Cold Lake Health Assessment

A study under the Regional Waterline Strategy and Governance Model Development Project

Prepared for:
Town of Bonnyville,
City of Cold Lake, and
Municipal District of Bonnyville

Prepared by:
Stantec Consulting Ltd.

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FINAL

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Sign-off Sheet

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Alberta Society of Professional Biologists
Karoliina Munter
1449
Professional Biologist

Prepared by

L. Karoliina Munter, M.Sc., P.Biol.

Co-authors:
Seifu Guangul, Ph.D., P.Eng, D.WRE
Nick De Carlo, B.Sc., P.Biol., QWSP
Stuart Morrison, Dip. B.Sc.
Greg Schatz, M.Sc., P.Biol

Reviewed by

John Orwin, Ph.D., P.Geo.

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Executive Summary

The Town of Bonnyville, the City of Cold Lake and the Municipal District of Bonnyville (the Partnership) are evaluating options for using Cold Lake as a long-term and sustainable regional drinking water source for communities in the region. The currently operating Cold Lake Regional Utility Services Commission (CLRUSC) provides water to the City of Cold Lake, 4 Wing Cold Lake, Cold Lake First Nations, and the Hamlets of Ardmore and Fort Kent.

The objective of this study is to evaluate the effects of further water withdrawals on the water level of Cold Lake and evaluate the effects of changes in water level on lake health. The study is intended to support the Partnership in evaluating regional water supply options.

Cold Lake is one of Alberta's deepest and largest lakes, and the lake spans across the Alberta-Saskatchewan border. A Cold Lake water balance was evaluated to gain an understanding of the current status of the lake water storage. For surface water withdrawals, data on water withdrawals for five Alberta water withdrawal *Water Act* licences were available. One of the five, Municipal District of Bonnyville No. 87 is a small licence for water use for dust suppression. Canadian Natural Resources Limited and Imperial Oil Resources Limited water licences are used for industrial operations, and the CLRUSC water licence is currently used to provide water for the City of Cold Lake, 4 Wing Cold Lake, Cold Lake First Nations, and the Hamlets of Ardmore and Fort Kent. The Cold Lake fish hatchery licence is for operating a government-owned fish hatchery adjacent to Cold Lake.

The highest projected future water need for the regional water line is 5,840 dam^3/year (2032 projection based on estimated population growth). The current CLRUSC water licence is for 6,000 acre-feet annually or 7,400 dam^3/year.

The effects of potential future water withdrawals from Cold Lake for a regional water supply by CLURSC were evaluated utilizing three scenarios: baseline (2005 to 2015), Scenario 1 (2012 projected estimate for the regional water line was applied to years 2005 to 2015), Scenario 2 (2032 projected estimate for the regional water line was applied to years 2005 to 2015). Under both scenarios the water level was simulated to change by very small amount: maximum modelled water level change was 4 mm and 8 mm for scenarios 1 and 2, respectively. These results indicate that regional water line withdrawals would have insignificant effect on Cold Lake water level.

Changes in lake levels from further water withdrawals are not expected to measurably affect aquatic biota, wetlands, riparian vegetation or wildlife due to the small predicted changes in lake water levels, 4-8 mm. This change is within the range of variability observed from 1954 to 2015, 1.574 m, and small in comparison to average yearly fluctuations of lake water levels, about 20 to 40 cm.

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Abbreviations

AENV	Alberta Environment (now AEP)
AEP	Alberta Environment and Parks
CLRUSC	Cold Lake Regional Utility Services Commission
COSEWIC	Committee on the Status of Endangered Wildlife in Canada
dam^3	cubic decametres ($1000*m^3$)
EC	Environment Canada
ESRD	Alberta Environment and Sustainable Resource Development (now AEP)
FAO	Food and Agriculture Organization of the United Nations
GOC	Government of Canada
masl	metres above sea level
Partnership	The Town of Bonnyville, the City of Cold Lake and the Municipal District of Bonnyville
PPWB	Prairie Provinces Water Board
SARA	*Species at Risk Act*
Water Survey of Canada	WSC

1.0 INTRODUCTION

The Town of Bonnyville, the City of Cold Lake and the Municipal District of Bonnyville (the Partnership) are evaluating options for using Cold Lake as a long-term and sustainable regional drinking water source for communities in the region. This evaluation follows a Regional Water Supply Functional Plan and Feasibility Study completed by AECOM in 2009, which concluded and recommended Cold Lake as the best regional source of drinking water (AECOM 2009).

The Municipal District of Bonnyville includes several communities in addition to the Town of Bonnyville and the City of Cold Lake (see Figure 1-1). The currently operating Cold Lake Regional Utility Services Commission (CLRUSC) provides water to the City of Cold Lake, 4 Wing Cold Lake, Cold Lake First Nations, and the Hamlets of Ardmore and Fort Kent (AECOM 2009). There is interest in expanding the regional system to include additional municipalities of Cold Lake IR 149B, Hamlet of La Corey, Hamlet of Cherry Grove, Elizabeth Métis Settlement, Town of Bonnyville, Village of Glendon, Hamlet of Therien, Kehiwin IR 123, and areas south of Moose Lake including the Summer Villages of Bonnyville Beach and Pelican Narrows (AECOM 2009).

The objective of this study is to evaluate the effects of further water withdrawals on the water level of Cold Lake and evaluate the effects of changes in water level on lake health. The study is intended to support the Partnership in evaluating regional water supply options.

1.1 STUDY AREA

The study area encompasses Cold Lake and the area that the lake drains (referred to as a subwatershed), which is located mostly in Saskatchewan (see Figure 1-1). Cold Lake is one of Alberta's deepest and largest lakes, and the lake spans across the Alberta-Saskatchewan border (Mitchell and Prepas 1990, Figure 1-2).

The Cold Lake subwatershed is not connected to the Beaver River within Alberta. The Cold River, the outlet of Cold Lake, flows eastward and joins the Beaver River in Saskatchewan. Several rivers and streams drain into this lake including the Medley River, draining the western part of the watershed, and the Martineau River, draining the Primose Lake and the eastern part of the watershed. Most of the small streams flow into the lake on the northern shore (Mitchell and Prepas 1990).

Table 1-1 Cold Lake Characteristics

Drainage Area (km^2)	Lake Area (km^2)	Drainage Area to Lake Area Ratio	Max Depth (m)	Mean Depth (m)
6,601	355	19:1	99.9	49.5

NOTES: Drainage area based on NRCan CDED DEM data. Cold Lake area based on National Hydro Network dataset. Depths based on available bathymetry data from Alberta Government.

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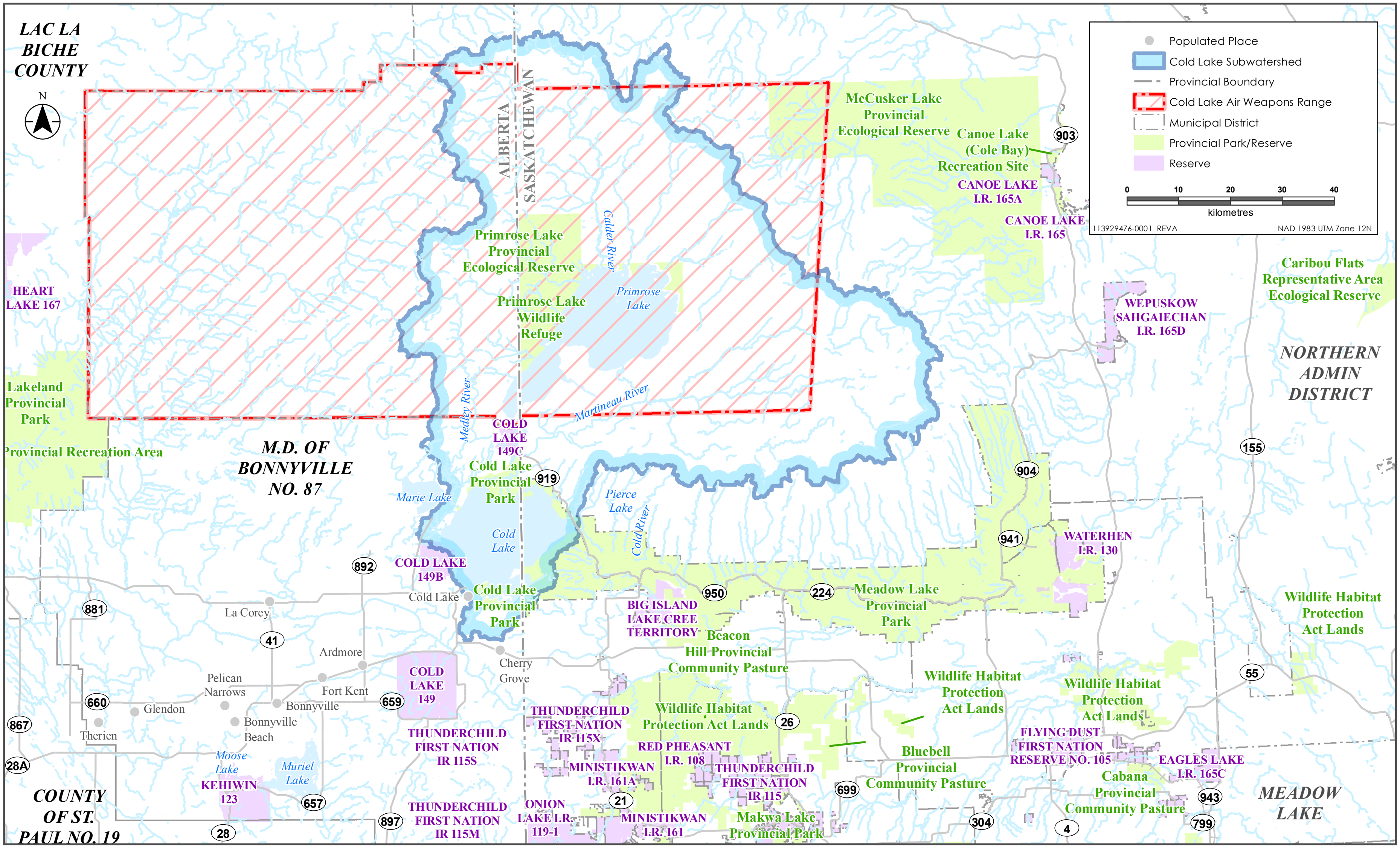

Sources: Base Data - NRCAN, Governments of Alberta and Saskatchewan

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Municipal District of Bonnyville and the Cold Lake Subwatershed

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COLD LAKE HEALTH ASSESSMENT

Figure 1-1

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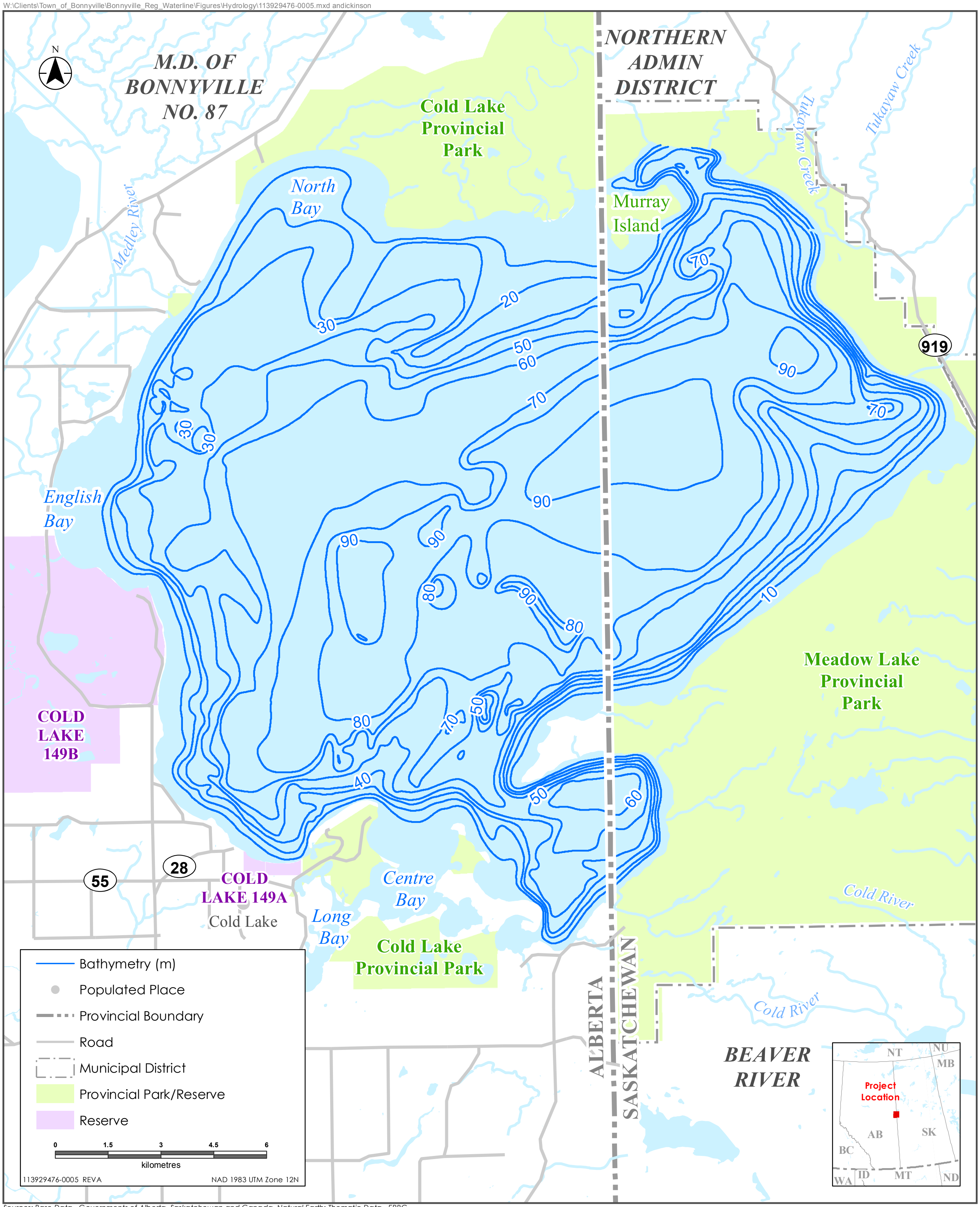

Sources: Base Data - Governments of Alberta, Saskatchewan and Canada, Natural Earth; Thematic Data - ERBC

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Cold Lake Bathymetry

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2.0 LAKE WATER BALANCE

This section provides an evaluation of the changes in lake water balance (i.e., water inputs and outputs) as a result of further water withdrawals from Cold Lake. Lake water balance is a key aspect of lake health along with the factors influencing water level in the lake, including surface water inflows, groundwater inflows, precipitation, evaporation, and water withdrawals.

The development of a water balance model was based on the principle of conservation of mass at a lake. The continuity equation, representing the conservation of mass, can be written as:

$$\left(\frac{I_1+I_2}{2}\right)\Delta t-\left(\frac{O_1+O_2}{2}\right)\Delta t=\Delta S+W+(E-P-G)A_L \quad (1)$$

Where, Δt is the time interval or simulation time step, I_1 and O_1 are the inflow and outflow at the start of the time step, respectively, I_2 and O_2 are the inflow and outflow at the end of the time step, respectively, ΔS is the change in storage during the time step, W is withdrawal, P is the precipitation, E is the lake evaporation, G is net groundwater contribution and A_L is the lake surface area.

Inflow includes surface runoff into a lake and groundwater inflow (if any). Outflow includes outflow though outlet channel, withdrawal of water, and groundwater outflow (if any). For this study, a net groundwater contribution was accounted for based on previous studies in the area by Parks et al. (2005).

Because accurate estimation of inflow hydrographs into Cold Lake was very difficult, Equation (1) was solved using a backward technique. As the above equation indicates, either recorded outflow hydrographs or stage-discharge relationships (rating curves) of the lake outlet are also required. Furthermore, historical recorded precipitation data and estimated historical evaporation data, stage-storage relationships and stage-area relationships are required to solve the continuity equation. These data were identified from public sources or estimated in this study. An existing Cold Lake water balance model was developed on a weekly basis utilizing a backward routing technique from 1974 to 2001. The current study extends the water balance to December 2015.

A water balance model for Cold Lake was originally developed by Alberta Environment (now Alberta Environment and Parks, AEP) in the early 1980s as part of the Cold Lake – Beaver River Water Management Study (AENV 1985). When the water management plan was re-visited for the Cold Lake – Beaver River basin in the mid 2000's, Stantec developed a water balance model that was based on the same method as the original early 1980s model (Stantec 2004, AENV 2006a). The method employed is referred to as a "backward routing technique", where the actual surveyed water level is used to estimate the ungauged water inflows into Cold Lake.

2.1 METHODS

The Cold Lake water balance model that was developed in 2004 by Stantec (Stantec 2004) covered data and analysis from 1974 to 2001. This water balance model was extended from to 2015. The model was updated to include the consideration of groundwater flow to Cold Lake. The basic inputs into the model are:

- weekly values of observed lake water level
- precipitation
- evaporation
- groundwater inflow
- observed outflow discharge and equation to compute stage-storage, stage-area and stage-outflow relationships (where outflow data do not exist)
- water withdrawals from Cold Lake

The primary output of the water balance model is simulated inflow into the lake.

2.1.1 Water Level and Climate Data

The analysis was extended until 2015 because quality controlled lake level data from Water Survey of Canada station Cold lake at Cold Lake (station ID 06AF002) was available until December 2015 (WSC 2017). In addition, daily precipitation and air temperature data for the same period were downloaded from Environment Canada's Cold Lake Airport climate station (ID: 3081680, EC 2017a). Seven-day average lake level and seven-day total precipitation were calculated based on the daily values.

2.1.2 Evaporation Data

Monthly Evaporation data from 2000 to 2009 for Cold Lake was obtained from AEP (ESRD 2013). However, there was no evaporation information available from 2009 to 2015. The evaporation data from ESRD (2013) was derived using Morton's method which requires wind speed and direction as well as lake geometry. However, as this data was not readily available, an approach to estimating evaporation based using Hargreaves method was applied. In this method, potential evaporation is estimated using air temperature and extra-terrestrial solar radiation. The equation for this method is given as follows (Maidment 1993):

$$E_t = a + b.\frac{1}{\lambda}.0.0023.\left(\frac{T_{max}+T_{min}}{2} + 17.8\right).\sqrt{T_{max} - T_{min}}.R_a \qquad (2)$$

where T_{max} is the maximum daily air temperature in °C, T_{min} is the minimum daily air temperature in °C, Ra is the extra-terrestrial solar radiation in MJ/m^2.day. Coefficients a, and b are lumped together to be determined for each month based on the ESRD's estimate of 2000-2009 evaporation values for Cold Lake. The extra-terrestrial solar radiation (in mm/day) for each day was estimated as follows

$$R_a = 15.392 \cdot d_r(\omega \cdot sin\phi \cdot sin\delta + cos\phi \cdot cos\delta \cdot sin\omega) \quad (3)$$

where ω is the sunset hour angle and calculated as

$$\omega = arccos(-tan\phi \cdot tan\delta) \quad (4)$$

φ (in radians) is the latitude of the gage
δ (in radians) is the solar declination angle for each day of the year, and calculated as follows

$$\delta = 0.4093 \cdot sin\left(\frac{2\pi}{365}J - 1.405\right) \quad (5)$$

where J is the Julian Day
and d_r is the relative distance between the Earth and the Sun given as,

$$d_r = 1 + 0.033 \cdot cos\left(\frac{2\pi \cdot J}{365}\right) \quad (6)$$

The Ra value calculated based on Equation (3) was in mm/day which should be multiplied by a factor of 2.45 to convert into MJ /m^2.day (FAO 1998).

$$\lambda = 2.501 - 0.002361T_s \quad (7)$$

Where λ is latent heat of vaporization and T_s is temperature of the water surface.

Initially Equation (2) was used with a = 0, and b = 1 to estimate daily potential evaporation values from 2000 to 2015. Then for the common period of 2000-2009, where there is estimate of evaporation from ESRD (2013) is also available, monthly coefficient were estimated as a ratio between ESRD (2009) and the estimate based on Equation (2). Table 2-1 below shows the coefficients for each month.

Table 2-1 Evaporation Coefficients

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Coefficient	0.65	1.72	1.09	0.98	0.82	0.76	0.76	0.81	0.84	0.65	0.02	0.53

For a validation of Stantec’s approach against ESRD (2013) estimate for period of 2000 to 2009, see Figure 2-1. For most part the Stantec estimates followed the ESRD estimates closely. The Stantec method was therefore applied to estimating of evaporation from 2010 to 2015.

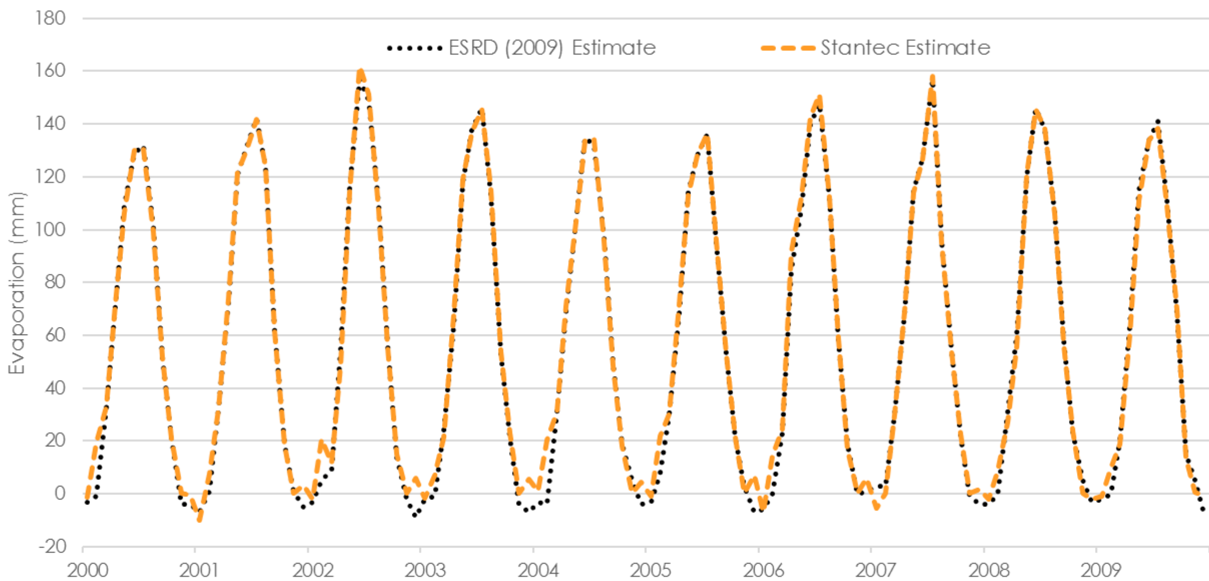

Figure 2-1 Comparison of Evaporation Data from ESRD (2009) and Data Calculated by Stantec from 2000 to 2009

2.1.3 Groundwater Inflow Data

Cold Lake is a known sink for groundwater discharge (i.e., it gains water from the groundwater system) in the basin based upon its depth and elevation relative to several aquifers in the area. Due to its depth, Cold Lake incises through several regionally extensive aquifers and as such is thought to be in hydraulic communication with much of the unconsolidated sediments above bedrock. In particular, buried valley aquifers confined within the pre-glacial Helina Channel system are thought to be in hydraulic communication with Cold Lake. In general, heads within these aquifers are higher than levels in Cold Lake, and as such groundwater discharges from these aquifers into Cold Lake (i.e., Cold Lake is a 'gaining' lake).

An estimate of groundwater discharge into Cold Lake was obtained from the Parks et al. (2005). In this study, a regional (basin scale) numerical groundwater flow model was constructed, calibrated and utilized to characterize the groundwater flow regime in the basin under both non-pumping and pumping (of groundwater) scenarios. Under a pumping scenario, where groundwater extraction from all licenses is occurring at full allocated rates, the steady state simulation suggests that groundwater discharge to Cold Lake is approximately 20,000 m^3/d. The model indicated that the difference between discharge rates between pumping and non-pumping scenarios was relatively small, at approximately 630 m^3/d, representing a 3% reduction in discharge. Thus, it appears that groundwater discharge to Cold Lake is relatively insensitive to allocated groundwater extraction rates (at the time of the 2005 study) in the basin.

2.1.4 Stage-Storage, Stage-Area and Stage-Outflow Relationships

The mathematical relationship between stage and storage of Cold Lake developed in a previous study (Hydroconsult 1998) was used in this study:

Volume = (370 * *Stage* -179,450) x $10^6 m^3$ (8)

Based on the stage-area relationship, the following linear relationship was developed for modeling purposes:

Lake area = 332.52 + 5.2963(*Stage* - 527.3) km^2 (9)

Based on the stage-discharge relationship of the lake outlet structure, the following mathematical relationships were developed for modeling purposes:

Outflow = 0; if Stage<534.39 m (10)

= 33.394(Stage-532.6)2+3.3614(Stage-534.39)-0.025; 534.39 <Stage <534.89

= $3.262 * e^{2.5184(Stage-534.39)}$; Stage > 534.89 m

As shown above, in the previous version of the water balance model, outflow was computed as function of lake level. However, WSC has been gathering outflow data since 1993 and this actual lake outflow data was used in the model for time period 1993 to 2015. The comparison between estimate of lake outflow and observed outflow is provided in Figure 2-2, which indicates that the Cold Lake water balance model closely replicated the observed outflow.

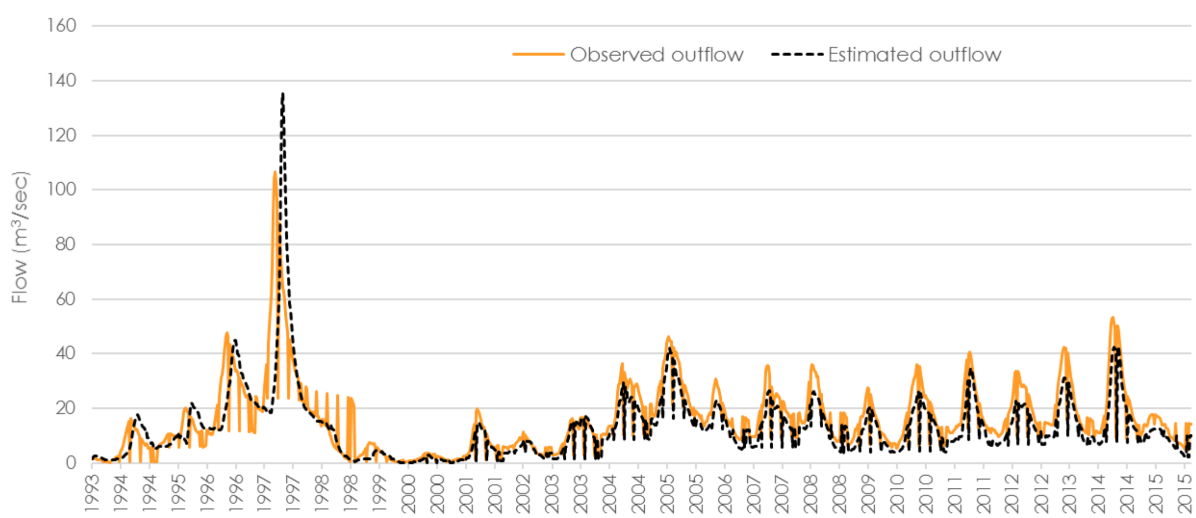

Figure 2-2 Comparison Between Observed and Estimated Cold Lake Outflow from 1993 to 2015

2.1.5 Water Withdrawals

2.1.5.1 Surface Water Withdrawal Licences

For a summary of the existing surface water allocations from Cold Lake, see Table 2-2 (Yan 2017, pers. comm.). No withdrawal licences for Cold Lake were identified on the Saskatchewan side of the lake.

Table 2-2 Existing Surface Water Allocations from Cold Lake

Approval Holder	Activity	Annual Allocation (m^3)	Effective Date	Expiry Date
Alberta Sustainable Resource Development	Management of fish - hatchery	6,996,300	1995-03-01	In perpetuity
Alberta Sustainable Resource Development	Management of fish - hatchery	2,200,001	2011-09-29	2021-09-28
Canadian Natural Resources Limited	Industrial - oilfield injection	2,629,654	2000-03-21	In perpetuity
Cold Lake Regional Utility Services Commission	Municipal - urban	6,660,800	1984-03-21	In perpetuity
'H' Evans Berries	Irrigation - crop	7,400	1995-10-12	In perpetuity
Imperial Oil Resources Limited	Industrial - oilfield injection	5,110,000	2011-10-31	2017-07-31
Municipal District of Bonnyville No. 87	Commercial - other	114,710	1982-09-14	In perpetuity
Municipal District of Bonnyville No. 87	Commercial - other	160	2014-07-08	2024-07-07
SOURCE: Yan 2017, pers. comm.				

2.1.5.2 Consumptive Water Use from Cold Lake

Data for water withdrawals from Cold Lake was received from AEP for 2005 to 2016 (Yan 2017, pers. comm.). Five Alberta water withdrawal *Water Act* licences have reported data on water withdrawals and returns available for Cold Lake (see Table 2-3, Figure 2-3):

- Canadian Natural Resources Limited (#78374-00-00)
- CLRUSC (#31772-00-00)
- Cold Lake fish hatchery (#30710-00-00, licence holder Alberta Sustainable Resource Development)
- Imperial Oil Resources Limited (#79923-01-00)
- Municipal District of Bonnyville No. 87 (#34733-00-00)

One of the five, Municipal District of Bonnyville No. 87 is a small licence for water use for dust suppression. Canadian Natural Resources Limited and Imperial Oil Resources Limited water licences are used for industrial operations, and the CLRUSC water licence is currently used to provide water for the City of Cold Lake, 4 Wing Cold Lake, Cold Lake First Nations, and the Hamlets of Ardmore and Fort Kent. The Cold Lake fish hatchery licence is for operating a government-owned fish hatchery adjacent to Cold Lake at Section 34-64-2 W4M.

Water returns were reported for Cold Lake fish hatchery, Imperial Oil Resources Limited, and CLRUSC. Out of these water returns, fish hatchery and Imperial Oil Resources Limited were assumed to return water to Cold Lake, and the water consumption was adjusted to reflect actual consumptive water use. CLRUSC returns water to the Beaver River, which does not affect the Cold Lake water balance positively. Therefore, the CLRUSC water returns were not included in the consumptive water calculations.

Table 2-3 Reported Consumptive Cold Lake Water Use from 2005 to 2016

Year	Cold Lake Fish Hatchery (dam³)	Canadian Natural Resources (dam³)	Cold Lake Regional Utility Services Commission (dam³)	Imperial Oil Resources (dam³)	Municipal District of Bonnyville No. 87 (dam³)	Total Consumptive Use (dam³)
2005	NR	182	2,362	3,153	NR	5,696
2006	NR	212	2,372	3,683	NR	6,267
2007	NR	244	3,306	3,777	NR	4,021
2008	NR	247	2,935	3,990	NR	4,237
2009	NR	348	2,624	3,439	NR	6,411
2010	NR	398	2,668	2,666	59	5,792
2011	12	451	2,800	2,317	46	5,627
2012	41	306	2,709	1,196	NR	4,253
2013	38	282	2,895	2,575	NR	5,790
2014	27	142	2,757	2,447	NR	5,372
2015	51	238	2,728	2,594	NR	5,612
2016	46	1,626	3,232	1,764	NR	6,669

SOURCE: Yan 2017, pers. comm.

NOTES: All values are in dam³/year. NR = not reported. Consumptive water use was calculated by subtracting water returns from water withdrawal volumes, except for CLRUSC water returns, which go to the Beaver River and do no return to the lake.

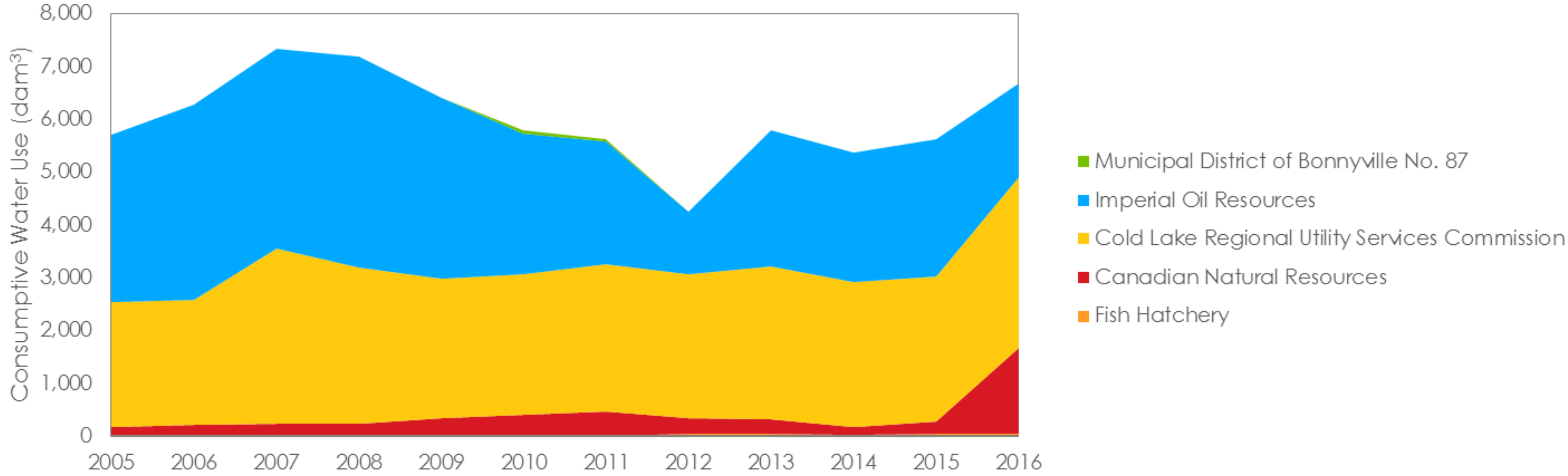

Figure 2-3 Reported Annual Cold Lake Consumptive Water Use from 2005 to 2016

2.1.5.3 Regional Water Line Projected Water Consumption

Water consumption estimates for the planned regional water line were sourced from AECOM (2009). An average daily demand was based on actual available water consumption data from previous years and projected water demand based on estimated population growth (AECOM 2009, see Table 2-4). An aggregate total of the projected average water demand was used in this report to assess the effects to lake heath (see Table 2-5).

The highest projected water need for the regional water line is 5,840 dam^3/year (see Table 2-5). The first draft of this report used the highest projected water need of 7,537 dam^3/year, which was based on the AECOM (2009) water use and population projections for the regional waterline. Subsequently, a revised highest projected water use was sourced from the Bonnyville Regional Water Services Commission 2017 Business Plan (BRWSC 2017) and adjusted to 5,840 dam^3/year. The current CLRUSC water licence (#31772-00-00) is for 6,000 acre-feet annually or 7,400 dam^3/year.

Table 2-4 Average Daily Water Demand Projections

		Actual	Projected		
Community	Metric	2006	2007	2012	2032
4 Wing Cold Lake	Population	2,800	2,800	2,800	4,800
	ADD (L/c/d)	661	375	375	375
	ADD (L/s)	21	12	12	21
Hamlet of Ardmore	Population	277	281	300	500
	ADD (L/c/d)	377	375	375	375
	ADD (L/s)	1	1	1	2
	Truck Fill (L/s)	1	1	1	1
	Total (L/s)	2	2	2	3
City of Cold Lake	Population	9,191	9,635	12,200	22,200
	ADD (L/c/d)	471	375	375	375
	ADD (L/s)	50	42	53	96
	Truck Fill (L/s)	1	1	1	1
	Total (L/s)	51	42	54	98
Hamlet of Cherry Grove	Population	-	-	300	500
	ADD (L/c/d)	-	-	375	375
	ADD (L/s)	-	-	1	2
Cold Lake IR 149	Population	914	935	1,050	1,500
	ADD (L/c/d)	164	375	375	375
	ADD (L/s)	2	4	5	7

Community	Metric	Actual	Projected		
		2006	2007	2012	2032
Cold Lake IR 149A	Population	85	87	98	140
	ADD (L/c/d)	-	375	375	375
	ADD (L/s)	-	0	0	1
Cold Lake IR 149B	Population	220	225	252	360
	ADD (L/c/d)	-	375	375	375
	ADD (L/s)	-	1	1	2
Elizabeth Métis Settlement	Population	600	616	700	1,000
	ADD (L/c/d)	-	375	375	375
	ADD (L/s)	-	3	3	4
Hamlet of Fort Kent	Population	166	167	175	300
	ADD (L/c/d)	399	375	375	375
	ADD (L/s)	1	1	1	1
	Truck Fill (L/s)	1	1	1	1
	Total (L/s)	2	1	2	3
Village of Glendon	Population	500	529	700	1200
	ADD (L/c/d)	585	375	375	375
	ADD (L/s)	3	2	3	5
Kehiwin IR 123	Population	1,007	1,037	1,200	2,000
	ADD (L/c/d)	-	375	375	375
	ADD (L/s)	-	5	5	9
Hamlet of La Corey	Population	-	-	100	200
	ADD (L/c/d)	-	-	375	375
	ADD (L/s)	-	-	0	1
Moose Lake Area	Population	1500	1532	1700	2500
	ADD (L/c/d)	-	375	375	375
	ADD (L/s)	-	7	7	11
Hamlet of Therien	Population	-	-	100	200
	ADD (L/c/d)	-	-	375	375
	ADD (L/s)	-	-	0	1
Town of Bonnyville	Population	6014	6307	8000	15000
	ADD (L/c/d)	407	375	375	375
	ADD (L/s)	28	27	35	65
	Truck Fill (L/s)	1	1	1	2
	Total (L/s)	29	28	36	67

Community	Metric	Actual	Projected		
		2006	2007	2012	2032

SOURCE: AECOM 2009

NOTES: ADD = average daily demand, L/c/d = litres/capita/day, L/s = litres/day. Truck fill refers to truck fill stations for drinking water. Total is the sum of average daily demand and truck fill stations (where applicable).

ASSUMPTIONS (from AECOM 2009):

- Growth projections were based on the information provided in Section 4 of AECOM (2009).
- Actual consumption data was provided by the respective municipalities.
- The growth rate for truck fill stations was assumed to be the same as population growth.

Table 2-5 Summary of Projected Drinking Water Consumption

Community	Metric	Actual	Projected		
		2006	2007	2012	2032
All Regional Communities	Population	23,274	24,151	29,675	46,000
	Average ADD (L/c/d)	438	375	375	375
	Total (L/s)	110	108	132	185
	Total (dam^3/y)	3,460	3,396	4,166	5,840

NOTES: Water demand for years 2006, 2007 and 2012 were calculated based on data presented in AECOM (2009). Water demand for year 2032 was based on the Bonnyville Regional Water Services Commission 2017 Business Plan (Draft 4, dated March 19, 2017).

ADD = average daily demand, L/c/d = litres/capita/day, L/s = litres/day, dam^3/y = cubic decametres (1,000 m^3) per year). Total is the sum of average daily demand and truck fill stations (where applicable).

2.2 COLD LAKE WATER LEVEL 1954 TO 2015

Water level in Cold Lake has been measured by Water Survey of Canada (station ID 06AF002) since October 1954 and currently, quality controlled data are available until December 2015 and provisional data were available up to March 2017 (see Figure 2-4). Over this period, water level fluctuated between 534.306 m above sea level (masl, measured Dec 19, 1992) and 535.881 masl (measured Jul 9, 1997). The difference between the minimum and maximum lake level is 1.574 m. The average water level between 1954 and 2015 was 534.902 masl. According to Environment Canada (EC 2017b), in the early 1990s, El Niño conditions had persisted for four years which may explain the low lake water level during this period (see Figure 2-4).

2.2.1.1 Water Withdrawal Restrictions

There is a two-step lake level cutoff applied to four *Water Act* licences for water withdrawal from Cold Lake: ‘H’Evans Berries, Cold Lake Fish Hatchery, Imperial Oil Resources and Canadian Natural Resources (see Figure 2-4). When Cold Lake reaches 534.62 masl the these licenced withdrawals must cut back withdrawals by up to 30% (this threshold does not apply to the

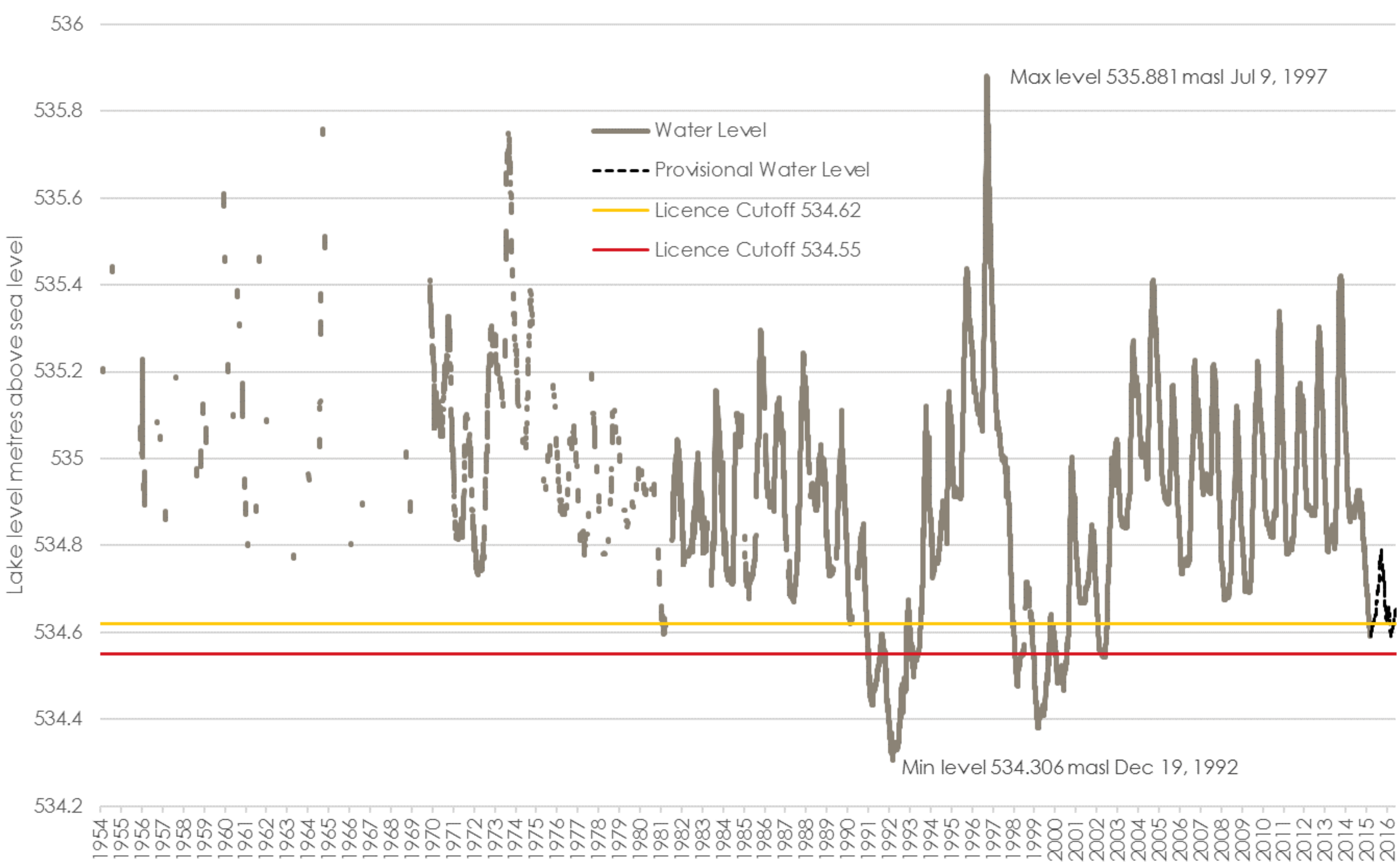

Figure 2-4 Cold Lake Water Level Measured at Water Survey of Canada Station 06AF002 from 1954 to 2017

'H'Evans Berries licence). When lake water level reaches 534.55 masl for two consecutive days, these licence holders must cease water withdrawals from Cold Lake. These cutoffs were established by AEP in order to maintain access to critical fish spawning habitats in Cold River and Long Bay (AENV 2006a). The Cold Lake was below 534.62 m and 534.55 m about 28% and 24% of the time between 1974 and 2015, respectively. The majority of the time the lake was below these cutoff levels occur from early 1990s to early 2000s, which coincides with the season of high evaporation and low lake water input.

2.2.1.2 Master Agreement on Apportionment

The Prairie Provinces Water Board (PPWB) was formed in 1948 to recommend water allocations among provinces (PPWB 2017). Generally, Saskatchewan is entitled to 50% of the natural flow at the provincial border of an interprovincial watercourse that flows eastward (PPWB 2017a). Some of the Cold Lake watershed originates within Saskatchewan resulting in an adjusted share of 68.4%, which Saskatchewan is entitled to (PPWB 2017b). Over the last two decades more than 90% of the apportionment flow to Saskatchewan has passed into the Cold River at the Cold Lake outlet (Figure 2-5).

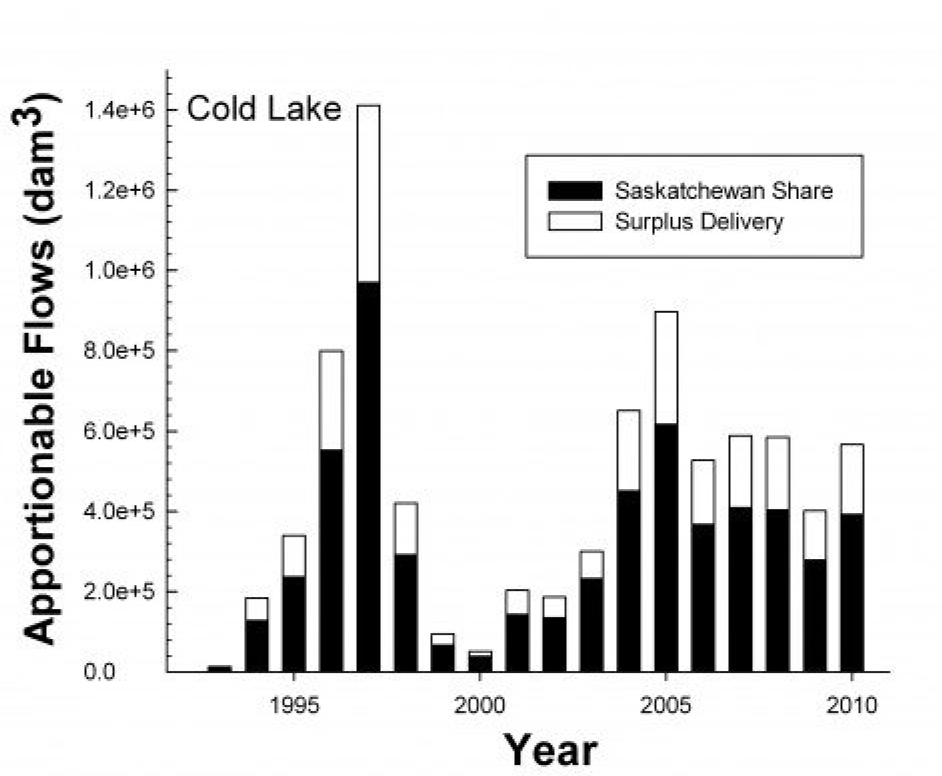

Figure 2-5 Apportionable Flows at the Outlet of Cold Lake (Station 06AF001)

2.3 LAKE WATER BALANCE 1974 TO 2015

The Cold Lake Water Balance Model was extended from 2002 to 2015 to cover the period 1974 to 2015. In addition, the model was updated to include a groundwater net contribution component based on past groundwater studies. The main climatic input into the model are precipitation and evaporation, each having an opposite effect on the lake water level. In addition, and depending on the magnitude, water withdrawal from the lake decrease the lake level. The outcome of the modeling exercise is the simulated inflows to the lake.

Using the fundamental hydrologic principle of water balance, and utilizing the backward routing technique, the weekly water balance model for Cold Lake was developed. As the developed model utilizes the recorded historical water level as input data, the simulated water levels will be exactly same as the measured water levels. The computed historical inflow hydrographs using this model can be used to evaluate the effect of additional withdrawal of water from this lake.

For the annual water balance components of Cold Lake, see Table 2-6. For the proportion of water gain into and water loss from Cold Lake, see Figure 2-6. For most of the years since 1974, the principal water gain to Cold Lake is through surface inflow from the contributing watershed. However, in the early 1990s direct precipitation on the lake constitute proportionally the largest water contribution.

Lake outflow constitutes the major way of water loss in Cold Lake for most of the years since 1974. However, lake evaporation became the largest contributor for water loss from the lake from early 1990s to mid of the 1990s and again from early 2000s to mid of 2000s. Known water withdrawal values exist from 2005 onwards as shown in Table 2-6 and Figure 2-6.

Table 2-6 Water Balance Components of Cold Lake from 1974 to 2015

Year	Precipitation (10^6m^3)	Net Inflow (10^6m^3)	Evaporation (10^6m^3)	Net Groundwater Contribution (10^6m^3)	Withdrawal	Outflow (10^6m^3)	Change in volume (10^6m^3)
1974	215.68	1291.71	225.42	7.28		1335.41	-46.16
1975	187.96	703.59	225.09	7.28		704.11	-30.37
1976	163.58	550.65	251.42	7.28		502.71	-32.62
1977	168.13	464.14	254.97	7.28		407.6	-23.02
1978	133.08	472.84	235.41	7.28		397.54	-19.75
1979	155.01	519.32	240.02	7.28		396.86	44.73
1980	158.04	445.04	242.65	7.28		357.38	10.33
1981	117.16	321.33	259.77	7.28		297.04	-111.04
1982	134.08	416.65	226.14	7.28		277.25	54.62
1983	130.37	385.41	216.03	7.28		289.37	17.66

Year	Precipitation (10^6m^3)	Net Inflow (10^6m^3)	Evaporation (10^6m^3)	Net Groundwater Contribution (10^6m^3)	Withdrawal	Outflow (10^6m^3)	Change in volume (10^6m^3)
1984	172.68	354.11	227.11	7.28		337.71	-30.75
1985	128.76	417.86	237.12	7.28		324.69	-7.91
1986	158.8	572.07	229.66	7.28		434.23	74.26
1987	154.05	412.29	215.92	7.28		429.23	-71.53
1988	187.75	506.55	237.81	7.28		389.83	73.94
1989	173.15	336.95	223.82	7.28		361.34	-67.78
1990	149.26	306.01	240.94	7.28		265.35	-43.74
1991	118.54	164.91	240.71	7.28		121.08	-71.06
1992	137.68	51.22	218.07	7.28		22.2	-44.09
1993	174.95	125.24	219.73	7.28		12.72	75.02
1994	159.78	354.25	241.32	7.28		193.11	86.88
1995	152.62	451.48	206.68	7.28		339.07	65.63
1996	186.85	871.59	191.95	7.28		795.52	78.25
1997	186.86	1422.67	222.66	7.28		1408.33	-14.18
1998	159.31	257.53	234.89	7.28		420.97	-231.74
1999	120.76	134.62	203.58	7.28		94.32	-35.24
2000	140.16	154.72	237.04	7.28		50.77	14.35
2001	132.96	345.64	255.2	7.28		203	27.68
2002	100.17	384.66	241.82	7.28		186.73	63.56
2003	214.14	277.39	245.57	7.28		299.21	-45.97
2004	172.53	816.2	236.46	7.28		648.28	111.27
2005	200.71	980.01	240.73	7.28	5.71	895.2	52.07
2006	161.45	585.71	256.17	7.28	6.292	526.91	-28.64
2007	190.6	585.19	250.3	7.28	7.336	587.22	-54.45
2008	140.34	749.99	253.9	7.28	7.09	583.43	60.28
2009	139.33	412.66	244.64	7.28	6.161	401.28	-86.65
2010	220.4	592.35	254.12	7.28	5.764	565.66	0.25
2011	181.92	711.19	257.74	7.28	5.658	594.28	48.37
2012	170.57	671.99	265.32	7.28	4.206	596.79	-12.27
2013	139.29	812.61	256.96	7.28	5.782	672.73	29.49
2014	169.29	799.29	244.08	7.28	5.404	750.02	-18.24
2015	157.6	512.58	269.25	7.28	6.244	386.78	21.43

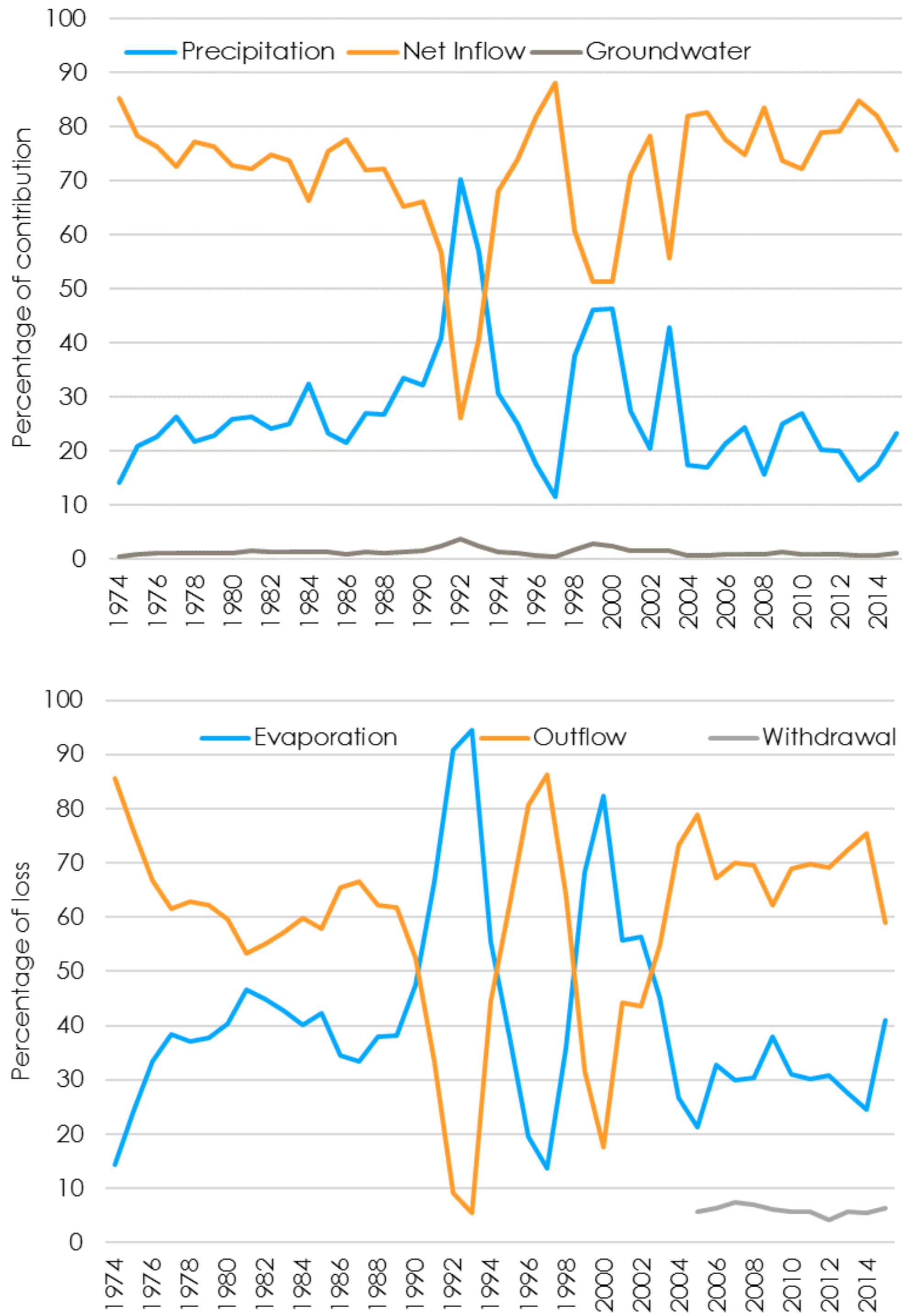

Figure 2-6 Relative Water Contributions and Losses in Cold Lake from 1974 to 2015

2.4 WATER BALANCE SCENARIOS WITH INCREASED CLRUSC WATER WITHDRAWAL

The effects of potential future water withdrawals from Cold Lake for a regional water supply by CLURSC were evaluated utilizing three scenarios (see Figure 2-7 and Figure 2-8).

Baseline: Water balance model results that reflect actual water withdrawals from Cold Lake 2005 to 2015

- return flows were assumed, where reported, to go back into Cold Lake, except for CLRUSC return flows, which go to the Beaver River and do not affect the lake water balance.

Scenario 1: CLRUSC/regional waterline water withdrawal was increased to 4,166 dam^3/year (2012 estimate, see Table 2-5) and applied to the water balance model between 2005 and 2015

- all other lake water withdrawals were kept the same (i.e., actual 2005 to 2015 data)
- the scenario provides an evaluation of how lake water level would have behaved in the last 10 years with the year 2012 projected level of CLRUSC withdrawal

Scenario 2: CLRUSC/regional waterline water withdrawal was increased to 5,840 dam^3/year (2032 estimate, see **Table 2-5**) and applied to the water balance model between 2005 and 2015

- all other lake water withdrawals were kept the same (i.e., actual 2005 to 2015 data)
- the scenario provides an evaluation of how lake water level would have behaved in the last 10 years with the year 2032 projected level of CLRUSC withdrawal

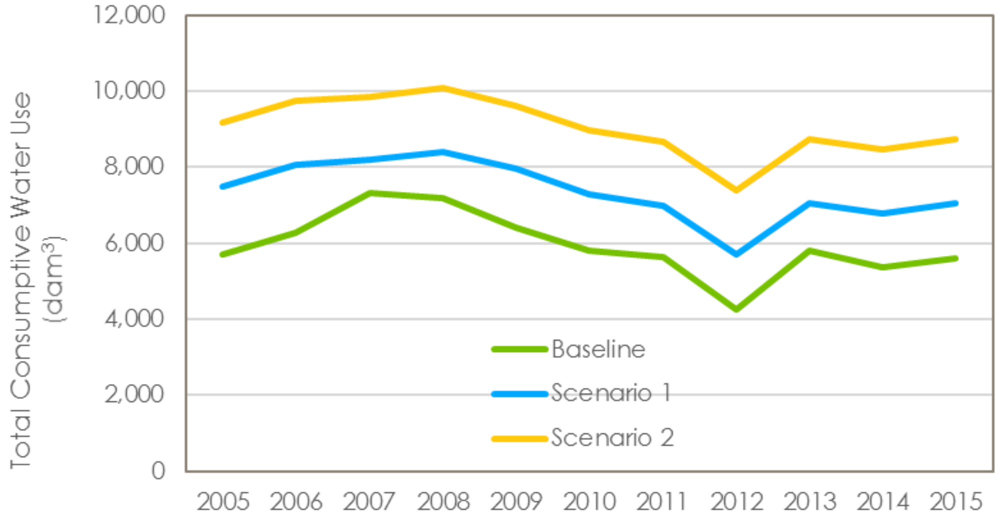

Figure 2-7 Total Consumptive Use of Water from Cold Lake Under Baseline (2005 to 2015) and Two Evaluation Scenarios

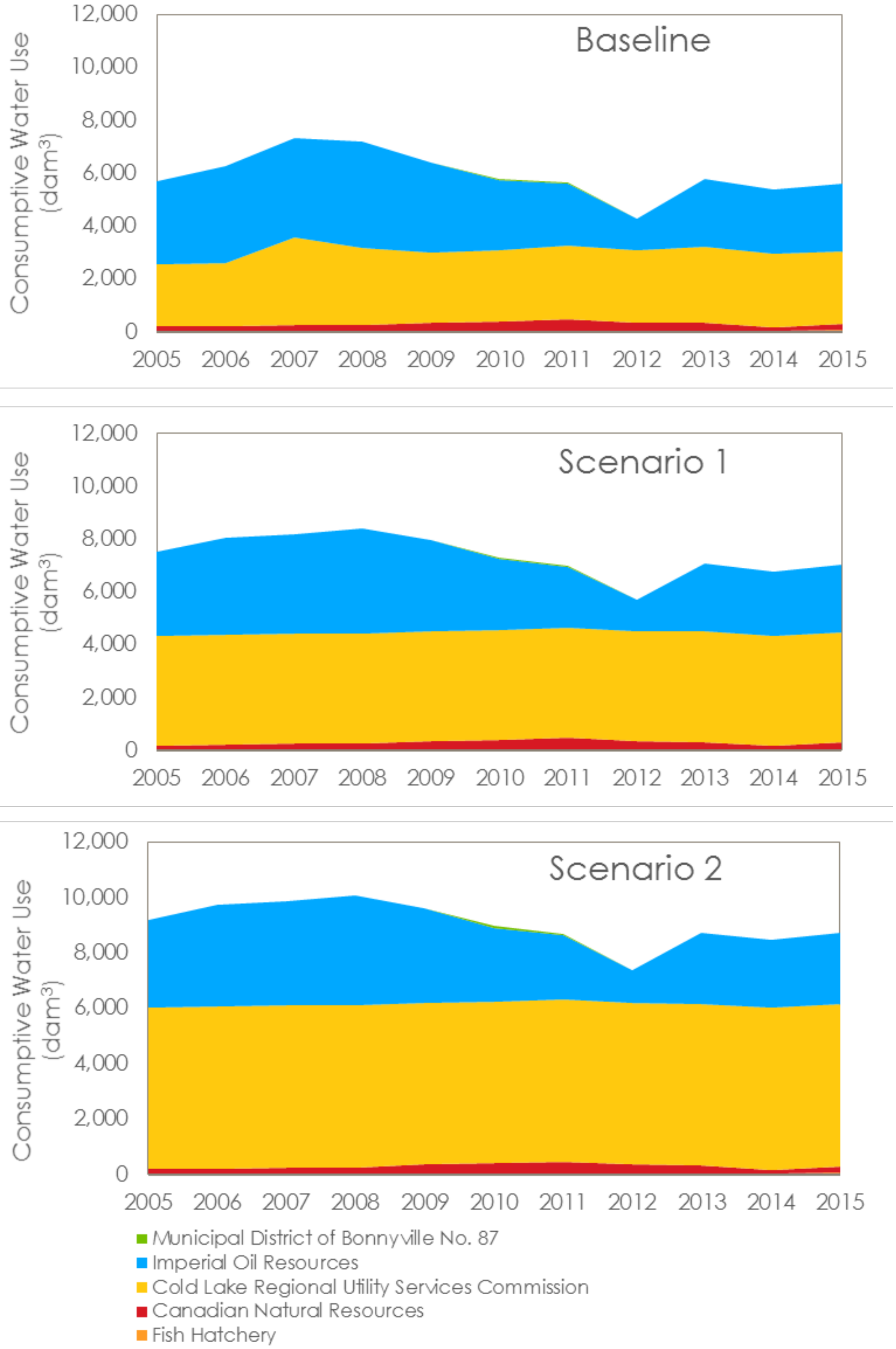

Figure 2-8 Cumulative Consumptive Use of Water from Cold Lake Under Baseline (2005 to 2015) and Two Evaluation Scenarios

2.4.1 Results

The lake level data was used in the model to determine lake volume (based on stage-volume relationships, Equation 8), lake area (based on stage-area relationship, Equation 9), and lake outflow (based on stage-outflow relationships, Equation 10).

Lake level changes for Scenario 1 and 2 were compared to baseline conditions between 2005 and 2015 (see Figure 2-9). Under both scenarios the water level was simulated to change by very small amount (4 mm and 8 mm for scenario 1 and 2, respectively), indicating the water withdrawal scenarios will have insignificant effect on Cold Lake level.

2.4.1.1 Apportionment

Potential changes to recorded flow (cumulative volume; dam^3) at the Cold Lake outlet were examined under scenarios 1 and 2. The proposed increases to CLRUSC water withdrawal under each scenario were subtracted from the available historical recorded flows and apportionable flows (dam^3) at the outlet of Cold Lake (monitoring station 06AF001) (PPWB 2017b). With increased CLRUSC water withdrawal, more than 90% of the apportionable flow to Saskatchewan is still predicted to flow from Cold Lake (Table 2-7).

2.5 CLIMATE CHANGE

Climate change-induced shifts in temperature and precipitation in Alberta can affect the hydrology of Cold Lake. For example, an increase in precipitation amount and intensity might increase the net surface input directly on the lake and from the surrounding watershed into the lake resulting in higher lake level. On the other hand, an increase in temperature and with more days being warmer than the baseline period might increase evaporation from the lake and surrounding watershed. This might result in decrease in decrease of net lake inflow hence lake level.

Reduced winter snowfall in the latter half of the twentieth century has contributed to the observed trend of declining streamflow in the Prairies. Water availability is a critical issue for many rivers in the southern Prairies, particularly during dry years. Predicted winter warming as a result of climate change will reduce snow accumulations across the Prairies. This reduction will cause declines in annual streamflow and a shift in streamflow timing to earlier in the year, resulting in lower summer water supplies (Sauchyn and Kulshreshtha 2008). It is possible that Cold Lake will receive less surface water inflow from spring snowmelt over the coming decades as a result of climate change. However, due to Cold Lake's size and the resulting water storage, the lake is anticipated to be a reliable long-term water source.

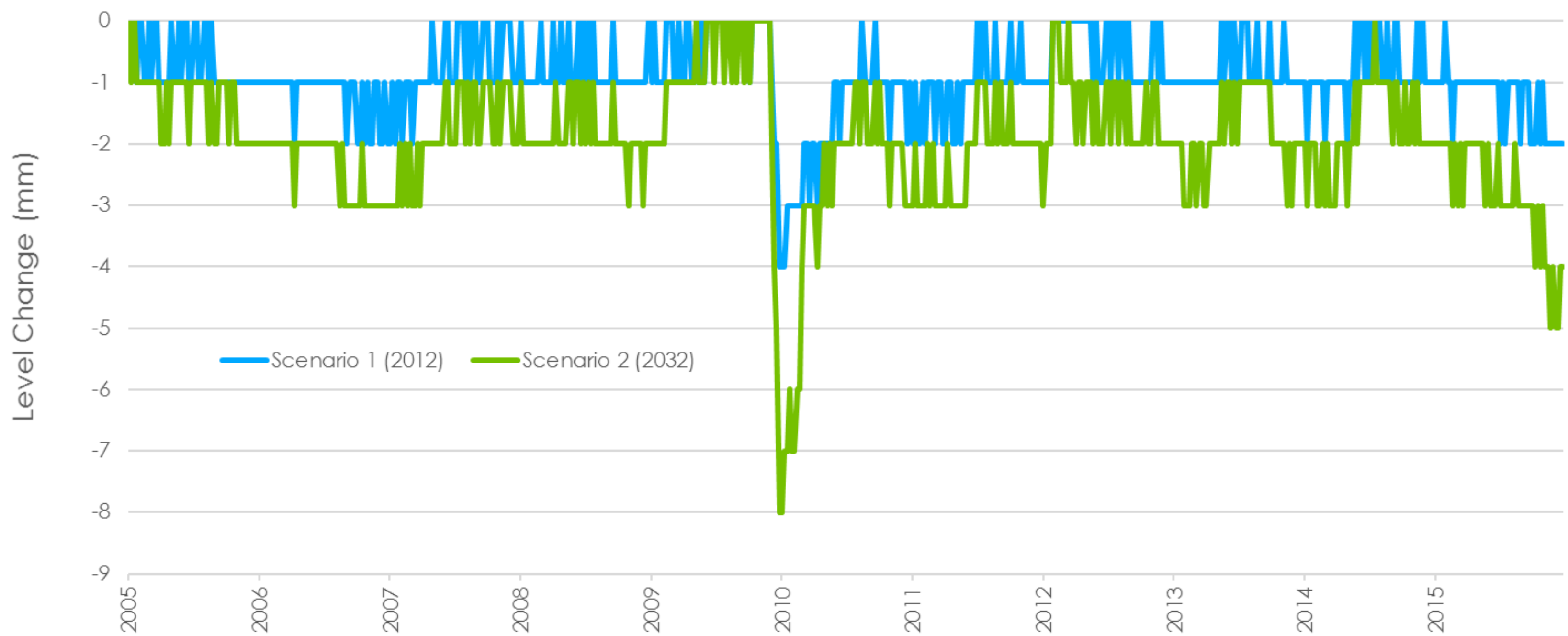

Figure 2-9 Cold Lake Water Level Change Scenarios

Table 2-7 Predicted Flow at Cold Lake Outlet and Percent Share of Apportionment for Scenarios 1 and 2

Year	Recorded Flow (dam^3)[a]	Apportionable Flow (dam^3)[a]	% Share of Apportionable Flow Passed to Saskatchewan	Estimated Recorded Flow - Scenario 1	% Share of Apportionable Flow Passed to Saskatchewan - Scenario 1	Estimated Recorded Flow - Scenario 2	% Share of Apportionable Flow Passed to Saskatchewan - Scenario 2
2005	896,633	902,443	99%	894,829	99%	893,155	99%
2006	527,738	536,723	98%	525,944	98%	524,270	98%
2007	588,770	598,190	98%	587,910	98%	586,236	98%
2008	585,000	591,000	99%	583,769	99%	582,095	98%
2009	402,000	407,800	99%	400,458	98%	398,784	98%
2010	567,000	574,000	99%	565,502	99%	563,828	98%

NOTES:

[a] Data source: PPWB (2017b)

3.0 LAKE HEALTH

This section provides an assessment of the potential effects of lake level fluctuations on the health of ecosystems, including aquatic biota, vegetation and wetlands, and wildlife, including waterfowl.

3.1 METHODS

3.1.1 Definition of Health

The study uses the following two general definitions of aquatic ecosystem health, which incorporate societal values in the definitions:

- A healthy ecosystem is sustainable and resilient to stress, maintaining its ecological structure and function over time similar to the natural (undisturbed) ecosystems of the region, with the ability to recover from disturbance, while continuing to meet social needs and expectations (Stantec 2005).
- Healthy environments imply normal aquatic communities, and normal physical and chemical environments. The practical definitions of "normal" are typically based on reference conditions, which are spatially and temporally variable, and depend on the type of aquatic environment (river, lake, or wetland) (Jacques Whitford 2005).

3.1.2 Literature Review

Existing data describing the ecosystem within Cold Lake and the watershed were identified from public sources, such as monitoring databases available online, and project applications for developments in the Cold Lake watershed. Ecosystem data for the Cold Lake watershed were reviewed and are summarized in the sections below. A description of the Cold Lake-Beaver River watershed was summarized by AENV in the Cold Lake-Beaver River State of the Basin Report series (AENV 2006b, 2006c). This report leverages the AENV (2006a, 2006b) reports where appropriate, and any direct quotes are indicated with italics.

3.2 AQUATIC BIOTA

Cold Lake has been classified as oligo-mesotrophic (Mitchell and Prepas 1990; AENV 2006b) and mesotrophic (Imperial Oil Resources 2016) lake, meaning that the lake has relatively low concentrations of nutrients and primary productivity. The lake has mean and maximum depths of about 50 m and 99 m, respectively, and exhibits strong thermal stratification during summer months (Mitchell and Prepas 1990; AENV 2006b; Beaver River Watershed Alliance 2013). The shallow littoral (i.e., shoreline) zone extends to a depth of about 4 m in Cold Lake (Mitchell and Prepas 1990); however, the littoral zone does not occupy a large area within the lake because of a steep increase in depth moving away from shore (see Figure 1-2). Most littoral zone habitat is found at the south end of the lake within Long Bay and Centre Bay (see Figure 1-2).

Long Bay has been identified as an important spawning area for several fish species in Cold Lake (Mitchell and Prepas 1990 and references therein; AENV 2006b; Imperial Oil Resources 2016 and references therein), and exhibits higher productivity (biomass) than other areas within the lake (Mitchell and Prepas 1990 and references therein; Imperial Oil Resources 2016 and references therein). Areas of dense aquatic vegetation and shallow depths with debris provide spawning habitat for northern pike, walleye, and yellow perch. Alberta Environment implemented thresholds (see Section 2.2.1.1) for water withdrawal to maintain access to critical fish spawning habitats in Cold River and Long Bay (AENV 2006a). Several studies of the aquatic ecosystem within Long Bay were conducted in the late 1970s and early 1980s; however, at the writing of this report Stantec has not been able to obtain the unpublished data from those studies.

Cold Lake has a diverse fish community (see Table 3-1). No fish species within Cold Lake are listed under the provincial *Wildlife Act* or federal *Species at Risk Act* (*SARA*). Historically, there have been commercial, recreational, and Indigenous fisheries in the lake harvesting species such as burbot, cisco, lake trout, lake whitefish, northern pike, walleye, and yellow perch. Commercial and recreational fishing pressure affected sport fish species in the lake, and some species have showed signs of over-exploitation in the past (AENV 2006). In an attempt to allow recovery of fish populations in several lakes, commercial fisheries in Alberta were closed in 2014 (AEP 2016).

3.3 VEGETATION, WETLANDS AND RIPARIAN AREAS

Vegetation cover in the Cold Lake drainage basin is largely undisturbed. Disturbance is concentrated on the south shore. The largest alteration or loss of natural vegetation is from the Town of Cold Lake and agricultural land. Smaller areas have been converted for roads (e.g., Highways 897 and 23), transmission lines and well sites. Only a few areas of impervious surface and altered water flow paths with potential to influence vegetation appear present.

Vegetation immediately surrounding Cold Lake is also largely native (USGS 2017, Microsoft 2017) and consists mainly of upland areas. Most of the lake shoreline is steep with water levels reaching depths of 10 m within 200 m or less of the shoreline, and lacks wetland or riparian vegetation cover. Wetland and riparian vegetation cover is likely absent due to fluctuations in water levels, wave action and ice scouring typical of many lakes. Wetland and riparian vegetation is limited to three main areas around the lake: west of Murray Island; English Bay, just south of Bank Bay; and Centre Bay/Long Bay complex (see Figure 3-1). These areas are sheltered and the lake profile less steep, about 1% to 0.5% (AENV, n.d.).

Table 3-1 Fish Species Documented within Cold Lake

Species Information			Legislated Protection		Scientific Review or Recommendation	
Family[a]	Scientific Name[a]	Common Name[a]	*SARA*[b] (Federal)	*Wildlife Act*[c] (Provincial)	COSEWIC[d] (Federal)	General Status[e] (Provincial)
Catostomidae (suckers)	*Catostomus catostomus*	longnose sucker	No Status	Not listed	Not assessed	Secure
	Catostomus commersonii	white sucker	No Status	Not listed	Not assessed	Secure
Cottidae (sculpins)	*Cottus cognatus*	slimy sculpin	No Status	Not listed	Not assessed	Secure
	Cottus ricei	spoonhead sculpin	No Status	Not listed	Not at Risk	May be at Risk
Cyprinidae (carps and minnows)	*Notropis atherinoides*	emerald shiner	No Status	Not listed	Not assessed	Secure
	Pimephales promelas	fathead minnow	No Status	Not listed	Not assessed	Secure
	Chrosomus neogaeus	finescale dace	No Status	Not listed	Not assessed	Undetermined
	Couesius plumbeus	lake chub	No Status	Not listed	Not assessed	Secure
	Rhinichthys cataractae	longnose dace	No Status	Not listed	Not assessed	Secure
	Margariscus margarita	pearl dace	No Status	Not listed	Not assessed	Undetermined
	Notropis hudsonius	spottail shiner	No Status	Not listed	Not assessed	Secure
Esocidae (pikes and mudminnows)	*Esox lucius*	northern pike*	No Status	Not listed	Not assessed	Secure
Gadidae (cods)	*Lota lota*	burbot*	No Status	Not listed	Not assessed	Secure
Gasterosteidae (sticklebacks)	*Culaea inconstans*	brook stickleback	No Status	Not listed	Not assessed	Secure
	Pungitius pungitius	ninespine stickleback	No Status	Not listed	Not assessed	Undetermined
Percidae (perches and darters)	*Etheostoma exile*	Iowa darter	No Status	Not listed	Not assessed	Secure
	Percina caprodes	logperch	No Status	Not listed	Not assessed	Undetermined
	Sander vitreus	walleye*	No Status	Not listed	Not assessed	Secure
	Perca flavescens	yellow perch*	No Status	Not listed	Not assessed	Secure
Percopsidae (trout-perches)	*Percopsis omiscomaycus*	trout-perch	No Status	Not listed	Not assessed	Secure
Salmonidae (trouts and salmons)	*Coregonus artedi*	cisco*	No Status	Not listed	Not assessed	Secure
	Salvelinus namaycush	lake trout*	No Status	Not listed	Not assessed	Sensitive
	Coregonus clupeaformis	lake whitefish*	No Status	Not listed	Not assessed	Secure

Species Information			Legislated Protection		Scientific Review or Recommendation	
Family[a]	Scientific Name[a]	Common Name[a]	*SARA*[b] (Federal)	*Wildlife Act*[c] (Provincial)	COSEWIC[d] (Federal)	General Status[e] (Provincial)

NOTES:

[a] Common and Scientific Names of Fishes from the United States, Canada, and Mexico (Page et al. 2013).

[b] *Species at Risk Act* (*SARA* 2002) (GOC 2017a).

[c] *Wildlife Act* – Wildlife Ministerial Regulation (Wildlife Regulation 1997).

[d] Committee on the Status of Endangered Wildlife in Canada (COSEWIC) (GOC 2017b).

[e] General Status of Alberta Wild Species (ESRD 2012).

*Denotes a sport fish species.

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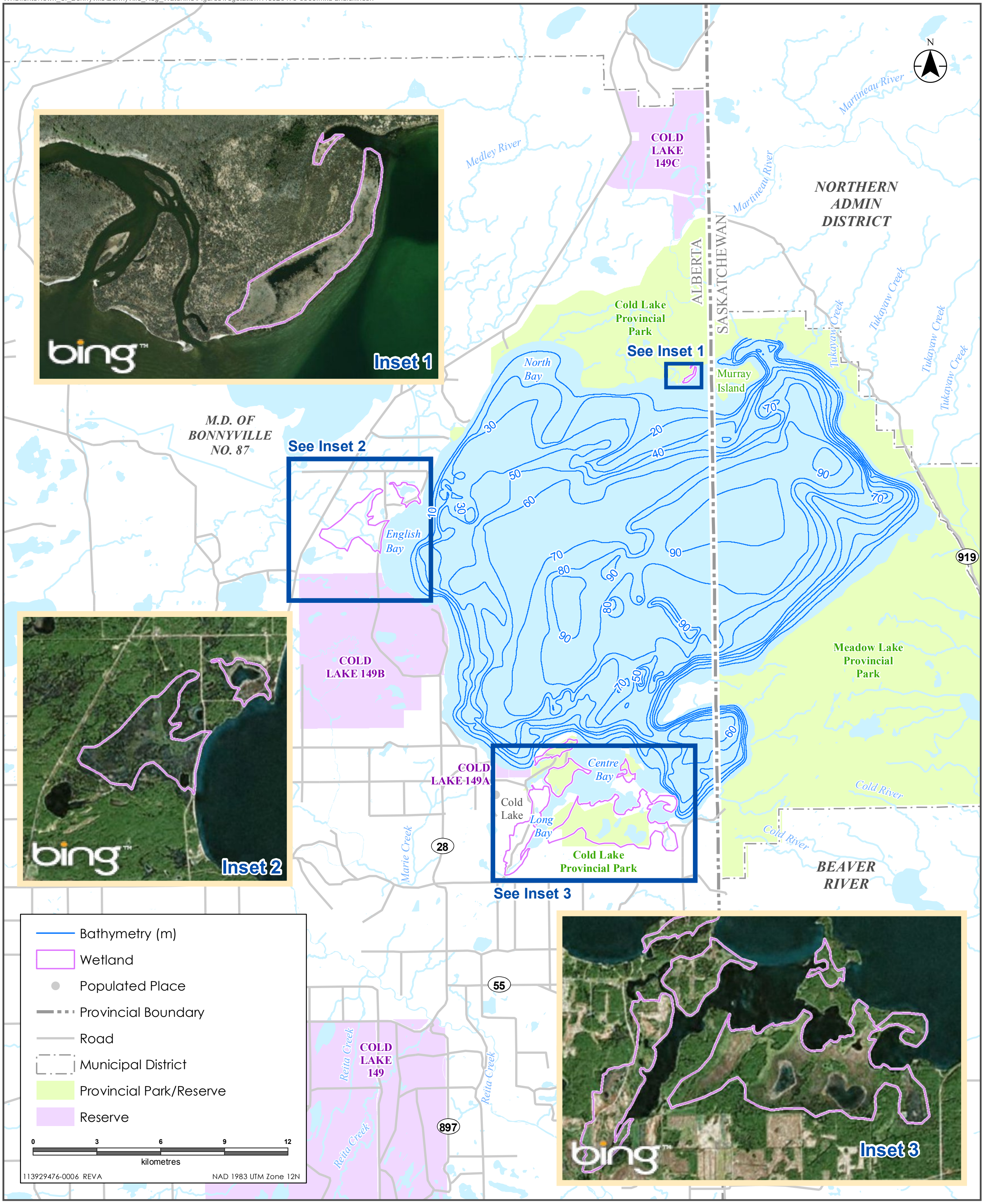

Sources: Base Data - Governments of Alberta, Saskatchewan and Canada, Natural Earth; Thematic Data - ERBC
Service Layer Credits: © 2010 DigitalGlobe Image courtesy of USGS © 2010 GeoEye Earthstar Geographics SIO © 2017 Microsoft Corporation

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

Wetland Shoreline Areas of Cold Lake

Stantec

COLD LAKE HEALTH ASSESSMENT

Figure 1-3

3.4 WILDLIFE

Cold Lake is large, deep and oligotrophic. Wildlife habitat within the lake and along the shore is influenced by the large size and depth of the lake and the shoreline topography. The main body is relatively low in wildlife productivity (Rippon [sic] 1985). Much of the shoreline is exposed to wave action and ice scour which prevents development of emergent vegetation suitable as wildlife habitat. The depth of the lake and the volume of water do not provide early spring water temperatures required for many wildlife species (Rippon [sic]1985). However, the mouth of the Martineau River and the Long Bay complex along the south shore of the lake are relatively shallow and provide the majority of suitable habitat for water-associated wildlife within Cold Lake (Rippin 2004). The Long Bay complex is physically separated from the main lake by a submerged sandbar. The shallower water and separation results in the Long Bay area having much different wildlife habitat types and availability than the main body of Cold Lake. This area becomes ice-free earlier in the year than the rest of Cold Lake and the earlier warming facilitates increased growth of vegetation and invertebrate abundance (Rippon [sic] 1985). The shallowness of the Long Bay area makes it more sensitive to changes in water level than the rest of Cold Lake and at times of low water (approximately 1 m below long-term average) the sandbar is exposed, effectively cutting Long Bay off from Cold Lake (Rippon [sic]1985).

Cold Lake is important for migratory birds in Alberta including waterfowl and waterbirds. The largest western grebe colony in Alberta exists in the Long Bay complex where emergent vegetation provides high quality nesting and foraging habitat and has been used for over forty years (ESRD 2013). Western grebe is considered Threatened in Alberta and Special Concern by the committee on Endangered Wildlife in Canada (COSEWIC) (AESCC 2014; COSEWIC 2014). The western grebe population of Cold Lake has been estimated as high as 2012 adult birds in 1978 (Kristensen and Nordstrom 1979 in ESRD 2013) and as low as 34 individuals in 2010 (Wollis 2010 in ESRD 2013). As a result, Cold Lake western grebe population has declined from nationally important to regionally important since 2003 (ESRD 2013).

Mammal species in the Cold Lake area include fisher, marten, mink, river otter, beaver, muskrat, Canada lynx, wolf, red fox, black bear, mule deer, white-tailed deer and moose. Amphibian and reptile species found in the area include Canadian toad, boreal chorus frog, wood frog, tiger salamander and red-sided garter snake.

Wildlife surveys for 57 lakes in the Cold Lake – Beaver River watershed were completed in 1980 and 1981 for the Cold Lake – Beaver River Water Management Plan (Rippon [sic]1985) focusing on aquatic mammals and water-associated birds. In 2003, similar surveys were completed on 28 of the originally surveyed lakes and changes to wildlife and wildlife habitat were summarised in Rippin (2004). Most changes between study periods were attributed to prolonged water deficit in the watershed. However, some bird species increased (e.g. gadwall, eared grebe, Franklin's gull. American white pelican, double-breasted cormorant, Canada goose) or decreased (e.g. lesser scaup, American coot, white-winged scoter) similar to broader trends seen across the prairie pothole region, and may not have changed in response to drought conditions in the Cold Lake – Beaver River basin. Data from the 1980-81 survey for Cold Lake itself was not available for comparison to 2003 data in Rippin (2004). However, because water levels in Cold Lake have remained relatively stable (fluctuations within <1 m from 1980 to 2003) it is likely that habitat conditions remained stable and that any significant changes in wildlife abundance would apply only to those species influenced by regional or continental population trends (Rippin 2004). Species observed during the 2003 survey included both those which prefer marsh-like habitats and those associated with large lakes, reflecting the size and diversity of habitats contained within Cold Lake.

Waterfowl and waterbirds are the wildlife groups most likely to be affected by changes in the water level of Cold Lake. Adequate water levels are an important factor to waterfowl reproduction and can affect nesting habitat availability, rates of nest and brood predation and access to food sources. The effects of reduced water levels on waterfowl populations can be influenced by species composition (e.g. divers vs. dabblers) and the characteristics of the waterbody, shoreline and surrounding area. Reduction of nesting and brood-rearing habitat caused by receding water levels depends on the topography of the basin (Rippon [sic] 1985). Low water levels may inhibit growth of emergent vegetation used as nesting cover and nest construction material. Loss of emergent vegetation has the greatest effect on species which use it for nest cover and nest material (e.g. diving ducks, grebes). Shorelines with low slopes tend to support more abundant emergent vegetation than those with steeper slopes. Low water levels can also reduce nesting success of waterfowl and waterbirds (e.g., Dzubin 1969; Pospahala et al. 1974; Markham 1982; Ringelman 2014). However, water level reductions associated with future water withdrawals for municipal use are not likely to affect waterfowl or waterbird populations at Cold Lake.

3.5 EFFECT OF PREDICTED WATER LEVEL CHANGES ON LAKE HEALTH

Changes in lakes levels from further water withdrawals are not expected to measurably affect aquatic biota, wetlands, riparian vegetation or wildlife due to the small predicted changes in lake water levels, 4-8 mm. This change is within the range of variability observed from 1954 to 2015, 1.574 m, and small in comparison to average yearly fluctuations of lake water levels, about 20 to 40 cm.

The hydrology of wetlands in English Bay has also potentially been affected by past construction of Highway 23. Highway 23 is crosses the wetland in English Bay, near the lake shore potentially limiting water flow to and from the lake. The submerged sandbar in the Centre Bay/Long Bay complex also likely helps stabilize water levels in this area and reduces the influence of variations in lake water levels.

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