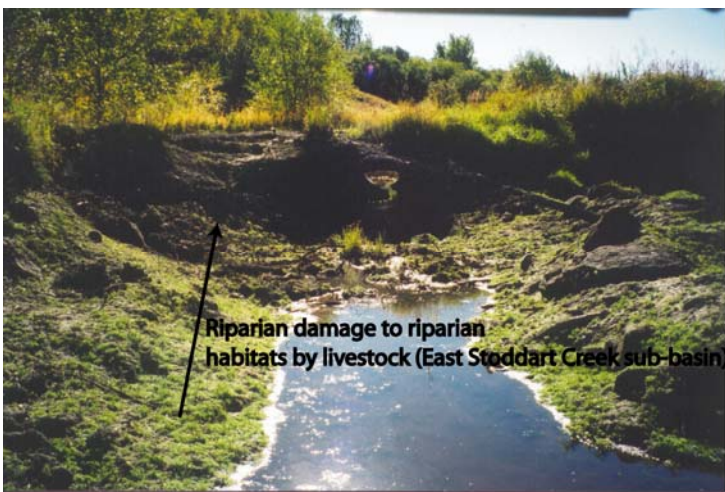


Plate 8. Riparian damage along East Stoddart Creek resulting from livestock access.



Plate 9. Livestock access to riparian habitats in Stoddart Creek sub-basin.

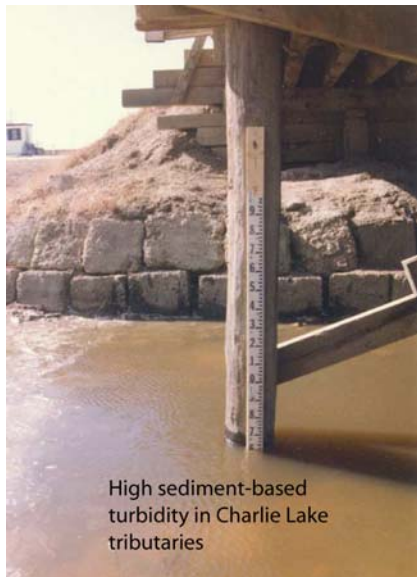


Plate 10. High sediment-based turbidity in Stoddart Creek (a major tributary to Charlie Lake)

High sediment-based turbidity in Charlie Lake tributaries

The results of our orthophoto analyses were consistent with those of the road-based surveys, such that they showed that most riparian habitats, particularly in the northern sub-basins, have been severely encroached upon by agricultural fields (Figures 2-8). As shown by the yellow highlights in Figures 2,3, 5 and 6, almost all riparian habitat along the mainstems of East Stoddart Creek, West Stoddart Creek and Coffee Creek have been moderately to severely impacted by fields and/or clearcuts. Given that 80% or more of the surface flows to Charlie Lake enters via these sub-basins, we believe that these riparian impacts have considerable adverse affects on both tributary and lake waters. The smaller sub-basins draining into the east and west sides of Charlie Lake have also been severely affected by land clearing (Figures 4, 6-8); however, given that these sub-basins contribute relatively little to the total water balance of Charlie Lake, land clearing in these sub-basins likely has comparatively minor affects on the quality of lake waters.

Ideally, the Charlie Lake Conservation Society should develop plans to restore all affected riparian zones in the watershed and initiatives to conserve existing healthy riparian habitats, with initial investment and efforts being directed to critical riparian habitats in the East Stoddart Creek, West Stoddart Creek and Coffee Creek

sub-basins. As described in more detail below, the primary objective of any future restoration in agricultural reaches should focus on the re-establishment of riparian vegetation, and the exclusion of livestock from riparian areas. Such projects could involve active planting activities by community volunteers and/or contractors, or more passive actions like fencing (to reduce riparian damage by livestock) to allow vegetation to re-establish through natural processes. Conversations that we have had with landowners indicate that natural vegetation establishes very quickly in the Charlie Lake watershed if protected from livestock and machinery; thus, active planting may not necessarily be required.

### *Oil & Gas Wells*

Examinations of 1:50,000 orthophotos identified about 136 wellhead sites in the Charlie Lake watershed, the vast majority of which are located in the northern sub-basins (Figures 2-8). Given that the orthophotos were constructed from airphotos taken in 1997, it is possible that more wellhead sites currently exist. It was also evident that not all of the identified wellheads are presently active.

Wellhead sites in the Charlie Lake watershed characteristically had very little vegetation cover and, as such, they typically had considerable surface areas of exposed soil. Exposed soils are susceptible to surface drying and fine particles can become airborne and adversely affect PM<sub>10</sub>-related (particles < 10 µm) air quality. In addition to affecting air quality, fugitive dust particles blown off exposed soils on wellhead sites can settle in stream channels and directly in Charlie Lake. While non-vegetated wellhead sites can contribute sediments to stream channels via aerial transfer, it appeared that the lack of appropriate water management on these sites was a more significant problem with respect to water quality impacts. As shown in Plate 11, some wellhead sites had water-collection ditches surrounding their down-slope perimeter. During snowmelt and rainy periods, substantial amounts of water can collect in these ditches. In at least some cases, small-diameter pipes were put through the down-slope ditch wall to permit drainage (Plates 12 and 13). The pressure of water moving through such cross-ditch drain pipes appears to cause substantial sediment erosion (Plates 12-14) and, we believe, sediment moved from these sites could eventually make its way into stream channels and into Charlie Lake.

There also appeared to be erosional problems in the ditches of private roads that provide access to wellhead sites (refer to *The Condition of Stream-Crossings (Culverts and Bridges) in the Charlie Lake Watershed with Reference to Water Quality (September to November 2002)* for additional information on water quality impacts resulting from roads) (Plate 15). In many cases, it appeared that roads were not constructed to minimise the erosion of the extremely fine watershed soils, with this being particularly evident in sloped regions of the watershed. In general, ditchline erosion was prevalent in the Charlie Lake watershed wherever roads were constructed on sloped ground.

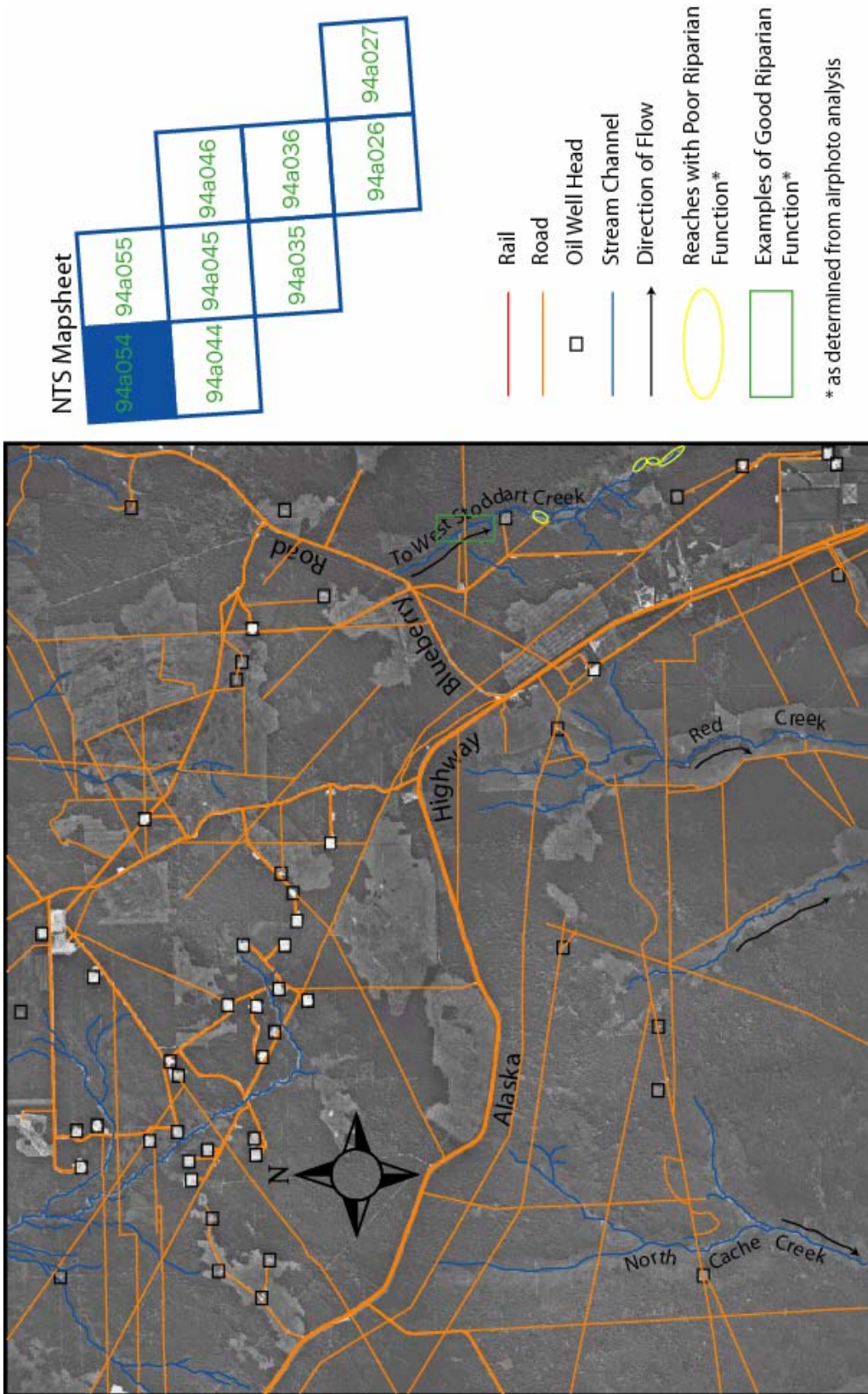


Figure 2. Northwest corner of Charlie Lake watershed showing northern extent of West Stoddart Creek sub-basin. Note that the region west of the Alaska Highway and North of Blueberry Road are not within the Charlie Lake watershed.

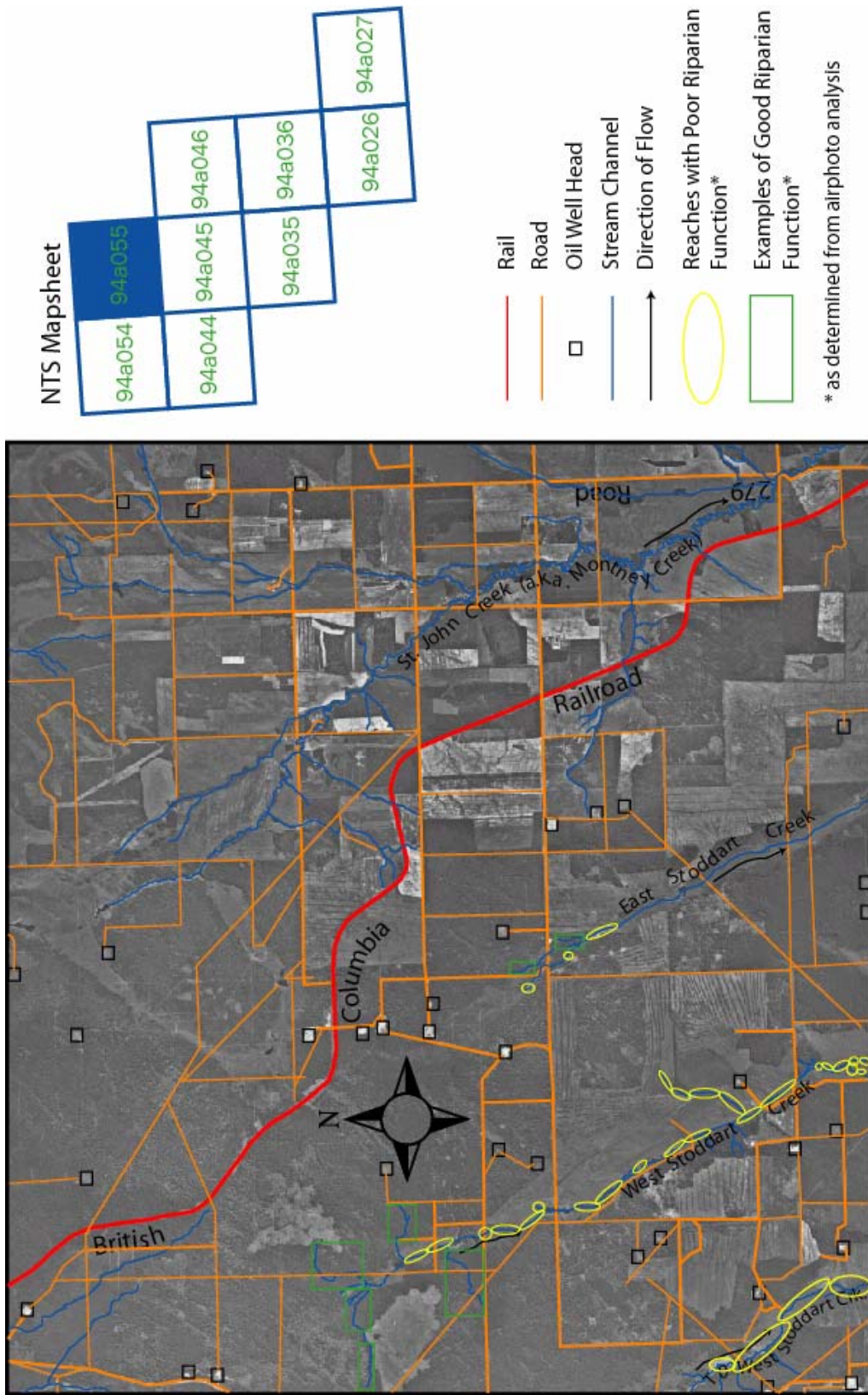


Figure 3. Northeast corner of Charlie Lake watershed showing northern extent of West Stoddart Creek and East Stoddart Creek. Note that St. John Creek is not within the Charlie Lake watershed.

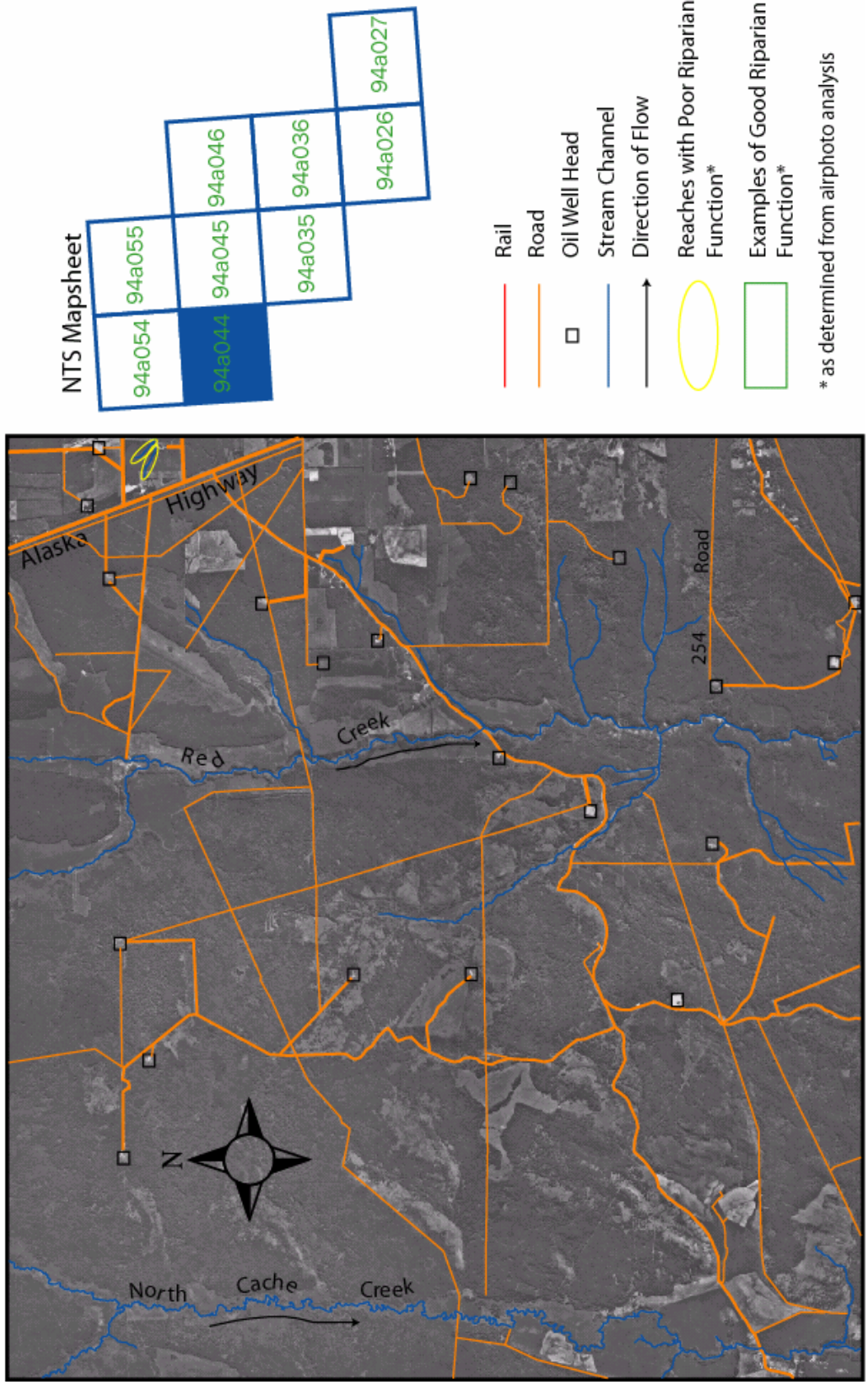


Figure 4. Small portion of northwestern side of Charlie Lake watershed. Note that only the small section to the east of the Alaska Highway is within the Charlie Lake watershed.

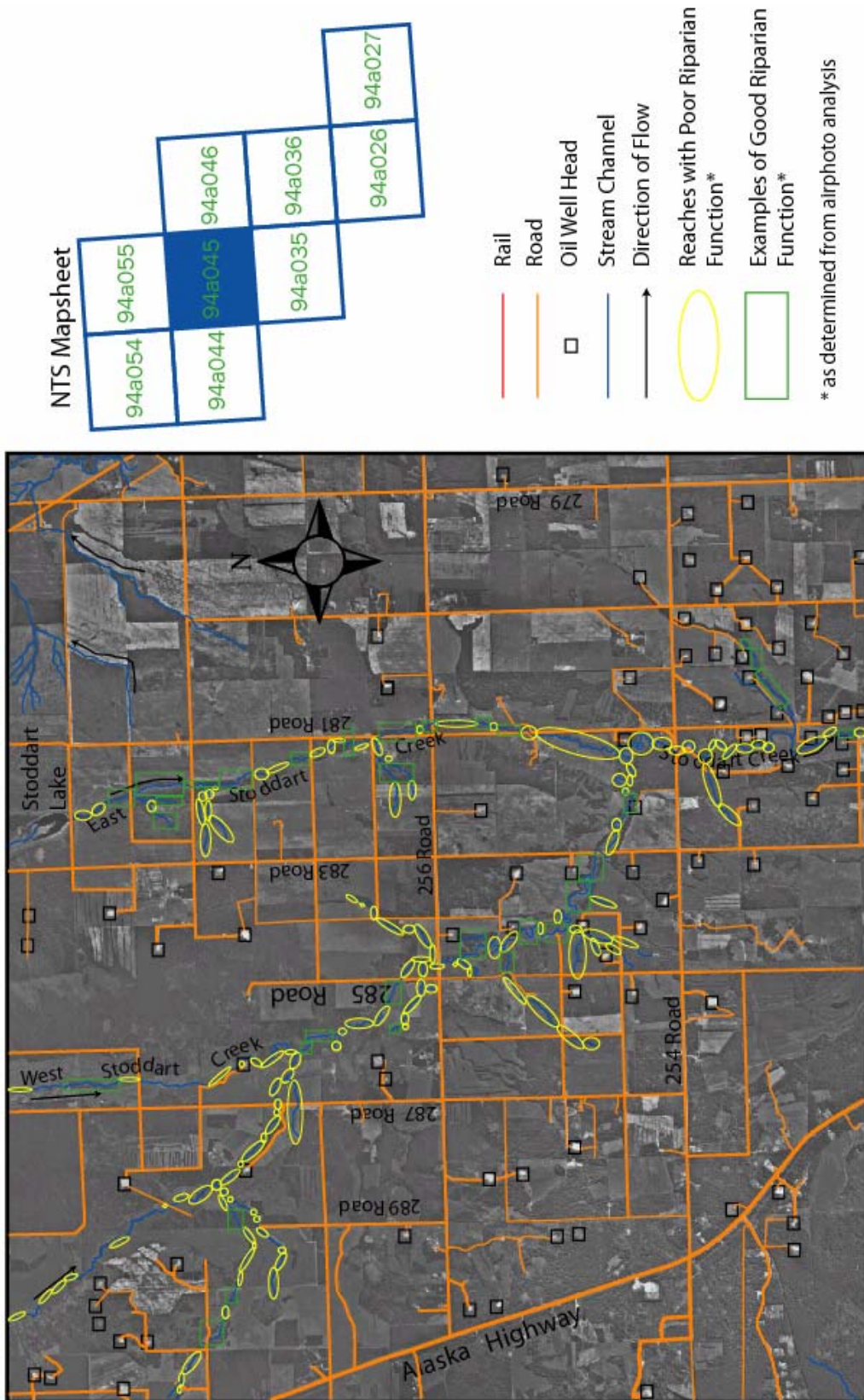


Figure 5. East and west branches of Stoddart Creek north of Charlie Lake. Only portions east of the Alaska Highway are in the Charlie Lake watershed.

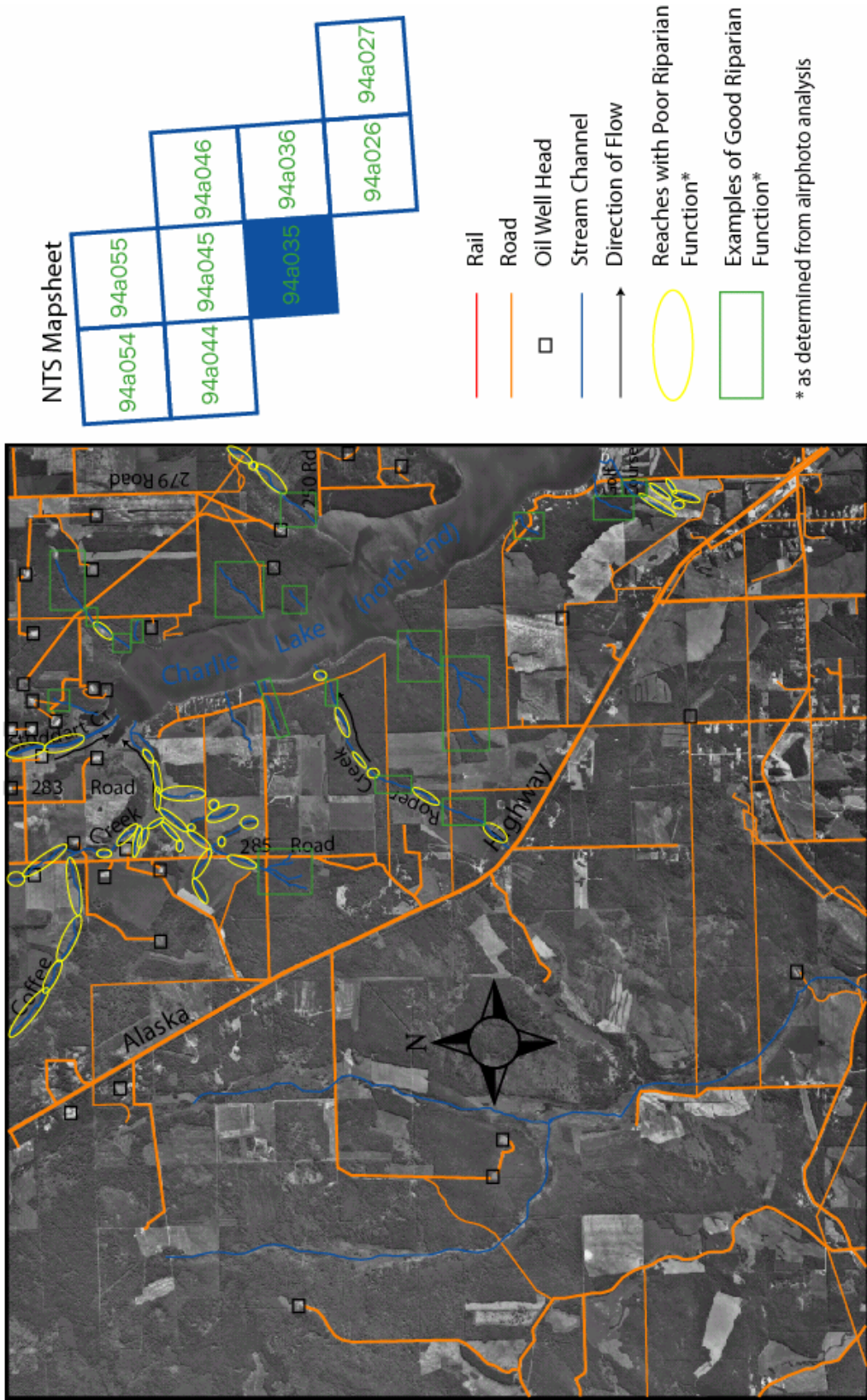


Figure 6. Northwestern side of Charlie Lake. Only regions east of the Alaska Highway are within the Charlie Lake watershed.

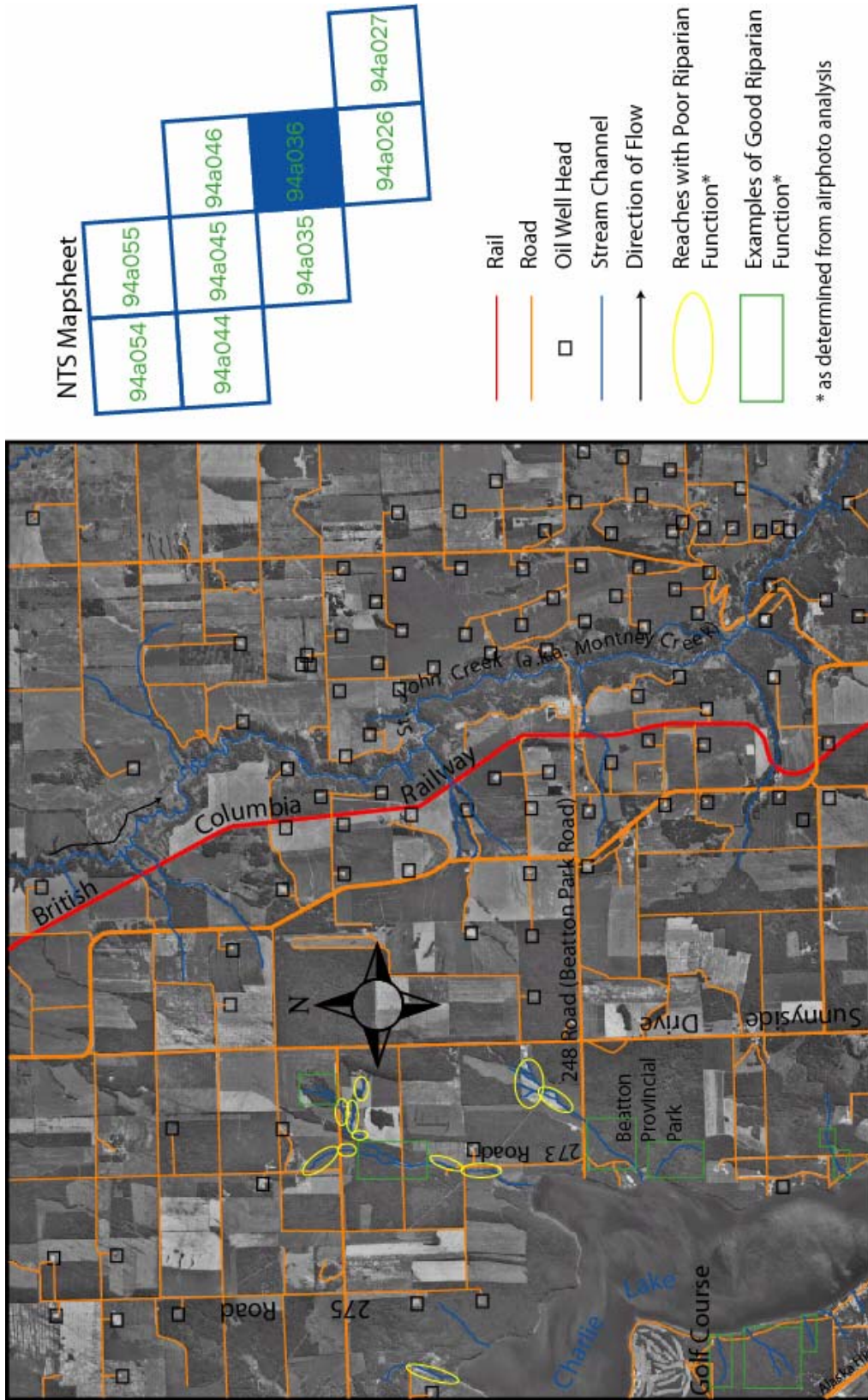


Figure 7. Southeastern side of Charlie Lake. Note that St. John Creek is not within the Charlie Lake watershed.

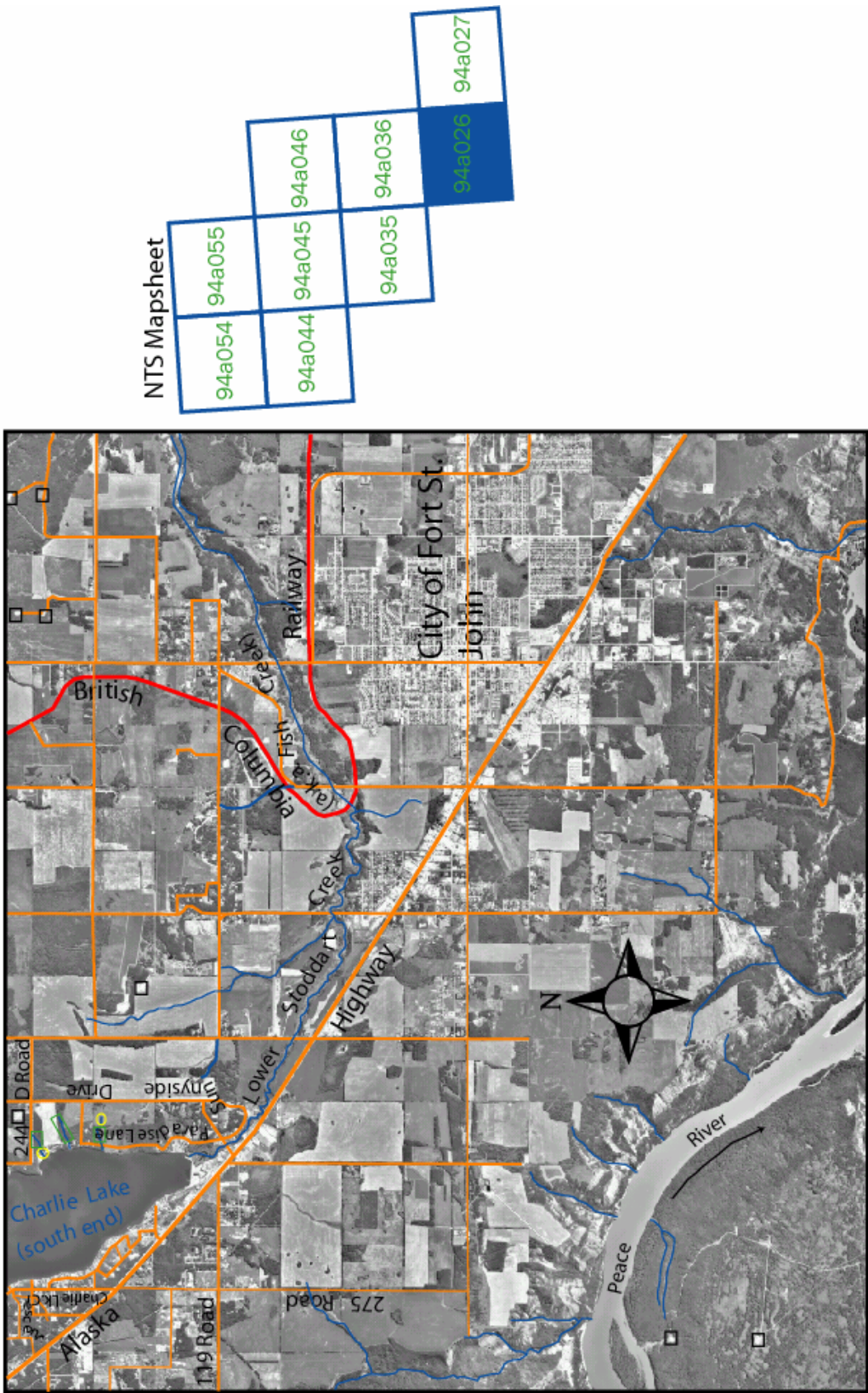


Figure 8. Southern extent of Charlie Lake showing outlet (Lower Stoddart Creek, a.k.a. Fish Creek).

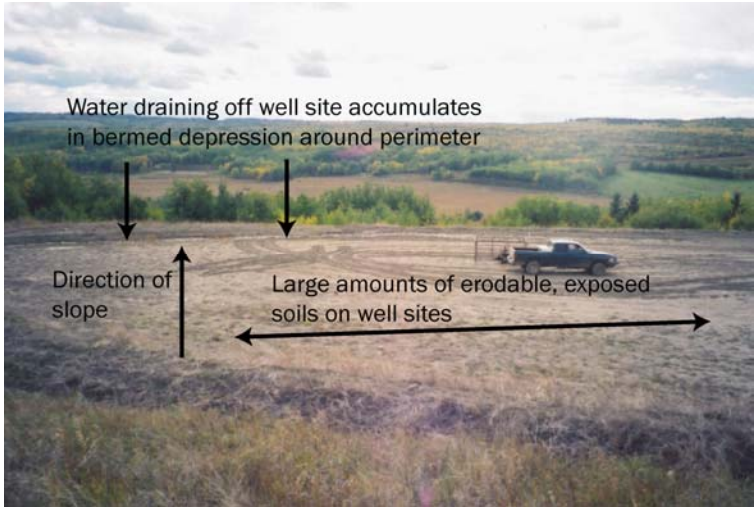


Plate 11. Exposed soils on oil and gas wellhead site. Note water retention ditch surrounding down-slope perimeter.



Plate 12. Small-diameter pipe used to drain water collection ditch on oil and gas wellhead site. Note extensive erosion down-slope of pipe resulting from the force of water through the pipe.



Plate 13. Small-diameter pipe that drains retention ditch on down-slope perimeter of oil and oil and gas wellhead. Note extensive sediment erosion resulting from the force of water through pipe.



Plate 14. Sediment erosion down-slope of wellhead drainage pipe continues for considerable distance.



Plate 15. Ditchline erosion observed on private oil and gas road. Ditchline erosion is a common occurrence in the Charlie Lake watershed, particularly where there is any sort of slope (fine sediment is highly erodable, and likely contributes to stream channel sediment loads).

## Management Options

### *Agricultural Lands*

We observed regions in the Charlie Lake watershed where riparian function has been severely impacted by agricultural activities. These impacts were the result of the encroachment of hayfields into riparian areas, and the access of livestock to stream channels. Both cases are undoubtedly contributing to the transport of sediment to stream channels, and ultimately to Charlie Lake where they accelerate lake shallowing and algal production. We also observed extensive areas of bare soil, particularly on the east side of Charlie Lake, that could further exacerbate the problem of sediment transport to stream channels and Charlie Lake. These issues will require a suite of actions to be taken in concert with an overall program that addresses the affects of agriculture in the entire watershed. For any change to begin in this domain, the Charlie Lake Conservation Society will need to develop strong working partnerships with involved landowners, particularly with those in the East Stoddart Creek, West Stoddart Creek and Coffee Creek sub-basins. Without the direct involvement

and participation of landowners, we believe that it will be extremely difficult, if not impossible, to address water quality issues in the Charlie Lake watershed.

In working towards the restoration of riparian habitats in agricultural reaches, we recommend that the Charlie Lake Conservation Society focus their efforts on project design, fundraising and advocacy on the behalf of landowners and other partners. Landowners themselves will have the expertise necessary to undertake fencing projects and the construction of off-channel watering facilities, but may not have the time required to write funding proposals and to administer any awarded funds. In this view, the Charlie Lake Conservation Society would develop project concepts and ideas with landowners, and then take on the responsibility of accessing funding sources to cover the costs of required materials and, in some cases, labour. Through community-level outreach, the Charlie Lake Conservation Society may even be able to find volunteers to help landowners with projects requiring large amounts of labour (e.g., fencing and fence maintenance). The Charlie Lake Conservation Society could also develop partnerships with work placement agencies (e.g., Human Resources Development Canada, Corrections Canada and University/College Co-operative Education Departments) that provide people with meaningful experiences to help them enter, or re-enter, the workforce.

We believe that water-quality improvement projects associated with the agricultural industry will require the following:

1. An acknowledgement that present practices can be modified for the betterment of both the environment and the industry,
2. Clear examples of how present agricultural practices can be integrated with effective riparian management,
3. Recognition by government, non-government and the community that changes are being sought by the agricultural industry,
4. Substantial funding/tax incentives to offset costs to individual landowners, and
5. Strong leadership.

Livestock impacts to riparian habitats can be mitigated in two general ways, using a variety of different management techniques:

1. Temporary exclusion of livestock from riparian habitats, and
2. Permanent exclusion of livestock from riparian habitats.

The premise of these management techniques is to limit where, when and for how long livestock are given access to riparian habitats. In each case, the selected technique limits the potential affects of livestock disturbance by restricting access during times when riparian vegetation is most vulnerable to trampling and grazing. Typically, livestock are not permitted to access riparian areas in the spring when banks are saturated with water, and during the autumn and winter months when plant reserves are low and vulnerable to grazing (Leonard et. al., 1997; Adams & Finch, 1998). By limiting the amount of time that livestock have access to riparian habitats, riparian shrubs, grasses and herbs will be protected from overgrazing and have the ability to recover from temporally-short disturbances. The temporary exclusion of livestock from riparian areas could require landowners to build new fencing (or modify pre-existing fencing), to closely monitor livestock behaviour, and, in extreme cases, restoration of riparian habitat may also require planting of riparian species; however,

we suspect that native vegetation will re-colonise impacted riparian habitats through natural processes if livestock are appropriately managed, and if crop fields are not permitted to encroach on riparian habitats. As described in Adams & Fitch (1998), there are a series of management tools that can be used to temporarily restrict livestock from riparian areas, including:

1. Rotational grazing,
2. Time-controlled grazing, and
3. Riparian pastures.

In each case, fencing is used to parcel the landscape into smaller units (pastures). Livestock are then moved from one unit to the next according to a predetermined schedule. Moving livestock from one pasture to another is presently done in the Charlie Lake watershed as a matter of course; however, the techniques listed above are specifically designed to benefit the health of riparian areas as opposed to the more general improvement of pasture. Table 1 describes the basic concepts of rotational grazing, time-controlled grazing and riparian pastures in view of how they can be used to temporarily restrict livestock from riparian habitats.

Table 1. Management options for limiting cattle access to riparian habitats: rotational grazing, time-controlled grazing and riparian pastures (summarised from Adams & Fitch (1998)).

Management Tool	Description
Rotational Grazing	Landowners subdivide their holdings into small grazing units (pastures), then livestock are moved between units following a pre-determined sequence of grazing and rest periods, targeting specific riparian areas for rest and protection. By following scheduled rest and grazing “rotations”, riparian areas are protected when they are particularly vulnerable to livestock grazing. Severely degraded riparian habitats may require extended periods of rest.
Time-Controlled Grazing	Time-controlled grazing dictates the duration of livestock foraging permitted in specific areas. Like rotational grazing, time-controlled grazing requires landowners to move livestock from unit to unit. With time-controlled grazing, riparian areas are only lightly grazed at only one time of the year and are rested for the remainder of the year. The duration of grazing needs to be carefully monitored by landowners under this management regime.
Riparian Pastures	A riparian pasture system is a type of rotational grazing system. The main difference with this system is that landowners need to fence areas similar “types”, e.g., riparian areas are fenced and isolated from non-riparian areas. Fenced areas are then grazed in a sequence such that riparian areas are protected during vulnerable times.

Unlike rotational grazing, time-controlled grazing and riparian pastures that permit livestock periodic access to riparian habitats and stream channels, management options that utilise corridor fencing permanently keep livestock away from streams. In many areas, corridor fencing is considered as a “last resort”. It is often used when other management strategies have not been successful. One of the main problems with corridor fencing is that extensive amount of fencing materials and fence maintenance can be required. Corridor fencing can, however, be essential if the soils in the area are sensitive to erosion all year round, or if riparian areas are severely degraded and cannot re-establish through natural processes. Despite these drawbacks, corridor fencing can be a valuable tool to demonstrate how resting riparian areas from grazing by livestock can benefit

riparian health. As such, it can be an important means by which to increase awareness of the potential problems associated with livestock and riparian health.

Riparian protection techniques, whether they employ temporary or permanent livestock exclusion methods, often require the construction of off-channel watering facilities. There are a variety of off-channel livestock watering options available to landowners in the Charlie Lake watershed. Most involve the movement of water from a current water source (e.g., springs, wells and dugout) by means of gravity, solar, wind, or animal power. There are also several types of systems that use the force of moving water (e.g., streams and rivers) to pump water to alternative areas. These systems, however, would have limited applicability in the Charlie Lake watershed due to intermittent nature of stream flows and predominance of low-gradient watershed slopes (G. Mottershead, Agriculture and Agri-Food Canada, Dawson Creek, Pers. Comm.). Listed below are alternative watering systems that have applicability in the Charlie Lake watershed:

1. Dugouts using access ramps - reinforced ramps made with gravel and often geotextile material that provide better footing for livestock at dugouts material at dugouts (Figure 9),
2. Solar pumps - pumps that use photovoltaic cells (solar panels) to pump water from a source (dugout, well or stream) to a stock tank (Figure 10),
3. Nose pumps - pasture pumps that are operated by livestock using their noses to physically pump water from a source to a small reservoir (Figure 11),
4. Gravity Feed systems - delivery systems used on sloping pastures where a dugout or dam is built that then delivers water through a pipeline downhill to a stock tank (Figure 12),
5. Pumped gravity - water is pumped from an elevated earthen reservoir and water then flows by gravity to a stock tank with float (Figure 13), and
6. Windmill pumps - use wind power to pump water from a source (dugout, well or stream) to a stock tank.

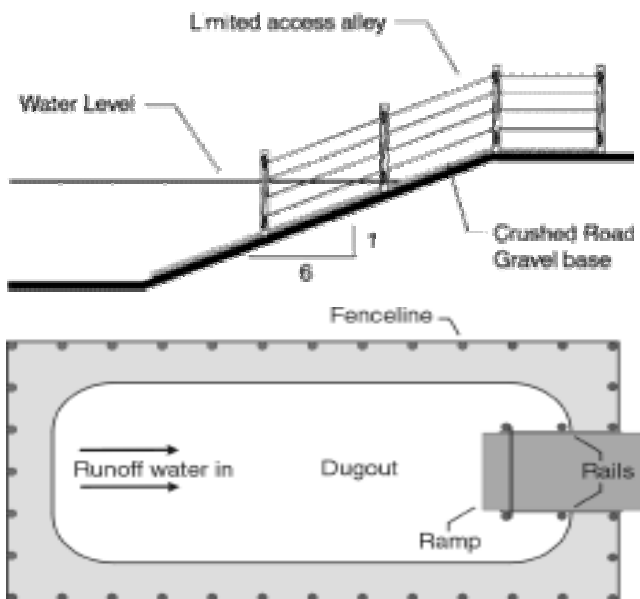


Figure 9. Schematic of a dugout with reinforced livestock access ramps (provided by Alberta Agriculture, Agricultural Engineering Branch, Food and Rural Development).

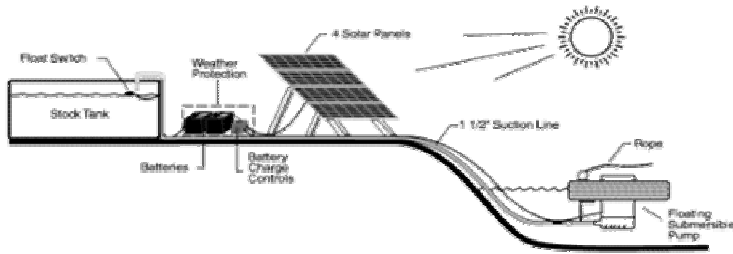


Figure 10. Schematic of a solar powered water pumping system that can be used in off-channel livestock watering facilities (provided by Alberta Agriculture, Agricultural Engineering Branch, Food and Rural Development).

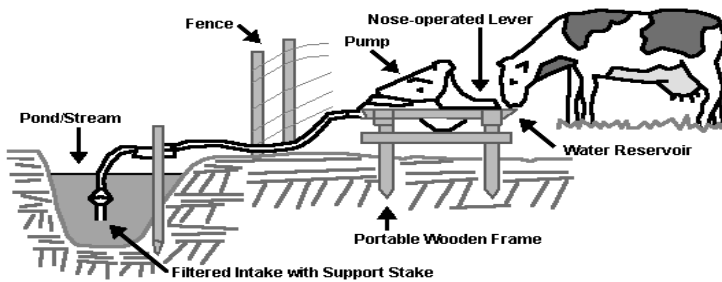


Figure 11. Schematic of nose pumping system that provides water to livestock (provided by King County District, 935 Powell Avenue, SW, Renton Washington, USA, 98055).

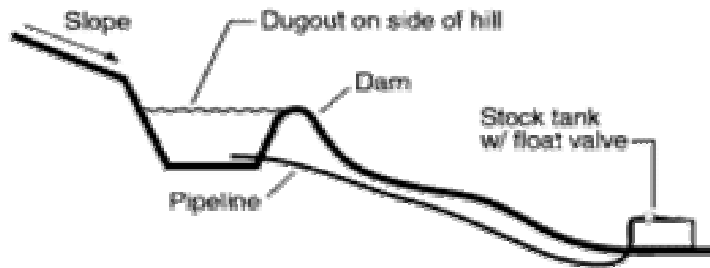


Figure 12. Schematic of a gravity-powered system that supplies water to livestock (provided by Alberta Agriculture, Agricultural Engineering Branch, Food and Rural Development).

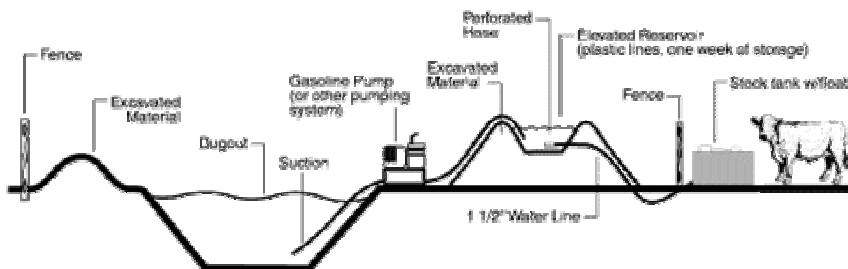


Figure 13. Schematic of a pumped-gravity system that supplies water to livestock (provided by Alberta Agriculture, Agricultural Engineering Branch, Food and Rural Development).

It can be reasonably assumed that if a dugout is required in addition to facility hardware, it will cost approximately \$4,000 for 1,500 m<sup>3</sup> (G. Mottershead, Agriculture an Agri-Food Canada, Dawson Creek, Pers. Comm.) plus maintenance costs. Estimates for other materials-related costs are given in Table 2.

For riparian function to improve in the vicinity of crop fields, fields will need to be contracted away from stream channels to permit riparian regeneration. The main problem associated the contraction of crop fields is that there would necessarily be a reduction in the area under cultivation, and this would have financial ramifications for landowners. For example, assuming that operations in the Charlie Lake watershed yield 1.2 tons/acre of hay (clover and grass mix) and that the average value of this hay is \$60/ton, every acre pulled out of production for riparian management could cost producers \$75. If the same fields are also used for grazing, there are additional losses. Assuming that grazing on these areas represents 0.5 tons/acre, the net loss as a result of riparian management would be an additional \$30/acre. Under this hypothetical scenario, producer losses for riparian management would be approximately \$105/acre (G. Ouellette, Crop Insurance Representative, BC Ministry of Agriculture, Food and Fisheries, Fort St. John, Pers. Comm.). Depending upon the size of area involved, losses to producers could be excessive.

Table 2. Estimated costs for construction of off-channel livestock watering facilities.

Watering System	Details	Approximate Costs
Access Ramp to Dugout	Cattle are given limited access to a constructed dugout via a hardened ramp.	<ol style="list-style-type: none"> <li>1. \$500 to fence and construct ramp</li> <li>2. \$.75/ft<sup>2</sup> without geotextile</li> <li>3. \$1.00/ft<sup>2</sup> with geotextile</li> </ol>
Solar Energy	Solar panels pump water from source to a stock tank.	\$3,000 - \$6,000 to fence and install the solar pump, solar panels, optional battery, water storage stock tank and cement pad
Gravity-Fed System	Water is delivered down slope from a constructed dugout via a pipe line to a stock tank with a float valve.	Shallowly buried Polyethylene pipe ~ \$5-6/m , water storage stock tank
Animal Operated Pumps	Animals learn to pump water (approx. 1 L/pump stroke) from a water source (well, stream, dugout). Can lift up to 6 m vertically.	<ol style="list-style-type: none"> <li>1. \$700 to fence and purchase pump (\$450 each)</li> <li>2. Installed cost of Frostfree Nosepump™ including pump, drilling or trenching, culvert, hose, lid, insulation rod, pipe and platform \$2000-\$5000</li> </ol>
Wind Power	Water is pumped via wind power from source to stock tank with float valve.	<ol style="list-style-type: none"> <li>1. \$2,000 - \$2,500 to set up Koenders windmill and air-operated pump, plus a 1,200 gallon plastic water tank, 500 gallon stock tank, cement pad and pipe</li> <li>2. \$3,500 - \$4,000 to fence and set up Dutch Industries - Delta Junior windmill, plus 1,200 gallon plastic water tank, 500 gallon stock tank and water pipe</li> </ol>

One way to offset financial losses associated with reducing the size of crop fields is the utilisation of conservation covenants with an appropriate conservation organisation, that can give landowners property-tax benefits based on the area of land reserved for conservation. Conservation covenants are a relatively new tool for protecting private land in British Columbia. They are voluntary legal agreements that are formulated by a landowner and a conservation organisation, or land trust, that typically restrict the use of, or require that improvements to, a given parcel of land for the protection of natural, historical, cultural, architectural, environmental, heritage, scientific, wildlife or plant-life values (Land Title Act, R.S.B.C. 1996; Hillyer & Atkins, 2000 – see <http://www.landcentre.ca/infodtl.cfm?ID=5173>). Conservation covenants are attached to the title, and as a result, they are legally binding on present and future landowners. The specifics of any one covenant are tailored to the desires of a particular landowner. Importantly, the landowner retains ownership of the land as well as all of the rights and privileges associated with ownership. In particular, the landowner can continue to live on, and work the land. The only restrictions on what can, and cannot be done on the land, are those agreed upon in the initial covenant.

Conservation covenants can be modified or cancelled, but only under exceptional circumstances. First, a conservation covenant can be modified through a written agreement between the landowner and the covenant holder. Second, a covenant holder can discharge the covenant. Third, someone with a legal interest in the land can submit an application to the court in order to have the covenant modified or cancelled (Hillyer & Atkins, 2000). Reasons that may prompt the court to grant modification or cancellation of a covenant include:

1. A change in CHARACTER of the land, or surrounding lands that may make the intended purposes of the covenant obsolete (e.g., a forest fire destroys the trees that the covenant was intended to protect),
2. If the use of the land is impeded, without benefit to others, if the conservation covenant is not modified or cancelled, and
3. If the covenant holder agrees to the modification or cancellation of the covenant (Hillyer & Atkins, 2000).

There are specific costs and responsibilities related to the establishment and maintenance of a conservation covenant (Table 3). The most costly expense in registering a covenant is in its initial establishment, with these costs being largely dependent upon the complexity of the covenant and, in particular, whether a full legal land survey and appraisal are required. Full legal surveys are often required to reduce the ambiguity of the area covered by the covenant for future landowners. Appraisals are typically required if the covenant significantly affects property value (S. Black, Okanagan Regional Manager, The Land Conservancy, Penticton, Pers. Comm.). Land trusts strongly advise landowners to consult with tax lawyers to examine the specific tax implications of each covenant. Apart of specific expenses, landowners are required to permit the covenant holder to visit the site annually to establish that the terms of the covenant are being satisfied. Furthermore, there are also costs associated with any appraisals that are required to accrue any tax benefits. Most, if not all, of these costs are typically the responsibility of the affected landowner; however, we believe that the Charlie Lake Conservation Society could assist landowners with fundraising to offset these costs. One way to minimise the potential costs of establishing covenants is to work with a conservation organisation, or land trust that is well versed in the use of covenants. Organisations experienced in covenant establishment often have resources and expertise that can help offset such costs.

By restricting potential development on a parcel of land, conservation covenants could result in the reduction of property values, such that properties may be less desirable to future landowners if there are restrictions placed upon their ability to re-develop lands set aside for conservation. However, reduced property values are

not a necessary consequence of conservation covenants being placed on land. Some individual buyers may seek out property that has certain natural attributes associated with the title; but, the potential remains that properties may be less attractive for re-sale should a covenant be placed upon them. To offset this, there are at least two ways in which a landowner can benefit economically from registering a conservation covenant on their property. First, a full appraisal would have to be undertaken to determine how the value of the land has changed as a result of placing a covenant on the title. If the value of the land has decreased, the covenant holder can issue a charitable tax receipt equivalent to the reduction in property value resulting from the covenant, which can be filed by the landowner to offset income tax (Hillyer & Atkins, 2000). Second, property taxes may be similarly reduced as a result registering a conservation covenant. The reduction of property taxes would be based upon a re-assessment of property values. A landowner would then apply for an appeal of the property tax assessment for any land removed from potential agricultural production/use. The value of the property tax reduction would be the difference in the value of the land with and without a conservation covenant (Hillyer & Atkins, 2000). Other changes to taxes as a result of registering a covenant may include changes in capital gains or other land transfer, probate, G.S.T. or pension amounts. The use of conservation covenants in the Charlie Lake Watershed has at least two potential applications:

1. Lakeshore living, and
2. Agricultural activities.

Table 3. Estimated costs associated with the establishment and monitoring of a conservation covenant.

Service	Approximate cost <sup>1</sup>	Responsibility
Legal fees to review covenant <sup>2</sup>	\$500	Land Trust & Landowner
Tax advice	\$500-\$1000	Landowner
Official survey	\$2,500-\$8,000	Landowner <sup>3</sup>
Appraisal	\$1000-\$5,000	Landowner <sup>3</sup>
Covenant monitoring	\$1,000/year	Land trust
Writing of covenant and preparation of Baseline Documentation Report (staff time)	\$10,000-\$15,000	Land trust

<sup>1</sup>Estimated costs courtesy of S. Black, Okanagan Regional Manager, The Land Conservancy, Penticton.

<sup>2</sup>Both the landowner and land trust are required to have a conservation covenant reviewed by a lawyer. The costs listed here assume that it would cost both parties the same amount (approximately \$500) each to have a covenant reviewed.

<sup>3</sup>These costs may be shared between the landowner and the land trust. They are dependent upon the land in question and the land trust involved.

The use of conservation covenants to protect lakeshore properties is widely used in British Columbia. Throughout British Columbia, people living along lakeshores have protected present day shorelines through the use of covenants. The Peace River Regional District through the Municipal Act recognises the use of conservation covenants and will grant property tax breaks to owners of land considered as "eligible riparian property", in exchange for that riparian land remaining free from development. This type of agreement presently requires an appropriate Regional District to be the covenant holder (PRRD, 2000).

The application of conservation covenants on agricultural land in British Columbia (e.g., land in the Agricultural Land Reserve) is less common, but is increasing. Recent changes to the Agricultural Land Reserve Act,

however, may make the use of covenants to protect portions of lands in the Agricultural Land Reserve more difficult. On May 14/2002, the Agricultural Land Commission passed Bill 21 – 2002. Section 22 (2), of Bill 21 gives the Agricultural Land Commission new statutory powers to refuse the application of conservation covenants. This new statutory power was intended to balance the need to maintain agricultural lands with the desire to protect important environmental values. Part of this policy is to ensure that there is no net loss of agricultural land as a result of conservation activities. Furthermore, there is a concern that the establishment of a conservation covenant for the purposes of maintaining, or creating wildlife habitat, especially waterfowl habitat, may result in future conflicts with the agricultural industry (N. Walkden, Special Assistant to the Executive Director, The Land Conservancy, Victoria, Pers. Comm.).

In theory, conservation covenants can be refused by the Agricultural Land Commission even if landowners and covenant holders are attempting to protect specific habitat features or to maintain ecological function (e.g., fencing of riparian habitat; WECL, 2002). Section 22(2) also removes the ability of a land trust or other conservation organisation to appeal decisions by the Agricultural Land Commission that pertain to the refusal of the registration of a conservation covenant (N. Walkden, Special Assistant to the Executive Director, The Land Conservancy, Victoria, Pers. Comm.).

We suggest that the Charlie Lake Conservation Society invite an representative from a land trust that is well versed in covenant application to give a presentation to landowners in the Charlie Lake watershed. This presentation can be a stand-alone presentation, or as part of a larger event, such as an annual general meeting. We would further suggest that separate presentations be given to lakeshore landowners and agriculturists, as the application of covenants in these two areas is slightly different. We would also suggest having a lawyer and a tax consultant who are familiar with covenants be invited to participate in this presentation(s). Finally, we would strongly suggest that members of the Peace River Regional District be a part of both presentations as responsibility of registering covenants is, in some areas, being passed on from the Agricultural Land Commission to the appropriate bodies within Regional Districts (N. Walkden, Special Assistant to the Executive Director, The Land Conservancy, Victoria, Pers. Comm.).

Conservation covenants will likely have a clear role to play on both lakeshore and agricultural properties in the Charlie Lake watershed. Lakeshore properties will be relatively easy to apply covenants to, given willing landowners. Agricultural lands, on the other hand, will likely be more difficult due to changes in the Agricultural Land Act. Ideally, any conservation covenant on agricultural lands in the Charlie Lake watershed will be structured in such as way as to minimise the chance of refusal by the Agricultural Land Commission. Covenants should be written to stress the maintenance of ecosystem function, the protection of clean water, and the benefits to the agricultural industry. In essence, conservation covenants should be written in such a way as to benefit working ranches and farms by ensuring their continued existence. Framed in this way, conservation covenants are more likely be effective tools to protect, enhance, or restore riparian areas on agricultural land in the Charlie Lake watershed. A more problematic obstacle is the lack of experience with conservation covenants in the Peace Region of British Columbia where only a few covenants presently exist. As a result, the knowledge of what covenants can and cannot accomplish in this region is largely unknown.

In many cases it is likely that with prevention from further degradation through the use of the livestock and crop management techniques described above, the riparian areas in the Charlie Lake watershed will recover naturally. If after management practices are modified and the riparian areas do not recover naturally, it may

be necessary to attempt to revegetate these areas manually. Fast-growing riparian shrubs planted at high densities are typically used to stabilise eroding banks, while grasses and legumes are used to control sheet, or surface erosion (Atwood & Scott, 1997). The use of plants to perform an engineering function is referred to as bioengineering (Schiechtl, 1980 as cited in Polster, 2001). There are a wide variety of bioengineering techniques that can be used to control erosion and the re-establish riparian function. Many of these techniques, while labour intensive, can be done with minimal machinery, and utilise inexpensive materials (e. g., plant cuttings, especially willow and dogwood). Although plant cuttings can typically be collected during periods of dormancy (i.e., winter months) from within the region where the restoration work is being undertaken, it is sometimes necessary to purchase cuttings from commercial horticulturists. The approximate costs of planting-ready shrub cuttings are given in Table 4.

Table 4. Price list of plants available for restoration work in riparian areas (from PRT Reid Collins, see <http://www.prtgroup.com/locations/rc/>). Cost estimates are based on a 500 minimum order of any one species, or the entire inventory of the species, whichever is less.

<b>Genus Species</b>	<b>Common Name</b>	<b>Sites*</b>	<b>Size</b>	<b>\$/plant (CDN)</b>
<i>Acer glabrum</i>	Douglas maple	M, D	412A	0.68
<i>Amelanchier alnifolia</i>	Saskatoon	M, D	412A	0.68
<i>Arctostaphylos uva-ursi</i>	Kinnickinnick	M, D	410A	0.47
<i>Betula papyrifera</i>	White Paper birch	R, M	415D	0.68
<i>Cornus stolonifera</i>	Red osier dogwood	R, M	415D	0.68
<i>Cornus stolonifera</i>	Red osier dogwood	R, M	412A	0.68
<i>Crataegus douglasii</i>	Black hawthorn	R, M	412A	0.68
<i>Crataegus douglasii</i>	Black hawthorn	R, M	415D	0.68
<i>Mahonia aquifolium</i>	Tall Oregon grape	M, D	412A	0.68
<i>Philadelphus lewisii</i>	Mock orange	M, D	412A	0.68
<i>Populus tremuloides</i>	Trembling aspen	M, D	415D	0.68
<i>Populus trichocarpa</i>	Cottonwood	M, R	415D	0.68
<i>Prunus virginiana</i>	Black choke cherry	D	412A	0.68
<i>Rosa acicularis</i>	Prickly rose	R, M, D	412A	0.68
<i>Rosa nutkana</i>	Nootka rose	R, M, D	412A	0.68
<i>Rosa woodsii</i>	Prairie rose	M, D	412A	0.68
<i>Salix bebbiana</i>	Bebb's willow	R, M, W	415D	0.68
<i>Salix scouleriana</i>	Scouler's willow	R, M, W	415D	0.68
<i>Shepherdia canadensis</i>	Buffalo berry	M, D	410A	0.47

\* R = Riparian, D = Dry, T = Transition, M = Moist

There are currently four common bioengineering methods used in riparian restoration (Polster, 2001):

1. Live bank protection,
2. Live silt fences,
3. Live palisades, and
4. Live staking.

Live bank protection is used to stabilise stream banks that have succumbed to the action of debris torrents. Typical live bank protection uses wattle fences (short retaining walls built from live cuttings) that are positioned such that they provide support for slumping stream banks (Figure 14). Growth of the cuttings provides both cover along the streams and a strong network of roots that help reduce potential future erosion. Live silt fences are rows of cuttings stuck into the streambed to slow water movement and to trap sediment (Figure 15). They are best suited for low velocity streams and ditches. As the cuttings grow, they produce a series of brushy areas that is characteristic of small streams and seepage areas. Live palisades are typically used where past land management has completely eliminated all riparian vegetation and has caused, or is leading to, extensive erosion. Live palisades are rows of large cottonwood cuttings that are placed in a trench 1- 2m from an eroding stream bank (Figure 16). Cuttings have to be at least 4 cm in diameter at the tip and at least 3 m long. They are “planted” such that at least 1 m of the stake or cutting remains above ground. Live palisades are often augmented with additional cuttings of smaller pieces of willow or dogwood. Live staking is the use of live cuttings to stabilise eroding and slumping slopes. Cuttings are simply inserted into the soft soils in the spring or fall (Figure 17). As the cuttings grow, the roots bind to the soil to prevent further erosion. Live stakes are often used in conjunction with normal seeding when seeding alone would prove, or has proven ineffective (i.e., as can occur in areas prone to sloughing).

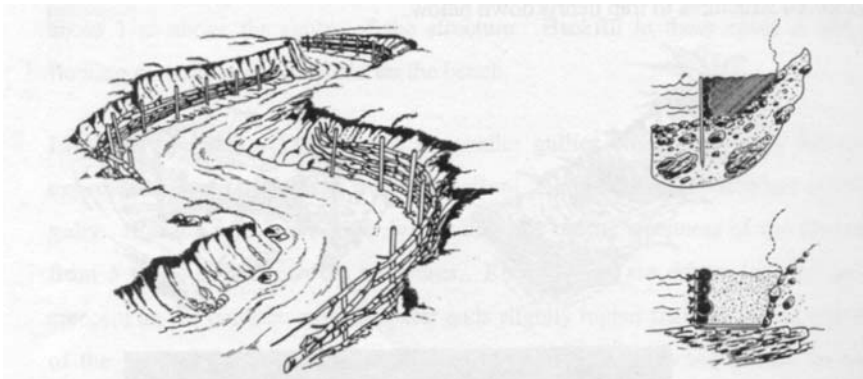


Figure 14. Schematic illustrating concept of live bank protection (from Polster, 2001).

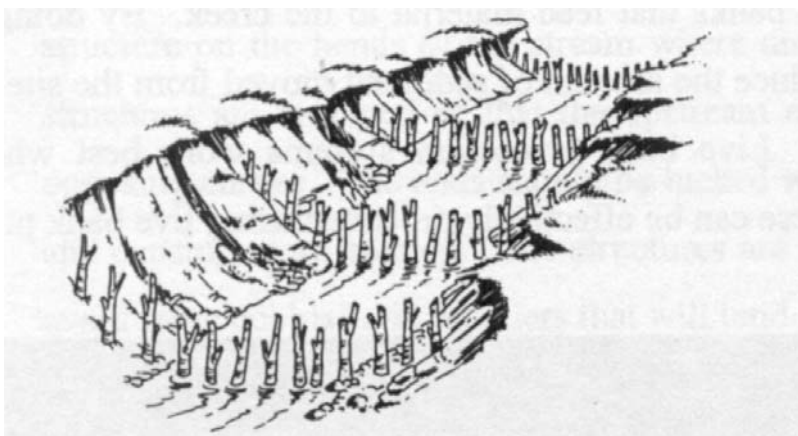


Figure 15. Schematic illustrating concept of live silt fencing (from Polster, 2001).

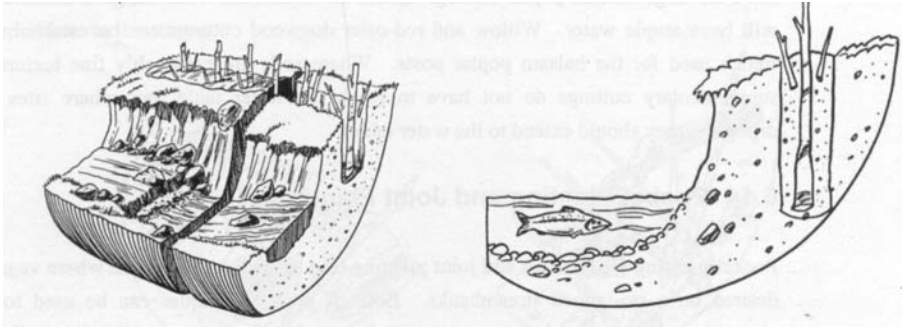


Figure 16. Schematic illustrating concept of live palisades (from Polster, 2001).

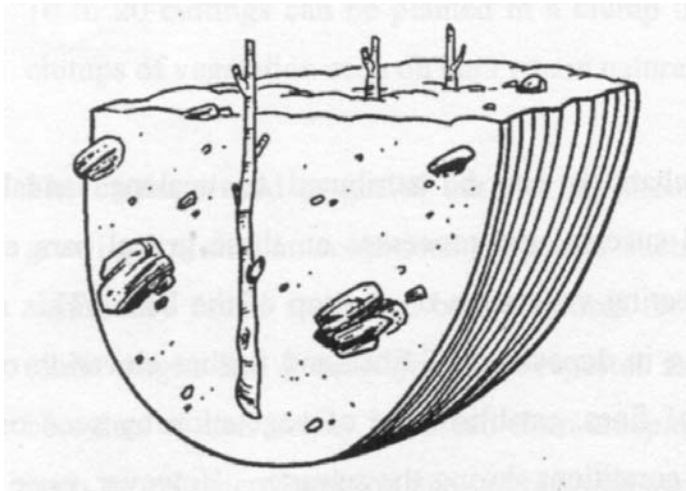


Figure 17. Schematic illustrating concept of live staking (from Polster, 2001).

The paragraphs above discuss methods that the Charlie Lake Conservation Society can employ to protect healthy riparian habitats and to restore those riparian habitats that have been adversely affected by livestock and crop field encroachment. Although unstable riparian zones are likely the major source of sediment in tributaries to Charlie Lake, exposed soils in fields outside of riparian regions can also contribute considerable amounts of fine sediment to tributaries, primarily through erosion caused by wind and water. In particular, crop fields that have undergone intensive tillage are subject to considerable erosion through the transport of fine particles and nutrients by both wind and water. Such erosion can be mitigated by employing conservation tillage practices (e.g., reduced or zero tillage), or by employing direct seeding. Both reduced or zero tillage and direct seeding aim to minimise soil disturbance during planting. Under zero tillage, planting is the only operation that disturbs the soil (Green, 1999). By comparison, direct seeding, allows some tillage to address immediate weed problems and to help alleviate high moisture conditions and heavy clay soil conditions. With direct seeding, the soil is not tilled in the spring before planting; rather, seeds are planted directly into stubble (Dunn, 1999). Research in the Peace River region of Alberta has shown that annual soil losses could be reduced by 53% using reduced tillage and 81% using zero tillage (Van Vliet et al., 1993 as cited at [www.reducedtillage.ca/soilconservation.html](http://www.reducedtillage.ca/soilconservation.html)). While helping to reduce erosion, conservation tillage practices and direct seeding have also been shown to increase moisture conservation, improve yields, reduce labour costs, reduce fuel consumption, and lead to equipment savings due to reduced operating needs (Coutts & Smith 1991; Vanderwel & Abday, 2001). It has also been noted that herbicide costs may increase under either scenario; however, these costs can be offset by reduced tillage-related costs (Vanderwel & Abday,

2001). Any movement to reduced tillage and or direct seeding will also require site specific consultation with government, industry, or associated groups (Dunn, 1999). In addition, reduced tillage and/or direct seeding techniques may require landowners to either purchase or modify current planting machinery.

Presently, it is difficult to determine which of the management tools that are generally applied to riparian management will be directly applicable to holdings in the Charlie Lake watershed. The use of any of the above management tools will depend upon the circumstances of individual landowners. Factors what will dictate the use of any of the above tools will be dependent upon the following:

1. How connected or isolated are the pastures of individual landowners?
2. How much additional fencing will be required?
3. How willing will a landowner be to move livestock more often than at present?
4. What kind of alternative watering facilities will be required?
5. How much will any of the above management practices and associated ancillary activities cost an individual landowner both in terms of capital costs and additional labour? and, how can such costs be offset?

### *Oil & Gas Wells*

We noticed problems with erosion at several oil and gas sites and in road ditches (primarily those on steeper slopes) that access wellhead sites. The erosion caused by improperly constructed roads and ditches is undoubtedly contributing to sediment loading in the creeks feeding Charlie Lake and ultimately the lake itself. This problem has been addressed in an ad hoc basis on one road. One of the steps that was taken (e.g., placing hay bales in ditches) is considered a maintenance-intensive, temporary construction measure only (BC MOF, 2002). Furthermore, other methods used in the same area (e.g., the placement of boulders in the ditchline) can actually exacerbate erosion (BC MOF, 2002). In addition, we observed water that had been pooling at a well head was being diverted through a small pipe over the edge of the well site. It was evident that the force of water through the pipe was causing substantial erosion downslope of the site.

Due to the fact that many roads that access well sites in the Charlie Lake watershed are constructed on private property, there are very few legislated safeguards to prevent the kinds of problems that we have observed. The only requirements in terms of engineering guidelines are for stream crossings. If roads do not cross streams, there are no regulations that guide road construction (B. Mitchell-Banks, Director, Compliance and Enforcement Branch, Oil and Gas Commission, Fort St. John, Pers. Comm.; J. Peterson, Development Approvals Technician, BC Ministry of Transportation and Highways, Prince George, Pers. Comm.). This is extremely problematic in the Charlie Lake watershed given that steep ditch gradients in erodable soils typically lead to higher incidences of erosion and increased sediment transport rates (BC MOF, 2002). Unfortunately, a result of the lack of guidelines for the construction of roads on private properties, has been that some roads in the Charlie Lake watershed have not been constructed to minimise surface and subsurface flows that can lead to excessive ditch or roadway erosion.

The Oil and Gas Commission advocates the development of a good working relationship between landowners and oil and gas companies so that problems associated with lease construction and operation can be minimised. The Charlie Lake Conservation Society can play a role in helping build these relationships by helping landowners understand their rights as they pertain to roads, ditches, well sites, and day-to-day operations on their properties. The Charlie Lake Conservation Society, working in conjunction with the Oil and Gas Commission, can help disseminate information about the potential water quality affects of wellhead sites

and associated water management practices, and advise landowners on how they can best structure lease agreements to assure that water quality impacts resulting from oil and gas-related activities on their land will be minimised.

Prior to lease agreements between a landowner and an oil and gas company are signed, the landowner should receive information regarding how to best negotiate a lease agreement. This information can be obtained from the Oil and Gas Commission in Ft. St. John. Once lease agreements are signed, landowners should then have the agreement notarised by a lawyer or notary public. This step, which is often ignored by landowners (B. Caze, Manager, Drilling & Completions, Oil and Gas Commission, Fort St. John, Pers. Comm.), can help prevent future problems associated with road construction or lease operation.

While there are no regulations governing the construction of roads on private property, a landowner can specify that roads be built to a specific standard in order to reduce, or prevent specific issues (e.g., surface erosion) from occurring. This demand would then become part of, or a condition of, the lease agreement. For example, a landowner can specify that any road and associated ditchlines conform, or adhere to a recognised standard (e.g., Ministry of Forest standards). Any such condition should then be notarised by a lawyer or notary public. If there is a dispute related to these conditions the oil and gas company in question can take this request to an arbitration board (B. Caze, Manager, Drilling & Completions, Oil and Gas Commission, Fort St. John, Pers. Comm.). The arbitration board would then rule if the request being made is reasonable. If landowners can make a case for the potential for erosion, it is unlikely that the arbitration board would rule against the landowner's request especially if a landowner can make a credible case for specific standards (B. Caze, Manager, Drilling & Completions, Oil and Gas Commission, Fort St. John, Pers. Comm.). The making of specific demands for future roads, ditch construction and water management on private property is an essential step to preventing future problems associated with sediment transport.

The problems associated with erosion along roads and ditches are issues that the Oil and Gas Commission regularly address. Any incidences of problems, especially those related to water quality, should first be reported by the landowner to the oil and gas company that operates the lease. If no remediation action is taken, the problem should then be reported to the inspectors of the Oil and Gas Commission in Ft. St. John. Once reported, the Oil and Gas Commission will dispatch inspectors to assess the complaint. Depending upon the severity of the specific problem, they will then inform the oil and gas company responsible that a problem has to be fixed. The oil and gas company is then obliged to fix the problem in ways that they deem appropriate. If the initial mitigation attempt does not fix the problem, the process has to be repeated until the problem is solved to the satisfaction of the Oil and Gas Commission (B. Caze, Manager, Drilling & Completions, Oil and Gas Commission, Fort St. John, Pers. Comm.).

Where water is accumulating at well sites, a landowner has to make a request to the company in question to remove the accumulated water. If this request is made, the company involved is obliged to pump the water off the site and dispose of it in an appropriate manner, as opposed to simply diverting it off site through pipes. Water has to be tested for hydrocarbon residue before it is discarded. Accumulated water cannot be disposed of in any other way. If water is not removed in a satisfactory way, landowners have the recourse of taking complaints to the Oil and Gas Commission in Ft. St. John.

There is a role for the Charlie Lake Conservation Society to play in issue of sediment transport arising from oil and gas activities. Working with landowners on these issues would be much the same as the process of disseminating information to lakeshore owners. Landowners would have to be contacted by phone, mail or by onsite visits. Interested landowners would then be given appropriate information pertaining to options and solutions to present problems, as well as ways to prevent problems from occurring in the first place. In this instance the CLCS would:

1. Contact landowners with oil and gas leases on their properties and provide them with information pertaining to rights regarding the protection of water quality.
2. With the permission of landowners, conduct an assessment of all roads leading to oil and gas leases. Pay particular attention to surface and ditchline erosion, and to any illegal pump-off activities.
3. Present findings to landowners, illustrate how problem areas may be affecting water quality in the water shed.
4. Provide landowners with options at their disposal including reporting problem areas to Oil and Gas Commission in Ft. St. John.
5. Monitor changes.

Some of the landowners that we spoke to expressed frustration regarding the specific problems related to oil and gas production on their lands. Consequently there is likely a portion of landowners that would readily accept, or be interested in receiving information and assistance regarding options to mitigate specific problems. The Oil and Gas Commission in Ft. St. John also has outreach information that would be applicable for this kind of program and has expressed interest in facilitating this type of initiative.

Any initiative associated with disseminating information regarding oil and gas development will require fairly extensive planning. A subcommittee of the Charlie Lake Conservation Society could organise and oversee the initiation of this program. Furthermore, the successful implementation of any such initiative may require paid employees, or a group of volunteers to make initial contacts and subsequent visits to affected landowners. If site assessments are to be considered, specific training of individuals would likely be needed. Funding for either option may represent an addition obstacle.

One caveat to consider before attempting a program that examines the relationship between the oil and gas industry and water quality in the Charlie Lake watershed may be a perceived anti-oil and gas development that the Charlie Lake Conservation Society could be labelled with. Similarly many landowners are active players in the oil and gas industry and may take exception to such a program. Due diligence on the part of the planning and implementation of this type of initiative would easily prevent these problems and associated conflicts from occurring.

## SPECIFIC RECOMMENDATIONS

### *Agricultural Lands*

There are numerous initiatives that are currently addressing agricultural issues as they relate to water quality in western North America. In almost all cases, these initiatives are community and producer driven. It is our belief that the Charlie Lake Conservation Society should model any projects in the Charlie Lake watershed on these proven success stories. To do so, we recommend that the Charlie Lake Conservation Society begin the process of building a producer-based watershed-working group by inviting the Cows and Fish Program or some other similar organisation to Charlie Lake. The Cows and Fish Program is an iterative program that begins with increasing awareness and builds towards the development of on-the-ground projects, monitoring and evaluation. This type of project will require the formation of an agricultural stewardship group that is either a sub-committee of, or separate from, the Charlie Lake Conservation Society.

One of the issues that can make or break an initiative that is intending to ask people to alter their practices is the initial acceptance of an alternative. In other words, is there a perceived need for change? Of particular importance is the transfer of the notion that livestock grazing can impair riparian function in streams, lakes and wetlands (FPB, 2002), and that grazing management based solely on upland areas does not maintain or improve riparian habitats that interface with surface waters (Leonard et. al. 1997). During our visits to the Charlie Lake watershed, some of landowners indicated that they believed that the impacts of agriculture on water quality are minimal in comparison to those of other industries and activities. Consequently, it is our belief that at this time it will be necessary to rationalise any changes that we wish to see occur to agricultural practices by illustrating that agriculture can affect water quality. In particular, it will be necessary to demonstrate how the disruption of riparian function, or having extensive areas of bare soil in upland areas, can lead to increased rates of sediment transport and hence the deterioration of water quality.

Once an introductory program has been initiated, and assuming that there is interest in continuing, we would then urge the Charlie Lake Conservation Society to help continue to build on the model used by the Cows and Fish Program. This model incrementally moves from learning about riparian function, to building teams to address management issues in specific areas, to using proven tools to address specific issues, to implementing voluntary solutions to maintain or restore riparian areas, and then, finally, to evaluation phases such as monitoring changes in both vegetation structure and water quality. It is important to note that the Cows and Fish Program is community-driven, and as such it relies on the community itself to manage and administer its projects. In fact this is typically how the Cow and Fish Program is most successful (K. Spicer, Northern/Central Region Coordinator, Cows and Fish Program, Canmore AB, Pers. Comm.). The Cows and Fish Program could be applied in the Charlie Lake watershed following the generalised pathway shown in Figure 18. At each step of the process, representatives from the Cows and Fish Program could be invited back to provide specific assistance and direction; or, the process could be self-driven if sufficient trust, expertise, and leadership are developed regionally.

One of the primary advantages of using the Cows and Fish Program is that program personnel are intimately involved in the agricultural industry, and so they fully understand both the needs of agricultural producers and related water quality issues. An additional benefit is that the Charlie Lake Conservation Society may be able to get the Cows and Fish Program to visit Charlie Lake for an initial workshop at no cost. Because the Cows and Fish Program is partially funded by the Agriculture and Agri-Food Canada, they often visit agricultural

communities to do an introductory workshop on riparian management (K. Spicer, Northern/Central Regional Coordinator, Cows and Fish Program, Canmore AB, Pers. Comm.).

The process of developing a community-driven program to improve riparian conditions in agricultural sub-basins will necessarily require an individual, or group of individuals, to take on a leadership role to help facilitate the various steps in the program. In Prince George, the Chilako Watershed Council has taken significant steps to address similar agricultural issues, with this program having a paid co-ordinator to ensure program continuity and to avoid burnout of volunteers. In other regions, the program has been initiated by a government agency person, or a member of an existing conservation organisation (K. Spicer, Northern/Central Regional Coordinator, Cows and Fish Program, Canmore, AB, Pers. Comm.). After these programs are initiated with the help of an outside facilitator, they are sustained internally by landowners and other interested parties that are directly involved in specific projects (K. Spicer, Northern/Central Regional Coordinator, Cows and Fish Program, Canmore, AB, Pers. Comm.). Potential funding for an initiative of this sort may be found through the Agriculture Environment Partnership Initiative, and perhaps through stakeholder agencies like the Department of Fisheries and Oceans, and BC Ministry of Water, Land and Air Protection. One specific initiative that is being planned through the Agriculture Environment Partnership Initiative that will complement any program initiated with or through the Cows and Fish Program is the Environmental Farm Planning Program that can further assist producers with stewardship initiatives over a wide range of on-farm activities. Ducks Unlimited Canada may also play an important role in any program associated with riparian management. They may be able to provide limited funding or technical expertise toward fencing and the development of off-site livestock watering facilities in the Charlie Lake watershed.

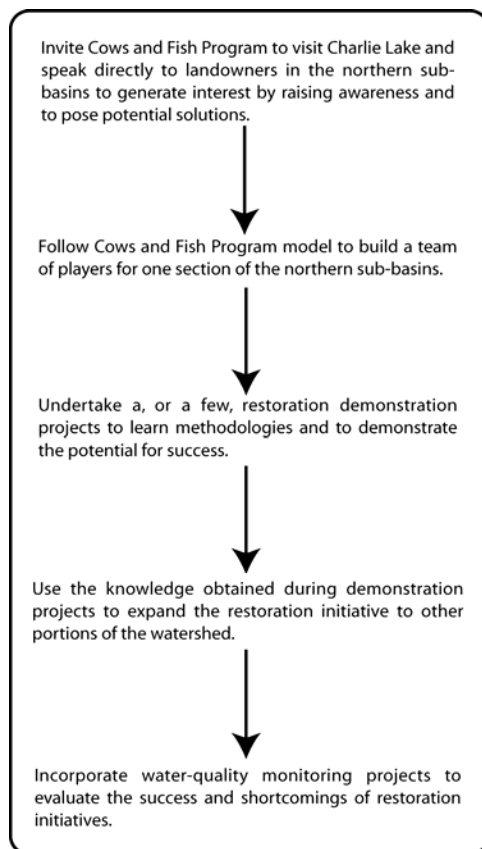


Figure 18. Flow chart for applying the Cows & Fish Program in the Charlie Lake watershed.

Any program that is designed to mitigate the affects of agriculture in the Charlie Lake watershed will have to be accepted and conceptually supported by affected landowners. The Cows and Fish Program has already visited the Charlie Lake watershed, and is therefore familiar to many of the current landowners. Furthermore, the Environmental Farm Planning Program has also been introduced to landowners in the Charlie Lake watershed and it will likely be delivered by a local agency. Whether either program will succeed in the area is largely dependent upon how the programs are delivered by the respective agencies, and how they are received by the broader population. The Charlie Lake Conservation Society is well placed to help facilitate both of these initiatives and should take a leadership role in doing so.

In view of the agricultural industry's impacts to water quality, we suggest that the Charlie Lake Conservation Society do the following:

1. Compile a list of potential government/non-government and industrial partners/stakeholders that may be able to provide funding, technical expertise and other support in regards to riparian restoration on agricultural lands. Discuss water quality issues in the Charlie Lake watershed with these partners, and determine the ways in which they may be able to contribute. Establish a proposal-writing sub-committee that will be responsible for developing proposal to, and agreements with, specific partners.
2. As above, the Charlie Lake Conservation Society should undertake research to determine a list of potential funding sources that will support riparian restoration work on agricultural lands. Once these sources are identified, the Society would need to determine the schedule for proposal deadlines, organisational and proposal format requirements. Some possible sources of funding are: (1) Habitat Conservation Trust Fund, (2) TD Friends of the Environment Foundation, (3) British Columbia Gaming Commission, (4) Habitat Stewardship Program (Department of Fisheries and Oceans), (5) Vancouver Foundation, and (6) EcoAction. As a start, the Charlie Lake Conservation could contact the BC Lake Stewardship Society and Department of Fisheries and Oceans to obtain information on these potential funding organisations and related documentation.
3. The Charlie Lake Conservation Society is currently working with the BC Lake Stewardship Society to sample water clarity, dissolved oxygen dynamics, algal biomass and nutrient concentrations in Charlie Lake. These data will be helpful in the assessment of the current limnological conditions of the lake, and it appears that the BC Lake Stewardship Society will be able to continue to support this program through the next couple of years. However, there are very few current water quality data available for the streams that drain into Charlie Lake, and such data will be needed to evaluate the success of any future riparian restoration projects. While we feel that it would be exceedingly expensive to undertake a sediment-source inventory of Charlie Lake's tributaries, we suggest that the Charlie Lake Conservation Society link their lake sampling program to a tributary sampling program. The analytical costs associated with such a program could likely be covered through the BC Ministry of Water, Land and Air Protection's laboratory budget, so long as labour costs are covered by the Charlie Lake Conservation Society or through volunteers. Since water quality can be highly variable in streams, and tends to change with changes in flow and precipitation events, tributaries to Charlie Lake would need to be sampled weekly during the spring months and about once every two weeks through the remainder of the year. Minor tributaries could be sampled at the point where they enter Charlie Lake; however, major tributaries (e.g., major branches of East Stoddart Creek, West Stoddart Creek and Coffee Creek) would need to be sampled at 2-3 locations to assess spatial

variability. The recommended parameters for a tributary monitoring program include: (1) ash-free total suspended solids (suspended sediment), (2) total and dissolved phosphorus and nitrogen forms (nutrients), (3) total organic carbon, and (4) bacteriology (e.g., *Escherichia coli*, *Enterococcus*, total and fecal coliforms). Periodic sampling for protozoan parasites like *Cryptosporidium* and *Giardia* could also be undertaken, and may be supported by the BC Ministry of Health and/or Northern Health Authority in conjunction with the BC Centre for Disease Control's Enhanced Water Laboratory (Vancouver). A tributary monitoring program would establish current baseline water quality conditions, from which future changes can be measured in relation of future restoration projects, i.e., baseline data provide a baseline for future project evaluation assessments. To reduce labour-related costs and further develop partnerships with landowners, the Charlie Lake Conservation Society should ask landowners to assist with the sampling program. For example, if the BC Ministry of Water, Land and Air Protection could cover laboratory and sample shipping costs and provide sample bottles, coolers and ice packs, the Charlie Lake Conservation Society could ask landowners to collect samples from stream reaches that flow through their land. The Charlie Lake Conservation Society could then gather the samples from participating landowners, package them and ship them to the laboratories (most of which are in Vancouver) and develop the database of results.

4. In this report, we have described several options for off-channel livestock watering and fencing and planting projects. The Charlie Lake Conservation Society should develop a database of suppliers of materials for these projects, with itemised costs. Such a database should be kept current so that the information can be readily accessed during the budgeting phases of proposal writing. The database could also be provided to landowners and loaded to the Charlie Lake Conservation Society website to promote interest.
5. Many riparian restoration projects will require extensive labour, and it may be unreasonable to expect landowners and Charlie Lake Conservation Society Directors and members to assume responsibility for all required labour on a volunteer basis. Depending on the rules associated with the various funding agencies (see above), some funds awarded to the Charlie Lake Conservation Society may be used to support the wages of individuals hired to work with agricultural landowners. There are also volunteer-based organisations such as Katimavik (<http://www.katimavik.org/>) who can provide volunteers, primarily youth, who are looking for meaningful work-related experiences. The Charlie Lake Conservation Society could also consider volunteers from Corrections Canada. Corrections Canada often has volunteer criminal offenders undertake labour such as roadside cleanups, brush clearing and other labour-intensive duties to help them develop skills and self esteem, so there may be a possibility of using them to construct fences and off-channel watering facilities and in riparian planting projects. While there could be problems associated with working with criminal offenders, by doing so the Charlie Lake Conservation Society would not only move forward with its endeavours to improve water quality, but it would provide great assistance to individuals who are working to improve their lives in a meaningful way.
6. As indicated in this report, conservation covenants could offset some of the costs associated with riparian conservation project by providing landowners with tax incentives. The Charlie Lake Conservation Society Directors should further study the benefits and costs of conservation covenants and determine how they may be applied to the Charlie Lake watershed. The Society should consider contacting an expert on

conservation covenants from The Land Conservancy in order to become familiar with the legalities and tax-related incentives of covenants.

7. Above all, the Charlie Lake Conservation Society needs to develop working partnerships with landowners, particularly those in the Stoddart Creek and Coffee Creek sub-basins, and initiate some on-the-ground pilot projects to work out the riparian restoration tools that are most suited to the Charlie Lake watershed. Potential sites for pilot restoration projects can be identified from the orthophotos provided in this report.
8. During our 2002 surveys, we collected several bottom-sediment samples from various sites in Charlie Lake. The sediments were collected in view of the potential for dredging nutrient-rich bottom sediments from Charlie Lake, and distributing them back onto the landscape in regions where soils are thin as the result of severe historic fires. One of the requirements of such a sediment dredging project would be first to determine whether there were high concentrations of contaminants (e.g., herbicide/pesticide residues, PAHs, chlorinated hydrocarbons, heavy metals, etc.) stored in the sediment that would preclude them from being distributed back onto agricultural land. In 2002/03, we were unable to secure funds to cover the analytical costs associated with sediment analyses; however, the collected sediments are still being stored in a freezer. We recommend that the Charlie Lake Conservation Society make arrangements with the BC Ministry of Water, Land and Air Protection (Prince George Regional Office) to have the sediments analysed for contaminants in fiscal 2004/05.

### *Oil & Gas Wells*

Through our investigations of oil and gas wellhead sites, we have determined that they have considerable potential to increase sediment transport rates in the Charlie Lake watershed. We recommend that the Charlie Lake Conservation Society consider the following projects as part of their long-term strategic plan:

1. Our wellhead site survey was far from comprehensive; however, given that we found substantial evidence of sediment erosion at the sites that we did visit, we recommend that the Charlie Lake Conservation Society undertake a survey of all active wellhead sites to assess sediment erosion. When visiting these sites, special attention should be given to ditch erosion along private roads leading to the well, and to mechanisms used to drain downslope water retention ditches. The Charlie Lake Conservation Society could undertake these surveys in conjunction with the Oil and Gas Commission and the various oil and gas companies. If it is found that a particular wellhead site drains water from retention ditches via overflow pipes, the Charlie Lake Conservation Society should explain to the owner and Oil and Gas Commission that water accumulating in retention ditches must be pumped and transported off site for proper disposal.
2. Although there may be a good reason to remove vegetation from wellhead sites, the Charlie Lake Conservation Society should work with the Oil and Gas Commission to determine whether it is feasible to vegetate (i.e., plant grasses or shrubs) on the sites to reduce water and wind erosion of fine surface soils.

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# Approaches to Improving Water Quality in Charlie Lake: Direct Lake Treatments and Lakeshore Living<sup>1</sup>

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(March 2004)

**Abstract:** The Charlie Lake Conservation Society is in the process of developing strategic concepts for projects to improve water quality conditions, and freshwater habitats, in the Charlie Lake watershed (north-eastern British Columbia, Canada). The projects recommended in the preceding chapters of this report describe landscape-level projects that could be undertaken in the sub-basins that drain into Charlie Lake, and focus primarily on making improvements to riparian function at stream crossing (culverts and bridges), oil and gas wellhead sites and on agricultural reaches that will reduce sediment transport rates to the lake. In this chapter, we consider four projects that can be undertaken within the lake basin itself, and in within the immediate foreshore, that would benefit water quality: (1) the acceleration of nutrient export rates by converting an existing epilimnetic (surface) water withdrawal to a hypolimnetic (deep water) withdrawal, (2) expansion of the existing sewage trunk system to remove domestic wastes from the watershed, (3) the reduction of internal nutrient (e.g., phosphorus and silica) loading rates by removing fine sediments (silt, clay and mud fractions) from the bottom of Charlie Lake, and (4) increasing community-level awareness through the implementation of an extension program. The results of our analyses suggest that the conversion of the existing epilimnetic water withdrawal to a hypolimnetic withdrawal would increase annual phosphorus exports from the current 30 Kg to 465 Kg (a 15-fold increase in annual phosphorus export), and that bottom sediment removal would export phosphorus from the lake basin at a rate of 1 kg phosphorus per 1,000 x 10<sup>3</sup> kg sediment (dry weight).

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The preceding chapters of the Charlie Lake Conservation Society strategic plan to improve water quality in the Charlie Lake watershed focused on describing three landscape-level factors that are believed to be contributing to the degradation of water quality: (1) sediment erosion at stream crossings (culverts and bridges), (2) water management on oil and gas wellhead sites, and (3) poor riparian function in agricultural reaches. In addition to describing the mechanisms by which these factors affect water quality in the Charlie

Lake watershed, we have attempted to provide the Charlie Lake Conservation Society with high-level strategic approaches for resolving the identified problems.

In addition to undertaking water quality restoration projects out in the sub-basins that drain into Charlie Lake, there are a number of projects that could be undertaken within the lake basin itself, and along the

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immediate foreshore, that would benefit water quality. The objective of this chapter of the Charlie Lake Conservation Society strategic plan is to describe such projects at a conceptual level. The potential projects that we have identified to date are: (1) the acceleration of nutrient export rates by converting an epilimnetic (surface) water withdrawal to a hypolimnetic (deep water) withdrawal, (2) expansion of the existing sewage trunk system to remove domestic wastes from the watershed, (3) the reduction of internal nutrient (e.g., phosphorus and silica) loading rates by removing fine sediments (silt, clay and mud fractions) from the bottom of Charlie Lake, and (4) increasing community-level awareness through the development of an extension program.

## Deepwater Withdrawal

Devon Canada Corporation currently holds a permit to withdraw water from Charlie Lake at a maximum rate 1.41 ft<sup>3</sup>/s (approx. 40 L/s) for the purpose of deep-well injection (see Land & Water British Columbia Inc., [http://www.elp.gov.bc.ca:8000/pls/wtrwhse/water\\_licences.input](http://www.elp.gov.bc.ca:8000/pls/wtrwhse/water_licences.input)) (Figure 1). According to permit file interpretations by French & Carmichael (1999), Devon Canada Corporation extracts water from a depth of about 2.2 m, based on maximum lake volume (lake surface at highest elevation). In this section of the Charlie Lake Conservation Society strategic plan, we describe in broad terms how Devon Canada Corporation's water withdrawal practices could be modified to improve water quality conditions in Charlie Lake in view of nutrient supplies and resulting algal blooms. Our analysis is based on our current understanding of depth-specific water chemistry and water withdrawal rates, and implementation of our recommendations would require a detailed cost analysis, development of structural designs by qualified engineers, and support by both Devon Canada Corporation and relevant regulatory authorities (e.g., BC Ministry of Water, Land and Air Protection and, perhaps, Department of Fisheries and Oceans Canada).

As described in Supplement 1 of this report (*Factors Controlling Algal Biomass in Three Shallow Eutrophic Lakes in Northern British Columbia, Canada: Charlie, Nulki and Tachick*), the availability of phosphorus (an important plant nutrient) largely controls the development of algal biomass in Charlie Lake, with concentrations of the element being a function of season (time of year) and depth in the water column. As shown in Figure 2, total phosphorus concentrations during the winter months, when Charlie Lake is frozen over, can approach 1 mg/L (extremely nutrient rich) in depth strata deeper than about 8 m. In comparison, phosphorus concentrations during the winter months in depth strata above 8 m (where Devon Canada Corporation withdraws water) are substantially less, averaging about 0.05 mg/L (Figure 2). If it is assumed that Devon Canada Corporation withdraws water at their maximum permitted rate of 40 L/s and that Charlie Lake, on average, is frozen over for 130 days/year, the expected volume of water withdrawn during periods when the lake is frozen over would be in the order of  $444 \times 10^6$  L. If we can further assume that the total phosphorus concentration in water withdrawn by Devon Canada Corporation averages 0.05 mg/L (typical surface-strata concentration observed in winter, see Figure 2), computations based on multiplying withdrawal volume by concentration would indicate that the present water withdrawal system extracts about 22 Kg total phosphorus per 130-day ice-covered period. However, if under a hypothetical situation Devon Canada Corporation withdrew water from phosphorus-rich deep strata (e.g., at 11-m depth where total phosphorus concentrations can approach 1 mg/L) at their maximum permitted rate, they would extract about 440 Kg total phosphorus (or 20-fold the current mass) from the lake per 130-day ice-covered period, which is a massive phosphorus export.

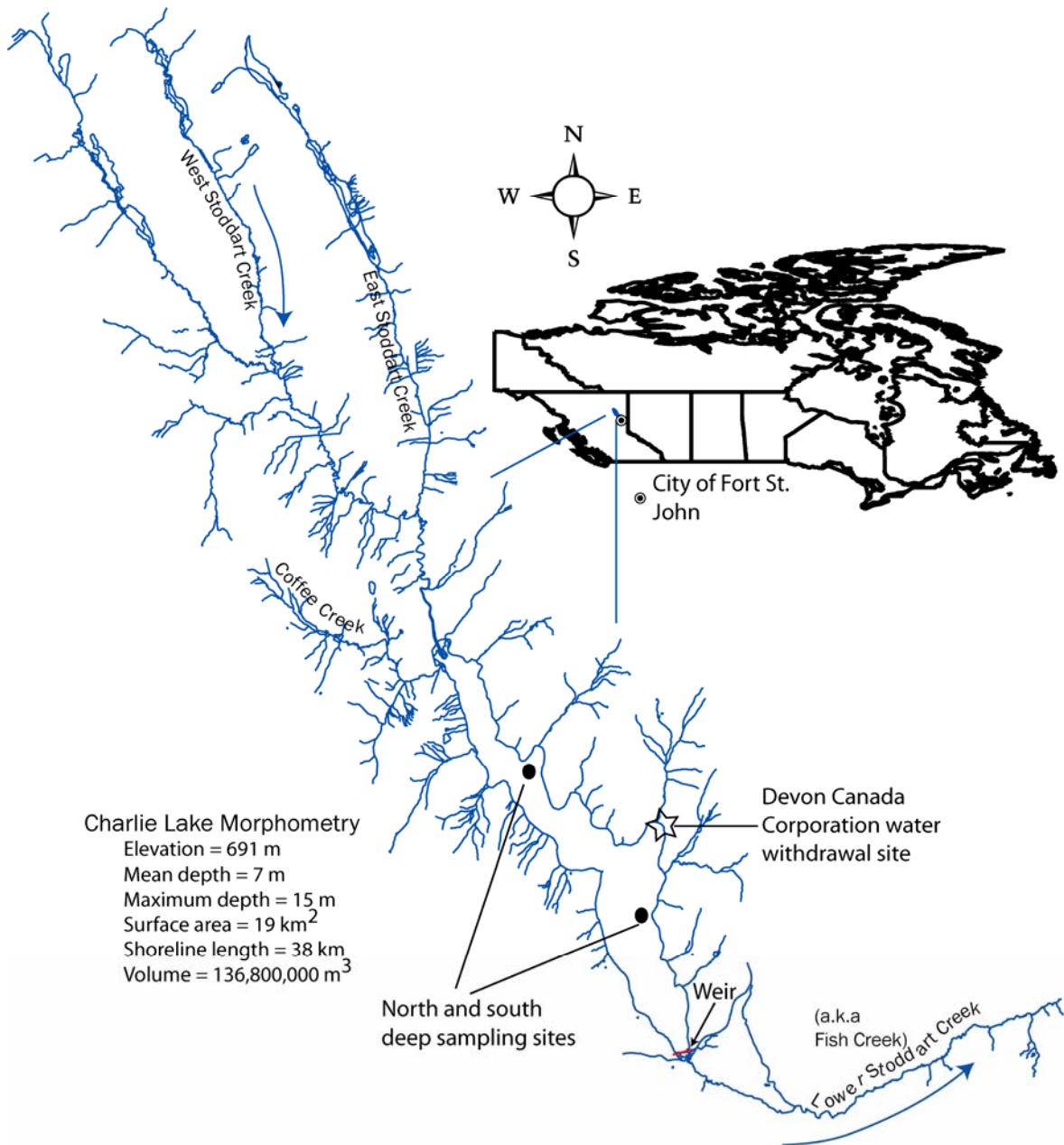


Figure 1. Map of Charlie Lake and major tributaries showing limnological sampling sites and location of Devon Canada Corporation water withdrawal.

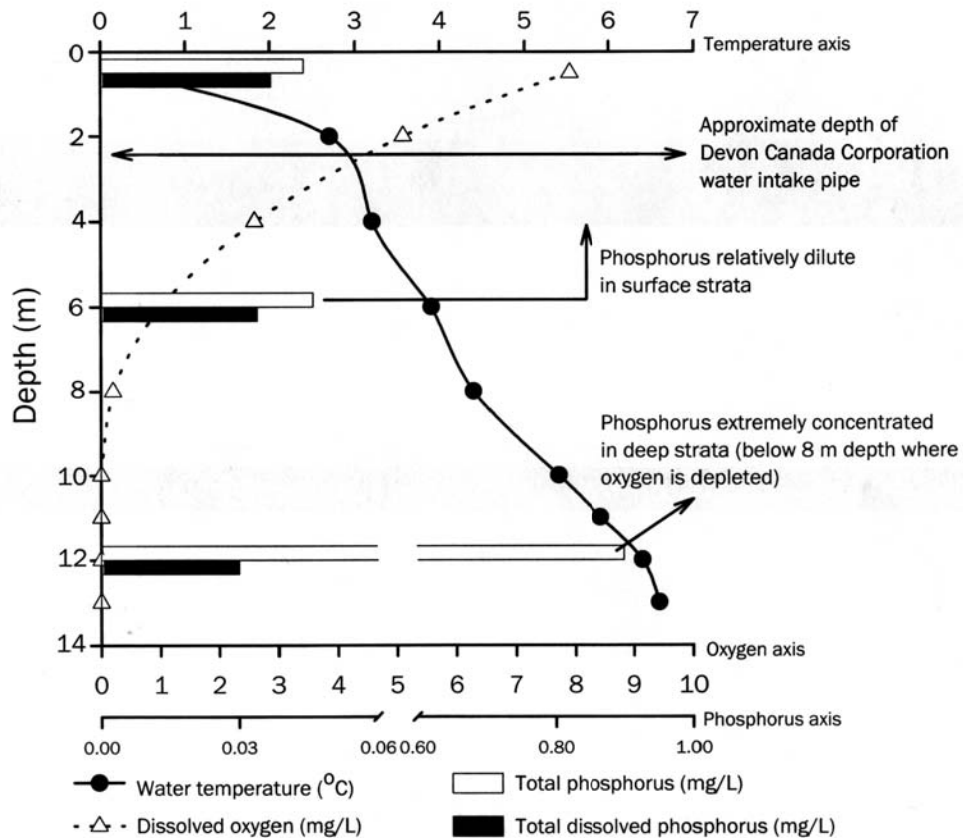


Figure 2. Representative winter (March 12/1992) profile of Charlie Lake (average of samples collected at north and south deep sites) showing variations in phosphorus and dissolved oxygen concentrations, and temperature from surface to bottom. Note that phosphorous concentrations are several-fold higher in bottom strata (below 8 m depth) than in surface strata during the ice-cover winter months, and that Devon Canada Corporation withdraws relatively nutrient-dilute water from 2.2 m depth.

As indicated above, the Devon Canada Corporation withdrawal exports phosphorus from Charlie Lake from a depth of 2.2 m at a rate of about 22 Kg per 130-day frozen over period (winter export), with this export being increased to about 440 Kg if the depth of the withdrawal pipe were to be increased to 11 m depth. To fully consider the benefits of increasing the depth of the Devon Canada Corporation water withdrawal, the mechanisms through which phosphorus enters deep strata during the winter months must be understood (see Supplement 1). Research has shown that the phosphorus that accumulates in the deep strata of Charlie Lake during ice-covered periods is “dissolved” out of sediments (silts, muds, clays) that have accumulated on the bottom of the lake. During spring overturn, the phosphorus-rich bottom waters are mixed to the surface strata and the entrained phosphorus stimulates algal growth. By increasing the depth at which water is withdrawn from the lake, the phosphorus that has accumulated in bottom muds over the past centuries, would be directly exported from the lake basin, and the exported amount would not be available to algae. Moreover, the current withdrawal system that removes water from surface strata is effectively removing water of relatively high quality (low phosphorus concentration), thereby further increasing phosphorus concentrations in surface strata during spring mixing events.

Phosphorus concentrations are also high in deep strata, as compared to surface strata, during the summer months when the lake is weakly stratified. As shown in Figure 3, which represents a typical summer-stratified profile, total phosphorus concentrations in hypolimnetic waters (strata below about 10 m depth) can approach 0.18 mg/L, whereas they are typically < 0.06 mg/L in surface strata. If it is assumed that Charlie Lake is thermally stratified for 40 days during each summer and that Devon Canada Corporation withdraws at its maximum permitted rate of 40 L/s over this period, the volume of water extracted per 40-day summer stratified period would be about  $138 \times 10^6$  L. With the present situation of this water being drawn from 2.2 m depth, and assuming an average total phosphorus concentration of 0.06 mg/L at this depth (Figure 3), this translates to a phosphorus export of about 8 Kg per 40-day summer stratified period. However, if Devon Canada Corporation were to withdraw water from 11 m depth (minimum) during summer stratified periods, a phosphorus export of about 25 Kg per 40-day summer stratified (or 3-fold current export) period would occur based on an average hypolimnetic phosphorus concentration of 0.18 mg/L.

Our computations based on temporal and depth-specific phosphorus concentrations and Devon Canada Corporation's maximum permitted withdrawal rate indicate that substantially more phosphorus would be exported from Charlie Lake during winter and summer-stratified periods if the depth of withdrawal was increased from the present 2.2 m to 11 m or deeper. Moreover, by withdrawing relatively nutrient dilute water from surface strata, the Devon Canada Corporation withdrawal is removing water of relatively high quality as opposed to removing more concentrated deep waters and is, thereby, concentrating nutrients during periods of thermal mixing. As suggested, the benefits of changing from a near-surface withdrawal to a deepwater (hypolimnetic) withdrawal would only occur during periods of inverse thermal stratification (winter months) and summer stratified periods when phosphorus accumulates in deep strata. Conversely, increasing the depth of water withdrawal would not be beneficial, in terms of phosphorus export, during periods of thermal mixing that regularly occur in the spring and autumn months and for short periods in the summer (i.e., phosphorus concentrations are typically the same from the surface to bottom during mixing events, so depth of withdrawal would not be a factor; Figure 4).

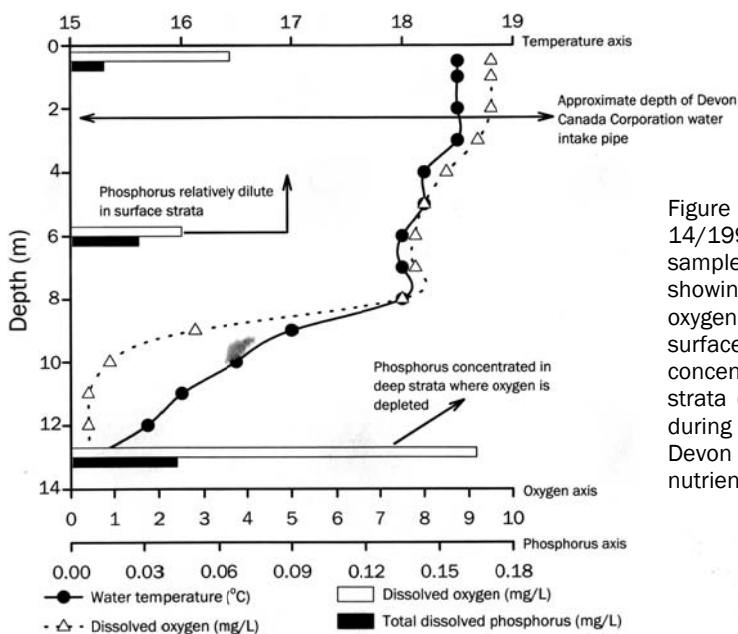


Figure 3. Representative summer stratified (July 14/1992) profile of Charlie Lake (average of samples collected at north and south deep sites) showing variations in phosphorus and dissolved oxygen concentrations, and temperature from surface to bottom. Note that phosphorus concentrations are considerably higher in bottom strata (below 12 m depth) than in surface strata during the ice-cover winter months, and that Devon Canada Corporation withdraws relatively nutrient-dilute water from 2.2 m depth.

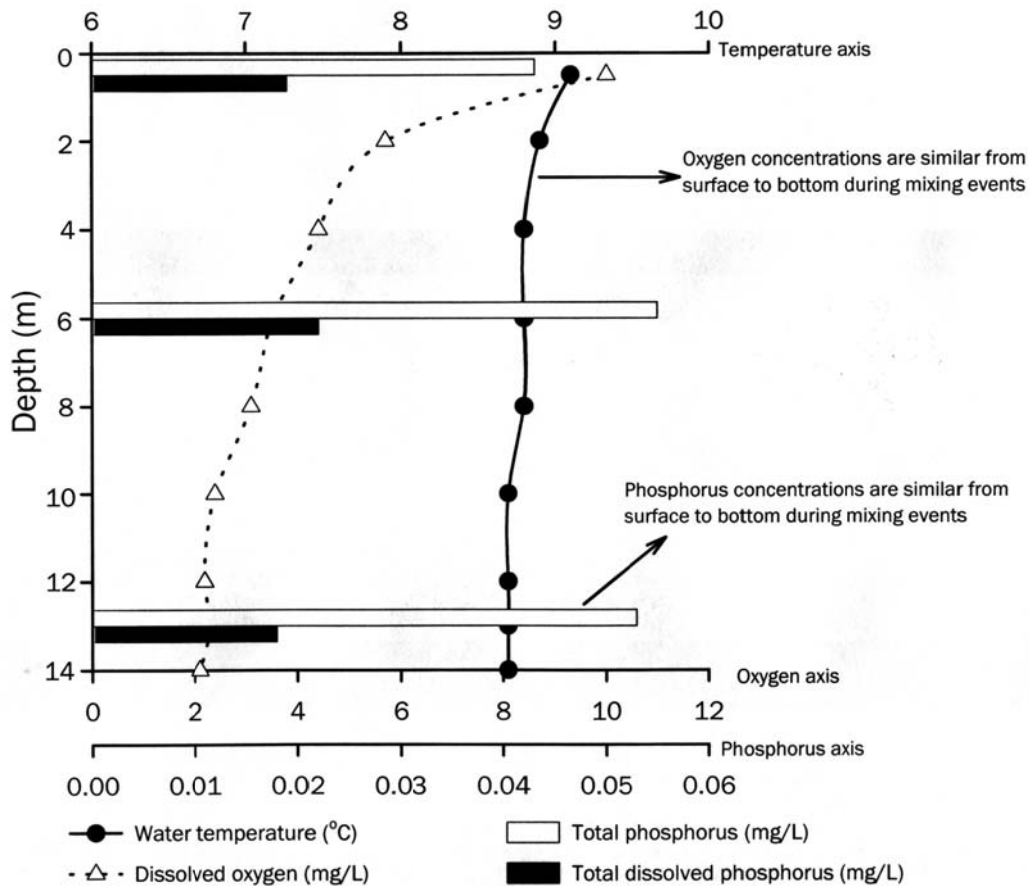


Figure 4. Representative profile (May 6/1992) of Charlie Lake during a period of thermal mixing when phosphorus concentrations and temperature are similar from surface to bottom (data represent averages of samples collected at north and south deep sites).

As part of their long-term strategic plan, the Charlie Lake Conservation Society should consider contacting Devon Canada Corporation to determine whether it would be feasible for them to extend their water intake pipe to a depth of 11 m, or deeper, to extract nutrient-rich deep waters rather than comparatively high-quality surface waters. One option might be for the withdrawal pipe to be extended to the south deep basin, or for the entire pumping facility to be re-located to a site closer to the south deep site (Figure 1). Such a deepwater withdrawal would not result in an immediate reduction in algal biomass; however, the withdrawal could result in improved water quality over several years of application.

## Domestic Wastes

Up until the early 1990s, most lakeshore residents were serviced by evaporative lagoons or mounded septic fields. As reported in Urban Systems Ltd. (undated report), some of these disposal systems were “leaky” and, as such, permitted untreated sewage to pond and flow within residential ditches. The BC Ministry of Environment, Lands and Parks (presently known as BC Ministry of Water, Land and Air Protection) periodically sampled two residential ditches and observed total phosphorus concentrations as high as 1.2 mg/L. Most total phosphorus concentrations observed in the two sampled residential ditches were considerably greater those observed in the surface strata of Charlie Lake, indicating that the ditches were enriching the lake with phosphorus. Moreover, the number of fecal coliform colonies cultured from samples of ditch water were exceedingly high (see French & Carmichael, 1999), indicating that the ditches were also a source of bacterial contamination.

In an effort to sanitise the water in residential ditches and reduce the rate of contaminant loading to Charlie Lake, most (but not all) lakeshore residences were connected to a trunk system that pipes domestic wastes out of the Charlie Lake watershed. Information provided in French & Carmichael (1999) indicates that the sewage trunk system removes about 261,000 m<sup>3</sup> of domestic wastewater from the Charlie Lake watershed annually, with this equating to an annual export of about 3,000 Kg of nitrogen and 40 Kg of phosphorus. As suggested above, most residences in the southwestern shoreline community are presently serviced by a proper sewer system; however, conversations with the Northern Health Authority and local residents indicate that some residences in the northern extents of the residential area are still not hooked into the sewer system.

To reduce nutrient and bacterial loading to Charlie Lake, we recommend that the Charlie Lake Conservation Society contact the agencies responsible for the sewage system to determine which residents are not presently connected. It may be possible for the Charlie Lake Conservation Society to apply for infrastructure and conservation grants to offset the cost of hooking the remaining residences into the sewage trunk system.

## Sediment Removal

Limnological research on Charlie Lake, and lakes having similar developmental origins, morphometry (basin shape, e.g., depth, volume, surface area, etc.), basin geology and ecology, has demonstrated that much of the annual nutrient (e.g., phosphorus and silica) loads to the water column are dissolved out of fine sediments (muds, clays, silts) that have deposited on the bottom (See Supplement 1: *Factors Controlling Algal Biomass in Three Shallow Eutrophic Lakes in Northern British Columbia, Canada: Charlie, Nulki and Tachick*). There is empirical evidence that the periodic releases of phosphorus and silica from bottom sediments control, in large, the bloom cycles of planktonic algae in Charlie Lake (see Supplement 1). Since sediments are the primary source of water column phosphorus and silica in Charlie Lake on an annual basis, and that these nutrients limit the rate of algal growth, we recommend that the Charlie Lake Conservation Society work with scientists and engineers to determine the feasibility of projects that would reduce the mass of phosphorus and silica stored in the bottom sediments of Charlie Lake. By reducing the mass of phosphorus and silica in bottom sediments, there would, if sufficient masses were removed, be a reduction in the volumetric loading rates of these nutrients to the water column and this should, over time, reduce the intensity of algal blooms. One way, and perhaps the most feasible way, of reducing the mass of phosphorus and silica from the bottom of Charlie Lake is to dredge and directly remove bulk sediment from the bottom, as opposed to using a chemical process (i.e., CaCO<sub>3</sub> injection) that would have short-lived, and less-predictable results and risks. In this section of the

Charlie Lake Conservation Society strategic plan, we describe, in a broad sense, the considerations that must be taken into account for this type of project.

To fully consider the benefits, and risks, of a bottom sediment removal project, it is first important to fully appreciate that nutrient loading through sediment release (so-called “internal loading”) is a natural process that occurs in most mesotrophic and eutrophic lakes – so, this process is not unique to Charlie Lake and, moreover, is not considered to be detrimental or negative in terms of water quality conservation. The origin of sediment-bound nutrients like phosphorus and silica must also be appreciated to understand the rationale for, and risks of, sediment dredging and removal projects. The depression, or basin, that Charlie Lake rests in was originally scoured out by the movement of glacial ice masses about 12,000 years ago. When the lake was originally formed through glacial scour, it would have been essentially “lifeless” in that there would have been very little algal growth, and no or very few fish or other life forms – the lake’s ecosystem was very simple and there was very little biological “production”. With ageing, more and more life forms established in the lake, and ecosystem-level complexity and species interactivity increased. With the establishment of a diverse array of life forms in Charlie Lake, the lake first began to “store” organic compounds (those formed by organisms) and nutrients within the basin via sedimentation, i.e., life forms (e.g., algae, plants, fish, bacteria, etc.) accumulate nutrients and organic matter in their tissues and, when they die, they sink to the bottom where this material accumulates over long periods of time. The nutrients and organic matter stored on the bottom can recycle back to the water column under certain conditions and promote further biological production; a materials recycling loop forms as lakes develop and age. Thus, the development of biological productivity within a lake leads to the internal (within-lake) accumulation and storage of nutrients and organic matter (which are incorporated within biological tissues), and these materials are recycled back to the water column where they can be re-incorporated into biological tissues.

As indicated, one source of sediment nutrients is biological material. However, there must be a continual input of nutrients to a lake to feed biological production or, overtime, all nutrients would eventually exit the lake via the outlet or through other means. It is well understood that small sediment particles like muds, clays and silts have electrical charges on their surfaces. Oppositely charged nutrients like phosphate ( $\text{PO}_4^-$ ) are “magnetically”, or electrostatically, bound, or attached, to the surface charges on these fine sediments. Thus, sediment carried into Charlie Lake through tributary flows is itself a nutrient source, i.e., sediments transported into the lake are carrying phosphate and other nutrients on their surfaces. In earlier chapters of the Charlie Lake Conservation Society strategic plan, we have explained that runoff from poorly-functioning road crossings, oil and gas well sites, and erosion from poorly vegetated riparian habitats are contributing substantial and, from certain locations, excessive sediment loads to tributary waters and, ultimately, to Charlie Lake. Fine sediments transported from the landscape to Charlie Lake eventually settle to the bottom where they accumulate and add to the mass of stored nutrients. The converse effect of this is that the land itself is losing valuable nutrient-rich soils that are necessary for agricultural production.

Excessive sediment erosion from the landscape to Charlie Lake has undoubtedly increased the natural ageing process and progressive shallowing of Charlie Lake, and has accelerated the rate of nutrient storage in the bottom of the lake basin. In a preliminary review of sediment chemistries measured for several BC lakes and rivers, we have learned that typical fine-textured sediments have phosphorus contents in the order of 1,000  $\mu\text{g/g}$  on a dry weight basis. Based on this typical phosphorus content, a metric tonne of dry lake sediment (or 1,000 Kg, which is not a huge volume) would be expected to have 1 Kg of elemental phosphorus associated

with it. Thus, to remove 1 tonne of phosphorus from the Charlie Lake basin, about 1,000,000 Kg (based on dried weight) of bottom sediment would need to be extracted.

In addition to reducing the mass of phosphorus stored in the bottom of Charlie Lake, sediment removal would also increase the volume of the lake by making the basin deeper, and this would reduce water consumption rates in relation to available water supplies. Nutrient-rich sediments removed from Charlie Lake could be appropriately mixed with agricultural soils and spread in areas where soils are thin to increase the potential for agricultural production. This would, in effect, be putting the sediments back to areas in the watershed from which they originally came (“undoing” past erosional events). However, prior to using the extracted lake sediments for agricultural purposes, they would need to be analysed for contaminants like oil and grease hydrocarbons, herbicide and pesticide residues, heavy metals and other compounds to ensure that they are not problematic in terms of agricultural use.

While bottom sediment removal may appear to be an ominous task in view of making improvements to water quality and reducing the intensity of algal blooms in Charlie Lake, it may be necessary to at least consider the feasibility of such projects because, even if all sediment sources in the watershed were successfully “capped-off”, the nutrient pool within lake sediments would maintain the lake’s eutrophic conditions for a very long-time into the future. In any event, such a sediment removal project would require assurances that sediment-based turbidity would not be excessive during the extraction process and, in all likelihood, a full environmental impact assessment and feasibility study.

## Lakeshore Living

Charlie Lake, like many lakes in British Columbia, has experienced development along its perimeter that has led to a significant alteration of natural shoreline habitat features. The development of lakeshore properties often entails the clearing of existing indigenous vegetation from lakeshore areas and replacing it with non-native grasses. Likewise, cabins and homes are often constructed close enough to the shoreline of lakes that a significant portion of the lakeshore is altered during construction. In both cases this conversion, or elimination of foreshore habitat, has three readily identifiable consequences. First, there is an increased influx of nutrients that result from both establishment and care of new lawns. Second, the elimination of foreshore vegetation can increase rates of shoreline erosion and surface water run-off. Third, the lack of natural shoreline habitat can reduce or eliminate potential nesting habitat for many species of birds including some waterfowl species (See Supplement 2: *The Birds of Charlie Lake: Results of an Eight-Year Systematic Survey of Lake and Shoreline Regions (1981 to 1988)*). Clearing of shoreline habitat also results in decreases of visual screening for nesting, feeding and resting birds, which in turn can lead to increased disturbance of these birds. Day-to-day lakeshore living can also result in the input of deleterious materials such as herbicides, pesticides, household cleaners, etc., through surface runoff, failing septic systems, or ground water seepage.

There are several key areas that could be addressed by the Charlie Lake Conservation Society with respect to lakeshore living along Charlie Lake. These fall into the following categories:

*Shoreline Care (Households and Businesses)* – e.g., maintaining or restoring proper riparian function;

*Responsible Lakeshore Living (Households, Businesses and Recreational Activities)* – e.g., using lake-friendly products in the home and in the yard, observing proper septic system functioning, engaging in responsible boating;

*Long-Term Protection (Current and Future Landowners)* – e.g., using conservation covenants for present and future protection (See Chapter 3: *Water Quality in the Charlie Lake Watershed: Affects of Agricultural- and Oil & Gas-Related Land Clearing*);

*Informed Development of Future Properties* – e.g., providing information to builders, future owners, municipal decision makers, and real estate agents on lakeshore development and living; encouraging the implementation of Lakeshore Guidelines and challenging individuals to go beyond the minimums of lakeshore guidelines; and

*Continued Lake Monitoring* – e.g., providing citizens with an opportunity to participate in lake management by belonging to a regional monitoring program.

All components of conservation-based lakeshore living should involve community-level participation, and the Charlie Lake Conservation Society could assume a leadership role in promoting and bringing about such participation.

## **Specific Recommendations**

### *Deepwater Withdrawal*

Our analysis indicates that benefits to water quality would be realised if the Devon Canada Corporation point of withdrawal was increased from its current depth of 2.2 m to a depth of 11 m. To investigate the potential of converting the Devon Canada Corporation epilimnetic withdrawal to a hypolimnetic withdrawal, the Charlie Lake Conservation Society will need to do the following:

1. Setup a meeting with Devon Canada Corporation to discuss the rationale and concept of converting their current withdrawal to a hypolimnetic withdrawal. For this project to be successful, Devon Canada Corporation will need to be in full support of it and be aware of the benefits and costs.
2. Setup a meeting with relevant regulatory authorities (e.g., BC Ministry of Water, Land and Air Protection, and Department of Fisheries and Oceans Canada) to discuss the project rationale and concept, and to determine the level of environmental assessment that would be required prior to project implementation. A limnologist with specific knowledge of Charlie Lake and engineering staff from Devon Canada Corporation should be present at this meeting.
3. If Devon Canada Corporation and the relevant regulatory authorities are in agreement with the project concept, the Charlie Lake Conservation Society should facilitate the development of engineering plans and cost analyses for the project in partnership with Devon Canada Corporation. One consideration that would need to be assessed is whether it would be most cost effective to extend the existing intake pipe to a location with sufficient depth, or to move the entire pumping facility to a location on the shoreline that is closer to a deep zone.

If the Charlie Lake Conservation Society and partners determine that the project is feasible, we recommend that a public meeting be held to inform community members about the project.

### *Domestic Wastes*

Discussions with the Northern Health Authority and local residents indicate that there are still some foreshore residences that are not connected to the sewage trunk system. We recommend that the Charlie Lake Conservation Society:

1. Obtain blue prints of the existing sewage trunk system to determine which foreshore residences are not currently connected to the system.
2. Undertake research to determine whether there are federal and/or provincial infrastructure grants that can be accessed for water quality conservation projects; specifically to cover the costs associated with extending the sewage trunk system to residences that are not currently connected.
3. If sufficient funds can be found to offset the costs of extending the sewage trunk system, the Charlie Lake Conservation Society should hold meetings with affected landowners to get their support for the project.
4. In regards to long-term residential planning, the Charlie Lake Conservation Society should work with the Peace River Regional District to ensure that houses and businesses constructed in the future are required to be connected to the sewage trunk system.

### *Sediment Removal*

Projects involving the removal of bottom sediments from Charlie Lake would very likely be subject to a partial, if not a full, environmental impact assessment. When first approached, regulatory authorities will most likely feel that such a project is not feasible and overly “grandiose”; however, there is considerable merit to at least considering the project such that the benefits to water quality could be significant. Charlie Lake has been the recipient of excessive sediment pollution for many years; thus, a sediment removal project would be an effort to remove “pollutants” from the lake.

If interested in undertaking a sediment removal project, the Charlie Lake Conservation Society will need to do and/or consider the following:

1. Develop an appropriate and efficient sediment extraction method. Discussions with Mr. Brian Stubbs (landowner in northern sub-basins) indicate that oil and gas companies have powerful vacuum systems that can draw in soil slurries; perhaps these vacuum pumps can be modified to vacuum bottom sediments from lakes.
2. A disposal plan for removed sediment would need to be developed and approved by relevant regulatory authorities. If the sediments were determined not contain deleterious substances, it may be possible to mix them with agricultural soils and compost them in areas where soils are thin (to enhance agricultural production).
3. A monitoring program would need to be undertaken in conjunction with any sediment removal project to assess any adverse affects and to quantitatively evaluate the success of the project in terms of

improvements to water quality and changes in ecology. The project could be viewed as being an “experimental treatment” and may be suitable for an M.Sc.- or Ph.D.-level graduate student project. Overall, a sediment removal project would require a full feasibility study (with cost/benefit analysis) and an environmental risk assessment.

### *Lakeshore Living*

To help reduce further degradation of water quality and aquatic habitats resulting from foreshore development, a program to increase community-level awareness of watershed issues and encourage participation in watershed-based activities and projects could be undertaken. This could be accomplished in a variety of ways including:

1. the development of a mobile display that could be used at various community functions as well as other materials specific to the mandate and activities of the Charlie Lake Conservation Society;
2. the development of informational signage at selected locations along the lake (e.g., at boat launches, golf course);
3. the creation of a resource center in the community to house interpretative material about lakeshore living (perhaps on the Petro Canada lands);
4. the development of a fully-functional and interactive website;
5. the production of a newsletter to provide periodic information on watershed issues, research, community events and the activities of the Charlie Lake Conservation Society (one option would be to use a format similar to BC Lake Stewardship Society newsletter);
6. development of school programs (if a fully-functional website is developed, schools should be made aware of it so that teachers can give their students access to it);
7. the continued use of the local media.

Promotion of the society itself should be a part of this initiative because any program attempting to address lakeshore living will ultimately require the recruitment of interested personnel to partake in future endeavours. The promotion of Charlie Lake as a unique area, and introducing the concept of foreshore living as means by which to promote an ecologically sound way of living on the lake in a passive way (e.g., through general promotional material) may, or may not be successful in encouraging responsible lakeshore living. It will therefore be important to accompany any passive promotion with a door-to-door campaign and regular community meetings at convenient times and venues. It is through this person-to-person contact that real change can be best accomplished. This can be achieved through the development of a landowner contact program.

Landowner contact programs generally introduce lakeshore residents and businesses to the complexities of living by a lake. These programs typically involve on-site visits to help individuals address the way in which they interact with the shoreline, conduct day-to-day operations, and use their boat. Site visits often cover the following areas of concern (contact BC Lake Stewardship Society for more information on landowner contact strategies):

1. prevention or mitigation of shoreline erosion,
2. monitoring and removal of invasive plants,
3. maintaining a healthy septic system,
4. building and maintaining low-impact docks,
5. promoting the use of lake-friendly products in the home and in the yard,

6. restoration of shoreline areas using native plants,
7. recommendations for responsible boating practices, and
8. encouraging long-term protection with the use of conservation covenants.

Landowner contact programs can be extremely effective in generating real, on-the-ground changes in land use; however, these programs rely on clear objectives, a well-crafted message, and a well-trained team of people to deliver the program. Difficulties in any of the above can cause landowner contact programs to falter. These landowner contact programs, while generally targeted to private residences, can be easily tailored for use with local businesses.

As has been the case in other regions of the British Columbia, landowner contact programs have led to the development of successful foreshore restoration/mitigation projects, e.g., the Okanagan Foreshore Development Project (H. Bennett, BC Lake Stewardship Society, Kelowna, BC, Pers. Comm.). Having at least one example of how a property can be restored without undue hardship will likely lead others to embark upon the same path. Possible projects could include mitigating shoreline erosion problems as those completed on Okanagan Lake (contact BC Lake Stewardship Society for details) or the rehabilitation of shoreline habitat by using simple bioengineering solutions (See Chapter 3: *Water Quality in the Charlie Lake Watershed: Affects of Agricultural- and Oil & Gas-Related Land Clearing*). If possible, it would also be extremely valuable to have a residence enter into conservation covenant to protect lakeshore to illustrate how a landowner can protect lakeshore habitat while also benefiting financially from proactive conservation (See Chapter 3 for information on conservation covenants). In lieu of constructing a demonstration restoration site on a private residence, the Charlie Lake Conservation Society might consider the construction of a demonstration site on a piece of public land, or at a private business.

One of the keys to preventing future degradation along the lakeshore will be to actively engage those parties that will be responsible for new development on the lake (e.g., local builders, government officials, real estate agents), or those that may come in to contact with future lakeshore property owners (e.g., real estate agents). The Peace River Regional District (PRRD) has taken a significant first step in addressing this issue by developing Lakeshore Development Guidelines (PRRD, 2000). The development of these guidelines was met with some opposition as they were seen as an additional layer of regulation. Consequently, they are and will remain for the time being as voluntary measures that will not be enforced. As such, these guidelines are being used as a means by which to influence potential development projects at the time of development (D. Kunz, Planner, Peace River Regional District, Dawson Creek, BC, Pers. Comm.).

It would be beneficial to take a further step along these lines by providing builders, developers, and real estate agents with additional information regarding lakeshore living and development. In so doing, one might be able to influence development at an earlier stage or before it is initiated. In addition, new lakeshore property owners should receive responsible lakeshore educational material either from the Charlie Lake Conservation Society or from real estate agents at the time that they take possession of their new properties.

While slow in their initial phases, these types of programs can have incredible outcomes. Over a two year period a BC Lake Stewardship Society-directed project in the Okanagan successfully completed five restoration projects, completed over 270 home site assessment visits, and contacted over 2,610 lakefront homeowners on Okanagan Lake by boat, foot, phone, and mail outs (OSBFP, 2003). The Charlie Lake watershed is well

suited for a comprehensive program that addresses responsible lakeshore living. The lake itself is large, but most parts of the lake, especially where the concentrations of people live, are easily accessible. There are also several agencies that can easily provide the necessary tools and services to begin and implement such a program. Furthermore, there are specific organisations that have a genuine interest in Charlie Lake; in particular, the BC Lake Stewardship Society, that has included Charlie Lake in its Volunteer Lake Monitoring Program.

Attempting to address the potential impacts of lakeshore living may be more cumbersome than trying to address the potential affects of agriculture. The reason for this is not that the issues are much different than those affecting agricultural land, rather, there are significantly more lakeshore landowners compared to the number of individuals who own or manage all of the lands in the upper reaches of the Charlie Lake watershed. As previously stated, there are a variety of solutions or tools to mitigate these potential problems. Any initiative geared at attempting any or all of the above suggestions will require extensive planning. A subcommittee of the Charlie Lake Conservation Society will be needed to organise and oversee the initiation of this program.

## References

- French, T.D. & N.B. Carmichael, 1999. Limnological aspects of Charlie Lake (Peace River drainage, British Columbia): a summary of data collected between 1974 and 1995. British Columbia Ministry of Environment, Lands & Parks, 1011 4<sup>th</sup> Avenue, Prince George, British Columbia, Canada, V2L 3H9. 115 pp. (+ appendices).
- OSBFP (Okanagan Similkameen Boundary Fisheries Partnership), 2003. Foreshore Protection Project Wrap-Up. Watershed Weekly, February 7, 2002. Okanagan Similkameen Boundary Fisheries Partnership Newsletter, Regional Stewardship Coordinator's Office, Westbank, BC.
- PRRD (Peace River Regional District), 2000. Lakeshore Development Guidelines. Appendix A: Lake Classification Matrix (<http://www.pris.bc.ca/prrd/services/developmentser/lakeshore/appendixa.htm>)
- Urban Systems Ltd., (undated). Charlie Lake servicing study. Prepared by Urban Systems Ltd. for the Peace-Liard Regional District. 70 pp.

# Appendix A

## Glossary of Terms

As described in the preceding chapters, the Charlie Lake Conservation Society has developed conceptual frameworks for projects that will, once implemented, improve the water quality of Charlie Lake, and the water quality of streams that drain into Charlie Lake. The water quality improvement projects described in the strategic planning documents were developed on the basis of our current understanding of the environmental processes that govern the physical (e.g., sediment and temperature), biological (e.g., primary productivity) and chemical properties of water and, in particular, the factors that contribute to cultural eutrophication. Given that the Charlie Lake Conservation Society's long-term strategic plan is largely science-based, the language used in the planning documents is often technical. Thus, the objective of this Glossary of Terms is to provide readers with definitions of technical terms used in the Charlie Lake Conservation Society's planning documents. The Glossary of Terms was compiled by Todd D. French, who used the following books for reference:

Isaacs, A., J. Daintith & E. Martin (Editors), 1991. *Concise Science Dictionary* (2<sup>nd</sup> Edition). Oxford University Press, New York, NY, USA. 758 pp.

Lee, R.E., 1989. *Phycology* (2<sup>nd</sup> Edition). Cambridge University Press, New York, NY, USA. 645 pp.

National Geographic Society, 1987. *Field Guide to the Birds of North America* (2<sup>nd</sup> Edition). The National Geographic Society, Washington, DC, USA. 464 pp.

Savage, C. 1985. *The Wonder of Canadian Birds*. Western Producer Prairie Books, Saskatoon, SK, Canada. 211 pp.

Wetzel, R.G., 2001. *Limnology: Lake and River Ecosystems* (3<sup>rd</sup> Edition). Academic Press, New York, NY, USA. 1006 pp.

Wetzel, R.G. & G.E. Likens, 1991. *Limnological Analyses* (2<sup>nd</sup> Edition). Springer-Verlag, New York. 390 pp.

**Aerobic** – in general, the term *aerobic* refers to respiration (the conversion of food, e.g., sugars, to carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O)) by organisms in the presence of oxygen (O<sub>2</sub>). Physiological processes that require the presence of oxygen. Most aquatic organisms are *aerobic*, with the exception of various bacteria. See also *Anaerobic*, *Bacteria*, *Oxygen*.

**Algae** – simple plants that live in aquatic, marine and moist environments that lack roots, stems, leaves and other organs. Benthic algae (those that attach themselves to the bottom of lakes and streams) have attachment structures called “holdfasts” that do not transfer nutrients or other materials from substrate (bottom sediment) to tissues (i.e., holdfasts are not true roots). Algae contain various chlorophylls in their chloroplasts; thus, they can use light energy to convert carbon dioxide (CO<sub>2</sub>) to carbohydrates (sugars). See also *Benthic*, *Nutrient*, *Chlorophyll*, *Chloroplast*, *Photosynthesis*, *Substrate*.

**Anaerobic** – the term *anaerobic* refers to the partial oxidation of food (e.g., carbohydrates) to create chemical energy. Physiological processes that are undertaken in the absence of oxygen (O<sub>2</sub>). *Obligate anaerobes* are

organisms that cannot use free oxygen for respiration. *Facultative anaerobes* are organisms that are normally *aerobic* but can respire *anaerobically* during periods of oxygen shortage. See also *Oxygen*, *Aerobic*.

**Anoxic** – refers to environments that do not have free oxygen (O<sub>2</sub>), or that have extremely low free oxygen concentrations (generally < about 1 mg/L). Organisms that require oxygen for respiration (e.g., fish, zooplankton, plants) cannot survive in *anoxic* conditions. Deep waters (hypolimnion) of eutrophic lakes can become *anoxic* during periods of summer and winter stratification as a result of organic decomposition. See also *Hypolimnion*, *Summer Stratification* and *Inverse Stratification* (= winter stratification), *Organic*, *Decomposition*, *Oxygen*.

**Anseriformes** – the taxonomic order of waterbirds composed of swans, geese and ducks. They are characterised by having a long neck, relatively short legs and webbed feet, and they most often have a broad “duck bill”.

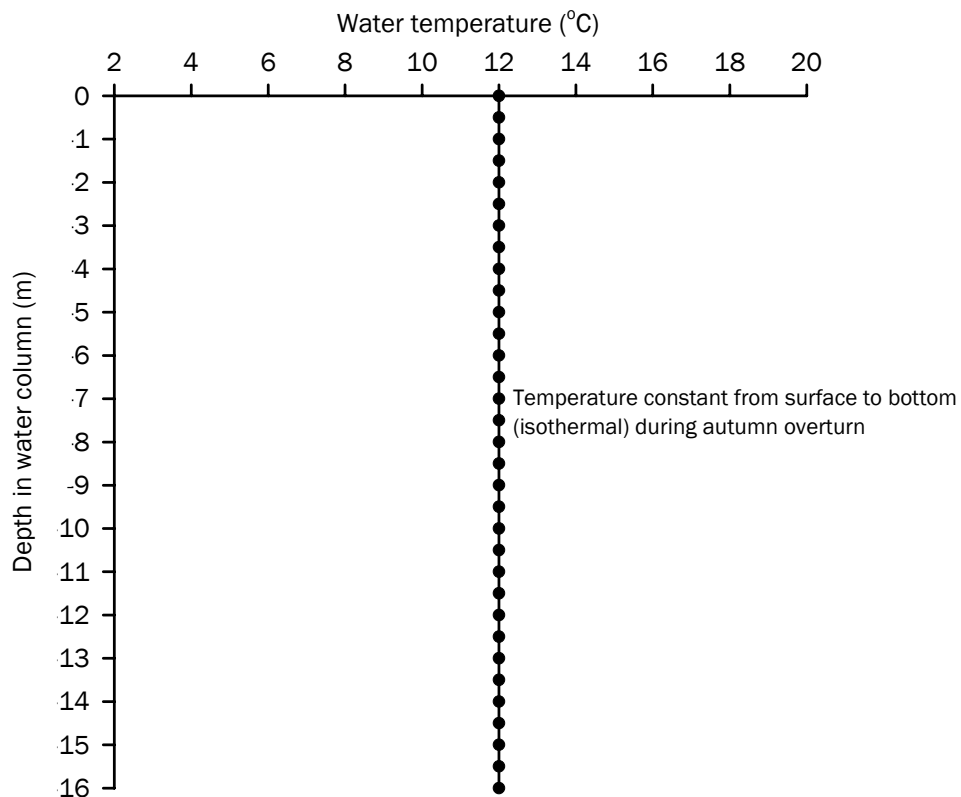
**Anthropogenic** – from Anthrop (Gr. for “man”) and Genic (Gr. for “producing”); thus, literally “produced by man”. In aquatic ecology, the term *anthropogenic* typically refers to substances (e.g., various types of pollution) and environmental effects that result from the activities of humans.

**Attached algae** – are those aquatic algae species that attach themselves to firm substrates such as rocks, plants, submerged wood (e.g., logs, sticks) and other materials. They attach themselves using a structure called a holdfast (not a root, in that a holdfast does not transport materials, such as nutrients). In simple terms, attached algae are a component of the “slime” that is often seen on rocks on the bottom of streams and shallow lake waters. *Attached algae* can be viewed as being the opposite of free-floating, or pelagic, algae that are not attached to a substrate (e.g., algae that form blooms in the water columns of many lakes). Most algal biomass in streams and rivers are attached forms; whereas most algal biomass in lakes are not attached forms (free-floating, pelagic forms). See also *Periphyton*, *Epilithic*, *Epipellic*, *Epiphyte*, *Algae*, *Substrate*, *Nutrient*.

**Autecology** – study of the ecology of a single organism, or a single species. In contrast, community ecology is the study of the processes that control the ecological function of a group of co-existing species. For example, there have been extensive *autecological* studies of many algal and fish species to determine species-specific nutrient, pH, and temperature requirements. See also *Algae*, *Nutrient*.

**Autotrophic** – refers to organisms that synthesise the organic materials that they require (e.g., carbohydrates, or sugars) from inorganic sources. *Autotrophs* do not need to consume other organisms (i.e., plants or animals) to obtain their required organic materials. *Photoautotrophic* organisms utilise photosynthesis to synthesise carbohydrates from inorganic constituents (e.g., algae, terrestrial plants, some bacteria). *Chemoautotrophic* organisms use energy derived from chemical reactions (not sunlight) to synthesise their required organic materials. See also *Heterotrophic* and *Mixotrophic* for comparison, *Photosynthesis*, *Inorganic*, *Organic*.

**Autumn overturn (= Autumn mixing)** - during the summer months, many temperate lakes are divided vertically into three compartments that typically do not mix with one another: (1) epilimnion (warm surface layer), (2) metalimnion (middle layer with steep temperature gradient) and (3) hypolimnion (cool bottom layer). Thus, most temperate lakes are warm on the surface and cool near the bottom during the summer months. As a result of changes in water density brought about by the cooling of air in the autumn, the three summer layers will mix with one another resulting in isothermal conditions (same temperature from surface to bottom). The water column mixing that occurs during the autumn months is referred to as “autumn overturn” or “autumn mixing”. See also *Summer stratification, Epilimnion, Metalimnion, Thermocline, Hypolimnion, Isothermal*.



**Bacillariophyte** - are a division of algae commonly referred to as “diatoms”. *Bacillariophytes* have the photosynthetic pigments chlorophyll *a* and chlorophyll *c*. They do not have flagella; thus, they are not mobile (they move with water currents). They are unicellular (single celled) organisms, but some species are colonial (several individual cells living attached to each other). They live in “glass houses” that are composed mostly of silica dioxide (SiO<sub>2</sub>). These glass houses are known as “frustules” and form sedimentary deposits/soils known as diatomaceous earth (the remains of dead Bacillariophytes). See also *Diatom, Photosynthesis, Algae, Chlorophyll, Silica, Frustule, Flagella*.

**Bacteria** – small life forms ranging in size from about 0.5 to 5  $\mu\text{m}$  in size (microorganisms). *Bacteria* are unicellular (individuals composed of only a single cell) organisms that do not have a distinctive membrane that surrounds the nucleus (part of a cell that contains DNA, or chromosomes). *Bacteria* typically reproduce asexually (i.e., not sexually through the formation of gametes by males and females). Some species have flagella (external “whip-like” structures that provide mobility). Some species of *bacteria* are aerobic (require oxygen,  $\text{O}_2$ ), while others are anaerobic (do not require oxygen for respiration). In aquatic ecosystems, *bacteria* are typically engaged in breaking down organic material (decomposition) and other chemical transformations; they are found in the water column, but are particularly abundant in or on bottom substrates (muds, sands, rock). See also *Aerobic*, *Anaerobic*, *Decomposition*, *Organic*, *Oxygen*, *Flagella*, *Substrate*.

**Bacteriological** – refers to the processes, functions and affects/effects of *bacteria*. See also *Bacteria*.

**Benthic** – refers to habitats on the bottom of lakes, ponds, rivers and streams, e.g., habitats on bottom substrates. This is opposed to limnetic (habitats above bottom, or in the water column). See also *Benthos*, *Limnetic*, *Substrate*.

**Benthos** – refers to organisms that live on the bottom of lakes, ponds, rivers and streams. Examples are epilithic algae (algae that are attached to rocks), epipellic algae (algae attached to sand), many aquatic insects that live on the bottom, and bottom dwelling fish. As a general rule, most biological activity in moving-water systems (rivers and streams) takes place in benthic environments; whereas most biological activity in lakes occurs in limnetic environments (i.e., in the water column, as opposed to on the bottom). See also *Limnetic*, *Benthos*, *Epilithic*, *Epipellic*.

**Biomass** – the mass of living material per unit volume of water, or unit area of substrate. Example of *biomass* per unit volume of water would be mass of fish flesh per cubic decimetre, mass of algal cells per mL, mass of chlorophyll *a* (an important photosynthetic pigment) per mL, and mass of zooplankton (invertebrate animals that live in water column, e.g., *Daphnia*) per cubic metre. Examples of *biomass* per unit area of substrate would be rooted plant mass per square meter of bottom sediment, mass of benthic invertebrates per square metre, mass of algal tissues per square cm of rock, mass of chlorophyll *a* per square cm of rock. Measures of biomass allow biologists to quantify the amount of biological material in a particular habitat or unit of space. See also *Invertebrate*, *Algae*, *Chlorophyll*, *Zooplankton*, *Substrate*.

**Bioperturbation** – refers to physical disturbances resulting from the movements and activities of organisms. In aquatic ecosystems, fish moving along the bottom (or building spawning nests), can disturb bottom sediments (clays, silts and sands). Burrowing invertebrate animals can also disturb bottom sediments. Disturbed sediments can move into the water column and increase turbidity. Sediments often have high concentrations of nutrients (e.g., phosphorus) electrostatically bound to their surfaces; thus, sediment disturbances by fish can substantially increase the rate of nutrient transfer from bottom muds to the water column in shallow lakes. See also *Turbidity*, *Sediment*, *Nutrient*, *Phosphorus*.

**Blue-green algae** - *blue-green algae* is a common term for “cyanobacteria”. The term cyanobacteria is, strictly speaking, more accurate in terms of biological structure and evolution. See also *Cyanobacteria*.

**Channel** – in general terms, *channels* are the longitudinal depressions on the earth's surface resulting from the movement of water. Depressions resulting from erosion (sediment movement) by moving water. River and stream waters flow within the confines of their *channel*, except during flood events where water moves across the highest point of the *channel*. See also *Erosion*, *Sediment*.

**Channel morphology** – broadly refers to the shape, or physical structure, of a stream or river channel. *Channel morphology* is often measured in terms of width (distance from bank to bank), depth (distance from channel bottom to highest point on bank), and sinuosity (degree of “straightness”, “meandering”, etc.). Measures of *channel morphology* are often used to assess the environmental effects of construction, roads, road crossings, land clearing and other human activities. For example, *channel morphology* is often affected by culverts and bridges that permit roads to cross over channels. One common effect of culverts is channel widening and deepening that results from increases in current velocity (i.e., flowing water is often “squeezed” through culvert resulting in increased velocity and horsepower, or erosional force). See also *Erosion*, *Channel*.

**Charadriiformes** - the taxonomic order of birds composed of the gulls, sandpipers, jaegers, terns and plovers. They tend to live along shores and beaches, and in marshes and meadows.

**Chlorophyll** – there are three primary types of *chlorophyll*: *chlorophyll a*, *chlorophyll b* and *chlorophyll c*. *Chlorophyll a* is found in all plants, including freshwater algae, and is the molecule that gives plants their green colour. *Chlorophylls* are large organic molecules that are the principal sites of light absorption in the light reactions of photosynthesis (the process that uses light energy to synthesise carbohydrates (sugars) from carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O)). See also *Photosynthesis*, *Algae*.

**Chlorophyte** – a group of algae characterised by having the photosynthetic pigments *chlorophyll a* and *chlorophyll c*. They also contain alpha, beta and gamma carotenes. *Chlorophytes* are thought to be the evolutionary precursor of higher terrestrial plants. Many species are mobile (flagella). See also *Algae*, *Photosynthesis*, *Chlorophyll*, *Flagella*.

**Chloroplast** – the organelles (compartments within the green coloured parts of plants, including freshwater algae) that contain *chlorophyll* molecules. *Chloroplasts* are the site of photosynthesis (the process that plants used to synthesise carbohydrates (sugars) from carbon dioxide (CO<sub>2</sub>) and water (H<sub>2</sub>O)). See also *Chlorophyll*, *Photosynthesis*.

**Chrysophyte** – a division of algae commonly known as the “golden-brown algae”. They have the photosynthetic pigments *chlorophyll a* and *chlorophyll c*. *Chrysophytes* are unicellular (single celled) organisms, but they are sometimes colonial (several cells living attached to one another). They have one or more flagella, and are thus mobile. See also *Algae*, *Photosynthesis*, *Chlorophyll*, *Flagella*.

**Coliform** – rod-shaped (bacillus) bacteria that live in anaerobic conditions in the gut (colon) of warm blooded animals. *Coliform* bacteria are indicators of fecal contamination of water. See also *Bacteria*, *Anaerobic*.

**Coraciiformes** – a taxonomic order of birds composed of the kingfishers. Commonly found along shorelines where there are dead trees for perching, and in areas with clear shallow water and lots of small fish.

**Cryptophyte** – a group of algae characterised by having the photosynthetic pigments chlorophyll *a* and chlorophyll *c*. They also have two types of carotene and biliproteins. One fascinating characteristic of *cryptophytes* is that they have some characteristics of both plants and animals. When there is sufficient light, *cryptophytes* can use photosynthesis to produce carbohydrates (sugars); however, when light levels are low (as is the case under ice in the winter) they can become heterotrophic (consuming organic material from the environment). Being able to switch from being an autotroph to a heterotroph is called mixotrophy. See also *Algae, Photosynthesis, Autotrophic, Heterotrophic, Mixotrophic, Organic*.

**Cryptosporidium (e.g., *Cryptosporidium parva*)** – a protozoan (microscopic single cell organisms, usually regarded as being “simple animals”) parasite found in the guts of a wide range of vertebrates, including humans. The presence of *Cryptosporidium* is an indicator of fecal contamination of water. *Cryptosporidium* infection in humans can cause an illness called cryptosporidiosis that results in severe gastrointestinal problems. *Cryptosporidium* oocysts (a type of cyst) can be very resistant to chlorine and other drinking-water disinfectants.

**Cultural eutrophication** - refers to the nutrient enrichment of freshwater and marine environments resulting from the activities of humans. *Cultural eutrophication* can result in increased macrophyte and algal growth, and have detrimental effects on ecosystem-level function. In North America, *cultural eutrophication* is commonly associated with the overuse of phosphate-containing detergents (phosphorus is a major plant nutrient), domestic wastes (sewage), fertiliser application, and soil runoff from land clearings. See also *Nutrient, Ecosystem, Macrophyte, Algae, Eutrophication, Phosphorus*.

**Cyanobacteria** - a type of bacteria that forms a large component of “algal” blooms observed in many temperate eutrophic lakes. *Cyanobacteria* are commonly referred to as blue-green algae or cyanophytes; however, they are now classified as being a type of bacteria and not as a type of algae, for molecular reasons that are beyond the scope of this report. *Cyanobacteria* have both algal and bacterial characteristics. *Cyanobacteria* only contain one type of chlorophyll: chlorophyll *a*, that gives them their characteristic green colour and the ability to photosynthesise. They also contain a pigment called phycocyanin that gives water a blue-coloured hue when there are dense populations of decomposing (rotting) *cyanobacteria*. Some *cyanobacteria* species have organelles (cellular structures) called heterocysts that give them the ability to fix atmospheric nitrogen (allowing them to grow in waters having very low nitrogen concentrations). See also *Photosynthesis, Bacteria, Nitrogen, Nitrogen fixation, Heterocyst, Chlorophyll, Decomposition*.

**Cyanophyte** – See *Cyanobacteria*. *Cyanophytes* are more correctly referred to as cyanobacteria.

**Decomposition** – chemical reaction in which a compound breaks down into simpler, and smaller, compounds or into elements. In freshwater ecosystem, *decomposition* typically refers to the breakdown, or “rotting” of, organic materials (mostly of biological origin). *Decomposition* is largely mediated by bacteria in freshwater ecosystems, most rapidly in the presence of oxygen (O<sub>2</sub>); thus, *decomposition* is fundamentally an oxidation reaction, such that oxygen is used to “burn” or consume organic materials and recycle them back to the environment. Of particular relevance, *decomposition* can deplete oxygen from lakes that have large amounts of organic materials in them, as is the case in eutrophic lakes (lakes having high biological productivity). See also *Organic, Eutrophic, Ecosystem, Oxygen, Bacteria*.

**Deposition** - refers to the settling of inorganic and organic solids from the water column of rivers, streams and lakes to the bottom. Where the term sedimentation refers to the sinking of inorganic and organic solids, whether or not they sink as far as the bottom, the term *deposition* is more specific in that it implies that sinking particles do settle on the bottom. See also *Sedimentation*, *Sediment*, *Inorganic*, *Organic*.

**Diatom** - refers to algae in Division Bacillariophyta. *Diatoms* are a group of algae characterised by having a cell wall composed largely of silica dioxide (SiO<sub>2</sub>), which is essentially glass. It is often said that *diatoms* live in “glass houses” (= frustule). As *diatoms* die, their glass frustules sink to the bottom and form what is commonly known as diatomaceous earth. *Diatoms* are unicellular (individuals composed of a single cell), but can be colonial (colonies formed by many individuals). They are extremely beautiful in appearance under a microscope, and come in two basic shapes: centric (spherical, sometimes looking like snow flakes) and pennate (elongate). In temperate lakes of North America, *diatoms* tend to bloom once in the spring shortly following ice off, and again in the autumn. *Diatoms* have the photosynthetic pigments chlorophyll a and chlorophyll c. The chlorophyll c results in them giving water a light “tea” colour during blooms. See also *Chlorophyll*, *Photosynthesis*, *Frustrule*, *Bacillariophyte*, *Algae*.

**Diffuse-source pollution** - refers to pollution to lakes, streams and rivers that does not originate from a specific or particular source. Often refers to sediment pollution that originates from expanses of cleared land. See also *Point-source pollution*.

**Dinophyte** - the taxonomic division of algae commonly known as dinoflagellates. These are the organisms that make up so-called “red tides” in marine environments. They contain the photosynthetic pigments chlorophyll a and chlorophyll c. They have flagella (often several); thus, they are mobile. They are protected externally by several plates called “thecal plates”. See also *Algae*, *Photosynthesis*, *Chlorophyll*, *Flagella*.

**Ecosystem** - refers to a system of interactions between living organisms and their nonliving environment. An *ecosystem* is the integrated function, processing and interactions of all environmental elements - living (life forms) and non-living (substrates, energies, chemicals) elements. The living elements affect one another and the non-living elements, and the non-living elements affect themselves and the living elements. See also *Substrate*.

**Ephemeral** - refers to stream channels that do not carry water all year round (i.e., streams that have temporary flows). Most *ephemeral* streams in interior British Columbia will carry flows during spring snowmelt, after which they dry up and only carry flows during heavy rain events. The term “*ephemeral*” is often confused with “intermittent”. Intermittent streams are streams that do not have a continuous channel, such that they flow on the surface for some of their length, but have segments (or reaches) that flow underground. See also *Channel*.

**Epilimnetic** - refers to the epilimnion of stratified lakes. See *Epilimnion*.

**Epilimnion** - During the summer months, many temperate lakes stratify vertically into three layers. The *epilimnion* is the surface layer composed of circulating warm water that is in contact with the atmosphere. Temperature is constant throughout the *epilimnion*; that is, the entire surface layer has the same temperature

(often 15 to 20 °C during summer). The metalimnion (also called the “thermocline”) is the layer that sits immediately below the *epilimnion*, and it is characterised by having a steep temperature gradient – it is a zone of rapid temperature change. Many people that swim in lakes have had first-hand experience with the metalimnion, such that the water will be comfortably warm on the surface (*epilimnion*), but the temperature drops off suddenly a couple of meters below the surface (the zone where the temperature starts to drop of is the beginning of the metalimnion). The third layer of a stratified lake is called the hypolimnion, and it sits below the metalimnion. The hypolimnion, therefore, is the bottom layer of a stratified lake. Like the *epilimnion*, the hypolimnion tends to have a constant temperature, but it is much cooler than the *epilimnion* – typically 4°C (maximum density of water). It is important to emphasise that the three layers of a summer stratified lake do not mix with one another, unless there is a major wind event. See also *Metalimnion*, *Thermocline*, *Hypolimnion*, *Summer stratification*.

**Epilithic** – from Epi (Gr. for “upon”) and “Lithos” (Gr. for “stone” or “rock”); thus, in aquatic ecology, the term *epilithic* refers to organisms that live on the surface of rocks. Most commonly, the term *epilithic* refers to algae and bacteria that grow on the surface of rocks (the so-called “slime” that grows on the rocks on the bottom of streams, rivers and lakes). See also *Algae*, *Periphyton*, *Epiphyte*, *Epipellic*, *Bacteria*.

**Epipellic** – from Epi (Gr. for “upon”) and “Pelo” (Gr. for mud, clay, silt and sand); thus, in aquatic ecology, the term *epipellic* refers to organisms that live on the surface of sediments. Most commonly, the term *epipellic* refers to algae and bacteria that grow on the surface of sediments on the bottom of streams, rivers and lakes. See also *Algae*, *Periphyton*, *Epiphyte*, *Epilithic*, *Bacteria*, *Sediment*.

**Epiphyte** – from Epi (Gr. for “upon”) and Phyte (Gr. for “plant”); thus, in aquatic ecology, the term *epiphyte* refers to organisms that live on the surface of plants (mostly rooted macrophytes, or so-called “weeds”). Most commonly, the term *epiphyte* refers to algae and bacteria that grow on the surface of rooted aquatic plants (weeds). See also *Algae*, *Macrophyte*, *Periphyton*, *Epilithic*, *Epipellic*, *Bacteria*.

**Erosion** – in the context of freshwater ecology, the term *erosion* most often refers to the movement of sediment (soil) by moving water and/or wind, machinery and livestock. Sediment is particularly susceptible to *erosion* when it is exposed to wind and moving water, i.e., when not stabilised by rooted vegetation. See also *Scour hole*, *Riparian*, *Sediment*.

**Euglenophyte** – a division of algae commonly known as the euglenas. They contain the photosynthetic pigments chlorophyll a and b. They have at least one flagella; thus, they are mobile. See also *Algae*, *Photosynthesis*, *Chlorophyll*, *Flagella*.

**Eutrophic** – refers to freshwater ecosystems (primarily lakes) that have a very high level of biological production. *Eutrophic* lakes are generally characterised by having high phosphorus concentrations (generally about 100 to 250 µg/L) in the water column and associated high algal biomasses (generally about 50 - 300 µg/L chlorophyll a). See also *Phosphorus*, *Biomass*, *Algae*, *Oligotrophic*, *Mesotrophic*, *Production*, *Chlorophyll* and *Hypereutrophic*.

**Eutrophication** – the process of a lake becoming eutrophic. *Eutrophication* is the process of nutrient enrichment (typically by phosphorus- and/or nitrogen-containing substances) and resulting changes in ecosystem function (typically significant increases in algal biomass and/or macrophyte biomass). Sometimes *eutrophication* can result in increased fish productivity; however, oxygen (O<sub>2</sub>) depletion resulting from biomass decomposition can result in the opposite – increased fish mortality. Lake *eutrophication* is highly problematic in areas with large human populations, and is often the result of enrichment by sewage, soil erosion, livestock, fertiliser and detergent use, and industrial effluents (e.g., pulp mills). See also, *Phosphorus, Nitrogen, Eutrophic, Nutrients, Ecosystem, Algae, Biomass, Macrophyte, Production, Oxygen*.

**Evaporation** - refers to the processes through which surface waters (e.g., lakes, rivers, streams, oceans, soil moisture, etc.) are transferred into the atmosphere. See also *Evapotranspiration*.

**Evapotranspiration** – is a type of evaporative process. *Evapotranspiration* refers to the transfer of surface waters (e.g., soil moisture, shallows of lakes, rivers and streams) to the atmosphere by plants. Plants draw water into their tissues, and then expel some of this water into the atmosphere through small openings in their leaves called stomata. See also *Evaporation*.

**External loading** – refers to materials and substances that enter a lake basin from sources outside of the basin. *External loading* most often refers to materials and substances that enter a lake basin via tributaries and groundwater; however, materials and substances can also enter lake basin through aerial fallout (e.g., dust, pollen, air pollutants that fall on the surface of a lakes). See also *Internal loading*.

**Falconiformes** – the taxonomic order of birds composed of the vultures, eagles, hawks and falcons. They are “raptors” characterised by having strong grasping feet, piercing claws and usually a sharply hooked beak for tearing flesh.

**Flagella** - a fine whip-like structure, up to about 150 µm in length, that protrudes from the surface of certain cells, particularly motile reproductive cells (e.g., sperm), bacteria, and some protozoans. Beating of *flagella* results in cell movement. Many types of freshwater and marine algae, protozoans and bacteria have *flagella* that provide mobility. See also *Bacteria, Protozoan, Algae*.

**Flushing rate** – is the number of times a lake replaces, or flushes, its entire volume in 1 year. Flushing rate can be calculated by dividing the sum of all outflow volumes (including volume losses through evaporation and evapotranspiration) by lake volume. See also *Evaporation, Evapotranspiration, Retention Rate*.

**Foreshore development** – refers to human-related activities that occur in the littoral and riparian (or near riparian) zones of lakes, rivers and streams. Most often refers to the construction of beaches, docks, boat launches, houses/cabins, roads, parks, etc.

**Frustrule** – refers to the cell wall of diatoms (a division of algae), that is rich in silica dioxide (SiO<sub>2</sub>) – or glass. *Frustrules* are the so-called “glass houses” that diatoms live in. The shape of a *frustrule* is unique to particular diatom species; this uniqueness is used by taxonomists to differentiate between species. *Frustrules* take a

very long time to decompose (they are not organic) and, thus, they tend to accumulate in the muds on the bottom of lakes where they form what is known as diatomaceous earth. See also *Diatom*, *Algae*, *Decomposition*, *Organic*, *Inorganic*, *Paleolimnology*.

**Fugitive dust** – is a term used by air quality meteorologists that refers to particles between 2.5 µm and 10 µm in size that are carried in the air and can be inhaled by humans. Often referred to as “inhalable particulates”. *Fugitive dust* is largely composed of fine soils windblown from exposed soils. Such particles can result in major air quality problems in areas that apply sand to roads, in areas with, for example, sandy log storage areas, and in agricultural areas with exposed soils. With relevance to aquatic ecology, *fugitive dust* does, to some extent, settle on the surface of lakes and streams where it contributes to the total sediment and nutrient loads. See also *Sediment*, *Nutrient*.

**Gaviiformes** – the taxonomic order of birds that is composed of the loons. They have a characteristic “laugh”-like call that most people that live on lakes are familiar with. They mainly feed on fish, crustaceans, amphibians and, occasionally, on the young of other waterbirds. Unlike most birds that have hollow, air-filled skeletons, loons have bone marrow which permits them to sink by increasing their overall density (they are relatively heavy in comparison to other birds).

**Giardia (e.g., *Giardia lamblia*)** - a protozoan (microscopic single cell organisms, usually regarded as being “simple animals”) parasite found in the guts of a wide range of vertebrates, including humans. The presence of *Giardia* is an indicator of fecal contamination of water. *Giardia* infection in humans can cause an illness called giardiasis or “beaver fever” that results in severe gastrointestinal problems. *Giardia* cysts can be very resistant to chlorine and other drinking-water disinfectants.

**GPS coordinate** – a geographical position, e.g., latitude north/longitude west, that is measured with an instrument (global positioning system) that tracks position with satellite-based information.

**Gruiformes** – the taxonomic order of birds that is composed of the rails and cranes. The majority are long-legged waders with long beaks that are used for grabbing fishes and small bottom-dwelling organisms.

**Heterocyst** – a thick-walled, hollow-looking, enlarged cell found in some species of cyanobacteria. The *heterocyst* is the site of nitrogen fixation in cyanobacteria. Reactions that take place in *heterocysts* break the triple bond between the two nitrogen atoms in atmospheric N<sub>2</sub>, making nitrogen available to cyanobacteria. The ability to “fix” atmospheric nitrogen makes it possible for cyanobacteria to attain high biomass in nitrogen deplete waters. See also *Cyanobacteria*, *Blue-green algae*, *Cyanophyte*, *Nitrogen*, *Nitrogen fixation*.

**Heterotrophic** – refers to organisms that acquire food energy from the intake and digestion of organic substances, normally plant or animal tissues. Organisms that cannot synthesise their own food (particularly carbohydrates, or sugars) from inorganic constituents. See for comparison *Autotrophic* (photosynthetic organisms, such as plants and some bacteria), *Mixotrophic*, *Organic*, *Inorganic*, *Photosynthesis*.

**Hypereutrophic** – lakes with extremely high nutrient (e.g., phosphorus and/or nitrogen) concentrations and associated extremely high plant (algae and/or macrophyte) biomasses. *Hypereutrophic* lakes typically have phosphorus concentrations > 250 µg/L and algal biomasses > 300 µg/L chlorophyll *a* during blooms. See also *Eutrophic, Oligotrophic, Mesotrophic, Nutrient, Phosphorus, Nitrogen, Algae, Chlorophyll, Biomass*.

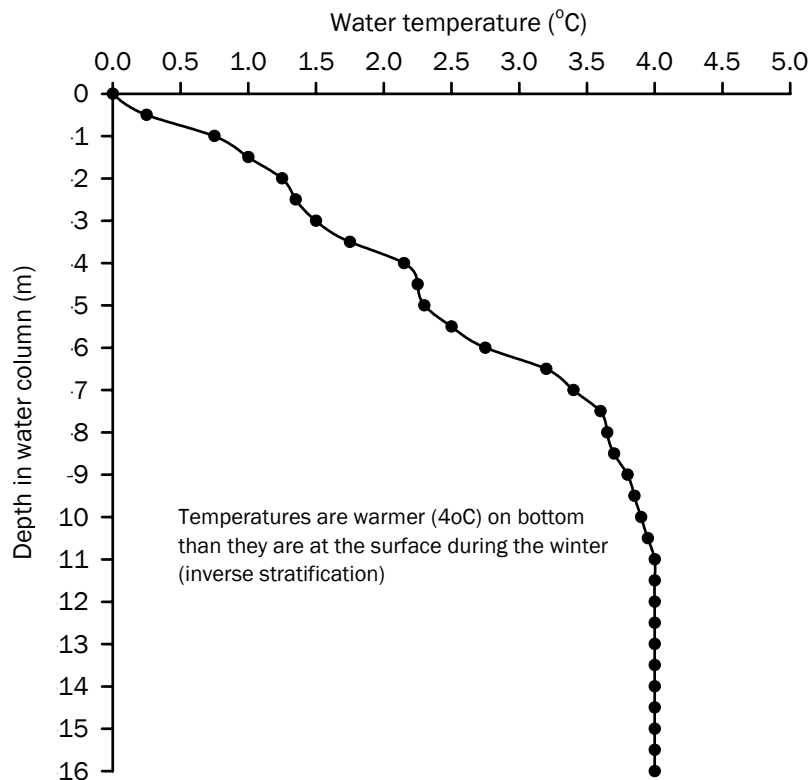
**Hypolimnetic** – refers to conditions, processes and associations of the hypolimnion. See also *Hypolimnion*.

**Hypolimnion** – many temperate lakes divide into three vertical sections, or compartments, during the summer months. The surface compartment, which is characterised by warm, circulating water, is known as the epilimnion. The middle layer, where temperature drops rapidly with increasing depth (> 1°C/m) is known as the metalimnion (= thermocline). The *hypolimnion* is the deepest layer of water in a summer stratified lake, and is characterised by having cold water (typically 4°C, temperature of water at maximum density). When a lake is stratified, the epilimnion, metalimnion and *hypolimnion* do not mix with one another, except during strong wind events. Since the epilimnion is in contact with the atmosphere, it is typically well oxygenated (rich with O<sub>2</sub>). However, in eutrophic lakes (lakes with high organic content), oxygen can be depleted in the *hypolimnion* via the result of decomposition (i.e., the *hypolimnion* cannot recharge its oxygen supply from the atmosphere because it does not mix with epilimnion or metalimnion). See also *Epilimnion, Metalimnion, Thermocline, Oxygen, Eutrophic, Decomposition, Summer Stratification*.

**Inorganic** – in aquatic ecology, the term *inorganic* largely refers to molecules that are not synthesised by organisms (e.g., not proteins, lipids/fats, carbohydrates/sugars, etc.). In broad terms, living organisms use *inorganic* compounds (e.g., CO<sub>2</sub>, various nutrients and minerals) to synthesise their tissues and macromolecules (i.e., large molecules like sugars, DNA, RNA, proteins, fats/lipids, etc.). When organisms die, they decompose (or rot) back to their inorganic components; such decomposition typically consumes oxygen (O<sub>2</sub>) in aquatic ecosystems, and can result in oxygen deficits (very low oxygen concentrations). See also *Organic, Nutrient, Decomposition, Oxygen*.

**Internal loading** – refers to materials and substances (e.g., nutrients like phosphorus and silica) that enter lake water from sources located within the lake basin. For example, phosphorus and silica can be *internally loaded* to lake water through processes that result in their release from bottom muds (fine sediments on the bottom of lakes) and from decomposing organisms (algae, rooted macrophytes and fish that contain these elements in their tissues). See also *Nutrients, Phosphorus, Silica, External loading, Sediment, Decomposition, Algae, Macrophyte*.

**Inverse stratification (= Winter stratification)** - during the summer months, many temperate lakes are divided into three vertical compartments that tend not to mix with one another: (1) epilimnion (warm surface layer), (2) metalimnion or thermocline (middle layer with steep temperature gradient) and (3) hypolimnion (cool, typically 4°C, bottom layer). Thus, virtually all temperate lakes are relatively warm on the surface, and cold on the bottom during the summer months – they are what is commonly referred to as “summer stratified”. In contrast, lakes show an opposite type (or *inverse stratification*) of layering during the winter months when they are frozen over. During the winter months, temperate lakes are most often relatively warm near the bottom (about 4 °C) and cool at the surface (about 0 °C) – so-called *inverse stratification*. See also *Epilimnion, Metalimnion, Thermocline, Hypolimnion, Summer stratification*.



**Isothermal** – or “*isothermy*” refers to the vertical temperature (or thermal) structure of lakes during periods of water column mixing as occurs in temperate lakes during spring overturn and autumn overturn and, sometimes, during the summer months with strong wind events. When a lake is *isothermal*, it is the same temperature from surface to bottom, i.e., no temperature change through water column. When a lake is *isothermal*, it means that the water column is “mixing”, or has recently mixed. As a result of this mixing, most chemical concentrations are the same from the surface to bottom. See also *Thermal, Spring overturn, Autumn overturn*.

**Limnetic** – in general, refers to functions, processes and associations that occur in the water column (as opposed to near bottom sediments) outside of the littoral region (zone along shorelines where aquatic macrophytes grow). *Limnetic* refers to off-shore regions of the water column. Compare to *Benthic* and *Littoral*. See also *Sediment, Macrophyte*.

**Limnological** – refers to the activities, processes and associations of limnology. See also *Limnology*.

**Limnology** – the study of the physical, chemical and biological characteristics, and their interactions, of lakes and other bodies of fresh water. Most commonly, *limnology* refers to the study of lakes; but some researchers broaden the term to include the study of freshwater rivers and streams. *Limnology* can be viewed as the freshwater equivalent of the science of oceanography.

**Littoral** – refers to the near-shore zone around the perimeter of a lake, or river, where rooted aquatic macrophytes (plants/weeds) grow. The *littoral* zone typically extends from the shore to the 2- to 5-m depth contours (depending on water clarity – rooted plants require sufficient light to permit photosynthesis). The zone around the perimeter of a lake that is shallow enough to permit photosynthesis to the bottom, or near bottom. See also *Macrophyte*, *Photosynthesis*.

**Macrophytes** – (from Gr. “Macro” meaning large, and Gr. “Phyte” meaning plant), literally “large plant”. *Macrophyte* is a general term for large (visible to the naked eye) plants that have vascularised tissues (e.g., true roots, xylem, phloem, leaves, etc.). Macrophytes are commonly referred to as aquatic “weeds”. Aquatic *macrophytes* come in four basic forms: (1) emergent (those that protrude from the surface of the water, e.g., cattails), (2) floating (those whose top leaves float on the surface, e.g., lily pads), (3) unrooted floating (those vascular plants that float on the surface and have roots that do not enter the soil/bottom sediment, e.g., duckweeds), and (4) submerged (those rooted forms that are completely submerged, e.g., aquatic milfoils, buttercups, bladderworts, pond weeds).

**Macrozoobenthos** – from Gr. “Macro” meaning large, “Zoo” meaning animal, and “Bentho” for bottom. Literally, “large animals that live on the bottom”. In aquatic ecology, *macrozoobenthos* refers to large (those that can be seen with the naked eye) animals (mostly invertebrates, and does not usually include bottom-dwelling fish) that live on the bottom of lakes and streams, such as clams, mussels, aquatic worms and insects.

**Mesotrophic** – refers to lakes with moderate nutrient (e.g., phosphorus and nitrogen) concentrations, and associated moderate levels of biological productivity. *Mesotrophic* lakes typically have phosphorus concentrations ranging from about 50 to 100 µg/L, and algal biomasses ranging from about 25 to 50 µg/L chlorophyll *a*. See also *Nutrient*, *Phosphorus*, *Nitrogen*, *Eutrophic*, *Hypereutrophic*, *Oligotrophic*, *Biomass*.

**Metalimnetic** – refers to functions and processes associated with the metalimnion, or thermocline. See also *Metalimnion*, *Thermocline*.

**Metalimnion** – same as “thermocline”. Many temperate lakes are divided into three vertical compartments during the summer months. The epilimnion is the surface layer of warm circulating water. The *metalimnion* (thermocline) is the layer that sits immediately below the epilimnion, and is characterised by having a steep temperature gradient (a decline of > 1°C per meter depth). The bottom layer of cold water (about 4°C) that sits below the *metalimnion* is the hypolimnion. The *metalimnion* lies between the epilimnion and hypolimnion. See also *Summer stratification*, *Epilimnion*, *Thermocline*, *Hypolimnion*.

**Mixotrophic** – refers to organisms that can obtain their nutrition through both heterotrophy (consuming organic food stuffs, e.g., carbohydrates – like most animals) and autotrophy (synthesising carbohydrates from inorganic carbon (CO<sub>2</sub>) and sunlight through photosynthesis – like most plants). Thus, *mixotrophic* organisms can be heterotrophic when external food sources are plentiful, but can turn to autotrophy (usually photosynthesis) when external food resources are scarce. The cryptophytes (an order of algae) are photosynthetic during the summer months, but turn to heterotrophy during the ice-covered winter months when light levels are low (it is thought that this group of algae is successful during the winter months as a

result of their mixotrophy). See also *Heterotrophic, Autotrophic, Algae, Cryptophyte, Photosynthesis*.

**Nitrogen (N)** – is a major plant and animal nutrient. The element is an essential component of proteins and nucleic acids (building blocks of RNA and DNA – genetic makeup of all life forms, and is therefore required by all organisms). In aquatic ecosystems, common forms of *nitrogen* include:  $NO_2$  (nitrite),  $NO_3$  (nitrate),  $NH_3$  (ammonia),  $NH_4$  (ammonium) and *particulate* (nitrogen incorporated into living tissues as protein or nucleic acids). Most aquatic plants (including algae) can only incorporate dissolved forms of *nitrogen* (i.e.,  $NO_2$ ,  $NO_3$ ,  $NH_3$ ,  $NH_4$ ). However, some species of cyanobacteria have the ability to break the triple bond in of atmospheric  $N_2$  and can, thus, utilise atmospheric *nitrogen* when *nitrogen* concentrations in the water are low. See also *Nutrient, Algae, Cyanobacteria, Heterocyst, Nitrogen Fixation*.

**Nitrogen fixation (N-fixation)** – chemical process in which atmospheric nitrogen ( $N_2$ ) is assimilated into organic compounds (e.g., proteins and nucleic acids) within living organisms. The ability to *fix nitrogen* is limited to certain bacteria (e.g., *Azobacter*) and certain cyanobacteria (e.g., *Anabaena*). The reaction requires substantial amounts of energy, with this being one of the reasons why fertiliser production has high energy requirements (i.e., the triple bond holding the N atoms together in atmospheric  $N_2$  is strong). *Nitrogen fixation* occurs in the heterocysts of some cyanobacteria. See also *Nitrogen, Organic, Cyanobacteria, Heterocyst*.

**Nutrient** – minerals, compounds and elements that are required by organisms. *Essential nutrients* are those that organisms need to take in from external sources (i.e., they cannot be synthesised within the body). Examples of critical *nutrients* in freshwater ecosystems are phosphorus, nitrogen, silica and iron. See also *Ecosystem, Phosphorus, Nitrogen, Silica*.

**Oligotrophic** – refers to lakes having very low concentrations of available nutrients (e.g., phosphorus and nitrogen) and associated low levels of biological productivity. *Oligotrophic* lakes tend to be deep and steep sided, and tend to have high water clarity. *Oligotrophic* lakes typically have phosphorus concentrations < 50  $\mu\text{g/L}$ , and algal biomasses < 25  $\mu\text{g/L}$  chlorophyll *a*. See also *Eutrophic, Hypereutrophic, Mesotrophic, Algae, Nutrient, Phosphorus, Nitrogen, Productivity, Chlorophyll*.

**Organic** – in broad terms, refers to large molecules that contain chains of carbon and oxygen ( $O_2$ ). In aquatic ecology, the term *organic* typically refers to large molecules of biological origin (e.g., proteins, nucleic acids, fats/lipids, sugars/carbohydrates). See also *Inorganic, Oxygen*.

**Oxygen (O)** – can be incorporated into many organic and inorganic compounds. Dissolved in water, *oxygen* is in the form of  $O_2$ ; that is, two *oxygen* molecules (O) bonded together. *Oxygen* is required for aerobic respiration (most plants and animals). The decomposition of organic matter is most efficient in the presence of *oxygen*; thus, *oxygen* depletion in aquatic ecosystems can occur when there is an abundance of organic material. See also *Organic, Inorganic, Aerobic, Decomposition*.

**Paleolimnological** – refers to processes, activities, and associations of paleolimnology. See also *Paleolimnology*.

**Paleolimnology** – refers to the study of how the physical, biological and chemical conditions of lakes have changed through time. Many scientists have used *paleolimnological* techniques to examine how lakes have changed through time in response to pollution (e.g., acid rain, nutrient loading), urbanisation, foreshore development, species introductions and land clearing. A commonly used technique is to core lake bottoms (sediment core) and then perform chemical and biological analyses on sediments from the surface of the core (most-recently deposited sediment) and those from deep in the core (cores often represent up to 300 years of past history). Scientists can compare the chemistry of recently-deposited sediments to historic sediments to assess chemical changes in the environment, and also compare the preserved remains of organisms (e.g., invertebrate carapaces, shells, diatom frustules, fish scales) found deep in the core to those found in the surface layers to assess biological changes. See also *Limnology*, *Sediment*, *Diatom*, *Frustrule*, *Foreshore development*).

**Passeriformes** – the taxonomic order of birds that are commonly referred to as “songbirds”. The largest order of birds, with nearly 5,000 species world wide. They are known for their complex behaviour and communicative calls (songs).

**Pelagic** – organisms that swim or drift in lakes, as opposed to those that live on the bottom or attached to a substrate (e.g., rocks, plants, woody debris). See also *Benthic*, *Substrate*.

**Pelecaniformes** – the taxonomic order of birds that is composed of the gannets, pelicans and cormorants. They are large, fish-eating birds that have a throat pouch that is most evident in pelicans.

**Periphyton** – a broad term for attached algae. Algae that live attached to a substrate. For example, epipellic algae (those that live on the bottom of lakes and rivers attached to muds, silts, clays and sands), epilithic algae (those that live on the bottom of lakes and rivers attached to rock) and epiphytic algae (those that live on the surfaces of higher plants) are specific types of *periphyton*. See also *Algae*, *Attached algae*, *Epipellic algae*, *Epilithic algae*, *Epiphytic algae*, *Substrate*.

**Phenology** – the *phenology* of a plant refers to the timing of its lifecycle; particularly to the time of year that it blooms or reproduces. The *phenology* of freshwater algae is species-specific, such that, in general, diatoms bloom in spring and autumn, cryptophytes bloom in the winter under ice, chlorophytes bloom in mid-summer and cyanophytes bloom in the late summer and early autumn. See also *Algae*, *Diatom*, *Cryptophyte*, *Chlorophyte*, *Cyanophyte*.

**Phosphorus (P)** – a major plant and animal nutrient that is known to be a key factor that limits biological productivity in most north temperate lakes. *Phosphorus* is a component of the “energy molecule” adenosine triphosphate (ATP) that almost all organisms use to store chemical energy; thus, *phosphorus* is an important element that gives energy to almost all life forms, including aquatic organisms. In addition, *phosphorus* is essential to many metabolic reactions, and is an important component of lipids (fats), bones, teeth, and nucleic acids (i.e., RNA and DNA – genetic building blocks of all life forms). See also *Nutrient*, *Nitrogen*, *Silica*.

**Photic zone** – refers to the upper layers of a lake where there is sufficient light to permit photosynthesis by macrophytes and algae. Often defined as 1% of surface irradiance (i.e., photosynthesis can occur to depths

having a minimum of 1% of the light at the surface). See also *Photosynthesis, Macrophyte, Algae*.

**Photosynthesis** – is the process that plants (algae, macrophytes) and some bacteria use to synthesise sugars (carbohydrate-based foods) from inorganic carbon (e.g., atmospheric CO<sub>2</sub>). *Photosynthesis* is an energy-requiring process, that is fuelled by sunlight and water (H<sub>2</sub>O). Oxygen (O<sub>2</sub>) is a by-product of *photosynthesis*, so is an important source of oxygen to aquatic ecosystems. The light-capturing molecules in *photosynthetic* organisms are known as chlorophylls. Most often, chlorophylls are stored in cellular organelles (membrane-bound compartments) call chloroplasts – chlorophylls give most plants a green colour. See also *Algae, Macrophyte, Bacteria, Inorganic, Oxygen, Chlorophyll, Chloroplast*.

**Phycology** – the scientific discipline that focuses on the study of algal taxonomy, ecology and physiology. The study of algae. See also *Algae*.

**Phytoplankton** – are algae that float or drift in the water column of lakes, as opposed to being attached to substrates like periphyton. *Phytoplankton* are the types of algae that are visible in the water column during summer and autumn blooms (they give water a green appearance during blooms). They are an important component of freshwater food chains (they are “primary producers”). See also *Algae, Periphyton, Epilithic algae, Epipellic algae, Epiphytic algae, Plankton, Substrate*.

**Plankton** – a broad term for the plants (macrophyte fragments, algae), animals and bacteria that float or drift in the water column of lakes. The *plankton* is a complex matrix of interacting organisms that affect the overall biology and chemistry of a lake. Scientists cannot consider the chemistry of a lake without consideration of the physiology and ecology of the *plankton*, and visa versa. See also *Macrophyte, Algae, Phytoplankton, Zooplankton*.

**Podicipediformes** – the taxonomic order of birds composed of the grebes. Legs are extremely far to the rear, and they do not have fully webbed feet. They are also characterised by having stubby wings and, in several respects, are similar to loons (a close evolutionary relative).

**Point-source pollution** – refers to pollution to air, water and soil that originates from a particular sources; for example, sewage treatment plant effluents, pulpmill effluents, industrial air emissions. See for comparison *Diffuse-source pollution*.

**Production** – in general, is the rate at which biological material (biomass) is synthesised in aquatic ecosystems. Quite often, *production* is measured in terms of how much carbon is synthesised, or produced, per unit time per unit volume or surface area (biological tissues are composed primarily of carbon-based compounds, so carbon is a good measure of the amount of biological material). It is a rate of biological *production*. The rate at which biomass is produced (biomass produced per unit time per unit area or volume). *Production* is sometimes defined as the rate of biological activity e.g., rate of oxygen (O<sub>2</sub>) consumption by aerobic organisms per unit time, rate of CO<sub>2</sub> production through respiration per unit time. See also *Ecosystem, Biomass, Oxygen, Respiration*.

**Productivity** – a measure of production. See also *Productivity*.

**Profundal** – is the zone of the bottom of lakes in regions deeper than the littoral zone. The *profundal* zone (or profundal “plain”) is the generally flat plain of the bottom of a lake that does not contain much biomass in the way of rooted aquatic plants or invertebrates. The *profundal* zone is generally where the carcasses of dead organisms (e.g., fish, plants, algae, invertebrates, etc.) accumulate. *Profundal* sediments are often rich in bacteria that work to decompose accumulating organic matter back to inorganic components. It is the primary area of “recycling” in a lake. Water immediately above *profundal* sediments (i.e., hypolimnion in summer stratified lakes) can become anoxic (very low oxygen, O<sub>2</sub>, concentrations) as the result of high decomposition rates. See also *Littoral, Biomass, Algae, Bacteria, Oxygen, Decomposition, Organic, Inorganic, Sediment, Hypolimnion, Anoxic, Summer stratification*.

**Protozoan** – unicellular, usually microscopic organisms regarded as being simple animals. See also *Cryptosporidium, Giardia*.

**Respiration** – the metabolic processes in animals and plants by which organic substances are broken down to simpler products with the release of energy which is incorporated into energy-storing molecules like adenosine triphosphate (ATP). Carbon dioxide (CO<sub>2</sub>) is given off during aerobic *respiration*. *Respiration* consumes oxygen (O<sub>2</sub>) from aquatic ecosystems. See also *Organic, Decomposition, Phosphorus, Photosynthesis, Aerobic*.

**Retention rate** – is the length of time it takes for a lake to fully replace its volume of water – usually measured in years. *Retention rate* is computed as the reciprocal of flushing rate (1/flushing rate). See also *Flushing rate*.

**Riparian** – the terrestrial environment surrounding a body of water (e.g., lake, stream, river) that is affected by the body of water. The water table tends to be near the surface in *riparian* zones; thus, *riparian* soils tend to have high moisture content. The species composition of *riparian* plant communities is often very different from that of upland plant communities that usually have drier soils. Dense rooting systems of healthy *riparian* plant communities stabilise *riparian* soils and, thereby, reduce sediment loading to streams. *Riparian* vegetation also provides shading to streams, reducing temperature fluctuations. Leaf litter and other organic debris falling into stream channels from *riparian* habitats is a major source of organic carbon of stream ecosystems. See also *Sediment, Erosion, Organic, Ecosystem*.

**Scour hole** – refers to a portion of a stream channel that has increased in size (width and/or depth) as a result of erosion by moving water. *Scour holes* often form immediately downstream of road culverts, particularly when a culvert is too small to support high stream flows. When water enters a culvert that is too small, flows are compressed and the velocity of the water increases. The increase in water velocity (= increased energy) increases the erosional force of the water; thus, channel sediments downstream of the culvert may experience substantial erosion (sediment movement). Such erosion often results in channel widening and increases in channel depth (a *scour hole*). *Scour holes* often result in culvert perching at the downstream end (i.e., bottom of culvert is elevated above stream channel) which can impair the ability of fish to move throughout a system. See also *Channel, Erosion, Sediment*.



Massive scour hole downstream of a highway in the Dawson Creek, British Columbia area (Tupper Creek).

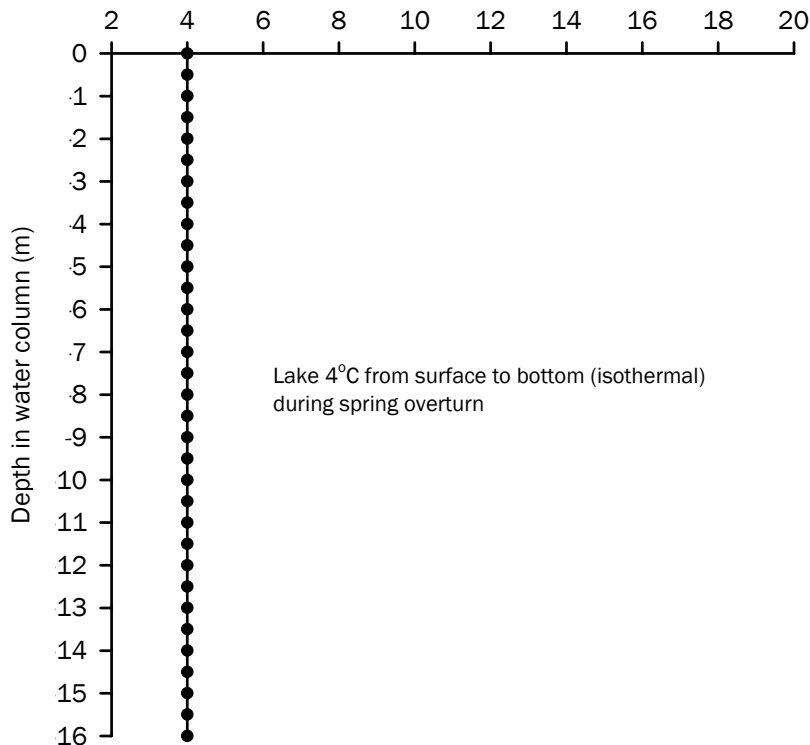
**Sediment** – in general terms, refers to solid particles that are suspended (*suspended sediments*) in the water column of rivers, streams and lakes, and to solid particles that have settled to the bottom of rivers, streams and lakes (*bottom sediments*). *Suspended sediments* and *bottom sediments* are typically thought of as being inorganic solids of mineral origin such as gravel, sand, silt and clay. Organic solids are not typically regarded as being *sediment*; however, organic solids are often mixed in with inorganic *sediment* (e.g., *sediments* rich in organic materials). *Suspended sediments* are indicators of erosion, whereas *bottom sediments* are indicators of deposition. See also *Inorganic, Organic, Erosion, Deposition*.

Grain size (mm)	Sediment class	Clastic texture terms	
>256	Boulder	Gravel – coarse grained	
64	Cobble	Gravel – coarse grained	
4	Pebble	Gravel – coarse grained	
2	Granule	Gravel – coarse grained	
1.0	Very coarse sand	Sand – medium grained	The commonly-used Wentworth Sediment-Size Scale.
0.5	Coarse sand	Sand – medium grained	
0.25	Medium sand	Sand – medium grained	
0.125	Fine sand	Sand – medium grained	
0.0625	Very fine sand	Sand – medium grained	
0.031	Coarse silt	Mud – fine grained	
0.0156	Medium silt	Mud – fine grained	
0.0078	Fine silt	Mud – fine grained	
<0.0039	Clay	Mud – fine grained	

**Sedimentation** – the process through which solids suspended in the water column of rivers, streams and lakes settle, or deposit, to or towards the bottom. While the term sediment most often refers to inorganic solids, *sedimentation* refers to the sinking of both organic and inorganic solids from the water column towards the bottom. The term *sedimentation* also refers to the sinking of dead organisms (e.g., plankton, fish, etc.). It is the process through which materials suspended in the water column become incorporated into the bottom sediment matrix. See also *Inorganic, Organic, Sediment, Plankton, Deposition*.

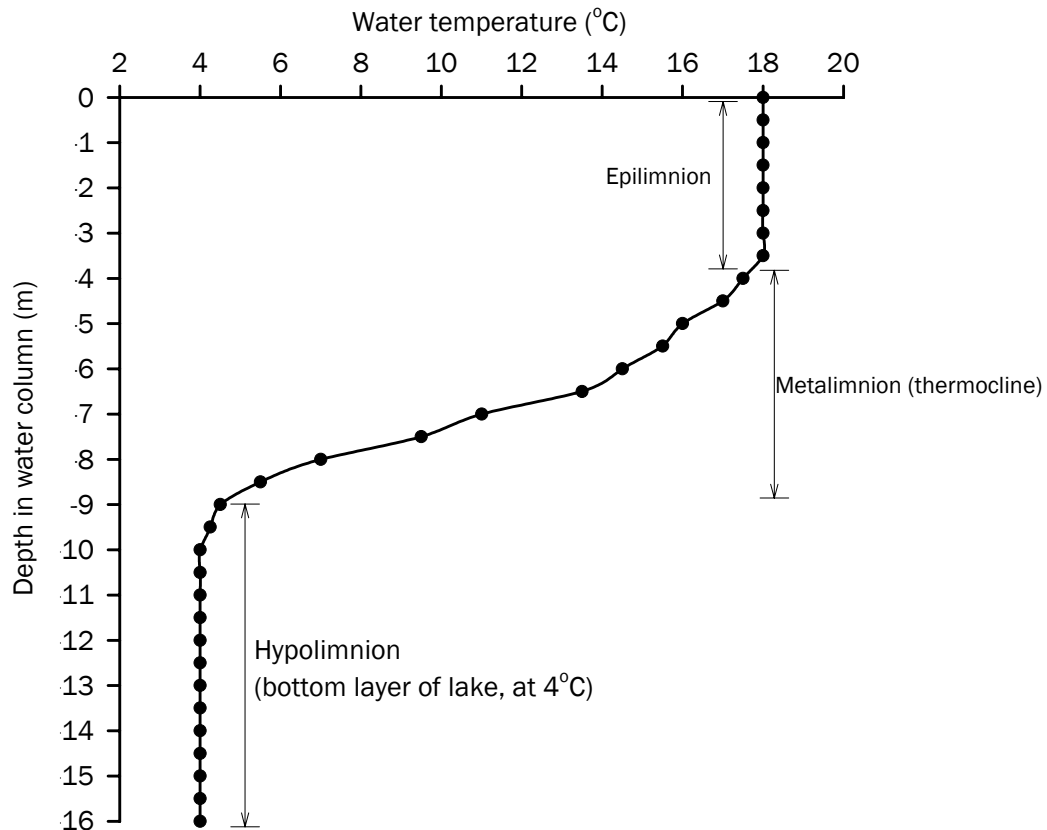
**Silica (Si)** – is an elemental nutrient that is required for the formation of diatom frustules. *Silica* is a major component of inorganic sands, and is the second most abundant element in the earth’s crust. A major component of diatomaceous earth. *Silica* largely enters the water column of lakes by dissolving out of bottom sediments and through the dissolution of diatom frustules. See also *Internal loading, Sediment, Nutrient, Frustule, Diatom*.

**Spring overturn (= Spring mixing)** - when lakes are frozen over during the winter months, they are typically inversely stratified: relatively warm water on bottom (typically 4°C) underlying colder surface layers (about 0 °C). Shortly following ice-off in the early spring, surface layers will begin to warm and the associated changes in water density will cause the water column to mix (*spring overturn*, or spring mixing). The mixing of the water column results in isothermal conditions (same temperature from surface of the lake to bottom). *Spring overturn* also results in a constant water chemistry from surface to bottom. See also *Autumn overturn, Isothermal, Inverse stratification*.



**Substrate** – in general, refers to a surface that organisms grow on. For example, the *substrate* for epiphytic algae is large plants, the *substrate* for epilithic algae is rock, and the *substrate* for epipelagic algae is sand. See also *Algae, Epiphyte, Epipelagic, Epilithic, Periphyton, Attached algae*.

**Summer Stratification** – refers to the layering of the depth strata of lakes that occurs during the summer months. The surface layer of a *summer stratified* lake is referred to as the epilimnion, and is characterised by relatively warm circulating water. Wave action in the epilimnion helps mix oxygen (O<sub>2</sub>) and carbon dioxide (CO<sub>2</sub>) and other atmospheric gases into the water. The layer immediately below the epilimnion is called the metalimnion (or thermocline), and is a zone of rapid temperature change; generally > 1°C decrease per meter of increased depth. The hypolimnion of a *summer stratified* lake extends from the bottom of the metalimnion to the bottom of the lake. The hypolimnion is characterised by having cool water (typically about 4°C) and may have low oxygen concentrations, particularly in eutrophic lakes. It is important to know that the three layers of *summer stratified* lakes do not mix with one another, except during strong wind events; thus, the chemistry and biology of these layers can be very different. See also *Epilimnion, Metalimnion, Thermocline, Oxygen, Inverse stratification, Spring overturn, Autumn overturn, Eutrophic*.



**Thermal** – refers to the heat energy of a lake. Variations in *thermal* energy (temperature) affect water circulation and biological productivity. See also *Production*.

**Thermocline** – same as metalimnion. See also *Metalimnion*.

**Trophic** – refers to the mechanism(s), or pathways, through which organisms obtain their nutrition. For example, photosynthetic organisms are referred to as “autotrophs”, and organisms that consume organic matter from external sources (most animals) are referred to as heterotrophs. The term “*trophic level*” refers to the various levels of the food chain (e.g., primary producers, herbivores, omnivores, carnivores/predators). See also *Autotrophic, Heterotrophic, Mixotrophic, Photosynthesis*.

**Turbidity** – refers to materials in the water that can scatter sunlight. Organic *turbidity* is the result of the presence of suspended dissolved and particulate organic matter, whereas sediment *turbidity* is the result of the presence of suspended sediment. Total *turbidity* refers to the combined *turbidity* of suspended organic and inorganic materials. In general terms, *turbidity* is a measure of water clarity: high *turbidity* = low water clarity. *Turbidity* in streams is primarily the result of sediment erosion and transport. See also *Organic, Inorganic, Sediment*.

**Zooplankton** – refers to the small (sometimes microscopic) invertebrate animals that live in the water columns of lakes and rivers. Some species are herbivorous, while others are predaceous. They are a primary food source of many fish species. See also *Plankton, Phytoplankton*.

# Appendix B

## Abbreviations, Acronyms & Symbols

The following is a list of abbreviations, acronyms and symbols used in the Charlie Lake Conservation Society's strategic planning documents.

### References to Units of Measure

°C: Degrees Celsius

<: Less than

≤: Less than or equal to

>: Greater than

≥: Greater than or equal to

=: Equal to

+/-: Plus or minus

%: Percent (proportion of 100 units)

Ave: Average

ft<sup>2</sup>: Square foot

ft<sup>3</sup>: Cubic foot

L: Litre (x 1,000 = m<sup>3</sup>)

mL: Millilitre (1/1,000 of a litre)

hrs: Hours

µg: Microgram (1/1,000,000 of a gram)

mg: Milligram (1/1,000 of a gram)

g: Gram (1/1,000 of a kilogram)

Kg: Kilogram (1,000 grams)

µm: Micrometer (1/1,000,000 of a metre)

mm: Millimetre (1/1,000 of a metre)

cm: Centimetre (1/100 of a metre)

m: Metre (1/1,000 of a kilometre)

m<sup>2</sup>: Square meter

m<sup>3</sup>: Cubic meter (1,000 litres)

Km: Kilometer (1,000 meters)

Km<sup>2</sup>: Square kilometre

NTU: Nephelometric turbidity units (a common measure of water turbidity)

vol: Volume

### References to Chemicals/Compounds

Chl a: Chlorophyll a

N: Nitrogen

NO<sub>3</sub>: Nitrate

NO<sub>2</sub>: Nitrite

Inorg-N<sub>diss</sub>: Dissolved inorganic nitrogen (sum of ammonium, ammonia, nitrate and nitrite)

O<sub>2</sub>: Dissolved oxygen

P: Phosphorus

Tot-P: Total phosphorus

Tot-P<sub>diss</sub>: Total dissolved phosphorus

PO<sub>4</sub>: Phosphate (an important plant and animal nutrient)

Si: Silica

Tot-Si<sub>diss</sub>: Total dissolved silica

### References to Currency

CDN: Canadian dollar

GST: Canadian Goods and Services Tax

### Miscellaneous References

a.k.a.: Also known as

GPS: Global positioning system

*n*: Sample size (number of samples measured or observed)

NTS: National Topographic Series maps

# Nose Pumps: Cattle Pump Their Own Water

*“Nose pumps increase water quality and herd health.”*

*Glenn Hogberg*

## Three Nose Pumps Evaluated

During the summers of '97 and '98 three different nose pumps were evaluated at the Hogberg's Ranch. (SE ¼ of section 12 Tp 78 Rg 19 W6M). The Hogberg's tried the nose pumps because they wanted to keep their recently built dugout clean, instead of allowing their cattle direct access to their dugout

Three nose pumps were used: **Lister, Eider, and Aquamat**. The dugout in a south sloping pasture, was fenced off with barbed wire. A wood platform was built that was higher than the water level on the east and west and plank fencing put around the nose pumps. Two of the pumps were bolted down to the platforms and placed on either side of the dugout. The 3<sup>rd</sup> pump was placed on a temporary platform of 2x8 planks that were staked into the ground on the west side of the dugout. The pumps were attached to a



Aquamat pump installed at Glenn Hogbergs

one-inch water line with a foot valve on the end. The foot valves were prevented from sinking into the mud by Styrofoam or 2x6 floats that were attached to the water lines. The floats were tethered to prevent drifting. There were 45 cow/calf pairs using the nose pumps at one time.

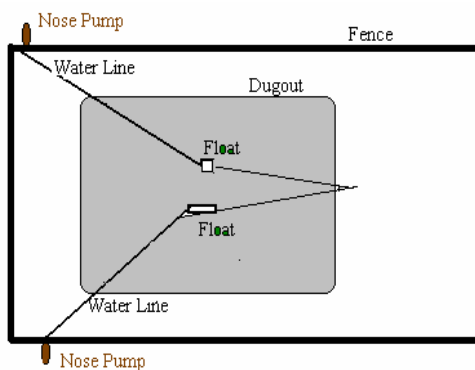
For more information about nose pumps call:

Glenn Hogberg  
(250) 843-7653

Brett Henschel  
PFRA office, Dawson Creek  
(250) 782-3116

## Advantages of Nose Pumps

The Hogbergs found that the nose pumps had advantages over most other types of watering systems. They provided a higher quality of water and level of health than allowing direct access to the dugouts. Cattle were not tromping around in the mud creating murky water (which can contribute to foot rot), getting their udders dirty, and infecting the water with high levels of bacteria from their feces. They were more cost effective than any other pumping system and they did not require outside energy to power them (which can cost more). They required very little maintenance and they are portable enough to be used in a rotational grazing system.



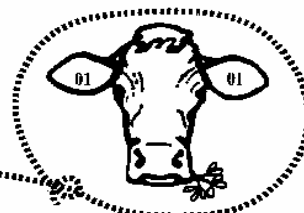
Nose pumps, water line and fencing installation diagram

Published by P.R.F.A. of BC

P.O. Box 908  
Dawson Creek, B.C.

V1G 1L6

Peace River Forage Association  
of British Columbia



*“Nose pumps can increase the longevity of a dugout.”*

*Ralf Hogberg*

For Information on :  
**Aquamat** contact:

Keddies Tack & Western Wear  
 9816 - 132nd Avenue  
 Grande Prairie, Alberta  
 (780) 532- 4888

**Lister** contact:

Feed & Ranch Supply Ltd  
 # 578  
 100 Mile House, BC  
 (250) 395- 2408  
 Pumps must be ordered from Germany if not in stock.

**Eider** contact:

Peavey Mart  
 1300 Alaska Ave.  
 Dawson Creek,  
 (250) 782- 4056

Dawson Co-op Service  
 10020 Parkhill Drive  
 Dawson Creek,  
 (250) 782- 3371

CRC Ranch Supplies  
 10117-17 th Street  
 Dawson Creek  
 (250) 782- 9893

## Considerations

Hogbergs did encounter some problems. The ground near the pumps was often saturated from the overflow water out of the bowls. It became soft and muddy around the pumps and the cows ended up creating a hole in front of the east pump.

Hogbergs feel this problem could be solved in 2 ways. The first would be to place gravel around the pumps (possibly put the geogrid under the gravel). The 2nd way would be to put the pumps in a tub to catch the water. The tub would also solve the problem for the calves under three to four months of age that can not operate the pump lever. With a tub the calves are able to drink the overflowing water while mom is pumping.



Eider pump

## Comparison of the Nose Pumps

Each of the pumps has their advantages and disadvantages, but Hogbergs like the Eider pump the most. Even though it has a lower volume per stroke than the Lister, it is lighter, easier for the cattle to pump, and more cost effective. The Aquamat is even cheaper and lighter than Eider, but the Eider pumps more per stroke, is stronger and has a larger bowl to pump the water into.

## Pump Specifications

	Lister	Eider	Aquamat
<b>Composition</b>	metal	metal	metal and plastic (bowl)
<b>Cost (1998)</b>	\$450	\$325 (foot valve included)	\$300
<b>Approx. Weight</b>	34 Kg	30 Kg	11 Kg
<b>Ease of pumping</b>	Hardest	Easier	Easiest
<b>Volume per stroke</b>	1.14 Liters	1 liter	0.57 Liters
<b>Pull water Height</b>	8.2 m (27 feet)	7.9 m (26 feet)	6.9 m (20 feet)
<b>Pull water Length</b>	400 m ( ¼ mile???)	79 m (Replace 1 foot vertical with 10 feet horizontal)	61 m (Replace 1 foot vertical with 10 feet horizontal)

## Cattle learn to pump

Each of the nose pumps is designed similarly to entice the cattle to learn how to obtain water through pushing the lever. The lowest part of the bowl, behind the lever, is where the excess water pools. Therefore, if the cattle wish to reach the water they must push the lever with their

nose. This in turn pumps the water into the bowl and the cows soon discover that if they push the lever they will get water. None of the Hogberg cattle had to be moved because they could not understand how to work the pump, but they did have to help pump the lever for a few cows to start with.

Compiled by: Heather Fossum & Kim Strasky

Water Projects Financially Assisted by: Prairie Farm Rehabilitation Administration office in Dawson Creek  
 Forage Facts Project Funding: Agriculture & Agri-Food Canada through Peace River Agriculture Development Fund, Investment Agriculture Foundation & all supporters of Forage Goods & Services Auction 2000

# Livestock Watering FACTSHEET



BRITISH  
COLUMBIA

Ministry of Agriculture and Food

Order No. 590.300-5

Agdex 716 / 725

June 1995

## Innovative Livestock Watering Options

This factsheet outlines options other than the traditional ones for watering livestock such as cattle or horses. These options would be considered when normal energy sources to pump water are not readily available or if environmental concerns limit access to natural watercourses.

### Livestock Water Sources

Water that can be developed for livestock use is available from three basic sources:

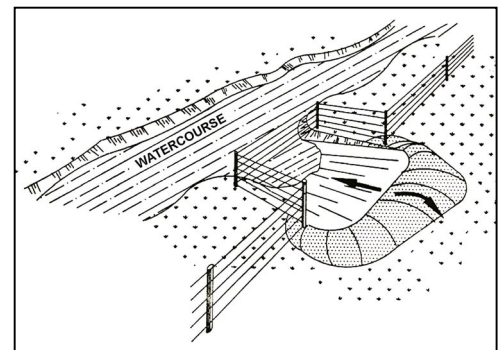
- ◆ The surface of the ground (surface water) which is the most common
- ◆ The ground (groundwater) which requires pumping
- ◆ Before it reaches the ground (water harvesting) which is the least common.

Each offers benefits and challenges as sources of livestock water. See BCMAF Factsheet number [590.304-3 Sources of Livestock Water](#) for an outline of traditional options for developing these.

The access and distribution of water may require pumping energy. It is the use of **on-site** energy sources that have brought about innovations in pumping livestock water.

### SURFACE WATER

This is usually the easiest and first to be considered for development. Creeks, ponds, and lakes offer water that livestock can access directly. As these sources may be impacted by livestock, a developed access is often used, as shown in *Figure 1*. The innovation to consider here is the support material under gravel on the access area for longer life in very muddy sites. See [Improved Livestock Access to Water Using Geogrids](#), BCMAF Factsheet number 590.303-3.



*Figure 1* Developed access to a natural water source

This developed access must be constructed:

- ◆ to **not allow** runoff to flow into the watercourse
- ◆ to restrict livestock from entering the water
- ◆ to allow periodic cleaning of the slope
- ◆ with firm footing such as gravel (consider using with geogrid)
- ◆ with bank protection where appropriate (using rock riprap, logs, or gabions).

See also [Why Keep Livestock Out of Watercourses?](#), BCMAF Factsheet number 590.303-1, for more details.

## Pumping Surface Water

It is often necessary to pump surface water and it is the energy source that defines many of the innovations. Energy may be:

1. Supplied on-site by **gravity** (including siphons)
2. Supplied on-site by **flowing water** (stream-driven pumps or ram pumps)
3. Supplied on-site by livestock (nose pumps);
4. Supplied on-site by the **sun** (using wind or photovoltaics), or
5. Delivered to the site (i.e., electricity or petroleum fuel).

These possibilities are discussed in the following sections and are some of the recent innovations.

### 1. Gravity

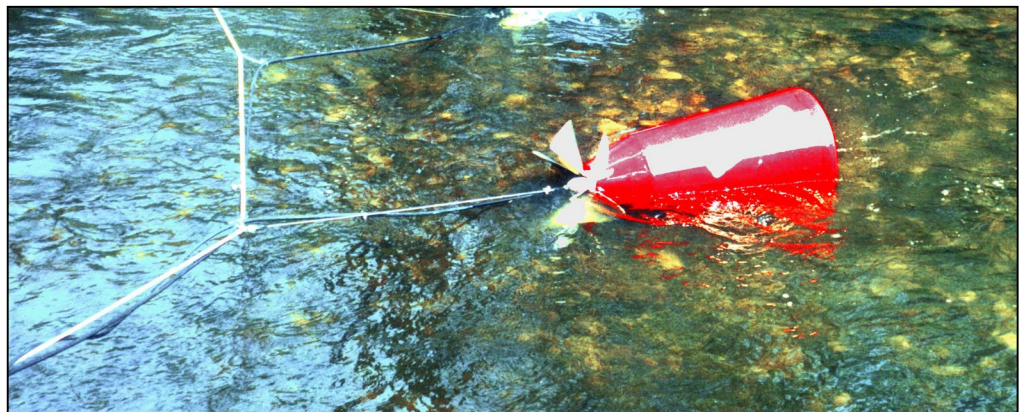
See the [B.C. Livestock Watering Manual](#), BCMAF number 590.300-2 for details.

### 2. Flowing Water Energy

The energy in flowing water can be used to operate an electrical generating turbine, a stream-driven pump, or a hydraulic ram pump. The latter two are used for livestock watering.

#### Stream-Driven Water Pump

This simple pump is operated by the energy in flowing water. It is suspended over a creek where the water drives the propeller blades, rotating the pump, as in *Figure 2*. Water moves up to a trough along the creek bank.



*Figure 2*

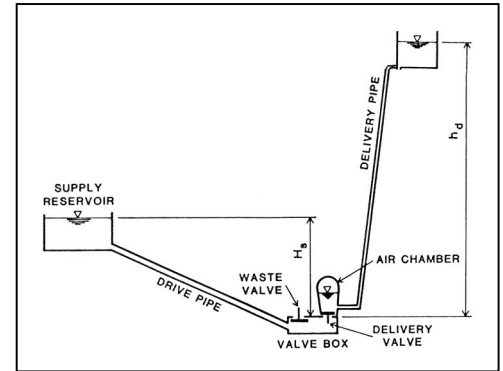
*Typical stream-driven water pump*

### Hydraulic Ram Pump

This is an old concept where a pump uses the "water hammer" effect to force a small amount of water up a delivery pipe. The remainder of the water is returned to the source.

A general rule is: 10 percent of the water can be pumped up a lift that is 10 times the fall of the supply water.

*Figure 3* shows a typical hydraulic ram pump system.



*Figure 3* Typical hydraulic ram pump system

### 3. Animal-Driven Water Pump

For water lifts of less than 20 feet, a simple animal-driven pump is available that will water 20 to 50 animals. The animal uses its nose to push a lever that operates a diaphragm pump to supply water. Some training is required. *Figure 4* shows a typical installation. These can pump from shallow wells, dugouts, or other water sources.



*Figure 4* Typical animal-driven water pump

### 4. Solar-Driven Water Pumps

These are either wind-powered or photovoltaic-powered systems that can pump surface water or groundwater.

#### Wind Pumps

These require **significant and steady** wind to be effective and the wind must be present during the correct time of year. Water can be directly pumped or a wind generator can charge batteries that power a pump on demand. An accurate assessment of the wind energy potential must be made before development of a site. Interior B.C. is generally poorly suited for wind-driven water pumping but sites have been developed, as in *Figure 5*.

## Photovoltaic Pumps

This term describes the process of converting sunshine into electricity. Special glass-covered panels face the sun and are either wired directly to a pump or wired to charge batteries. **Figure 6** shows a typical photovoltaic water pumping system. See also [Livestock Water Pumping Using Solar Energy](#), BCMAF Factsheet number 590.306-4, describing two systems in B.C.



**Figure 5** Typical wind driven water pump



**Figure 6** Typical photovoltaic water pumping system

## 5. Other Energy

Energy for pumping water can be brought to the site in the form of utility electricity or petroleum fuel. These systems are discussed in other publications.

## GROUNDWATER

This source of livestock water requires pumping to the surface to utilize and is therefore a limitation on its use. Only some of the previous pumps can be used (as in **Figures 5** and **6**). In cases of deep water wells, the amount of energy required (and therefore increased costs) will limit development.

## WATER HARVESTING

This is simply the collection and storage of water from an area treated to increase precipitation runoff. While demonstrated in B.C., it has not been used to any extent. Less expensive surface water and groundwater development possibilities should be considered first. See the [B.C. Livestock Watering Manual](#), BCMAF publication number 590.300-2 for details.

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### FOR FURTHER INFORMATION CONTACT

Lance Brown, Regional Engineering Technologist  
Phone: (604) 371-6064  
Email: [Lance.Brown@gems6.gov.bc.ca](mailto:Lance.Brown@gems6.gov.bc.ca)

### RESOURCE MANAGEMENT BRANCH

Ministry of Agriculture and Food  
162 Oriole Road  
Kamloops, B.C. CANADA V2C 4N7

## Pasture Water Systems for Livestock

In the past, livestock were turned out to pasture and allowed to walk through and drink from any slough, creek, river or lake available to them. When these water sources were not available, dugouts were constructed.

Today, allowing livestock direct access to surface water sources is a concern to livestock producers and to other water users. The practice is also problematic for the livestock itself.

Livestock producers want to provide a safe, reliable supply of good quality water for their livestock. Many producers want to increase their management to better utilize their pastures for livestock production. Livestock producers, like other water users, want to do their part to protect both natural and constructed water sources from environmental damage. In addition, observing livestock behaviour around water sources and on pasture provides information about livestock concerns and preferences.

### Direct watering problems

Allowing livestock direct access to surface water sources has led to a number of problems:

#### Environmental problems:

- damage to banks of streams and dugouts
- siltation problems in spawning areas for fish
- loss of riparian habitat and vegetation
- loss of water storage in dugouts and streams
- nutrient build-up in both the source and downstream water bodies
- rapid growth of weeds and algae
- deterioration in water quality

#### Herd health problems:

- increased exposure to water-transmitted diseases, bacteria, virus and cysts infections
- blue green algae toxins
- foot rot
- leg injuries
- stress

- death by drowning or being stuck in mud
- reduced rates of gain



#### Poor pasture utilization:

- poor nutrient transfer caused by an accumulation of manure at the water source
- overgrazing near the water source

### Pasture water system trials

Both poor access to water and poor water quality can affect livestock behavior and production on pasture. In a pasture trial, however, it is extremely difficult to isolate what, how and when these factors become significant. There are so many variables in the cattle, the pasture grass, the water source and water quality.

Some pasture studies have shown a significant increase in cattle production where water was pumped to them versus direct watering from dugouts. Other studies have shown little or no improvement in livestock production. The studies have all shown that although cattle prefer that good quality water be pumped to them, versus direct watering from a dugout, their behavior is not consistent.

For instance, some studies have shown that cattle, given a choice of clean well water versus dirty dugout water, will drink more clean well water one

day and do the opposite the next day. This complexity aside, the combined benefits of pasture water systems strongly support keeping cattle out of water.

## Pasture water systems benefits

The benefits of a well planned and constructed pasture water system include:

- water source protection, thus longer water source life
- improved herd health
- increased livestock production, in some situations
- better pasture utilization
- riparian protection and, thus, a more environmentally friendly livestock industry



Where livestock are allowed direct access for watering, the loss in dugout water storage and additional maintenance costs range from \$200 to \$500 per year for an average pasture dugout.

## Pasture water system options

Today, a variety of livestock watering methods are available to suit any type of pasture and location. The power options to move water to livestock include solar, wind, fuel, stream flow, mainline electricity and gravity flow. Selecting the most appropriate one can be a challenge.

Establish a list of priorities and try to use some of the natural advantages of the site and equipment. Factors to consider:

- type and location of available water source(s)
- site location(s) and conditions (remote location, topography, riparian features)
- type of grazing system (intensive or extensive)
- number of livestock

- access to power source (mainline power, solar, wind, animals, etc.)
- pumping system (amount of lift, automated versus manual)
- flexible and portable
- reliability and maintenance
- temporary or seasonal water storage
- cost/benefit and cost/animal
- personal preference

## Livestock watering alternatives

### Access ramps

An access ramp is the minimum improvement that can be made to a water source (Figure 1a & b). Ramps are most appropriate for large herds of livestock in remote locations (i.e., rangeland pastures) where animals are seldom checked or moved. The reinforced ramps provide better footing for livestock drinking from dugouts, sloughs and streams where soft soils (e.g., peat) exist.

These ramps require a relatively low slope of 5 to 6 feet for every foot of drop. Simply lay down a strip of crushed road gravel preferably with sizes from 1½ inch diameter down to 10 to 15 percent fines. The gravel layer should be a minimum of 1 foot thick. Start the gravel layer 10 to 15 feet back from the water's edge and continue down below the lowest water level of the dugout. A small caterpillar or 4-wheel drive tractor is used to compact the gravel.

In soft soil conditions, a plastic polygrid or geogrid should be placed under the gravel to provide added support. The material comes in 3 or 4 metre wide rolls and can be overlapped for wider ramps.

The water source is usually fenced off, so livestock can only drink from the access ramp. However, some producers have found that fencing is not necessary because once the cattle have convenient access to water, with good footing, they will water almost exclusively from the ramp.

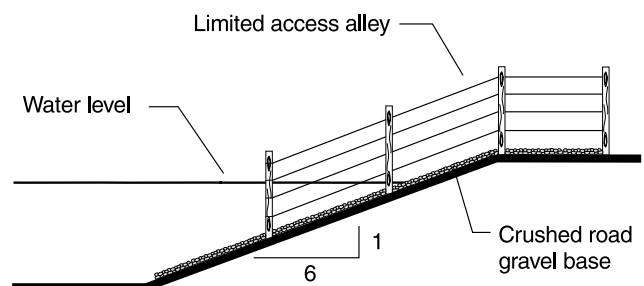


Figure 1a. Cross section view of access ramp

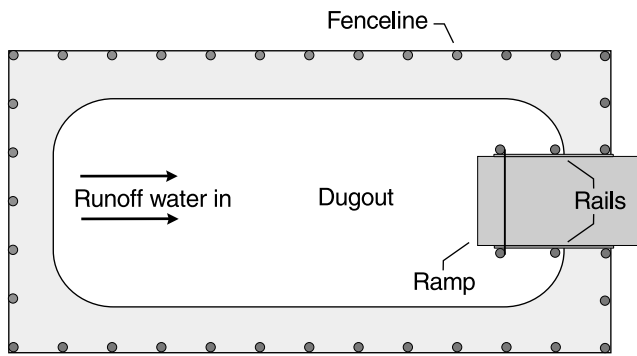


Figure 1b. Plan view of access ramp

## Water hauling

Although it may seem like a step back in time, water hauling can be a viable alternative. In intensive livestock grazing management, cattle are sometimes moved daily from pasture to pasture. Access to water is often the limiting factor. By utilizing an old truck with a main storage tank and an easily-moved stock tank, the watering source can be continuously relocated throughout the pasture along with the cattle. The nutrients from the manure are more evenly distributed and are kept on the same field.

## Water storages

Alternative energy powered water pumping systems (including fuel, solar and wind powered systems) all require water storage. The water storage tanks or reservoirs provide the necessary livestock water between pumping cycles. Most are raised above the stock tank to allow for the gravity flow of water. They are generally sized to hold a three to seven day supply of water for cattle. For sizing the water storage, the following cattle water consumption rates are recommended for cattle on pasture:

- yearling steers or heifers – 8 gallons per day
- cow-calf pairs – 12 gallons per day

**Note:** These are average water consumption rates for cattle on pasture. On hot summer days, peak water consumption can reach 1.5 times these numbers.

Water storages can be made from almost anything as long as they safely store water at a reasonable cost. The most common are plastic, fiberglass, concrete or metal tanks, elevated earthen reservoirs, grain bin rings, large rubber tires, or large stock watering tanks. The cost of water storages ranges from about 5 cents per gallon to over \$1.00 per gallon. The lowest cost water storage (5 to 10 cents per gallon) is the elevated earthen reservoir (Figure 2).



Figure 2. Elevated earthen reservoir with woven polyethylene liner.

## Gravity-fed systems

Gravity-fed systems are ideal systems on sloping pasture land where it is possible to locate a dugout or dam up slope from a watering site. A pipeline can then be run from the dugout down slope into a stock tank. As a rule, the water level in the dugout should be at least 5 feet higher than the stock tank plus 1 foot additional height for every 100 feet of pipeline to the stock tank (Figure 3).

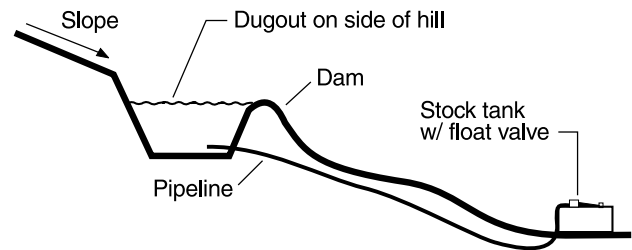


Figure 3. Gravity-fed system

Gravity-fed systems can also be used for springs where there is sufficient elevation drop to the stock tank. On long, undulating and/or steep drops, extra care should be taken to avoid leaks or air blockages. Consult a knowledgeable contractor or consultant if unsure.

## Pumped gravity flow reservoirs

These reservoirs are generally constructed by digging a small reservoir on top of the excavated dirt piles from a dugout (similar to Figure 2). A standard backhoe can construct these in a few hours. The reservoir is then lined with a woven polyethylene liner to prevent seepage and to keep the water clear. The reservoir bottom must be higher than the top of the stock tank. This approach will provide adequate gravity flow from the reservoir through the water line and float valve assembly and into the stock tank (Figure 4).

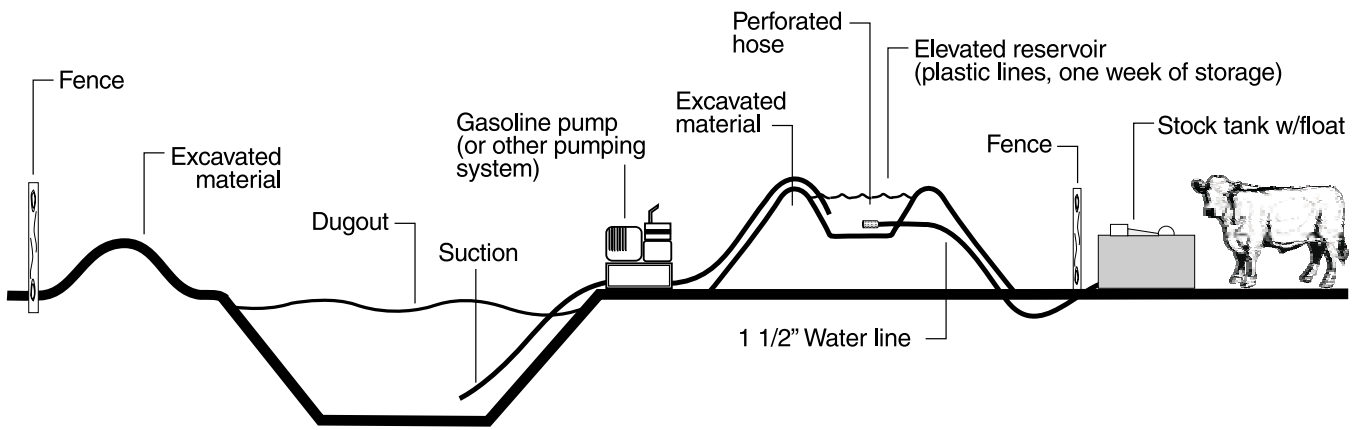


Figure 4. Pumped gravity flow reservoirs

Selecting the proper size water line and a high capacity, low pressure float valve are also important to ensure adequate flow rates. Table 1 shows the dimensions, water volumes and costs for a typical elevated earthen reservoir.

Table 1. Elevated earthen reservoir water volume and costs

Reservoir dimensions (ft)		Approximate water volume (imperial gallons)	Estimated costs of reservoir & plastic liner
length x width x depth Top	Bottom		
25 x 15 x 5	15 x 5 x 5	5,000	\$350
35 x 15 x 5	25 x 5 x 5	10,000	\$500
40 x 20 x 5	30 x 10 x 5	15,000	\$650
45 x 20 x 5	35 x 10 x 5	20,000	\$800
45 x 25 x 5	35 x 15 x 5	25,000	\$1,000
45 x 45 x 5	35 x 35 x 5	50,000	\$2,000

Note: The woven polyethylene liner used for estimating costs is 31 cents per square foot. Reservoir water volumes are calculated using side and end slopes of 1:1.

### Animal operated pasture pumps

These pasture pumps are commonly called nose pumps because cattle operate them by pushing them with their noses (Figure 5). The pump provides a very low cost (i.e., \$10/cow-calf pair) pumping system and is good for about 30 to 40 cow-calf pairs.

There are five or six types of nose pumps being sold in Alberta. Some of the pumps are slightly easier to push than others. They all supply approximately 1 litre of water for every stroke of the nose device. The pumps can lift water a maximum of 20 vertical feet and, with the use of a shallow buried pipeline, can also be offset a quarter of a mile or more from the water source. Minimizing the amount of elevation lift from the water makes it easier for cows and calves to operate the pump. Shallow burial of the pipeline is recommended once the best locations for the pumps have been determined.



Figure 5. Nose pump

These pasture pumps are very reliable and easy to move from pasture to pasture. However, the cattle will take a day or so to learn how to operate the pump. This training period is done best at the farmyard after calving and before the cows go out on pasture. Small calves will generally not learn to operate the pumps until they are about 300 pounds. There are several options to overcome this problem. One is to fill a stock tank with water where only calves have access. Another option is to collect some of the water pumped by the cows into a small tub or stock tank for the calves to drink.

### Pipelines

Shallow buried pipelines are ideal for farms with a very intensive rotational grazing system within a one mile distance of existing water and mainline power. Pipelines allow livestock producers to better utilize their water source (i.e., usually a well or dugout) rather than constructing many small dugouts scattered around the pastures. They are very flexible systems, and watering sites can be located at the preferred location rather than where a dugout will fill from runoff.

For shallow burial (approximately one foot deep) of the pipeline, some producers are using a ripper type plough mounted on the three-point hitch of a tractor (Figure 6). A 1-inch diameter plastic pipe can be installed for about 50 cents per foot. It is important to design the system properly to ensure the right combination of pipe size and stock tank. For more information on pipeline systems, refer to the pipeline worksheet at Alberta Agriculture's web site [www.agric.gov.ab.ca](http://www.agric.gov.ab.ca).



Figure 6. Pasture pipeline plough

Some producers are also using deeply buried pipelines in several of their pastures close to home. They can then use these pastures year round for pasture as well as for feeding, bedding, calving and weaning areas. This approach helps to reduce animal disease problems as well as manure hauling and spreading costs.

**Caution:** It is very important to phone **Alberta First Call** to identify the location of shallow buried utility lines before any trenching is done. In future, shallow buried pipeline systems will likely become more popular because of their many advantages and due to the shift to more intensive grazing systems.

## Gas powered pumping systems

These systems are a low cost alternative for pumping water to larger herds of livestock. They work well in combination with an elevated reservoir system, containing about one week's water storage. The pumps are very portable and can be moved easily from one water source to the next (Figure 7).



Figure 7. Automated gas powered generator system

Some producers are using a gas powered generator to run a submersible well or dugout pump. These systems can be automated to start on a float switch device located in a stock tank or reservoir. Both pumps and generators can be used for other purposes on the farm. These systems can be sized to pump a large volume of water from dugouts or even deep wells.

## Solar powered pumping systems

Solar systems are becoming more popular because of their reliability and low maintenance. They can be used to pump water from dugouts and wells. An array of solar panels collect and convert sunshine into electrical energy, which can be used to pump water or be stored by rechargeable batteries (Figure 8). Due to the variation in sunshine intensity, a minimum of three days water or battery storage is required.

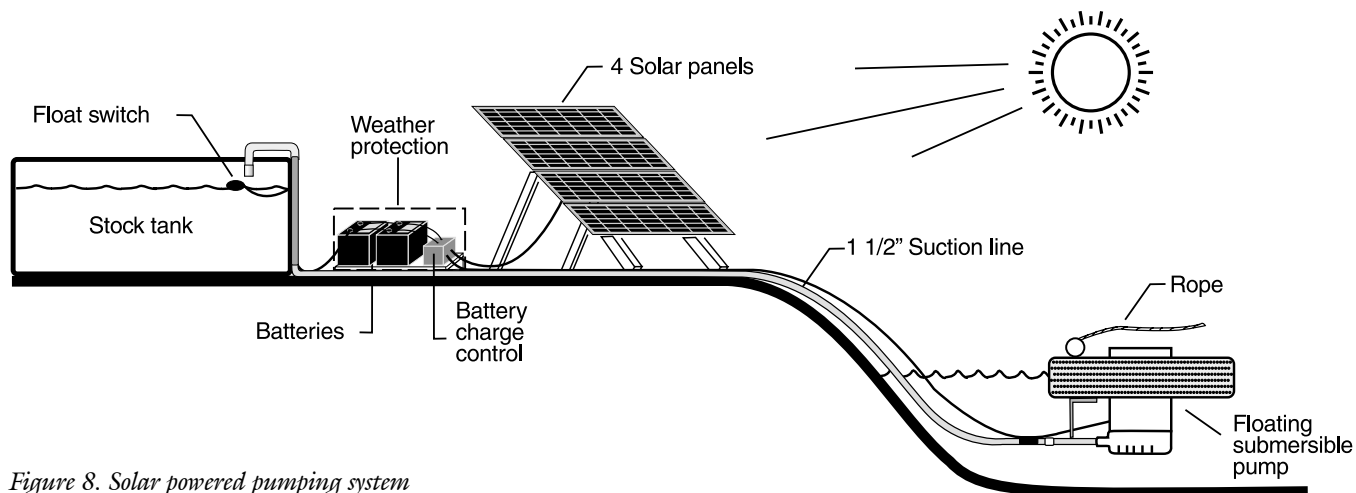


Figure 8. Solar powered pumping system

For the solar direct systems without batteries, it is important to match the solar panel's output (in watts) to the power requirements of the pump for maximum efficiency. For solar systems with batteries, it is important to select good quality deep cycle type batteries (e.g., recreation vehicle type). It is also important to install electrical controls that have both low and high voltage disconnects. These protect the battery from under or over charging conditions, which will drastically reduce battery life. Obviously, a sunny spot is desired for these systems, but also choose a location that is not in plain view and is sheltered from high winds.

Solar powered systems have the added advantage of pumping the most water on hot sunny days when cattle are drinking lots of water. Excess power can be used to energize an electric fence for the pasture. Although the initial costs of this system are somewhat higher than for others, they will last for many years. The portability of the solar pumping system is another advantage.

### Wind powered pumping systems

Windmills perform best in areas that have higher than average wind speeds, such as the southern parts of the prairie provinces. For central and northern areas of the prairies, where wind speeds are lower, consider adding additional water storage such as an elevated earthen reservoir.

Windmills can be used to pump from dugouts and wells. Windmills should be placed on higher ground where they have good exposure to the wind, such as the excavated dirt pile from a dugout. Also, locate them away from trees as far as possible – at least 15 to 20 times the height of the trees (Figure 9).



Figure 9. Wind powered pumping system

There are presently two windmills that can be used for both dugout water pumping and dugout aeration. The initial costs of the system are somewhat high, but most of the windmill systems are very reliable and will last for many years. The windmill system should have at least

three days of water storage. Be prepared to use an alternate pumping method or haul water during prolonged calm periods.

See Comparison of Livestock Watering Systems (Table 2) for further information on these systems.

### Optional pumps

Other pumps used to convey from the source to livestock are:

- hydraulic ram pumps\*
- sling pumps\*
- paddle pumps\*
- air compressor pumps

\* These are water pumps that require flowing water to operate and, as a result, have limited use in Alberta.

### Groundwater sources

In parts of the Canadian Prairies, surface water does not provide a dependable source of water for livestock. The lack of surface water runoff and/or porous soils for storing water are a huge challenge. In these areas, producers drill wells and pump water into stock tanks, large water storages or dugouts for their livestock. For remote locations, gas pumps or animal operated (nose) pumps can be used for shallow wells of 20 feet lift or less. Wind and solar powered systems can be designed for deeper wells (Figure 10).



Figure 10. Solar powered well system

Often, the most viable alternative is a portable generator and submersible pump running water into an earthen reservoir and/or stock tank. Generator systems can also be automated, similar to the remote starting devices for automobiles. In this situation, a float switch is located in the reservoir or stock tank. The float switch starts the generator and pump when the reservoir tank is low and shuts it off when it is full.

In the future, it is expected that livestock producers will rely much more on groundwater for their pasture water systems because of its availability and generally better water quality for livestock production. Improved pumping systems will also play an important role in the use of groundwater.

### **Winterizing pasture water systems**

In the last few years, some producers have installed winterized pasture water systems. The reasons for these systems include:

- extending the pasture grazing season
- lack of water at the farmyard site
- winter feeding of cattle on pasture to reduce manure hauling costs
- provide increased flexibility for separating cattle at weaning and calving times
- to prevent manure build-up in the calving areas
- animal health problems associated with all of these

With the proper planning and design, almost all the pasture water systems can be modified and used through the winter.

## **Summary**

No matter the size of a livestock watering system, proper planning and design play an important role. A good installation cannot compensate for an inadequate water source. Good quality water and quantity are both vital. Off-stream livestock watering systems are also an important tool in protecting riparian areas. Table 2 is a brief summary outlining the pros and cons for the livestock watering options mentioned in this publication.

The Alberta Farm Machinery Research Centre (AFMRC) is involved in testing solar and wind powered water pumping systems for equipment manufacturers. For more information and reports on their work, please contact the AFMRC office in Lethbridge at (403) 329-1212.

For further information on all types of livestock watering systems, contact the Agricultural Water Specialists with Alberta Agriculture, Food and Rural Development at the following locations:

Lethbridge	(403) 381-5846
Red Deer	(403) 340-5324
Leduc	(780) 986-8985
Fairview	(780) 835-2291
Edmonton	(780) 427-4182

Or at our website: [www.agric.gov.ab.ca](http://www.agric.gov.ab.ca)

**Table 2. Comparison of livestock watering systems**

Livestock watering practice	Impact on water source and livestock	Cost factor (1999 prices)
<b>Direct access</b>	<ul style="list-style-type: none"> <li>• 5 - 10% loss in water storage/year</li> <li>• deterioration in water quality</li> <li>• animal health and production concerns</li> <li>• environmental concerns along streams, etc.</li> </ul>	<ul style="list-style-type: none"> <li>• dugout construction costs</li> <li>• high dugout maintenance – \$150 - 300/year</li> </ul>
<b>Restricted access ramp</b>	<ul style="list-style-type: none"> <li>• marginal loss in water storage</li> <li>• reduced water quality, animal health and production concerns</li> </ul>	<ul style="list-style-type: none"> <li>• \$500 to fence and construct ramp</li> <li>• moderate dugout maintenance costs – \$100/year</li> <li>• \$.75/ft<sup>2</sup> without geotextile</li> <li>• \$1.00/ft<sup>2</sup> with geotextile</li> </ul>
<b>Water hauling</b>	<ul style="list-style-type: none"> <li>• same comments as for pipeline</li> </ul>	<ul style="list-style-type: none"> <li>• system and hauling cost</li> </ul>
<b>Gravity-fed</b>	<ul style="list-style-type: none"> <li>• no loss in water storage</li> <li>• no negative effect on water quality, animal health and production concerns</li> </ul>	<ul style="list-style-type: none"> <li>• system cost</li> <li>• low maintenance costs for dugouts/dam – \$50/year</li> </ul>
<b>Pumped gravity flow water reservoirs</b> (built on top of the excavated spoil piles)	<ul style="list-style-type: none"> <li>• slight increase in water storage</li> <li>• no negative effect on water quality, animal health and production</li> </ul>	<ul style="list-style-type: none"> <li>• \$2,500 - \$3,000 to fence, construct and line the reservoir, plus purchase a 5-hp gas pump, 500 gallon stock tank, water pipe and install a cement pad around the tank</li> </ul>
<b>Animal operated pasture pumps</b>	<ul style="list-style-type: none"> <li>• no loss in water storage</li> <li>• no negative effect on water quality, animal health and production</li> <li>• two-day training period for livestock to learn pump operation</li> </ul>	<ul style="list-style-type: none"> <li>• \$700 to fence and purchase pump (\$450 ea.)</li> <li>• maximum of 30 - 40 cow-calf pairs/pump</li> <li>• low maintenance costs for dugout and pump \$50/year</li> </ul>
<b>Pipeline</b>	<ul style="list-style-type: none"> <li>• no negative effect on water quality, animal health and production</li> </ul>	<ul style="list-style-type: none"> <li>• \$.50 - \$1.00 per lined foot</li> <li>• pipe can be buried shallow for summer pasture and drained in the fall</li> <li>• allow the use of neighbouring sources of water wells, dugouts, etc.</li> </ul>
<b>Solar pumping systems</b>	<ul style="list-style-type: none"> <li>• slight increase in water storage</li> <li>• no negative effect on water quality, animal health or production</li> </ul>	<ul style="list-style-type: none"> <li>• \$3,000 - \$6,000 to fence and install the solar pump, solar panels, optional battery, water storage stock tank and cement pad</li> <li>• capacity of 50 - 400 cow-calf pairs</li> </ul>
<b>Windmills</b>	<ul style="list-style-type: none"> <li>• slight increase in water storage</li> <li>• no negative effect on water quality, animal health or production</li> <li>• some air-operated pumps actually improve dugout water quality by aeration</li> <li>• must pump the water storage full during extended periods of calm weather</li> </ul>	<ul style="list-style-type: none"> <li>• \$2,000 - \$2,500 to set up Koenders windmill and air-operated pump, plus a 1200 gallon plastic water tank, 500 gallon stock tank, cement pad and pipe</li> <li>• capacity (at approx. 10 ft lift) for 50 cow-calf pairs in central Alberta, up to 100 cow-calf pairs in windy southern Alberta</li> <li>• \$3,500 - \$4,000 to fence and set up Dutch Industries – Delta Junior windmill, plus 1,200 gallon plastic water tank, 500 gallon stock tank and water pipe</li> <li>• capacity (at approx. 10 ft lift) is estimated to be 200 cow-calf pairs in central Alberta and 400 cow-calf pairs in southern Alberta</li> <li>• moderate maintenance of dugout and system \$100 - \$150/year</li> </ul>

Note: Dugout maintenance will mainly involve chemical control of plant algae plus excavation costs for cleaning dugouts where direct access occurs.

# Solar Pumping Systems

## Putting the Sun to Work for You

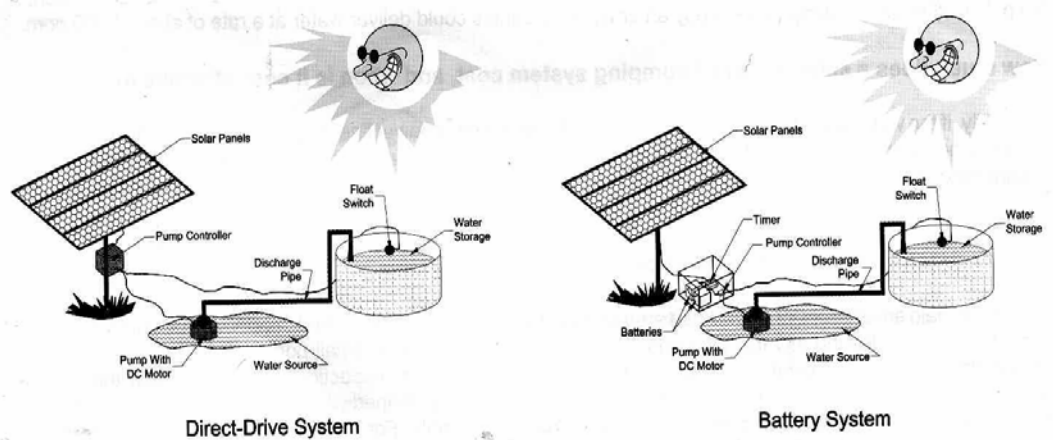
### Solar System Features:

- \* good for remote locations
- \* reliable
- \* very little maintenance
- \* inexpensive to run
- \* initial costs higher than other systems

Diagram and information for this page courtesy of Prairie Farm Rehabilitation Admin.

### Improved cattle health with solar watering systems

Three forage producers, Harvey Wood, Ben Hansen and Fred Burres have tried solar watering systems for their spring, summer and fall watering needs and found it to be a great way to go. Compared to a free access dugout, solar watering systems help increase the longevity and decrease dugout maintenance. They improve cattle health by providing higher quality water, cleaner udders and less chance of contacting foot rot.



### For more information call:

- \* Harvey Wood, Rose Prairie (250) 827 3449
- \* Ben Hansen, Taylor (250) 789 3484
- \* Fred Burres, Farmington (250) 843 7074
- \* Brett Henschel, PFRA, Dawson Creek (250) 782 3116
- \* Jim Forbes, BCMAFF (250) 784 2225
- \* Sandra Burton or Kim Strasky, Farmington (250) 789 6885

### Advantages

All 3 producers agree: the main advantages over other remote water systems are low maintenance and ease of use.

The only maintenance chores are keeping the batteries topped up with distilled water and keeping the panels free of dirt and dust. The system must be checked daily to make sure the batteries are functioning and like any water system, the pump, pipes and hoses need checking. Overall though the system rarely has any problems, and is relatively inexpensive to run.

Another plus is portability and flexibility. Producers can modify the system for use in remote pastures or to fit their own grazing operation

### Considerations

The main consideration is the initial cost of the system and components. The solar panels are about \$800 each for the 48 watt panels, but, don't forget, the life expectancy for the panels is 20 years.

Another challenge is keeping the right amount of charge on the batteries. When powering both an electric fence and the water system, the grass under the fence may grow too tall, touch the fence and drain the batteries. Ben keeps an extra set of batteries charged and ready to go. When Fred first set his system up the battery controller that was supposed to keep the batteries from overcharging kept burning out. Fred's solution was to get 2 more 12 volt batteries to take any extra current and not have a controller.

Published by P.R.F.A. of BC:

P.O. Box 908  
Dawson Creek, B.C.  
V1G 1L6

Peace River Forage Association  
of British Columbia



*"The thing I like best about the system is that it is so simple and maintenance free and I have learned I can trust it".*  
Fred Burres

### Dealers & Suppliers:

CAP Solar, Olds Alberta  
(403) 556 8779  
(403) 556 7799  
www.capsolar.com

Keddies Tack & Western,  
Grande Prairie, AB  
(780) 532 4888

Northern Alternate Power  
Systems—The Solar Store  
Fairview, AB  
1 866 835 6277  
(780) 835 3032

Kelln Solar, Lumsden, SK  
1 888 731 8882

*"It works well and it keeps the cows out of the dugout."*

Harvey Wood

*"The cost of a basic complete system has gone down in the last few years and this would probably be a good way to go now."*

Ben Hansen

### The flexibility of using solar

The 3 producers each put his own spin on how the system can be setup, so there seems to be lots of flexibility. They all talked to the solar dealers when planning their systems, or when having any initial setup problems, and found them to be quite knowledgeable.

**Harvey Woods** system has been in place since August 1998 when a water shortage forced him into looking for watering alternatives. Utilizing the Prairie Farmers "The Book", he located a solar dealer.

Harvey says "you need to know what the vertical lift is from your dugout to the tank and how many head you will be watering." He decided on two 46 watt stationary solar panels that charge two 6 volt deep cycle golf cart batteries that run his CAP International 12 volt pump. The pump sends water through a 2" hose to a 200 gallon stock tank. The tank is placed  $\frac{3}{4}$  of the way under a 5 wire fence. The fence is reinforced by wooden planks. The pump provides 2000 gallons. of water on an average day over 10 ft of lift. It will fill the stock tank on demand in 5 to 7 minutes. Harvey likes this system because it keeps the cows out of the dugout and gives them a source of clean water.

**Ben Hansen's** system has been operating since 1997 providing water for his 40 cow/calf pairs. He has the ability to move the system to either of his 2 dugouts. It takes about 2 days to move. He has an 800 amp battery that powers the water pump and his fencer. The diaphragm pump sends the water straight to a 500 gallon tank for the cattle. The screened pump has a foot valve that sits in a 5 gallon pail. The two 48 watt solar panels are stationary and adjusted for maximum amount of sun.

Ben feels that the system provides an excellent, efficient way to power his pump and fence. He says "solar panels are good in rotational grazing situations especially in remote locations. They are a renewable, non polluting source and are easy to install and relocate."



Solar system setup at Fred Burres

**Fred Burres'** system was set up as a demo with cooperation from PRFA of BC, PFRA and BCMAFF 3 years ago.

The system has a floating pump that sends water to a 1000 gallon tank. It is then fed to a 500 gallon tank on demand by a homemade float valve. His two 48 watt solar panels charge four 12 volt batteries that power the pump. The panels are equipped with a solar tracking unit that allows them to follow the path of the sun for maximum efficiency. The 1000 gallon tank stays on the back of a trailer as does the pole that holds the panels. The 500 gallon tank is taken off and put  $\frac{3}{4}$  of the way under an electric fence so the 120 cow/calf pairs can't get at the float valve end. Fred sets up or packs up the system in about an hour but he hopes to invent a quicker way to roll up the hoses.



Water tank set up at Fred Burres

**The flexibility of solar** is currently being explored by some PRFA of BC members, demonstrating solar powered winter watering systems.

**Compiled by:** Kim Strasky & Sandra Burton

**Remote Water Systems Funded by:** Prairie Farm Rehabilitation Administration, Agriculture Canada

**Forage Facts Project Funded by:** the Peace River Agriculture Development Fund, Investment Agriculture Foundation, PRFA of BC and all the donators and supporters at their Forage Goods & Services Auction on Feb. 5, 2000.

# Seismic Operations and the Landowner



*What are your rights  
as a landowner?*



OIL AND GAS COMMISSION

## Seismic Operations and the Landowner

This brochure is intended to provide the surface owner or occupant with general information and an understanding of their rights regarding seismic operations. The information is a general guide and may not cover all situations.



The seismic avoidance technique protects harvestable timber and provides refuge for wildlife, balancing protection of our environment with development of our resources.

## *What are your rights?*

Landowners have rights regarding seismic operations. A seismic operator may not enter onto property without first obtaining the approval of the landowner. It is up to the landowner to negotiate the terms of the contract.

## *How is the project regulated?*

Seismic project operators are required to follow legislation under the Petroleum and Natural Gas Act, Part 4 ([www.qp.gov.bc.ca/statreg/stat/P/96361\\_01.htm](http://www.qp.gov.bc.ca/statreg/stat/P/96361_01.htm)) and the Geophysical Exploration Regulations ([www.qp.gov.bc.ca/statreg/reg/P/PetNatGas/361\\_98.htm](http://www.qp.gov.bc.ca/statreg/reg/P/PetNatGas/361_98.htm)) as well as guidelines under the Oil and Gas Handbook, Part 4, (available from Crown Publications\*). The Oil and Gas Commission (OGC) is responsible for regulating oil and gas activities in British Columbia.

\* Crown Publications, 250-386-4636, [www.crownpub.bc.ca](http://www.crownpub.bc.ca)

## *What is the sequence of events typical of a seismic operation?*

① The landowner and the seismic company or their agent negotiates a written agreement. Although there are no standard agreements, companies generally follow standard corporate compensation guidelines. A stream crossing agreement may also be required, in conjunction with an approval by the OGC, as the company must have your consent to cross streams on your land. The landowner should ensure details are fully explained and specifics of the entire project are written into the agreement from project commencement to cleanup to reinspection.

- ② Proposed seismic lines and access routes are established.
- ③ Vegetation and/or snow may be cleared across the land marked for study.
- ④ Markers are placed along the length of each seismic line.
- ⑤ If dynamite is used, the standard method is to drill shot holes, load the dynamite charge, and plug the holes according to government regulations.
- ⑥ Seismic instrumentation is placed on the ground surface to record vibrations from the energy source (dynamite or “vibroseis” truck) reflected back from the subsurface formation.
- ⑦ Upon completion of the seismic project the company or its agent pays the landowner any outstanding fees and compensation for damage according to terms of the agreement. The landowner is asked to sign a release form. The company is responsible for damage that becomes evident after the release has been signed. It is recommended that the landowner ensures that cleanup is completed or will be completed under non-frozen conditions.
- ⑧ The OGC requires company representatives to reinspect all lands for refuse and slash control to ensure government standards are met. This is usually done in the spring or summer following projects. It is in the landowner’s best interests to allow entry for reinspection.

# SEISMIC OPERATIONS

## What is a seismic operation?

Seismic operations are conducted to determine if there are suitable underground formations that contain petroleum or natural gas. This is done by analyzing the reflected vibration waves originating from an energy source created near the surface. Energy sources are generally either dynamite or “vibroseis” trucks which generate vibrations.

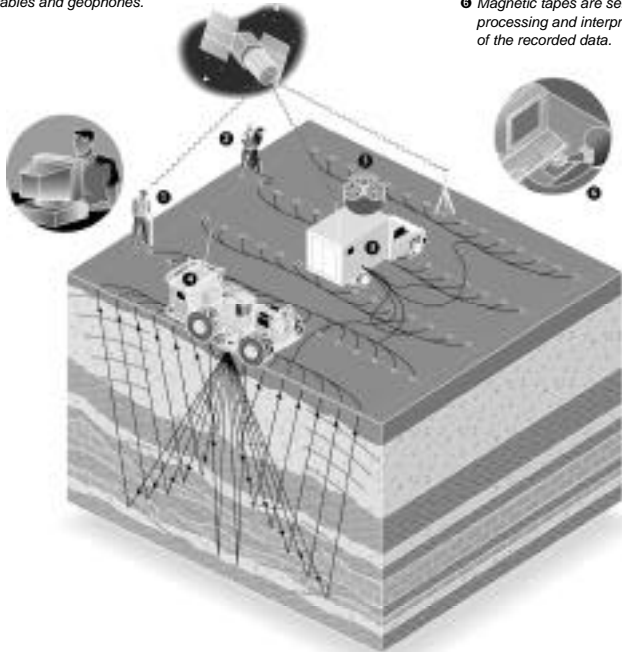
There are two types of seismic operations:

- > The 2D seismic method uses single lines of regularly spaced geophone stations with energy source points established along the lines.
- > The 3D seismic method uses a uniform and evenly spaced grid of lines.

### Vibroseis 3D seismic method

#### Key steps:

- 1 Surveyors use satellite-based global positioning system (GPS) to find precise locations for vibration source and geophones.
- 2 Seismic crew lays out cables and geophones.
- 3 Cables are attached to recording system.
- 4 Vibrator trucks generate a controlled vibration force of up to 32 tonnes at each source point.
- 5 Underlying geologic structures reflect some of the vibrations back to the surface where the geophones convert them into electrical impulses that are recorded on magnetic tape.
- 6 Magnetic tapes are sent for processing and interpretation of the recorded data.



Courtesy of the Petroleum Communication Foundation

## What are the minimum distances a project should be from structures or residences?

Shot hole drilling must be a minimum distance from farm structures or residences. The following minimum distances are defined in the Geophysical Exploration Regulations:

Facility	Non-explosive Method (metres)	Explosive Method	
		Charge weight in kilograms	Distance (metres)
Residence or place of public concern	50	All	180
Water well	100 (vibroseis) 50 (other than vibroseis)	All	180
Driveway, gateway or buried water pipelines	5	All	10
Survey monument or buried telephone or telecommunication line	1	All	1
Oil or gas pipeline (measured from the center line of the pipeline) and an oil or gas well	15	0 >2 >4 >6 >8 >10 >20	2 <4 <6 <8 <10 <20 <40
			32 45 55 64 72 101 143

## Questions or concerns?

Please see the contact information panel at the end of this brochure for who to contact if you have questions or concerns.



## **Questions you may want to ask when negotiating an agreement for a seismic project:**

- What is the resource company name, contact person's name, and phone number?
- What is the company representative's name and phone number.
- Where exactly will the project line(s) be placed and where will access be?
- What is the anticipated commencement date and the expected completion date?
- Will water flow or sample tests be done on water wells before and after construction?
- If a water well is impacted, what measures are the company prepared to take?
- What are the cutline widths and methods?
- Will a change in the proposed seismic line and access routes mitigate potential damage?
- Will livestock, crops, buildings and/or fences be affected?
- If a flowing hole becomes evident, what happens next?
- Will a preliminary cleanup be done immediately following the project's completion?
- When will reinspection and final clean-up be done?
- What are the restoration plans?
- How will the post-project damage be dealt with?

## **Who to contact if you have questions or concerns**

Your first contact should be the resource company's representative (eg.: referral agent). In most cases, the company representatives do their best to ensure they have satisfied your requests and concerns. If you are not satisfied you should contact the company directly.

The Oil and Gas Commission encourages companies and landowners to resolve their concerns. If resolution is not possible, assistance is available from the Oil and Gas Commission's Geophysical Program Manager, the Compliance and Enforcement Branch or the Stakeholder Relations and Communications Branch.

For further information, please contact:



### **OIL AND GAS COMMISSION**

Stakeholder Relations and Communications Branch

200, 10003 – 110 Ave

Fort St. John, BC, V1J 6M7

Phone: (250) 261-5700

Fax: (250) 261-5744

**24 Hour Emergency Response:**

**(250) 261-5700**

[www.ogc.gov.bc.ca](http://www.ogc.gov.bc.ca)

# Maximum Disturbance Review Criteria

## Operational Code and Guideline



OIL AND GAS COMMISSION  
200, 10003 – 110 Ave  
Fort St. John, BC, V1J 6M7  
Phone: (250) 261-5700  
Fax: (250) 261-5744

[www.ogc.gov.bc.ca](http://www.ogc.gov.bc.ca)



OIL AND GAS COMMISSION

The Oil and Gas Commission (OGC and Commission) regulates oil and gas activities and pipelines in British Columbia to provide for the sound development of the oil and gas sector, by fostering a healthy environment, a sound economy and social well being. A Commission goal is to provide transparency and consistency in regulatory delivery. A series of operating codes and guidelines are developed to assist our clients, First Nations and stakeholders.

## **Oil and Gas Commission Responsibilities**

The responsibilities of the Oil and Gas Commission – relevant acts, specified enactments and regulations

- ▶ Oil and Gas Commission Act
- ▶ Petroleum and Natural Gas Act
- ▶ Pipeline Act
- ▶ Water Act
- ▶ Forest Act
- ▶ Forest Practices Code of British Columbia Act
- ▶ Land Act
- ▶ Waste Management Act
- ▶ Heritage Conservation Act

Copies of the regulations are available at the Oil and Gas Commission or

**[www.ogc.gov.bc.ca](http://www.ogc.gov.bc.ca)**

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OIL AND GAS COMMISSION  
200, 10003 – 110 Ave.  
Fort St. John, BC, V1J 6M7

Phone: (250) 261-5700

Fax: (250) 261-5744

## MDRC OPERATING CODE

The Maximum Disturbance Review Criteria (MDRC) Operating Code is a tool to provide guidelines for oil and gas construction contractors and service firms conducting business in British Columbia.

### Purpose

The purpose of the MDRC Operating Code is to describe preferred maximum disturbance allowances for the development of:

- Wellsites
- Access routes
- Right of way for pipelines, and
- Other associated project requirements such as remote sumps, decking sites, camp sites and borrow pits.

### Objective

- To encourage companies, construction contractors and service firms to reduce environmental impact and consider land use and water management techniques in development plans and operational strategies.
- To specify acceptable parameters for typical oil and gas development activities.

## The Oil and Gas Commission Application Review Process

Compliance with provincial and federal legislation is mandatory.

The MDRC Operating Code tables are included in this guideline and provide recommendations to clients regarding:

1. Planning strategies and application preparation
2. Size and spacing of new disturbance
3. Construction techniques

***Each application will be examined on an individual basis.***

Information related to planning objectives, construction requirements, environmental characteristics, and area photographs will aid Oil and Gas Commission review staff.

**Construction proposals that meet the objectives of the MDRC will require a less prescriptive review, expediting application review time.**

**Rationale *must* be provided for any project or associated activity that exceeds MDRC guidelines. This information may be included in the Timber Harvesting and Field Assessment Form, or as an attachment.**

## WELL SITES MDRC Code Requirements

### Project Planning and Application Preparation

#### **Clearings and setbacks**

- ▶ Use existing clearings and multi-well pad drilling where possible.
- ▶ Well site edge (*and other associated disturbances*) must be setback from the breaks or banks of classified streams and water bodies (*as per Forest Practices Code Act*).

#### **Access**

- ▶ Note or show route of potential pipeline right of way with well application.
- ▶ Avoid cutting new access to water removal sites.

#### **Watercourses**

- ▶ Watercourses in the immediate vicinity of new disturbance should be identified and classified.
- ▶ Water required for drilling should be drawn from lakes or ponds greater than 5 hectares in area. A permit is required before water can be taken from natural water sources.▼

#### **Photography and assessment reports**

- ▶ Submit any reports, photographs of the project area, assessments and/or studies\*\* with application.

### Size and Spacing

- ▶ Well center must be a minimum of 80 metres from any public road or railroad right-of-way; and 100 metres if the content of the well is sour.
- ▶ Well sites can be next to pipeline right-of-ways, but if it is within 60 metres, consent of the land or tenure holder is required.
- ▶ Flare stacks must be at least 50 metres from the well center and must have a blackened area with a radius of 1.5 times the stack height, free of vegetation - 10m for cultivated areas and 30m for forested areas.
- ▶ Trailers located on leases must be 50 metres from the well center.

### Construction Techniques

- ▶ Feather edge of the lease, deviating from the conventional square-shape. Blend site in with the landscape and consider aesthetics.
- ▶ Use low-impact construction techniques such as pad matting or muskeg flip.

## ACCESS ROUTES MDRC Code Requirements

### Project Planning and Application Preparation

#### **Clearings and setbacks**

- Use existing open seismics, cleared rights-of-way, existing abandoned trails, and/or other open corridors.\*

#### **Access**

- Details of access route, including presence and percent of slopes, width and condition of seismic lines to be used, should be submitted with application.
- Permanent access routes should run parallel to pipeline routes.
- In sensitive or Special Management Areas, companies should, where possible, coordinate access plans with other users.
- Variations to access width maximums must be approved by the OGC.
- New temporary well access on Crown Land, which requires new cut and/or stream crossings, must be applied for on the well application and must be clearly marked and labeled on maps.

#### **Water Sources**

- Access to water sources can not be considered under the Application for Well Authorization and should be included on water use application.▼

#### **Photography and assessment reports**

- Submit any reports, photographs of the project area, assessments and/or studies\*\* with application.
- Reclamation strategies should be submitted with the application.

### Size and Spacing

- Temporary summer access roads should be no more than 15 metres wide if using borrow pits, and 20 metres wide if using ditch cut for padding.
- Temporary winter access shall be a maximum of 10 metres in width.
- Permanent access shall be a maximum of 20 metres wide.
- Standard corridor width for access roads with adjacent pipeline right-of-way is 25 metres.
- Variable width access should be considered in areas with challenging terrain or other features where extra operating area is required.
- A distance of 80 metres must be maintained between access and flare pits/stacks and flare line ends.

### Construction Techniques

- Temporary summer access roads should not be constructed as high-grade roads.
- Where new construction methods are proposed, a concise supplement detailing material, design and operational information should be included with application.  
**Note:** *Materials with the potential to cause environmental damage or contamination by way of function, nature or composition (eg. aspen corduroy) will not be approved unless measures are taken to ensure no damage will occur.*

## RIGHT OF WAY FOR PIPELINES

## MDRC Code Requirements

### Project Planning and Application Preparation

#### **Clearings and setbacks**

- Use existing open seismics, cleared rights-of-way, existing abandoned trails, and/or other open corridors.\*

#### **Access**

- Locate pipeline right of way adjacent to well access and incorporate cleared areas of log decks, camps, etc.
- Should extra temporary work space be required due to excessive debris or snow load, and/or terrain limitations, details must be included with application (or amendment) for consideration.

#### **Watercourses**

- A water use application is required for hydrostatic testing.▼

#### **Photography and assessment reports**

- Submit any reports, photographs of the project area, assessments and/or studies\*\* with application.

### Size and Spacing

- Standard pipeline right-of-way size is 15 metres. A total 25-metre wide corridor is acceptable when the pipeline runs adjacent to an access road.
- Maximum corridor width of 50 metres may be allowed if there is a multi-use and/or multi-party use corridor (it is encouraged that companies locating pipelines as close as safely and functionally possible to limit disturbance).

### Construction Techniques

- When crossing streams or creeks via bore or directional drilling techniques, alternate access routes should be considered if there are no crossing structures in place. New crossings will not be authorized, if an existing route is available.

\* Hand cut and avoidance type seismics are considered low impact disturbance. These should not be proposed as a new line if adjacent seismic or other linear corridors are within functional distance of operations.

\*\* A fisheries study may be requested by the OGC for contentious crossings. A fisheries professional may be required to monitor construction in and around contentious crossing areas.

▼ Water sources required for drilling must be applied for as per Sec. 8 of the Water Act  
<http://www.ogc.gov.bc.ca/documents/forms/streams/ogc-081shorttermwateruse.doc>

## OTHER MDRC Code Requirements

### Project Planning and Application Preparation

#### **General**

- Locate log decks, borrow pits, temporary campsites, remote sumps and work spaces in existing clearings.
- Centralized sites should be considered.

#### **Temporary Camps and Decking Sites**

- If no clearings exist within operational area, site locations should be considered in the following order:
  - a) Areas of disturbance created on the project
  - b) Non-marketable vegetation/timber; non-commercial forest
  - c) Immature deciduous/coniferous
  - d) Mature deciduous/coniferous
- Centralized camps must not be located in gravel pits without sewage containment.

#### **Borrow Pits and Remote Sumps**

- Should be tested to ensure appropriateness of site and results submitted with application.
- Water diversion will NOT be permitted from stocked borrow pits, or those occupied by nesting waterfowl or beavers.  
**Note:** *Signage should be posted at borrow pits, which have been stocked.*
- A permit is not required for water diversion from borrow pits.

### Size and Spacing

#### **Temporary Camps and Decking Sites**

- Standard campsite – 2400m<sup>2</sup>
- Standard decking site – 1200m<sup>2</sup>

#### **Borrow Pits and Remote Sumps**

- Typical borrow pit size is 4800 m<sup>2</sup>
- Standard remote sump size 3600 m<sup>2</sup> may be considered for multi-project use. A list of wells feeding the sump must be provided with application.

### Construction Techniques

#### **General**

- Where possible, feather the edges of new-cut clearings.

#### **Borrow Pits**

- Within the clearing, pits should be set back 15 metres from the road edge for pipeline placement.

## Wildlife and Fisheries Considerations

If special wildlife/habitat features are encountered in the field, pictures and details should be submitted with the application to assist review staff.

A guideline for minimum construction setbacks and habitat values is noted below:

Trumpeter Swan Nest	200 metres
Other nesting sites (eg. Osprey stick nest, sandhill crane ground nests)	100 metres
Mineral licks (minimum setback)	100 metres
Bear dens (apply to winter construction only)	50 metres
Beaver ponds and bull trout streams – see riparian set backs, Forest Practices Code	

**Note:** *Additional setbacks may be required due to lack of topographical relief, sparse vegetation density, extensive use of habitat, and other special considerations.*

Companies are encouraged to have wildlife/habitat professionals assess areas where a large amount of crown land disturbance is proposed, and/or where ecological sensitivities are present.

***Timing windows for fish bearing streams and wildlife lambing/calving, rutting and winter-range may apply.***

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If you have any questions or comments regarding the MDRC Operating Code, please contact an Oil and Gas Resource Officer at the Oil and Gas Commission

**Oil and Gas Resource Officer  
(250) 261-5700**





## SOLAR-POWERED WATER PUMPING SYSTEMS FOR LIVESTOCK WATERING

Livestock have traditionally been turned out to pasture and allowed to walk through and drink from any slough, creek, river, lake or dugout. It is increasingly being recognized by livestock producers and other water users that allowing livestock direct access to surface water sources is a concern due to impacts on water quality and detrimental effects on the livestock itself. Livestock producers also recognize that range management is often constrained by the distribution of natural water supplies.

To provide a safe, reliable supply of good-quality water for livestock while reducing negative impacts on water quality and the environment in general, and to enhance range management, it is often necessary to convey water from the source to a remote location. However, the availability of power supplies on the open range is often limited, so some alternate form of energy is required for water conveyance. One water-conveyance option available to producers is a photovoltaic or solar-powered pump.

### What is a solar-powered pump?

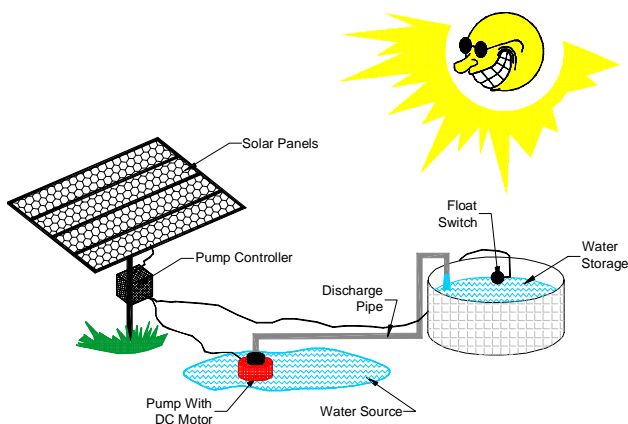
A solar-powered pump is a normal pump with an electric motor. Electricity for the motor is generated on-site through a solar panel which converts solar energy to direct-current (DC) electricity. Because the nature of the electrical output from a solar panel is DC, a solar-powered pump requires a DC motor if it is to operate without additional electrical components. If a pump has an alternating-current (AC) motor, an inverter would be required to convert the DC electricity produced by the solar panels to AC electricity. Due to the increased complexity and cost, and the reduced efficiency of an AC system, most solar-powered pumps have DC motors.

### What happens when clouds obscure sunlight?

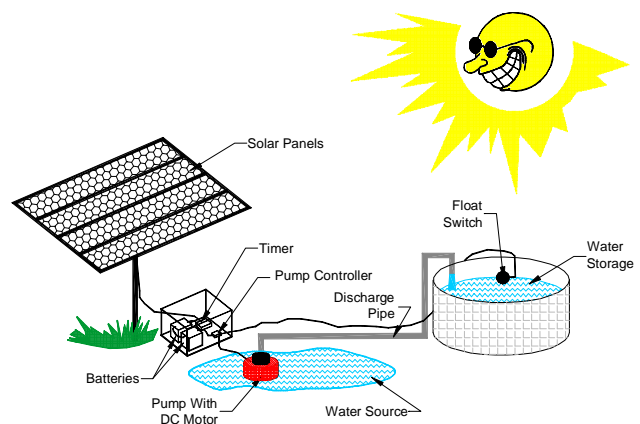
Solar-powered pumps will naturally work best on sunny days, which is fortunate because cattle will consume more water on hot, sunny days. But, water is still required on cloudy days. Solar panels still produce some electricity when it is cloudy, but their output is diminished. To ensure that ample water is always available for livestock, solar-powered water pumping systems should incorporate storage sufficient to supply water requirements for three or four days.

### What does a solar-powered pumping unit consist of?

The components comprising a solar-powered pump depend on whether the pumping system is a direct-drive system or a battery-operated system. The following sketches illustrate the components comprising these two systems:



Direct-Drive System



Battery System

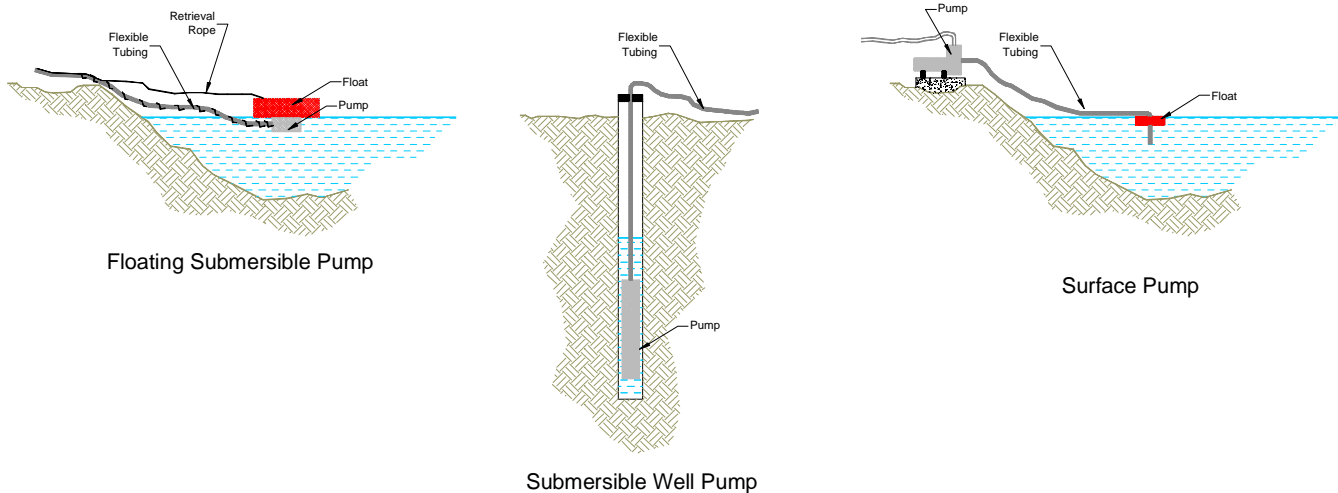
Both systems should incorporate a water-storage facility, but the water-storage component of the battery-powered system can be reduced in size relative to the direct-drive system due to the fact that the batteries effectively provide some storage.

### What other considerations are there?

For the direct-drive systems, it is important to match the power output of the solar array with the power requirements of the pump to maximize efficiency. For the battery-powered systems, it is important to use good-quality deep-cycle batteries and to incorporate electrical controls such as blocking diodes and charge regulators to protect the batteries. Some solar panels incorporate the electrical control elements.

### What kinds of solar-powered pumps are commonly used?

Solar-powered pumps for livestock water supplies are available in a wide variety of configurations. If the water source is a dugout, floating pumps are available. If the water source is a well, submersible centrifugal pumps are often used. For dugouts, streams and shallow wells, self-priming surface centrifugal or positive-displacement pumps can be used. Whatever kind of pump is used, it is especially important in low-voltage applications like solar energy, that care is taken to ensure that the pump is matched to head and discharge requirements of the application.



### How much water can a solar-powered pump deliver?

Solar-powered pumping systems can be configured to meet a wide variety of demands. The amount of water a solar-powered pump can deliver is a function of how far the water has to be lifted, the distance it has to travel through a delivery pipe (and the size of pipe), the efficiency of the pump being used, and how much power is available to the system. Power can be increased by adding more solar panels. For example, a  $\frac{1}{2}$  h.p. pump supplied by three 50-watt panels can deliver water at a rate of about  $1\frac{1}{2}$  gpm to a location 30 m higher than the source. As a comparison, a 3 h.p. low-lift irrigation pump powered by an array of 60 panels could deliver water at a rate of about 1,000 gpm.

### How much does a solar-powered pumping system cost, and when is it cost-effective to use one?

Generally, if the water source is further than about a kilometre from a power line, it will be less expensive to use solar power rather than extending the power line. The cost of a solar-powered pumping system will naturally vary according to its capabilities, but the cost of most systems for stockwatering applications ranges between \$2,000 and \$6,000.

### What is required to maintain a solar-powered pumping system?

One of the main advantages of a solar-powered pumping system is its simplicity and durability. The pump is the only part of the system having any moving parts, and it comprises a relatively small portion of the total system cost. Unless the system is installed in an extremely dusty area, occasional inspection of the wiring and the general

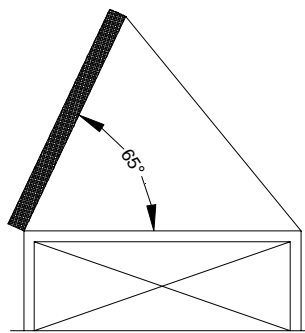
appearance of the panels will be all that is necessary. Panels can be cleaned with plain water and a soft cloth. The frequency of inspection should match the amount of storage available. For example, if the system incorporates a three-day supply of water and/or energy in storage, then it should be inspected at least every three days.

### What should be considered when locating and installing a solar-powered pumping system?

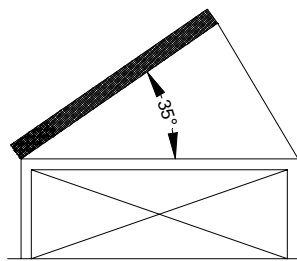
One of the advantages of solar-powered pumping systems is their simplicity, and because of this, they can be easily assembled and installed by the user. When a solar-powered pumping system is purchased, the supplier should supply total system designs and electrical drawings, as well as assembly, installation and set-up instructions.

The photovoltaic array (solar panels) can be mounted on a post or frame, but whatever the array is mounted on, it should be stable enough to withstand strong winds. The array should ideally be oriented toward true south, but deviations of 15 degrees east or west should not significantly affect performance. Some systems are available with devices that track the sun as it moves across the sky, but for most stockwatering applications, the increased efficiency derived from such systems is generally not worth the added cost and complexity. However, some users have found that tracking units significantly enhance the performance of direct-drive systems.

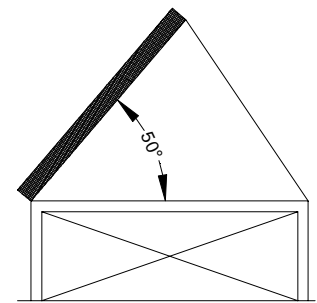
The solar panels should be tilted at an angle to horizontal to maximize power output. If the panel is to be fixed for year-round use, the tilt angle should equal the latitude of the site. If the panel mount has an adjustable tilt angle, the tilt angle should be equivalent to the site latitude minus 10 to 15 degrees in the summer, whereas in winter, the tilt angle should equal the latitude plus 10 to 15 degrees. The following sketches illustrate typical tilt angles for most mid-latitudes on the Canadian Prairies:



Winter

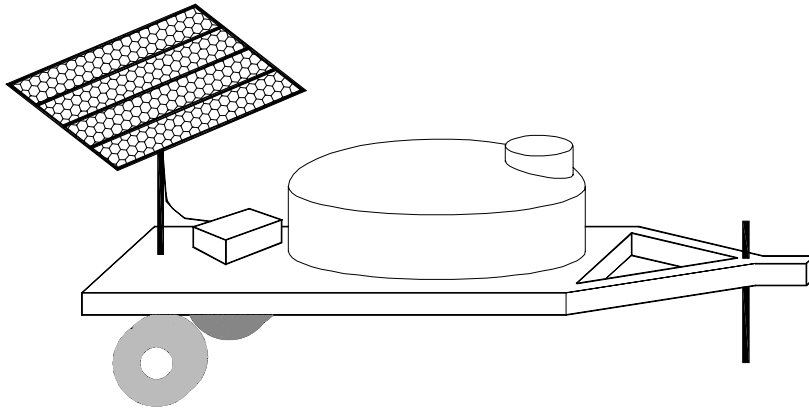


Summer



Year-Round

Batteries and electrical components should be housed in a vented, weather-proof enclosure. For late-season or winter use, the enclosure should be insulated. The solar panels and the battery enclosure should also be protected from damage that might be caused by cattle. Small solar pumping systems that incorporate two or three panels can be easily moved, which can be a major advantage for applications such as rotational grazing systems. The panels, battery-enclosure and a storage tank can all be mounted on a trailer or skid, and the pump and piping can be disconnected for transport.



Trailer-Mounted Unit



The Bigger Picture

Solar-powered water pumping systems are just one of many options available to producers interested in managing their rangelands, providing improved water quality for their livestock and protecting their water supplies. For additional information on other livestock watering systems, as well as solar-powered water pumping systems, contact your local PFRA office.



# Community-based Action Program for Shorelines (CAPS) Orientation

This 2 hour orientation to CAPS introduces you to the program and our products and services. It also provides information about how your group/organization can deliver its' conservation or stewardship program more effectively and presents an opportunity to discuss ideas with others. The orientation is open to interested groups and individuals, government agencies, municipalities, and non-government organizations.

## BENEFITS OF HOSTING A CAPS ORIENTATION

Hosting an orientation for your community or group provides an opportunity to:

- Discover how the program can be adapted to your community needs
- Discuss successes of past approaches
- Meet a diverse group with common interests
- Build and strengthen community relationships/partnerships
- Promote co-operation and develop networks
- Increase community awareness of local issues
- Share ideas/concerns

## OUTLINE OF ORIENTATION

Participants give a brief description of their group/organization, what shoreline issues/concerns they would like to address and any other information they feel is of interest. Following participant introductions is a discussion of other CAPS components provided by *The Living by Water Project (LbyW)*, these include:

- Conservation Action Marketing Clinic ②
- Shoreline Forum ③
- Healthy Shorelines ④
- Shoreline Resident Workshop (several options) ⑤
- Elected Municipal Representatives Clinic ⑥
- Homesite Assessor Training ⑦
- local realtors' program
- and various forms of communication support

*\*\*For more detailed information on the numbered CAPS components please refer to the corresponding pages.*

## SUPPORT FROM YOU

To host a CAPS event/ activity the local logistical support required from your group/organization may include:

- Billet/accommodations for presenter(s)
- Room rental for workshop/presentation; food service if needed
- Local advertising
- Audio/visual equipment
- Printed materials- *LbyW* has printed materials available

The CAPS initiative operates under the umbrella of *LbyW*, helping provide support, training and resources that in turn helps motivate citizens in shoreline conservation and restoration efforts. *LbyW* is an action-oriented program, focussing on the positive role that individuals and communities can play in helping protect, conserve and restore shorelines.

For more information contact:  
Tania Mund  
**The Living by Water Project**  
Ph: 250-832-7405, Fax: 250-832-6874  
Email: shorelines@jetstream.net  
www.livingbywater.ca





## Community-based Action Program for Shorelines (CAPS) Logistical Support

**The Living by Water Project (LbyW)** provides the following at no charge (subject to current funding):

- In some cases facilitator(s) for workshops, clinics, presentations and training sessions
- In some cases facilitator's transportation costs to and from your community
- Some logistical and administrative support
- *LbyW* displays (available on loan)

### **LOGISTICAL SUPPORT FOR CAPS**

Your group/organization is responsible for the following logistical support (costs and organizing) and any additional support (next section) when hosting any CAPS event(s):

- Billet/Accommodations for facilitator(s)
- Room rental for workshops/clinics/presentations/training
- Local promotion/advertising (radio, TV, newspaper) if necessary
- Food service if needed
- Audio/Visual Equipment:
  - ▶ Standard overhead projector with back-up bulb
  - ▶ 2 large projection screens
  - ▶ 35 mm slide projector with back-up bulb, horizontal carousel style
  - ▶ TV & VCR
  - ▶ Flip chart with dry erase pens (black, red, green)
  - ▶ Tables for overhead and slide projectors and necessary extension cords

If your group/organization would like any of *LbyW*'s supplementary printed products and/or promotional materials, please refer to order form.

### **ADDITIONAL SUPPORT**

Some events may require items, additional to the above list, to be provided by the hosting group/organization:

#### **CAPS Orientation\*; Shoreline Forum; Healthy Shorelines**

- 1 - small table for participant sign-in
  - 2 - 8 ft tables for displays and promotional items
- \*CAPS Orientation only - CAPS handout set for each participant (provided by *LbyW*)

#### **Conservation Action Marketing Clinic**

- Participants for the Conservation Action Marketing Clinic should be charged at least \$20.00 per participant, this helps cover the cost of materials and binder they receive during the clinic.

#### **Workshop-in-a-Box**

- Computer (with projector) for Power Point presentation or standard overhead projector.  
*\*\*Please note: all shipping/handling charges for Workshop-in-a-Box (unless it accompanies the facilitator) and any costs incurred due to shipping damage or kit loss is the borrower's responsibility.*

### **Shoreline Resident Workshop**

- If you wish a *LbyW* representative to facilitate the workshop for your group there will be some additional charges as this workshop is not offered under the CAPS program.
- To help offset some of the workshop costs, we recommend the hosting group/organization make a charge for each participant. Financial commitment from participants often results in increased attendance and a greater perception of value. If a workshop is free there may be a perception that the information is of reduced value.

### **Soil Bioengineering Demonstration**

- Organize arrangements for expert and cover their fee and travel costs
- Organize local field demonstration sites

### **Shoreline Clinic for Elected Municipal Representatives**

- Municipal Representatives handout package and copy of "On the Living Edge– Your Handbook for Waterfront Living" - cost for supplies is \$20.00 per participant.

### **Homesite Assessor Training (HAT)**

- *LbyW* folder with Field Guide, information sheets, and copy of "On the Living Edge– Your Handbook for Waterfront Living" - cost is \$25.00 per participant.
- Organize local shoreline home visit sites
- Local resource template (provided by *LbyW* for you to fill out local information)

### **Realtors' Shoreline Awareness Program**

- Copies of "On the Living Edge– Your Handbook for Waterfront Living" can be organized through either the hosting group building the book cost into the seminar fee (with bulk purchase rates available depending on number of participants) **or** *LbyW* can sell handbook to each participant at retail cost of \$14.95 (+ tax totals \$16.00) at the time of the event.

### **\*NOTE:**

*Please where possible have all A/V equipment set up for the facilitator at least 30 minutes prior to start of event– this is very important so the facilitator can personally welcome participants. If *LbyW* displays are required for an event, the facilitator will need access to the room one hour before the start of the event.*

*A suggestion for beverages, ask participants to bring their own mug and possibly have a few extra on hand; and for food service please use reusable plates/cutlery where possible.*

### **LbyW POLICY ON PARTICIPANT FEES/CHARGES:**

*LbyW* recommends either no charge or a donation box for the following events: CAPS Orientation, Shoreline Forum and Healthy Shorelines. Events where participant charging is suggested to help cover cost of materials include: Conservation Action Marketing, Shoreline Resident Workshop, and Homesite Assessor Training.

For more information on CAPS contact:

***The Living by Water Project***

Ph: 250-832-7405, Fax: 250-832-6874

Email: shorelines@jetstream.net

www.livingbywater.ca





## Healthy Shorelines

“Healthy Shorelines” is an introductory presentation providing a place to share information, showcase successes, and educate citizens about the role and value of healthy, natural shorelines. The scope of the event is up to you. Some communities focus specifically on shoreline residents, others open it to the community at large, helping to raise awareness about the “sustainability” of shorelines in their community and the challenges facing them.

### HOSTING “HEALTHY SHORELINES” BENEFITS YOU AND YOUR COMMUNITY BY:

- Providing shoreline residents with practical information (e.g. erosion, water quality, shoreline buffers), and making them aware of the available community resources.
- Offering increased networking opportunities that can result in new relationships and surprising new community partnerships.
- Raising awareness about your initiatives helps increase your community profile.
- Publicly recognizing and rewarding volunteers helps promote and sustain ongoing volunteer efforts.
- Increased media coverage and publicity around shoreline issues benefit everyone!

### HOW WE CAN HELP

*Living by Water Project (LbyW)* resources and support available to help you host a successful Healthy Shorelines presentation include:

- Facilitation by a *LbyW* representative, featuring a “taste” of the *LbyW* Shoreline Residents’ Workshop; including facilitation training for a representative of your group - following a “learning by doing” approach.
- “**On the Living Edge – Your Handbook for Waterfront Living**” - a must-read for all shoreline residents, the handbook presents practical information on a wide range of topics and is a valuable resource to have on hand for community residents.
- A variety of **educational and outreach materials** including Waterfront Living (freshwater) and Coastal Living (marine) brochures; Action Checklists for shoreline residents and shoreline visitors; brochures and activity sheets for kids; Shoreline Ambassador Program; Shoreline Event and Activity Manual.

A Healthy Shorelines presentation is offered under our **Community-based Action Program for Shorelines (CAPS)** initiative, under the umbrella of *The Living by Water Project*.

For more information contact:

Tania Mund

***The Living by Water Project***

Ph: 250-832-7405, Fax: 250-832-6874

Email: [shorelines@jetstream.net](mailto:shorelines@jetstream.net)

[www.livingbywater.ca](http://www.livingbywater.ca)





## Homesite Assessor Training

Looking for assistance in developing a shoreline or streamside “landholder” contact program in your community? Or are you currently running a program that could be improved to better meet the needs of shoreline residents? Consider a training program for Homesite Assessors, developed to meet your needs in carrying out effective home visits to help bring about sustained behaviour change.

### **BENEFITS TO YOUR GROUP INCLUDE:**

- Assistance in training staff/volunteers
- Practical in-the field experience
- Support materials such as the *Homesite Assessors’ Field Guide* and “*On the Living Edge - Your Handbook for Waterfront Living*”

*“The Living by Water Project has been extremely helpful to the Christina Lake Stewardship Society . . . they trained a local youth in the shoreline protection program....We felt the [home visit] program was very worthwhile.”*

Carlo Crema (President) & Brenda LaCroix (Stewardship Coordinator)  
Christina Lake Stewardship Society

### **LEARN ABOUT:**

- Providing effective and friendly customer service
- Providing practical information and customized recommendations to waterfront residents
- Using Conservation Marketing to promote home visits
- Integrating elements of our Shoreline Ambassador Program and Shoreline Action Challenge to motivate residents to action
- Reporting and record keeping

*“. . . The Living by Water Project developed and facilitated a Homesite Assessment Training Workshop for planners in partnership with the Regional District of Nanaimo. Planners from five local governments participated in the workshop and feedback from participants was very positive”*

Brigid Reynolds, Planner  
Regional District of Nanaimo

### **FORMAT:**

A two day program typically includes a field component where two model home visits are conducted. Recommended number of participants is 10-12 people with a maximum number of 15. You are encouraged to find two local shoreline/streamside residents to volunteer their property for a demonstration home visit. Ideally, the properties would illustrate some of your main concerns or common problems affecting shoreline property in your community. See page 2 for outline.

*“[Clive Callaway] has been an excellent model for Homesite Assessment when he trained a number of SeaChange Volunteers . . .”*

Nikki Wright (Director)  
SeaChange Marine Conservation Society

### **We provide ongoing support to your home visit program through:**

- Funding templates to help you subsidize this service
- Marketing kits to help you advertise and promote the program
- Possible referral and assistance in recruiting shoreline residents in your area
- Listserv for trained assessors

*“What a wonderful positive, hands on opportunity to learn, share and protect our shoreline properties, water quality and quantity...Thank you Living by Water for your Homesite Assessment Program”*

Dave Smith (Past President)  
Kanaka Education and Environment Partnership

# Model Homesite Assessor Training

Sample Format (may vary)

## DAY 1

### Session 1 - Indoors

- I. Welcome and Snapshot (1 ½ hr)
  - Introductions, participants give brief description of interest, what you want to get out of workshop
  - snapshot of *LbyW* - focus on H.A.P.
- II. Working with Customers (1 ¼ hrs)
  - Applying the Principles of Conservation Marketing
  - Understanding Your Audience
  - Creating Positive Relationships
  - Easing Client Fears
  - Gender Issues
  - Tips for Assessors

### III. Technical

(Part 1 - 1 hr; Part 2 in Session 3)

- Healthy shoreline indicators
- Information on erosion, septic systems, invasive plants, replanting native plants, etc.
- Resources for Assessors and recommendations for further learning

### Session 2 - Outdoors

- ½ hour travel time
- 1 ½ hrs home visit #1
- ½ hour travel time
- 1 ½ hrs home visit # 2

## DAY 2

### Session 3 - Indoors

#### III. Technical cont'd (Part 2 - 3 ½ hrs)

#### IV. How to Conduct a Home Visit (2 ½ hrs)

- Life Made Easier
- Dealing with Challenging Clients
- How much advice/information to offer
- If You Don't Know
- The Soft Sell
- Site Warmup

- The Home Visit form
- "How Healthy is My Shoreline" form
- Shoreline Action Checklists

#### V. Record keeping/Administration (1 hr)

- Pre-visit and post visit checklists
- Home Visit Customer Information Kit

#### VI. Wrap up (½ hr)

- Questions

**Note:** video clips also shown during lunch breaks; 15 min breaks in morning and afternoon

For more information contact:

Tania Mund

***The Living by Water Project***

Ph: 250-832-7405, Fax: 250-832-6874

Email: [shorelines@jetstream.net](mailto:shorelines@jetstream.net)

[www.livingbywater.ca](http://www.livingbywater.ca)



*Working towards healthier human and wildlife habitat  
along the shorelines of Canada*



## Shoreline Clinic for Elected Municipal Representatives

As an elected municipal representative, do you find yourself increasingly caught between the complex requirements of environmental laws aimed at protecting water quality and fish/wildlife habitat, and citizens' concerns over issues such as private property rights? Do you feel there is a lack of solid information to help balance these concerns?

To help you make better informed decisions about shoreline development, we have created a private clinic for elected municipal representatives. The clinic provides an opportunity to discuss issues and concerns and presents the many benefits of healthy natural shorelines: how they help protect water quality, safeguard property values, support tourism and recreational needs, improve community appeal, are cost-effective to maintain, and much more.

### PRESENTATION TOPICS:

**1. What is a healthy shoreline anyway?** - Explores the choices and consequences of various shoreline management practices.

**2. The benefits of healthy, natural shorelines** - Looks at case studies such as Hamilton Harbour, Ontario which experienced increasing property values after a clean up of the harbour; and the State of Maine which demonstrated decreasing property values as lake water quality declined. Other benefits include the protection of fish stocks, wildlife and many species at risk, as well as protection of water quality and quantity as populations grow.

**3. The evolving trend toward natural shorelines** - Did you know they're becoming the "IN" fashion? Natural doesn't have to mean "wild and weedy"! Learn about how a shoreline program for realtors and a new book "On the Living Edge - Your Handbook for Waterfront Living" are helping change shoreline fashions.

**4. Why people are so passionate about their shorelines** - Discover how a local shoreline forum can help develop a community-based shoreline vision.

*"Living by Water Project programs and materials have been a great asset to our outreach and education initiatives and would benefit other local governments dealing with shoreline issues".*

Michelle Kam, Watershed Coordinator for the City of Kelowna

The City held a very successful "Living by Water Dessert Evening", which attracted 175 stream and lakeside residents.

*"[A Shoreline Open House] is an excellent opportunity to educate the public on issues related to the care and stewardship of our creeks, wetlands and foreshore. We are very keen to provide a venue for a session on foreshore issues".*

Ken Bennett, Environmental Services Manager, Corporation of the District of North Vancouver

You'll also learn about:

**Using educational and motivational materials and programs** that employ modern Conservation Action Marketing tools and techniques to:

- help shoreline residents save time and money
- protect their health and wealth
- help with voluntary compliance in support of new and evolving environmental standards

A case study featuring the Regional District of Nanaimo shows how it successfully utilized *The Living by Water (LbyW)* materials and programs to assist in its urban growth strategy.

**How matters of “due diligence” relate to healthy, natural shorelines** and how some soil bio-engineering techniques can be successfully employed on degraded shorelines with substantial cost savings.

**Who’s involved in shoreline conservation and stewardship** in your local area, in the province, and what resources are available.

### **CLINIC FORMAT**

Generally a 1½ to 2 hour private meeting format is suggested; open only to elected municipal representatives (and staff, if required). A concluding luncheon (optional) provides the opportunity for further discussion. Depending on the availability of the facilitator, other options could be considered.

### **WHO IS PRESENTING?**

The clinic is part of our province-wide initiative, **Community-based Action Program for Shorelines (CAPS)**, working under the umbrella of the highly successful *Living by Water Project*.

Our unique approach leaves out judgment, blame and partisan positions in favour of a client-centred approach (the client being shoreline residents, local conservation and stewardship groups, and local government). We customize our programs and activities to meet the identified needs of each community.

*Facilitator **Clive Callaway** is an educator, waterfront resident, co-founder of the Living by Water Project and co-author of “On the Living Edge - Your Handbook for Waterfront Living”. Along with co-founder/co-author Sarah Kipp, he has been awarded the Gold award in the “Clean Water” category of the Canadian Environment Awards program for 2002.*

*Clive has both a construction and land-use planning background and has carried out shoreline development policy work for regional districts, prepared development guidelines for municipalities and the private sector, and has conducted many workshops and seminars. Clive has also owned and managed a waterfront resort catering to educational and recreational stays (Elder hostel and eco-tourism). He holds a Master of Environmental Design Degree from the University of Calgary in urban and regional planning and has acted as a developer in the conversion of his own resort to a bare land strata.*

*The Living by Water Project* is a Canada-wide partnership of conservation and stewardship groups working with other interested organizations and agencies. We focus on the positive role individuals can play in protecting, conserving and restoring natural shorelines in their communities.

For more information contact:

Tania Mund

***The Living by Water Project***

Ph: (250) 832-7405, Fax: (250) 832-6874

Email: [shorelines@jetstream.net](mailto:shorelines@jetstream.net)

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# Community-based Action Program for Shorelines (CAPS)

Over the last four years, in developing *The Living by Water Project (LbyW)* and working with community groups throughout the province, we were often asked for help – ranging from assistance to a small group writing a funding proposal to guidance in preparing a presentation for shoreline residents. Groups also frequently expressed interest in our workshop, homesite assessor training or shoreline action challenge program – and requested our support in implementing them.

The Community-based Action Program for Shorelines (CAPS) initiative is the result of these requests, providing support, training and resources to help your community group/organization in shoreline conservation and stewardship efforts. We hope that it will meet your needs and that together, we can continue working to protect, conserve and restore shorelines in BC and the Yukon.

## BENEFITS

Some of the many benefits that you and your community will receive through the CAPS “learning by doing” approach are:

- **Skills** - your group will gain valuable skills in conservation action marketing, home visits, evaluation, etc.
- **Customized service** - because we come to **you**, your group guides how CAPS is delivered in your community.
- **Building relationships** - we emphasize cooperation with a variety of interest groups– conservation, stewardship and cottager groups, elected municipal officials, realtors, land appraisers, home inspectors, municipal planners and others.
- **Products** - you’ll have access to a selection of existing and new *LbyW* products, including some specifically developed for our CAPS program (like our Conservation Action Marketing handbook). Our Green Guest Guide is being upgraded, and our new Coastal Living brochure is already produced. Other CAPS items include, templates for proposals, monitoring, and final reports to funders, helping you increase your chances of receiving grants.
- **Positive “on-the-ground” changes** - our products and services are designed with your audience in mind, helping you connect with, and motivate, local marine/ freshwater shoreline residents take positive actions in helping to protect, conserve or restore shorelines on their property.

As *LbyW* is in service to groups and agencies, we work to provide you with support, materials and resources needed to help you achieve your goals and get your messages out. Our approach is reflected in the following text:

<p><b>Tell me...</b>I will forget Understand me...I will listen Show me...I will remember Involve me...I will understand Respond to my needs...I will act Remind and support me.... <i>I will keep doing</i></p>
--

## CAPS FEATURES

Support and resources to choose from include:

- ① **CAPS Orientation** - introduction to our program, products, services and brief discussion of each topic ② through ⑦ including communication support (2 hrs)
- ② **Conservation Action Marketing Clinic** - discusses the importance of marketing and how to market effectively with valuable marketing tips provided (1 day)
- ③ **Shoreline Forum** - a community forum to help raise awareness about the importance of healthy shorelines for your community, address local shoreline issues/concerns, and develop networks/relationships (½ - 1 day)
- ④ **Healthy Shorelines** - an introductory presentation for citizens and shoreline residents; provides an opportunity to share and focus on the role and value of community shorelines (1½ - 2 hrs)
- ⑤ **Shoreline Resident Workshop** - a workshop to help shoreline residents learn more about how to protect their own shorelines. Three workshop options:
  - Shoreline Resident Workshop* - a 1 to 1½ day workshop based on the book, "On the Living Edge— Your Handbook for Waterfront Living", led by a *LbyW* facilitator
  - Workshop-in-a-Box* - a portable "do-it-yourself" kit, provided on loan from the *LbyW* office, to help you facilitate a Shoreline Resident Workshop
  - Shoreline Resident Workshop/ Workshop-in-a-Box plus Soil Bioengineering Demonstration* - combines the Shoreline Resident Workshop or Workshop-in-a-Box with a day-long Soil Bioengineering Demonstration for more "hands-on" experience
- ⑥ **Shoreline Clinic for Elected Municipal Representatives** - the benefits of healthy shorelines and "due diligence" issues to help municipal officials make better informed decisions on shoreline development (1½ - 2 hrs with optional luncheon discussion)
- ⑦ **Homesite Assessor Training** - indoor/outdoor training and program support for staff/volunteers in conducting shoreline home visits (2 days)

### and...Communication support, including:

- *LbyW* 's Realtors' Shoreline Awareness Program - a breakfast/luncheon featuring information about effective marketing, benefits of natural shoreline property and "due diligence" for realtors, appraisers, and home inspectors
- Model media event notices, press releases, articles and Public Service Announcements; our Shoreline Event & Activity Manual; Shoreline Action Challenge Program; promotional materials, brochures, handouts...and more!
- "On The Living Edge - Your Handbook for Waterfront Living" - bulk purchase rates are available
- Proposal templates for a variety of funding applications (e.g., EcoAction, FEF), monitoring and reporting

For more information on CAPS contact:

***The Living by Water Project***

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# Realtors' Shoreline Awareness Program

*Lakefront, beachfront, streamside - Are you marketing shoreline residential property effectively?*

Announcing a Realtors' Shoreline Awareness Program . . . to support you and your clients when purchasing or selling marine/ freshwater shoreline property!

## WHAT REALTORS ASK US . . . AND HOW WE CAN HELP

- **How can I improve my service image and better serve my clients?** By becoming more informed, providing practical resources, offering information on shoreline concerns (e.g. septic systems, setbacks, erosion etc.), and directing clients to useful and available resources (e.g. low-interest loans).
- **How can I decrease my workload and increase my sales of shoreline properties?** By improving your ability to match your client to the property.
- **How can I reduce the risk of litigation?** By becoming better informed on shoreline jurisdictional overlap, regulations and property disclosure.

## FIVE TOOLS

Our program offers five tools to complement your ongoing professional development and assist you in serving your clients:

1. A handbook for shoreline residents
2. An informal breakfast or luncheon clinic in selected communities (1-1½ hours)
3. A professional development seminar through participating Regional Real Estate Boards (1½ -2 hours)
4. On-the-ground support (e.g. shoreline home visits)
5. Future web-based support.

Our book, "On the Living Edge— Your Handbook for Waterfront Living" is a valuable tool for you and your clients. Written by shoreline residents for shoreline residents (both prospective and current), the handbook guides readers through the pitfalls and challenges of building and living by water. Topics discussed, ranging from permits and legislation to septic and water systems, are written in a clear and easy-to-understand manner. As part of your customer service package you may wish to offer the handbook, along with brochures and other support materials, to your clients.

Additional support services include:

- Shoreline home visits (available in participating communities), provides clients with customized information and recommendations for protecting their property while saving time and money.
- *Living by Water* Loan Program- a special program in the Lower Mainland area, offering an interest rebate for loans up to \$20,000 on shoreline protection or restoration projects; support which might make the difference to a sale.
- Online resources and support will also be provided in the future at [www.livingbywater.ca](http://www.livingbywater.ca).

## WHY THIS PROGRAM?

We understand your need to constantly upgrade your knowledge and skills in order to deal with the changing marketplace (e.g. new construction products, building codes, or differing levels of government regulations). Also, overlapping jurisdictions of shoreline properties can be a source of confusion for you and your clients, and in some cases can have adverse effects on the market value of shoreline properties.

Our program provides you with practical information and helps educate you on the important “services” that healthy natural shorelines provide. Healthy shorelines protect or enhance property values, protect property from erosion, and safeguard water quality. By becoming more informed of these functions, your ability to market features of a healthy shoreline property increases, while the property price reflects a more accurate value of its’ “services”.

Some comments about the program and handbook from people in the realty business:

*“In recent years the environment has had a major effect on the real estate industry. We have dealt with hazardous waste/contaminated sites, Forest Land Reserve, flood plains, etc.; the list goes on. Each of these areas of concern involves awareness and liability issues...The opportunity to have a course available to highlight concerns, potential liabilities, funding possibilities and sources of assistance [related to shorelines] is a worth while consideration.”*

Ian Lindsay, a Qualicum realtor

*“Just to let you know how much we appreciate your new book. It’s so valuable to our clients, many of whom are purchasing shoreline property for the first time. We’ve made it company policy to provide a book to every waterfront purchaser that goes through our office.”*

Brad Potter, a Bridge Lake (100 Mile House) realtor

**Appraisers and home inspectors are also encouraged to attend the program, providing an opportunity for all professions to work together and share ideas, helping to make your work that much easier.**

*Living by Water* is in service to provide information about the value and functions of healthy natural shorelines through our community-based education and awareness initiatives. Our resources and support are designed to stimulate changes in attitude about the many features that make shoreline property desirable.

For more information contact:  
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# Factors Controlling Algal Biomass in Three Shallow Eutrophic Lakes in Northern British Columbia, Canada: Charlie, Nulki and Tachick Lakes<sup>1</sup>

Todd D. French<sup>2</sup> and N. Bruce Carmichael<sup>3</sup>

(March 2004)

**Abstract:** The cultural eutrophication of lakes in the northern interior of British Columbia (Canada) is of ever increasing concern. To improve our understanding of the factors that control biomass cycles and taxon-specific bloom periodicity in these lakes, surface-strata samples for chl *a* and taxonomy were collected in conjunction with depth-profile samples for nutrient concentrations (P, N, Si), temperature and O<sub>2</sub> concentrations and pH at two limnetic deep sites in Charlie (a lake that develops hypolimnetic O<sub>2</sub> deficits during summer stratified periods), and Nulki and Tachick (well-mixed lakes that do not develop limnetic O<sub>2</sub> deficits in the summer) lakes. The results indicate that surface-strata algal biomass in the lakes tracked Tot-P, Tot-P<sub>diss</sub> and, in Charlie Lake, Tot-Si<sub>diss</sub> concentrations and, moreover, that the nutrient loads that appeared to trigger algal blooms came primarily from within-lake sources (internal loading). The data further showed that internal P- and Si- loading rates can be considerable in lakes that develop hypolimnetic O<sub>2</sub> deficits and in lakes that do not develop such deficits.

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The deterioration of water quality and ecosystem-level function resulting from cultural, or anthropogenic, eutrophication is of major concern in North America and, perhaps, the world over. Nutrient additions to rivers and streams typically result in increased benthic production, e.g., rooted macrophytes and associated epiphytes, epilithic algae and bacteria (Dunnette & Avedovech, 1983; Bushong & Bachmann, 1989; Bothwell, 1992; Dubé et al., 1997; French & Chambers, 1997; Perrin & Richardson, 1997), whereas such additions to

lakes more often result in increased algal productivity in the water column (Schindler et al., 1971; Schindler & Lean, 1974; Vincent et al., 1991). While algae are important components of lake ecosystems in that they are the primary sources of organic carbon, excessive growths resulting from point- and diffuse- source nutrient pollution can lead to extreme water fouling and

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trophic-level failures such as summer and/or winter fish kills (Barica & Mathias, 1979; Kenefick et. al, 1992; Kotak et. al, 1993).

Whether influenced primarily by natural or human-induced factors, algal productivity in lakes typically cycles with season and temporal shifts in biologically-important conditions like temperature (Masaki & Seki, 1984; Davison, 1991; Macedo et al., 2001), water clarity and light penetration (Tilzer & Goldman, 1978; Smith, 1979; Stewart & Wetzel, 1986; Stauffer, 1991; Fahnenstiel et al., 2000), hydrology (Talling, 1986; Zafar, 1986), herbivory (Jackson, 1980; Lehman & Sandgren, 1985) and nutrient availability (Lund, 1949; Megard & Smith, 1974; Hecky et al., 1986). Few, if any, studies have investigated the seasonal patterns of algal abundance and species-specific phenology in lakes located in northern British Columbia (Canada); however, data presented in reports by government (e.g., French & Carmichael, 1999) and consulting (e.g., AEE, 1999) ecologists have indicated through observational inferences and analyses of temporally-collected chl *a* samples that, in a broad sense, there is typically a minor spring bloom composed primarily of diatoms and a major cyanophyte bloom during the late summer and early autumn in this region.

The cultural eutrophication of lakes in the interior of British Columbia, which is thought to be resulting from the combined effects of agricultural- and forestry-related deforestation and associated nutrient runoffs, sediment erosion from roads and stream crossings and resulting increases lake in-filling and nutrient loading rates, and nutrient-rich urban and industrial wastes, is of ever increasing concern. In the early 1990s, several lake-user groups developed partnerships with the provincial government to initiate field-based studies to better understand the dynamics of algae communities in interior British Columbia lakes and the environmental factors associated with the development of blooms. The premise for undertaking these studies was that the results may assist with the design and implementation of projects that could slow cultural eutrophication rates and, ultimately, improve conditions in the lakes and watersheds as a whole. The objective of the present study was to describe the annual cycles of algal biomass in Charlie Lake (a lake that develops hypolimnetic O<sub>2</sub> deficits during summer stratified periods) and Nulki and Tachick lakes (well-mixed lakes that do not develop limnetic O<sub>2</sub> deficits in summer). Biomass cycles and, for Charlie Lake, taxon-specific bloom periodicity, were assessed in relation to environmental shifts in nutrient availability (P, N and Si), thermal structure and O<sub>2</sub> concentrations, and pH.

## Study Lakes

### *Nulki and Tachick lakes*

The Nulki-Tachick watershed is located in British Columbia's (western Canada) central interior, about 90 km west of the City of Prince George (population 80,000) and 15 km south Vanderhoof (population 4,300) (Figure 1). Elevations in the watershed range from 760 m at the surface of Nulki and Tachick lakes to 1,340 m at Corkscrew Creek's headwaters in the Nulki Hills. Although the southern-most edge of the watershed has steep gradients (hilly to mountainous), most of the watershed is flat to gently sloped (3 to 7% gradient). The watershed lies within the Sub-boreal Spruce biogeoclimatic zone, a montane zone that dominates the central interior of British Columbia. Being derived from glaciofluvial processes, soils in the Nulki-Tachick watershed are dominated by moderate to well-drained clayey, sandy and gravelly textures (Farstad & Laird, 1954).

Nulki Lake has four tributaries: Stoney, Bear, Corkscrew and Second creeks which drain into the lake from the south and south-west (Figure 1). A fifth tributary, Sinkut Creek, was diverted away from the lake and into the Sinkut River in the mid-1940s. However, flows in 1997 were high enough that some of Sinkut Creek's water

by-passed the diversion point and flowed into the south-eastern corner of Nulki Lake (original point of entrance). Nulki Lake is drained from the north by Middle Stoney Creek, which flows for 3 km to where it drains into the eastern-most point of Tachick Lake. Tachick Lake is also fed by Tachick Creek, which flows into the lake's west end. Tachick Lake is drained by Lower Stoney Creek, which flows into the Nechako River near the town of Vanderhoof. The Nechako River is one of the largest tributaries of the Fraser River which flows in a south-westerly direction through the British Columbia interior to where it enters the Pacific Ocean at Vancouver (population 2 million). The Nechako-Fraser systems have historically supported the early life stages of continentally-important sockeye salmon (*Oncorhynchus nerka*) and chinook salmon (*Oncorhynchus tshawytscha*) populations, and all life stages of rainbow trout (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), burbot (*Lota lota*), the regionally-endangered white sturgeon (*Acipenser transmontanus*) and a variety of minnows (Cyprinids), suckers (*Catostomus* spp.) and whitefishes (*Prosopium* spp. and *Coregonus* spp.).

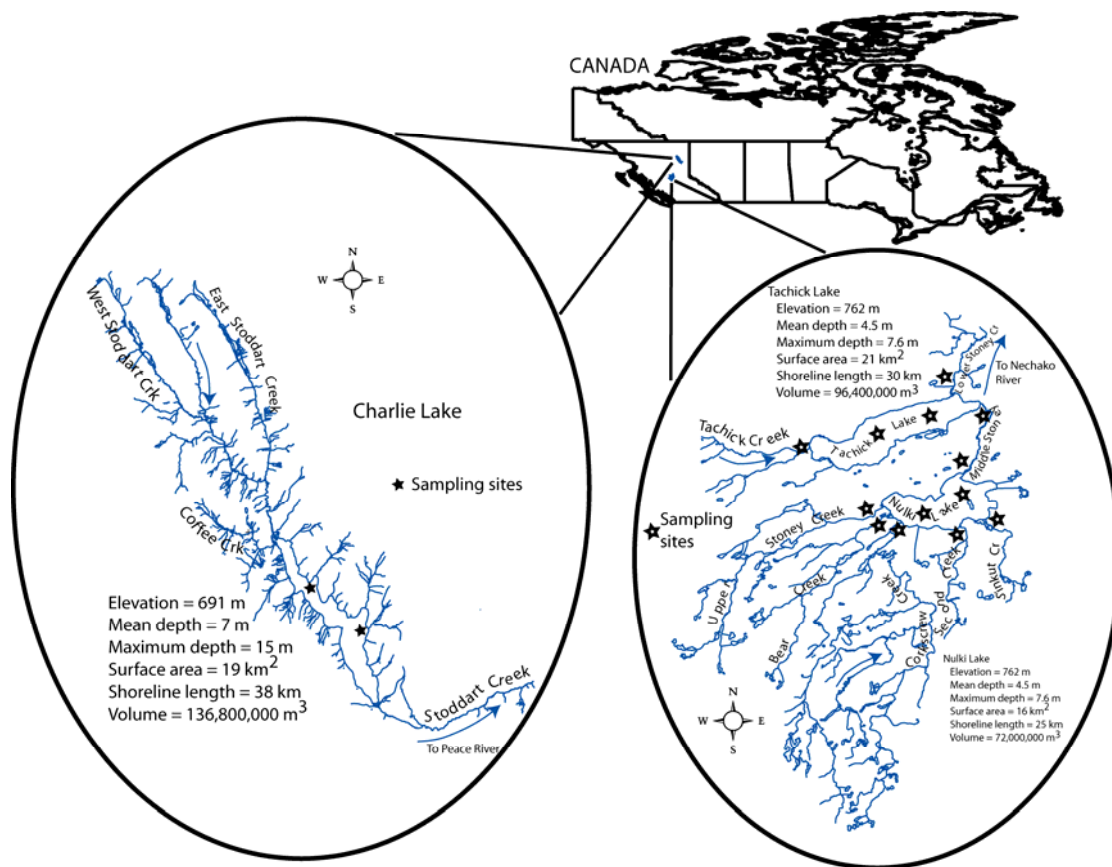


Figure 1. Maps of Charlie (Arctic drainage), Nulki and Tachick (Pacific drainage) lakes showing the location of sampling sites and morphometric statistics. Sampling sites were located at the deepest parts of the lakes.

The Nulki-Tachick watershed drains approximately 440 km<sup>2</sup> (estimated from 1:50,000 contour maps and includes the surface area of all lakes). Nulki Lake has a surface area of 16 km<sup>2</sup>, a volume of 72 x 10<sup>6</sup> m<sup>3</sup>, a shoreline length of 25 km and mean and maximum depths of 4.5 m and 7.6 m, respectively (Figure 1). The mean and maximum depths of Tachick Lake are the same as those of Nulki Lake. However, having a surface area of 21 km<sup>2</sup>, a volume of 96.4 x 10<sup>6</sup> m<sup>3</sup> and a shoreline length of 30 km, Tachick Lake is slightly larger than Nulki Lake. Nulki Lake has a flushing rate of about 1.3 vol/year, with that of Tachick Lake estimated as being

slightly slower at 1.0 vol/year. Shallow depths have permitted both lakes to develop extensive rooted macrophyte communities that are dominated by Canada pondweed (*Elodea canadensis*), coontail (*Ceratophyllum demersum*) and northern watermilfoil (*Myriophyllum exalbescens*), all of which grow in thick beds that extend to the lakes' surfaces in littoral areas. Macrophyte beds are most extensive in the western bays of Tachick Lake and in the outlet bay of Nulki Lake, where they can extend 100 m or more from shore.

Although it is widely believed that foreshore development (cabins and resorts) and agricultural and forestry-related land clearing within the watershed have accelerated eutrophication processes we suspect, given their shallow depths and low-gradient watersheds, that the lakes were highly productive even before human settlement (Rawson, 1955; Vallentyne, 1974). The long axes of Nulki and Tachick lakes are oriented in the direction of prevailing westerly winds. This orientation, in combination with the flat topography and shallow depths, makes the lakes highly susceptible to wind mixing, with large waves forming with even the slightest of winds. The turbulent nature of the lakes precludes them from developing stable thermal strata during the open-water seasons. During windy periods, water movements can disturb bottom sediments to the point where sediment is visibly mixed through the water columns.

### *Charlie Lake*

Charlie Lake is located in north-eastern British Columbia, approximately 9 km north-west of Fort St. John (population 16,000) (Figure 1). The watershed lies entirely within the Boreal-White-and-Black Spruce biogeoclimatic zone. Perhaps due to the frequency of historical forest fires and current land-management practices, forests in the Charlie Lake area are dominated by early seral species, with the most-dominant tree species being trembling aspen (*Populus tremuloides*). With the exception of the north-eastern shoreline of Charlie Lake which is steeply faced (sheer cliffs), the relief of the watershed is generally low (flat to gently rolling) to moderate (6 to 15% gradient) (Lord & Green, 1986). Reavie et al. (1995) used paleolimnological techniques to make inferences about the trophic history of Charlie Lake. They concluded that Charlie Lake was eutrophic before humans settled in the watershed, but that P concentrations in the lake have increased 3-fold since the early 1900s when settlers began clearing the landscape for agriculture and other uses. In support of this conclusion, French & Carmichael (1999) showed that P concentrations in Charlie Lake tributaries that flow through cleared lands are substantially higher than those observed in nearby control streams that flow through relatively intact catchments. According to recent estimates, 1,500 to 2,000 people live along the lake's shoreline with most of these people living in subdivisions developed on the south-western shores. Most shoreline residences are presently connected to a sewage system that pumps domestic wastes out of the watershed; however, homes and cabins were serviced by septic fields up until the early 1990s, many of which were known to seep into ditches that drained directly into the lake. Observations made from air photos and ground surveys indicate that  $\geq 50\%$  of Charlie Lake's watershed has been cleared for agriculture and other purposes. Surveys of 20 culvert-type tributary road crossings undertaken during the summer and autumn 2002 showed that 10 (50% of those surveyed) were perched well-above the stream channel and that several were too small in relation to the size of the channel. Large scour holes were often present downstream of culverts, suggesting that poorly functioning road crossings may be contributing substantial sediment and sediment-bound nutrient loads to Charlie Lake.

Charlie Lake has a shoreline length of 38 km, a volume of  $1.4 \times 10^8 \text{ m}^3$ , a surface area of  $19 \text{ km}^2$  and drainage area of  $281 \text{ km}^2$ . With mean and maximum depths of 7 and 15 m, Charlie Lake is somewhat deeper than Nulki and Tachick lakes. Charlie Lake's flushing rate of about 0.2 vol/year is considerably slower than those of

Nulki and Tachick lakes. Lake levels and outflow from the lake are controlled by a weir that was constructed across the outlet in the early 1980s. Lake-level data indicate that the weir resulted in a surface elevation increase of slightly more than 1 m. Although our datasets do not permit us to describe changes in lake ecology associated with the increase in lake depth, anecdotal information provided by several long-term watershed residents suggests that sediment-related turbidity has increased since the weir was constructed (presumably from shoreline erosion) and that the rooted macrophyte community virtually disappeared except for at the north end of the lake where macrophytes are still abundant. Charlie has 21 tributaries, most of which are ephemeral and dry up shortly after spring run off. The two largest tributaries (Stoddart and Coffee creeks) enter the lake from the north and, together, drain nearly 80% of the watershed. Charlie Lake is drained from the south by Lower Stoddart Creek (a.k.a. Fish Creek) (Figure 1). Lower Stoddart Creek flows for 20 km to where it joins the Beatton River which flows into the Peace River. The Peace River flows in a north-easterly direction to Great Slave Lake and subsequently into the Mackenzie River drainage which ultimately empties into the Beaufort Sea/Arctic Ocean.



Charlie Lake is located in a flat to gently rolling watershed that has had a large proportion of its land area cleared for agriculture and other purposes. Historic fires have also contributed to the maintenance of early seral tree species.



Unstable stream crossings in the Charlie Lake watershed are contributing sediment and sediment-bound nutrient loads to the lake and are thought to be accelerating lake in-filling and eutrophication rates.

The species composition of Charlie Lake's fish community is considerably different than that in the Nulki-Tachick watershed. Where the species inhabiting the Nulki-Tachick watershed are characteristic of the Pacific drainage, the species found in Charlie Lake are more representative of Peace-Arctic systems and include northern pike (*Esox lucius*), walleye (*Stizostedion vitreum*), yellow perch (*Perca flavescens*), burbot and a variety of forage species like spottail shiner (*Notropis hudsonius*), longnose sucker (*Catostomus catostomus*), flathead chub (*Platygobio gracilius*), reidside shiner (*Richardsonius balteatus*), trout perch (*Percopsis omiscomaycus*) and brook stickleback (*Culeae inconstans*) (Hambleton & Hambleton, 2002).



Overhead view of Charlie Lake's outlet (Lower Stoddart Creek, locally known as Fish Creek). The arrow is pointing to the weir that was constructed across the lake outlet. The weir regulates lake levels and has increased the maximum elevation of the lake's surface by about 1 m.

## Materials & Methods

### *Nulki and Tachick lakes*

Nulki and Tachick lakes were sampled once every two weeks between May 7 (spring) and November 12 (late autumn) 1997, and once in February 1998 when they were ice covered. Water samples for Tot-P and Tot-P<sub>diss</sub> were collected from near the surface (1-m depth) and near the bottom (1 m above sediments) at two deep sites (6 to 7-m depth) in each lake (Figure 1). Water for Tot-P<sub>diss</sub> analysis was filtered through a sterile syringe-fitted Nalgene® cellulose-acetate membrane (0.45 µm pores) in the field immediately after collection. O<sub>2</sub> and temperature profiles (0.5-m intervals from surface to bottom) were taken at each site with a calibrated YSI meter (Model 52). The pH of surface and bottom waters was measured in the field with an Accumet AP10 meter calibrated to pHs 4, 7 and 10. Samples (250-mL at 1-m depth) for algal biomass determinations (chl *a* concentration) were collected at the two deep sites, and at six limnetic sites randomly selected on each sampling trip. The samples were homogenised in a clean plastic pail; then two duplicate 500-mL sub-samples were taken. Each sub-sample was filtered through a 47-mm diameter Whatman® glass-fibre filter (1.2 µm). Non-filterable chl *a* residues were preserved on the filter with several drops of MgCO<sub>3</sub> and freeze-dried in an opaque thermos with desiccant stones. Tot-P and Tot-P<sub>diss</sub> (ascorbic acid – molybdate blue colourimetry to 0.002 mg/L, within 24 hr of collection) and chl *a* (MgCO<sub>3</sub> – acetone extraction to 0.1 µg/L) analyses were done by Environment Canada's Pacific Environmental Sciences Centre (Vancouver, BC). To facilitate P-loading computations (see below), P concentrations were converted to mass by multiplying average Tot-P concentration by lake volume. It was believed that the average of observed concentrations was an appropriate value from which to estimate the mass of P in the lakes because horizontal and vertical concentration gradients in the lakes were negligible (lakes were well mixed during the open-water season).

All Nulki-Tachick tributaries and outlets were sampled at their mouths and lake exits, respectively, for Tot-P and Tot-P<sub>diss</sub> once every three to five days between April 18 and May 7 (five freshet sampling trips) and once every two weeks between May 7 and November 12 1997 (13 sampling trips). Flows were measured continuously in Corkscrew Creek (Nulki Lake's primary tributary) (Figure 1), with a stage-calibrated pressure transducer. Flows in the smaller tributaries and outlets were measured when water samples were collected, with the velocity-area procedure described in Gordon et al. (1992). The Price AA current meter used to measure cross-channel velocities was calibrated by the federal government's National Calibration Service Laboratory (Burlington, Ontario) twice during the field season to ensure that it was functioning properly; once prior to the first sampling trip and again about half way through the summer.

Tributary P loads to Nulki and Tachick lakes were computed for the 1997 open-water season (May 7 to November 12) by multiplying Tot-P concentrations by flow. For days between sampling trips, Tot-P concentrations and flows were estimated by lineal interpolation (regression-based data filling between measured values). P exports via lake outlets were computed in the same manner. Rainwater volumes deposited on the lake surfaces were estimated daily by multiplying rain quantities (measured in mm) by lake surface. Rain quantities were measured with an MSC rain gauge (35-mm opening) positioned near Vanderhoof (15 km north of the Nulki-Tachick watershed). Daily rainwater P loads to the lakes were computed by multiplying rainwater volumes (m<sup>3</sup>) by an assumed Tot-P concentration of 30 mg/m<sup>3</sup> (Shaw et al., 1989; Wetzel, 1983: p. 280). Dry (e.g., dust, pollen, aerosols) atmospheric P loading rates were assumed to approximate 0.07 mg Tot-P/m<sup>2</sup>/day (Shaw et al., 1989).

## *Charlie Lake*

Charlie Lake was sampled monthly between April and November (ice-free months) and at least twice per year during winter ice-covered periods (December to March) for the duration 1990 to 1994. Vertical temperature and O<sub>2</sub> profiles (1-m intervals from surface to bottom) were taken at two deep sites (15-m depth), one located in the northern half of the lake and the other in the south (Figure 1), with a calibrated YSI O<sub>2</sub>-temperature meter. Samples for algal biomass (chl *a* concentration) were collected at arms reach at the deep sites, and processed as described for Nulki and Tachick lakes. To assess how algal biomass cycles in relation to potential nutrient availability, water samples for nutrient analyses were collected from the surface (1-m depth), mid-depth (or metalimnion during stratified periods) and from about 1 m above the bottom sediments (hypolimnion during stratified periods). Prior to initiating this study, we did not know which nutrient(s), if any, limited algal production in Charlie Lake so we chose to analyse our water samples for both P- (Tot-P and Tot-P<sub>diss</sub>) and N- (NO<sub>2</sub>+NO<sub>3</sub>+NH<sub>4</sub>, or Inorg-N<sub>diss</sub>) based nutrients, which are largely believed to limit or co-limit algal production in northern temperate lakes (e.g., Dillon & Rigler, 1974; Schindler, 1977; Schindler et al. 1971; Smith, 1979; Prepas & Trew, 1983; Chang & Petersen, 1995). Lund (1954, 1955), Schelske et al. (1984), Hecky et al. (1986), French et al. (2000), and Koski-Vähälä et al. (2001) presented evidence that diatoms can be seasonally limited by Si availability, presumably because they require the element for frustule formation, and that Si concentrations in the water column, like P concentrations, are largely controlled by within-lake equilibria; thus we also analysed our 1990 and 1991 water samples for total dissolved Si concentration (Tot-Si<sub>diss</sub>). Water samples for dissolved fractions (e.g., Tot-P<sub>diss</sub>, Tot-Si<sub>diss</sub> and Inorg-N<sub>diss</sub>) were not filtered on site as they were for Nulki and Tachick lakes; rather, they were filtered in the laboratory within 24 hr of collection. Samples were kept cold and in the dark during the time between collection and analysis. Tot-P, Tot-P<sub>diss</sub> (ascorbic acid – molybdate blue colourimetry to 0.002 mg/L), chl *a* (MgCO<sub>3</sub> – acetone extraction to 0.1 µg/L), Tot-Si<sub>diss</sub> (HCl digestion, loss-on-ignition procedure to 0.5 mg/L), NO<sub>2</sub> (diazotizing with sulfanilamide and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride, colourimetry to 0.02 mg/L), NO<sub>3</sub> (cadmium reduction to NO<sub>2</sub>, colourimetry to 0.02 mg/L) and NH<sub>4</sub> (nesslerization method to 0.005 mg/L) analyses were done by Zenon Environmental Laboratories (Burnaby, BC). The pH of surface, mid-depth and bottom waters was measured in the laboratory with a calibrated meter when nutrient analyses were being performed. The analytical methods used for water analyses closely followed those described in Greenberg et al. (1992).

The taxonomic composition (taxon-specific cell counts) of Charlie Lake's algal community was described from 1-L surface samples (1-m depth) collected at the north and south deep stations in the years 1984 (September 22 and 26), 1988 (April 28, May 31), 1990 (May 15, August 15, September 11, October 15), 1991 (March 27, May 8 and 30, June 20, July 23, September 10, October 24) and 1992 (March 12, May 6). While the irregular sampling schedule precluded us from undertaking a detailed analysis of algal population dynamics at a taxonomic level, these data do provide useful information on how community composition changes seasonally.

## **Results**

### *Nulki and Tachick lakes*

Near-surface algal biomass ranged from 1 to 112 µg/L chl *a* (Ave = 35 µg/L) in Nulki Lake, and from <1 to 101 µg/L chl *a* (Ave = 29 µg/L) in Tachick Lake during the period May 1997 to February 1998 (Figure 2). Biomass in Nulki Lake was relatively low from May to mid-July (6 to 27 µg/L chl *a*) and from late October to February (1 to 11 µg/L chl *a*). Biomass maxima in Nulki Lake (71 to 112 µg/L chl *a*) occurred between late July and early October with brief biomass declines, presumably resulting from the combined affects of grazing, sedimentation/sinking, parasitism, cell mobility, changes in light and nutrient availability, decomposition,

parasitism (Jassby & Goldman, 1974; Porter, 1977; Tilzer & Goldman, 1978; Lehman & Sandgren, 1985; Humphries & Lyne, 1988; Miyajima et al., 1994; Gervais, 1998; Fahnenstiel et al., 2000; Kvitsov et al., 2000) and, perhaps, strong wind-mixing that may have resulted in the dilution of near-surface chl a (Toetz, 1981; Visser et al. 1996), occurring in mid-August (decline to 35  $\mu\text{g/L}$  chl a) and mid-September (decline to 19  $\mu\text{g/L}$  chl a) (Figure 2a).

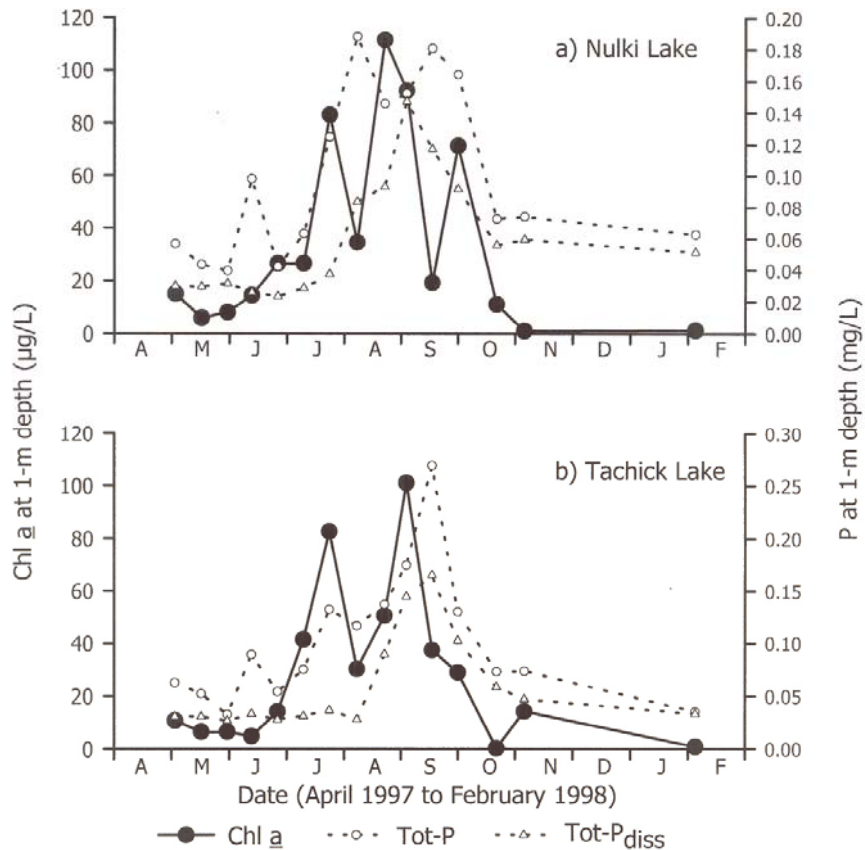


Figure 2. Chl a, Tot-P and Tot-P<sub>diss</sub> patterns observed in Nulki (panel a) and Tachick (panel b) lakes for the period April 1997 to February 1998. Maximum chl a and P concentrations were associated with internal P loading events (see Figure 3). Data shown are the averages of concentrations observed at the east and west deep sites.

As observed in Nulki Lake, algal biomass in Tachick Lake was relatively low in May and June (5 to 14  $\mu\text{g/L}$  chl a) and from late October to February (<1 to 14  $\mu\text{g/L}$  chl a), with biomass maxima (83 to 101  $\mu\text{g/L}$  chl a) occurring between mid-July and mid-September (Figure 2b). The mid-August and mid-September biomass declines observed in Nulki Lake were also observed in Tachick Lake; however, biomass in Tachick Lake did not increase again after the mid-September decline, as it did in Nulki Lake (Figure 2). Although taxonomic analyses of the lakes' algal communities were not undertaken as part of this study, data presented in a consultant's report indicate that near-surface grab samples for taxonomy were collected from Nulki Lake in early July 1989 and late August 1996, and from Tachick Lake once in late August 1996. As presented in AEE (1999), blooms in Nulki Lake were dominated (in terms of cell numbers) by the cyanophyte (or blue-green algae/cyanobacteria) species *Aphanizomenon flos-aquae*, *Anabaena flos-aquae* and *Anacystis* spp. While very few *Anacystis* and *Anabaena* were observed in the Tachick Lake grab sample, *Aphanizomenon flos-aquae* densities in Tachick Lake were similarly high.

Near-surface algal biomass in Nulki and Tachick lakes generally tracked Tot-P and Tot-P<sub>diss</sub> concentrations measured at 1-m depth (Figure 2). The low biomasses observed in Nulki Lake during the spring, early summer and late autumn were associated with relatively low average Tot-P and Tot-P<sub>diss</sub> concentrations of 0.06 and 0.04 mg/L, respectively (Figure 2a). In comparison, the summer biomass maxima observed in Nulki Lake occurred when Tot-P (Ave = 0.16 mg/L) and Tot-P<sub>diss</sub> (Ave = 0.10 mg/L) concentrations were seasonally high. A similar positive association between P concentration and algal biomass was observed in Tachick Lake, such that the low spring, early summer and late autumn biomasses occurred when Tot-P (Ave = 0.06 mg/L) and Tot-P<sub>diss</sub> (Ave = 0.03 mg/L) concentrations were low, and the high mid-summer biomasses when Tot-P (Ave = 0.15 mg/L) and Tot-P<sub>diss</sub> (Ave = 0.09 mg/L) concentrations were high (Figure 2b). The high P concentrations observed in Nulki and Tachick lakes between mid-July and early October occurred several weeks after the period of maximum external loading (i.e., tributary + atmosphere sources), suggesting that the P loads that were associated with the summer and autumn algal blooms came largely from within-lake sources (Figure 3). In agreement with this conclusion, mass balance computations based on differences between external P loads to the lakes and P export via outlet streams showed that 97% of the P that entered Nulki (12,382 kg P) and Tachick (17,694 kg P) lakes during high biomass periods came from within the lakes (Table 1). The contribution of within-lake P sources to the total P budget of the lakes was also substantial between May and mid-July, being about 70% over this time period for both lakes (Table 1).

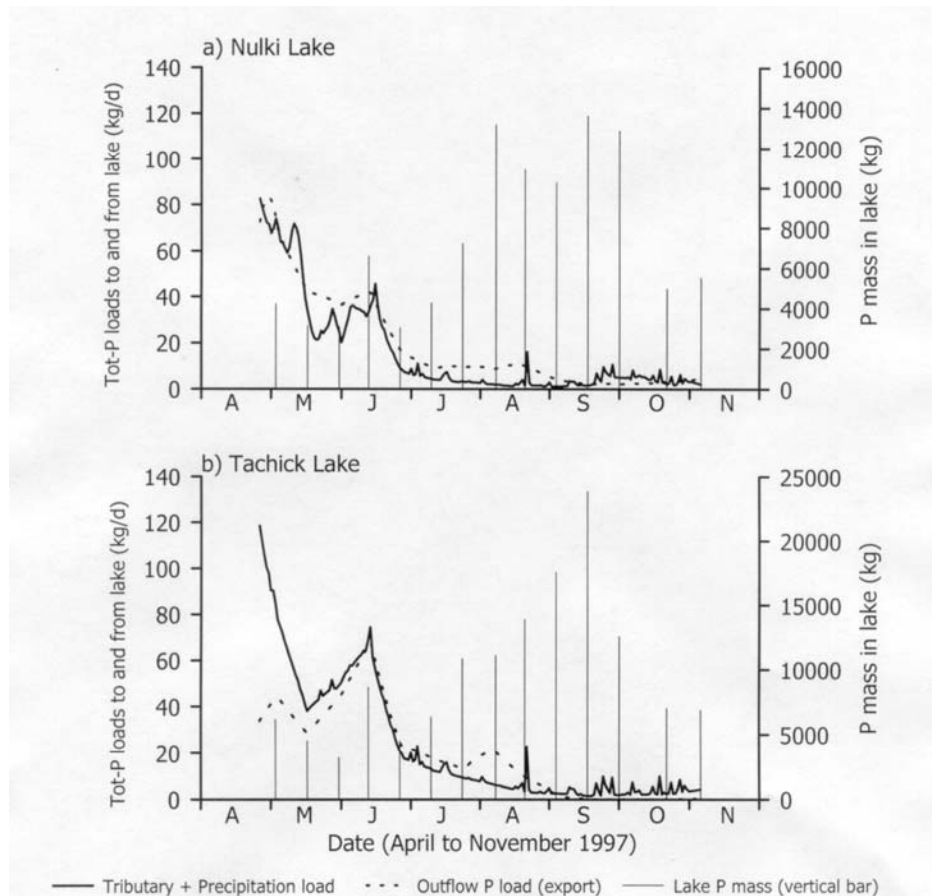


Figure 3. External P loading (tributary + atmospheric) and P export (outlet streams) rates to and from Nulki (panel a) and Tachick (panel b) lakes, and estimated P mass in lakes (vertical bars). External P loading and P export via outlets were approximately equal in August and September when the P mass in the lakes was greatest, suggesting that the observed increase in P mass was the result of internal loading processes.

Table 1. Phosphorus loading rates to Nulki and Tachick lakes for the period May to October, 1997.

Period	Tributary load (Total kg P)	Atmosphere (Total kg P)	Internal (Total kg P)	Total (Total kg P)
I. Nulki Lake				
May to mid-July	2,018 (28%)	122 (2%)	4,993 (70%)	7,133
Mid-July to early October	199 (2%)	162 (1%)	12,382 (97%)	12,743
II. Tachick Lake				
May to mid-July	3,000 (29%)	159 (2%)	7,224 (69%)	10,383
Mid-July to early October	413 (2%)	214 (1%)	17,694 (97%)	18,321

Given that their east-west orientation, topographic exposure and shallow depths make them highly susceptible to wind-induced mixing, it is not surprising that Nulki and Tachick lakes were functionally isothermal (typically < 1-°C variation from surface to bottom, and always < 3-°C variation) throughout the May to November ice-free period (Figure 4a). Reflecting the high degree of thermal mixing, Tot-P and Tot-P<sub>diss</sub> concentrations were uniform from the surface to 1 m above the bottom of both lakes during the ice-free seasons, even during the mid-July to early October periods of intense internal P loading. Similarly, O<sub>2</sub> concentrations changed little from the surface to 1 meter above the bottom in both lakes during the ice-free period and were typically > 7 mg/L through the water column. Water temperatures in both lakes increased from about 5 °C in early May to nearly 20 °C in June through mid-September, with temperatures gradually decreasing through the autumn and winter months (Figure 4a). The seasonal pH profiles of Nulki and Tachick lakes were similar in pattern to those observed for chl *a* and P, such that surface and bottom pHs were high (typically >9) when algal biomass and internal P loading were greatest, and relatively low (typically ≤8) when biomass and internal P loading were lowest (Figure 4b). While the lakes were typically well mixed during the ice-free months, they were inversely stratified (i.e., temperature increased with increasing depth) and anoxic below 5-m depth in February when they were frozen over. February Tot-P and Tot-P<sub>diss</sub> concentrations in Tachick Lake were about 3-fold higher in the deep anoxic strata (0.14 and 0.08 mg/L, respectively) than they were near the surface (0.04 and 0.03 mg/L); however, winter P concentrations in Nulki Lake were relatively uniform from the surface to the bottom during the winter sampling trip.

### Charlie Lake

Although Charlie Lake is located 350 km north-east of Nulki and Tachick lakes, and within a different watershed and biogeoclimatic zone, the seasonal biomass cycle of Charlie Lake's algal community was remarkably similar to that observed in Nulki and Tachick lakes. As in Nulki and Tachick lakes, biomass maxima (93 +/- 18 µg/L chl *a*; Ave +/- 1 S.E.) in Charlie Lake were consistently observed between mid-July and mid-September over the years 1990 through 1994, with biomasses being comparatively low for the periods January to April (4 +/- 2 µg/L chl *a*) and October to December (23 +/- 8 µg/L chl *a*) (Figure 5a). Although biomass maxima in Charlie Lake were most conspicuous during the late summer and early autumn, the lake appears to experience a minor, yet notable, bloom in early May just after ice off (Figure 5a; Figure 6). The species composition of Charlie Lake's algal community is variable, with some species being most prevalent

during winter and spring months, and others dominating, in terms of cell numbers, the community in the early summer and autumn months (Figure 6). As observed during the winters of 1991 and 1992, the algal community was strongly dominated by cryptophytes (*Chroomonas* spp. and *Cryptomonas* spp.) and chrysophytes (*Mallomonas* spp. and *Dinobryon* spp.) during ice-covered months when the lake was inversely stratified (Figure 6; Table 2). Following spring melt and the onset of spring mixing, community dominance shifted to strongly favour the bacillariophytes (diatoms) which had an average density of just over 8,000 cells/mL (or 90% total cell count) for the month of May (Figure 6). The spring bacillariophyte bloom was primarily represented by centric forms (Centrales) like *Cyclotella* spp. and *Stephanodiscus* spp. (Table 2). During the month of June when the lake was typically weakly stratified, the algal community was dominated by the chlorophyte species *Sphaerocystis schroeteri*, *Eudorina* spp., *Quadrigula lacustris* and *Schroederia* spp., which together comprised about 90% (or 1,000 cells/mL) of the total cell count during our single June observation (Figure 6; Table 2). As shown in Figure 6, total cell counts were typically < 1,000 cells/mL from March through June when the community was dominated by either cryptophytes, chrysophytes, bacillariophytes or chlorophytes, with a brief density maximum approaching, on average, nearly 10,000 cells/mL during the spring (early May) bacillariophyte bloom (Figure 6). However, following late summer/autumn thermal mixing events, cell densities increased dramatically, typically reaching a maximum density in September when total cell counts averaged nearly 80,000 cells/mL (Figure 6). The late summer/autumn blooms were comprised primarily of a mixture cyanophytes in the orders Nostocales, Oscillatoriales and Chroococcales. Our observations indicate that *Aphanizomenon flos-aquae*, *Oscillatoria tenuis* and *Anacystis aeruginosa* were, in terms of cell numbers, the dominant species in the late summer/autumn blooms (Table 2). Although bacillariophytes only comprised a small proportion (<1%) of the total cell count during the months of August and September, they also increased in abundance following late summer/autumn mixing as they did following spring mixing (Figure 6). The spring and late/summer bacillariophyte blooms were similar in that they both occurred after thermal mixing events; however, where the spring blooms were comprised primarily of centric forms the late summer/autumn blooms were dominated by pennate forms (Pennales) like *Fragilaria capucina* (Table 2). Another notable difference between the spring and late summer/autumn bacillariophyte blooms was that the spring blooms attained densities (Ave = 8,000 cells/mL) several-fold greater than the late summer/autumn blooms (Ave = 700 cells/mL).

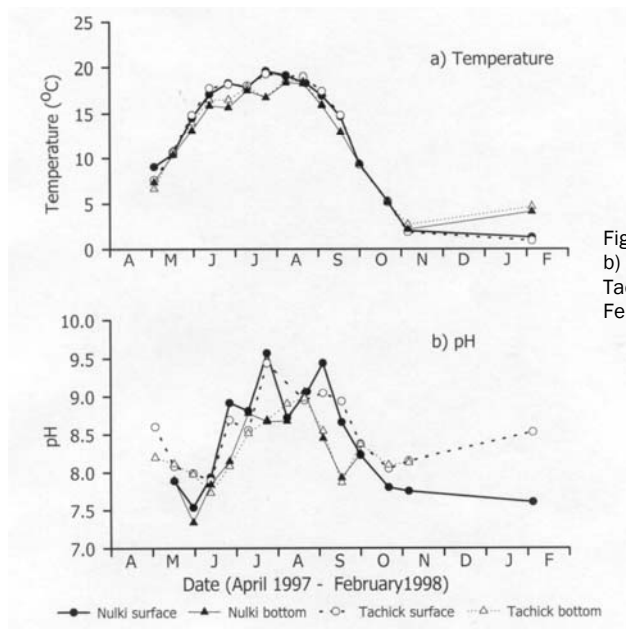
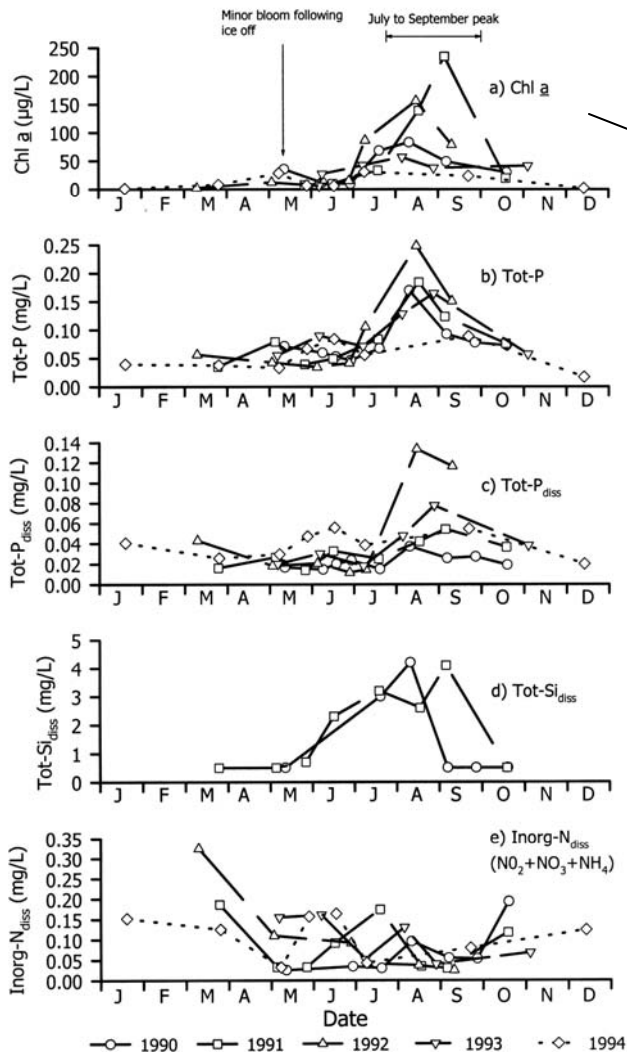


Figure 4. Temperature (panel a) and pH (panel b) of surface and bottom waters in Nulki and Tachick lakes during the period April 1997 to February 1998.



Dense algal bloom observed in Charlie Lake during the late summer/early autumn. Observed turbulence caused by a boat motor.

Figure 5. Chl  $a$  (panel a), Tot-P (panel b), Tot-P<sub>diss</sub> (panel c), Tot-Si<sub>diss</sub> (panel d) and Inorg-N<sub>diss</sub> (panel e) patterns observed in Charlie Lake during the period 1990 to 1994. As shown, algal biomass (chl  $a$ ) at 1-m depth tracked P and Si concentrations. Data shown are the averages of concentrations observed at the south and north deep sites.

As were Nulki and Tachick lakes, Charlie Lake was inversely stratified during the winter months when it was frozen over, with strata below 6-m depth being effectively anoxic (Figure 7a,b). Tot-P concentrations (nearly 1 mg/L) in the deep anoxic strata were several-fold greater than those in strata above 6 m (0.04 mg/L) which had O<sub>2</sub> concentrations up to 8 mg/L (Figure 7a,b). Winter Si profiles in Charlie Lake resembled winter P profiles, such that Tot-Si<sub>diss</sub> concentrations were elevated to nearly 18 mg/L in the anoxic strata below 6-m depth, as compared to the aerobic strata above 6 m that had concentrations typically < 3 mg/L (Figure 8a). The vertical profile data indicate that winter stratification usually breaks down sometime between ice-off and early to mid-May when the lake mixes and develops isothermal conditions (Figure 7c). During spring mixing, the P- and Si-enriched deep waters mixed with the relatively dilute surface waters, with this mixing resulting in a substantial increase in surface-strata concentrations (Figures 7c and 8b). The vertical profile data collected between 1990 and 1994 indicate that Charlie Lake becomes stratified following spring mixing, with stratified

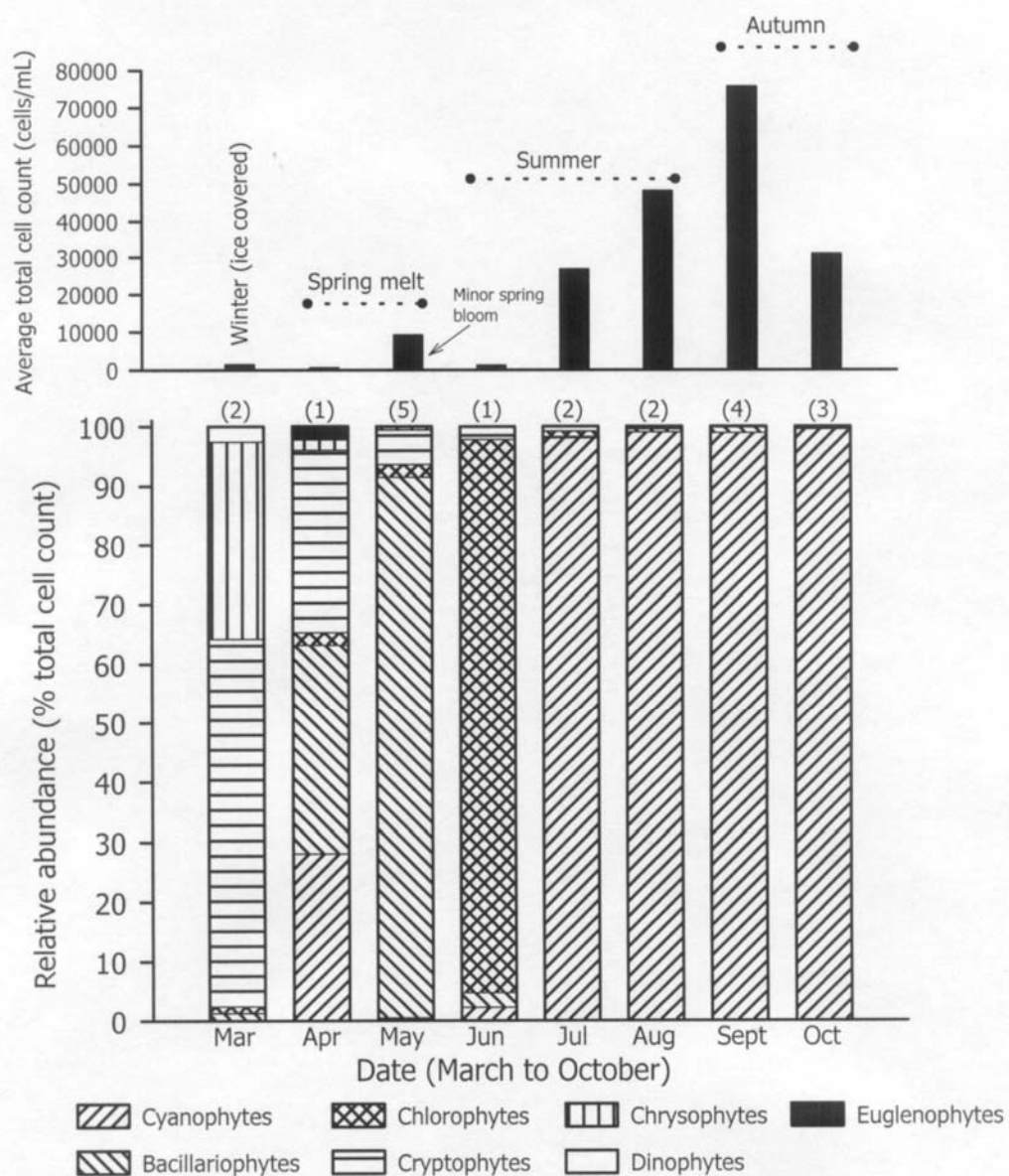


Figure 6. Average total algal cell count (top panel) and taxon-specific relative abundance (bottom panel) observed in Charlie Lake during the period 1984 to 1992. Relative abundance estimates were based on average cell counts observed during a particular month. Bracketed numbers above bars are the total number of observations made during a particular month (for example, data for the month of May was based on five taxonomy samples collected in that month over the period 1984 to 1992).

periods typically extending from late-may/early June through mid-July/early August (Figure 7d,e,f). The data indicate that thermal stratification in Charlie Lake was somewhat unstable, such that short isothermal periods occurred during the summer months following strong wind events that can cause considerable turbulence. As occurred during the ice-covered winter months, deep strata in Charlie Lake became nearly anoxic during summer-stratified periods (Figure 7f). The primary difference in the degree of deep-water anoxia between winter and summer-stratified periods was that the thickness of the anoxic zone was about 8 m during the winter (bottom up to 6-m depth strata; Figure 7a) and only about 3.5 m during summer-stratified periods

(bottom up to 10.5-m depth strata; Figure 7f), with this difference, we believe, being primarily attributable to wind energy that is present during open-water seasons and absent during ice-covered winter months. Vertical Tot-P, Tot-P<sub>diss</sub> and Tot-Si<sub>diss</sub> concentration gradients observed during summer stratified periods were similar to those observed during winter months when the lake was inversely stratified, such that concentrations in deep anoxic strata were substantially greater than those in aerobic surface strata (Figures 7f and 9a). However, where deep-water Tot-P concentrations approached 1 mg/L during the winter months, they only approached 0.18 mg/L during summer-stratified periods (Figure 7b,f). Similarly, Tot-Si<sub>diss</sub> concentrations observed in deep strata during the winter months (nearly 18 mg/L; Figure 8a) were substantially greater than those observed during summer-stratified periods (< 7 mg/L; Figure 9a). With the onset of cooling autumn temperatures, thermal stratification in Charlie Lake is typically lost between mid-July and mid-August (Figure 7g,h). Late summer/autumn mixing results in the P- and Si-enriched deep waters being circulated with more-dilute surface waters and, thereby, the nutrient enrichment of the photic zone (Figures 7g,h and 9b). Given that the increases in P and Si concentrations observed during the early spring and late summer/autumn months appeared to originate within bottom strata and that they did not occur in association with freshet or other high-runoff periods, it is highly likely that the concentration maxima were the result of internal-loading processes.

Table 2. Species composition of Charlie Lake's algal community as observed at the north and south deep sites for the period 1984 to 1992. VR means observed "very rarely".

Taxon	Maximum observed abundance (cells mL <sup>-1</sup> )	Taxon	Maximum observed abundance (cells mL <sup>-1</sup> )	Taxon	Maximum observed abundance (cells mL <sup>-1</sup> )
<b>a) Cyanophyta (blue-greens)</b>		<b>b) Bacillariophyta (diatoms)</b>		<b>c) Chlorophyta (greens)</b>	
Order Nostocales		Order Pennales		Order Chlorococcales	
<i>Anabaena</i> sp.	135	<i>Achnanthes minutissima</i>	VR	<i>Ankistrodesmus</i> sp.	VR
<i>Anabaena affinis</i>	VR	<i>Amphora</i> sp.	3	<i>Ankistrodesmus falcatus</i>	5
<i>Anabaena flos-aquae</i>	582	<i>Asterionella formosa</i>	639	<i>Ankyra</i> sp.	3
<i>Aphanizomenon</i> sp.	3	<i>Cocconeis</i> sp.	VR	<i>Botryococcus braunii</i>	VR
<i>Aphanizomenon flos-aquae</i>	365,838	<i>Cyamatopleura</i> sp.	3	<i>Dictosphaerium</i> sp.	VR
Order Oscillatoriales		<i>Cyamatopleura solea</i>	VR	<i>Elaktothrix</i> sp.	VR
<i>Lyngbya</i> sp.	VR	<i>Cymbella</i> sp.	5	<i>Elaktothrix gelatinosa</i>	16
<i>Oscillatoria limnetica</i>	233	<i>Cymbella affinis</i>	VR	<i>Nephrocystium</i> sp.	VR
<i>Oscillatoria tenuis</i>	71,231	<i>Diatoma</i> sp.	3	<i>Oocystis</i> sp.	10
<i>Pseudoanabaena catanata</i>	73	<i>Epithema</i> sp.	VR	<i>Oocystis borgei</i>	VR
Order Chroococcales		<i>Epithema soxer</i>	VR	<i>Pediastrum</i> sp.	1
<i>Agmenellum</i> sp.	VR	<i>Eunotia</i> sp.	3	<i>Quadrifida</i> sp.	3
<i>Agmenellum tenuissima</i>	VR	<i>Fragilaria</i> sp.	907	<i>Quadrifida lacustris</i>	260
<i>Anacystis</i> sp.	10	<i>Fragilaria capucina</i>	1,884	<i>Scendesmus</i> sp.	VR
<i>Anacystis aeruginosa</i>	20,229	<i>Fragilaria construens</i>	434	<i>Scendesmus quadricauda</i>	10
<i>Anacystis limneticus</i>	VR	<i>Fragilaria crotonensis</i>	10	<i>Schroederia</i> sp.	238
<i>Aphanocapsa</i> sp.	VR	<i>Frustrulia</i> sp.	VR	<i>Schroederia judayi</i>	245
<i>Coelosphaerium</i> sp.	VR	<i>Gomphonema</i> sp.	VR	<i>Schroederia setigera</i>	5
<i>Coelosphaerium naegelianum</i>	980	<i>Navicula</i> sp.	25	<i>Sphaerocystis schroeteri</i>	1,333
<i>Dactylococcopsis</i> sp.	VR	<i>Nitzschia</i> sp.	3	<i>Selanastrum</i> sp.	VR
<i>Gomphosphaerium</i> sp.	50	<i>Pleurosigma</i> sp.	VR	<i>Tetraedron minimum</i>	VR
<i>Gomphosphaerium naegelianum</i>	5,986	<i>Synedra</i> sp.	1	Order Volvocales	
<i>Gomphosphaerium pallidum</i>	VR	<i>Synedra uina</i>	5	<i>Chlorogonium</i> sp.	5
<b>d) Cryptophyta (cryptomonads)</b>		<i>Tabellaria</i> sp.	32	<i>Eudorina elegans</i>	34
Order Cryptomonadales		<i>Tabellaria fenestrata</i>	5	<i>Eudorina</i> sp.	438
<i>Chroomonas acuta</i>	2,018	Order Centrales		<i>Volvox</i> sp.	31
<i>Cryptomonas</i> sp.	175	<i>Coscinodiscus</i> sp.	VR	<i>Pandorina morum</i>	51
<i>Cryptomonas acuta</i>	336	<i>Cyclotella</i> sp.	190	Order Tetrasporales	
<i>Cryptomonas marssonii</i>	8	<i>Cyclotella bodanica</i>	3	<i>Gloeocystis</i> sp.	13
<i>Cryptomonas ovata</i>	473	<i>Cyclotella glomerata</i>	81	Order Zygnematales	
<b>e) Chrysophyta (golden-browns)</b>		<i>Melosira</i> sp.	41	<i>Closterium</i> sp.	VR
Order Ochromonadales		<i>Stephanodiscus</i> sp.	104	<i>Cosmarium</i> sp.	3
<i>Dinobryon</i> sp.	12	<i>Stephanodiscus astera</i>	40,178	<i>Staurastrum</i> sp.	3
<i>Dinobryon divergens</i>	172	<i>Stephanodiscus niagarae</i>	59	<i>Staurastrum natator</i>	VR
<i>Mallomonas</i> sp.	26	<b>g) Euglenophyta (euglenas)</b>		<i>Staurastrum paradoxum</i>	VR
<i>Mallomonas akromos</i>	1,263	Order Euglenales			
<b>f) Dinophyta (dinoflagellates)</b>		<i>Euglena</i> spp.	8		
Order Dinokontae		<i>Trachelemonas</i> spp.	12		
Dinoflagellate spp.	125				
<i>Ceratium hirundinella</i>	3				

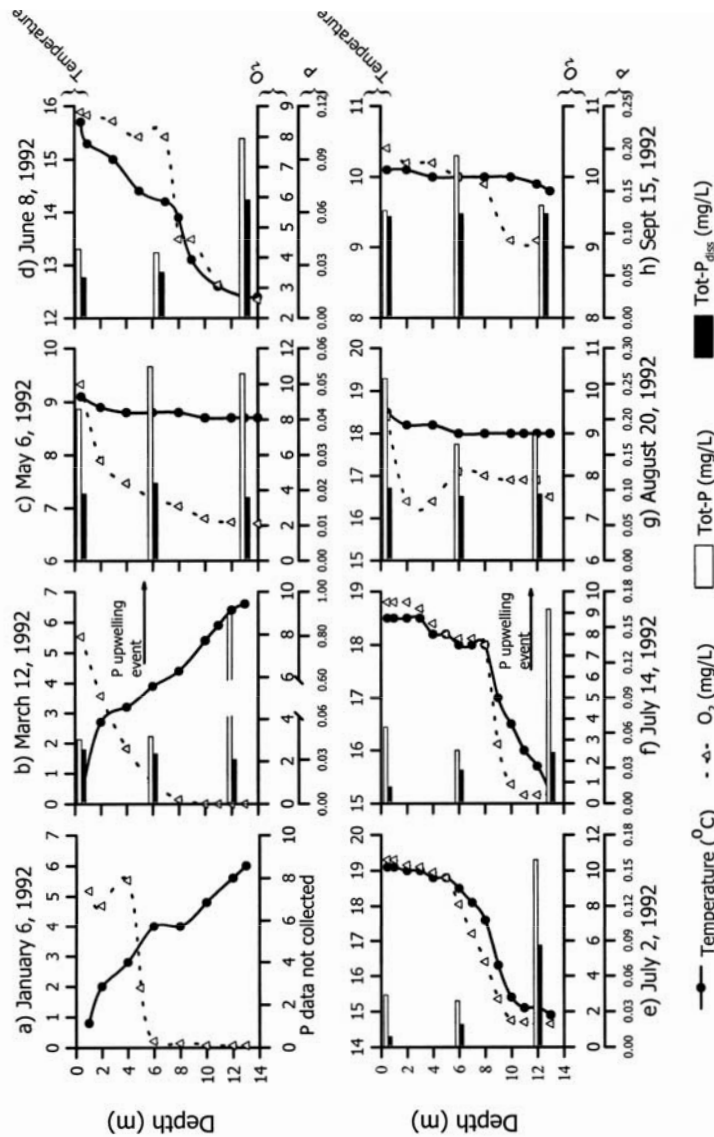


Figure 7. Representative temperature, O<sub>2</sub>, Tot-P and Tot-P<sub>diss</sub> profiles observed in Charlie Lake (January to September, 1992). As shown, P-enriched bottom waters are carried to the surface where the entrained P can be used by phytoplankton: once during spring mixing (panels b and c) and again during late-summer mixing (panels f and g). Data shown are from the north deep site.

While the spring and late summer/autumn increases in near-surface P and Si concentrations were clearly linked to thermal mixing events that carried enriched bottom waters to surface strata, seasonal changes in near-surface Inorg-N<sub>diss</sub> concentrations did not appear to be associated with thermal mixing events. Unlike P and Si that accumulated in deep strata during the winter and summer-stratified months, differences between bottom and near-surface Inorg-N<sub>diss</sub> concentrations were negligible throughout the study period. Near-surface Inorg-N<sub>diss</sub> concentrations were generally the highest during the ice-covered winter months (e.g., March and April), when they reached nearly 0.35 mg/L (Figure 5e). There were no clear patterns in Inorg-N<sub>diss</sub> concentration between the months of May through July, but concentrations tended to decline to < 0.1 mg/L in August through mid-September during cyanophyte biomass maxima (Figure 5e). Inorg-N<sub>diss</sub> concentrations increased again in October and November following the late summer/autumn blooms and the onset of winter (Figure 7e).

As occurred in Nulki and Tachick lakes, near-surface pH was in the range of 9.0 to 9.5 during the late summer and early autumn when algal biomass was greatest, and was typically  $\leq 8.0$  when algal biomass was minimal (Figure 10a). While the pH in deep strata was  $> 9.0$  in August and September 1992, seasonal patterns in pH were less evident in deep strata than they were in near-surface strata (Figure 10b), suggesting that seasonal changes in near-surface pH may be the direct result of algal photosynthesis.

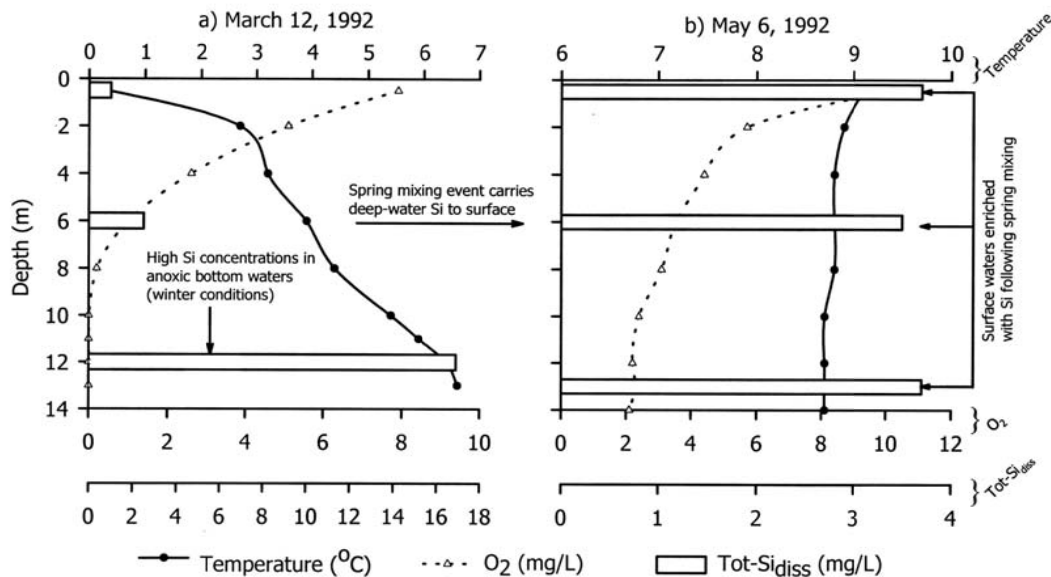


Figure 8. Representative winter (panel a) and spring (panel b) Tot-Si<sub>diss</sub> profiles observed in Charlie Lake in 1992. As shown, Si concentrations build up in bottom waters during the winter months. The Si-enriched bottom waters are carried to the surface during spring mixing. The deep-water Si carried to the surface during spring mixing may stimulate spring diatom production.

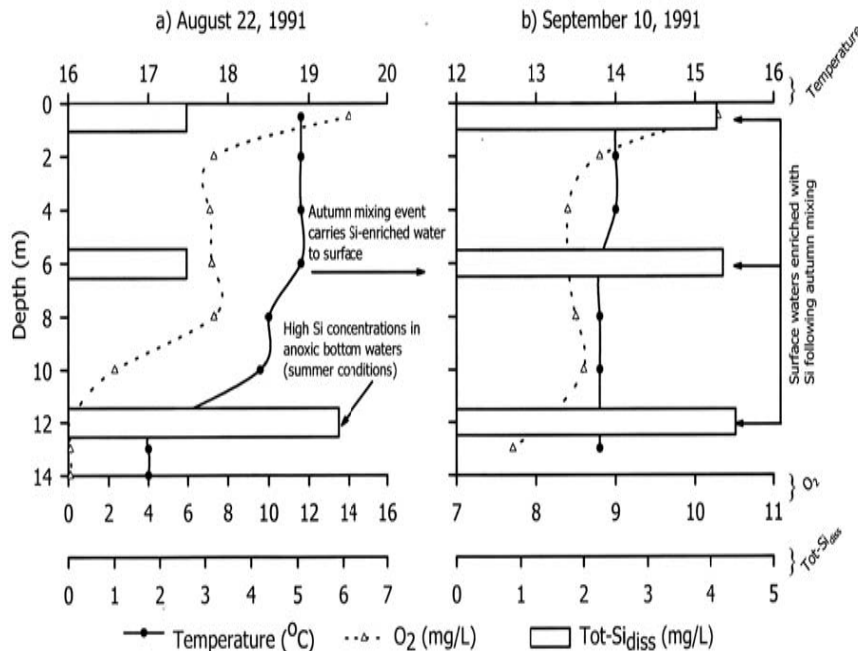


Figure 9. Representative late summer (panel a) and autumn (panel b) Tot-Si<sub>diss</sub> profiles observed in Charlie Lake in 1991. As shown, Si-concentrated hypolimnetic waters are carried to the surface during autumn mixing, perhaps stimulation late-summer/autumn diatom production.

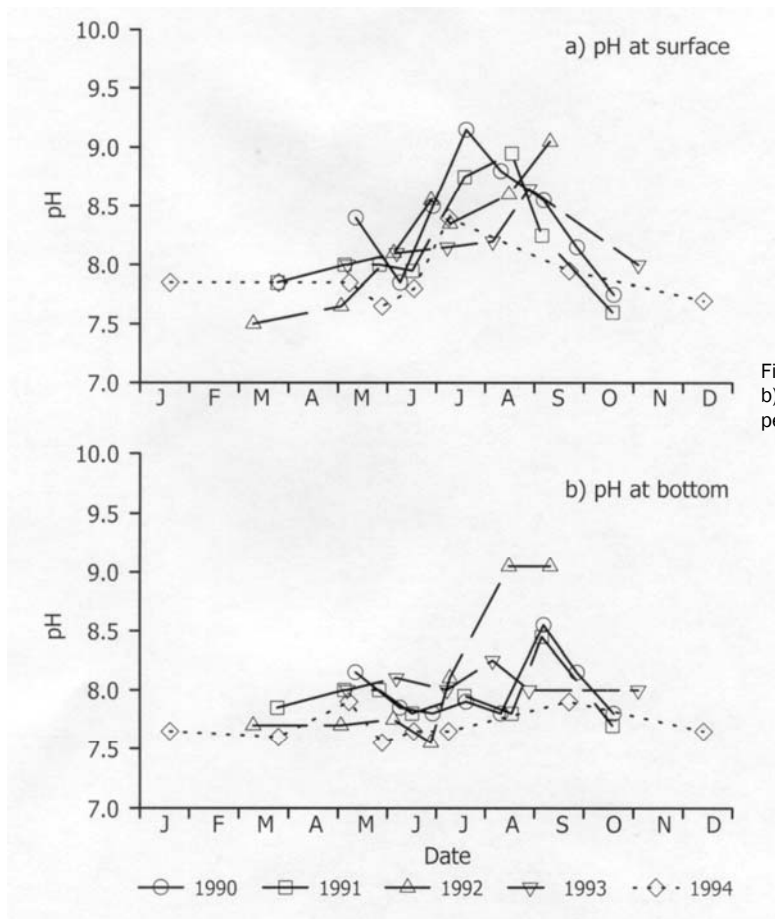


Figure 10. Surface (panel a) and bottom (panel b) water pH observed in Charlie Lake during the period 1990 to 1994.

## Discussion

The seasonal succession and biomass cycles of freshwater algal communities have been described for many large and small lakes in equatorial/tropical (Kalff, 1983; Talling, 1966, 1986; Zafar, 1986), north and south temperate (Lund, 1954, 1955; Megard & Smith, 1974; Smith, 1979; Hecky et al., 1986; Munawar & Munawar, 1986) and, to lesser extents, in polar (Rawson, 1953; Kalff, 1967; Sheath, 1986; Roberts & McMinn, 1996) regions of the world (see *Hydrobiologia*, Vol. 138 review series). From our investigations of algal seasonality in Charlie, Nulki and Tachick lakes it was determined that seasonal patterns of algal biomass in surface strata were consistent with respect to timing from year to year. Data collected from Charlie Lake over the period 1990 through 1994 showed that biomass maxima consistently occurred during the late summer (mid-July) through early autumn (mid-September) when chl  $a$  maxima almost always exceeded 100  $\mu\text{g/L}$  and, in more extreme cases, approached 250  $\mu\text{g/L}$  (Figure 5a). In contrast, biomass minima in Charlie Lake consistently occurred during the autumn (late September through November) and during the winter months (December through March) when the lake is almost always frozen over. While algal biomass was always greatest in Charlie Lake during the late summer/early autumn bloom, our data show that there was typically a temporally-short, low-biomass bloom in the early spring (late April/early May) shortly following ice off, when biomass maxima sometimes approached 50  $\mu\text{g/L}$  (Figure 5a).

Although Nulki and Tachick lakes are located more than 300 km away from Charlie Lake and are within a completely different watershed and biogeoclimatic zone, the cycle of algal biomass observed over the period May through February 1997/98 in the hydrologically-connected lakes was remarkably similar to that observed in Charlie Lake, such that surface-strata biomass maxima in Nulki and Tachick lakes were also greatest during the late summer/early autumn and minimal during the late autumn and ice-covered winter months (Figure 2). As indicated, similarities in biomass cycles observed across the three study lakes were highly evident in terms of periodicity on a seasonal basis; however, the data further indicate that the biomass cycles of Nulki and Tachick lakes were almost identical even over temporally-shorter periods. As shown in Figure 2, distinct chl *a* maxima of slightly greater than 80 µg/L occurred in Nulki and Tachick lakes in mid-July, and then again in both lakes in early September when biomasses approached 120 µg/L chl *a*. In the time period between the mid-July and early-September biomass maxima, there were notable declines in biomass (down to 40 µg/L chl *a*) that occurred concurrently in both lakes (Figure 2). Immediately following the distinct biomass maxima observed in early September, biomasses again declined abruptly, and concurrently, in both lakes (Figure 2). Thus, our data show that despite the substantial geographic distance between the Nulki-Tachick watershed and Charlie Lake, patterns in algal biomass were similar on a seasonal basis in all three study lakes, but that the biomass cycles of Nulki and Tachick lakes were most similar. The greater similarity between biomass cycles observed in Nulki and Tachick lakes could be explained by the fact that the lakes are located within 3 km of each other (i.e., they are located in environments of similar land use, climate, soils and geology), they have similar morphometry and long-axis orientation, and that they have similar trophic structure in terms of fish and rooted macrophyte species.

As suggested above, we found it interesting that biomass seasonality was so similar between the hydrologically-connected lakes in the Nulki-Tachick watershed and Charlie Lake in that the watersheds are geographically distant from each other and because of their differences in terms of basin morphometry, orientation and trophic composition. However, case studies presented in the literature would seem to indicate that biomass cycles are, in a broad sense, similar between lakes located in temperate regions irregardless of basin morphometry, watershed geology/soils and other relevant characteristics. For example, from surveys undertaken by Munawar & Munawar (1986), it was shown that spring and late-summer chl *a* maxima regularly occur in the North American Great Lakes, which are orders of magnitude larger and deeper than Nulki, Tachick and Charlie lakes, and, moreover, are considerably different with respect to trophic structure, water use and watershed development. Similarly, plots and information provided in Hecky et al. (1986) showed similar algal-bloom periodicity in two very large, but shallow, multi-basin lakes located in Manitoba, Canada (Lake Winnipeg and southern Indian Lake). Chl *a* maxima in Shagawa Lake (Minnesota), a lake being similar in length to Nulki and Tachick lakes but considerably deeper, consistently occur in late August/early September with biomass typically having a rapid decline shortly following the bloom (Megard & Smith, 1974) as was observed in our study lakes. Schindler (1977), in his work in the Experimental Lakes Area, showed that *Aphanizomenon* blooms typically occur during the late summer/early autumn in Canadian Shield lakes, and Lund (1949) showed that spring diatom blooms typically occur during the spring months in English lakes. In contrast, algal biomass cycles in more tropical environments, as observed in southern India (Zafar, 1986) and Africa (Talling, 1986), appear to be less regular with respect to timing and linked more to hydrologic events (e.g., runoff periods) and short-term changes in temperature and water circulation than to limnological changes that occur between winter and summer (spring) and summer and winter (autumn).

Our data show that the timing of the late summer/autumn chl *a* maxima observed in Nulki, Tachick and Charlie lakes coincided with periods when surface-strata Tot-P and Tot-P<sub>diss</sub> concentrations were greatest (Figure 2; Figure 5a,b,c) and, with reference to the Charlie Lake dataset, when near surface Tot-Si<sub>diss</sub> concentrations were highest (Figure 5d). Conversely, chl *a* minima in the study lakes generally occurred when the surface-strata concentrations of these nutrients were at their lowest. The minor spring chl *a* maxima observed in Charlie Lake also appeared to occur in conjunction with elevated, albeit slightly, nutrient concentrations (Figure 5a,b,c). Given that P and Si (for diatoms) are essential for algal growth, we suspect that it is the seasonal inputs of these elements to surface strata that stimulates the growth of algae during the spring and late summer/autumn months in Nulki, Tachick and Charlie lakes. Furthermore, because the nutrient loads to the study lakes did not occur during or immediately after runoff events, it seems reasonable to conclude that the nutrients that stimulated spring and late summer/autumn algal blooms in the study lakes came from within-lake sources (i.e., internal nutrient loading). As illustrated by the representative profile data shown in Figures 7,8 & 9, deep strata in Charlie Lake were effectively anoxic during the winter months when the lake was frozen over and during the summer months when the lake was weakly stratified. The accumulation of P in the deep strata of Charlie Lake during the winter and summer stratified months (Figure 7b,d,e,f) is suspected to be largely the result of the redox-mediated dissolution of P from profundal sediments, which is known to occur rapidly at sediment-water interfaces in the absence of O<sub>2</sub>, and/or via the decomposition of P-containing organics (e.g., Mortimer, 1971; Schindler & Lean, 1974; Holdren et al., 1977; Larsen et al., 1981; Nürnberg, 1984; Lehman, 1988; Carignan & Lean, 1991). The data show that the P-rich bottom waters in Charlie Lake are mixed through the water column during the spring following the melting of surface ice (Figure 7a,b,c) and then again during the late summer/early autumn when thermal stratification is disrupted (Figure 7e,f,g). Thus, the results would suggest that mixing events that carry P-rich bottom waters to the photic zone during the spring and late summer/autumn months play a role in stimulating algal blooms in Charlie Lake. The significance of such internal P-loading has also been demonstrated for Chesapeake Bay (Virginia/Maryland) where up to 74% of phytoplankton P demands are supplied by sediments (Cowan & Boynton, 1996), in the relatively small and shallow Halfmoon and Nakamun lakes in Alberta (Canada) where sediments were shown to contribute nearly 1,500 kg and 150 kg Tot-P, respectively, to the water column during seasonally-anoxic periods (Riley & Prepas, 1984), in Shagawa Lake (Minnesota) where about ½ of the annual P supply (2,000 to 3,000 kg) to the water column is supplied by bottom sediments (Larsen et al., 1981), and in Lake Washington where up to 95% of the algal P demand is provided by within-lake sources (Lehman, 1980).

Processes controlling the within-lake cycling of Si are not as well understood as those for P, primarily because there have been comparatively few studies on the dynamics of Si in lakes. As was the case for P, profile data from Charlie Lake showed that Tot-Si<sub>diss</sub> accumulated in bottom strata during the winter and summer stratified periods when O<sub>2</sub> was depleted (Figure 8; Figure 9), as has been shown to occur in Lake Michigan (Schelske et al., 1984), Lake Mendota, Wisconsin (Stauffer, 1986) and Toolik Lake, Alaska (Cornwell & Banahan, 1992). The Si-rich bottom waters in Charlie Lake were then mixed through the water column during the breakdown of thermal stratification in the spring and late summer/autumn months, at which time the element would become more available to diatoms in the photic zone (Figure 8; Figure 9). Thus, it is our contention that Si upwelled from bottom waters during the spring and late summer/autumn months, in concert with the concurrent upwelling of P (Figure 7) and, perhaps, other essential elements, creates a nutritional environment in the photic zone that promotes seasonal diatom blooms in Charlie Lake (e.g., Lund, 1954; Schelske & Stoermer, 1971; Schelske et al., 1984; Bennion & Smith, 2000). Research undertaken by Conway et al. (1977), Parker et al. (1977), Conley et al. (1988), Gibson et al. (2000) and Koski-Vähälä et al. (2001) has shown that much of

the biologically-available Si that is utilised seasonally by diatoms in lakes is generated through the dissolution of frustules, and/or other biogenic Si sources such as sponge spicules and components chrysophytes and various protozoans and aquatic plants (e.g., Lanning & Eleuterius, 1985; Newberry & Schelske, 1986; Cornwell & Banahan, 1992; Conley & Schelske, 1993; Peinerud, 2000), that were formed and deposited to deep strata during previous growing seasons. However, while this could very well be the case for our study lakes, our current datasets will not permit us to draw conclusions regarding the within-lake sources of Si.

Experimental work undertaken to determine the environmental factors that control the mineralisation and solubility of biogenic Si have shown that Si is transferred from sediments to the water column most readily when pH is > 9, O<sub>2</sub> concentrations are very low, and at rates that increase with increasing ambient temperature through the range 10 - 20°C (Bailey-Watts, 1976a,b; Barker et al., 1994; Tuominen et al., 1998; Gibson et al., 2000). The effects of increased pH and low O<sub>2</sub> concentrations on Si release from sediments is thought to occur because hydroxyl anions (OH<sup>-</sup>) can displace silicate anions (H<sub>2</sub>SiO<sub>4</sub><sup>-</sup>) from sediment surfaces via competitive ion exchange and, like P, the desorption of silicate anions from sediment is influenced by redox potential since the anions are adsorbed to Fe- and Al-oxides (e.g., Hingston et al., 1967; Obihara & Russell, 1972; Koski-Vähälä et al., 2001). Warmer temperatures may increase the rate of Si release from bottom sediments by promoting the decomposition and biological processing of Si-containing organic matter (e.g., Gibson et al., 2000). The results of experimental work that has demonstrated the effects of pH, redox and temperature on Si release from lake sediments may partially explain why Tot-Si<sub>diss</sub> concentrations in Charlie Lake were elevated in the spring and late summer/autumn months, such that O<sub>2</sub> concentrations were depleted in deep waters in the winter and late summer/autumn (i.e., low redox) and pH and temperature were elevated during the late summer/autumn algal blooms (Figure 7; Figure 10). The elevated pHs observed during the late summer/autumn in Charlie Lake (Figure 10) were most likely the result of intense algal photosynthesis (e.g., Andersen, 1974; Jacoby et al., 1982; Søndergaard, 1988). The generated hydroxyl anions would have made contact with bottom sediments during water column mixing events, at which time they could exchange with silicate anions adsorbed to sediment surfaces. Such mixing events would also result in the warming of bottom waters.

While the limnological conditions in Charlie Lake during the winter and summer stratified months (e.g., deep-water anoxia), would clearly promote the release of P and Si from bottom sediments, the conditions observed in Nulki and Tachick lakes, particularly during the late-summer months when internal P loading appeared to be most prevalent (Figure 2; Figure 3), were not as evident in terms of their influence on sediment P release. Our thermal profile data for Nulki and Tachick lakes showed that the lakes were thoroughly mixed during all of our sampling trips when they were not ice covered, such that vertical temperature differences and, thus, O<sub>2</sub> and P concentration gradients were negligible in the lakes (Figure 4a). Moreover, the profile data for Nulki and Tachick lakes indicate that the water close to the bottom sediments was typically well oxygenated during the ice-free months and, therefore, conditions would not have been suitable for redox-mediated P release from bottom sediments. However, the results of *in situ* and laboratory experiments presented in Jacoby et al. (1982), Jensen & Andersen (1992), Ojila & Reddy (1995), Koski-Vähälä et al. (2001) and Macedo et al. (2001) have clearly shown that P can be released from bottom sediments under aerobic conditions when the pH is alkaline (> 9) and when the water overlying bottom sediments is warmer than about 15 °C. As seems to be the case for Si (above), concentrated hydroxyl anions present in alkaline waters can compete with phosphate anions (e.g., H<sub>2</sub>PO<sub>4</sub><sup>-</sup>) for exchange sites on the surfaces of bottom sediments, and warm temperatures can promote the decomposition and biological processing of P-containing organics (Andersen, 1975; Kamp-

Nielsen, 1975; Jacoby et al., 1982; Jensen & Andersen, 1992; Koski-Vähälä et al., 2001). Thus, the warm temperatures (up to 20 °C; Figure 4a) and high pHs (> 9; Figure 4b) observed throughout the water column in Nulki and Tachick lakes during the summer months may be sufficient to promote significant P release from bottom sediment despite the aerobic/oxidising conditions.

Other potential within-lake P sources and processes that could contribute P and other essential elements to the water columns of Nulki and Tachick lakes under aerobic conditions include the thick aquatic macrophyte beds that line the perimeter of both lakes (Barko & Smart, 1980; Carpenter, 1980; Landers, 1982; Rørslett et al., 1986; Reddy & DeBusk, 1991), the upward movement of sediment-bound P resulting from wave-related turbulence that can mechanically disturb and re-suspend bottom sediments in the shallow lakes (Søndergaard et al., 1992; Reddy et al., 1996) and the bioperturbation of bottom sediments and excretion by fish and invertebrates (Lamarra, 1975; Gallep et al., 1978; Henriksen et al., 1980; Holdren & Armstrong, 1980). With regards to the potential importance of P release to the water column through the decomposition of macrophyte tissues, Jacoby et al. (1982) showed that macrophyte decomposition in Long Lake (Washington) during the winter months contributes 200 - 400 kg of P per year to the water column, or 25 - 50% of the total external P load. Furthermore, increases in pH resulting from macrophyte photosynthesis during the growing season could itself contribute to P release from sediments in littoral regions (e.g., Frodge et al., 1990). Although macrophyte decomposition in Nulki and Tachick lakes could supply substantial amounts of P to the water column and, thereby, promote algal growth, macrophyte contributions to the P load to Charlie Lake are expected to be minimal because the macrophyte community in the lake is very sparse based on observations made during sampling trips.

As described above, controlled *in situ* and laboratory experiments have demonstrated that P and Si can be released from lake sediments in aerobic conditions at high pHs, as a result of competitive exchange reactions between OH<sup>-</sup>, H<sub>2</sub>SiO<sub>4</sub><sup>-</sup> and H<sub>2</sub>PO<sub>4</sub><sup>-</sup>. Given that high rates of photosynthesis by algae (Figure 4b; Figure 10a,b) and macrophytes can dramatically increase pH and, thus, OH<sup>-</sup> concentrations, it would seem reasonable for us to suggest, as was done by Koski-Vähälä et al. (2001), that there is a “biofeedback” loop that links algal growth to processes that control P and Si release from bottom sediments and, thus, the seasonal availability of nutrients that promote further growth. In this view, and using Nulki and Tachick lakes as an example, we can hypothesise that the onset of late-summer algal blooms is stimulated by warming water temperatures and the supply of nutrients that are present in the water column at that time. Then pH increases with increasing photosynthesis rates and, with water-column mixing, hydroxyl anions produced via photosynthesis come into contact with bottom sediments resulting in the release of nutrients like P and Si which further promotes algal growth. Thus, it would appear to us that the onset of late-summer algal blooms creates a chemical environment that initiates internal-loading processes that, in turn, further promote growth.

The results of our taxonomic surveys of Charlie Lake showed, in general, that cryptophytes and chrysophytes dominated the algal community during the winter when the lake was frozen over, with diatoms dominating the community during the spring following mixing, and chlorophytes during the early summer (Figure 6). Cyanophytes clearly dominated the community from July through October, when cell densities increased dramatically to the order of 80,000 cells mL<sup>-1</sup> from early-season densities that were typically < 10,000 cells/mL (Figure 6). This pattern of dominance shifting through seasons is similar to those described in comprehensive textbooks (e.g., Wetzel, 1983), and in Lund (1949, 1954, 1955), Megard & Smith (1974), Hecky et al. (1986), Stewart & Wetzel (1986) and Visser et al. (1996). It was beyond the scope of this

investigation to discern the mechanisms that control taxon-specific bloom periodicity; however, studies on the autecology and nutritional physiology of cryptophytes and chrysophytes (e.g., Rothhaupt, 1996; Gervais, 1998; Holen, 1999; Roberts & Laybourn-Parry, 1999) have demonstrated that representative species in these groups can grow in cold low-light environments, and that they can become heterotrophic when light levels are too low for them to fix sufficient amounts of carbon via photosynthesis. Thus, the so-called “mixotrophic” capabilities of cryptophytes and chrysophytes may permit them to do well in Charlie Lake during the dark winter months when the lake is frozen over and in the very early spring. As shown in Figure 5e, Inorg-N<sub>diss</sub> concentrations in the surface strata of Charlie Lake typically decline in late August and early September when dense cyanophyte blooms tend to occur. The overwhelming success of cyanophytes during this time of year may be a function of the ability of heterocystic species to fix atmospheric N<sub>2</sub> and their ability to float high in the water column (i.e., many species have gas vacuoles) and shade out competing species (Smith, 1979; Humphries & Lyne, 1988; Lee, 1989; Visser et al., 1996).

## Conclusions

The primary objective of this study was to describe the environmental factors that control algal bloom periodicity in Nulki, Tachick and Charlie lakes. Our primary findings were that the lakes typically have a minor, low-biomass bloom in the spring shortly after surface ice melts and a major, high-biomass bloom in the late summer/early autumn, and that the blooms are associated with internally-loaded nutrients like P and Si. From the results of our study, we were hoping to be able to suggest specific lake- and watershed-based restoration options that would slow the rate of cultural eutrophication and improve water quality. However, given that bloom dynamics in the lakes are being controlled on a year-to-year basis by internal nutrient-loading processes, reversing the effects of eutrophication could prove to be very difficult and may require the control of nutrient release from bottom sediments while concurrently taking action to control the external loads contributed through human activities.

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# The Birds of Charlie Lake: Results of an Eight-Year Systematic Survey of Lake and Shoreline Regions (1981 to 1988)<sup>1</sup>

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**Abstract:** As the largest and deepest lake in the Peace Region outside of the Williston Reservoir watershed, Charlie Lake is thought to be the single most-important body of water in the Hudson's Hope-Fort St. John Boundary area from a migrant waterbird perspective. More than 500 systematic bird surveys were undertaken from a single fixed-point at seven locations along the Charlie Lake shoreline over the period 1981 to 1988. Over the course of these surveys, approximately 90 bird species representing nine taxonomic orders were observed either on/above, or along the shoreline of Charlie Lake. Orders Charadriiformes (gulls, sandpipers, jaegers, terns and plovers) and Anseriformes (swans, geese and ducks) the most diverse in terms of species richness, being represented by 40 and 30 species, respectively. These orders were also the most-highly represented in terms of total number of individuals, with about 59,800 and 72,000 birds in each group counted over the 1981 to 1988 sampling period, respectively. In view of the survey results, we provide four major recommendations for the further incorporation of birds into the Charlie Lake Conservation Society's Strategic Plan that consider the following: 1) the possible designation of Charlie Lake as an Important Bird Area, 2) feasibility of wetland development, 3) littoral plant communities, 4, extension programs and, 5) environmental monitoring.

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Of the 270 bird species that have been recorded to date in the North Peace region, 38 species (or 14%) are known to be year-round residents, with the remaining 232 (or 86%) species being seasonal migrants. Of the migratory species, 79 are waterfowl (swans, geese and ducks), with the other migratory species being loons, grebes, cormorants, bitterns and herons, gulls, sandpipers, jaegers, terns and plovers, rails, and other so-called waterbirds. As the term "waterbirds" implies, all species in these groups require wetlands and/or open-water for at least some components of their life cycle.

Charlie Lake, Cecil Lake, and Boundary Lake provide some of the most-important wetland habitats for waterbirds in British Columbia north of the Peace River. As the largest and deepest lake in the Peace Region outside of the Williston Reservoir watershed, Charlie Lake (Figure 1) is thought to be the single most-important

body of water in the Hudson's Hope-Fort St. John-Boundary Lake area from a migrant waterbird perspective; yet, the lake has not received special designation or protection from either the federal or provincial governments, an oversight that we believe is due almost entirely to lack of regional bird data and information. The only publication to date that

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has dealt in any detail or scope with birds in the Peace River Region of British Columbia was published in 1939: *The Vertebrate Fauna of The Peace River District of British Columbia* by Ian McTaggart Cowan (BC Provincial Museum). The McTaggart Cowan paper presents the results of a single field season's work in the Swan Lake area, near Dawson Creek. Through our work with the Charlie Lake Conservation Society, we were introduced to a naturalist that resided near Charlie Lake for many years (Mr. Chris Siddle) and undertook systematic waterbird surveys of the lake over an eight-year period (1981 to 1988). The records of these surveys represent a major source of unpublished information on the natural history of Charlie Lake. The objective of this report is to document the results of these surveys and to provide recommendations for future bird survey work in view of monitoring ecosystem-level changes and the progress/success of any future watershed restoration projects.

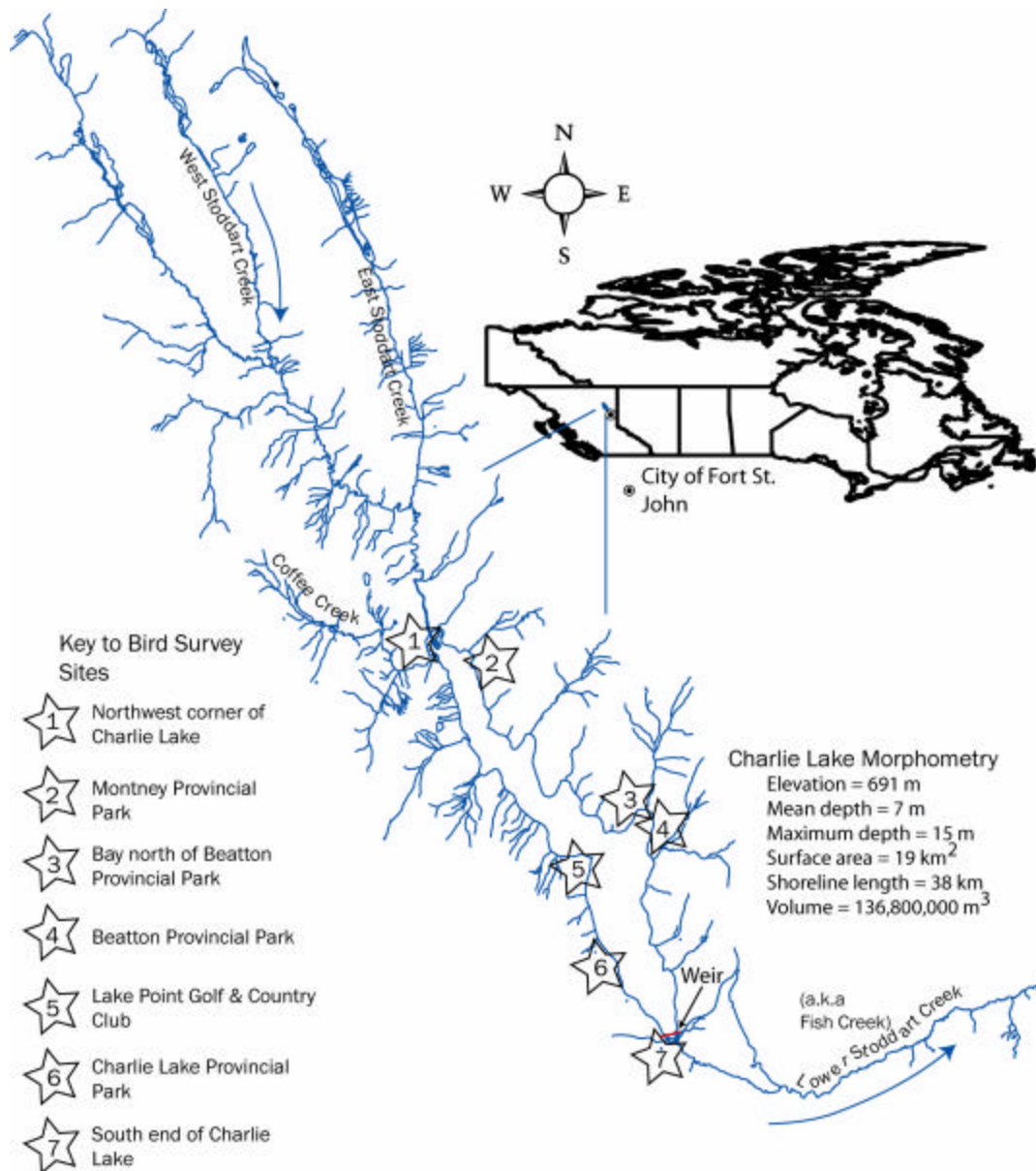


Figure 1. Distribution of bird observation sites utilised during the 1981 to 1988 surveys of Charlie Lake, showing major sub-basins.

## Materials & Methods

Five-hundred and twenty nine surveys, conducted almost exclusively by one observer (Mr. Chris Siddle), were undertaken from a single fixed-point at seven locations along the Charlie Lake shoreline over the period 1981 to 1988 (Figure 1; Table 1): (1) northwest corner of Charlie Lake, (2) Montney Provincial Park, (3) bay north of Beatton Provincial Park, (4) Beatton Provincial Park, (5) Lake Point Golf & Country Club, (6) Charlie Lake Provincial Park and (7) south end of Charlie Lake. On each sampling trip, all identifiable birds were counted through 7- or 8-power binoculars and a spotting scope (Spacemaster 50mm 20-45X for 1981-1987/Kowa 77mm 20-60X for 1988). Distance from the observer was not recorded, and the duration of each counting period was not uniform either within or between years; thus, precise spatial and temporal measures of bird density could not be reliably estimated in relation to lake zonation.

When birds could not be identified to the level of species they were, whenever possible, identified to the closest taxonomic category. For example, when it was difficult to identify an individual with confidence as being a Barrow's goldeneye (*Bucephala islandica*) or a common goldeneye (*Bucephala clangula*), it was recorded, in broad terms, as being a goldeneye. With large flocks, numbers were estimated by groups of ten, and occasionally (once a month) complete actual counts were made and compared to estimated counts as a reliability check.

Table 1. Number of bird surveys conducted at each Charlie Lake site (Figure 1) during the years 1981 to 1988.

Location	Year								Grand total
	1981	1982	1983	1984	1985	1986	1987	1988	
Northwest corner of Charlie Lake	-	2	2	-	-	1	-	-	5
Montney Provincial Park	-	1	1	-	-	2	5	4	13
Bay north of Beatton Provincial Park	2	10	14	18	13	13	7	7	84
Beatton Provincial Park	6	11	13	20	9	19	14	20	112
Lake Point Golf & Country Club	-	-	1	-	1	8	8	13	31
Charlie Lake Provincial Park	1	4	8	6	16	17	13	17	82
South end of Charlie Lake	32	31	23	29	22	20	23	22	202
<b>Grand Total</b>	<b>41</b>	<b>59</b>	<b>62</b>	<b>73</b>	<b>61</b>	<b>80</b>	<b>70</b>	<b>83</b>	<b>529</b>

## Results

### *Taxonomic Representation*

Over the course of the 1981 to 1988 bird surveys, approximately 90 species representing nine taxonomic orders were observed either on/above, or along the shoreline of Charlie Lake: Order Gaviiformes (loons), Order Podicipediformes (grebes), Order Pelecaniformes (cormorants), Order Anseriformes (swans, geese and ducks), Order Falconiformes (eagles and falcons), Order Coraciiformes (kingfishers), Order Gruiformes (rails), Order

Charadriiformes (gulls, sandpipers, jaegers, terns and plovers), and Order Passeriformes (songbirds). A complete species listing, by taxonomic order, is provided in the Appendix.

Orders Charadriiformes and Anseriformes were the most diverse in terms of species richness, being represented by 40 and 30 species, respectively (Figure 2). Although substantially less diverse in terms of species richness, songbirds, grebes, loons, eagles and falcons, rails and kingfishers were observed during the course of almost all sampling years (Table 2). By comparison, only a single cormorant observation was made during the entire 1981 to 1998 study period; a double crested cormorant (*Phalacrocorax auritus*) observed during one of the 41 surveys undertaken in 1981 (Table 2c).

Orders Charadriiformes and Anseriformes were also the most-highly represented in terms of total number of individuals, with about 59,800 and 72,200 birds in each group counted over the 1981 to 1988 sampling period, respectively (Figure 3). The comparatively large Charadriiformes population was largely due to the proportionately-high abundance of two species: the Bonaparte's gull (*Larus philadelphia*) and the Franklin's gull (*Larus pipixcan*) (Table 2). Similarly, the large Anseriformes population was primarily due the high abundance of four species: the lesser scaup (*Aythya affinis*), the bufflehead (*Bucephala albeola*), the common goldeneye and the white-winged scoter (*Melanitta fusca*) (Table 2).

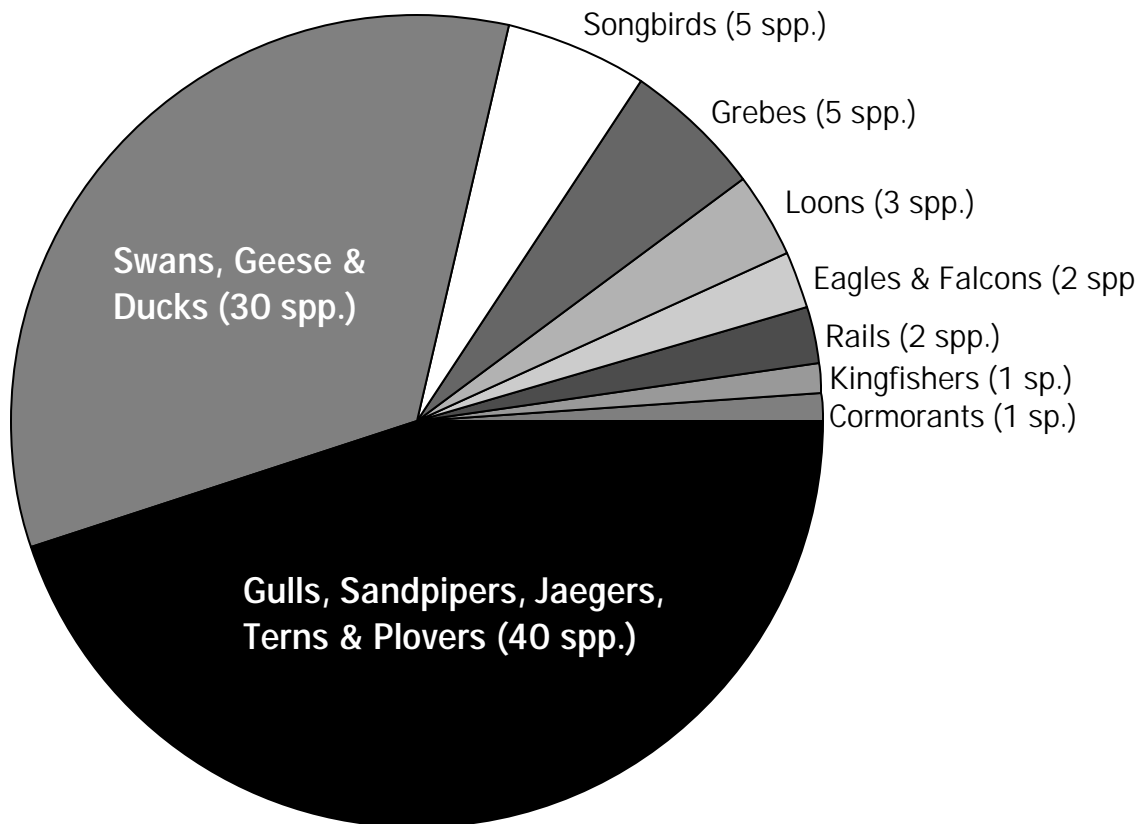


Figure 2. Species richness in each of the taxonomic orders observed during the 1981 to 1988 Charlie Lake bird surveys.

Table 2. The number of individual birds recorded per sampling period during each survey year ( $n$  = number of surveys undertaken in specified year): a) loons, b) grebes, c) cormorants, d) swans, geese and ducks, e) eagles and falcons, f) kingfishers, g) rails, h) gulls, sandpipers, jaegers, terns and plovers, and i) songbirds.

a) Loons (Order Gaviiformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 ( $n = 41$ )	1982 ( $n = 59$ )	1983 ( $n = 62$ )	1984 ( $n = 73$ )	1985 ( $n = 61$ )	1986 ( $n = 80$ )	1987 ( $n = 70$ )	1988 ( $n = 85$ )
Common Loon	0.49	0.42	0.63	0.40	0.52	1.03	0.39	0.64
Pacific Loon	-	0.05	0.42	0.92	0.13	2.03	0.36	0.05
Red-throated Loon	-	0.02	0.13	0.01	-	0.01	0.04	0.01

b) Grebes (Order Podicipediformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 ( $n = 41$ )	1982 ( $n = 59$ )	1983 ( $n = 62$ )	1984 ( $n = 73$ )	1985 ( $n = 61$ )	1986 ( $n = 80$ )	1987 ( $n = 70$ )	1988 ( $n = 85$ )
Pied-billed Grebe	0.02	0.02	-	-	-	-	-	-
Horned Grebe	2.37	1.03	4.24	2.32	1.15	1.06	1.04	2.52
Red-necked Grebe	0.27	0.46	1.42	1.30	0.75	1.53	1.59	0.79
Eared Grebe	0.15	0.69	0.26	0.23	0.08	0.38	0.24	0.26
Western Grebe	-	0.07	0.29	0.22	0.36	0.20	0.30	0.07
Grebe species	-	-	-	-	0.43	0.25	-	-

c) Cormorants (Order Pelecaniformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 ( $n = 41$ )	1982 ( $n = 59$ )	1983 ( $n = 62$ )	1984 ( $n = 73$ )	1985 ( $n = 61$ )	1986 ( $n = 80$ )	1987 ( $n = 70$ )	1988 ( $n = 85$ )
Double crested Cormorant	0.02	-	-	-	-	-	-	-

## d) Swans, geese and ducks (Order Anseriformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 (n = 41)	1982 (n = 59)	1983 (n = 62)	1984 (n = 73)	1985 (n = 61)	1986 (n = 80)	1987 (n = 70)	1988 (n = 85)
Greater White-fronted Goose	-	-	-	0.01	-	-	0.79	-
Canada Goose	-	0.02	0.68	1.12	0.08	0.13	0.29	1.47
Trumpeter Swan	-	-	-	-	-	-	0.49	1.41
Tundra Swan	-	-	-	0.08	0.03	0.04	-	-
Swan species	-	-	-	0.01	-	-	-	0.53
Gadwall	0.22	0.15	0.23	0.29	0.10	0.05	0.11	0.26
Eurasian Wigeon	-	-	0.02	-	-	-	-	-
American Wigeon	3.73	4.63	5.52	4.33	1.34	7.68	0.23	3.89
Mallard	6.12	7.34	3.97	4.40	3.66	6.64	1.21	7.64
Blue-winged Teal	3.17	0.81	0.13	1.36	0.28	0.04	0.34	0.19
Cinnamon Teal	-	0.02	-	-	0.02	-	0.01	-
Green-winged Teal	1.46	3.59	0.63	0.64	0.54	0.11	0.14	0.94
Northern Shoveler	1.27	0.64	8.69	2.44	1.25	3.34	3.61	14.61
Northern Pintail	1.15	2.39	0.47	1.08	0.59	0.78	0.59	5.35
Canvasback	2.00	0.98	15.15	3.79	5.66	1.04	4.46	2.18
Redhead	1.71	0.46	0.16	0.33	0.18	0.34	0.29	1.08
Ring-necked Duck	0.61	0.64	0.13	0.42	0.10	0.89	0.67	0.99
Greater Scaup	0.02	0.02	-	-	-	-	-	-
Lesser Scaup	54.24	36.75	44.65	32.85	27.07	40.40	34.33	97.94
Scaup species	-	-	-	-	-	-	1.43	-
Harlequin Duck	-	-	-	-	-	0.01	-	-
Surf Scoter	1.02	1.71	4.16	5.53	8.44	6.96	1.01	2.67
White-winged Scoter	7.15	9.93	4.65	10.34	6.25	9.91	1.49	2.52
Black Scoter	-	-	-	-	-	-	0.04	-
Oldsquaw	0.17	0.05	2.39	1.93	1.46	0.80	1.57	0.44
Bufflehead	13.56	23.17	22.27	21.34	8.79	21.48	21.01	19.59
Common Goldeneye	20.39	14.88	6.16	12.05	5.26	8.46	11.50	55.11
Barrow's Goldeneye	1.15	2.98	2.87	3.73	3.72	5.56	2.86	15.71
Goldeneye species	1.61	17.95	6.69	-	-	0.63	16.29	-
Hooded Merganser	-	0.03	-	-	0.02	0.25	0.09	0.31
Common Merganser	0.24	-	0.05	0.11	0.08	-	0.16	0.15
Red-breasted Merganser	0.07	0.12	0.21	0.04	0.02	0.11	0.16	0.11
Ruddy Duck	0.24	0.39	0.06	0.22	0.20	0.83	0.14	0.13
Duck species	0.29	-	-	-	-	0.38	14.29	15.29

(March 2004)

Supplement 2 (Birds of Charlie Lake)-6

e) Eagles and falcons (Order Falconiformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 (n = 41)	1982 (n = 59)	1983 (n = 62)	1984 (n = 73)	1985 (n = 61)	1986 (n = 80)	1987 (n = 70)	1988 (n = 85)
Osprey	-	0.03	0.03	-	-	-	-	-
Bald Eagle	0.12	0.07	0.08	0.04	0.05	0.06	0.06	0.09

f) Kingfishers (Order Coraciiformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 (n = 41)	1982 (n = 59)	1983 (n = 62)	1984 (n = 73)	1985 (n = 61)	1986 (n = 80)	1987 (n = 70)	1988 (n = 85)
Belted Kingfisher	0.02	0.03	-	0.01	-	-	0.01	0.01

g) Rails (Order Gruiformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 (n = 41)	1982 (n = 59)	1983 (n = 62)	1984 (n = 73)	1985 (n = 61)	1986 (n = 80)	1987 (n = 70)	1988 (n = 85)
Sora	0.24	-	0.02	0.04	-	-	-	-
American Coot	0.24	0.34	0.10	1.82	0.02	9.03	2.31	14.88

## h) Gulls, sandpipers, jaegers, terns and plovers (Order Charadriiformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 (n = 41)	1982 (n = 59)	1983 (n = 62)	1984 (n = 73)	1985 (n = 61)	1986 (n = 80)	1987 (n = 70)	1988 (n = 85)
Black-bellied Plover	-	0.02	0.03	-	0.02	-	-	-
American Golden-Plover	0.02	0.05	0.08	0.07	-	-	-	0.01
Semipalmated Plover	0.63	0.15	0.02	0.32	0.02	0.08	-	0.04
Killdeer	4.27	0.76	0.10	0.22	0.16	0.04	0.16	0.07
Greater Yellowlegs	0.10	-	0.02	0.01	-	-	0.04	0.04
Lesser Yellowlegs	6.27	3.27	0.11	3.01	0.30	0.31	0.34	2.81
Willet	-	-	-	0.03	-	-	-	-
Solitary Sandpiper	0.10	0.08	-	0.12	0.02	0.01	-	0.02
Spotted Sandpiper	1.61	0.78	0.81	0.81	0.21	0.41	0.66	0.33
Upland Sandpiper	-	-	-	-	-	-	0.03	-
Western Sandpiper	0.02	-	-	-	-	-	-	-
Least Sandpiper	0.54	0.22	-	0.78	0.18	0.01	0.04	0.21
White-rumped Sandpiper	0.02	-	-	0.01	0.10	-	-	-
Baird's Sandpiper	0.41	0.24	0.03	0.52	0.51	0.13	-	0.29
Pectoral Sandpiper	0.76	1.10	0.08	2.86	1.93	0.08	-	0.08
Stilt Sandpiper	0.02	-	-	-	-	-	-	0.18
Semipalmated Sandpiper	1.07	0.46	0.05	0.59	1.02	0.09	-	0.45
Sandpiper species	-	-	-	-	-	0.38	-	-
Whimbrel	0.02	-	0.02	-	-	-	-	-
Hudsonian Godwit	-	0.03	-	-	-	0.11	-	-
Ruddy Turnstone	-	-	-	-	-	0.03	-	-
Sanderling	-	0.05	-	0.01	0.03	0.01	0.03	-
Short-billed Dowitcher	0.05	0.03	-	-	-	0.01	-	0.04
Long-billed Dowitcher	1.80	0.56	0.11	0.14	0.41	-	-	0.01
Common Snipe	0.24	0.15	0.03	0.11	0.11	-	0.11	0.01
Wilson's Phalarope	1.59	0.47	0.18	0.30	-	0.01	-	0.05
Red-necked Phalarope	1.71	1.49	0.26	0.66	1.23	10.00	-	2.94
Phalarope species	-	1.69	-	-	0.98	3.78	0.59	1.18
Parasitic Jaeger	-	0.03	-	0.01	-	0.01	-	-
Franklin's Gull	22.12	18.00	0.69	3.23	10.21	0.81	0.06	10.35
Bonaparte's Gull	67.61	177.15	72.10	66.30	56.61	51.48	32.84	187.01
Mew Gull	0.29	7.73	2.13	0.44	0.15	0.10	0.14	0.13
Ring-billed Gull	1.78	0.29	0.29	0.07	0.13	0.01	0.26	0.11
California Gull	0.15	0.02	0.02	0.45	-	-	-	-
Herring Gull	1.63	3.12	0.50	0.07	0.16	0.10	-	0.21
Glaucous-winged Gull	0.02	-	0.03	-	-	-	-	-
Sabine's Gull	-	0.10	0.08	0.03	0.02	0.01	0.07	0.01
Little Gull	-	-	0.02	-	-	-	-	-
Gull species	0.34	0.05	0.29	5.52	2.93	0.41	1.90	0.24
Arctic Tern	-	-	0.19	-	-	0.05	0.01	0.01
Common Tern	0.05	0.05	0.02	0.01	-	0.33	0.04	0.14
Forster's Tern	-	-	-	-	-	-	-	0.05
Black Tern	3.05	1.93	0.23	0.45	0.02	-	-	1.94

(March 2004)

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i) Songbirds (Order Passeriformes)

Species	Total Count Per Lake Survey (average/survey)							
	1981 (n = 41)	1982 (n = 59)	1983 (n = 62)	1984 (n = 73)	1985 (n = 61)	1986 (n = 80)	1987 (n = 70)	1988 (n = 85)
Tree Swallow	10.54	0.12	1.03	32.36	-	-	-	-
Violet-green Swallow	0.02	-	-	0.01	-	-	-	-
Bank Swallow	-	0.02	0.02	5.53	-	-	-	0.05
Cliff Swallow	0.27	-	0.03	6.56	-	-	-	-
Barn Swallow	0.51	0.39	0.06	7.49	0.08	0.48	0.14	-

### *Distribution Patterns*

The large flocks of Bonaparte's gulls observed in the summer and autumn months were almost invariably congregated near the centre of Charlie Lake. These flocks would typically extend northward from Charlie Lake Provincial Park past the Lake Point Golf & Country Club from July through October. Flocks of Pacific loons (*Gavia pacifica*), red-throated loons (*Gavia stellata*), and large flocks surf scoters (*Melanitta perspicillata*) and white-winged scoters generally occurred in the middle of the lake between Beatton Provincial Park and Charlie Lake Provincial Park. Western grebes (*Aechmophorus occidentalis*), Sabine's gulls (*Xema sabinii*), common terns (*Sterna hirudo*), Arctic terns (*Sterna paradisaea*), and the few-observed parasitic jaegers (*Stercorarius parasiticus*) also congregated in this area. This spatial distribution was maintained through spring, summer and autumn months.

The large bay on the east side of Charlie Lake immediately to the north of Beatton Provincial Park (a.k.a. Beatton Park Bay) appears to be an excellent spring staging area for most dabblers and the *Aythya* clan (diving ducks), except for the greater scaup (*Aythya marila*) which was rarely seen on the lake and was usually found at the south end where individual birds were observed near the outlet weir. Typical bird clusters in the bay north of Beatton Provincial Park were composed of ring-necked ducks (*Aythya collaris*), redheads (*Aythya americana*), canvasbacks (*Aythya valisineria*), lesser Scaups, American wigeons (*Anas americana*), mallards (*Anas platyrhynchos*), northern pintails (*Anas acuta*), green-winged teals (*Anas crecca*), and ruddy ducks (*Oxyura jamaicensis*).

The northwest corner of the lake supported a high diversity of waterbirds including dabbling and diving ducks and grebes. In particular, large numbers of American wigeon, and lesser scaup were recorded in this area during recent (autumn 2002) follow-up surveys. Waterbirds appear to congregate in this portion of the lake, perhaps due to the presence of extensive stands of emergent vegetation.

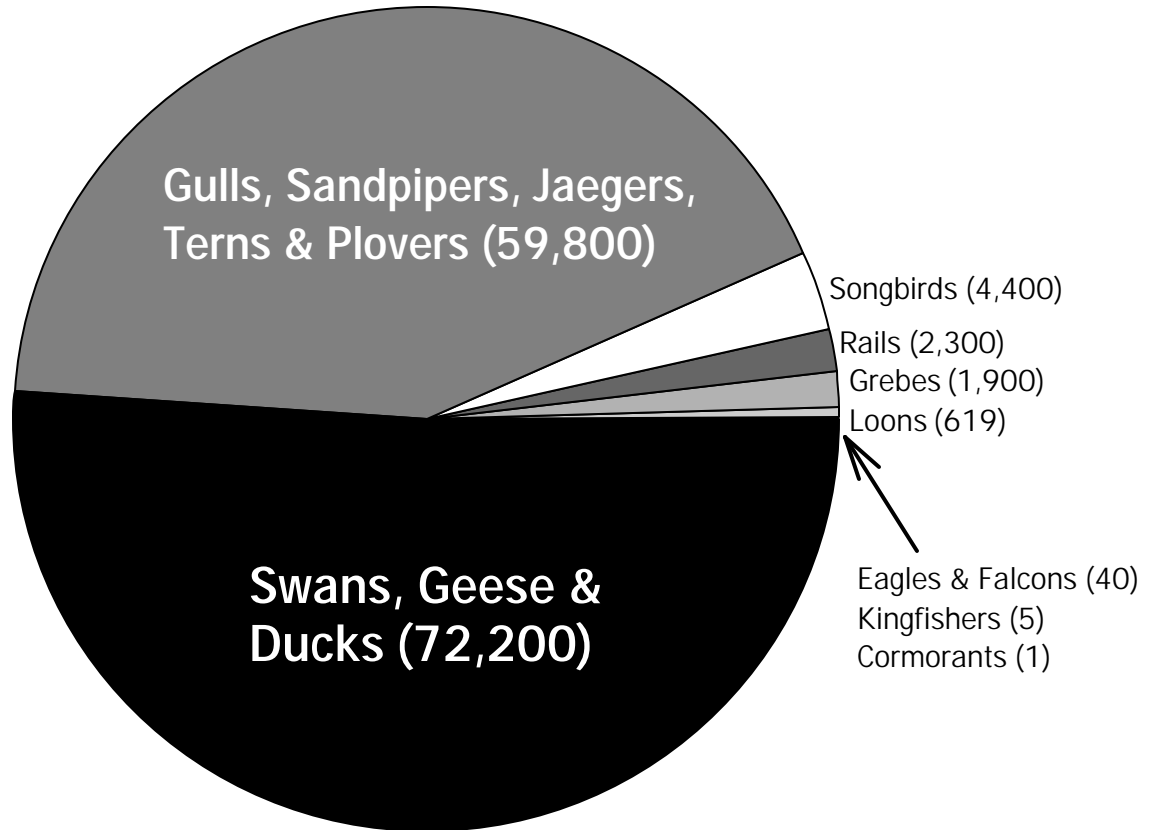


Figure 3. Approximate total number of individuals observed in each taxonomic order during the course of the 1981 to 1988 Charlie Lake bird surveys.

## Discussion

Charlie Lake ranks among the most important migratory stopover sites for many bird species that occur in the North Peace region. Due to its large size and relatively deep waters, Charlie Lake attracts many "deeper-water" migrants like loons and Barrow's goldeneye that tend avoid the more marshy and shallow lakes in the region. In addition, Charlie Lake has a greater diversity of habitat types than Cecil or Boundary lakes. These habitats include deeper open-water, shallow open-water, marsh, swampy shore, deciduous wooded-shore, mixed-forest shore, cliffs, and human developments (e.g., dikes, boat launches, picnic areas, lawns, residential yards, golf course). Consequently, Charlie Lake supports a greater diversity of waterbirds than either of nearby Cecil Lake or Boundary Lake.

Due to limitations associated with the sampling methodology used during the 1981 to 1988 surveys, it is unclear as to how the species composition/relative abundance of Charlie Lake bird populations have changed over time. In particular, the ecological effects of the water-control structure at the south end of Charlie Lake (constructed during the early 1980s) remains largely undocumented. It is possible that the construction of this weir and the associated 1-m increase in maximum water level may have reduced the availability of habitat types required by shore-nesters like shorebirds (e.g., beach, mudflats, marsh, etc.). Surveys at the City of Fort

St. John (about 10 km south of Charlie Lake) sewage lagoons indicate that the city lies within a major migratory shorebird flyway. Consequently, any activity that limits the availability of habitats that these species utilise (e.g., beaches and mudflats) would have reduced the capability of Charlie Lake to support these species to its potential capacity.

One documented effect of the weir at the south end of the Charlie Lake was the channelising of lower Stoddart Creek (a.k.a. Fish Creek, outlet of Charlie Lake) and the ditching and filling of the marsh on either side of lower Stoddart Creek. A significant wetland including sedge meadows, bordered by spruce forests and areas of large cottonwood was found immediately downstream of Charlie Lake prior to the construction of the weir (see *The Vertebrate Fauna of The Peace River District of British Columbia* by Ian McTaggart Cowan, BC Provincial Museum, 1939). This marsh and the southern regions of Charlie Lake thus formed an area of high biodiversity, containing nesting habitats for grebes, puddle ducks, diving ducks, cavity nesting ducks, rails and coots, a few shorebirds (especially snipe), as well as swallows, edge songbirds like some species of warbler (e.g., yellowthroats, waterthrushes), blackbirds, and marsh sparrows. With lower water levels in early autumn, the outlet marsh would have also been excellent shorebird habitat. Much of this habitat would have been lost as the weir was first constructed, then more when dried areas were filled for the construction of a parking development. Extensive effort has been undertaken to mitigate the loss of habitat immediately downstream of the weir. For example, Ducks Unlimited Canada has expended a significant amount of time and energy in the enhancement of the remaining wetlands in this section of the lake.

While there have been significant changes to natural habitats in the Charlie Lake watershed over the past several decades, Charlie Lake is still an important site for regional bird populations. Recent autumn surveys indicate that the lake is currently being used by at least 25 species of waterbirds. Of particular interest were large numbers of lesser scaup (>1,000) and Bufflehead (>800) that were recorded during a single day in October 2002 (B. Harrison, Ducks Unlimited Canada, Dawson Creek, BC, unpubl. data).

There are numerous remaining concerns regarding human activity on Charlie Lake. One concern is the activity of powerboats and other personal watercraft. When approached by boats, the typical response of waterfowl is to either take flight or dive. Excessive disturbance can result in substantial energetic stress. This is of particular concern during migration, when birds need to maximise energetic uptake and, conversely, to minimise energetic losses. Powerboats can also affect breeding birds. The wakes produced by powerboats and other types of personal watercraft can damage the nests of red-necked grebes and, possibly, common loons.

The development of property along the shores of Charlie Lake is also of concern. The reduction of natural shoreline habitat that often accompanies development can reduce or eliminate potential nesting habitat for many species of birds including some waterfowl species. Clearing of shoreline habitat also results in decreases of visual screening for nesting, feeding and resting birds, which in turn can lead to increased disturbance of these birds.

## Recommendations

Birds are incredibly diverse in terms of species-specific habitat requirements, reproductive niches and migratory behaviour and, thus, are considered to be excellent indicators of ecosystem-level health and function. Moreover, the activities of birds in combination with their sounds and beauty are pleasing to people and make living near lakes all the more pleasurable. Through our general analysis of Mr. Chris Siddle's 1981 to 1988 bird survey data, we have learned a great deal about the diversity of birds that utilise Charlie Lake and surrounding shoreline. The following recommendations are based on our increased appreciation for the birds of Charlie Lake, and their potential for monitoring environmental change and for developing watershed-level conservation programs:

1. *Charlie Lake as an Important Bird Area* - The Charlie Lake Conservation Society should consider working in partnership with Ducks Unlimited Canada (Dawson Creek office) and Environment Canada to determine whether the past and current status of migratory bird populations in the Charlie Lake watershed warrant the lake being designated as an "Important Bird Area (IBA)" (<http://www.ibacanada.com/>). Such a designation may result in increased ecosystem conservation efforts and investment in the Charlie Lake watershed, and may be a draw for eco-tourism and research scientists/graduate students.
2. *Feasibility of Wetland Development* - Many of the bird species observed during Mr. Chris Siddle's surveys would benefit from the development of open-water wetlands, and the conservation of existing wetlands. The Charlie Lake Conservation Society should consider undertaking an inventory of wetlands in the Charlie Lake watershed, and seasonal surveys to describe how birds utilise these wetlands. As indicated, wetlands are critical for the success of many bird species, but they are also important in the maintenance of good water quality in that they act as filters for sediment and chemicals. After completing overview wetland surveys of the Charlie Lake watershed, the Charlie Lake Conservation Society should partner with Ducks Unlimited Canada to develop plans for wetland development in the upper watershed, particularly in the east/west and Coffee Creek sub-basins (major inflows to Charlie Lake). Plans should focus efforts in areas where natural wetlands may have existed in the past, but should also consider options for the construction of artificial wetlands that could be incorporated into the landscape. Given that many of the water quality issues in the watershed are related to sediment and nutrient transport, such wetlands could slow the rate of transport to Charlie Lake. Such wetlands would also benefit waterbirds and outdoors-related opportunities for residents.
3. *Littoral Plant Communities* – Emergent plant communities at the north end of Charlie Lake undoubtedly provide habitat for many waterbirds and improve water quality through filtration and absorption processes. However, increases in lake level resulting from the outlet weir has likely decreased the abundance of both submerged and emergent plants in much of Charlie Lake's littoral area, including the northern regions. Moreover, structures associated with shoreline residential development (e.g., docks, dikes, breakwaters, etc.) have likely further reduced habitat for emergent plants. The Charlie Lake Conservation Society should survey the aquatic plant communities at the north end of Charlie Lake to document species composition, the relative abundance of the various species, and environmental correlates of plant abundance (e.g., bottom sediment characteristics, slope of bottom contours, etc.). Following these surveys, the Charlie Lake Conservation Society should undertake a full shoreline survey of Charlie Lake to identify areas that

have potential to support the aquatic plant species observed at the north end. The Charlie Lake Conservation Society could work with experts on aquatic plant ecology to develop methods to re-establish plant communities in suitable locations around the lake. Such plant communities would reduce shoreline erosion rates, increase water clarity and nutrient uptake rates. The plant communities would also increase structural heterogeneity which should, in time, increase community-level diversity and, ultimately, provide bird habitat.

4. *Extension Programs* - For conservation programs to be successful over the long-term, the community at large needs to be supportive, enthusiastic and directly engaged. In this report, we have summarised the results of Mr. Chris Siddle's 1981 to 1988 bird surveys of Charlie Lake and documented the species composition and relative abundance of both migrant and resident species that utilise the lake. We have several recommendations that follow-up on the survey work undertaken by Mr. Chris Siddle. 1) *Development of Informational Signage* - The Charlie Lake Conservation Society should take high-quality photographs of waterbirds in the Charlie Lake watershed, do literature reviews on the habitat-requirements, basic biology and migratory patterns of these birds and construct poster-style signs to place at boat launches, parks and important wetlands. These signs could describe the effects of boat traffic on birds and explain how people can minimise disturbance. By encouraging people to be considerate of birds while on the lake, shoreline erosion resulting from boat wakes may also be reduced. 2) *Compilation of a Regional Bird Manual/Guidebook* – The Charlie Lake Conservation Society should consider developing a professionally-designed guidebook to the birds of Charlie Lake. Such a guidebook should include photographs, features that distinguish species, text on basic biology and habitat requirements/sensitivities and information on regional prevalence. The guidebook would be useful to residents, outdoors enthusiasts, and the Charlie Lake Conservation Society may even be able to sell copies of it at a profit to earn funds to support conservation work and research. 3) *Engaging Students and Researchers* – The Charlie Lake Conservation Society should try to engage academic institutions such as Northern Lights College and the University of Northern British Columbia. Biology and environmental studies students at these institutions are often asked, as part of their course work, to design and undertake a small research project that will be graded by their instructor. We encourage the Charlie Lake Conservation Society to contact biology/environmental studies instructors and inform them that there are potential projects for students (e.g., on birds, environmental, water quality, etc.) to work on in the Charlie Lake watershed. Such projects would not only provide information to the Charlie Lake Conservation Society, but they would also develop interest in up and coming professionals. Students could even get involved in the development of a regional bird guidebook (see above).
5. *Environmental Monitoring* – In previous chapters of this strategic plan, we have emphasised the importance of riparian zones along tributaries to Charlie Lake and around the lakeshore in the maintenance of water quality. It is quite likely that the structure and function of near-shore bird communities is also dependent on riparian conditions. As shown, bird surveys to date have focussed on observances made on or near the lake. We suggest that the Charlie Lake Conservation Society develop a seasonally-based bird checklist out away from the lake along major tributaries and in riparian areas where restoration projects are going to be undertaken. Using such surveys as baseline data, the Charlie Lake Conservation Society will have data that can be used to assess ecosystem change and changes in response to restoration work.

# A YEAR IN THE LIFE OF CHARLIE LAKE

## THE BIRDS OF CHARLIE LAKE

### Preamble

*The following is a narrative of how the bird populations of Charlie Lake change seasonally, and was written by Mr. Chris Siddle (a naturalist who lived near Charlie Lake for many years). It is hoped that this narrative, coupled with the species check-list can be repackaged and made available for distribution by the Charlie Lake Conservation Society.*

### January to early April:

*Charlie Lake is frozen throughout the winter. The fields around the lake may be the winter home to the occasional Snowy Owl, though this species is more regular around North Pine. Small flocks of Sharp-tailed Grouse may be encountered in the farming country north or southwest of the lake. Northern Goshawks are resident though usually scarce except following a Snowshoe Hare "boom" cycle. Resident woodpeckers include Downy, Hairy and Three-toed woodpeckers. Resident passerines include Common Ravens, Gray Jays, Blue Jays, Black-billed Magpies, Black-capped Chickadees, Boreal Chickadees, Northern Shrikes, Snow Buntings, Common Redpolls, Hoary Redpolls, and Evening Grosbeaks. At the very end of this period, one or two Killdeer may appear on the open fields and slough edges at the south end of the lake, marking the beginning of spring.*

### April 15 to April 30:

*Waterfowl appear in numbers at ponds and marshes in the area, though the Lake will remain frozen until sometime between latest April and the first week of May. The outflow slough at the south end thaws much earlier and is a good place to look for several ducks including Common Goldeneyes, Green-winged Teal, Mallards, American Wigeon, Canvasbacks, and Ring-necked Ducks. Occasionally a few Common Mergansers will appear on the outflow slough. Common Snipe may be heard overhead giving their curious and spooky sounding "winnowing", the sound of air rushing through the outspread outer tail feathers. Some sheltered bays may develop open water. In such situations look for Green-winged Teals, Redheads, Ring-necked Ducks and Long-tailed Ducks. Ring-billed and Franklin's gulls appear on the ice of Charlie Lake by the end of this period. Common Loons can land on open leads as early as April 28. Flocks of Tundra Swans may appear over the lake as they fly north to their arctic nesting grounds.*

### May 1 to May 15:

*Charlie Lake thaws rapidly. The open leads are home to many early-arriving waterfowl. The first ten days of May are the best time in spring for seeing large numbers of birds. Both the south end and the big bay north of Beatton Provincial Park are excellent spots. Look for small flocks of Red-necked Grebes, Horned Grebes and Eared Grebes. Horned Grebes will move on to nest on small ponds throughout northern Canada, while Eared Grebes nest in large colonies on shallow lakes like Cecil and Boundary lakes. The Cecil Lake colony may be 1000-3000 pairs in a good year. Red-necked Grebes and Common Loons are especially common in the bay north of the Park. Almost everyone is familiar with the haunting call of the loon, but few people are ready for*

*the comic donkey-like braying of courting Red-necked Grebes. Yet it is a characteristic sound of spring at Charlie's Lake. Bonaparte's Gulls arrive in small numbers at first early in the month, but during the second and third weeks may appear in the hundreds. These birds will continue north but will reappear following breeding in July. Ducks that flock to the big bay north of Beaton include Northern Shovelers, Blue-winged Teals, Cinnamon Teals (rare), Redheads (uncommon), Canvasbacks, Lesser Scaups, and Surf Scoters. Also in the aspen forests around the lake look for the rare and local Broad-winged Hawk, which has extended its breeding range into northeastern and central British Columbia from Alberta during the past three decades.*

## **May 16 to May 31:**

*As spring progresses the first waterfowl begin to nest. Mallards are incubating eggs in their ground nests hidden in long grass and brushy edges along the shore. However, migration also continues for the majority of species. This is the best time to search for Red-throated Loons and Pacific Loons, which, unlike the Common Loon, stop only briefly on Charlie Lake in migration and are quite uncommon. In the centre of the lake, between Beaton and Charlie Lake provincial parks, also look for a few Western Grebes, the largest of North America's grebes, which some years spend the whole summer far out on the lake. This is also a good time to search through flocks of American Wigeon for the much rarer Eurasian Wigeon. Females are almost indistinguishable but male Eurasians with their brick-red heads with creamy crowns and light gray bodies are easily differentiated from the green masked male Americans. Cinnamon Teals, small bright red ducks, frequent in southern BC, appear in the North Peace only rarely. Look for Cinnamon Teals among the more common Blue-winged Teals. During the final week look for one or two hundred White-winged Scoters, big black "sea ducks" that nest locally across northern BC. It is at this time of the spring that the arrival of a cold front, such as a prolonged rain or snowstorm can "ground" hundreds and sometimes thousands of migrant birds. Flocks of hundreds of swallows, including Tree, Barn, Cliff, Bank and a few Violet-green swallows may perch forlornly in bare trees while the cold temperatures prevent the appearance of their insect prey. Shorebirds, including rarities such as Hudsonian Godwits, White-rumped Sandpipers, American Golden Plovers, will land and attempt to feed along lakeshores and even on muddy roadways. The poorer the late spring weather, the more birds will be stopped cold in migration. Bad weather is no excuse to not visit the lake for the birder at this time! In any weather, Red-necked Phalaropes pass through toward the end of the month, and also large flocks of Franklin's Gulls arrive from their breeding range in the Prairie Provinces.*

## **June:**

*The diversity of waterfowl is still very high with many duck species present either as late migrants or summer residents. Also look for Common Terns, Arctic Terns (rare), and Sabine's Gulls (rare). The widespread Spotted Sandpiper is nesting around the lake at this time. It will lay its four excellently camouflaged eggs in a slight depression next to a bush or weedy patch, often at the forest edge or upper beach. June is also the best month to spot the uncommon Common Nighthawk, a high flying member of the goatsucker family, so named because of ancient European folklore about such birds' reputed habits of stealing milk from goats during the night. Nighthawks are locally known as bullbats for their aerial displays in which the bird will make a rapid shallow dive toward the ground, creating a deep hollow booming. A few gulls can frequent the lake including Herring and Ring-billed gulls. Many of these birds are nonbreeding immatures. Look for small flocks of Bonaparte's Gulls arriving toward the end of the month. These are either post-breeders or more likely nonbreeders. From mid-June onwards, American Wigeon and Northern Pintails are incubating eggs in nests hidden on shore.*

## **July:**

*With the arrival of summer, the first few post-breeding Horned Grebes appear off Beatton Provincial Park about mid July. Broods of American Wigeon ducklings paddle in shallow areas about mid month. Broods of Lesser Scaup ducklings appear with their mothers from about mid month onwards. Occasionally two or more broods will amalgamate, giving the one or two attending hens up to 20+ ducklings swimming in animated "rafts" behind them. Southbound migration is already beginning for many shorebirds! At this time shorelines attract adult sandpipers that have left their northern breeding grounds already. The most frequent species include Lesser Yellowlegs, Solitary Sandpipers, Least Sandpipers, Semipalmated Sandpipers, Baird's Sandpipers, Pectoral Sandpipers, and Long-billed Dowitchers. The lucky birder may find rare types like the occasional Hudsonian Godwit or Western Sandpiper. From mid-July onwards watch for small groups of Black Terns. There may be adults accompanied by fledged juveniles beginning their journey south. By month's end Tree Swallows have migrated south and only rare stragglers can be found.*

## **August:**

*For many birds August represents early fall rather than summer. The short boreal summer is definitely winding down as small groups of Common Loons gather off the golf course about this time. About mid month flocks of up to 200 Northern Shovelers arrive. From mid August onwards, small numbers of migrant Sharp-shinned Hawks pass through the woodlands around the lake. In low water years look for shorebirds along the beach at Beatton Provincial Park and other locations. Sometimes the diversity of sandpiper species can almost equal that to be found at better-known shore-birding spots like the Fort St. John sewage lagoons or Boundary Lake. Species will include Least Sandpipers, Semipalmated Sandpipers, Baird's Sandpipers, and Lesser Yellowlegs, and may also include uncommon species like Stilt Sandpipers and Short-billed Dowitchers. August is also the time to watch for Parasitic Jaegers (rare). Although the vast majority of Jaegers migrate by sea, a few appear each year on inland lakes, pursuing and robbing gulls and terns of their food. From mid-month onwards look for the occasional Belted Kingfisher. The generally silty waters of North Peace streams and rivers prevent the kingfisher from spotting its prey, small fish, so the bird is absent or rare from much of the area. However, during almost every August and September a few kingfishers pass through, often lingering a day or two at Charlie Lake.*

## **September:**

*American Golden-Plovers may appear in small numbers in open areas like the south end of the lake during the first half of September. This is a good time to look for Pied-billed Grebes around the south end. The Pied-billed is the least common grebe in the North Peace, nesting quite locally at shallow lakes like Boundary Lake. It appears on Charlie Lake only as a very rare migrant. Flocks of Northern Shovelers appear, often off Montney Centennial Park. Small numbers of Northern Pintails can be found in shallow areas. Canvasbacks begin to appear as fall migrants about mid month. By mid month Blue-winged Teals and Spotted Sandpipers have departed for the south. Look all month for the rare Sabine's Gull, a high arctic nester, which fairly regularly uses the lake as a short stopover on its journey to South America oceanic waters. Horned Grebe and Surf Scoter migration peaks about mid month.*

## October to November 15:

*Small numbers of the uncommon Hooded Merganser appear at the north and south ends of the lake. Why this species, common in southern BC but largely absent from northeastern BC, arrives on a northern lake a month before freeze-up is not known. The big bay north of Beaton Provincial Park is once again a good spot to find flocks of several species of waterbirds including American Wigeons, Canvasbacks, Ring-necked Ducks, Lesser Scaups, Surf Scoters, Buffleheads, Common Goldeneyes and Ruddy Ducks. October is a good month to find small groups of Long-tailed Ducks (formerly called Oldsquaws). These very vocal arctic breeders are most frequent in the centre of the lake and are visible with the aid of a good spotting scope from Charlie Lake Provincial Park. The centre is also a prime location for the uncommon Red-breasted Merganser. Small numbers of Canvasbacks are frequent during the second half of October. Thousands of Lesser Scaup, one of the commonest ducks on the lake, gather from late September through October, as do hundreds of Buffleheads, more common now than at any other time of year. Large numbers of Common Goldeneyes are among the last waterfowl to depart as the lake freezes over. Also look for lesser numbers of Barrow's Goldeneyes as well. Check the centre of the lake for the final flocks to depart. Sometimes they contain rare birds, notably once a Harlequin Duck. Charlie Lake usually freezes sometime between the last days of October and the first week or two of November. As the lake freezes, the pans of new ice grind against each other in an odd symphony of tinkles, squeaks, hisses, and cracks, signalling the end of another year for waterfowl at this northern lake.*

Appendix  
List of Bird Species Observed by C.  
Siddle During the Course of the 1981  
to 1988 Charlie Lake Surveys

### **A) Loons (Order Gaviiformes)**

1. Common Loon (*Gavia immer*)
2. Pacific Loon (*Gavia pacifica*)
3. Red-throated Loon (*Gavia stellata*)

### **B) Grebes (Order Podicipediformes)**

1. Pied-billed Grebe (*Podiceps auritus*)
2. Horned Grebe (*Podiceps auritus*)
3. Red-necked Grebe (*Podiceps grisegena*)
4. Eared Grebe (*Podiceps nigricollis*)
5. Western Grebe (*Aechmophorus occidentalis*)

### **C) Cormorants (Order Pelecaniformes)**

1. Double crested Cormorant (*Phalacrocorax auritus*)

### **D) Swans, geese and ducks (Order Anseriformes)**

1. Greater White-fronted Goose (*Anser albifrons*)
2. Canada Goose (*Branta canadensis*)
3. Trumpeter Swan (*Cygnus buccinator*)
4. Tundra Swan (*Cygnus columbianus*)
5. Gadwall (*Anas strepera*)
6. Eurasian Wigeon (*Anas penelope*)
7. American Wigeon (*Anas americana*)
8. Mallard (*Anas platyrhynchos*)
9. Blue-winged Teal (*Anas discors*)
10. Cinnamon Teal (*Anas cyanoptera*)
11. Green-winged Teal (*Anas crecca*)
12. Northern Shoveler (*Anas clypeata*)
13. Northern Pintail (*Anas acuta*)
14. Canvasback (*Aythya valisineria*)
15. Redhead (*Aythya americana*)
16. Ring-necked Duck (*Aythya collaris*)
17. Greater Scaup (*Aythya marila*)
18. Lesser Scaup (*Aythya affinis*)
19. Harlequin Duck (*Histrionicus histrionicus*)
20. Surf Scoter (*Melanitta perspicillata*)
21. White-winged Scoter (*Melanitta fusca*)
22. Black Scoter (*Melanitta nigra*)
23. Oldsquaw (*Clangula hyemalis*)
24. Bufflehead (*Bucephala albeola*)
25. Common Goldeneye (*Bucephala clangula*)
26. Barrow's Goldeneye (*Bucephala islandica*)
27. Hooded Merganser (*Lophodytes cucullatus*)
28. Common Merganser (*Mergus merganser*)
29. Red-breasted Merganser (*Mergus serrator*)
30. Ruddy Duck (*Oxyura jamaicensis*)

### **E) Eagles and falcons (Order Falconiformes)**

1. Osprey (*Pandion haliaetus*)
2. Bald Eagle (*Haliaeetus leucocephalus*)

## F) Kingfishers (Order Coraciiformes)

1. Belted Kingfisher (*Ceryle alcyon*)

## G) Rails (Order Gruiformes)

1. Sora (*Porzana carolina*)
2. American Coot (*Fulica americana*)

## H) Gulls, sandpipers, jaegers, terns and plovers (Order Charadriiformes)

1. Black-bellied Plover (*Pluvialis squatarola*)
2. Lesser Golden-Plover, a.k.a American Plover (*Pluvialis dominica*)
3. Semipalmated Plover (*Charadrius semipalmatus*)
4. Killdeer (*Charadrius vociferus*)
5. Greater Yellowlegs (*Tringa melanoleuca*)
6. Lesser Yellowlegs (*Tringa flavipes*)
7. Willet (*Catoptrophorus semipalmatus*)
8. Solitary Sandpiper (*Tringa solitaria*)
9. Spotted Sandpiper (*Actitis macularia*)
10. Upland Sandpiper (*Bartramia longicauda*)
11. Western Sandpiper (*Calidris mauri*)
12. Least Sandpiper (*Calidris minutilla*)
13. White-rumped Sandpiper (*Calidris fuscicollis*)
14. Baird's Sandpiper (*Calidris bairdii*)
15. Pectoral Sandpiper (*Calidris melanotos*)
16. Stilt Sandpiper (*Calidris himantopus*)
17. Semipalmated Sandpiper (*Calidris pusilla*)
18. Whimbrel (*Numenius phaeopus*)
19. Hudsonian Godwit (*Limosa haemastica*)
20. Ruddy Turnstone (*Arenaria interpres*)
21. Sanderling (*Calidris alba*)
22. Short-billed Dowitcher (*Limnodromus griseus*)
23. Long-billed Dowitcher (*Limodromus scolopaceus*)
24. Common Snipe (*Gallinago gallinago*)
25. Wilson's Phalarope (*Phalaropus tricolor*)
26. Red-necked Phalarope (*Phalaropus lobatus*)
27. Parasitic Jaeger (*Stercorarius parasiticus*)
28. Franklin's Gull (*Larus pipixcan*)
29. Bonaparte's Gull (*Larus philadelphia*)
30. Mew Gull (*Larus canus*)
31. Ring-billed Gull (*Larus delawarensis*)
32. California Gull (*Larus californicus*)
33. Herring Gull (*Larus argentatus*)
34. Glaucous-winged Gull (*Larus glaucescens*)
35. Sabine's Gull (*Xema sabinii*)
36. Little Gull (*Larus minutus*)
37. Arctic Tern (*Sterna paradisaea*)
38. Common Tern (*Sterna hirundo*)
39. Forster's Tern (*Sterna forsteri*)
40. Black Tern (*Chlidonias niger*)

### **I) Songbirds (Order Passeriformes)**

1. Tree Swallow (*Tachycineta bicolor*)
2. Violet-green Swallow (*Tachycineta thalassina*)
3. Bank Swallow (*Riparia riparia*)
4. Cliff Swallow (*Hirundo pyrrhonota*)
5. Barn Swallow (*Hirundo rustica*)

Checklist of the Birds of Charlie Lake, BC 2004

Group	Species	Spring migration	Summer resident	Summer migration	Fall migration	Breeds on / around lake	Comments
Loons	Common Loon	C	C	C	C	Y	Common in small numbers from spring through fall
	Pacific Loon	R	-	-	R	-	Rare to very uncommon spring and fall migrant
	Red-breasted Loon	R	-	-	R	-	Rare spring and fall migrant Occurs in mid May and again from mid Aug to mid Oct
Grebes	Pied-billed Grebe	UC	-	-	UC	-	Very rare migrant
	Horned Grebe	C	-	-	C	-	Common spring and fall migrant
	Red-necked Grebe	C	-	-	C	-	Common spring and fall migrant Uncommon summer resident
	Eared Grebe	C	-	-	C	-	Common spring and fall migrant in small numbers
	Western Grebe	UC	VUC	-	UC	-	Uncommon but annual spring and fall migrant Very uncommon summer resident
	Greater White-fronted Goose	R	-	-	R	-	Very rare migrant
Swans, Ducks & Geese	Snow Goose	A	-	-	-	-	Very rare migrant
	Canada Goose	UC	-	-	UC	-	Although common in the North Peace, uncommon migrant on the lake
	Trumpeter Swan	R	-	-	R	-	Although increasing as a breeder in the North Peace, a rare migrant on the lake
	Tundra Swan	VR	-	-	VR	-	Very rare spring and fall migrant Prefers flooded fields and shallower lakes for stopovers
	Gadwall	UC	-	-	UC	-	Uncommon spring and fall migrant in small numbers No breeding records though it does nest elsewhere in the North Peace
	Eurasian Wigeon	A	-	-	-	-	Accidental in spring migration
	American Wigeon	C	-	-	C	Y	Common spring and fall migrant, occasionally in flocks of 100-300 birds Common breeder
	Mallard	C	-	-	C	Y	Common spring and fall migrant Common breeder
	Blue-winged Teal	UC	-	-	UC	Y	Uncommon spring and fall migrant Occasionally breeds
	Cinnamon Teal	VR	-	-	-	-	Very rare spring migrant
	Northern Shorelark	C	-	-	C	-	Common spring and fall migrant Occasionally bred, formerly, in south end marsh
	Northern Pintail	UC	-	-	UC	-	Uncommon spring and fall migrant May become briefly abundant in late Apr and early May Former breeder in small numbers at south end marsh
	Green-winged Teal	C	-	-	C	-	Common in very small numbers as a spring and fall migrant Formerly bred in south end marsh
	Carrivaback	C	-	-	C	-	Common spring and fall migrant in small numbers Occasionally flocks of 100+ birds occur in early May Formerly occurred, and perhaps bred, during the summer at the south end
	Redhead	UC	-	-	UC	-	Uncommon spring and fall migrant
	Ring-necked Duck	UC	-	-	UC	-	Uncommon spring and fall migrant
	Greater Scaup	VR	-	-	-	-	Very rare spring migrant
	Lesser Scaup	C	-	-	C	-	Common spring and fall migrant Bred most commonly at the S end marsh before it was drained, also breeds elsewhere around the lake. Fall migrants appear during Aug and numbers build throughout the fall
	Harlequin Duck	-	-	-	A	-	One female or immature, 7 Nov 1986 off Charlie L. Provincial Park
	Surf Scoter	C	-	-	C	-	Common spring and fall migrant in small numbers Occurs throughout May and early June, re-appearing in mid-August through October
	White-winged Scoter	C	-	-	C	-	Common spring and fall migrant More abundant than the Surf Scoter Occasionally occurs as a summer resident, perhaps as molting makes
	Black Scoter	-	-	-	VR	-	Very rare fall migrant
Ontonow	UC	-	-	UC	-	Uncommon spring and fall migrant No flock over 75 has been recorded	
Bufflehead	C	-	-	C	-	Common spring and fall migrant Largest flocks (100-300 birds) occur in Sept and Oct Occasional summer resident in very small numbers One brood recorded at the south end	
Common Goldeneye	C	-	-	C	Y	Common spring and fall migrant Most plentiful in late Apr and early May and Oct Frequent into early June Occasionally breeds	
Barnow's Goldeneye	C	-	-	C	-	Common spring and fall migrant though not as abundant as the Common Goldeneye No breeding records Small flocks of adult males are occasional in June	
Hooded Merganser	-	-	-	R	-	Rare fall migrant with most records in October One Apr record	
Common Merganser	R	-	-	-	-	Rare spring migrant, with most records from Apr until mid May Occasional in summer with one breeding record One late fall record	
Red-breasted Merganser	R	-	-	R	-	Rare spring and fall migrant	
Ruddy Duck	UC	-	-	UC	-	Uncommon spring and fall migrant in small numbers	

Checklist of the Birds of Charlie Lake, BC 2004

Group	Species	Spring migration	Summer resident	Summer migration	Fall migration	Breeds on / around lake	Comments
Hawks & Eagles	Osprey	VR	-	-	-	-	Very rare spring migrant, with all four records from the first half of May
	Bald Eagle	-	UC	-	-	Y	One or two pairs appear to be summer residents and may breed. Recorded from Apr 20 to Nov 7
	Northern Harrier	UC	-	-	UC	-	Uncommon spring and fall migrant. One nesting record
	Sharp-shinned Hawk	R	-	-	R	-	Rare spring and uncommon fall migrant
	Northern Goshawk	-	R	-	-	Y	Rare resident. Numbers increase, matching the populations of cycles of Varying Hares. One nesting record
	Broad-winged Hawk	-	VR	-	-	-	Very rare summer resident.
	Red-tailed Hawk	-	UC	-	-	-	Uncommon summer resident.
	Rough-legged Hawk	R	-	-	R	-	Rare spring and fall migrant
Falcons	Golden Eagle	-	R	-	-	-	Rare resident
	American Kestrel	UC	-	-	UC	-	Uncommon spring and fall migrant
Ralls & Coots	Merlin	-	UC	-	-	-	Uncommon summer resident
	Sora	UC	-	-	UC	Y	May breed in very limited numbers at north end. Requires marsh for nesting. Likely an uncommon migrant.
	American Coot	UC	-	-	UC	-	Uncommon, occasionally abundant, spring and fall migrant. Largest numbers (100-300) usually occur at the north or south ends.
Plovers	Black-bellied Plover	VR	-	-	VR	-	Very rare spring and fall migrant
	American Golden-Plover	-	-	-	VR	-	Very rare fall migrant. One spring record
Sandpipers	Semipalmated Plover	UC	-	-	UC	-	Uncommon spring and fall migrant
	Killdeer	-	UC	-	-	Y	Uncommon summer resident with breeding records from the south end
	Greater Yellowlegs	VR	-	-	R	-	Very rare spring migrant. Rare fall migrant, appearing as early as late July
	Lesser Yellowlegs	C	-	-	C	-	Common spring and fall migrant. Appears as early as late Apr. Small numbers may occur through June, with migrant south-bound adults appearing in early July. Leaves by mid-Sept.
	Solitary Sandpiper	UC	-	-	UC	-	Uncommon spring and fall migrant
	Willet	A	-	-	-	-	Accidental
	Spotted Sandpiper	-	C	-	-	Y	Common and wide spread summer resident. Nesting records from several locations. Usually departs by mid-Sept.
	Upland Sandpiper	-	-	-	VR	-	Very rare early fall migrant. Both records from mid-Aug.
	Whimbrel	VR	-	-	-	-	Very rare spring migrant
	Hudsonian Godwit	VR	-	VR	-	-	Very rare spring and summer migrant
	Ruddy Turnstone	VR	-	-	VR	-	Accidental
	Sanderling	C	-	-	VR	-	Very rare spring and fall migrant
	Semipalmated Sandpiper	UC	-	-	VR	-	Very rare spring and fall migrant
	Western Sandpiper	C	-	-	VR	-	Common spring and fall migrant in small numbers. Occasional in June
	Least Sandpiper	R	-	A	-	-	One record (8 Jul 1981 s. end) at Charlie Lake but rare migrant in rest of North Peace.
	White-rumped Sandpiper	UC	-	-	UC	-	Uncommon spring and fall migrant. Occurs in small numbers
Baird's Sandpiper	UC	-	-	UC	-	Rare but probably regular spring migrant, appearing in the second half of May	
Pectoral Sandpiper	UC	-	-	UC	-	Uncommon spring and fall migrant	
Stilt Sandpiper	VR	-	-	VR	-	Uncommon spring and fall migrant. South-bound migrants may appear as early as mid-July	
Buff-breasted Sandpiper	A	-	-	VR	-	Very rare spring and fall migrant	
Short-billed Dowitcher	R	-	-	R	-	Accidental	
Long-billed Dowitcher	R	-	-	R	-	Rare spring and fall migrant	
Common Snipe	-	UC	-	-	-	Formerly an uncommon spring and fall migrant to the marsh at the south end. Now encountered much less frequently	
Wilson's Phalarope	UC	-	-	UC	-	Uncommon summer resident at the south end marsh	
Red-necked Phalarope	UC	-	-	UC	-	Formerly an uncommon summer resident which probably nested around the south end marsh. Still an uncommon spring and fall migrant	

Checklist of the Birds of Charlie Lake, BC 2004

Group	Species	Spring migration	Summer resident	Summer migration	Fall migration	Breeds on/ around lake	Comments	
Jaegers, Gulls & Terns	Pacific Jaeger	-	-	VR	-	-	Very rare summer migrant	
	Franklin's Gull	C	-	-	C	-	Common spring migrant and early summer resident. Numbers dramatically drop off by the end of June. A few immatures appear as residents throughout July and Aug.	
	Bonaparte's Gull	VC	C	C	C	-	Very common spring migrant. Abundant summer resident. Adults migrate through in May. Immatures appear in June. Adults reappear in July and may linger in numbers until mid Oct.	
	Mew Gull	UC	-	-	UC	-	Uncommon spring and fall migrant. Very small numbers appear in summer	
	Ring-billed Gull	UC	-	-	UC	-	Uncommon spring and fall migrant and summer resident	
	California Gull	R	R	-	-	-	Rare spring migrant and summer resident	
	Herring Gull	UC	-	-	UC	-	Uncommon spring and fall migrant. Small numbers of immatures visit in summer	
	Glaucous-winged Gull	-	VR	-	-	-	Very rare, irregular summer visitor	
	Glaucous Gull	-	-	A	-	-	One record of a second-year bird 21 Jun - 10 Jul 1980 at south end	
	Sabine's Gull	VR	-	-	-	-	Very rare late spring migrant. Very rare fall migrant, mainly in Sept	
	Line Gull	-	-	A	-	-	One record of a first summer bird 9 Jun - 13 Jun 1983 at south end of lake	
	Arctic Tern	-	-	VR	-	-	Very rare migrant in late May and early June. Very rare fall migrant in late Aug and early Sept	
	Common Tern	VR	R	-	R	-	Very rare spring migrant. Rare summer visitor and fall migrant	
	Foster's Tern	A	-	A	-	-	2 adults and 2 first summer birds 6 Jun 1988 south end. One adult 27 May 1988 at south end.	
	Black Tern	UC	-	UC	-	-	Uncommon spring migrant in late May and early June. Adults seem to appear with imm at the S marsh in mid July until drainage in 1982. Adults and imm appear as south bound migrants in early to mid Aug.	
	Swallows	Tree Swallow	C	-	-	C	-	Common spring migrant sometimes in flocks of 500+ when cold fronts strike. Uncommon summer resident
		Violet-green Swallow	R	-	-	-	-	Rare spring migrant
Barn Swallow		UC	-	-	UC	-	Uncommon spring and fall migrant	
Chimney Swallow		VUC	-	-	VUC	-	Very uncommon spring and fall migrant	
Barn Swallow		UC	UC	-	UC	-	Uncommon spring migrant. Uncommon summer resident. Uncommon fall migrant	

Checklist Key

Migrant  
Summer resident

Uses Charlie Lake as a stop-over location during migration.

Occurs during summer months. May be non-breeders, as Western Grebes are, or post-breeding molting males, as with some waterfowl and Bonaparte's Gull

1-2 records. These records are from outside the species' usual range of distribution. Willet is an example.

Not annual but has occurred 2-8 times during the surveys. Occurrences is irregular. Silt Sandpiper is an example.

Annual but occurs a very few times a year and usually only in small numbers.

Occurs in very few numbers, but on a regular basis

Regular but present only a few times a year. Red-necked Phalarope is an example.

Present in season. May occur in small numbers or be more abundant. Common Loon is a good example.

Virtually certain to be found, often in numbers, such as Franklin's Gull in late spring/ early summer.

Acknowledgements

This checklist was prepared by Barry Booth and is based on the surveys of Charlie Lake by Chris Stodie

Additional observations to this checklist are welcomed. Nest records of all species are especially desired.

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