Screening Tool to Identify Low Risk Withdrawals from Lakes in Alberta and Northeast British Columbia

March 2016

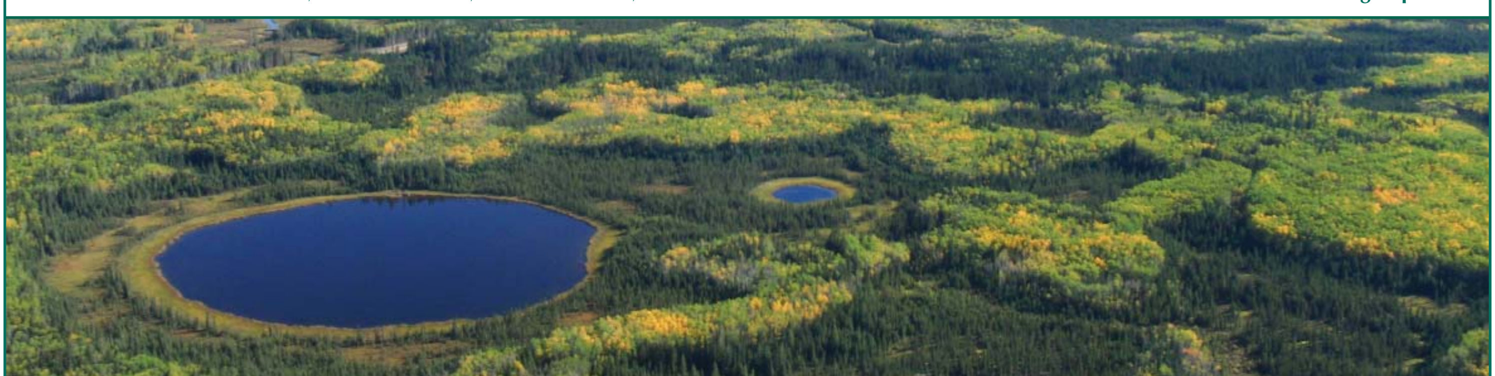
Prepared for:

Petroleum Technology Alliance Canada
Calgary, Alberta

and

British Columbia Oil and Gas Research and Innovation Society
Victoria, British Columbia

#200 - 850 Harbourside Drive, North Vancouver, British Columbia, Canada V7P 0A3 • **Tel: 1.604.926.3261** • Fax: 1.604.926.5389 • **www.hatfieldgroup.com**



SCREENING TOOL
TO IDENTIFY LOW RISK WITHDRAWALS FROM LAKES IN ALBERTA AND NORTHEAST BRITISH COLUMBIA

Prepared for:

PETROLEUM TECHNOLOGY ALLIANCE CANADA
SUITE 400, CHEVRON PLAZA
500 – FIFTH AVENUE S.W.
CALGARY, AB T2P 3L5

BRITISH COLUMBIA OIL AND GAS RESEARCH AND INNOVATION SOCIETY
300, 398 HARBOUR ROAD
VICTORIA, BC V9A 0B7

Prepared by:

HATFIELD CONSULTANTS
#200 - 850 HARBOURSIDE DRIVE
NORTH VANCOUVER, BC
CANADA V7P 0A3

MARCH 2016

PTAC7367

VERSION 5

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ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
AEP	Alberta Environment and Parks
AER	Alberta Energy Regulator
AESRD	Alberta Environment and Sustainable Resources Development
CMA	Catchment Management Agency (South Africa)
CMS	Catchment Management Strategy (South Africa)
CRWE	Complementary Relationship Wet-surface Evaporation model
CRLE	Complementary Relationship Lake Evaporation
DEP	Department of Environmental Protection (Florida)
DFO	Fisheries and Oceans Canada (Department of Fisheries and Oceans)
DO	Dissolved oxygen
EMC	Ecological Management Class (South Africa)
EU	European Union
GRDC	Global River Data Centre
JOSMP	Joint Oil Sands Monitoring Program
MAP	Mean Annual Precipitation
MAT	Mean Annual Air Temperature
MFL	Minimum Flows and Levels (Florida)
NES	National Environmental Standard (New Zealand)
NEWT	NorthEast Water Tool (British Columbia)
NPS	National Policy Statement for Freshwater Management 2014 (New Zealand)
NWRS	National Water Resource Strategy (South Africa)
NWT	Northwest Territories
NWWT	NorthWest Water Tool (British Columbia)
TOOL	Preliminary Draft Tool for Sustainable Withdrawal from lakes in Alberta and NE BC (this document)
PFRA	Prairie Farm Rehabilitation Administration (now Agriculture and Agri-Food Canada)
PRISM	Parameter-Elevation Regressions on Independent Slopes
Q	Discharge
RAMP	Regional Aquatics Monitoring Program
RDM	Resource Directed Measure (South Africa)
RISC	Resources Information Standards Committee (British Columbia)
RQO	Resource Quality Objective (South Africa)
SEPA	Scottish Environment Protection Agency
SNIFFER	Scotland and Northern Ireland Forum for Environmental Research
STU	Short Term Use (British Columbia)
TDL	Temporary Diversion License (Alberta)
UK	United Kingdom
WFD	Water Framework Directive (European Union)
WMD	Water Management District (Florida)
WSP	Water Supply Plan (Florida)

ACKNOWLEDGEMENTS

We would like to thank Petroleum Technology Alliance Canada (PTAC) and BC Oil and Gas Commission (BC OGC) for their funding of this project through the Alberta Upstream Petroleum Research Fund (AUPRF) and the BC Oil and Gas Research and Innovation Society (BC OGRIS).

We wish to thank the officials and regulators who provided their time and expertise to discussions relating to lake withdrawals. Discussions with these experts were of great value. In Alberta, this includes Rick Nutbrown and Ernst Kerkhoven (Alberta Energy Regulator), Andrew Paul, Michael Seneka and Thorsten Hebben (Alberta Environment and Parks). In BC, this includes Allan Chapman (BC Oil and Gas Commission), and Jennifer Turner (Ministry of Environment). Internationally, this includes Jack Winters (Alaska Department of Fish and Game), Don Medellin (South Florida Water Management District), Lawrence Kees (Environment Southland, New Zealand), Tony Quickfall (Waikato Region, New Zealand), Andrew Duthie (Hatfield Consultants, formerly Oryx Environmental, South Africa), Heather MacKay (FHB Consulting Services Inc., formerly South Africa Department for Water Affairs and Forestry), Jan van Staden (Breede-Gouritz Catchment Management Agency, South Africa), and Jenny Davies and Richard Gosling (Scottish Environment Protection Agency, SEPA).

Finally, we would also like to thank the January 21, 2016 workshop participants for their time and input to the tool. Their feedback was an important piece to support the development of a defensible and practical screening tool to identify potential low risk withdrawals from lakes.

EXECUTIVE SUMMARY

This document outlines the development of a screening tool to identify lake withdrawal limits that have a low risk of unacceptable environmental effects.

This preliminary tool was developed following a review of methodologies used in other jurisdictions, current environmental considerations for Alberta and British Columbia water license applications, and available hydrologic data.

The tool allows proponents to determine conservative lake withdrawal volumes and lake level drawdown limits. The approach is designed to be applicable to gauged and ungauged lakes greater than 0.1 km^2 in size and located within Alberta and Northeast BC. The approach is intended to be primarily desktop-based, but may use site-specific data (if available). The tool may be used to quickly steer a proponent away from areas where withdrawals may pose a higher risk, and towards more hydrologically favourable lakes (e.g., lakes with greater volume, depth and runoff). The tool uses publicly available hydroclimatic datasets, and preliminary datasets have been created where suitable ones were not previously available.

The screening tool is based on four main considerations:

1. *Is there surplus water available for licensing?*
2. *Does the proposed withdrawal have a low potential of affecting overwintering fish?*
3. *Does the proposed withdrawal have a low potential for unacceptable impacts to habitat and associated environmental values?*
4. *Does the proposed withdrawal have a low potential for unacceptable reductions to downstream flows?*

Multiple approaches to address these considerations and answer these questions were considered during the development of the tool. These approaches were assessed to determine which considerations were likely to be limiting (i.e., which considerations resulted in the most conservative withdrawal criteria), and those limiting criteria were consolidated into a simple set of withdrawal limits. Proposed withdrawals that are below the proposed coarse screening limits are anticipated to have a lower likelihood for unacceptable environmental impacts.

Proposed withdrawals that exceed the withdrawal limits in this tool may still pose a low risk to environmental values; however, additional, site-specific information is required to more accurately assess potential impacts under these circumstances.

AMENDMENT RECORD

This report has been issued and amended as follows:

Issue	Description	Date	Approved by	
1	Internal draft of preliminary draft protocol for discussion purposes	20151117		
2	second draft of preliminary draft protocol for discussion purposes	20151216		
3	Preliminary draft of protocol issued to January 21, 2016 workshop participants	20160113		
4	Draft final screening tool to identify low risk withdrawals from lakes in Alberta and Northeast British Columbia	20160331		
5	Final screening tool to identify low risk withdrawals from lakes in Alberta and Northeast British Columbia	20160331	Dan Moats Project Director	Tim Bennett Project Manager

1.0 INTRODUCTION

Hatfield Consultants (Hatfield) is pleased to provide Petroleum Technology Alliance Canada (PTAC) and the British Columbia Oil and Gas Research and Innovation Society (BC OGRIS) with this report documenting the development of low risk lake withdrawal limits, for use in Alberta and Northeast BC.

This study was completed under PTAC Recipient Agreement 15-WIPC-06, using funding from the Alberta Upstream Petroleum Research Fund (the "AUPRF Fund" and the BC OGRIS).

This document summarizes:

- The approach undertaken to develop the suggested withdrawal limits;
- Results of a high-level review of existing guidance documents and readily available hydroclimatic and lake level data for the study area;
- Environmental considerations for incorporation into withdrawal limits, and suggestions from a technical workshop attended by representatives from government, industry and consulting; and
- Preliminary suggestions for criteria to screen proposed lake withdrawals.

1.1 OBJECTIVES

The objective of the study was to develop a tool (i.e., an analytical methodology or screening approach) to identify maximum withdrawals that would not result in unacceptable impacts to selected environmental values within a lake.

The tool is intended to:

- Be desktop based, practical, and defensible;
- Incorporate key environmental considerations into low risk or short term water diversion applications in Alberta and Northeast BC, as outlined in policy and guidance;
- Identify if a proposed withdrawal is expected to have a low risk for unacceptable impacts to environmental or other resource values; and
- Support water diversion applications (e.g., short term use of water, water licenses, temporary and permanent diversion licenses) in Alberta and Northeast BC.

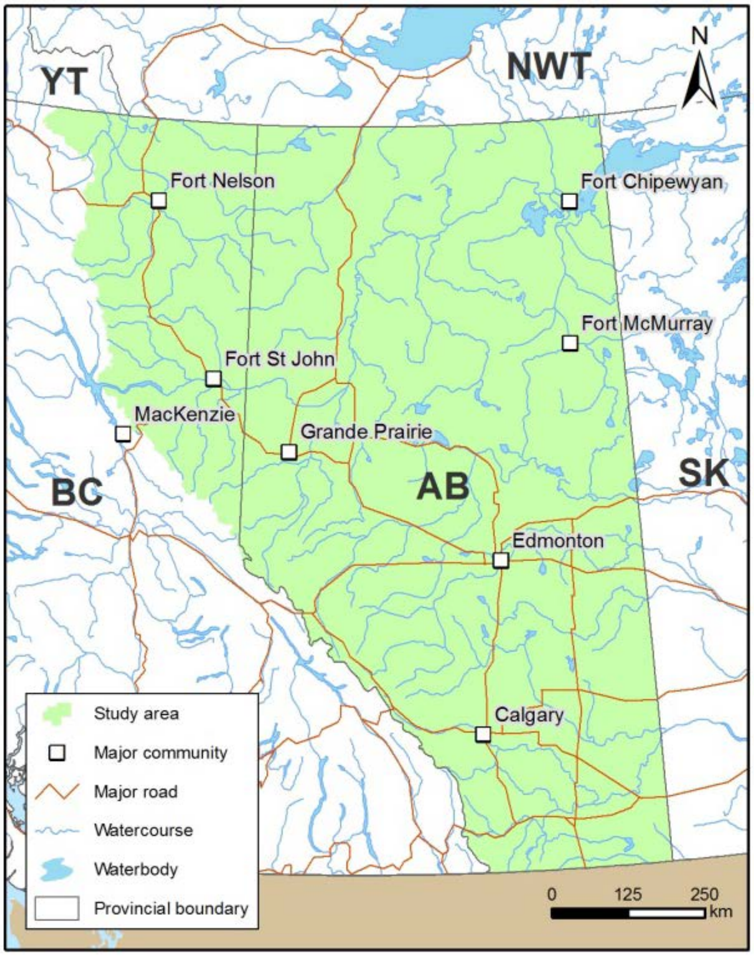
This tool may be overly conservative in some cases, as it is intended to be supported by limited regional data, which will often be compiled through a desktop review. As such, a proposed lake withdrawal may pose a low risk for adverse impacts and not meet the screening criteria within this tool.

It should be noted that the results of this study (i.e., information obtained during the development of the tool, and suggested preliminary withdrawal limits) are provided as guidance. The suggested approach to establishing screening withdrawal limits should not be interpreted to be prescriptive, as other approaches may also be appropriate and defensible.

1.2 APPLICATION AREA

The intended application area for this tool is defined as the province of Alberta and Northeast BC (Figure 1), which includes the portion of BC north of about 54 degrees latitude, extending roughly north from Willison Lake to the Yukon border. The Northeast BC boundaries are the same as those used in the NorthEast Water Tool (NEWT 2015).

Figure 1 Intended Tool Application Area: Alberta and Northeast British Columbia.



2.0 APPROACH

The hypothesis is that a desktop tool could be developed to set conservative withdrawal limits using upon a simple water balance approach and hydrological data. This approach was also considered suitable as a desktop, screening method because:

- Hydrological factors are fundamental drivers of other environmental variables (e.g., Gaboury and Patalas 1984, Riis and Hawes 2002, Furey et al. 2004, McGowan et al. 2005, Cott et al. 2008a, 2008b);
- There is existing informal guidance for lake withdrawals using a water balance approach, in Alberta and possibly other jurisdictions;

- Hydrologic approaches have been developed to establish environmental flow requirements in a number of jurisdictions (e.g., Leeper et al. 2001, SNIFFER 2006), including instream flow needs in Alberta and BC;
- A variety of regional hydrometric and climatic data sources and tools are readily available for Alberta and Northeast BC; and
- Regional data for a number of Alberta and BC lakes could provide insight into their “natural” behavior (e.g., typical lake level fluctuations) and suggest conditions that would be unlikely to result in unacceptable environmental impacts.

The development of the tool included the following steps:

1. High level review of lake withdrawal guidance and policy in Alberta, BC, and other selected jurisdictions (literature review);
2. Identification of specific environmental considerations for water permitting in Alberta and BC;
3. Assessment of available hydrometric and climatic data sources for Alberta and BC;
4. Compilation of Alberta and BC lake level data and assessment of “baseline” conditions for Alberta and Northeast BC lakes, including historical lake level fluctuations and climate normals;
5. Development of a preliminary draft tool, outlining environmental considerations and screening criteria;
6. Presentation and discussion of the preliminary tool at a technical workshop. Workshop invitees included government staff (Alberta Energy Regulator (AER), Alberta Environment and Parks (AEP), BC Ministry of Forests, Lands and Natural Resource Operations (FLNRO), BC Oil and Gas Commission (OGC)), industry and consultants;
7. Revision of the preliminary tool to reflect workshop comments and feedback; and
8. Finalization of a preliminary screening tool.

The results of these steps are summarized in the following sections.

3.0 RESULTS

The following section presents the results of the jurisdictional review, pertinent Alberta and BC policy and guidance, a summary of regional hydrological and climatic data sources, and a discussion of baseline conditions for lakes in Alberta and Northeast BC. The materials discussed in this section were used to inform the identification of key screening considerations (Section 4) and the development of a suggested tool (Section 5).

3.1 JURISDICTIONAL REVIEW

A high level review was completed to provide an indication of pertinent environmental and lake withdrawal policies and guidance applied in selected North American, European, African and Australasian jurisdictions. That review included a literature (e.g., web) search and interviews with regulators. The jurisdictions reviewed included: Alaska, Northwest Territories (NWT) and Nunavut, Florida, United Kingdom (UK), New Zealand and South Africa. The results of the review are described in the following sub-sections and summarized in Appendix A1.

This review should be considered a collection of case studies rather than a comprehensive review of existing international lake withdrawal legislation, policy, or guidance. Reviews of existing lake level studies have also been undertaken and reported by other jurisdictions and agencies, notably the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER 2005a).

Although specific approaches varied widely, the tools and guidelines identified by this review tended to fall into one of two general groups, depending on the context and objectives:

- Broad-based “rules of thumb” for changes in lake level or percentage of under-ice volume. These are intended to be easily applied, and are often used as a coarse scale initial screening for risk. These rules are more likely to be used in areas where water resources are relatively abundant and demand is relatively low (i.e., areas of low risk for mining of the water resource), such as Alaska and the Canadian North (although exceptions to the rules may be made for specific higher-risk sites). Documentation for these rules is generally not extensively reported.
- Site-specific standards that are established in accordance with government tools and objectives. These standards often incorporate, as a first step, a classification of risk and/or identification of priority waterbodies, and are frequently based on information from multiple sources that include expert opinion, water balance modeling, and/or hydrologic/hydraulic modeling, They are commonly in practice in areas where all or a portion of the jurisdiction faces significant water supply pressures (e.g., Florida, UK, New Zealand, South Africa) and tend to be relatively time- and labor-intensive to apply.

However, jurisdictions often provide flexibility on a case-by-case basis (e.g., for non-priority waterbodies) and may allow for use of multiple approaches in either category depending on level of risk and ecological sensitivity.

The summaries below also include discussion of some older standards and guidelines. For example, the original tools and guidelines for the UK and New Zealand have been superseded by revised approaches; however, they are included in this report because they are well documented and are considered to have value as examples.

3.1.1 Alaska

Alaska’s large land area, low population density, and extensive surface water resources contribute to an overall abundance of freshwater in the state. The primary consumptive water uses in Alaska are public supply and mining (Maupin et al. 2014).

Water use is regulated and permitted by the Alaska Department of Natural Resources (ADNR) and Alaska Department of Fish and Game (ADF&G). These two agencies work together to review water use permit applications and establish criteria for withdrawals. A primary consideration for water permitting is the protection of fish and fish habitat.

Alaska does not appear to have specific guidelines for open-water lake withdrawals. However, the ADNR and ADF&G specify the simple theoretical rules for winter withdrawal restrictions depending on the fish population of the lake (NSBDPCS 2014). The following rules were developed by regulatory agencies for use where no data exist to support a different withdrawal volume (Cott et al. 2008a, NAS 2003):

- Non-fish bearing lakes: A maximum of 20% of the total calculated lake volume (including ice) can be withdrawn (as liquid water or ice chips harvested). Because the total lake volume does not exclude any assumed volume of water taken up in ice, this scenario allows for the largest withdrawal volume.
- Lakes with non-sensitive fish species: A maximum of 30% of under-ice water volume can be withdrawn, assuming an ice thickness of five feet.
- Lakes with sensitive fish species: A maximum of 15% of under-ice water volume can be withdrawn, assuming an ice thickness of seven feet.

These rules are primarily in use on the North Slope, where the majority of Alaska's large industrial withdrawals occur, although they may be used in other locations statewide if needed. The proponent is required to provide measurements of the lake areal extent and bathymetry, from which allowable withdrawal volumes are calculated. The assumed ice thicknesses are considered to be conservative estimates.

Sensitive lakes (e.g., lakes containing fish species that are near their maximum latitude) are evaluated on a case-by-case basis. Withdrawals from these lakes are not necessarily prohibited, but may be subject to additional monitoring requirements. There is no designated minimum lake size for withdrawals, but the regulatory review processes guide industry usage towards lower quality habitat areas and as few water sources as possible.

A higher withdrawal allocation may also be permitted under special conditions. In some cases the higher allocation is contingent upon the collection of baseline water chemistry and dissolved oxygen (DO) depth profiles (the baseline data generally consist of a single pre-withdrawal measurement) followed by monthly updates on the DO profile while withdrawals are underway. For long-term, large volume withdrawals, the ADNR and ADF&G may require a lake recharge estimate. This estimate is generally required on an annual basis, but it may no longer be required if adequate recharge is determined to be met. In areas with poor quality habitat such as flooded gravel mines, exceptions are often made to withdrawal limits and limits may be potentially increased (e.g., to 30-50% of under-ice volume).

3.1.2 Northwest Territories and Nunavut

Although population pressures are low in northern Canada, winter development activities such as ice road construction and exploratory drilling often require substantial water withdrawals.

Water use licensing is administered by one of five settlement area water boards in the NWT, and by the Nunavut Water Board in Nunavut. Similar to Alaska, the NWT and Nunavut have identified protection of fish and fish habitat as a key objective in regulation of water use.

Fisheries and Oceans Canada (DFO), in conjunction with industry and regional regulators, developed a simple rule-based tool for winter water withdrawal from ice-covered waterbodies. The tool sets the following criteria for winter withdrawals, with criteria based on maximum lake depth (as determined by bathymetric surveys) and estimated maximum ice thickness based on latitude (DFO 2010):

- Total water withdrawal in one ice-covered season must not exceed 10% of the available under-ice water volume (accounting for cumulative use in cases where multiple users are withdrawing from a single waterbody);
- Waterbodies with less than 1.5 m of free water beneath the maximum ice thickness are not to be considered for water withdrawal; and
- Any waterbody with a maximum expected ice thickness greater than or equal to its maximum depth is exempt from the 10% withdrawal limit.

The tool does not apply to waterbodies specifically exempted by the DFO (e.g., Great Bear Lake, Great Slave Lake, Gordon Lake) or to water withdrawals of less than 100 m^3 over the course of one ice-covered period. Additional measures recommended by the tool to mitigate the impacts of water withdrawal include withdrawing water from the deep areas of waterbodies (>2 m below the ice surface) and proper screening of water intakes (DFO 1995).

3.1.3 Florida

Florida contains abundant freshwater resources; however, numerous competing water demands and drought periods have substantially limited water availability in the state over the past several decades. Public supply and agricultural irrigation are the largest water uses in the state (FLDEP 2014a, Maupin et al. 2014).

Water resources in Florida are managed by the state Department of Environmental Protection (DEP) and five water management districts (WMDs). The DEP delegates much of the responsibility for water management to the WMDs. The primary environmental objective for water management in Florida is protection of the water resource from “significant harm” (defined by each WMD), which includes protection of fish and wildlife that are dependent on water. Criteria for lake withdrawals in Florida are set as part of regional Water Supply Plans (WSPs), which are developed through a collaborative process administered by the DEP, WMDs, regional public water supply utilities, and other stakeholders. The WSPs, revised every five years with a 20-year planning horizon, are based on a scientific foundation of knowledge about the regional water supply, including planning-level estimates of water availability, environmental assessments, and projections of population changes and associated water demand.

Minimum Flows and Levels (MFLs) are defined for major waterbodies in Florida based on natural seasonal fluctuations in water levels, topography, soils and vegetation, environmental requirements, and other considerations such as navigation and recreation (Section 62-40.473 Florida Administrative Code, Leeper et al. 2001). Multiple MFLs may be defined for a system based on magnitude and timing of flows and water levels. Waterbodies are prioritized for MFL establishment on the basis of environmental, cultural, and historical importance and the potential for significant harm to the water resource from current and planned water withdrawals (FLDEP 2014b). If it is determined that water flows or levels are below the relevant MFL, or will fall below an established MFL within the next 20 years, the WMD must develop and implement a recovery or prevention strategy.

For example, the South Florida Water Management District (SFWMD) has defined a conceptual framework for setting MFLs based on the following scientifically-based hierarchy of severity (Angelo et al. 2008, SFWMD 2014):

- Harm: Temporary loss of water resource functions taking 1-2 years to recover under normal rainfall conditions. Consumptive water use permitting targets the avoidance of harm.
- Significant harm: Temporary loss of water resource functions taking more than 2 years to recover under normal rainfall conditions. MFLs are established to prevent significant harm.
- Serious harm: Permanent or irreversible loss of water resource functions. Drought restrictions may be imposed to prevent serious harm.

3.1.4 United Kingdom

Water availability in the United Kingdom is unevenly distributed, with a high degree of geographic variability. Rainfall and available water are higher in Scotland and Northern Ireland, where populations are comparatively low. Conversely, the southern UK, particularly southeast England, receives relatively less rainfall and has a greater population, causing high demand and low availability of water resources (WRAP 2011, RGS 2012). Public water supply is the largest consumptive use of freshwater in the UK (WRAP 2011).

Water policy in the UK is guided by the European Union's Water Framework Directive (EU WFD), which became law in December 2000. The WFD sets a watershed-based approach for protection of all waters, including rivers, lakes, estuaries, coastal waters, and groundwater. It requires the classification of defined waterbodies into one of five ecological status classes on the basis of biological and physical criteria: high, good, moderate, poor, and bad. The general objective of the WFD is to achieve "good status" (defined as a slight deviation from reference conditions) for all European waters by 2015. EU member countries are responsible for developing environmental standards that relate to the boundaries of the WFD status bands.

In the UK, overall implementation of the WFD is administered by national environment agencies, but much of the practical application of the directive is conducted by river basin management districts. Management plans are established for major river catchments, and each management plan defines specific targets and management strategies, which in turn guide the regulatory approach to water licensing (e.g., UK EA 2009, TF 2010).

In accordance with the WFD, the primary objective of lake level management in the UK is to maintain or achieve "good status" (limited exceptions apply in cases when a waterbody is so heavily modified that "good status" is considered unachievable). Environmental standards defining ecological status were initially developed by the Scotland and Northern Ireland Forum for Environmental Research (SNIFFER) in a project referred to as WFD48 (SNIFFER 2005a, 2005b, 2006). Those standards were originally defined in consideration of lake sensitivity and expressed as allowable withdrawal limits as a percentage of outflows. Lake-specific sensitivity was based on catchment land cover and geology, lake depth, lake altitude, lake area, season of assessment, and lake basin form. The sensitivity scores correspond to an acceptable modified water level for each ecological status class in summer or winter, referenced to the level of the sill at the outlet of the lake. The water level standards were converted to corresponding percent flow reductions using the Chezy hydraulic equation (SNIFFER 2006). The resulting set of standards allowed lake withdrawals of between 5-30% of the net inflow. A subsequent review (Gosling and Hatton-Ellis 2012, DEFRA 2014, UKTAG 2014) indicated that the original standards were overestimating the severity of relatively small changes in lake levels. Following this review, the standards were revised from a volumetric flow basis to a surface area basis, with "surface area" defined as the area of overlying water extending from the shore to a depth of 5 meters greater than the depth at which rooted plants or bottom-living algae grow (to account for impacts to aphotic habitat), or in shallower lakes, the whole area of the lake's surface. Under the revised standards, a lake would fall into the "good status" category if the maximum daily percent reduction in surface area was less than 5% of the modeled natural lake surface area for 99% of the days in a given year. Compliance with the standards is assessed by modeling natural and influenced lake levels, and by using bathymetry to assess corresponding changes in habitat (Gosling and Hatton-Ellis 2012, DEFRA 2014, UKTAG 2014). For most shallow lakes, this standard translates to a water level change of 20-50 cm (UKTAG 2014).

3.1.5 New Zealand

Water resources are generally abundant in New Zealand, although demand is increasing and is greatest in the driest regions of the country. Agricultural irrigation is the greatest consumptive water use, followed by industrial and public supply (Feltham 2011).

The regulatory basis for water management in New Zealand is the Resource Management Act of 1991 (RMA). The RMA establishes the existing process for water management through regional councils. The councils are tasked with developing regional water management plans that identify values and establish objectives for freshwater areas (e.g., ES 2010, EC 2011). The New Zealand government identifies two compulsory national values for freshwater, which serve as the fundamental objectives of freshwater management in the country: the health and mauri (life essence) of water and the health and mauri of people. Additional national values with defined minimum acceptable states include the health and mauri of the environment, food resources, agricultural cultivation and animal drinking water, preservation of sacred waters, municipal and domestic water supply, economic or commercial development, and navigation (New Zealand Government 2014).

At the time of this report, the New Zealand government was in the process of a long-term, comprehensive reform program for freshwater management (initiated in 2009). As of November 2015, a proposed National Environmental Standard (NES) on Ecological Flows and Water Levels, intended to complement the existing process for establishing flows and water levels, remained on hold pending decisions of the freshwater reform program (NZ MfE 2014).

Assessment methods used to set lake withdrawal limits are based on consideration of potential risk posed by the withdrawal. The NES guidelines originally proposed in 2008 recommended specific risk criteria for hydrological change to lakes, based on lake level ranges and rates of fluctuation (Table 1). These criteria were set by an expert group comprised of individuals from national science agencies and regional councils.

Table 1 New Zealand proposed risk criteria for hydrological change to lakes.

	Relative Degree of Risk Under a Potential Change to Hydrological Regime		
	Low Risk	**Medium Risk**	**High Risk**
All lakes	Patterns of lake level seasonality (relative summer vs. winter levels) remain unchanged from the natural state	Patterns of lake level seasonality (relative summer vs. winter levels) show a reverse from the natural state	Patterns of lake level seasonality (relative summer vs. winter levels) show a reverse from the natural state
Shallow lakes (≤10 m maximum depth)	<10% change in median lake level <10% change in mean annual lake level fluctuation	10-20% change in median lake level 10-20% change in mean annual lake level fluctuation	>20% change in median lake level >20% change in mean annual lake level fluctuation
Deep lakes (>10 m maximum depth)	<0.5 m change in median lake level <10% change in mean annual lake level fluctuation	0.5-1.5 m change in median lake level 10-20% change in mean annual lake level fluctuation	>1.5 m change in median lake level >20% change in mean annual lake level fluctuation

Sources: Beca 2008, NZ MfE 2008

After establishing risk, suitable technical methods for assessing lake water level and outlet flow requirements (i.e., withdrawal limits) can be selected from a matrix. That matrix lists a spectrum of potential methods, with complexity of methods increasing in accordance with the degree of risk and significance of lake ecological values (Beca 2008, NZ MfE 2008). For example, the water level requirements for a lake with low proposed degree of hydrological alteration and low value significance could be established on the basis of simpler methods (e.g., historical record or expert opinion), while water level requirements for a potential high impact to a high value lake would need to be supported by extensive analysis including modeling of water quantity and quality and a geomorphological assessment.

In practice, New Zealand regional water management plans have superseded the proposed NES recommendations. Regional water management plans use a wide variety of approaches for setting water level and flow thresholds. Determination of appropriate limits for water allocation incorporates both quantitative and qualitative information on potential impacts of changes, and may require the proponent to conduct field studies, modeling to quantify impacts, and/or a water balance assessment (e.g., ES 2010). Applications for water withdrawal are generally assessed on a case-by-case basis.

3.1.6 South Africa

As the 30th driest country in the world with low rainfall and high evaporation rates, South Africa has extremely limited water resources (SA GCIS 2014). Agriculture is the largest demand of water in the country. Urban use, industry, and mining are also major water consumers (UNESCO 2006).

The federal water management framework for South Africa is enshrined in the National Water Resource Strategy (NWRS), which defines the geographic boundaries of the water management areas (SA DWA 2013). Much of the implementation of water policy is conducted by Catchment Management Agencies

(CMAs), which are responsible for managing water resources in collaboration with local stakeholders (at the time of this report, the establishment of CMAs was ongoing, with projected completion anticipated in 2016). The mission of the CMAs is to manage water resources to meet basic human needs, promote equitable access to water, and facilitate social and economic development. The CMAs develop Catchment Management Strategies (CMS) and register water use.

The primary national objective for water management in South Africa is to maintain the Water Reserve, which consists of a Basic Human Needs Reserve (defined as a minimum of 25 liters per person per day) and an Ecological Reserve (the water quantity and flow regime required to protect and sustain aquatic ecosystems). The secondary national objective is to prioritize water use outside of the Reserve volume (i.e., the water available for allocation) on the basis of greatest socioeconomic benefit. These objectives must be considered in all water allocation decisions. The Water Reserve is calculated as part of water availability assessments conducted for each CMS (e.g., BGCMA 2011, ICMA 2013). Water use beyond the Reserve volume is regulated by licensing. Natural lakes are not common in South Africa and, in many cases, are in protected areas where withdrawals are not permitted; therefore, much of the focus of water management is on regulated lakes.

Resource Directed Measures (RDMs) are a key strategy used by catchment management agencies to define site-specific objectives and set regulatory targets (e.g., Harding 1999a, Harding 1999b, SA DWAF 1999). The RDM consists of an assessment of the waterbody’s present ecological status, definition of the Ecological Management Class (EMC), and establishment of Resource Quality Objectives (RQO). The EMC is described as one of four status categories ranging from A (unmodified) to D (largely modified) and is based on the present status (i.e., the degree of change from reference conditions) and the ecological, social, and cultural importance of the waterbody. After the EMC is established, RQOs are set to define and quantify the specific targets (e.g., water levels) that are necessary to achieve the EMC. For example, a lake with an existing moderate degree of modification but low ecological and social importance might be assigned an EMC of C (moderately modified), indicating that management objectives should sustain the current state, while a lake with moderate existing modification and low social importance but high ecological importance might receive an EMC of B (largely natural), indicating that management objectives must target restoration.

3.2 CONSIDERATIONS FOR ALBERTA AND BRITISH COLUMBIA WATER PERMITS

3.2.1 Alberta

In Alberta, lake water withdrawals require a temporary diversion license (TDL) or term license. These licenses are issued by the Alberta Energy Regulator (AER) or Alberta Environment and Parks (AEP).

License applications are reviewed by provincial staff, who consider water availability and potential environmental impacts amongst a number of other factors. Those considerations are also identified in a number of pertinent policy and guidance documents that may be relevant to lake withdrawals. These include administrative guidance for approvals to protect surface waterbodies (Alberta Environment 1999), guidance on lake water withdrawals (Kerkhoven 2015) and guidance on instream environmental flow needs (e.g., Locke and Paul 2011).

AER has draft, informal guidance on setting allocation limits for up to 500,000 m^3/year on ungauged lakes (Kerkhoven 2015). While this lake withdrawal guidance is not universally applied, it is an accepted desktop approach and is comprised of the following simple rules:

- The lake should have a net annual outflow;
- The withdrawal should not exceed more than 10% of the mean annual outflow of the lake, to protect downstream waterbodies; and
- The withdrawal should not cause more than 0.1 m of lake drawdown, to protect littoral and riparian habitat under low flow conditions.

Cumulative impacts are handled identically, and sums of withdrawals in a watershed should not exceed these rules. The rules are intended to be applied to TDLs, which are short-term and can be cancelled, and low risk term license applications. Applicants are asked to provide the surface waterbody location, annual volume required, pumping rate, and purpose of the diversion.

Alberta's guidance for instream flow needs similarly outlines a desktop approach, comprising the following rules:

- The withdrawal cannot reduce natural, instantaneous stream flows by more than 15%; and
- Daily flows cannot be reduced below a minimum ecosystem base flow, corresponding to the 80th percentile exceedance of weekly or monthly flow.

These Alberta policy and guidance documents suggest that key considerations for temporary and term license applications could include: water supply and demand; littoral and riparian habitat; and downstream environmental flow needs.

Term licenses may also require more information and be more complex than TDLs. For example, term licenses may be associated with an environmental assessment or water management planning area. In simple cases, assessment of term licenses may informally follow the rules describe above for TDLs. However, more complex term license applications may require additional information (e.g., pertaining to impacts on the aquatic environment and instream or water conservation objectives) and are often assessed by provincial specialists, such as limnologists, hydrologists, and biologists.

3.2.2 British Columbia

In BC, water withdrawals typically require either a Short Term Use (STU) approval (maximum duration 24 months) or a Water License. Water withdrawal approvals and licenses are typically issued by statutory decision makers (SDM), designated under the *Water Act*, who are responsible for specific regions or activities across the province. Water permitting associated with oil and gas related activities is administered by the BC Oil and Gas Commission (OGC); whereas other water permitting is typically administered by regional staff within the Ministry of Forests, Lands and Natural Resource Operations.

BC currently has a number of policy and guidance documents that outline environmental considerations pertinent to water withdrawals and risk management criteria, and provide potential approaches that may be adopted by SDMs. These documents include environmental flow need policies (BC MOE 2015) and guidance on instream environmental flow needs (Hatfield et al. 2003, 2007; Lewis et al. 2004).

BC's environmental flow need policy is based on the following principles:

- Key aspects of the natural hydrograph should be maintained by restricting hydrologic alterations to within a percentage-based range around natural or historic flow variability;
- Hydrology information on natural or "naturalized" flows is used as a proxy for biological performance because historic flows are typically easier to measure and synthesize than ecological metrics like fish abundance; and
- Statistical means can mask year-to-year variability while percentile flows can provide a more complete picture of hydrological variability.

Environmental flow considerations for water withdrawals could include: freshwater ecosystems that support fish and other aquatic life; and the magnitude of the reduction in lake shoal area (e.g., maximum 10% as a screening benchmark).

The BC OGC also has specific guidance relating to STU applications (Oil and Gas Commission Short Term Use of Water Application Manual; OGC 2014). That guidance outlines the following environmental requirements for STU approvals:

- Applicants must complete a water supply and demand assessment if the withdrawal exceeds 10,000 m^3 / year;
- The maximum winter (December 15-March 31) withdrawal volume is limited to 10 cm maximum drawdown as a function of lake area (regardless of the watershed area for the lake), except where field-based monitoring evidence provides clear support that sufficient inflow to a lake or discharge in a stream is available to support the requested water withdrawals during the winter period. This winter rule is intended to protect overwintering fish; and
- Maximum open-water (April 1-December 15) withdrawal volume is based on estimated water availability as calculated by NEWT (2015). These maximum volumes correspond to 15% of average monthly runoff, calculated as cumulative water demand for all existing water licenses and STUs, limited to a 10 cm maximum drawdown.

These BC policy and guidance documents suggest that key considerations for short term water use and license applications include: water supply and demand; aquatic and littoral (shoal) habitat; overwintering fish, and downstream environmental flow needs.

3.3 READILY AVAILABLE DATA SOURCES AND TOOLS

A number of readily-available hydroclimatic datasets are summarized in Table 2 below. These include data sources for runoff, lake evaporation, and precipitation. Other regional and site-specific data sources may be available to proponents.

Several custom datasets were generated by Hatfield to assess monthly precipitation, shallow lake evaporation, and runoff. These are also listed in Table 2, and are described in more detail in Sections 3.3.1.1 to 3.3.1.3.

Table 2 Data sources for lake water levels, discharge, precipitation, evaporation, and runoff in Alberta and British Columbia.

Data Type	Data Source	Time Step	Format and Access	Comments
Lake levels and discharge	Water Survey of Canada (Environment Canada 2015)	Daily	Environment Canada Data Explorer – HYDAT v1.2.30, publicly available	Database current as of July 2015
	Alberta Energy Regulator	Daily to episodic manual measurements	Miscellaneous streams and lake levels database, by request	Data for 10 stations provided (Islam and Seneka 2015)
	The Regional Aquatics Monitoring Program (RAMP) / Joint Oil Sands Monitoring Program (JOSMP)	Daily	http://www.ramp-alberta.org	
Precipitation	ClimateWNA, ClimateAB, ClimateBC	Mean annual and 30-year climate normals (various periods)	Desktop software and http://climatewna.com/ Climate data are provided for lat/long/elevation point queries	Site-specific and elevation-adjusted data generated using a combination of weather station data, a digital elevation model, and expert knowledge (Wang et al. 2012, Hamann 2015)
	Dr. Andreas Hamann (University of Alberta)	Mean annual and 30-year climate normals (various periods)	http://ualberta.ca/~ahamann/data/climatewna.html	As above, but regional grids are available here, 2.5 arc min resolution
	Environment Canada	30-year climate normals	http://climate.weather.gc.ca/climate_normals/index_e.html	1981-2010, 1971-2000, 1961-1990 for Canadian cities
Shallow Lake Evaporation	Alberta: AESRD 2013	Mean annual and mean monthly (1980-2009)	Tabular data publicly available, interpolated and gridded to 5 km by Hatfield	Calculated using the Morton Method (Morton 1982)
	British Columbia: WREVAP model	Monthly, mostly 1981-2010	Gridded for NE BC by Hatfield at 5 km resolution	Calculated using the Morton method in WREVAP (McMahon et al. 2013); supplemented with 1971-2000 data when more recent data were not available. Described in Section 3.3.1.

Table 2 (Cont'd.)

Data Type	Data Source	Time Step	Format and Access	Comments
Runoff	Prairie Farm Rehabilitation Administration[1] (PFRA; Cole 2013, AAFC 2013)	50^{th} percentile annual 1950-2006	Isopleth maps	Selected because of its spatial coverage across BC and AB and its correspondence to WSC datasets
	Statistics Canada (2009)	1971-2009	Isopleth maps	Not selected for use in analysis, PFRA dataset preferred
	Alberta Ministry of Transportation (2006)	Unknown timespan	Isopleth map	Not selected for use in analysis, presents "design runoff"
	Global Runoff Data Centre Global Composite Runoff Fields (Fekete et al. 2002)	Unknown timespan	Gridded global monthly runoff http://www.compositerunoff.sr.unh.edu/	Not selected for use in analysis due to unrealistic runoff estimates in the study area
	NorthEast Water Tool (NEWT)	Monthly	http://geoweb.bcogc.ca/apps/newt/newt.html	Monthly discharge estimates for user-selected catchments. Data coverage is Northeast BC. Also provides maximum allocatable water volumes and existing water allocation volumes.
	Custom-made gridded runoff maps calculated using HYDAT data	Monthly	This report and by request to Hatfield, 5 km cell size	Described in Section 3.3.1

[1] Now Agriculture and Agri-Food Canada.

3.3.1 Generated Data and Maps

3.3.1.1 Precipitation

Maps of monthly precipitation for Alberta and BC were extracted from PRISM-generated climate grids of western North America (Wang et al. 2012, Hamman 2015). PRISM combines weather station data, a digital elevation model, and expert knowledge of climate patterns to provide site-specific and elevation-adjusted climate data (Wang et al. 2012). These data were obtained as 30-year climate normals (1961-1990 and 1981-2010). Precipitation data were re-gridded to a 5 x 5 km cell size from an original grid resolution of 2.5 arc min.

3.3.1.2 Shallow Lake Evaporation

Monthly shallow lake evaporation maps were generated using Morton's Method, specifically the Complementary Relationship Wet-surface Evaporation model (CRWE; Section 3.3.1.2). CRWE provides reliable estimates of evaporation for lakes up to approximately 30 m deep (McMahon et al. 2013, supplementary material). For deeper lakes, the Complementary Relationship Lake Evaporation (CRLE) model should be used. Both models are incorporated into the WREVAP model, which is publicly available at http://people.eng.unimelb.edu.au/mpeel/morton.html. Morton's method is currently the preferred method for calculating shallow lake evaporation (McMahon et al. 2013).

Alberta

Shallow lake evaporation data for Alberta were obtained from Alberta Environment and Sustainable Resource Development (AESRD 2013). Isopleths of Morton's monthly shallow lake evaporation values were interpolated on a 5 x 5 km grid of Alberta.

Northeast British Columbia

No modern maps of shallow lake evaporation in Northeast BC were identified, so these data were calculated using the model WREVAP (McMahon et al. 2013). WREVAP uses the Morton's Method, with inputs of latitude, longitude, annual precipitation, monthly air temperature, relative humidity, and sunshine hours. Thirty-year climate normal data were used. WREVAP performance was first evaluated by checking modelled shallow lake evaporation against published values (AESRD 2013) for Fort McMurray, Edmonton, and Calgary. Next, shallow lake evaporation was calculated for four Northeast BC cities: Fort St. John, Prince George, Fort Nelson, and Dawson Creek. Sunshine hours were not available from Fort Nelson and Dawson Creek. For Fort Nelson, sunshine hours were estimated using mapped "mean hours of bright sunshine" and Dease Lake sunshine hours (Atlas of Canada 1958). For Dawson Creek, sunshine hours for Fort St. John were used.

Next, shallow lake evaporation values at two data-sparse regions in Northeast BC were estimated using WREVAP. All inputs to WREVAP were readily available except for sunshine hours. These locations are in the foothills of the northern Rocky Mountains (58.81º latitude, -124.5º longitude; 56.2º latitude, -122.6º longitude) and are at the same latitudes as Dease Lake, BC and Fort St. John, BC, where sunshine hour climate normal data are available. The use of sunshine hours from these sites is justified by their similar latitudes and climates to the sites being modelled, and their apparent similarities of annual bright sunshine hours (Atlas of Canada 1958).

Shallow lake evaporation estimates for BC were then combined with the Alberta dataset to produce continuous 5 x 5 km monthly grids for the study area. The approach of interpolating shallow lake evaporation between locations where climate normal data are available was conducted because it is consistent with the methodology in AESRD 2013.

3.3.1.3 Discharge and Runoff

In Alberta, annual estimates of runoff are available from several data sources (Table 2). Discharge monitoring data are available through the Water Survey of Canada, the HYDAT database (Environment Canada 2015), and the GRDC (Table 2); however, the GRDC dataset was evaluated and found to provide unrealistic runoff estimates in the study area.

To assess baseline monthly runoff conditions in Alberta, hydrometric data from selected WSC stations were extracted from the HYDAT v1.2.30, July 2015 database and evaluated to assess trends. Data were extracted for the 1961-1990 period, from stations with at least 15 years of data available, <5,000 km^2 watershed areas, and located on unregulated systems.

Modelled monthly discharge is available for watersheds in Northeast BC through the NorthEast Water Tool (NEWT 2015).

3.4 BASELINE CONDITIONS

Baseline hydroclimatic conditions in the study area were evaluated prior to developing the tool, and are summarized below. The variables described below are considered to be primary hydroclimatic controllers of lake level and lake outflow (Kerkhoven 2015). Hydrological baseline conditions that were evaluated include lake level fluctuations, lake outflow, and regional runoff. Climatic baseline data variables include precipitation, shallow lake evaporation, and air temperature. Wherever possible, common 30-year baseline conditions were used (1961-1990); any exceptions are noted below.

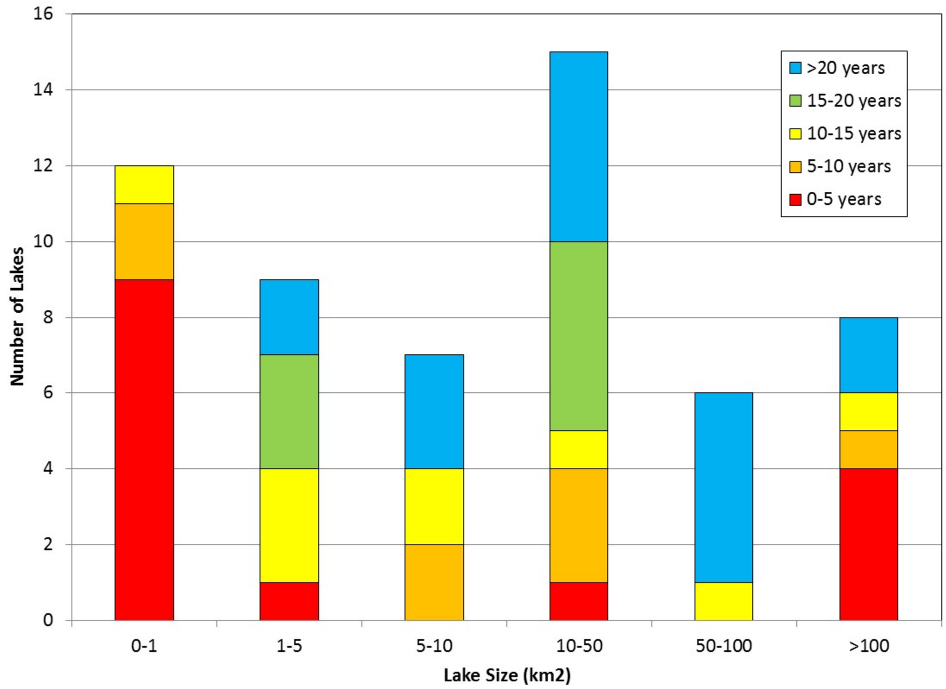
3.4.1 Lake Levels

Daily data were extracted from stations that monitor lake level and discharge downstream of lake outlets (Section 3.3). Data were obtained for lakes in Alberta, BC, and western Saskatchewan; the latter to address a data gap in the southeast of Alberta. Daily water level data for unregulated lakes were obtained from the Water Survey of Canada HYDAT database. Additional data were also obtained from the AEP Miscellaneous Streams and Lake Level database (Islam and Seneka 2015), and from other monitored lakes in Alberta. Where possible, stations with corresponding outlet discharge records were identified. This produced an initial dataset of 202 lakes; 55 of which had records longer than 30 years. This dataset was refined (e.g., to remove stations not classified as unregulated) and a list of the lakes evaluated is provided in Appendix A2.

Unfortunately, none of the lakes in BC were located within the project study area (i.e., Northeast BC) and many of the lakes were regulated and/or known to have water licenses. As such, the BC lake dataset is not discussed in detail in this report. Where possible, inferences about seasonal lake level behavior in Northeast BC lakes were drawn from lakes in northern Alberta.

The number of lakes evaluated in Alberta, grouped by lake area and length of record, are summarized in Figure 2. Half of the Alberta dataset includes small (defined here as less than 1 km^2) to medium sized lakes (defined here as 1 to 10 km^2).

Figure 2 Number of Alberta lakes evaluated, grouped by size and record.



Generally, the observed annual pattern of level fluctuations for Alberta lakes can be divided into a winter period (December-March) and an open-water period (April-November). The winter period generally corresponds to the period of ice cover, although ice cover may not persist through the winter for lakes at lower elevations and lower latitudes. At the beginning of the water year on November 1, lake levels decline as a greater proportion of precipitation falls as snow and surface runoff inputs decrease, typically reaching an annual low between January and March. Recharge may begin in March or April, as air temperatures rise above freezing, ice cover melts, and precipitation inputs increase. Lake levels can reach an annual highs in May or June, corresponding to freshet. Rain events in the late summer and fall may cause brief increases in lake level, but the general summer and fall trend is declining.

Figure 3 illustrates seasonal trends in lake levels for a medium sized (2 km^2) lake in Alberta (i.e., WSC Station 05EE008, Vermillion Park Lake near Vermillion). Figure 4 shows lake levels over the period of record, illustrating lake level variability and longer term trends, for that lake. A similar seasonal pattern of lake level fluctuations is expected throughout the study area, including lakes in Northeast BC. Hydroclimatic conditions in northeastern BC are generally similar to northern Alberta.

Monthly and annual lake level fluctuations were also calculated from the daily data. Minimum, median, and maximum lake level fluctuations for all lakes in the dataset are summarized in Table 3. Figure 5 and Figure 6 show the average monthly lake level fluctuations and the total ranges of observed monthly lake levels for the small to medium sized Alberta study lakes (i.e., < 10 km^2 in area).

The monthly level fluctuations for each lake were calculated by taking the difference between the daily maximum and daily minimum lake level in each calendar month, for every year in the record. The average monthly level fluctuation was calculated as the sum of the monthly level fluctuations divided by the number of years of record. The total range in monthly lake levels was calculated as the difference between the absolute maximum and absolute minimum daily lake level in any given month, over the entire period of record for each lake.

The annual level fluctuations for each lake were calculated by taking the difference between the daily maximum and daily minimum lake level in each year, for every year in the record. The average annual level fluctuation was calculated as the sum of the annual level fluctuations divided by the number of years of record.

Table 3 Average lake level fluctuations over the periods of record, Alberta lake dataset (m)

Period	Month	Lake Level Fluctuation[1] (m)		
		Min	Median	Max
Annual		0.132	0.341	>1
Winter	November	0.011	0.027	0.207
	December	0.017	0.048	0.139
	January	0.015	0.034	0.143
	February	0.015	0.041	0.101
	March	0.019	0.028	0.159
Open Water	April	0.016	0.070	0.460
	May	0.041	0.094	0.980
	June	0.052	0.094	0.736
	July	0.056	0.104	0.592
	August	0.047	0.087	0.278
	September	0.043	0.075	0.204
	October	0.028	0.05	0.172

[1] Based on observed periods of record for stations in the current dataset. The periods of record span between 4 and 30+ years for the lakes in the dataset.

The average monthly level fluctuations varied significantly between the study lakes. The smallest monthly level fluctuations ranged from approximately 1 to 6 cm over the course of the year, while median monthly fluctuations ranged from 3 to 10 cm. The average annual level fluctuations ranged from approximately 13 cm (minimum) to over 1 m (maximum), with a median value of 34 cm.

Monthly lake levels appear to vary much more between years than within a year, and (as expected) the total observed range in lake levels for a given month appears to be related to the length of the period of record. Generally, lakes with longer periods of record exhibit a larger observed total variation in monthly lake levels. For the Alberta lake dataset and considering all available data over each lakes' period of record, the minimum monthly variation in lake level was between 10 and 25 cm (depending on the calendar month), while the median monthly variation was between 35 cm and 95 cm (depending on the calendar month).

Statistical analyses were undertaken to evaluate the magnitude and frequency that lake levels were above their minimum monthly values (based on their historic datasets). Figure 7 illustrates the height of lake levels over their historic monthly minimum values, for 70%, 80% and 90% of the period of record.

Figure 8 compares the median values for the average monthly level fluctuations within the small (< 1 km^2), medium (1-10 km^2), and larger (>10 km^2) lakes in the Alberta dataset. There does not appear to be a substantial difference in the magnitude of monthly lake level fluctuations in these three sizes of Alberta lakes.

Figure 3 Seasonal lake levels at "Vermillion Park Lake near Vermillion" Alberta (WSC Station 05EEC008).

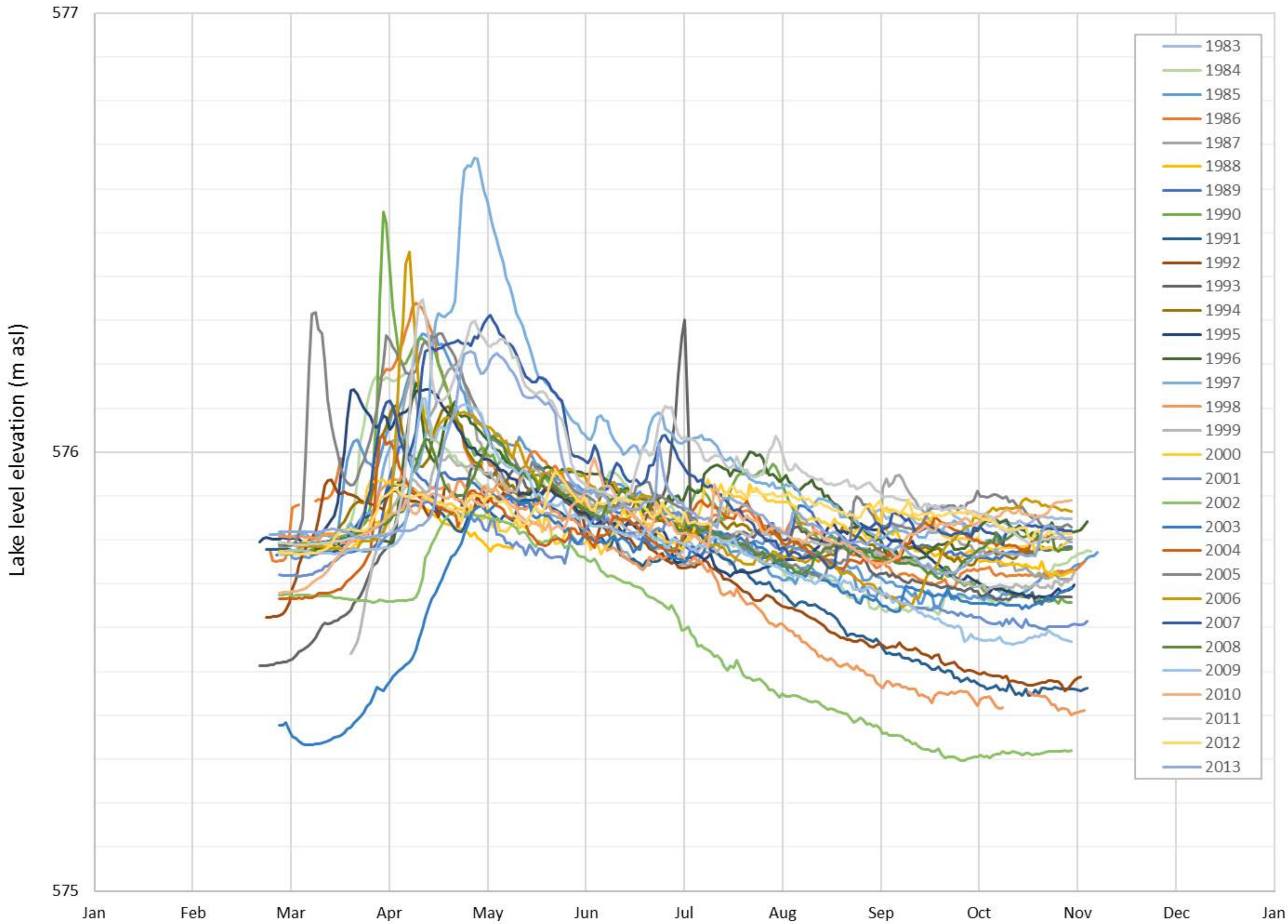


Figure 4 Lake level trends over time at "Vermillion Park Lake near Vermillion" Alberta (WSC Station 05EEC008).

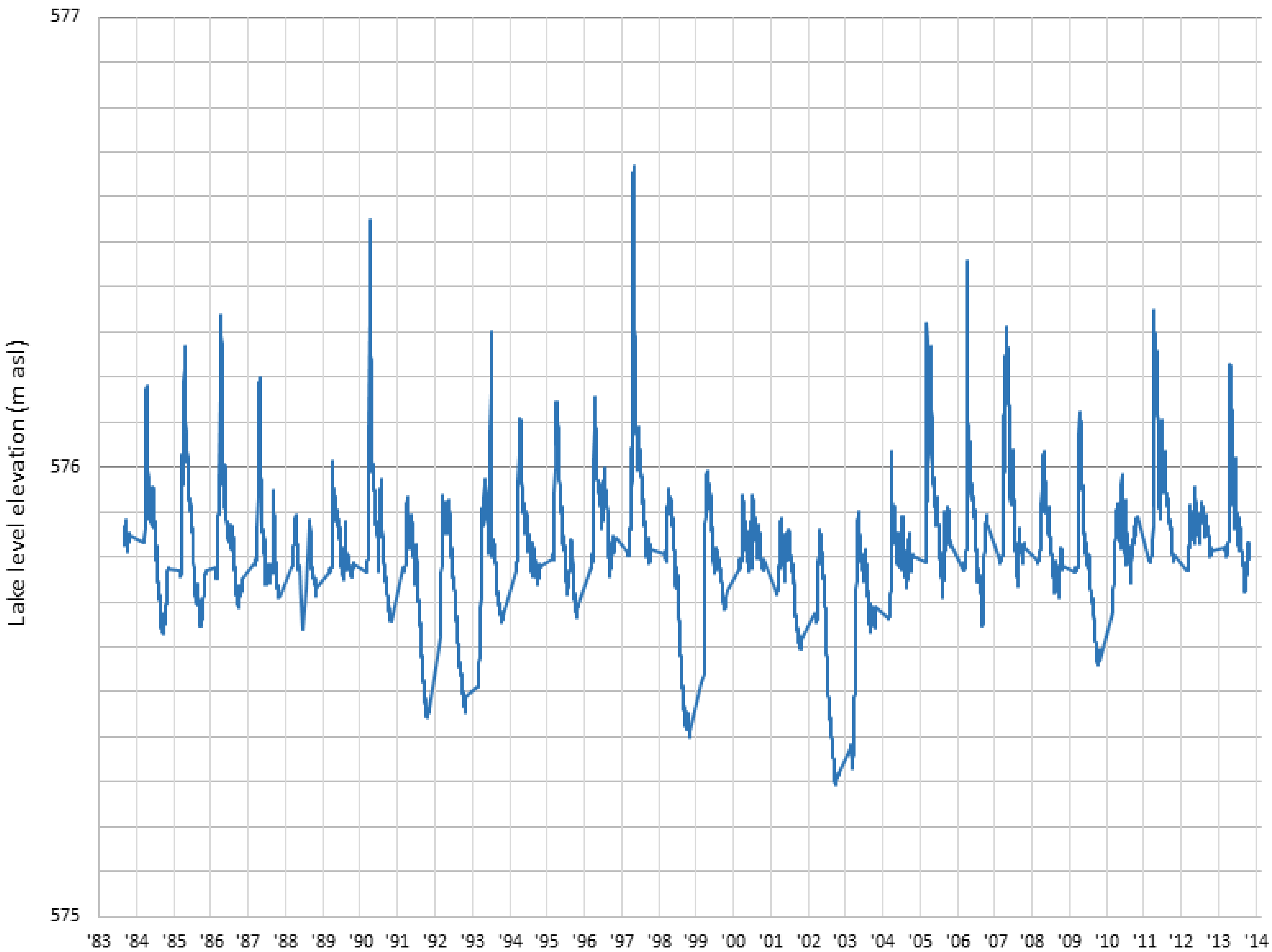


Figure 5 Average variation in monthly lake level for small to medium sized lakes (Alberta lake dataset).

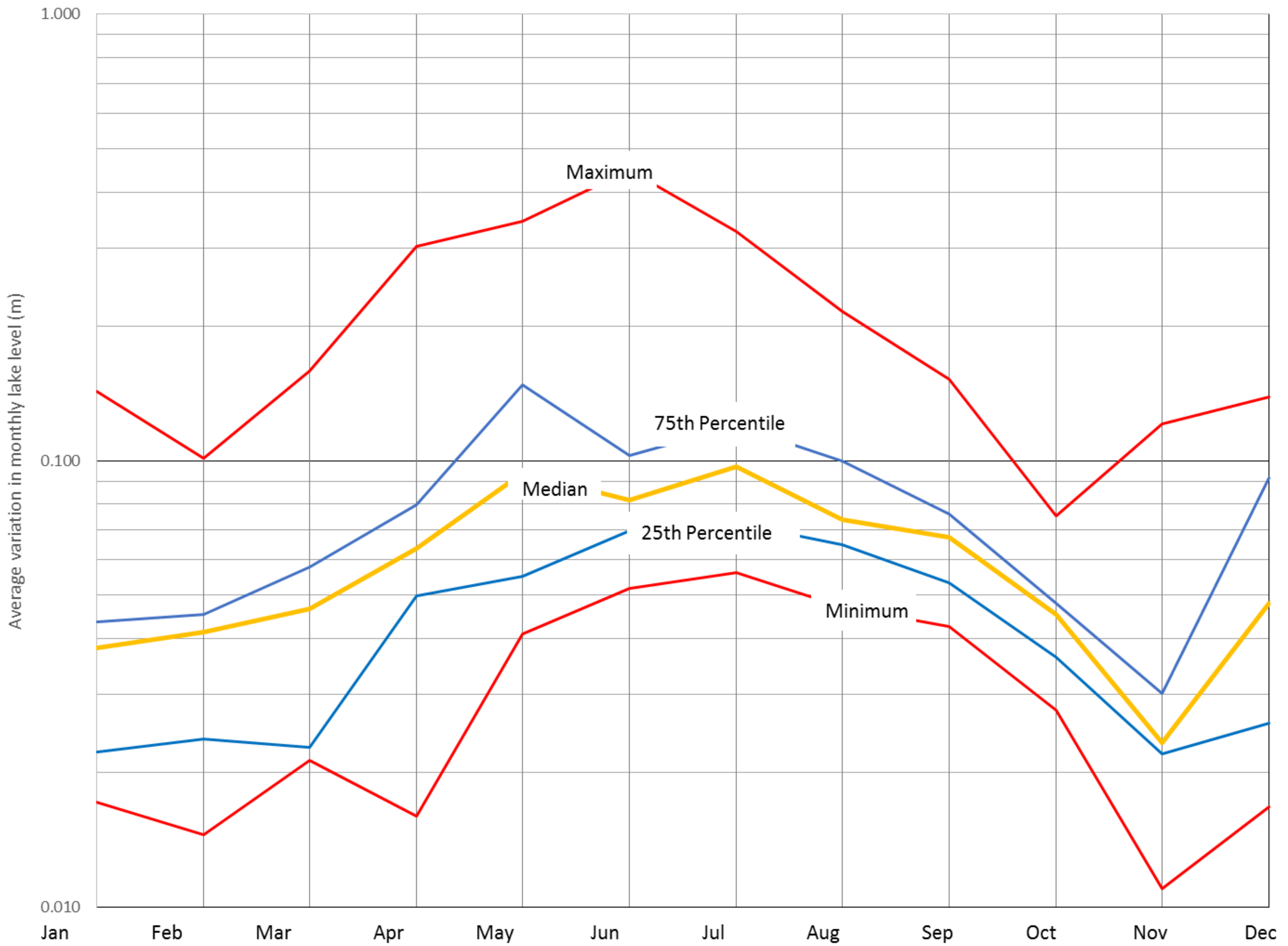


Figure 6 Observed range in monthly lake levels for small to medium lakes (Alberta lake dataset).

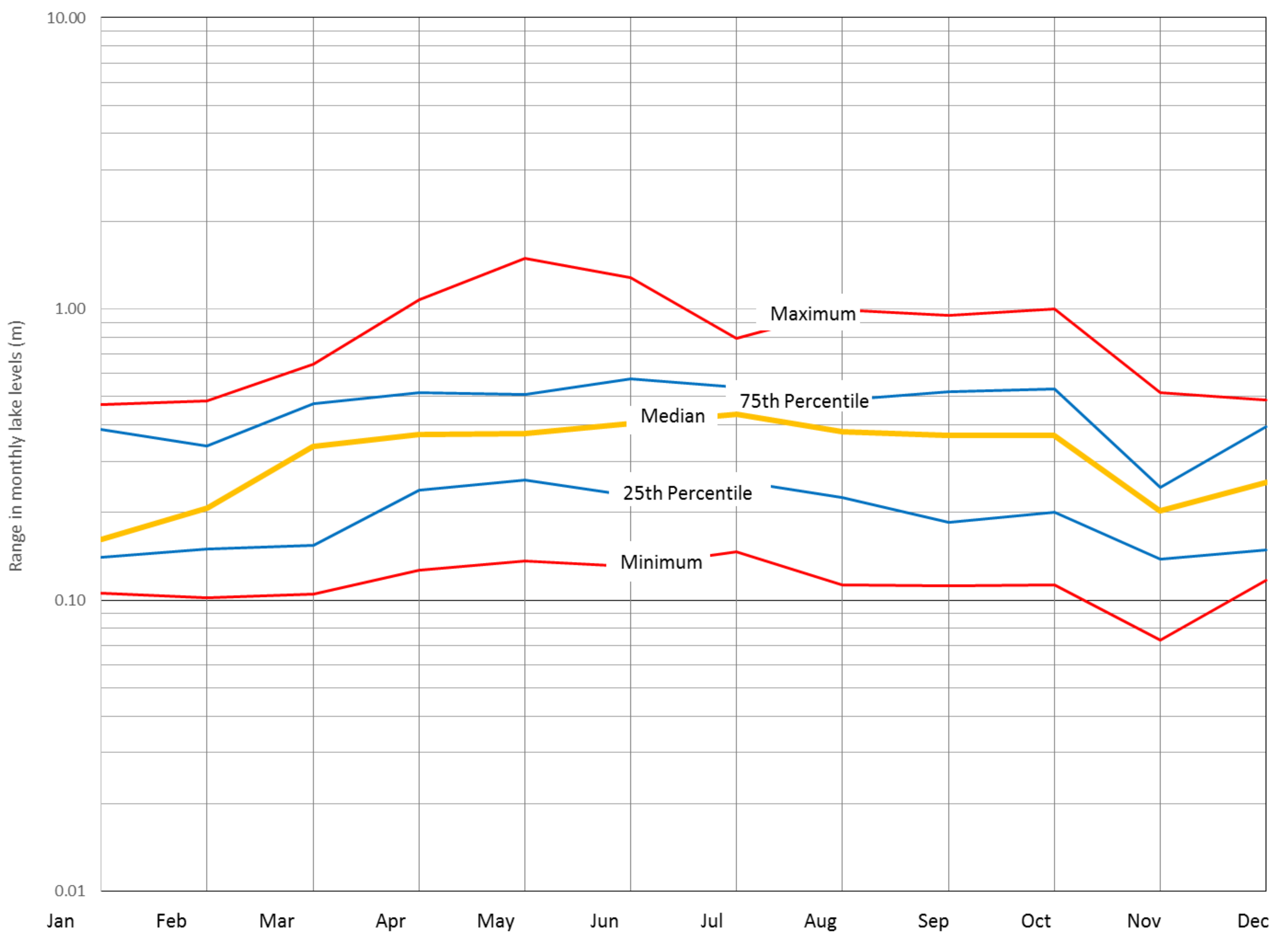


Figure 7 **Height of water over minimum monthly lake levels for specified percentile of period of record (average lake in the Alberta dataset).**

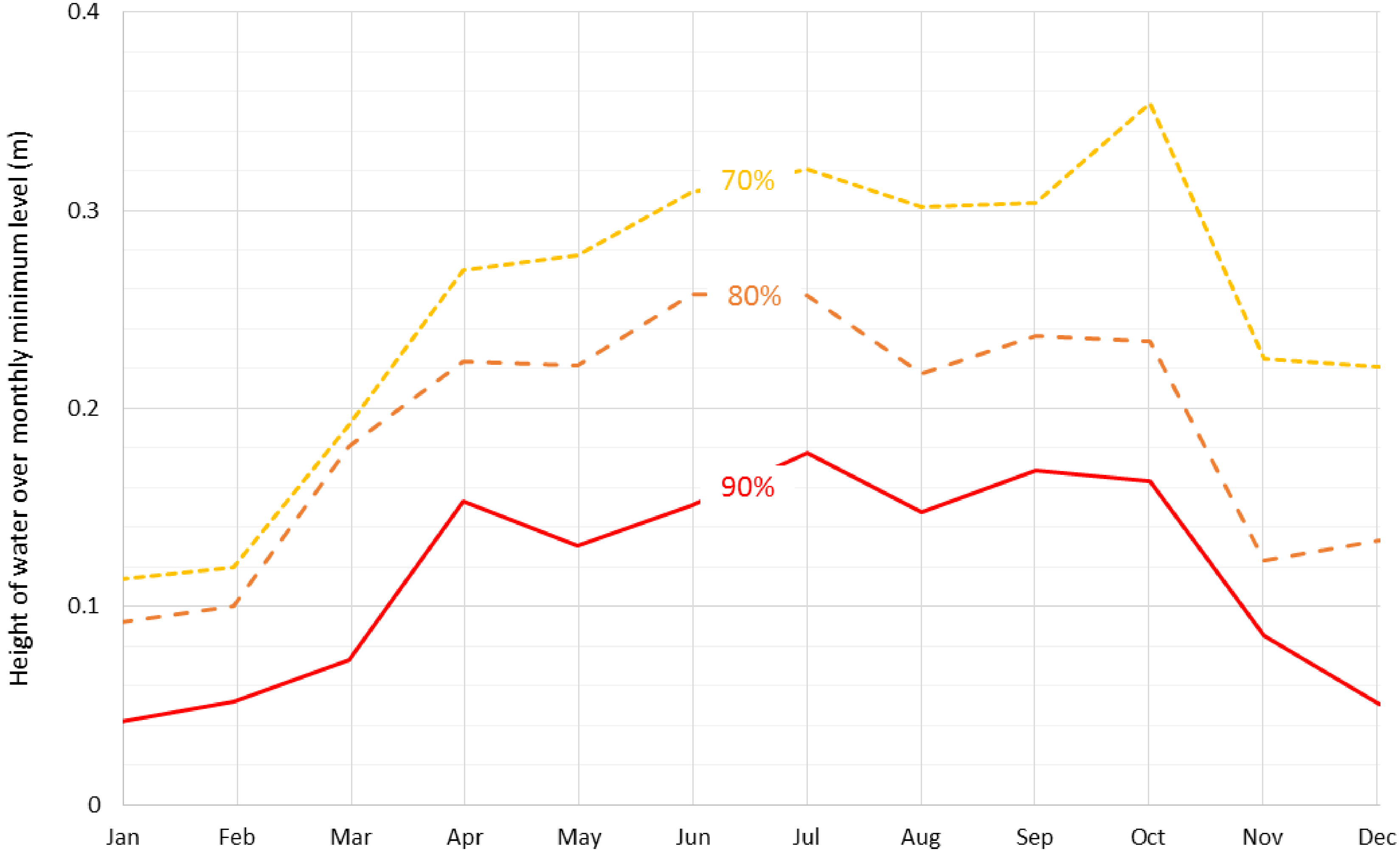
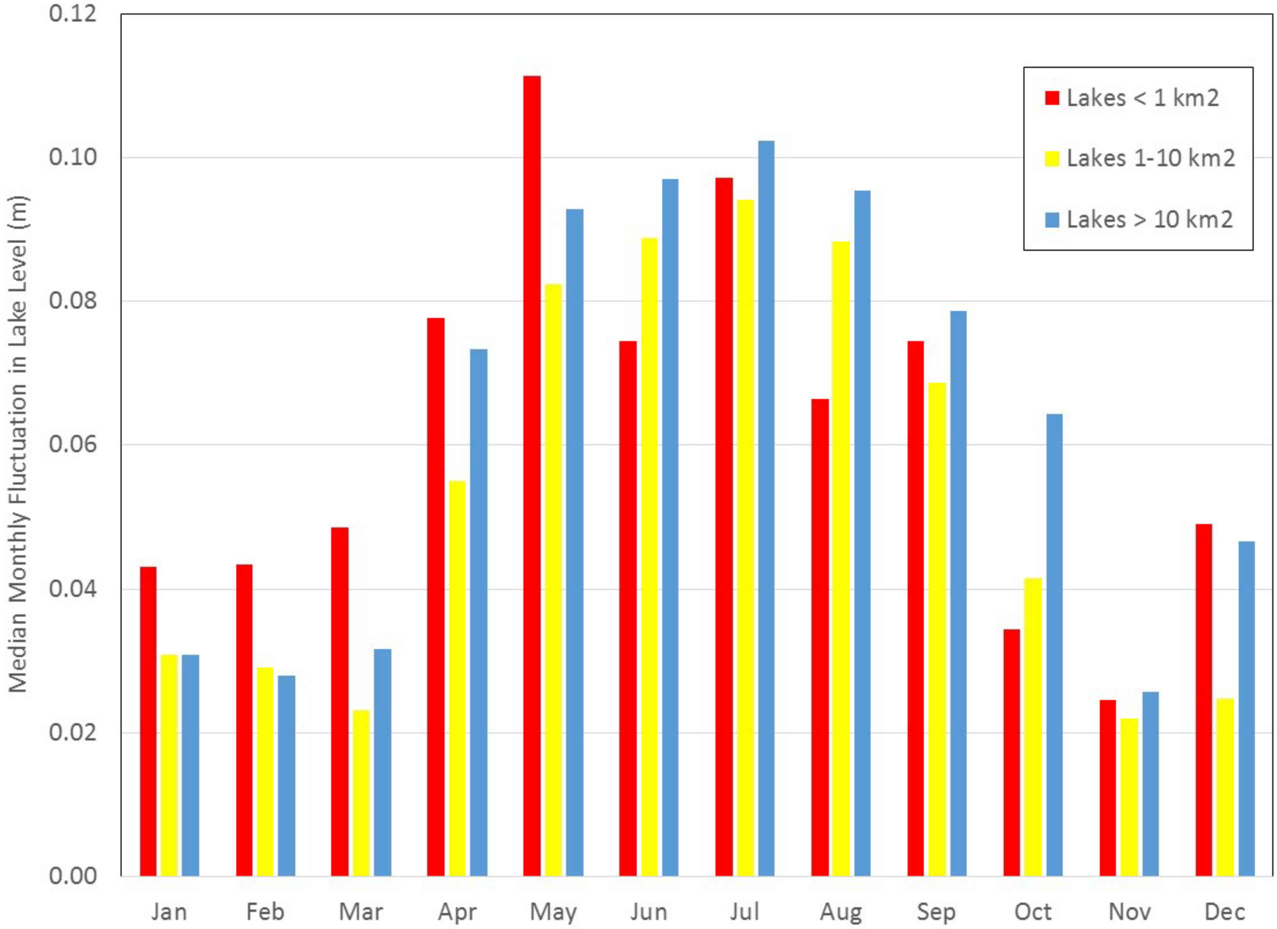


Figure 8 Comparison of median monthly lake level fluctuations in Alberta lakes.



3.4.2 Lake Outflow

Although very few long-term records of lake outflow are available from hydrometric stations, some generalizations can be made. Outflows are highest during freshet and decline throughout summer and fall. In lakes with significantly glacierized catchments, a secondary late summer peak is expected. In smaller lakes and smaller catchments, outflow ceases in winter when the outlet freezes. Larger lakes may flow throughout winter. Outflows also cease any time the lake level descends to the sill elevation.

3.4.3 Precipitation

Alberta

Precipitation in Alberta is generally lowest in the eastern prairies and highest in the western mountains. The southeastern portion of the province (east of Calgary and south of Edmonton and Lloydminster) is the driest (annual precipitation 300-350 mm), and the far northeastern corner near Wood Buffalo National Park has similarly low annual totals. Precipitation is highest in a small mountainous area near Waterton Lakes National Park, where annual precipitation reaches 800 mm. Precipitation is similarly high (500 to 700 mm) in the Rockies near the British Columbia border, and along a band extending from the Rockies to Lesser Slave Lake that separates drier regions to the north and south.

Northeast British Columbia

Precipitation in Northeast BC to the east of the Rockies is relatively uniform, with annual totals of 450 mm in Fort Nelson, Fort St. John, and Dawson Creek. Precipitation increases slightly to the south, reaching 600 mm in Tumbler Ridge. Precipitation increases more substantially westward into the Rockies, reaching about 900 mm in the western portion of the study area.

3.4.4 Shallow Lake Evaporation

Alberta

Annual shallow lake evaporation in Alberta, calculated using Morton's Method and data from 1980-2009, is presented in AESRD 2013. Provincial maxima of about 850 mm occur in the southeast portion of the province (south of Medicine Hat). This low-latitude portion of the province is dry and sunny (Atlas of Canada 1958). Provincial minima of about 575 mm occur in the north of the province (north of Fort Chipewyan), which is a cool, high latitude area that coincides with the lowest annual sunshine hours in Alberta (1,800-1,900 hours/year). Between these southern and northern extremes, shallow lake evaporation decreases steadily from south to north, with the exception of the northeast portion of the province.

Monthly shallow lake evaporation is lowest in winter months, and lowest in northerly portions of the province. Negative evaporation values in winter are presented in AESRD (2013), and were calculated in the WREVAP modelling; this is considered to be an inaccurate representation of actual conditions resulting from a known model deficiency (McMahon et al. 2013 supplementary material). Maximum monthly lake evaporation occurs in summer, especially in the southeast of the province, and especially in August (up to 175 mm).

Northeast BC

Annual lake evaporation generally decreases westward from the Alberta boundary into the northern Rocky Mountains. Annual totals range from about 450 mm to 650 mm in the most northwestern portion of the study area. Lake evaporation is near zero in winter months, begins increasing in March, and reaches a maximum of 100-200 mm in June and July before decreasing again in fall. As noted in Section 3.3.1.2, confidence in calculated shallow lake evaporation decreases towards the northern Rocky Mountains and the western boundary of the study area. Data presented from this region should be considered preliminary.

3.4.5 Runoff

Alberta

Median annual runoff in Alberta is highly variable. Runoff totals of up to about 1,000 mm occur in the Rockies along the British Columbia border between Edmonton and Calgary. Moving eastward from the Rockies, runoff decreases rapidly in the foothills, measuring 25-40 mm in Edmonton, Red Deer, and Calgary. Runoff north of Edmonton is generally low (<100 mm), with the exception of the far west of the province (up to 800 mm), and a localized area south of Lesser Slave Lake (up to 200 mm). Minima in the north occur along the western portion of the Peace River (north of Grande Prairie) and the Steen River. The southeast portion of the province is the driest; runoff north of Lethbridge and Medicine Hat, south of Red Deer and in Palliser's Triangle is less than about 15 mm. The minimum annual runoff in this region is about one millimetre, which occurs north of Red Deer River, about 50 km west of the Saskatchewan border (AAFC 2013).

Monthly runoff in Alberta is also highly variable. Runoff is consistently highest in the Rockies, even in winter. Maximum runoff occurs in the Rockies from June through August, where up to 688 mm of runoff has been documented in a single month (Peyto Creek at Peyto Glacier in August; a small high elevation, highly glacierized catchment). By contrast, runoff in August in other portions of the province is near its annual minimum in late summer. For example, runoff in the Palliser's Triangle region is much less than one millimetre per month in August. In moderate to smaller catchments in this area, runoff is minimal in winter, peaks in March to May, and is minimal again following snowmelt runoff in later summer. Runoff variability across the province is greatest in April and May, with the timing of peak flow controlled by latitude and elevation.

Northeast British Columbia

Runoff in BC is generally consistent in the northeastern plains and increases westward with elevation into the Rocky mountains. Minima of about 75 mm occur west of Grande Prairie, and maxima of about 500 mm occur east of the northern portion of Williston Lake.

Runoff typically rises rapidly in spring and reaches its peak in May during the snowmelt runoff period. Peak runoff is delayed and magnitude increases moving westward into the Northern Rocky Mountains provincial park, in response to increasing elevation and decreasing air temperature. Runoff in winter months (December to March) is often very low, especially in smaller to moderate sized catchments, and especially in February (NEWT 2015).

4.0 DISCUSSION

4.1 SCREENING CONSIDERATIONS

Based on an evaluation of the environmental factors considered in current Alberta and BC water licensing decisions, and existing policy and guidance, it is suggested that a screening tool include the following four considerations:

- Water availability;
- Impacts to habitat (aquatic and riparian);
- Impacts to overwintering fish; and
- Impacts to downstream environmental flow requirements (or instream flow needs).

Specific methods to evaluate these four considerations were developed based on science-based rationale and approaches adopted in other jurisdictions. These methods are outlined in the following sub-sections.

4.1.1 Water Availability

It is recommended that a screening assessment of water availability be conducted to confirm that: (i) water withdrawals will not result in ongoing (i.e., year-on-year) net drawdown of the lake, and (ii) there is water available for allocation (annual supply exceeds known demand).

The first objective is based on discussions with Alberta provincial regulators, which indicate that "mining a lake" is unacceptable. On an annual basis, lake levels should not be reduced beyond what can be replaced by inflows. This immediately excludes withdrawals from lakes that are not predicted to have a mean annual spill or discharge.

The second consideration is also consistent with existing BC guidance and water management practice, where potential water allocations are evaluated based on water supply and existing licensed demand. In the northeast, the total supply and demand are estimated on a monthly time step using BC NEWT.

To limit the potential for unacceptable and ongoing lake drawdowns, the following criteria are recommended:

- Withdrawals should only occur from lakes that exhibit a net, positive annual discharge (spill).
    - For the purposes of this desktop screening tool, the maximum theoretical water supply available for allocation is based on the mean annual discharge. However, the use of mean values does not account for climatic variation (e.g., wet years or dry years). It may be appropriate to use another more conservative metric or index to set the maximum water volume available for allocation, or to consider adaptive management measures; and
- The maximum annual withdrawal volume should not exceed the annual spill from the lake, after consideration of current water demand (i.e., allocations to known, pre-existing water licencees).

Methods to evaluate these criteria are explained below.

4.1.1.1 Screening to assess if a lake has a positive mean annual discharge

Mean annual discharge can be calculated using a simple water balance equation (after Kerkhoven 2015):

$$Q = A_L\left(P - E + R\left(\frac{A_W}{A_L} - 1\right)\right) \quad (1)$$

Where:

Q = mean annual discharge volume in a year (m^3); A_L = lake area (m^2); P = mean annual precipitation (m); E = mean annual evaporation (m); R = mean annual runoff (m); A_W = watershed area (m^2). A_w and A_L can be calculated using GIS software.

This equation can also be used as part of a screening tool to evaluate if a lake is likely to have a positive mean annual spill, i.e., $Q > 0$ m^3/yr, as:

$$\mathrm{A_L}\left(\mathrm{P} - \mathrm{E} + \mathrm{R}\left(\frac{\mathrm{A_W}}{\mathrm{A_L}} - 1\right)\right) > 0 \quad (2)$$

Further rearranging this equation, a lake may be expected to have a positive mean annual spill if:

$$\frac{\mathrm{A_W}}{\mathrm{A_L}} > \frac{\mathrm{E-P}}{\mathrm{R}} + 1 \quad (3)$$

Where A_W/A_L represents the watershed to lake area ratio. A map of interpolated annual [(E-P)/R]+1 values for the study area is presented in Figure 9.

The regional climate data and calculated annual ratios shown in Figure 9 suggest that a lake would be expected to have a positive mean annual spill in northern Alberta if the watershed to lake area ratio exceeds 5:1 (and in some areas exceeds 2:1). In southeastern Alberta, the watershed to lake area ratio might have to exceed 50:1 before a positive mean annual spill is expected. In Northeast BC, most lakes would be expected to have a positive mean annual spill if the watershed to lake area ratio exceeds 5:1.

This relationship was also qualitatively assessed for a subset of 12 study lakes, using measured flows and satellite imagery (i.e., by looking for outlet streams from lakes with and without predicted mean annual spill). The results suggest that the simple water balance provides a reasonable indicator of spill.

4.1.1.2 Supply-Demand Assessment

It is suggested that the maximum allowable withdrawal volume not exceed the mean annual spill (calculated from a water balance approach; Section 4.1.1.1, Equation 1) minus total annual demand from pre-existing water licenses, where this demand is known. This supply-demand assessment could also be carried out at a monthly time step, if data are available.

In Alberta, a list of basin licenses can be obtained from AER / AEP.

In Northeast BC, the total annual and inferred monthly demand from pre-existing water licenses can be determined from NEWT.

4.1.2 Maintenance of In-Lake Overwintering Fish Habitat

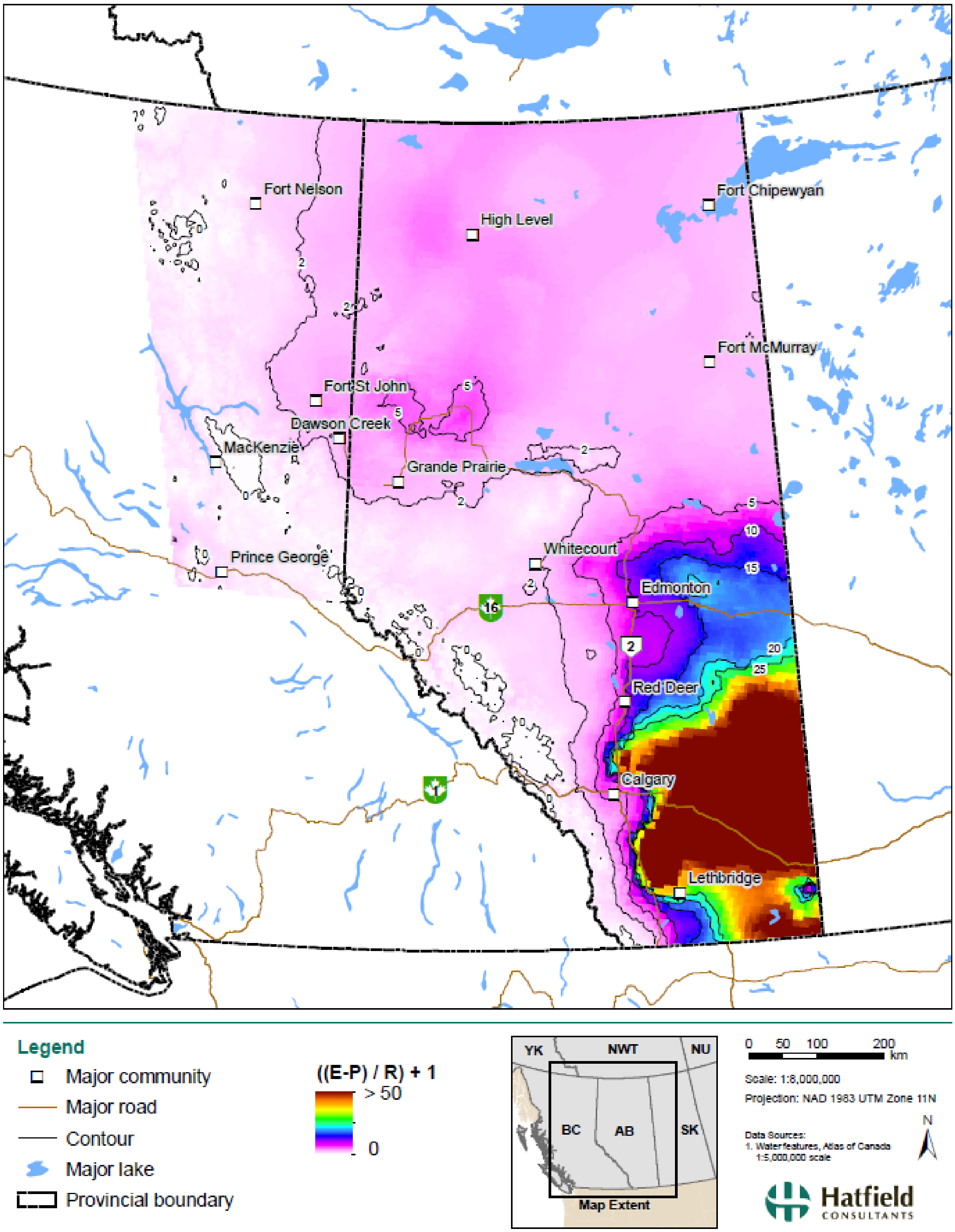
A key issue of concern related to winter withdrawals is a reduction in dissolved oxygen (DO) concentrations in water and resultant impacts to overwintering fish. Northeast BC and other jurisdictions currently impose simple rules of thumb for winter withdrawals to limit the potential for this occurrence, based on percentages of water depth or volume.

If fish have not been confirmed to be absent from a lake, it is suggested that a maximum winter withdrawal threshold be imposed to reduce the potential for unacceptable impacts to overwintering fish. Fish absence could be ascertained using one of the following assessment techniques:

- Obtaining information from government agencies to confirm whether the lake and downstream reaches have been assessed and classified as non-fish bearing; or
- Field sampling in accordance with BC methodology, which specifically addresses aquatic habitat assessment in support of applications for water extraction (Lewis et al. 2004). Among other criteria, this methodology specifies that sampling procedures must adhere to the Resources Information Standards Committee (RISC) tool (RISC 1997), and that determination of fish absence must be made in two consecutive years at the time of year when fish are most likely to be present.

There appears to be only limited rationale to support these rules of thumb. For example, the DFO guidance for NWT is based on a minimum under ice water depth (1.5 m) and maximum withdrawal corresponding to 10% of the under ice water volume. That rule appears to be based on a study on four lakes in the NWT (Cott et al 2008), which indicated that winter withdrawal of 10% of the under ice volume in a study lake did not alter the oxygen concentration profile beyond the range of climate-related variations observed the previous winter, and did not cause an observable change in total volume-weighted oxygen or volume of overwintering

Figure 9 Annual [(E-P)/R]+1 (E=shallow lake evaporation, P=precipitation, R=runoff) for Alberta and Northeast British Columbia.



habitat. The NWT study was conducted at a relatively limited temporal and spatial scale, and as such, the conclusions should not be assumed to be directly applicable to lakes with differing physical, chemical, and biological characteristics. However, the 10% withdrawal limit may be reasonable for Alberta and BC lakes that would be expected to have less ice cover (therefore proportionately greater under ice water volume) and a shorter ice-covered period, but potentially a higher biological oxygen demand than the northern lakes for which the limit was developed. Accordingly, it is suggested that a winter withdrawal threshold could be based upon 10% of the under ice water volume. This rule could also be used to develop an equivalent under ice water depth threshold, based on assumptions of bathymetry and maximum ice thickness. For example, 10% of the water volume in a cuboidal or columnar shaped lake would be present in the top 10% of the lake's depth, whereas 10% of the water volume in an inverted trapezoidal pyramid or conical shaped lake would be present in the top 3.5% of the lake's depth.

Lake ice thickness could be measured or assigned a conservative maximum ice thickness value (e.g., lake ice as thick as one metre has been described in Alberta; Mitchell and Prepas 1990). A maximum ice thickness of one metre is corroborated by extensive winter field work on lakes in Northeast Alberta (north of Fort McMurray), which is one of the coldest regions in the study area (Hamman 2015). A proponent could also estimate lake ice thickness at a site of interest, using one of several simple models to predict ice growth using accumulated freezing-degree days (e.g., Gow and Govoni 1983, Ashton 1989, Gilbert 1991).

4.1.3 Maintenance of Habitat and Associated Values

A number of simple rules of thumb have been used to restrict changes to habitat to within acceptable levels in North America and other jurisdictions. These rules include maximum lake level variations (e.g., < 10 cm, < 10% change in median lake level) and maximum reductions in shoal area or lake surface area (e.g., < 10% reduction in littoral habitat or shoal area, < 5% reduction in lake surface area).

For the purposes of desktop screening, it is suggested that a maximum drawdown might be the most practical way to specify a withdrawal threshold to maintain aquatic habitat and associated values. A maximum drawdown threshold could be based upon consideration of:

- Existing guidance;
- The timing and magnitude of pre-existing (e.g., natural or baseline) fluctuations in lake levels;
- The importance of maintaining habitat during certain times of the year;
- The statistical potential for a given drawdown to lower lake levels below pre-existing minimum values;
- The magnitude of the associated potential reduction in shoal area or lake surface area; and
- The potential for permanent, unacceptable adverse effects associated with that drawdown amount.

In consideration of the above, a maximum annual lake level drawdown of 10 cm is proposed as a screening threshold for the maintenance of habitat, as:

- It is consistent with existing guidance for Alberta and Northeast BC;
- It is a relatively small proportion of the typical annual fluctuation observed in Alberta lake levels. The median annual level variation in the Alberta study lakes was 0.35 m;

- It is a relatively small proportion of the observed range in monthly levels observed in Alberta lakes. Monthly levels were observed to range up to approximately 0.4 m over the period of record (median lake in the dataset);
- An additional 10 cm drawdown generally will not decrease lake levels below their historic monthly minimum (i.e., observed lake levels were an average of 10 cm above the historic minimum 80% of the time, for 80% of the lakes in the Alberta dataset);
- A 10 cm drawdown would not be expected to reduce littoral area[1] or lake surface area by more than 10%, based on a minimum lake area of 0.1 km^2 and minimum lake bed slope of 100:1; and
- An annual maximum drawdown of 10 cm is not likely to have notable effects on plants, invertebrates, and the fish and wildlife species that rely on them. Vegetation and benthic macro-invertebrates can adapt to change occurring at a small spatial change, especially if that change is infrequent. Nor should a 10 cm drawdown over the course of a year affect riparian ecosystem components such as large trees for riparian raptors to nest in, or shorelines and vegetated islands used by nesting water birds.

4.1.4 Maintenance of Downstream Environmental Flow Requirements

The requirement to maintain minimum instream flows for environmental needs is specified in both Alberta and BC policy (BC MOE 2014, Locke and Paul 2011). Specific Instream flow need thresholds for fish are also specified in Alberta (Locke and Paul 2011) and OGC guidance (OGC 2014); both indicate that withdrawals should not reduce natural, instantaneous stream flows by more than 15%. The Alberta guidance also specifies that daily flows should not be reduced below a minimum ecosystem base flow, corresponding to the 80^{th} percentile exceedance of weekly or monthly flow.

Based on the pre-existing policy and guidance, it is suggested that the screening threshold to maintain downstream environmental flow needs within acceptable levels should correspond to a maximum 15% reduction in monthly lake outflows. It is proposed that the 15% criterion be applied to monthly outflows as opposed to a longer term period (e.g., open water period or annual), in order to better maintain the natural hydrograph and ensure withdrawals do not entirely occur within a short timeframe and at a sensitive time of the year (e.g., withdrawal of an annual allotment entirely within a low flow month or during a short time period coinciding with a critical life stage for a particular species). Conservative, desktop methods available to estimate monthly outflows include:

- Use of a simple water balance equation (e.g., Kerkhoven 2015) and monthly values for runoff and climate variables to predict monthly lake outflow; or
- Other modelling approaches, such as regional analysis, or use of a distributed monthly water balance model.

These criteria may not be applicable during winter months when outlets may be frozen, and no lake outflow is present.

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[1] The littoral zone is defined as the zone between the high water mark and the bottom of the photic zone (Alberta Government 2014). For the purposes of this tool, the bottom of the photic zone is conservatively assumed to have a maximum value of 5 m.

4.1.4.1 Use of a Water Balance Equation to Conservatively Estimate Monthly Outflow

This simple screening approach is intended to provide a conservative (low) estimate of monthly lake outflows. The calculation consists of a simple water balance equation (equation 4, below).

$$Q = A_L\left(P - E + R\left(\frac{A_W}{A_L} - 1\right)\right) \qquad (4)$$

Where Q = monthly lake outflow (m^3), P = monthly precipitation (m), E = monthly evaporation (m), R = monthly runoff (m), A_W = watershed area (m^2), A_L = lake area (m^2).

Potential data sources for each of these parameters are described in Section 3.3 and summarized in Table 3. These are not the only data sources available; if a proponent can provide a science-based justification for the use of other datasets, they may do so.

Table 4 Potential hydroclimate data sources for use in the calculation of monthly lake outflow.

Monthly hydroclimate variable	Alberta	Northeast British Columbia
Shallow lake evaporation	AESRD 2013	Hatfield-generated map
Precipitation	ClimateAB or ClimateWNA	ClimateBC or ClimateWNA
Runoff	WSC Station	NEWT

* Hatfield has generated gridded, interpolated maps of monthly shallow lake evaporation in the project area; these maps and the data they contain are available upon request.

Peer reviewed and published data sources are available for shallow lake evaporation and precipitation rates in Alberta, but no data sources that provide monthly runoff for a statistically appropriate time-period (e.g., 30 years) were identified; however, annual runoff is available from the PFRA (AAFC 2013). In this case, a "monthly disaggregation" approach is suggested to estimate monthly runoff to lakes from the annual runoff value. This approach is not intended to accurately model monthly discharge; rather the objective is to obtain a conservative estimate of monthly lake outflow that can be used to ensure that downstream flows are not unacceptably reduced. This approach was developed by first assembling discharge records from hydrometric stations in Alberta (n=40; >30 years record; <2,500 km^2 catchment area; unregulated; year-round operation; Hydat V1.2.30, July 2015 database). Monthly average discharges were converted to percent distributions for each station. For each month, the minimum percent discharge was selected from the 40-station dataset. Summaries of percent monthly flow distributions are presented in Figure 10 and Table 5. Calculated monthly lake outflows were then multiplied by 15% to determine maximum monthly withdrawal.

Peer-reviewed and published data sources are available for precipitation and runoff in Northeast BC (Table 4). Maps of shallow lake evaporation were generated for the region using the approach described in Section 3.3.1.2 and AESRD 2013.

Figure 10 Summary of monthly flow percentages in Alberta rivers. The shaded region represents the standard deviation around the mean.

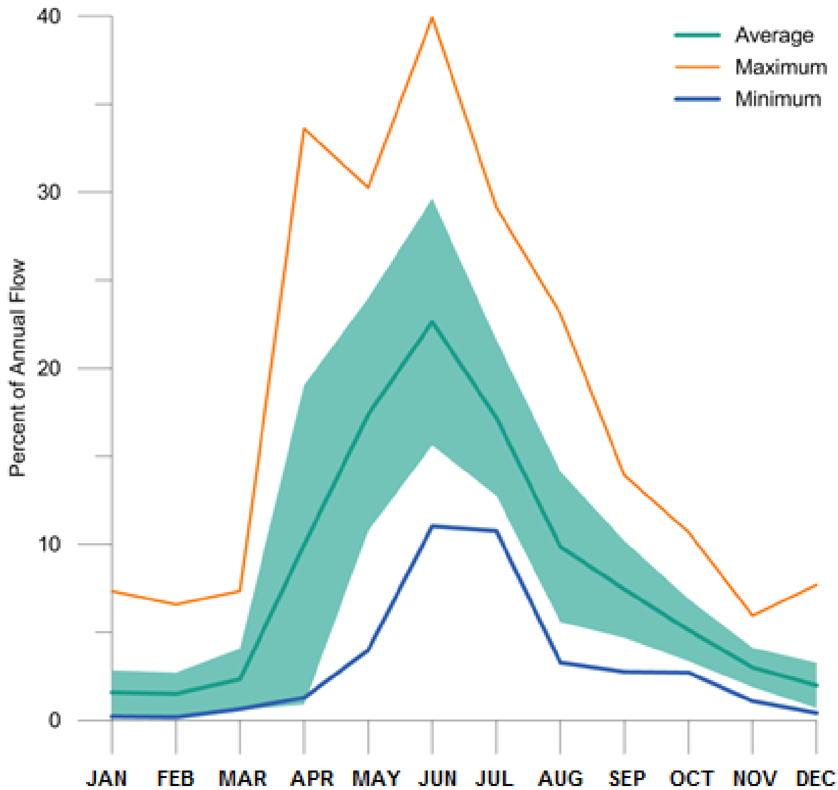

Table 5 Minimum monthly flow in Alberta rivers and potential monthly withdrawal limits, expressed as a percentage of annual flow.

Month	Minimum Monthly flow* (as % of mean annual flow)	Monthly withdrawal Limit** (as % of mean annual flow)
January	0.22	0.03
February	0.18	0.03
March	0.64	0.10
April	1.28	0.19
May	3.98	0.60
June	11.02	1.65
July	10.75	1.61
August	3.28	0.49
September	2.75	0.41
October	2.71	0.41
November	1.09	0.16
December	0.42	0.06
Annual Total	**38.32****	**5.74**

* This desktop method provides a conservative underestimate of pro-rated monthly flows, as it is based on the most conservative streams in the dataset.

** Based on 15% of minimum monthly flow

If a proponent can demonstrate that any of these monthly flow percentages are unrealistic or overly conservative for their sites of interest, then they can be replaced with more accurate values. Guidance for alternate approaches are also described below.

4.1.4.2 Other Modelling Approaches

Many hydrologic modelling approaches could be used to either calculate the runoff component of the water balance equation described above, or directly calculate lake outflow. Summaries and reviews are available, for example, in Beckers et al. (2009) and Dingman (2002). Potential categories of modelling include (but are not limited to) the following:

- **Regional analysis:** if long-term runoff data from representative hydrometric stations are available, and if a proponent can demonstrate that these data are representative of the watershed upstream of their lake of interest, then results from regional analyses can be used as input to the water balance equation. Long-term monitoring data are considered representative if they come from a basin with similar elevation, physiography, surface cover, climate, and if the runoff regime is similar. Regional analysis could take the form of the "drainage area ratio unit discharge" technique (e.g., Emerson et al. 2005), where runoff from a representative gauged catchment is assumed to be equivalent to runoff in the ungauged catchment.

- **Distributed or lumped hydrologic modelling:** a model could be developed to estimate monthly runoff. The hydrologic model should be accepted by the scientific community, used in the region, and thoroughly calibrated and validated (e.g., see review in Beckers et al. 2009).

- **Distributed monthly water balance model:** this approach is based on the water balance equation Q=P-ET (Q=precipitation, P=precipitation, ET=evapotranspiration) and uses gridded precipitation and evapotranspiration as inputs. Data are adjusted at the catchment scale for physiography, gauged WSC stations, or a multivariate regression technique (e.g., Chapman et al. 2011, Moore et al. 2012).

- **Other methods for runoff prediction in ungauged basins:** for example, see Hrachowitz (2013).

4.2 WORKSHOP

A workshop was held in Calgary, Alberta on January 21, 2016, to solicit feedback on a preliminary draft protocol (screening tool) and selected case studies. Invitees to the workshop included representatives from industry, the Government of Alberta, the BC Oil and Gas Commission, and private consultancies. A summary of the workshop agenda and feedback is provided in Appendix A3.

The preliminary tool presented at the workshop was based on the four key environmental considerations identified earlier (Section 4.1), namely: water availability; impacts to habitat (aquatic and riparian); impacts to overwintering fish; and, impacts to downstream environmental flow requirements (or instream flow needs).

That tool included the following maximum withdrawal limits:

- Maximum water available for allocation – equal to the estimated mean annual discharge, after consideration of existing allocations;
- Maximum winter withdrawal volume – corresponding to 10% of the under-ice volume or 3.5% of under-ice depth, assuming a minimum lake depth of 1.5 m;
- Maximum monthly withdrawal volume to protect habitat during open water – corresponding to a 10 cm drawdown over the lake surface area; and
- Maximum monthly withdrawal volume to protect downstream flows – corresponding to 15% of estimated monthly outflows.

In that preliminary tool, each of these thresholds were evaluated independently and the final withdrawal limits corresponded to the most conservative (i.e., limiting) threshold.

Feedback provided at, and following, the workshop indicated that the four considerations were a good starting point, but identified specific concerns with the overly-conservative technical approaches to set thresholds associated with each consideration. The feedback also suggested that a screening tool should focus on a simplified desktop approach. That simplification could include focusing on just those considerations that are likely to limit proposed withdrawals. A summary of stakeholder feedback, review comments and recommendations is provided in Table 6.

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Table 6 Summary of stakeholder feedback used to inform screening tool revision and recommendations for next steps.

Area	Feedback	Screening Tool Revision and/or Recommended Next Steps
Lake level dataset and assessment of current conditions	Ensure regulated lakes are not included.	Known regulated lakes and lakes with significant licensed volumes were removed from the lake dataset. Information on regulated lakes and licensed volumes for Alberta was not available for this assessment. ***Recommendation***: the Alberta lake dataset should be updated after license information becomes available.
	Assess and discuss long term trends.	Additional discussion was added to this report. ***Recommendation***: further discussion could be provided in a subsequent phase, after compiling additional lake data, if required to support tool revision.
	Limited to no representative lakes for boreal lakes in Northeast BC.	Limited data readily available for Northeast BC to do a representative lake area specific analysis. ***Recommendation***: additional relevant lake data should be compiled, and the lake dataset re-evaluated and updated as a next step. Potential data sources could include government files (e.g., lake-specific application records) and industry data. Regionally specific withdrawal rules could also be considered.
	Refine lake level analysis according to lake area.	
	Characterize physiographic and hydroclimatic variability within the study area and consider regionally-specific withdrawal rules.	
Calculation steps	Some calculation steps to evaluate the four considerations may be redundant.	Preliminary assessment shows that some of the four considerations will be limiting under all cases evaluated – the screening tool was streamlined to only include calculation steps that are deemed limiting.
Winter withdrawal thresholds	Remove the minimum under-ice depth threshold of 1.5 m. It is inconsistent with existing guidance and potentially over-conservative.	Existing guidance and literature do not appear to provide a transparent rationale or basis for the requirement to have a minimum 1.5 m under-ice water depth cutoff for withdrawal. The proposed tool no longer includes a minimum 1.5 m under-ice water depth threshold.
	A 3.5% of under-ice depth withdrawal limit appears excessive. For any lake greater than 2.9 m maximum under ice depth, the winter drawdown would be >10 cm.	The limited literature and associated guidance (NWT) suggests that 10% of under ice water volume (corresponding to an inferred 3.5% - 10% under-ice water depth, depending on bathymetry) is a reasonable threshold. No rationale is provided to support the theory that a 10 cm limit should be imposed to maintain under-ice DO on larger / deeper lakes. However, another recommendation (below) to apply a drawdown threshold (e.g., 10 cm) to maintain habitat year round could set an upper limit to winter withdrawals.
	Fish bearing lakes that go anoxic in winter should not be opened to unlimited withdrawals, and actually require additional protection.	Suggested approaches to allow unrestricted winter withdrawals in the absence of oxic water conditions were removed, as they may not be protective and they require field data (i.e., not consistent with a desktop approach).
	Requirement to collect DO data for shallow lakes (less than 1.5 m) may be overly conservative and onerous in a region dominated by small lakes.	
Habitat protection threshold	A static drawdown rule may not be representative or practical (e.g., 10 cm volume equivalent withdrawal may not actually draw down levels 10 cm during freshet). Drawdown limits could be set for each month according to hydrologic conditions in each month.	Agreed. A volume limit based on 10 cm drawdown over the lake area will be over conservative during flowing (e.g., open water) conditions as it doesn't represent the actual volume required to draw down lake levels under non-static (flowing) conditions. A preliminary analysis based on the stage-discharge relationships for over 50 rivers in northern Alberta suggests that adherence to environmental flow thresholds (maximum reduction of 15% of outflows) should not draw down lake levels by more than 10 cm. As such, the downstream environmental flow is considered limiting, and the 10 cm threshold is not explicitly considered in the revised tool (under flowing conditions). The 10 cm threshold may still be reasonable under static (non-flowing) conditions. **Recommendation:** Further detailed analysis to confirm that the 15% flow threshold will not draw down lake levels more than 10 cm may be warranted. In addition, more analysis could be completed to derive alternate drawdown limits.
	A volume limit corresponding to 10 cm drawdown multiplied by the lake-area may be over-conservative and non-representative. An alternative could include setting benchmarks before withdrawal, and setting a threshold relative to that benchmark.	
	These thresholds should be applied year round.	

Table 6 (Cont'd.)

Area	Feedback	Screening Tool Revision and/or Recommended Next Steps
Protection of downstream Environmental Flows	Should always apply and not be restricted to systems with fish downstream and lakes with defined outlet channels. Should also apply in winter.	The screening tool has been revised to consider this recommendation for lakes where winter outflows are predicted. It is considered to be conservative and more in line with Alberta guidance.
	The use of water balance models at a monthly time step was questioned; it was felt that sensitivity and error analysis was required before implementation.	Agreed – it may be difficult to estimate representative, average monthly flows with precision. However, a fine time step (e.g., monthly as opposed to seasonal) is considered to be more appropriate to protect habitat and downstream flows, based on the potential narrow time windows corresponding to important fish life stages and habitat use during certain times of the year. It is also consistent with existing Alberta guidance. The suggested desktop approach for estimating monthly flows is based on mean annual flow and the minimum monthly flow distribution values from a dataset of over 50 streams in Alberta. This may provide a non-representative, but potentially overly-conservative estimate of monthly flows. In addition, it may be possible to estimate more representative, average monthly flows using regional data from nearby hydrometric stations or an alternate modelling approach. ***Recommendation***: a sensitivity and error analysis could be undertaken as a next step to verify the conservatism in the current desktop approach.
	Consider reducing the 15% of net outflow rule to 10-12%. The Alberta Desktop allows 15% reduction of flow 80% of the time and 0% flow reduction 20% of the time. This would suggest a possible criteria corresponding to a time-weighted average of 12% reduction in flows.	The screening tool is based on a 15% reduction, as it is not clear that a lower threshold (e.g., 10% or 12%) would still be protective under lower flow conditions that would occur 20% of the time. In addition, regulatory tools (e.g., temporary withdrawal restrictions) could be put into place to protect downstream flows during extreme low flow periods or drought. ***Recommendation***: Undertake further investigation to assess reduced monthly flow limits under periods anticipated to correspond to lower flow periods (e.g., based on relative hydroclimatic conditions, etc.)
Hydroclimate variability and use of mean climate values	Concern was raised over the use of average or median hydroclimatic statistics, given natural variability. Effects from multi-decadal climate patterns, climate change, and hydroclimatic conditions in the year of licensing should be considered. Suggestions include: scaling the lake's mean annual allocation volume using a ratio of the estimated current year water supply to the historic long-term median using nearby hydrometric station data; and using an exceedance percentile for hydroclimatic data.	Agreed. ***Recommendation***: Effects from longer term climate patterns could be incorporated into a screening tool. A future version of the tool could consider reduced monthly flow limits under periods anticipated to correspond to lower flow periods (e.g., based on relative hydroclimatic conditions, etc.)
Availability of current water demand data	The lack of a publicly available database of water licenses in Alberta. Data are available, but only on request, and often take long periods of time to arrive. This limits the ability to quickly assess cumulative upstream impacts at proposed withdrawal sites.	Agreed.
Other factors	The hydrologic effects of beaver dams should be accounted for.	Beaver dams and groundwater interactions will be very difficult to incorporate into a desktop screening tool. These may be more appropriately covered in a site-specific assessment, if the screening suggests the potential for impacts or if proposed withdrawals exceed conservative screening thresholds.
	Groundwater should be considered. It was recognized that this will be very difficult from a desktop perspective; however, it was noted that groundwater recharge is very important in some lakes.	

5.0 SCREENING THRESHOLDS

This screening tool is intended to provide conservative lake withdrawal limits that are expected to result in a low likelihood of unacceptable effects to identified environmental factors. It is intended to be primarily desktop based, and to outline a simplified (streamlined) approach to identify potential low risk lake withdrawals.

The approach is comprised of comparisons of proposed monthly, winter and annual withdrawal volumes with calculated maximum monthly, winter and annual screening limits. These criteria are summarized in Table 7, and are based on the following considerations:

1) Four environmental factors, namely:
   a. water availability;
   b. impacts to habitat (aquatic and riparian);
   c. impacts to overwintering fish; and
   d. impacts to downstream environmental flow requirements (or instream flow needs);
2) The thresholds that are expected to limit the maximum withdrawal volume, namely:
   a. Maintenance of under-ice dissolved oxygen and habitat, for winter withdrawals where no lake outflows are predicted;
   b. Maintenance of under-ice dissolved oxygen and downstream flows, for winter withdrawals where lake outflows are predicted; and
   c. Maintenance of downstream environmental flows, for open water withdrawals.

Proposed withdrawals that are less than the proposed winter and monthly withdrawal limits in Table 7 are considered to pose a low risk of adversely impacting environmental values. Other resource values (e.g., wildlife, amphibians, birds, riparian habitat) may also be implicitly considered or protected, as it is expected that lake levels and outflows will generally remain within an acceptable range.

It should be noted that proposed withdrawals that exceed these conservative screening criteria may also pose a low risk to environmental values; however, additional, site-specific information is required to more accurately assess potential impacts under those circumstances.

6.0 LIMITATIONS

The proposed tool only applies to ecological needs in lakes and lake outflows; social and cultural needs are not explicitly considered within the scope of this work. Some potential sources of uncertainty in the data used to evaluate and develop screening limits include:

- **Varying climate normal periods**. Wherever possible, 30-year baseline data from 1961-1990 were chosen. In some cases, other 30-year normal data had to be used (e.g., shallow lake evaporation: 1980-2009, AESRD 2013);

Table 7 Maximum lake withdrawal limit screening calculations.

<table>
<tr><th>Season</th><th colspan="2">Withdrawal Limit</th></tr>
<tr><td>WINTER
(November to March)</td><td>No predicted lake outflows[a] –
Maximum winter withdrawal volume =
Either:
10 cm x Lake Area[b], minus existing winter allocation volume
or
10% of under-ice lake volume[c], minus existing winter allocation volume,
whichever is less</td><td>Lake outflows predicted –
Maximum withdrawals must comply with both monthly and winter volume limits:
Maximum, monthly withdrawal volume =
15% of monthly outflows[d], minus existing monthly water allocation volume
and
Maximum winter withdrawal volume =
10% of under-ice lake volume[b], minus existing monthly water allocation volume</td></tr>
<tr><td>OPEN WATER
(April to October)</td><td colspan="2">Maximum, monthly withdrawal volume =
15% of monthly lake outflows[d], minus existing cumulative, monthly water allocation volumes</td></tr>
<tr><td>ANNUAL TOTAL[e]</td><td colspan="2">Maximum, total annual withdrawal volume = lesser of:
Mean annual discharge minus total annual allocation volume[e], and
The sum of maximum winter and open water period withdrawals, calculated above.</td></tr>
</table>

(a) Requirements to maintain downstream flows may not be necessary if there are no predicted lake outflows.

(b) Under static (no inflow or outflow) conditions, a withdrawal volume corresponding to 10 cm multiplied by the lake surface area would be expected to result in lake drawdown of 10 cm.

(c) If lake bathymetry data are unavailable, under-ice lake volume could potentially be estimated based on assumptions about lake profile. Assuming a conical profile, 10% of the under ice volume would be held in the top 3.5% of the water column.

(d) a maximum reduction in monthly outflows of 15% would also be expected to limit lake level drawdown to within an acceptable range (e.g., less than 10 cm drawdown and 10% reduction in littoral habitat).

(e) This annual total only needs to be considered if winter withdrawals are proposed and there are no predicted winter lake outflows. If lake outflows are predicted to occur year round, then other conditions (e.g., 15% of monthly outflow threshold) will limit the total annual withdrawal.

- **Spatial coverage and representativeness of lake dataset**. It is assumed that the lake level database used to derive minimum monthly drawdown limits is representative of the study area as a whole. No lake level records were available from Northeast BC;
- **Spatial coverage of runoff data**. It is assumed that the database used to derive the minimum monthly flow distribution in Alberta is a representative subsample of rivers in the province;
- **Potential uncertainty in gridded data**. The shallow lake evaporation dataset for Northeast BC is a newly generated dataset, and PFRA runoff maps (AAFA 2013) are small-scale. These data should be ground-truthed before being considered verified and accurate in the study area at a local scale;
- **Temporal change in hydroclimate**. As climate changes, water availability and lake levels also change. The applicability of historical datasets will need to be periodically assessed;
- **Lakes in glacierized catchments**. Lakes influenced by glacial outflow will have different lake levels, lake outflow volumes, and timing of outflow relative to lakes in unglacierized catchments. Insufficient records from lakes located in glacierized catchments were available to develop a separate tool for these systems;

- The assumption that stage-discharge relationships for streams will be similar to, and representative of, lake outlets, and changes in stream or outlet stage will correspond to changes in lake levels; and

- Lakes that receive significant glacial inflow likely have larger outflow volumes and higher ranges in lake level than similar lakes from unglacierized catchments. Therefore, application of the 10 cm drawdown rule to lakes in glacierized catchments is also likely conservative.

6.1 RECOMMENDATIONS

A number of potential issues and recommendations have been identified during the development of this draft screening tool. Potential next steps to refine this screening tool could be based upon prioritization of the issues or concerns raised. Those issues and recommendations are summarized in Table 8, below.

Table 8 Potential Screening Tool issues and recommendations for next steps.

Issue	Recommendation(s)
Use of mean values for hydroclimate variables and flows	In lieu of mean annual flow, evaluate alternate metrics or indices to set the maximum amount available for allocation.
	Develop withdrawal best practices, monitoring requirements and adaptive management procedures to address low flow conditions.
	Develop reduced monthly flow limits under periods anticipated to correspond to lower flow periods (e.g., based on relative hydroclimatic conditions, etc.).
The representativeness of the dataset used to evaluate baseline lake behaviour	Compile additional pertinent lake data and re-evaluate the lake dataset. Potential data sources could include government files (e.g., lake-specific application records) and industry data.
	Update the lake dataset to incorporate Alberta license information.
	While only WSC data from stations classified as unregulated were used, these stations should be evaluated to confirm that the lakes are actually unregulated and that there are no significant existing water allocations.
Representativeness of approaches used to estimate monthly flows	Undertake a sensitivity and error analysis to verify the conservatism in the suggested desktop approach using a minimum monthly flow distribution.
	Develop an Alberta tool similar to the BC NEWT or NWWT tools.

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APPENDICES