2015 Alpine Area Lakes Recharge Studies

ConocoPhillips Alaska

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ACRONYMS AND ABBREVIATIONS

ADF&G	Alaska Department of Fish and Game
ADNR	Alaska Department of Natural Resources
Michael Baker	Michael Baker International
BPMSL	British Petroleum Mean Sea Level
CPAI	ConocoPhillips Alaska, Inc.
CRD	Colville River Delta
GIS	Geographic information system
GPS	Global positioning system
HWM	High water mark
NAD83	North American Datum of 1983
NRCS	Natural Resources Conservation Service
Mgal	Million gallons
SWE	Snow water equivalent
TBM	Temporary benchmark
WSE	Water surface elevation

1.0 INTRODUCTION

Conoco Phillips Alaska, Inc. (CPAI) withdraws water and ice from lakes within the Colville River Delta (CRD) to build ice rods and pads in the winter. These roads and pads are temporary infrastructure supporting maintenance and operations. The construction of ice roads and pads requires withdrawal of millions of gallons of fresh water and ice chips from area lakes, typically between December and May.

Stipulations of Alaska Department of Fish and Game (ADF&G) Fish Habitat Permits and Alaska Department of Natural Resources (ADNR) Temporary Water Use Permits require CPAI to document seasonal recharge at specific water withdrawal lakes. Michael Baker International (Michael Baker) conducted late season snow surveys and spring lake recharge studies to monitor water levels and provide photo documentation for permit compliance. This report summarizes the hydrologic observations, measurements, and analyses.

Michael Baker was supported during field monitoring by CPAI Alpine Environmental Coordinators, Umiaq/LCMF, LLC, and Pathfinder Aviation. All Michael Baker and support team members are recognized for their contribution to an incident-free field effort.

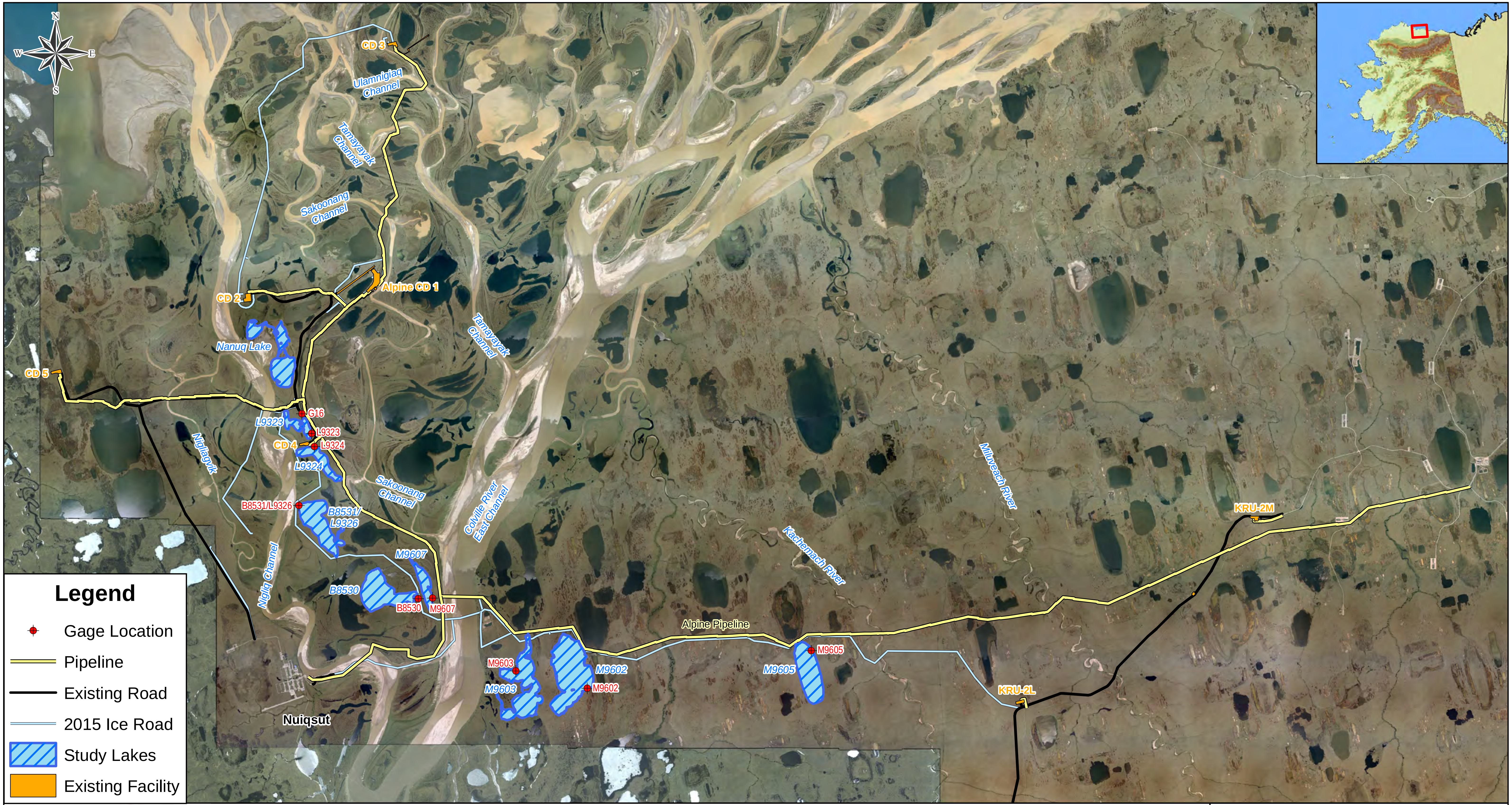
1.1 STUDY OVERVIEW

The objectives of the 2015 Alpine Area Lakes Recharge Studies include collection and analysis of spring breakup recharge data at nine water withdrawal lakes. Lake studies included observations and photos, gage water surface elevation (WSE) measurements, and late season snow surveys.

The lakes are grouped as the Detailed Study Lake and General Study Lakes. The 2015 Detailed and General Study Lakes are listed in Table 1.1 and the locations are shown on Figure 1.1.

Table 1.1: 2014 Alpine Area Detailed and General Study Lakes

Detailed Study Lake	M9602
General Study Lakes	B8530, B8531/L9326, L9323, L9324, M9603, M9605, M9607, and Nanuq Lake



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2015 ALPINE AREA LAKES RECHARGE STUDY

FIGURE: 1.1

(SHEET 1 of 1)

Visual observations and photos focused on key hydrologic features, including peak water levels, hydraulic connectivity with other bodies of water, and inflow/outflow locations. Existing staff gages were restored during spring breakup setup and data was collected when Michael Baker field personnel were in the vicinity of these lakes.

A late-season snow survey was conducted for Lake M9602 prior to breakup. The catchment basin for Lake M9602 was delineated prior to field work using available topography and aerial imagery. Basin-specific snow water equivalent (SWE) was calculated using data collected during the snow surveys. Potential snowmelt contribution was calculated using SWE values and delineated catchment basin areas. Estimated available recharge volumes were calculated using WSE data and delineated lake specific area.

1.2 LAKE RECHARGE BACKGROUND

Annual recharge of lakes in the CRD occurs as a result of spring breakup flooding, snow melt, and precipitation. Spring breakup flooding and snow melt (considered overland flow) were investigated. Lake elevation, proximity to streams, and local topography typically dictate the recharge mechanism. Lakes located within annually inundated stream floodplains or hydraulically connected areas recharge primarily from spring breakup flood flows. Lakes not inundated because of distance or topographical limitations depend solely on snowmelt runoff and precipitation for recharge. Lake recharge from spring breakup flooding and snow melt is assessed based on the presence of a peak in a WSE hydrograph, visual observations of inflow/outflow, and/or visual observations of overland flooding.

The magnitude of spring breakup flooding fluctuates from year to year in terms of stage and discharge. If flood stage is relatively low, bankfull recharge may not occur, depending on topography and elevation. In addition, breakup flow extents are affected by the unpredictable establishment and release of ice jams. Presence and location of ice jams can determine whether a lake becomes hydraulically connected to a stream recharge source regardless of flood magnitude.

The amount of snowmelt runoff a lake receives depends on terrain, topography, and the properties of the snow in the catchment basin. While vegetation is not a major factor affecting snow distribution in the arctic, terrain has a major effect. Terrain-based snow surveys allow for more accurate determinations of mean catchment snow values and produce sufficient spatial snow information for most hydrological studies (Woo 1997).

SWE of a basin can be determined by the depth and density of snow within a catchment in the spring when melting occurs; it is directly proportional to the quantity of potential snowmelt recharge. SWE will vary with the type of terrain and may be presented as a weighted, basin-specific value. For lakes sharing similar topographical and climatological features with those previously studied, average SWE values may be multiplied by catchment basin area to calculate a conservative estimate of potential snowmelt recharge. This method was previously used for lakes M9602 and M9605 (Michael Baker 2010); a comparison of the 2010 thru 2015 results is included in Section 4.1.5.

In this study, the lake catchment basin terrain is designated as lake or tundra. Lake areas were assumed to contribute all snowmelt based on analysis of snow survey data and estimated recharge volumes. Not all tundra snowmelt will directly contribute to lake recharge because of variations in vegetation and topography relative to the lake. The quantity of snowmelt retained in tundra areas differs for each lake catchment basin.

Kane et al. (1999) performed a study in the Kuparuk River Basin to determine an average quantity of snowmelt retained in tundra areas of lake catchment basins as a percentage of total potential snowmelt contribution, based on estimated recharge quantities. Study findings suggest applying an average runoff coefficient of 0.67 to tundra SWE as a reduction factor to account for snowmelt retention.

In 2007, Michael Baker performed a recharge monitoring study for lakes within the CRD. Results suggested an average tundra SWE runoff coefficient of 0.67, further validating the value obtained by Kane et al. (Michael Baker 2007). Similar topography and proximity to the CRD basin justifies using a runoff coefficient of 0.67 for calculating the total estimated snowmelt contribution for Lake M9602.

2.0 PERMITS AND WATER USE

CPAI requires water sources for building ice roads and ice pads, drilling, drinking water, and general operations. ADNR, ADF&G, or both agencies grant permits on the condition of CPAI compliance with temporary water use requirements to regulate water withdrawal and maintain conditions supportive of fish habitat. To maintain fish habitat, lakes must seasonally recharge water volumes borrowed during the winter season and lost naturally through evaporation. Fish Habitat and Temporary Water Use permits stipulate the water withdrawal quantities for each water year. Additionally, these permits specify the form of water that may be borrowed from each lake – liquid only, specific quantities of liquid and ice, or a total of both without designation of individual quantities. Ice aggregate removal is permitted over naturally grounded portions of the lake 4 feet deep or less. A water year is defined as one year beginning and ending with spring breakup (June through May). Actual withdrawal quantities are reported by CPAI per water year; these numbers are compared to the maximum water withdrawal allowed. If two permits are issued for one lake, the maximum water withdrawal by CPAI is less than or equal to the lesser allowable quantity.

Lakes M9602, M9603, M9605, and Nanuq Lake were permitted for specific borrow quantities of liquid and ice. The remaining fivelakes were permitted for a total quantity of liquid and/or ice without designation of individual quantities. Lakes M9602 and M9605 were used as both liquid and ice sources. Nanuq Lake was used as an ice source only. The remaining lakes were used as liquid sources. A total water quantity only was reported for Lake M9603.

Table 2.1 summarizes the permits regulating water use, purpose, and permitted versus actual withdrawal volumes by form at the ten water withdrawal lakes. The permitted and actual withdrawal volumes are based on third and fourth quarter 2014 and first and second quarter 2015 water use reports (CPAI 2014a, 2014b, 2015a, and 2015b).

Table 2.1: Summary of Permitted and Actual Withdrawal Volumes

2015 Alpine Area Lakes Recharge Study										
Lake	**Permit**		**Permit Expiration**	**Water Use Purpose**	**Permitted Volume[1]**			**Withdrawal Volume[3]**		
	ADF&G	**ADNR**			**Liquid**	**Ice**	**Total Water[2]**	**Liquid**	**Ice**	**Total Water**
					(Mgal)					
B8530	FG03-III-0383	TWUP A2013-145	12/15/2018	Ice Road/Pad	:::	:::	32.00	13.45	0.00	13.45
B8531/L9326	FG03-III-0382	TWUP A2008-180/TWUP A2013-145	12/16/2013 12/15/2018	Ice Road/Pad	:::	:::	6.59	4.23	0.00	4.23
L9323	FH03-III-0380	TWUP A2008-181/TWUP A2013-146	12/15/2018	Ice Road/Pad	:::	:::	8.51	7.62	0.00	7.62
L9324	FG03-III-0381	TWUP A2013-146	12/15/2018	Ice Road/Pad	:::	:::	1.65	0.39	0.00	0.39
M9602	FH05-III-0327	TWUP A2010-119	12/2/2015	Ice Road/Pad	0.78	30.63	31.41	0.66	4.70	5.36
M9603	FH05-III-0338	TWUP A2011-154	12/8/2016	Ice Road/Pad	8.72	14.53	23.25	:::	:::	8.32
M9605	FH05-III-0328	TWUP A2010-119	12/2/2015	Ice Road/Pad	8.52	13.62	22.14	4.65	3.41	8.06
M9607	FH03-III-0384	TWUP A2008-180/TWUP A2013-145	12/15/2018	Ice Road/Pad	:::	:::	5.47	2.16	0.00	2.16
Nanuq Lake	FH06-III-0150	TWUP A2011-51	12/11/2016	Ice Road/Pad	0.13	34.55	34.68	0.00	12.09	12.09
Notes	1 Per water year. Some permits do not stipulate specific liquid/ice volumes. 2 Total permitted withdrawal may be either ice, water, or a combination 3 Total withdrawal volume between June 1, 2014 and May 31, 2015. Specific liquid/ice withdrawal volumes not available when not stipulated in permit. ::: n/a									

3.0 STUDY METHODS

3.1 CATCHMENT BASIN AREA DELINEATION (DETAILED STUDY LAKE)

The catchment basin for Lake M9602, including lake and tundra areas, was delineated using satellite imagery, topographic maps, and visual assessment of the local topography prior to the field study. Topographic data for this area is limited and as a result, the catchment basin delineation for Lake M9602 is subjective. In addition to limited topography, seasonal data about nearby water bodies such as wetlands and ponds with potential to contribute to recharge, is lacking. These areas have additional capacity and were not included within the catchment basin delineation.

3.2 WATER SURFACE ELEVATIONS SURVEYS

Changes in WSE were measured at each study lake except Nanuq Lake. WSE monitoring was conducted at eight study lakes during 2015 pre-breakup, breakup, and post-breakup.

Photo 3.1: Staff gage at Lake L9324, pre breakup; May 3, 2015

Gages were rehabilitated for 2015. A staff gage assembly consists of a metal gage faceplate mounted on a two-by-four timber. The timber is attached with U-bolts to a 1.5-inch wide angle iron driven approximately 2 feet into the ground. All gages installed are indirect-read staff gages; meaning, the values read on the gage faceplate do not directly correspond to a known elevation. Photo 3.1 shows the gage setup at Lake L9324. A tabulated list of gage and temporary benchmark (TBM) locations is included in Appendix A.

Standard differential leveling techniques were used to establish staff gage elevations with local TBMs. A single new TBM was installed when a preexisting TBM was farther than ¼ mile from the study lake. New TBMs were all given an arbitrary elevation of 100.00 feet. An arbitrary elevation of 100.00 feet is typically used to avoid confusion with actual British Petroleum Mean Sea Level (BPMSL) elevations, which are much lower in the surrounding terrain.

Elevations of the staff gages at lakes L9323 and L9324 were based on preexisting TBMs tied to BPMSL elevations. Elevations of gages at the remaining five lakes were based on TBMs established in 2011 and 2012 with arbitrary elevations of 100.00 feet. WSE recorded at staff gages tied to arbitrary elevations are relative to each other and used to illustrate a change in WSE for the specific lake; they are not tied to BPMSL elevations.

Pre-breakup WSE was located at all lakes, except lakes M9602 and M9605, by using an electric drill to auger a 2-inch sampling hole in the ice covering the lake. Because ice was grounded in the sample area at lakes M9602 and M9605, top of ice elevations were substituted for pre-breakup WSE for analysis. Top of ice elevations vary from actual WSE depending on ice thickness and density, snow cover, and location; they are used as a conservative approximation (Michael Baker 2002). Ice surface elevation was determined through differential leveling. WSE was calculated by subtracting measured freeboard from the ice surface elevation at the sample location. Freeboard was measured using a pocket rod.

During site visits, the observed water level on the gage faceplates was recorded. When accessible, chalk was applied to the angle iron during each site visit to capture high water marks (HWM). Subsequent HWMs were recorded during site visits when floodwaters removed the chalk. In some cases, HWMs were not evident.

When water levels were not sufficiently high to be recorded on the staff gage face plates, standard differential leveling techniques were used to measure WSE. The horizontal position of each staff gage and TBM was recorded using a handheld global positioning system (GPS) in North American Datum of 1983 (NAD83). Gage readings associated with local ponding were recorded, but were not used to generate the lake recharge hydrograph.

3.3 SNOW WATER EQUIVALENT SURVEY (DETAILED STUDY LAKE)

3.3.1 DOUBLE SAMPLING METHOD

A double sampling method snow survey was conducted on Lake M9602, as recommended in industry papers and the 2007 CRD lakes recharge report (Michael Baker 2007). Prior to fieldwork, snow sampling points were identified along predetermined transects.

Each snow survey transect was positioned to align across or perpendicular to snow features such as drifts and local topography (Woo 1997). Measurements were recorded by measuring snow depth and mass at a smaller number of sample points, and by measuring only snow depth at a larger number of sample points.

For this survey, terrain was identified in the field as either lake (based on the presence of ice) or tundra (based on the presence of vegetation) for each sample collected. Terrain was verified using existing maps in geographic information system (GIS) format.

3.3.2 SAMPLING TRANSECTS AND POINTS

Aerial imagery and topographic contours were used to delineate the lake catchment basin. Transects were aligned radiating outwards from the estimated center of the lake to the edge of the drainage basin to account for variability of drifted snow across the ice and at and over banks. Additional transects were selected to capture irregularities, including basin arms or other departures from a classic bowl shape.

Sampling points were then established along transects at a uniform spacing of approximately 200 feet. The total number of sampling points was dependent on the length of each transect and the anticipated variability in snow within the terrain unit. By placing a sampling point at the intersection of transects and spacing sampling points at a uniform distance along transects, random sampling was accomplished. Each terrain type covered by a single transect included at least one snow mass sampling point. Sampling points were stored in two GPS units.

At Lake M9602, the snow layer had been disturbed. Snow clearing to access surface ice had created berms and snow drifts had formed. Additional snow had re-covered previously cleared lake surfaces, though not necessarily to the median natural depth. Snowmelt contribution from the berms was considered an additional lake recharge source. To estimate berm quantities, snow mass and depths were sampled along representative transects and berm areas were found by recording circumnavigation tracks in a GPS unit. Berm snowmelt contribution calculations were performed assuming natural median snow depth on the cleared areas was reached at the time of investigation.

3.3.3 Snow Density Sampling

Density measurements were conducted according to procedures outlined in *National Resource Conservation Service (NRCS) Snow Survey Sampling Guide* (NRCS 2006) and *British of Columbia Snow Survey Manual* (BC Ministry of Environment 1981), using a $1^5/_8$-inch ID Model 3600 Mt. Rose (Standard Federal) snow sampling tube and scale (Photo 3.2). This sampler was chosen based on its common acceptance and use by the NRCS. Snow depth alone was sampled using a graduated snow pole.

Photo 3.2: Collecting core using Mt. Rose Snow Sampler (Model 3600); April 25, 2015

If shallow snow was encountered having a SWE of less than 2 inches, estimated by having a depth of less than twelve inches, bulk sampling was conducted (NRCS 2006). Bulk sampling is a grouping of multiple samples collected in the immediate area of the sample point, recording sample depth of each sample and averaging, then weighing pooled core samples. Bulk samples are then divided by the number of samples collected to determine an average weight for the sample location (Michael Baker 2007).

3.3.4 Snow Water Equivalent Lake Recharge Methods

The methods and equations used in this report for calculating SWE and the potential recharge contribution are the same used in the Michael Baker 2007 report. Terrain-specific average snow depths were collected by field crews using the graduated snow pole and snow sampler. To calculate the terrain specific snow depth for each lake catchment, Equation 1 was used.

Equation 1 - Terrain Specific Snow Depth of Catchment

$$d_i = \left[\sum_{l=1}^{p} d_l \right] \Big/ p$$

$d_i = Terrain\ Specific\ Snow\ Depth\ of\ Catchment\ (in)$
$l = Individual\ Sample$
$p = Total\ Number\ of\ Terrain\ Specific\ Depth\ Samples$
$d_l = Measured\ Snow\ Depth\ (in)$

Terrain specific average snow densities were then calculated using the snow sampler's cross sectional area, core depth, and the weights of the snow samples using Equation 2.

Equation 2 – Terrain Specific Snow Density of Catchment

$$\rho_i = \left[\sum_{k=1}^{m} \left(\frac{M_{snow}}{A_{core} d_{snow}} \right)_k \right] \Big/ m$$

$\rho_i = Terrain\ Specific\ Snow\ Density\ of\ Catchment\ (lb/in^3)$
$k = Individual\ Sample$
$m = Total\ Number\ of\ Terrain\ Specific\ Core\ Samples$
$M_{snow} = Measured\ Mass\ of\ Snow\ Sample\ (lb)$
$A_{core} = Area\ of\ Sampling\ Tube\ (in^2)$
$d_{snow} = Depth\ of\ Snow\ Sample\ (in)$

Using the terrain specific snow densities, terrain specific SWE were then calculated using Equation 3.

Equation 3 – Terrain Specific SWE of Catchment

$$SWE_i = \frac{(\rho_i d_i)}{\rho_w}$$

$SWE_i = Terrain\ Specific\ Snow\ Water\ Equivalent\ of\ Catchment\ (in)$
$\rho_i = Terrain\ Specific\ Snow\ Density\ (lb/in^3)$
$d_i = Terrain\ Specific\ Snow\ Depth\ (in)$
$\rho_w = Density\ of\ Fresh\ Water\ (lb/in^3)$

An area weighted SWE was calculated for the catchment basins using Equation 4. This calculation is based on Woo (1997) and Rovansek, Kane, and Hinzman (1993).

Equation 4 – Catchment Specific, Area Weighted SWE

$$SWE_C = \frac{\left(\sum_{i=1}^{n} \rho_i d_i A_i \Big/ \sum_{i=1}^{n} A_i \right)}{\rho_w}$$

$SWE_C = Catchment\ Specific\ Snow\ Water\ Equivalent\ (in)$
$i = Terrain$
$n = Total\ Terrains\ Sampled\ in\ Catchment$
$\rho_i = Terrain\ Specific\ Snow\ Density\ (lb/in^3)$
$d_i = Terrain\ Specific\ Snow\ Depth\ (in)$
$A_i = Terrain\ Specific\ Area\ (ft^2)$
$\rho_w = Density\ of\ Fresh\ Water\ (lb/in^3)$

Total calculated potential snowmelt contribution (V_P) and estimated recharge (V_O) were calculated for each lake using Equation 5 and Equation 6. The 2007 delta-wide runoff coefficient of 0.67 was applied to snowmelt contributed from tundra areas to account for reduced tundra contribution.

Equation 5 –Total Calculated Potential Snowmelt Contribution, per Lake

$$V_P = C_1 \left(SWE_l\ A_l + 0.67\ SWE_t\ A_t \right)$$

$V_P = Total\ Calculated\ Potential\ Snowmelt\ Contribution\ (gal)$
$C_1 = Gallons\ of\ Water\ /\ ft^3\ /\ in$
$SWE_l = Lake\ Specific\ Average\ Snow\ Water\ Equivalent\ (in)$
$SWE_t = Tundra\ Specific\ Average\ Snow\ Water\ Equivalent\ (in)$
$A_l = Lake\ Specific\ Area\ (ft^2)$
$A_t = Tundra\ Specific\ Area\ (ft^2)$
$0.67 = 2007\ Delta - wide\ Runoff\ Coefficient$

Equation 6 – Estimated Recharge, per Lake

$$V_O = C_2 A_l WSE_\Delta$$

$V_O = Estimated\ Recharge\ (gal)$
$C_2 = Gallons\ of\ Water / ft^3$
$A_l = Lake\ Specific\ Area\ (ft^2)$
$WSE_\Delta = Difference\ Between\ Pre-Breakup\ and\ Peak\ WSE\ (ft)$

3.4 LAKE RECHARGE OBSERVATIONS

Each lake was monitored throughout breakup by WSE measurement and/or visual observations. Monitoring records include direct WSE measurements, photographs, and field notes.

Hydrographs showing change in WSE over time were the primary method used to assess lake recharge. Recession of floodwaters is evident in a negative slope in the graph after peak stage, this indicates a lake has recharged over bankfull conditions and is discharging excess water by means of overbank flow.

Visual observations of overland flooding and outflow conditions were used to support hydrograph evidence of lake recharge, or, where applicable, as primary evidence of recharge for lakes where hydrograph data isn’t available. Observation of excess water discharging from a lake is an indication of recharge over bankfull conditions. Aerial photographs were taken from a helicopter using a GPS camera. Photos were taken from various perspectives to capture the extent of snow melt, flow pattern, potential lake water recharge sources, and hydraulic connectivity with other water bodies. Written documentation of visual observations combined with time-stamped GPS photos support identification of each lake’s recharge mechanism(s), extent, and timeline.

3.5 2014/2015 ICE ROAD CONTRIBUTIONS

As-built drawings for the 2014/2015 ice road construction season were used to estimate the volume of ice road melt water recharge that contributed to the Lake M9602 catchment basin. Ice road contributions to local hydrology were determined using an estimated value of one million gallons of water per mile of ice road (ASCG 2005).

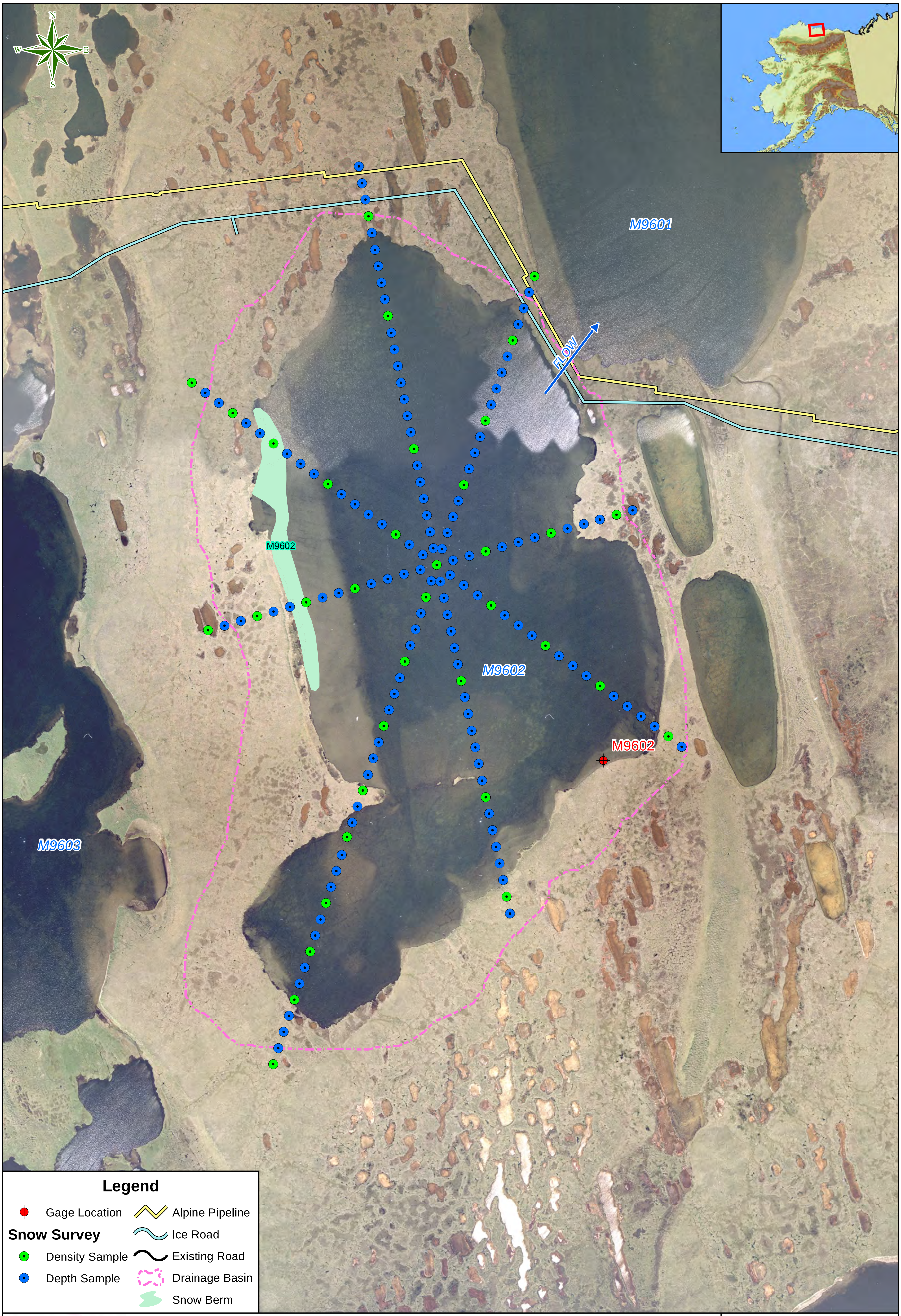
4.0 STUDY RESULTS

4.1 DETAILED STUDY LAKE: LAKE M9602

The catchment basin delineation, snow surveys, SWE calculation results, WSE observations, lake recharge observations, and historical comparison for the detailed study lake, Lake M9602, is presented in this section.

4.1.1 CATCHMENT BASIN DELINEATION

Catchment basin delineations for Lake M9602 are presented in Figure 4.1. The lake area was taken from bathymetry reports (Appendix B) and GIS data provided by CPAI.



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M9602

DRAINAGE BASIN DELINEATION

& SNOW SURVEY LOCATIONS

FIGURE: 4.1

(SHEET 1 of 1)

4.1.2 SNOW SURVEY AND SNOW WATER EQUIVALENT

A snow survey was conducted prior to CRD spring breakup setup at Lake M9602 on April 24, 2015.

Average snow depths on the lake surface and the tundra in the Lake M9602 catchment basin were both greater than in 2014 (Michael Baker 2014). Compared to 2014, the average density of the snow cover on both the lake and the tundra was lowerfor 2015. The 2015 average SWE for the lake was higher than in 2014, but the average SWE for the tundra was lower. However, the 2015 Lake M9602 catchment basin weighted SWE was greater than in 2014.

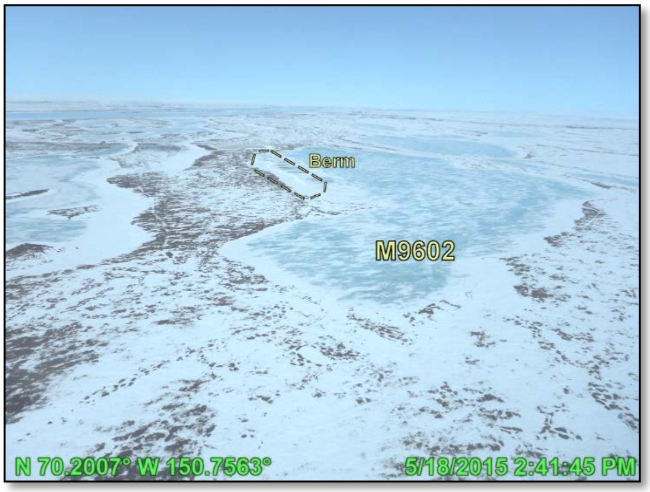


Photo 4.1: Berm location at Lake M9602, looking north; May 18, 2015

A snow berm was present on the east side of Lake M9602 and is shown in Photo 4.1. The contribution of snowmelt from the berm was determined by estimating the berm volume and historical berm density data (Michael Baker 2014). The snow survey summary for Lake M9602 is presented in Table 4.1. Comprehensive snow survey data sheets are included in Appendix C.

Table 4.1: Lake M9602 Snow Survey Summary

Lake	Study Year	Area[1] (ft^2)		Average Snow Depth (in)		Average Density (lb/in)		Average SWE (in)		Catchment Basin Weighted SWE[2] (in)
		Lake	Tundra	Lake	Tundra	Lake	Tundra	Lake	Tundra	
M9602	**2015**	**28,071,377**	**14,571,032**	**11.2**	**18.2**	**0.010**	**0.009**	**3.24**	**4.31**	**3.60**
M9602	2014	28,426,616	14,677,378	8.3	15.8	0.011	0.010	2.55	4.45	3.19
Notes:		1. Calculated from delineated drainage basins determined from aerial imagery minus the area encompassed by berms 2. Specific to feature per lake and tundra contribution based on respective areas.								

4.1.3 WATER SURFACE ELEVATION AND OBSERVATIONS

WSE was measured during and after spring breakup at Lake M9602. Multiple attempts to measure pre-breakup WSE through holes drilled into the lake ice were unsuccessful; only grounded ice was encountered at all locations investigated. Surveyed top of ice elevations were averagedand used as a conservative approximation for analysis purposes.

Melting of snow and ice at Lake M9602 generally occurs more slowly than at other lakes in the study area because it is located outside the flood boundaries of the CRD and therefore receives little or no overland flow. During breakup monitoring, with much of the lake ice still intact, no flow was observed into or out of Lake M9602.

By the middle of May, much of the snow in the drainage basin at Lake M9602 had melted. On May 17, warm temperatures accelerated the melting process. Peak flooding in the CRD occurred on the night of May 21 and during this time, no associated overland flow was observed entering Lake M9602 (Photo 4.2). Final WSE was measured on June 29 with all snow and ice in the catchment basins melted. On June 29, outflow was observed from Lake M9602 into Lake M9601 on the northeast side of the lake (Photo 4.3). WSE data and graphic representations for Lake M9602 are presented in Table 4.2.

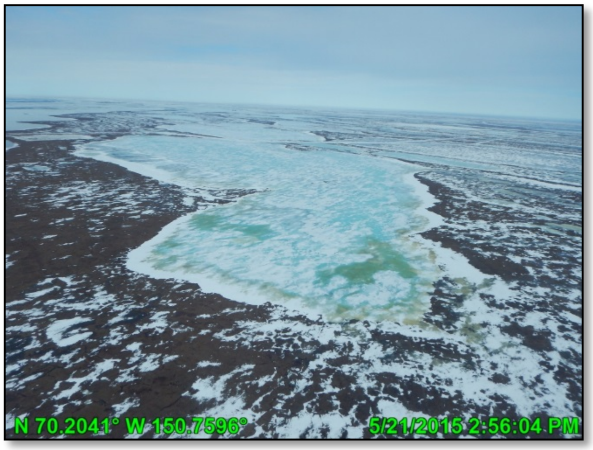


Photo 4.2: No overland flow observed entering Lake M9602, looking north; May 21, 2015

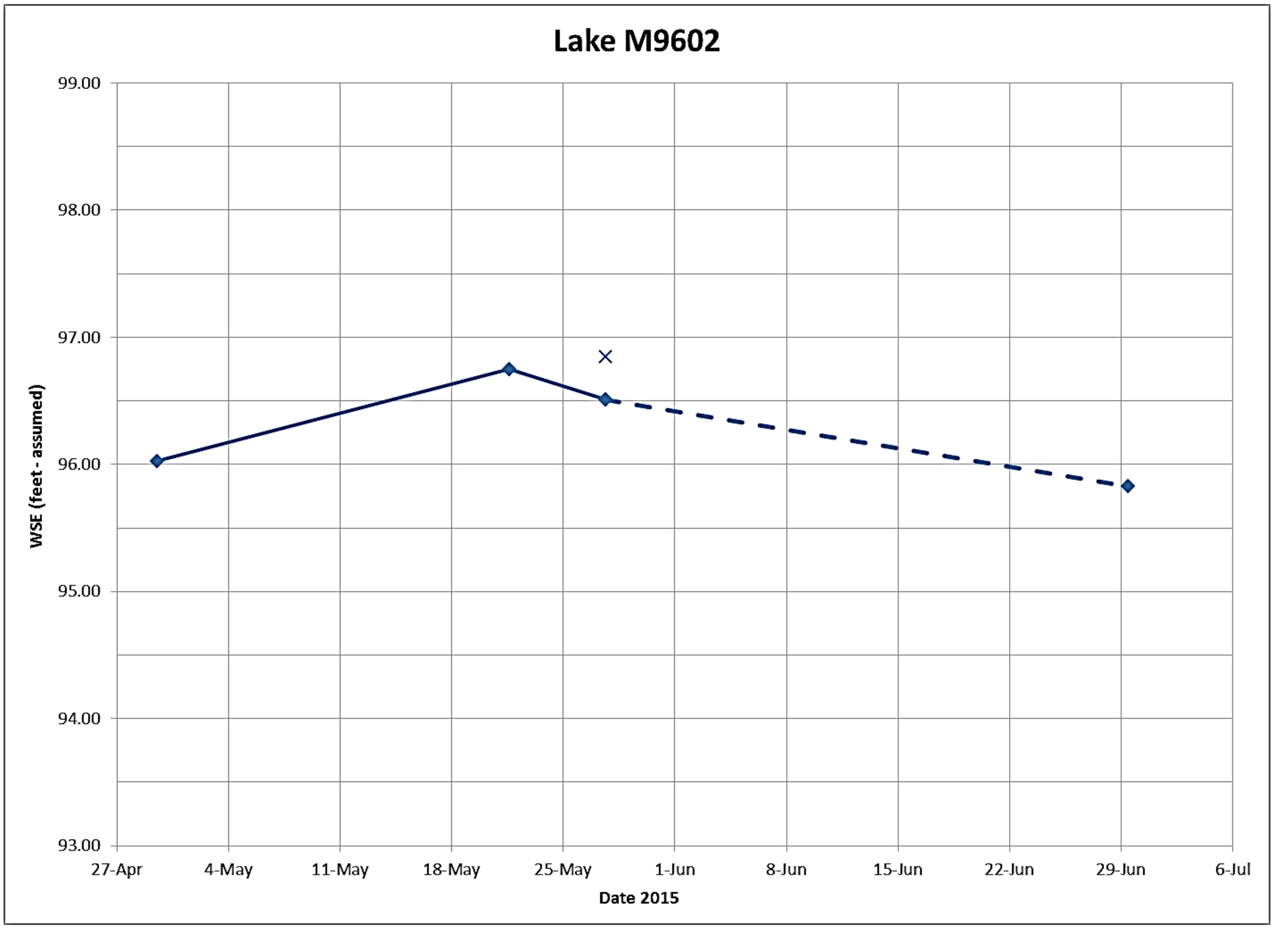
Photo 4.3: Outflow observed from Lake M9602 into Lake M9601, looking east; June 29, 2015

Table 4.2: WSE Data for Lake M9602

Date & Time	WSE (feet - assumed)	Observations
4/29/15 12:00 PM	*96.03*	*Grounded ice observed; elevation represents top of ice elevation*
5/21/15 3:00 PM	96.75	
5/27/15 3:32 PM	96.51	HWM at 96.85 feet
6/29/15 10:15 AM	95.83	Outflow observed on northeast side of lake

Notes:

1. Elevations are assumed based on TBM M9602-X at 100.00 feet, installed by Michael Baker in May 2011
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct
3. HWM indicated on chart by "X." Timing of HWM is when it was recorded, not when high water occurred.



4.1.4 LAKE RECHARGE

During the 2015 monitoring season, Lake M9602 recharged over bankfull conditions as indicated by a rise and recession of WSE as presented in the hydrograph (Table 4.2). This is verified by observations of channelized outflow to Lake M9601 (Photo 4.4)..

Photo 4.4: Channelized outflow from Lake M9602 into Lake M9601, looking north; June 29, 2015

Potential snowmelt contribution to recharge was calculated based on lake and tundra areas in the catchment basin and SWE as obtained from the snow survey that took place on April 24. Contribution from the berm was also included.

Estimated recharge volume was determined by multiplying the surface area of the lake by the difference between observed HWM elevation and the pre-breakup top of ice elevation. Using the top of ice elevation provides a conservative estimate of recharge volume as the actual WSE is likely lower and would result in a larger difference between peak WSE and initial WSE. The values are presented with calculated potential snowmelt contributions and permitted and actual water use quantities for Lake M9602 in Table 4.3.

Table 4.3: Lake M9602 Spring Breakup Recharge Summary

Lake	Calculated Potential Snowmelt Contribution[1]				Estimated Recharge[2]	Permitted Annual Water Use[3]	Actual Water Use[4]
	Lake	Tundra	Ice Road	Total			
	(mgal)						
M9602	56.4	26.7	0.3	86.1	154.4	31.41	5.36
M9602 Berm	2.7	0.0	-				
Notes:	1. Using the 2007 delta-wide runoff coefficient (0.67) and 2015 SWE. 2. Area of lake surface multiplied by the difference between peak WSE and the pre-breakup top of ice elevation. As a result, the estimated recharge quantities are likely lower than actual recharge. 3. Per AK DNR Fish Habitat Permit FH05-III-0327 Amendment #2 4. Total combined liquid and ice as water equivalent per CPAI water use report.						

4.1.5 HISTORICAL RESULTS

Historical potential snowmelt contributions to Lake M9602 are shown in Table 4.4. The catchment basin of Lake M9602 contained higher overall SWE than in 2014. The drainage basin delineation was refined in 2011 (Michael Baker 2011); this delineation was used in the succeeding years, including 2015.

Table 4.4: Comparison of Historical Results – Lake M9602

Comparison of Historical Calculated Potential Snowmelt						
Lake	**2010[1]**	**2011**	**2012**	**2013**	**2014**	**2015**
	(Mgal)					
M9602	48.3	101.1	77.5	75.1	75.7	86.1
Note:	1. Determined based on empirical data					

4.2 GENERAL STUDY LAKES

The lake recharge results and WSE data for the General Study Lakes are presented in this section.

4.2.1 WATER SURFACE ELEVATION

WSE was measured before, during, and after spring breakup at lakes B8530, B8531/L9326, L9323, L9324, M9603, M9605, and M9607. Only aerial observations were performed at Nanuq Lake. Throughout the study period, photos were taken to document changes at the lakes (Appendix D).

In general, WSE at the General Study Lakes increased during the breakup flood event and decreased because of outflow as water levels subsided. During the 2015 monitoring season, many lakes in the CRD received recharge flow as a result of extensive overland flooding. The WSE data and hydrographs are presented in Table 4.5 through Table 4.11.

Table 4.5: WSE Data for Lake B8530

Date & Time	WSE (feet - assumed)	Observations
5/1/15 11:30 AM	95.15	Ice elevation at 95.80 feet, freeboard at 0.65 feet
5/27/15 4:12 PM	95.40	HWM at 96.29 feet
6/29/15 11:10 AM	95.15	No outflow observed

Notes:

1. Elevations are assumed based on TBM B8530-X at 100.00 feet, installed by Michael Baker in May 2012
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct
3. HWM indicated on chart by "X." Timing of HWM is when it was recorded, not when high water occurred.

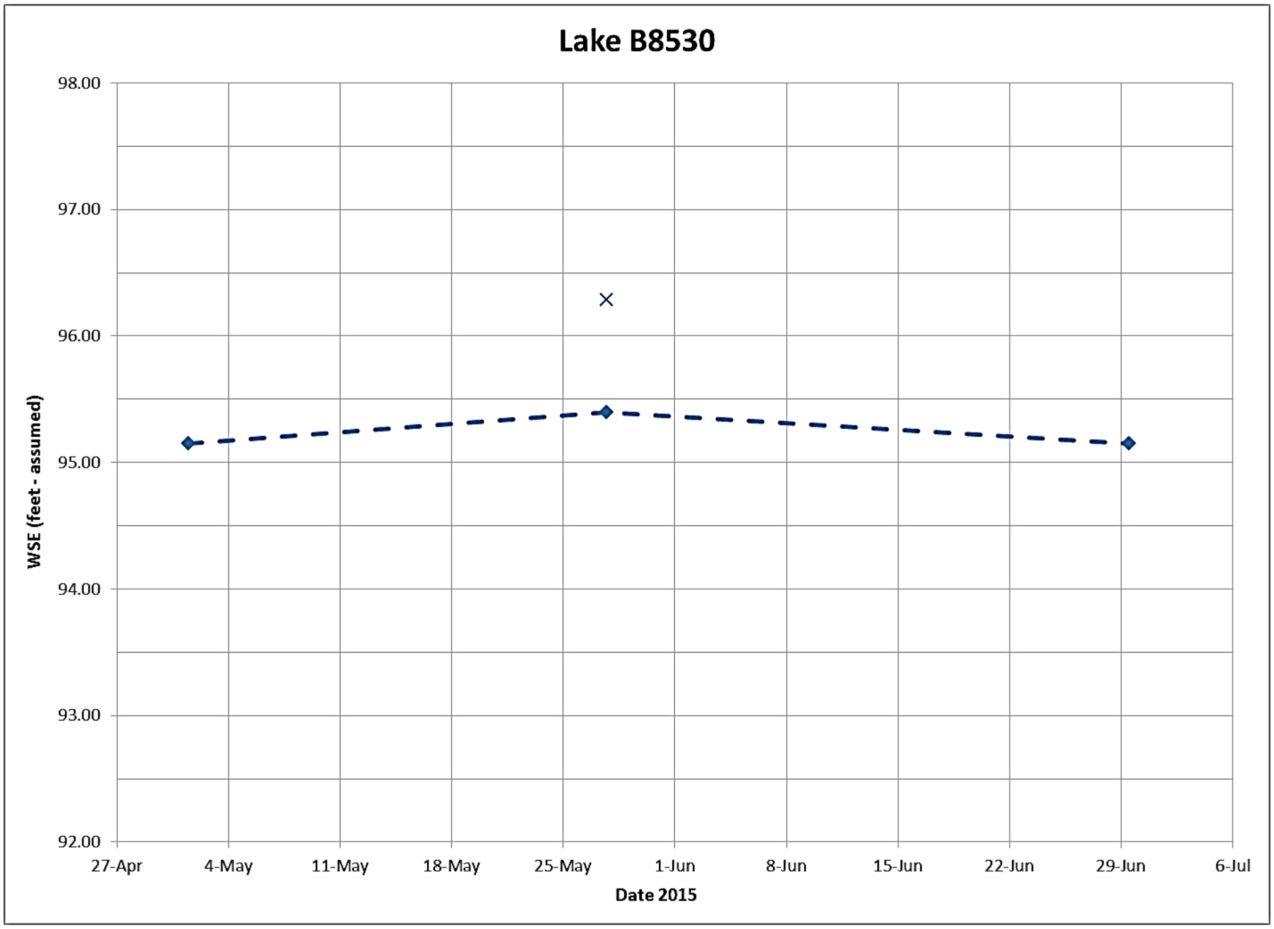


Table 4.6: WSE Data for Lake B8531/L9326

Date & Time	WSE (feet - assumed)	Observations
5/1/15 12:20 PM	90.86	Ice elevation at 91.10 feet, freeboard at 0.24 feet
5/27/15 4:21 PM	92.73	No HWM found; gage was likely overtopped
6/29/15 11:30 AM	90.84	Outflow through ponded channels into Toolbox Creek

Notes:

1. Elevations are assumed based on TBM B8531/L9326-X at 100.00 feet, installed by Michael Baker in May 2011
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct

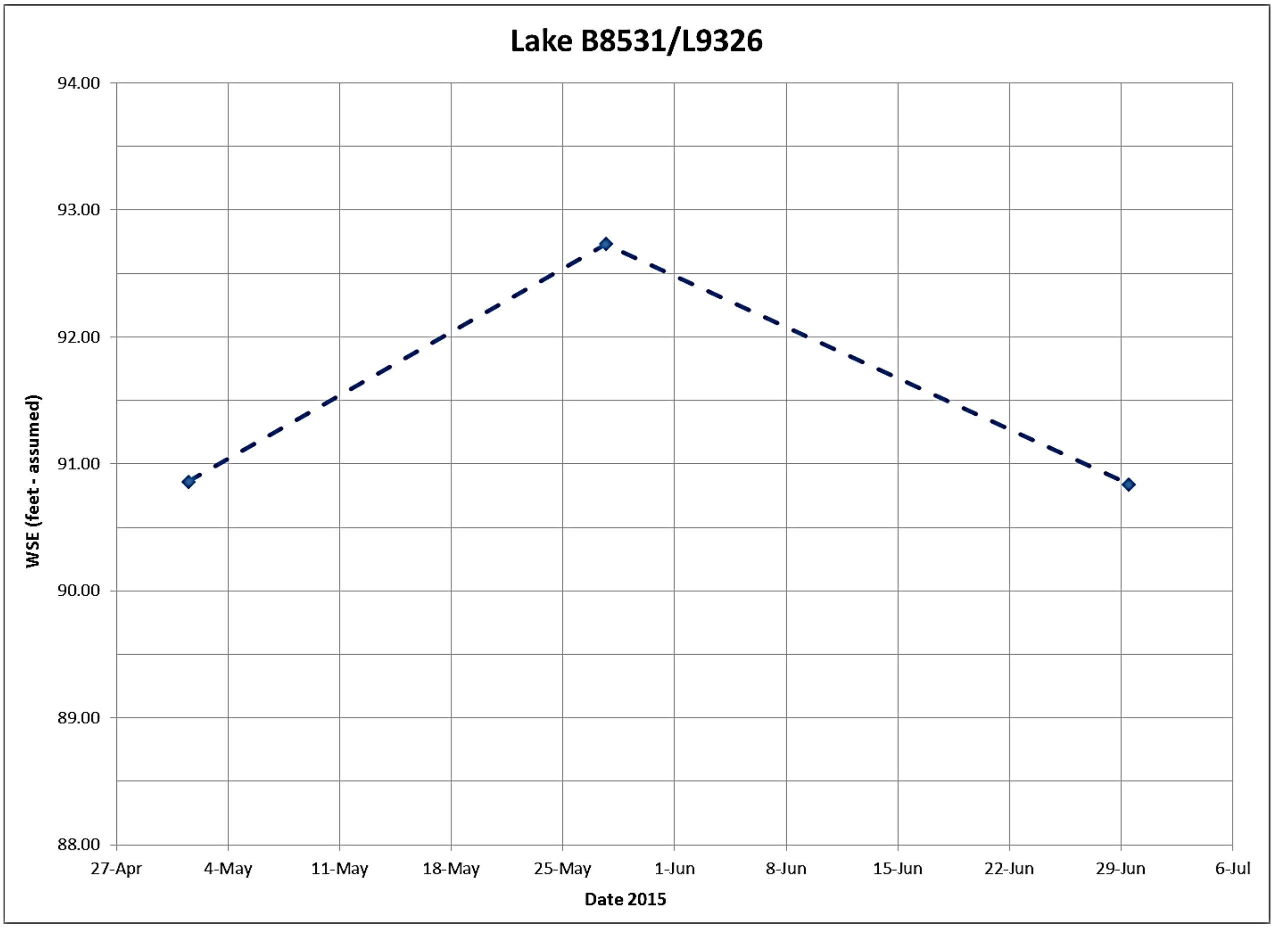


Table 4.7: WSE Data for Lake L9323

Date & Time	WSE (feet - BPMSL)	Observations
5/3/15 3:15 PM	7.95	Ice elevation at 8.32 feet; freeboard at 0.37 feet
5/22/15 2:20 AM	15.43	Gage 16 HWM at culvert battery on north side of lake[4]
6/28/15 4:45 PM	8.07	No outflow observed

Notes:

1. Elevations are based on NANUQ 4 at 12.579 feet BPMSL, surveyed by LCMF in July 2014
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct
3. High water mark indicated on chart by "X." Timing of HWM is when it was recorded, not when high water occurred.
4. Unsafe to wade to L9323 gage; gage 16 was hydraulically connected to Lake L9323 at this WSE.

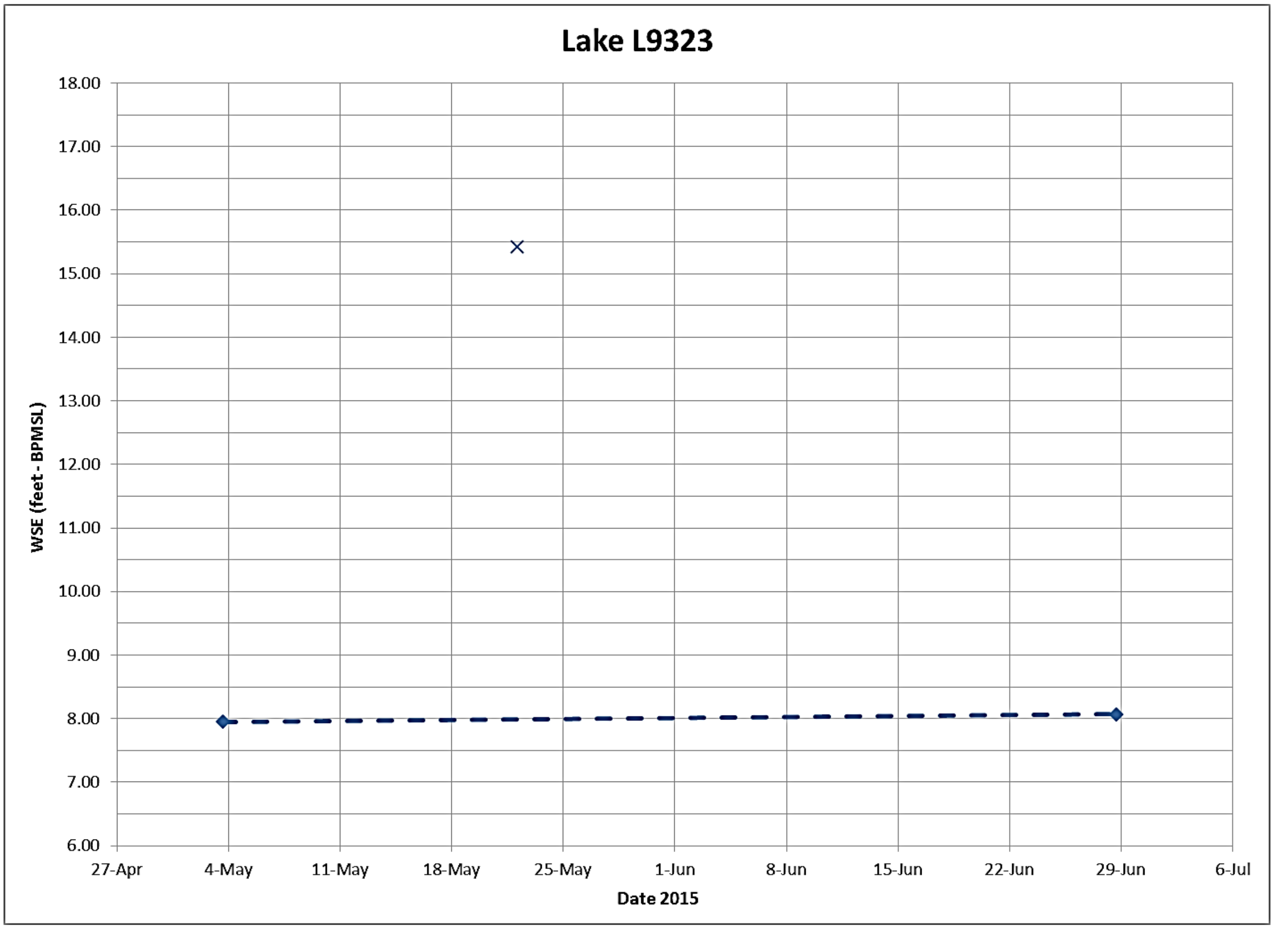


Table 4.8: WSE Data for Lake L9324

Date & Time	WSE (feet - BPMSL)	Observations
5/3/15 5:00 PM	3.90	Ice elevation at 4.60 feet, freeboard at 0.70 feet
5/20/15 4:30 PM	10.43	
5/20/15 4:30 PM	10.47	
5/21/15 12:45 PM	14.24	Gages overtopped - survey to lathe placed nearby at edge of water
5/23/15 2:15 PM	11.53	
5/28/15 6:00 PM	5.99	
6/28/15 5:05 PM	4.70	Outflow south into paleolake

Notes:

1. Elevations are based Monument NANUQ 5 at 17.461 feet BPMSL, surveyed by LCMF in May 2011
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct
3. A HWM not recorded at this location because all gages were overtopped

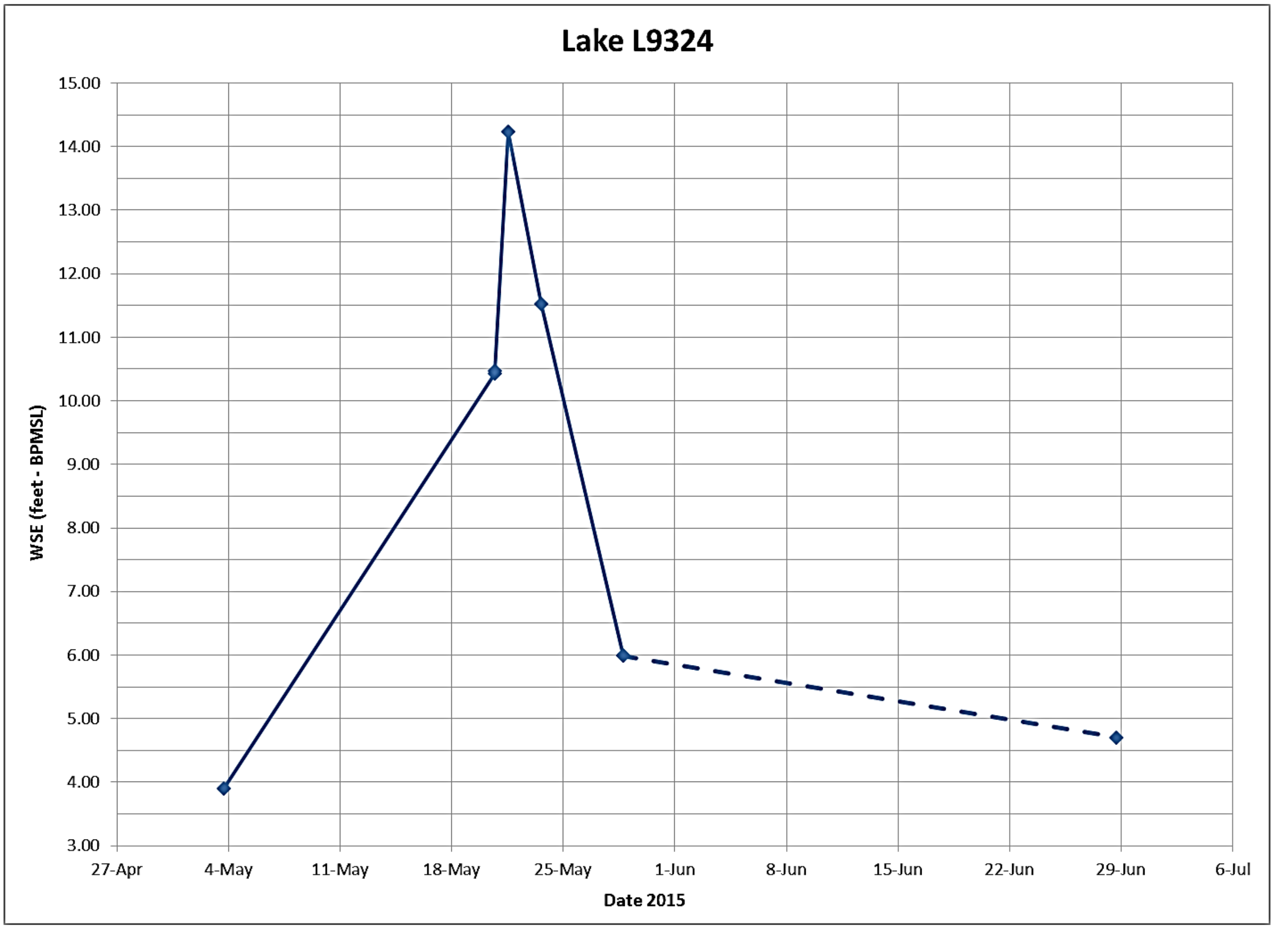


Table 4.9: WSE Data for Lake M9603

Date & Time	WSE (feet - assumed)	Observations
4/29/15 12:45 PM	96.41	Ice elevation at 96.73 feet; freeboard to WSE 0.33 feet
5/27/15 3:19 PM	98.75	
6/29/15 10:55 AM	96.63	Outflow observed on north side of lake under Alpine Pipeline

Notes:

1. Elevations are assumed based on TBM M9603-X at 100.00 feet, installed by Michael Baker in May 2011
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct

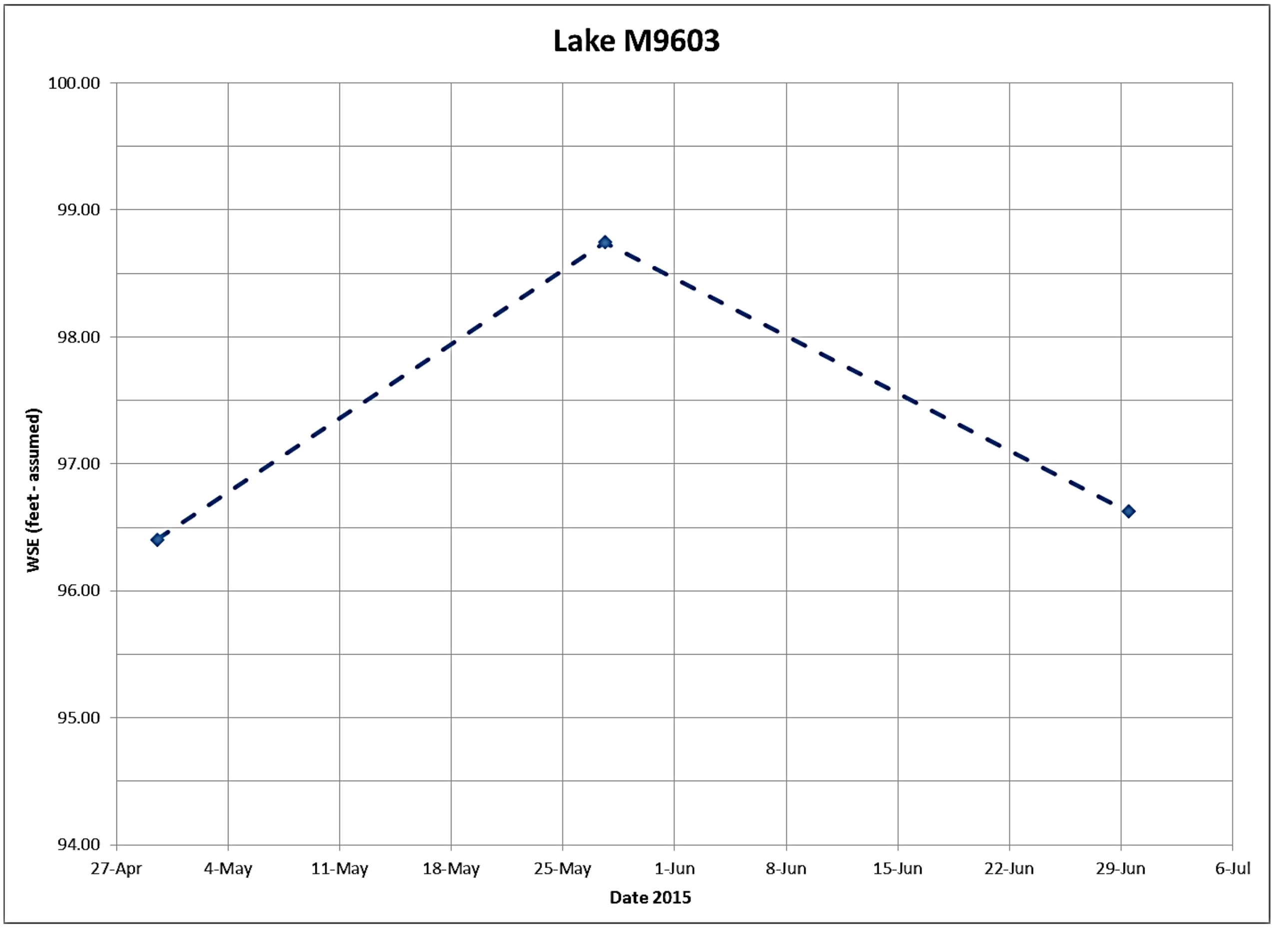


Table 4.10: WSE Data for Lake M9605

Date & Time	WSE (feet - assumed)	Observations
5/2/15 1:50 PM	*97.18*	*Grounded ice observed; elevation represents top of ice elevation*
5/21/15 3:08 PM	97.82	
5/27/15 3:43 PM	97.96	HWM at 98.14 feet
6/29/15 9:45 AM	96.99	Outflow observed on north side of lake under Alpine Pipeline

Notes:

1. Elevations are assumed based on TBM M9605-X at 100.00 feet, installed by Michael Baker in May 2011
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct
3. HWM indicated on chart by "X." Timing of HWM is when it was recorded, not when high water occurred.

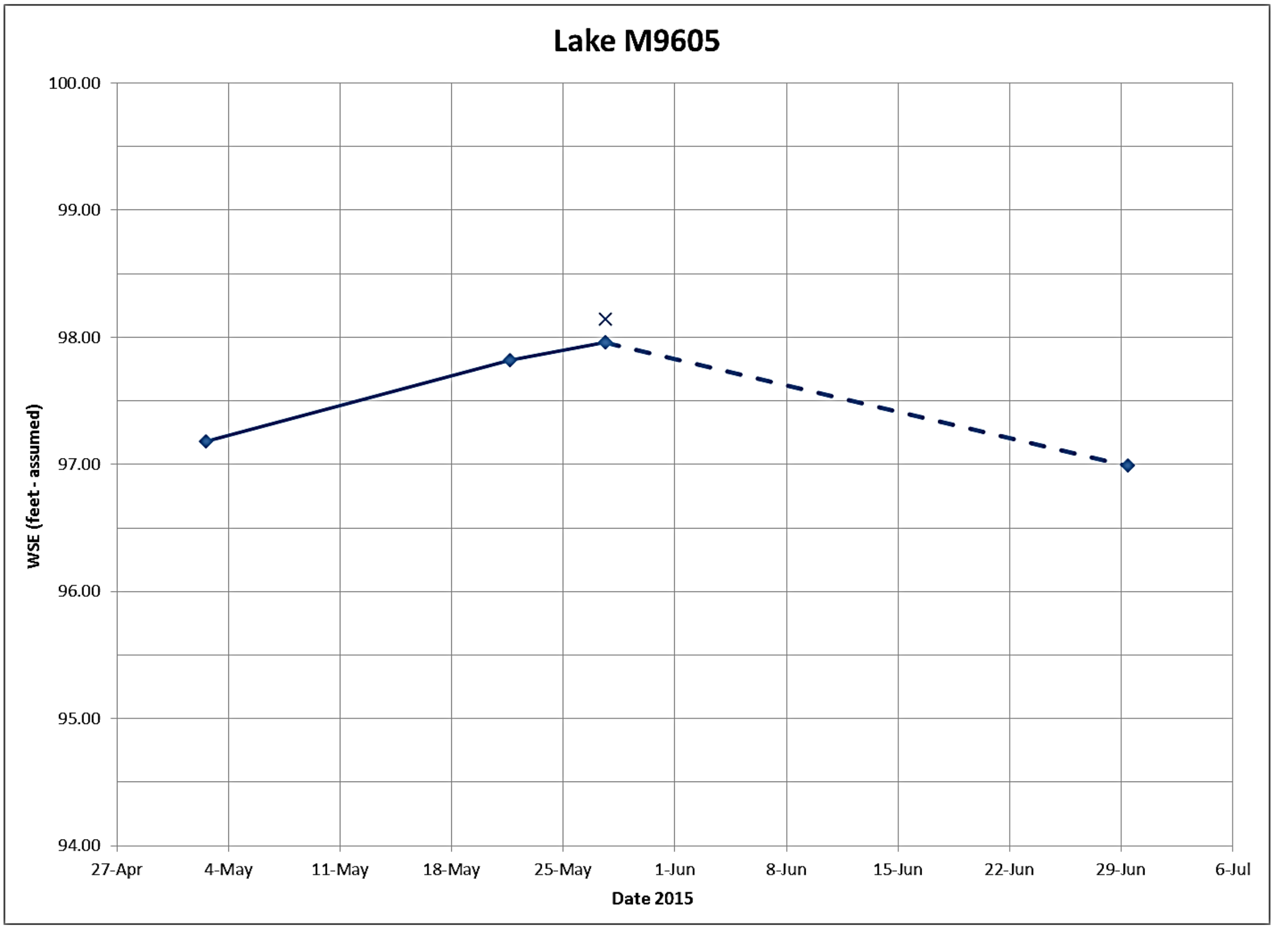
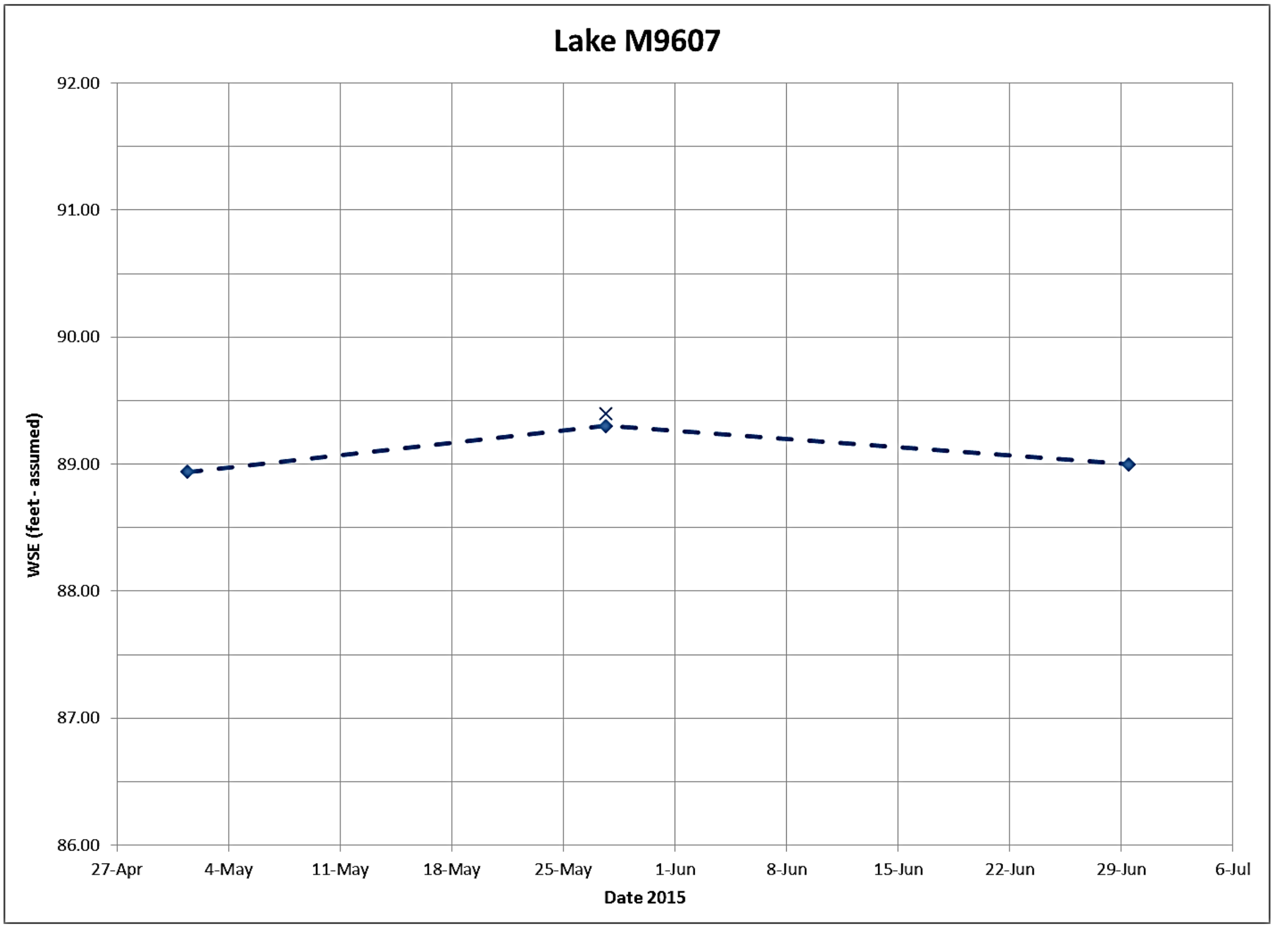


Table 4.11: WSE Data for Lake M9607

Date & Time	WSE (feet - assumed)	Observations
5/1/15 10:20 AM	88.94	Ice elevation at 89.50 feet, freeboard at 0.56 feet
5/27/15 4:05 PM	89.30	HWM at 89.40 feet
6/29/15 11:05 AM	89.00	No outflow observed

Notes:

1. Elevations are assumed based on TBM M9607-X at 100.00 feet, installed by Michael Baker in May 2011
2. Dashed line indicates a greater time interval between observations and that the change in WSE is not likely direct
3. HWM indicated on chart by "X." Timing of HWM is when it was recorded, not when high water occurred.



4.2.2 LAKE RECHARGE

Most General Study Lakes were observed to fully recharge over bankfull conditions during the 2015 monitoring season. This was evident by visual observations and the rise and recession of WSE in the hydrographs.

All of the General Study Lakes except Lake B8530 should be considered hydraulically isolated during the remainder of the year. Lake B8530 remains hydraulically connected to Lake M9608 during the open water season.

4.3 SUMMARY

A compilation of 2015 hydrologic observations and a summary of lake recharge, including the primary recharge mechanism, hydraulic connections, and estimated bankfull WSE are presented in Table 4.12.

Table 4.12: Summary of 2015 Hydrologic Recharge Observations

Study Lake	Recharge to Bankfull	Primary Recharge Mechanism	Additional Hydraulic Connection[1]		Estimated Bankfull WSE[3] (ft - BPMSL)
			Flow In	Flow Out	
Detail Study Lake					
M9602	√	Local melt	No channelized drainage into lake	Lake M9601 (northeast) via small drainage	95.8 [4,5]
General Study Lakes					
B8530[2]	√	Nigliq Channel (south)	Overland flow from south	No channelized drainage out of lake	95.1 [4]
B8531/L9326	√	Nigliq Channel (west)	Overland flow from south	Flow into Nigliq via Toolbox Creek	90.8 [4,5]
L9323	√	Nigliq Channel (west)	Overland flow from south and west	No channelized drainage out of lake	8.1
L9324	√	Sakoonang via paleolake (southeast)	Overland flow from south and east	Flow into Nigliq via Toolbox Creek	4.7
M9603	√	East Channel (west)	Overland flow from west	Channelized flow into Lake L9334/M9506 (north)	96.6 [4,5]
M9605	√	Local melt	No channelized drainage into lake	Unnamed lake via small drainage (north)	97.0 [4,5]
M9607	√	Nigliq Channel via Lake B8530 (southwest)	Overland flow from south and west	No channelized drainage out of lake	89.0 [4]
Nanuq Lake	√	Nigliq Channel (west)	Overland flow from south and west	Lake M9524 (northwest)	--*

Notes:

-- Recharge based on visual observation

1. Observations between April 24 and June 29, 2015. Unless specified, hydraulic connections are likely seasonal only.
2. Additional annual connection with Lake M9608 (west)
3. Bankfull WSE estimated based on gage readings for all years available
4. Bankfull WSE based on assumed elevation of 100.00 feet
5. Bankfull WSE estimated during active outflowing of water from the lake; actual bankfull WSE is likely lower

* Michael Baker lacks data to estimate bankfull WSE

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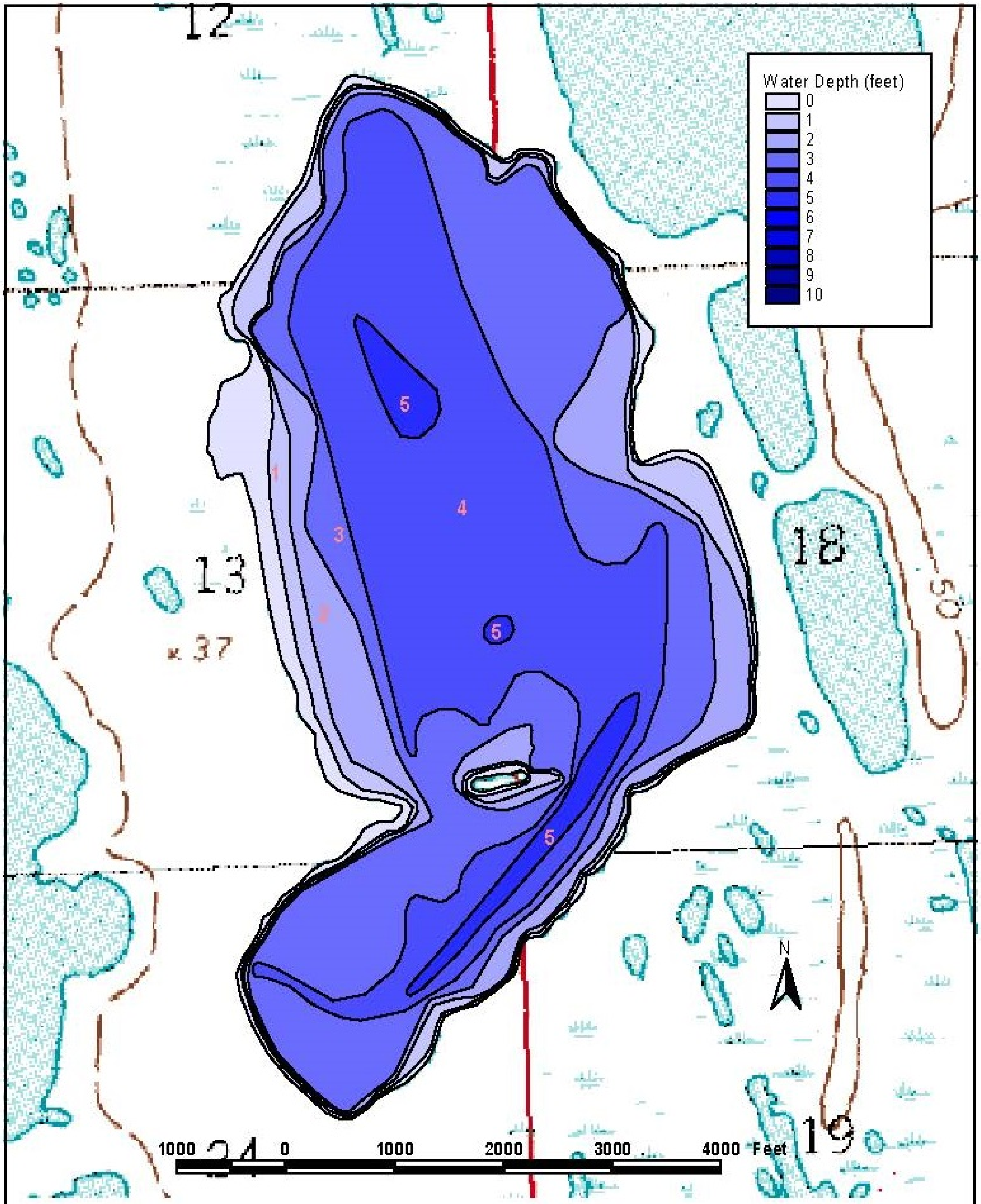
Appendix A Gage and TBM Locations

Monitoring Location	Site Name	Type	Latitude[1]	Longitude[1]
B8530	B8530-A	Gage	70.2437°	-150.8818°
	B8530-X	TBM	70.2436°	-150.8816°
B8531/L9326	B8531/L9326-A	Gage	70.2727°	-150.9947°
	B8531/L9326-B	Gage	70.2727°	-150.9947°
	B8531/L9326-X	TBM	70.2726°	-150.9953°
L9323	L9323-A	Gage	70.2956°	-150.9840°
	NANUQ 4	TBM	70.2954°	-150.9814°
L9324	L9324-A	Gage	70.2915°	-150.9826°
	L9324-B	Gage	70.2915°	-150.9826°
	L9324-C	Gage	70.2915°	-150.9826°
	NANUQ 5	TBM	70.2917°	-150.9807°
M9602	M9602-A	Gage	70.2159°	-150.7231°
	M9602A	TBM	70.2158°	-150.7230°
	M9602-X	TBM	70.2158°	-150.7229°
M9603	M9603-A	Gage	70.2212°	-150.7897°
	M9603-X	TBM	70.2213°	-150.7896°
	M9603-Z	TBM	70.2213°	-150.7895°
M9605	M9605-A	Gage	70.2304°	-150.5177°
	M9605A	TBM	70.2305°	-150.5174°
	M9605-X	TBM	70.2306°	-150.5175°
M9607	M9607-A	Gage	70.2440°	-150.8684°
	M9607-X	TBM	70.2443°	-150.8665°
Nanuq Lake	Nanuq Lake	Aerial Photos	70.3225°	-151.0129°

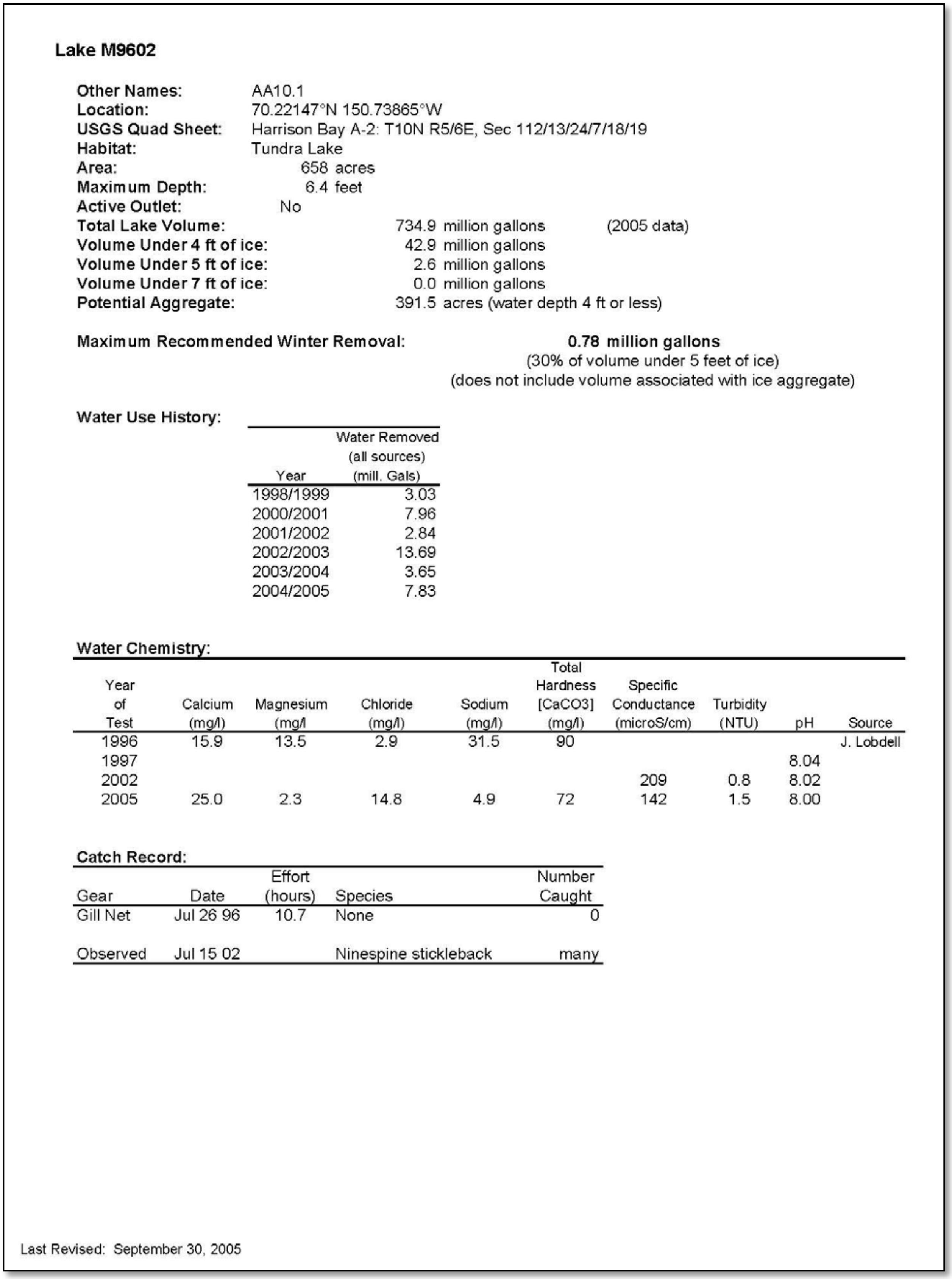
Note
1: Locations are referenced to NAD83 datum in decimal degrees.

Appendix B Lake Bathymetry: Lake M9602



Depth contours of lake M9602 based on transects surveyed on July 12, 2005
(depths in 1 foot intervals)

(not to be used for navigation or to direct use of heavy equipment)



Lake M9602

Other Names: AA10.1
Location: 70.22147°N 150.73865°W
USGS Quad Sheet: Harrison Bay A-2: T10N R5/6E, Sec 112/13/24/7/18/19
Habitat: Tundra Lake
Area: 658 acres
Maximum Depth: 6.4 feet
Active Outlet: No
Total Lake Volume: 734.9 million gallons (2005 data)
Volume Under 4 ft of ice: 42.9 million gallons
Volume Under 5 ft of ice: 2.6 million gallons
Volume Under 7 ft of ice: 0.0 million gallons
Potential Aggregate: 391.5 acres (water depth 4 ft or less)

Maximum Recommended Winter Removal: **0.78 million gallons**
(30% of volume under 5 feet of ice)
(does not include volume associated with ice aggregate)

Water Use History:

Year	Water Removed (all sources) (mill. Gals)
1998/1999	3.03
2000/2001	7.96
2001/2002	2.84
2002/2003	13.69
2003/2004	3.65
2004/2005	7.83

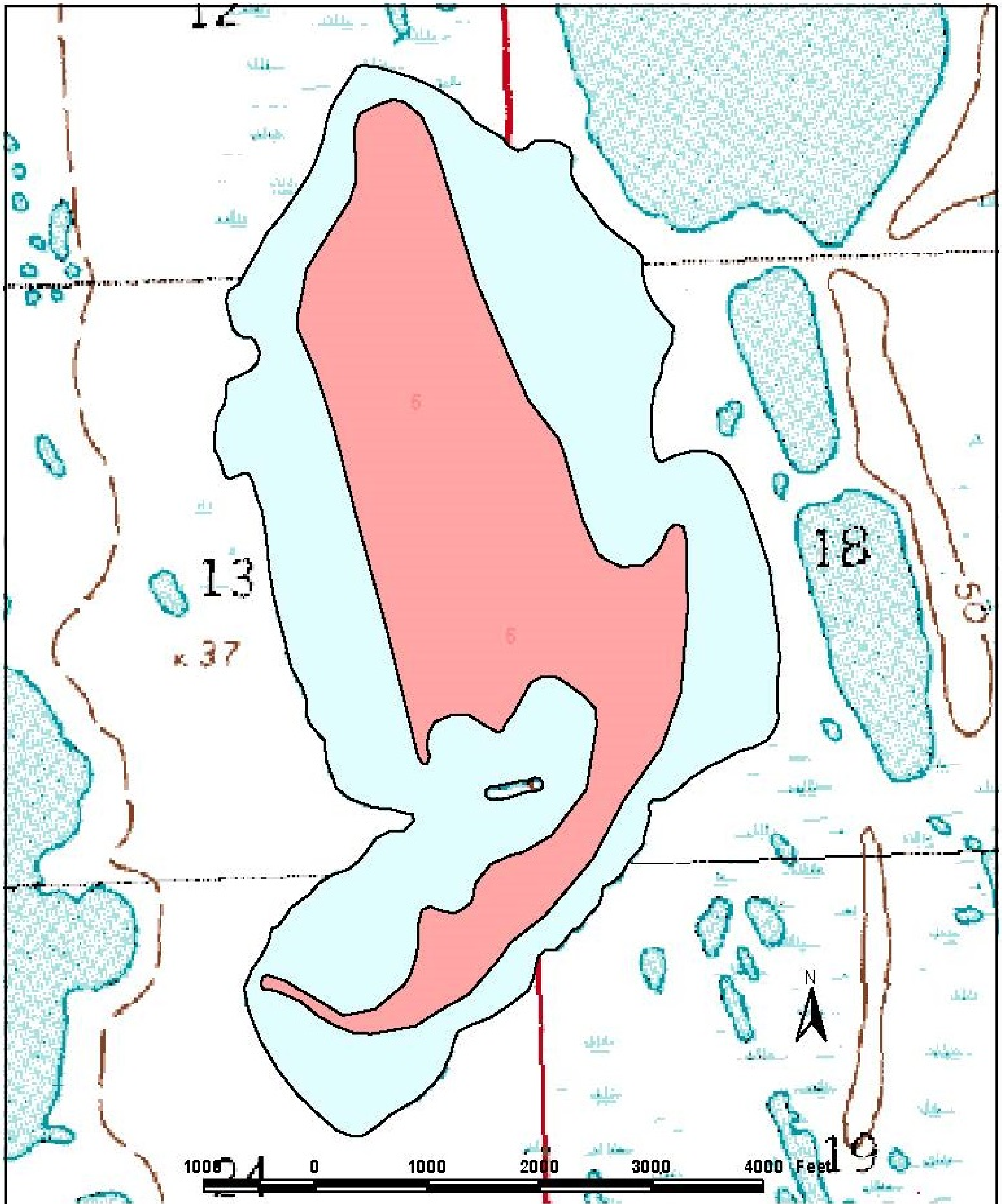
Water Chemistry:

Year of Test	Calcium (mg/l)	Magnesium (mg/l	Chloride (mg/l)	Sodium (mg/l)	Total Hardness [CaCO3] (mg/l)	Specific Conductance (microS/cm)	Turbidity (NTU)	pH	Source
1996	15.9	13.5	2.9	31.5	90				J. Lobdell
1997								8.04	
2002						209	0.8	8.02	
2005	25.0	2.3	14.8	4.9	72	142	1.5	8.00	

Catch Record:

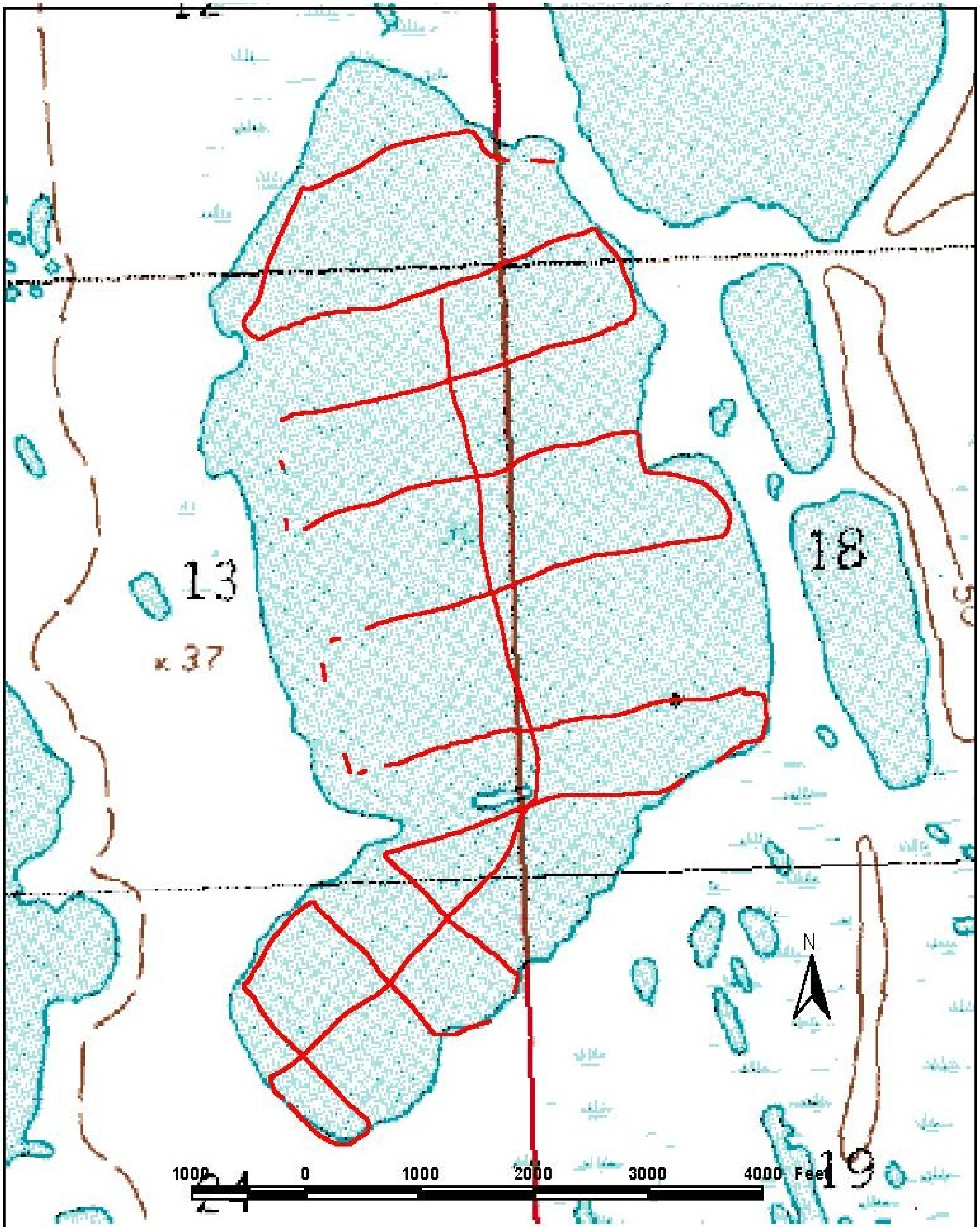
Gear	Date	Effort (hours)	Species	Number Caught
Gill Net	Jul 26 96	10.7	None	0
Observed	Jul 15 02		Ninespine stickleback	many

Last Revised: September 30, 2005



Regions of lake M9602 less than 4 fet deep (light shaded) and likely to be available for ice chips, based on transects surveyed on July 12, 2005 .

(not to be used for navigation or to direct use of heavy equipment)



Depth transects measured at lake M9602 on July 12, 2005.

Appendix C Snow Survey Sheets: Lake M9602

C.1 Pooled Snow Survey Data

Pooled Snow Survey Data Sheet

Date: 4/24/2015 **Start Time:** 11:00 **End Time:** 18:30 **Observers:** MNU, JPK, GNW

Catchment Basin: M9602 **Driving Wrench Used:** Mt. Rose **Tube Section Used:** 0-62"

Snow Sample No.	Pooled Sample #	Terrain Type	Snow Depth (in)		Calculations	
			w/ Dirt Plug	w/o Dirt Plug		
PS0231	1	**Lake**	0.0	14.0	**Bucket & Core Weight (lb) =**	3.18
	2		0.0	14.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	15.0	**Average Mass (lb) =**	0.32
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22231173		**Sum (in) =**	**43.5**	**Average Density (lb/in^3) =**	**0.011**
Longitude	-150.7389197		**Average (in) =**	**14.5**	**Average SWE (in) =**	**4.27**
PS0241	1	**Lake**	0.0	11.5	**Bucket & Core Weight (lb) =**	3.32
	2		0.0	11.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	11.0	**Average Mass (lb) =**	0.28
	4		0.2	11.0	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22491448		**Sum (in) =**	**44.5**	**Average Density (lb/in^3) =**	**0.012**
Longitude	-150.7364185		**Average (in) =**	**11.1**	**Average SWE (in) =**	**3.67**
PS0251	1	**Lake**	0.3	7.0	**Bucket & Core Weight (lb) =**	2.81
	2		0.1	7.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	6.5	**Average Mass (lb) =**	0.15
	4		0.0	6.5	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22699336		**Sum (in) =**	**27.0**	**Average Density (lb/in^3) =**	**0.011**
Longitude	-150.7344143		**Average (in) =**	**6.8**	**Average SWE (in) =**	**1.97**
PS0261	1	**Lake**	0.0	15.5	**Bucket & Core Weight (lb) =**	3.56
	2		0.0	16.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	16.5	**Average Mass (lb) =**	0.45
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22960021		**Sum (in) =**	**48.5**	**Average Density (lb/in^3) =**	**0.013**
Longitude	-150.7319045		**Average (in) =**	**16.2**	**Average SWE (in) =**	**5.96**
PS0271	1	**Tundra**	0.0	18.5	**Bucket & Core Weight (lb) =**	2.96
	2		2.0	18.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	15.0	**Average Mass (lb) =**	0.25
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.23168395		**Sum (in) =**	**52.0**	**Average Density (lb/in^3) =**	**0.007**
Longitude	-150.7298981		**Average (in) =**	**17.3**	**Average SWE (in) =**	**3.29**
PS0281	1	**Lake**	0.0	10.5	**Bucket & Core Weight (lb) =**	3.22
	2		0.0	11.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	11.0	**Average Mass (lb) =**	0.25
	4		0.0	10.5	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22277357		**Sum (in) =**	**43.0**	**Average Density (lb/in^3) =**	**0.011**
Longitude	-150.7342523		**Average (in) =**	**10.8**	**Average SWE (in) =**	**3.34**

Note 1: Locations are referenced to NAD 83 datum.

Pooled Snow Survey Data Sheet

Date:	4/24/2015	**Start Time:**	11:00	**End Time:**	18:30	**Observers:**	MNU, JPK, GNW
Catchment Basin:	M9602	**Driving Wrench Used:**	Mt. Rose	**Tube Section Used:**	0-62"		

Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Calculations**	
			w/ Dirt Plug	**w/o Dirt Plug**		
PS0291	1	**Lake**	0.0	10.0	**Bucket & Core Weight (lb) =**	3.08
	2		0.0	10.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	10.0	**Average Mass (lb) =**	0.22
	4		0.0	10.0	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22338863		**Sum (in) =**	**40.0**	**Average Density (lb/in^3) =**	**0.010**
Longitude	-150.7280341		**Average (in) =**	**10.0**	**Average SWE (in) =**	**2.87**
PS0301	1	**Tundra**	0.5	9.5	**Bucket & Core Weight (lb) =**	2.96
	2		0.0	9.5	**Empty Bucket Weight (lb) =**	2.22
	3		3.0	10.5	**Average Mass (lb) =**	0.19
	4		2.5	9.5	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22400278		**Sum (in) =**	**39.0**	**Average Density (lb/in^3) =**	**0.009**
Longitude	-150.721822		**Average (in) =**	**9.8**	**Average SWE (in) =**	**2.47**
PS0311	1	**Lake**	0.0	6.5	**Bucket & Core Weight (lb) =**	2.88
	2		0.0	7.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	7.0	**Average Mass (lb) =**	0.17
	4		0.0	7.0	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22102913		**Sum (in) =**	**28.0**	**Average Density (lb/in^3) =**	**0.011**
Longitude	-150.7336766		**Average (in) =**	**7.0**	**Average SWE (in) =**	**2.20**
PS0321	1	**Lake**	0.0	11.0	**Bucket & Core Weight (lb) =**	3.14
	2		0.0	11.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	11.0	**Average Mass (lb) =**	0.23
	4		0.0	11.0	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.21974611		**Sum (in) =**	**44.0**	**Average Density (lb/in^3) =**	**0.010**
Longitude	-150.7284328		**Average (in) =**	**11.0**	**Average SWE (in) =**	**3.07**
PS0331	1	**Lake**	0.0	5.5	**Bucket & Core Weight (lb) =**	2.98
	2		0.0	7.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	8.0	**Average Mass (lb) =**	0.19
	4		0.0	8.0	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.21846184		**Sum (in) =**	**29.0**	**Average Density (lb/in^3) =**	**0.013**
Longitude	-150.723185		**Average (in) =**	**7.3**	**Average SWE (in) =**	**2.54**
PS0341	1	**Tundra**	0.0	15.0	**Bucket & Core Weight (lb) =**	3.24
	2		0.0	21.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	16.0	**Average Mass (lb) =**	0.34
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.21685553		**Sum (in) =**	**52.5**	**Average Density (lb/in^3) =**	**0.009**
Longitude	-150.7166237		**Average (in) =**	**17.5**	**Average SWE (in) =**	**4.54**

Note 1: Locations are referenced to NAD 83 datum.

Pooled Snow Survey Data Sheet

Date:	4/24/2015	**Start Time:**	11:00	**End Time:**	18:30	**Observers:**	MNU, JPK, GNW
Catchment Basin:	M9602	**Driving Wrench Used:**	Mt. Rose	**Tube Section Used:**	0-62"		

Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Calculations**	
			w/ Dirt Plug	**w/o Dirt Plug**		
PS0351	1	**Lake**	0.0	14.5	**Bucket & Core Weight (lb) =**	3.38
	2		0.0	15.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	15.5	**Average Mass (lb) =**	0.39
	4				**Core Area (in^{2}) =**	2.0739
	5				**Freshwater Density (lb/in^{3}) =**	0.0361
Latitude	70.22126793		**Sum (in) =**	**45.0**	**Average Density (lb/in^{3}) =**	**0.012**
Longitude	-150.7398871		**Average (in) =**	**15.0**	**Average SWE (in) =**	**5.16**
PS0361	1	**Lake**	0.0	10.0	**Bucket & Core Weight (lb) =**	3.02
	2		0.0	11.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	10.5	**Average Mass (lb) =**	0.20
	4		0.0	11.0	**Core Area (in^{2}) =**	2.0739
	5				**Freshwater Density (lb/in^{3}) =**	0.0361
Latitude	70.21917447		**Sum (in) =**	**43.0**	**Average Density (lb/in^{3}) =**	**0.009**
Longitude	-150.7418271		**Average (in) =**	**10.8**	**Average SWE (in) =**	**2.67**
PS0371	1	**Lake**	0.1	9.5	**Bucket & Core Weight (lb) =**	3.00
	2		0.0	9.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	9.5	**Average Mass (lb) =**	0.20
	4		0.0	9.0	**Core Area (in^{2}) =**	2.0739
	5				**Freshwater Density (lb/in^{3}) =**	0.0361
Latitude	70.21708226		**Sum (in) =**	**37.0**	**Average Density (lb/in^{3}) =**	**0.010**
Longitude	-150.7437655		**Average (in) =**	**9.3**	**Average SWE (in) =**	**2.60**
PS0381	1	**Tundra**	0.0	24.0	**Bucket & Core Weight (lb) =**	3.70
	2		0.0	23.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	23.5	**Average Mass (lb) =**	0.49
	4				**Core Area (in^{2}) =**	2.0739
	5				**Freshwater Density (lb/in^{3}) =**	0.0361
Latitude	70.2149929		**Sum (in) =**	**70.5**	**Average Density (lb/in^{3}) =**	**0.010**
Longitude	-150.7457053		**Average (in) =**	**23.5**	**Average SWE (in) =**	**6.59**
PS0391	1	**Lake**	0.0	13.5	**Bucket & Core Weight (lb) =**	3.00
	2		0.0	13.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	13.5	**Average Mass (lb) =**	0.26
	4				**Core Area (in^{2}) =**	2.0739
	5				**Freshwater Density (lb/in^{3}) =**	0.0361
Latitude	70.21348659		**Sum (in) =**	**40.5**	**Average Density (lb/in^{3}) =**	**0.009**
Longitude	-150.747151		**Average (in) =**	**13.5**	**Average SWE (in) =**	**3.47**
PS0401	1	**Lake**	0.0	11.5	**Bucket & Core Weight (lb) =**	3.02
	2		0.0	12.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	12.0	**Average Mass (lb) =**	0.20
	4		0.0	11.5	**Core Area (in^{2}) =**	2.0739
	5				**Freshwater Density (lb/in^{3}) =**	0.0361
Latitude	70.21133102		**Sum (in) =**	**47.0**	**Average Density (lb/in^{3}) =**	**0.008**
Longitude	-150.749074		**Average (in) =**	**11.8**	**Average SWE (in) =**	**2.67**

Note 1: Locations are referenced to NAD 83 datum.

Pooled Snow Survey Data Sheet

Date: 4/24/2015 **Start Time:** 11:00 **End Time:** 18:30 **Observers:** MNU, JPK, GNW

Catchment Basin: M9602 **Driving Wrench Used:** Mt. Rose **Tube Section Used:** 0-62"

Snow Sample No.	Pooled Sample #	Terrain Type	Snow Depth (in)		Calculations	
			w/ Dirt Plug	w/o Dirt Plug		
PS0411	1	**Lake**	0.0	8.0	**Bucket & Core Weight (lb) =**	2.58
	2		0.0	7.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	7.5	**Average Mass (lb) =**	0.09
	4		0.0	7.5	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.21133102		**Sum (in) =**	**30.5**	**Average Density (lb/in^3) =**	**0.006**
Longitude	-150.749074		**Average (in) =**	**7.6**	**Average SWE (in) =**	**1.20**
PS0421	1	**Lake**	0.1	22.5	**Bucket & Core Weight (lb) =**	3.82
	2		0.1	22.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	22.5	**Average Mass (lb) =**	0.53
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.20976553		**Sum (in) =**	**67.5**	**Average Density (lb/in^3) =**	**0.011**
Longitude	-150.7505275		**Average (in) =**	**22.5**	**Average SWE (in) =**	**7.12**
PS0431	1	**Tundra**	0.0	25.0	**Bucket & Core Weight (lb) =**	3.20
	2		0.0	25.0	**Empty Bucket Weight (lb) =**	2.22
	3				**Average Mass (lb) =**	0.49
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.2081966		**Sum (in) =**	**50.0**	**Average Density (lb/in^3) =**	**0.009**
Longitude	-150.7519805		**Average (in) =**	**25.0**	**Average SWE (in) =**	**6.54**
PS0441	1	**Lake**	0.0	10.0	**Bucket & Core Weight (lb) =**	3.10
	2		0.0	10.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	10.0	**Average Mass (lb) =**	0.29
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.20610691		**Sum (in) =**	**30.0**	**Average Density (lb/in^3) =**	**0.014**
Longitude	-150.7539271		**Average (in) =**	**10.0**	**Average SWE (in) =**	**3.92**
PS0451	1	**Lake**	0.0	17.0	**Bucket & Core Weight (lb) =**	3.52
	2		0.0	17.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	17.0	**Average Mass (lb) =**	0.43
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22152207		**Sum (in) =**	**51.0**	**Average Density (lb/in^3) =**	**0.012**
Longitude	-150.7466745		**Average (in) =**	**17.0**	**Average SWE (in) =**	**5.79**
PS0461	1	**Tundra**	0.0	14.0	**Bucket & Core Weight (lb) =**	2.96
	2		0.0	15.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	15.0	**Average Mass (lb) =**	0.25
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22058363		**Sum (in) =**	**44.0**	**Average Density (lb/in^3) =**	**0.008**
Longitude	-150.7513259		**Average (in) =**	**14.7**	**Average SWE (in) =**	**3.29**

Note 1: Locations are referenced to NAD 83 datum.

Pooled Snow Survey Data Sheet						
Date: 4/24/2015	**Start Time:** 11:00		**End Time:** 18:30		**Observers:**	MNU, JPK, GNW
Catchment Basin: M9602		**Driving Wrench Used:**		Mt. Rose	**Tube Section Used:**	0-62"
Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Calculations**	
			w/ Dirt Plug	**w/o Dirt Plug**		
PS0471	1	**Lake**	0.0	8.5	**Bucket & Core Weight (lb) =**	2.84
	2		0.0	8.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	8.5	**Average Mass (lb) =**	0.16
	4		0.0	8.5	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22011148		**Sum (in) =**	**34.0**	**Average Density (lb/in^3) =**	**0.009**
Longitude	-150.7606424		**Average (in) =**	**8.5**	**Average SWE (in) =**	**2.07**
PS0481	1	**Lake**	0.0	10.5	**Bucket & Core Weight (lb) =**	3.18
	2		0.0	10.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	11.0	**Average Mass (lb) =**	0.24
	4		0.0	10.5	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22327824		**Sum (in) =**	**42.5**	**Average Density (lb/in^3) =**	**0.011**
Longitude	-150.7428506		**Average (in) =**	**10.6**	**Average SWE (in) =**	**3.20**
PS0491	1	**Lake**	0.0	14.0	**Bucket & Core Weight (lb) =**	2.98
	2		0.0	14.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	13.5	**Average Mass (lb) =**	0.25
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22488656		**Sum (in) =**	**42.0**	**Average Density (lb/in^3) =**	**0.009**
Longitude	-150.7493975		**Average (in) =**	**14.0**	**Average SWE (in) =**	**3.38**
PS0501	1	**Tundra**	0.0	27.0	**Bucket & Core Weight (lb) =**	3.58
	2		0.0	28.0	**Empty Bucket Weight (lb) =**	2.22
	3				**Average Mass (lb) =**	0.68
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22617411		**Sum (in) =**	**55.0**	**Average Density (lb/in^3) =**	**0.012**
Longitude	-150.7546322		**Average (in) =**	**27.5**	**Average SWE (in) =**	**9.08**
PS0511	1	**Tundra**	0.0	19.0	**Bucket & Core Weight (lb) =**	3.34
	2		0.0	17.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	19.0	**Average Mass (lb) =**	0.37
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22714289		**Sum (in) =**	**55.0**	**Average Density (lb/in^3) =**	**0.010**
Longitude	-150.7585574		**Average (in) =**	**18.3**	**Average SWE (in) =**	**4.98**
PS0521	1	**Tundra**	1.0	14.5	**Bucket & Core Weight (lb) =**	2.86
	2		0.0	12.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	14.5	**Average Mass (lb) =**	0.21
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22810672		**Sum (in) =**	**41.0**	**Average Density (lb/in^3) =**	**0.008**
Longitude	-150.7624991		**Average (in) =**	**13.7**	**Average SWE (in) =**	**2.85**
Note 1: Locations are referenced to NAD 83 datum.						

Pooled Snow Survey Data Sheet

Date:	4/24/2015	**Start Time:**	11:00	**End Time:**	18:30	**Observers:**	MNU, JPK, GNW
Catchment Basin:	M9602	**Driving Wrench Used:**	Mt. Rose	**Tube Section Used:**	0-62"		

Snow Sample No.	**Pooled Sample #**	**Terrain Type**	**Snow Depth (in)**		**Calculations**	
			w/ Dirt Plug	**w/o Dirt Plug**		
PS0531	1	**Lake**	0.0	9.5	**Bucket & Core Weight (lb) =**	2.86
	2		0.0	9.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	9.0	**Average Mass (lb) =**	0.16
	4		0.0	10.0	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.22605936		**Sum (in) =**	**38.0**	**Average Density (lb/in^3) =**	**0.008**
Longitude	-150.7412199		**Average (in) =**	**9.5**	**Average SWE (in) =**	**2.14**
PS0541	1	**Lake**	0.0	7.5	**Bucket & Core Weight (lb) =**	2.62
	2		0.0	7.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	8.0	**Average Mass (lb) =**	0.10
	4		0.0	7.0	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.2303431		**Sum (in) =**	**30.0**	**Average Density (lb/in^3) =**	**0.006**
Longitude	-150.7438502		**Average (in) =**	**7.5**	**Average SWE (in) =**	**1.34**
PS0551	1	**Tundra**	1.0	7.0	**Bucket & Core Weight (lb) =**	2.60
	2		0.0	8.0	**Empty Bucket Weight (lb) =**	2.22
	3		1.0	8.0	**Average Mass (lb) =**	0.10
	4		0.0	6.5	**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.23355907		**Sum (in) =**	**29.5**	**Average Density (lb/in^3) =**	**0.006**
Longitude	-150.7458255		**Average (in) =**	**7.4**	**Average SWE (in) =**	**1.27**
PS0561	1	**Lake**	0.0	15.0	**Bucket & Core Weight (lb) =**	3.18
	2		0.0	15.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	15.0	**Average Mass (lb) =**	0.32
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.218576		**Sum (in) =**	**45.0**	**Average Density (lb/in^3) =**	**0.010**
Longitude	-150.7364278		**Average (in) =**	**15.0**	**Average SWE (in) =**	**4.27**
PS0571	1	**Lake**	0.0	18.0	**Bucket & Core Weight (lb) =**	3.64
	2		0.0	18.0	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	17.0	**Average Mass (lb) =**	0.47
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.21482518		**Sum (in) =**	**53.0**	**Average Density (lb/in^3) =**	**0.013**
Longitude	-150.7339683		**Average (in) =**	**17.7**	**Average SWE (in) =**	**6.32**
PS0581	1	**Tundra**	4.0	16.0	**Bucket & Core Weight (lb) =**	2.76
	2		0.0	16.5	**Empty Bucket Weight (lb) =**	2.22
	3		0.0	15.5	**Average Mass (lb) =**	0.18
	4				**Core Area (in^2) =**	2.0739
	5				**Freshwater Density (lb/in^3) =**	0.0361
Latitude	70.21161097		**Sum (in) =**	**48.0**	**Average Density (lb/in^3) =**	**0.005**
Longitude	-150.7318615		**Average (in) =**	**16.0**	**Average SWE (in) =**	**2.40**

Note 1: Locations are referenced to NAD 83 datum.

C.2 Snow Depth Survey Data

Snow Depth Survey Data Sheet					
Date:	4/24/2015		**Start Time:**	11:00	**Observers:** MNU, JPK and GNW
Catchment Basin:	M9602		**End Time:**	18:30	
Snow Sample No.	**Terrain Type**	**Snow Depth (cm)**	**Snow Depth (in)**	**Location**	
				Latitude	**Longitude**
SS0851	Lake	29.0	11.4	70.22283325	-150.738418
SS0861	Lake	16.5	6.5	70.22335578	-150.7379151
SS0871	Lake	17.3	6.8	70.22387722	-150.7374134
SS0881	Lake	27.5	10.8	70.22439497	-150.7369151
SS0891	Lake	34.7	13.6	70.22543365	-150.7359155
SS0901	Lake	15.0	5.9	70.22595526	-150.7354135
SS0911	Lake	22.7	8.9	70.22647477	-150.7349135
SS0921	Lake	15.2	6.0	70.22751513	-150.733912
SS0931	Lake	21.5	8.5	70.22803824	-150.7334084
SS0941	Lake	8.7	3.4	70.22855784	-150.7329095
SS0951	Lake	22.7	8.9	70.22907877	-150.7324066
SS0961	Lake	92.0	36.2	70.2301219	-150.7314022
SS0971	Tundra	20.2	7.9	70.23064376	-150.7308998
SS0981	Tundra	28.0	11.0	70.23116419	-150.7303986
SS0991	Lake	12.3	4.9	70.2224657	-150.7373636
SS1001	Lake	37.7	14.8	70.22261591	-150.7358018
SS1011	Lake	20.0	7.9	70.22292729	-150.7326978
SS1021	Lake	30.0	11.8	70.22308127	-150.7311413
SS1031	Lake	15.3	6.0	70.22323474	-150.72959
SS1041	Lake	30.0	11.8	70.22354227	-150.7264803
SS1051	Tundra	23.3	9.2	70.2236955	-150.72493
SS1061	Tundra	40.0	15.7	70.22384888	-150.7233786
SS1071	Tundra	40.3	15.9	70.224156	-150.7202721
SS1081	Lake	27.3	10.8	70.22199146	-150.7376104
SS1091	Lake	19.7	7.7	70.2216706	-150.7362985
SS1101	Lake	20.3	8.0	70.22134949	-150.7349859
SS1111	Lake	37.0	14.6	70.22070877	-150.7323671
SS1121	Lake	27.0	10.6	70.22038733	-150.7310531
SS1131	Lake	25.3	10.0	70.22006663	-150.7297424
SS1141	Lake	25.0	9.8	70.21942542	-150.7271222
SS1151	Lake	35.0	13.8	70.21910464	-150.7258117
SS1161	Lake	42.0	16.5	70.21878345	-150.7244993
SS1171	Lake	20.0	7.9	70.21814056	-150.7218727
SS1181	Lake	20.0	7.9	70.21782012	-150.7205637
SS1191	Lake	37.0	14.6	70.2174985	-150.7192497
SS1201	Lake	85.0	33.5	70.21717689	-150.717936
SS1211	Tundra	47.3	18.6	70.21652671	-150.7153305
SS1221	Lake	20.0	7.9	70.22178979	-150.7394035
SS1231	Lake	26.0	10.2	70.22074473	-150.740372
SS1241	Lake	23.3	9.2	70.22022153	-150.7408564
SS1251	Lake	14.2	5.6	70.21969792	-150.7413421

Snow Depth Survey Data Sheet					
Date:	4/24/2015		**Start Time:**	11:00 AM	**Observers: MNU, JPK and GNW**
Catchment Basin:	M9602		**End Time:**	6:30 PM	
Snow Sample No.	**Terrain Type**	**Snow Depth (cm)**	**Snow Depth (in)**	**Location**	
				Latitude	**Longitude**
SS1261	Lake	37.3	14.7	70.21865076	-150.7423124
SS1271	Lake	26.3	10.4	70.21812731	-150.7427973
SS1281	Lake	33.7	13.3	70.2176042	-150.743282
SS1291	Lake	21.3	8.4	70.21655906	-150.7442501
SS1301	Lake	38.3	15.1	70.21603611	-150.7447345
SS1311	Lake	39.0	15.4	70.21550755	-150.7452253
SS1321	Lake	44.7	17.6	70.21446928	-150.7461857
SS1331	Lake	36.5	14.4	70.21394684	-150.7466695
SS1341	Lake	22.8	9.0	70.21290095	-150.7476442
SS1351	Lake	30.8	12.1	70.21237842	-150.7481219
SS1361	Lake	22.3	8.8	70.21185564	-150.7486059
SS1371	Lake	17.7	7.0	70.21080815	-150.7495648
SS1381	Lake	15.3	6.0	70.21028596	-150.7500592
SS1391	Lake	32.3	12.7	70.209243	-150.7510247
SS1401	Lake	21.0	8.3	70.20872005	-150.7515087
SS1411	Tundra	36.3	14.3	70.20767407	-150.7524768
SS1421	Tundra	52.3	20.6	70.2071523	-150.7529596
SS1431	Tundra	48.3	19.0	70.20662885	-150.7534441
SS1441	Lake	30.3	11.9	70.22215482	-150.74047
SS1451	Lake	34.0	13.4	70.22199816	-150.7420176
SS1461	Lake	15.0	5.9	70.22184083	-150.7435712
SS1471	Lake	29.0	11.4	70.22168359	-150.7451245
SS1481	Lake	54.0	21.3	70.22136927	-150.748228
SS1491	Lake	10.0	3.9	70.22121244	-150.7497769
SS1501	Lake	118.3	46.6	70.2208982	-150.7528792
SS1511	Tundra	32.7	12.9	70.22074096	-150.7544306
SS1521	Tundra	43.3	17.1	70.22042697	-150.75753
SS1531	Tundra	45.3	17.8	70.22026696	-150.7590894
SS1541	Lake	35.0	13.8	70.22263435	-150.7402315
SS1551	Lake	36.7	14.4	70.22295898	-150.7415369
SS1561	Lake	16.0	6.3	70.2236007	-150.7441621
SS1571	Lake	20.0	7.9	70.22392298	-150.7454729
SS1581	Lake	30.0	11.8	70.22424409	-150.7467792
SS1591	Lake	16.0	6.3	70.22456529	-150.7480861
SS1601	Lake	30.0	11.8	70.22520885	-150.7507046
SS1611	Lake	47.3	18.6	70.22553097	-150.752015
SS1621	Lake	40.0	15.7	70.22585266	-150.753324
SS1631	Tundra	70.0	27.6	70.2264953	-150.7559394
SS1641	Tundra	45.0	17.7	70.22681734	-150.75725
SS1651	Tundra	25.0	9.8	70.22746266	-150.7598786
SS1661	Tundra	40.0	15.7	70.22778461	-150.7611872

Snow Depth Survey Data Sheet

Date:	4/24/2015		**Start Time:**	11:00 AM	**Observers: MNU, JPK and GNW**
Catchment Basin:	M9602		**End Time:**	6:30 PM	
Snow Sample No.	**Terrain Type**	**Snow Depth (cm)**	**Snow Depth (in)**	**Location**	
				Latitude	**Longitude**
SS1671	Lake	24.0	9.4	70.22284725	-150.7392483
SS1681	Lake	38.7	15.2	70.22338076	-150.7395796
SS1691	Lake	34.3	13.5	70.22391628	-150.7399044
SS1701	Lake	30.0	11.8	70.2244523	-150.7402334
SS1711	Lake	34.0	13.4	70.22498933	-150.740563
SS1721	Lake	37.7	14.8	70.22552552	-150.7408922
SS1731	Lake	28.0	11.0	70.2265927	-150.7415473
SS1741	Lake	18.0	7.1	70.2271247	-150.7418741
SS1751	Lake	20.0	7.9	70.22766089	-150.7422031
SS1761	Lake	31.0	12.2	70.22819448	-150.7425307
SS1771	Lake	20.0	7.9	70.22873277	-150.7428612
SS1781	Lake	10.0	3.9	70.2292698	-150.743191
SS1791	Lake	12.3	4.9	70.2298059	-150.7435202
SS1801	Lake	10.0	3.9	70.23087963	-150.7441797
SS1811	Lake	10.7	4.2	70.23141649	-150.7445094
SS1821	Lake	18.7	7.3	70.23195192	-150.7448383
SS1831	Lake	14.7	5.8	70.23248426	-150.7451653
SS1841	Tundra	35.0	13.8	70.23302305	-150.7454962
SS1851	Tundra	49.3	19.4	70.23409425	-150.7461544
SS1861	Tundra	80.0	31.5	70.23462751	-150.7464819
SS1871	Tundra	29.3	11.5	70.23516906	-150.7468123
SS1881	Lake	30.7	12.1	70.22178283	-150.7385313
SS1891	Lake	25.0	9.8	70.22124605	-150.7381722
SS1901	Lake	23.0	9.1	70.22070835	-150.7378233
SS1911	Lake	25.0	9.8	70.22017334	-150.7374754
SS1921	Lake	25.7	10.1	70.21963865	-150.7371247
SS1931	Lake	15.0	5.9	70.21910691	-150.7367723
SS1941	Lake	30.0	11.8	70.21804458	-150.7360798
SS1951	Lake	31.0	12.2	70.2175073	-150.7357269
SS1961	Lake	22.0	8.7	70.21696927	-150.7353741
SS1971	Lake	31.0	12.2	70.21643333	-150.7350226
SS1981	Lake	27.0	10.6	70.21589982	-150.7346677
SS1991	Lake	31.0	12.2	70.2153612	-150.7343197
SS2001	Lake	25.0	9.8	70.21428966	-150.7336141
SS2011	Lake	29.7	11.7	70.21375582	-150.7332673
SS2021	Lake	24.0	9.4	70.21322239	-150.7329176
SS2031	Lake	19.0	7.5	70.2126857	-150.7325658
SS2041	Tundra	157.0	61.8	70.21214708	-150.7322128
SS2051	Tundra	54.7	21.5	70.21107025	-150.7315071

Appendix D Alpine Area Lakes Recharge Study Photos

D.1 Lake B8530

Photo D.1: Lake B8530 pre-breakup, looking northeast; May 18, 2015

Photo D.2: Lake B8530 during breakup – recharging from overland flooding, looking west; May 23, 2015

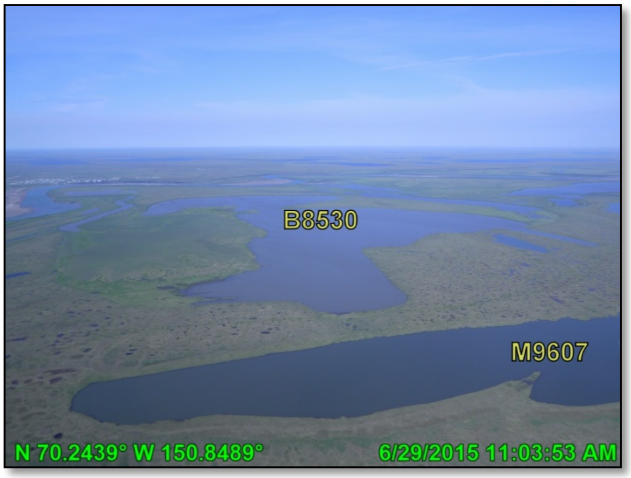


Photo D.3: Lake B8530 post-breakup, looking west; June 29, 2015

D.2 Lake B8531/L9326

Photo D.4: Lake B8531/L9326 pre-breakup, looking northwest; May 18, 2015

Photo D.5: Lake B8531/L9326 during breakup recharged from overland flooding, looking northwest; May 22, 2015

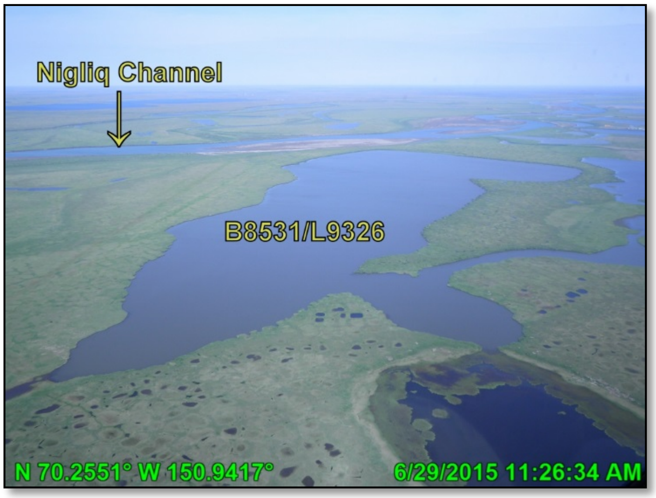


Photo D.6: Lake B8531/L9326 post-breakup, looking northwest; June 29, 2015

D.3 Lake L9323

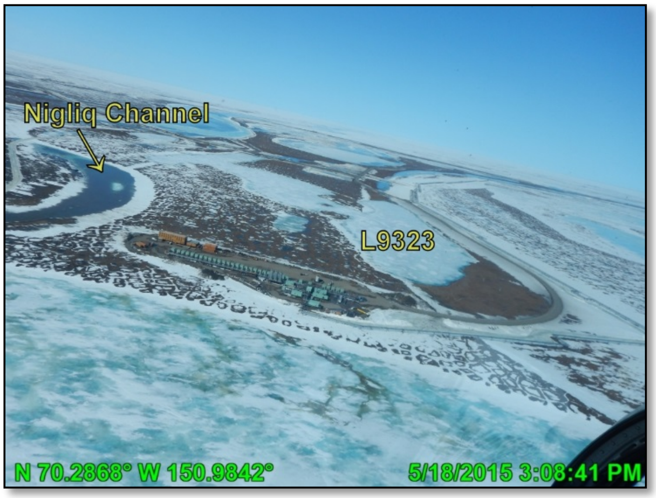


Photo D.7: Lake L9323 pre-breakup, looking north; May 18, 2015

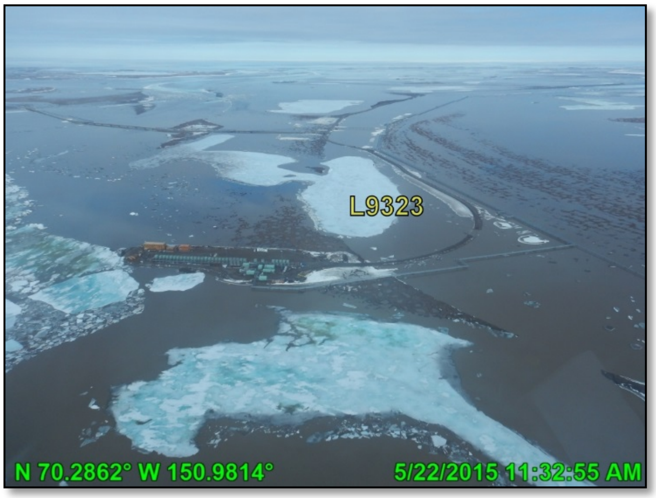


Photo D.8: Lake L9323 during breakup – recharged from overland flooding, looking north; May 22, 2015

Photo D.9: Lake L9323 post-breakup, looking north; June 29, 2015

D.4 Lake L9324

Photo D.10: Lake L9324 pre-breakup, looking north; May 18, 2015

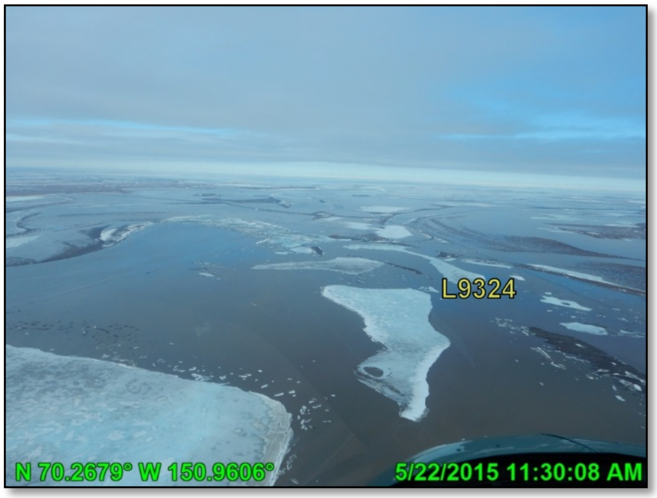


Photo D.11: Lake L9324 during breakup – recharged from overland flooding, looking north; May 22, 2015

Photo D.12: Lake L9324 post-breakup, looking north; June 29, 2015

D.5 Lake M9602

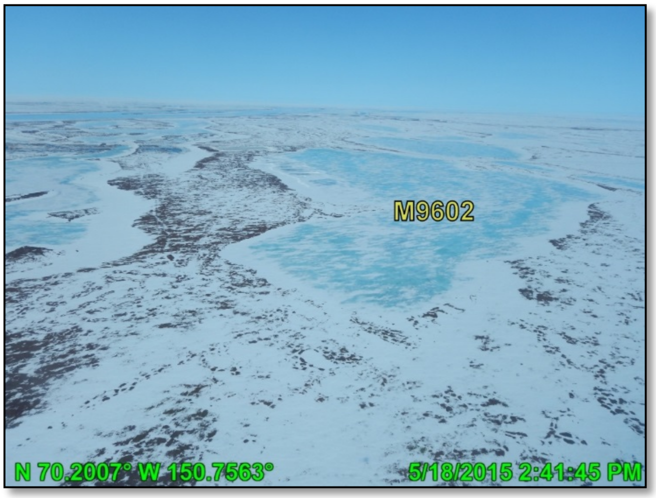


Photo D.13: Lake M9602 pre-breakup, looking north; May 18, 2015

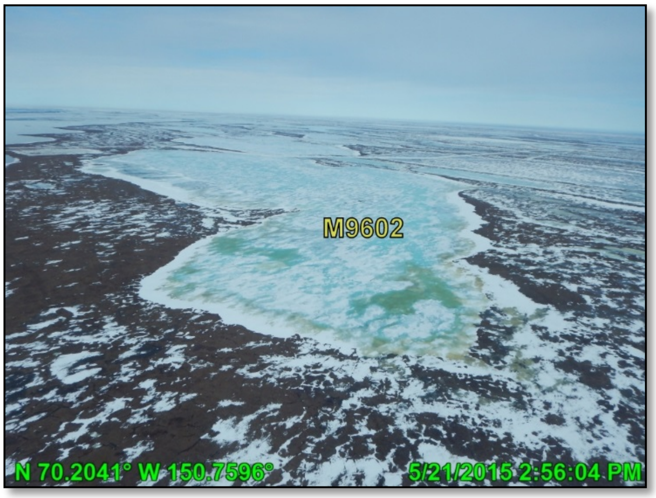


Photo D.14: Lake M9602 during breakup, looking north; May 21, 2015

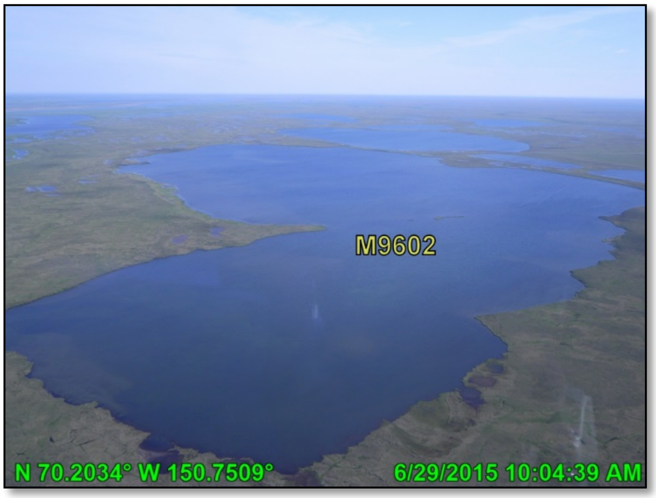


Photo D.15: Lake M9602 post-breakup, looking north; June 29, 2015

D.6 Lake M9603

Photo D.16: Lake M9603 pre-breakup, looking north; May 18, 2015

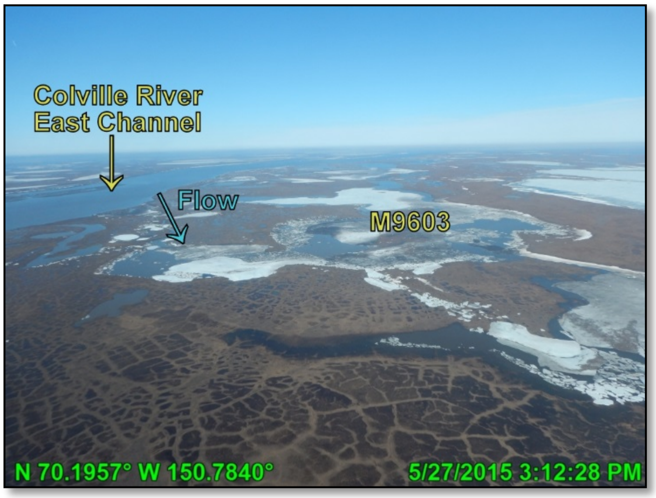


Photo D.17: Lake M9603 during breakup – recharging from overland flooding, looking north; May 27, 2015

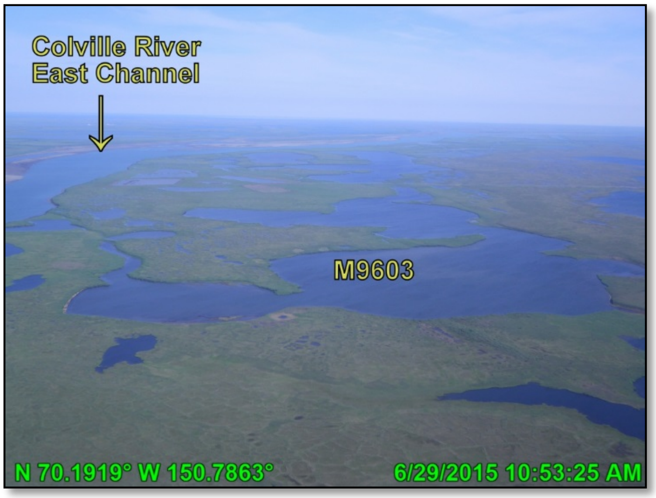


Photo D.18: Lake M9603 post-breakup, looking north; June 29, 2015

D.7 Lake M9605

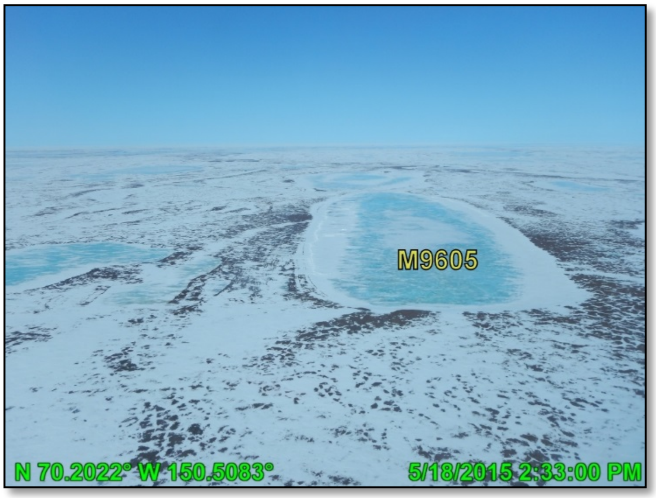


Photo D.19: Lake M9605 pre-breakup, looking north; May 18, 2015

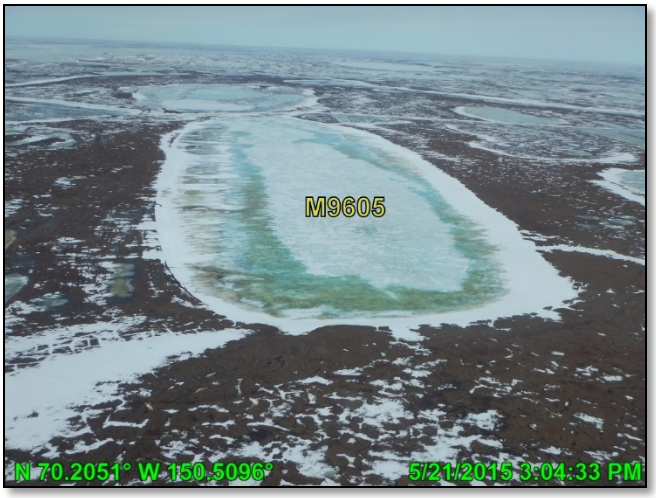


Photo D.20: Lake M9605 during breakup, looking north; May 21, 2015

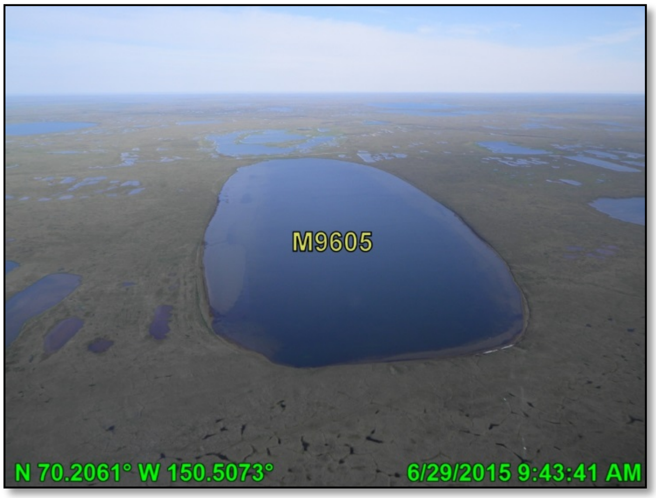


Photo D.21: Lake M9605 post-breakup, looking north; June 29, 2015

D.8 Lake M9607

Photo D.22: Lake M9607 pre-breakup, looking north; May 18, 2015

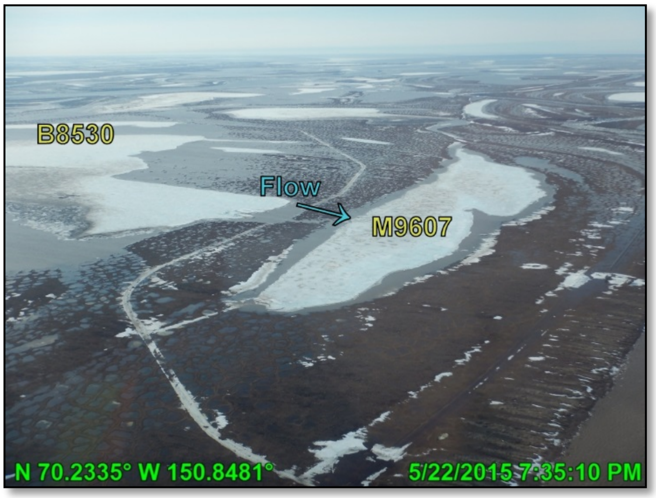


Photo D.23: Lake M9607 during breakup – recharging from overland flooding, looking northwest; May 22, 2015

Photo D.24: Lake M9607 post-breakup, looking northwest; June 29, 2015

D.9 Nanuq Lake

Photo D.25: Nanuq Lake pre-breakup, looking northwest; May 18, 2015

Photo D.26: Nanuq Lake during breakup – recharged from overland flooding, looking southwest; May 22, 2015

Photo D.27: Nanuq Lake, post-breakup, looking northwest; June 29, 2015

2015 Alpine Area Lakes Recharge Studies

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INTERNATIONAL