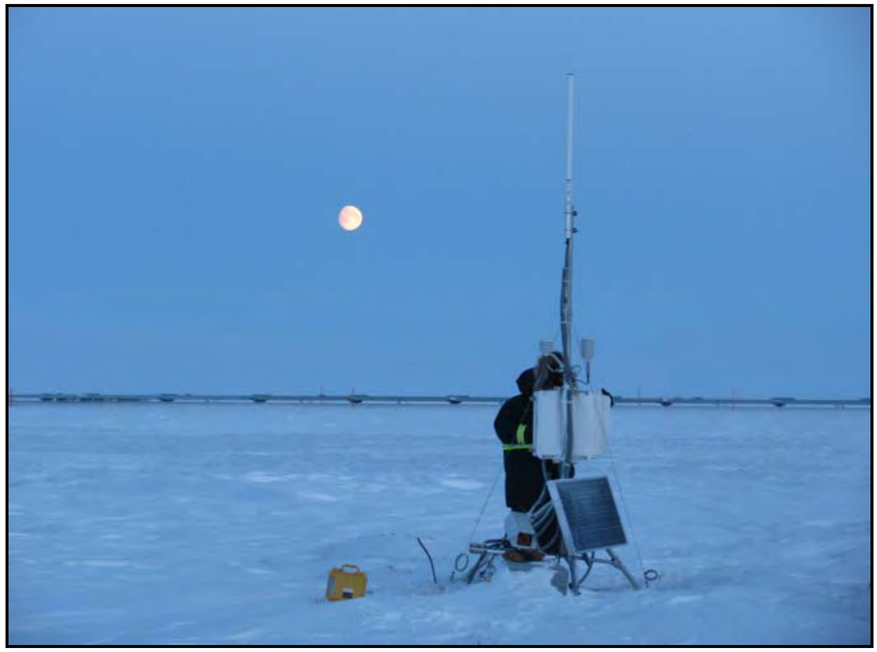
North Slope, Alaska, Snow-Course and Lake Survey Data: November 2010



Michael Lilly preparing to install camera at 2L met station.
Photo by Jeff Murray, November 2010.

by

Jeff Murray, Kristie Hilton, and Michael Lilly

December 2010

Arctic Transportation Networks Project

Report GWS.TR.10.05

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by

Jeff Murray[1], Kristie Hilton[1], and Michael Lilly[1]

A report on research sponsored by:

- U.S. Department of Energy
- National Energy Technology Laboratory
- Alaska Department of Natural Resources
- ConocoPhillips Alaska, Inc.
- Bureau of Land Management
- Geo-Watersheds Scientific

December 2010

Arctic Transportation Networks Project

Report Number GWS.TR.10.05

[1]Geo-Watersheds Scientific, Fairbanks, AK

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Fairbanks, Alaska
December 2010

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DISCLAIMER

CONVERSION FACTORS, UNITS, WATER QUALITY UNITS, VERTICAL AND HORIZONTAL DATUM, ABBREVIATIONS AND SYMBOLS

Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	25.4	millimeter (mm)
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (mm)
mile (mi)	1.609	kilometer (km)
	Area	
Acre	43559.826	square feet (ft^2)
Acre	0.407	hectare (ha)
Square foot (ft^2)	2.590	square mile (mi^2)
square mile (mi^2)	2.590	square kilometer (km^2)
	Volume	
gallon (gal)	3.785	liter (L)
gallon (gal)	3785	milliliter (mL)
Cubic foot (ft^3)	23.317	liter (L)
Acre-ft	1233	cubic meter (m^3)
	Velocity and Discharge	
foot per day (ft/d)	0.3048	meter per day (m/d)
Square foot per day (ft^2/d)	.0929	square meter per day (m^2/d)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second (m^3/sec)
	Hydraulic Conductivity	
foot per day (ft/d)	0.3048	meter per day (m/d)
foot per day (ft/d)	0.00035	centimeter per second (cm/sec)
meter per day (m/d)	0.00115	centimeter per second (cm/sec)
	Hydraulic Gradient	
foot per foot (ft/ft)	5280	foot per mile (ft/mi)
foot per mile (ft/mi)	0.1894	meter per kilometer (m/km)
	Pressure	
pound per square inch (lb/in^2)	6.895	kilopascal (kPa)

Units

For the purposes of this report, both English and Metric (SI) units were employed. Common regulations related to tundra travel and water use on the North Slope, Alaska, uses combinations of both English and SI units. The choice of “primary” units employed depended on common reporting standards for a particular property or parameter measured. Whenever possible, the approximate value in the “secondary” units was also provided in parentheses. Thus, for instance, snow depth was reported in inches (in) followed by the value in centimeters (cm) in parentheses.

Physical and Chemical Water-Quality Units:

Temperature:

Water and air temperature is given in degrees Celsius (°C) and in degrees Fahrenheit (°F). Degrees Celsius can be converted to degrees Fahrenheit by use of the following equation:

°F = 1.8(°C) + 32

Snow Water Equivalent (SWE):

Water content of a given column of snow is determined by knowing the depth of the snowpack and density.

$$SWE = d_s * \rho_s / p_w$$

where:

d_s = snow depth

ρ_s = snow density

p_w = density of water.

Electrical Conductance (Actual Conductivity and Specific Conductance):

In this report conductivity of water is expressed as Actual Conductivity [AC] in microSiemens per centimeter (µS/cm). This unit is equivalent to micromhos per centimeter. Elsewhere, conductivity is commonly expressed as Specific Conductance at 25°C [SC25] in µS/cm which is temperature corrected. To convert AC to SC25 the following equation can be used:

$$SC25 = \frac{AC}{1 + r(T - 25)}$$

where:

SC25 = Specific Conductance at 25^{o}C, in µS/cm

AC = Actual Conductivity, in µS/cm

r = temperature correction coefficient for the sample, in ^{o}C

T = temperature of the sample, in ^{o}C

Milligrams per liter (mg/L) or micrograms per liter (µg/L):

Milligrams per liter is a unit of measurement indicating the concentration of chemical constituents in solution as weight (milligrams) of solute per unit volume (liter) of water. One thousand micrograms per liter is equivalent to one milligram per liter. For concentrations less than 7,000 mg/L, the numerical value is the same as for concentrations in parts per million (ppm).

Millivolt (mV):

A unit of electromotive force equal to one thousandth of a volt.

Vertical Datum:

"Sea level" in the following report refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929), a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called *Sea Level Datum of 1929*.

Horizontal Datum:

The horizontal datum for all locations in this report is the North American Datum of 1983 or North American Datum of 1927.

Abbreviations, Acronyms, and Symbols

AC	Actual conductivity
ADOT&PF	Alaska Department of Transportation and Public Facilities
ADNR	Alaska Department of Natural Resources
ASTM	American Society for Testing and Materials
atm	Atmospheres
ATN	Arctic Transportation Networks
C	Celsius (^{o}C)
cm	Centimeters
DO	Dissolved oxygen
DVM	Digital voltage multi-meter
F	Fahrenheit (^{o}F)
ft	Feet
GWS	Geo-Watersheds Scientific
in	Inches
kg	Kilograms
km^2	Square kilometers
kPa	Kilopascal
lb/in^2	Pounds per square inch
m	Meters
mg/L	Milligrams per liter
µg/L	Micrograms per liter
mi^2	Square miles
mm	Millimeters
µS/cm	Microsiemens per centimeter
mV	Millivolt
NGVD	National Geodetic Vertical Datum
NRCS	Natural Resources Conservation Service
NWIS	National Water Information System
ORP	Oxygen-reduction potential
ppm	Parts per million
QA	Quality assurance
QC	Quality control
Sag	Sagavanirktok River
SC25	Specific conductance at 25°C
SWE	Snow water equivalent
UAF	University of Alaska Fairbanks
USACE	U.S. Army Corps of Engineers, Alaska District
USGS	U.S. Geological Survey
WERC	Water and Environmental Research Center
WWW	World Wide Web
YSI	Yellow Springs Instruments

PROJECT COOPERATORS

The Arctic Transportation Network project covers a large area of the North Slope and benefits from a number of positive partnerships, all contributing to the overall project objectives.

- U.S. Department of Energy, National Energy Technology Laboratory (NETL)
- ConocoPhillips Alaska, Inc. (CPA)
- Bureau of Land Management
- Alaska Department of Natural Resources
- The Nature Conservancy
- Northern Alaska Environmental Center
- North Slope Borough
- National Weather Service
- Geo-Watersheds Scientific
- University of Alaska-Fairbanks
- Idaho National Laboratory
- Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE)

ACKNOWLEDGEMENTS

This material is based upon work supported by the U.S. Department of Energy [National Energy and Technology Laboratory] under Award Number DE-FE0001240. Field coordination and logistics support were provided by ConocoPhillips Alaska. Additional support was provided by other project cooperators, North Slope Borough, Bureau of Land Management, Bureau of Ocean Energy Management Regulation and Enforcement, National Weather Service, and Geo-Watersheds Scientific, in the form of financial and in-kind match. Alaska Department of Natural Resources provided data and supporting information for snow survey sites in the study area.

North Slope, Alaska, Snow-Course and Lake Survey Data: November 2010

INTRODUCTION

Geo-Watersheds Scientific (GWS), University of Alaska Fairbanks (UAF), and Idaho National Laboratory (INL), together with project cooperators, initiated a study in October 2009 to collect field data for the development of management tools for various aspects of Arctic Transportation Networks (ATN). Some of the variables collected include data from meteorological and lake stations (such as snow-depth, air and soil temperatures, unfrozen soil moisture, precipitation, wind and radiation data). Data is also collected at selected lakes and reservoirs. Lake data may include snow depth and density data, water-quality and water-level measurements and general observations of watershed conditions.

Snow depth is considered an important variable by regulatory agencies, since tundra travel operations (Alaska state lands) in the Coastal Tundra Area can only commence once a spatially consistent snow depth of 6 in (15 cm) in the coastal plain management areas, or 9 in (23 cm) in the Foothills management areas is maintained. Soil temperatures are also used to manage tundra travel on Alaska state lands. The soil temperature must reach 23° F (-5°C) at a depth of 12 in (30 cm) (Bader, 2004) to meet tundra travel management criteria. The intent of the soil temperature criteria is to ensure frozen soil strengths are adequate in terms of reaching maximum soil strength. Many meteorological factors determine when these conditions will be met. An established network of meteorological stations and increased manual snow measurements – both amount collected and number of sites visited – will improve the understanding of the timing and amount of snow distribution and will assist in the development of predictive and management tools.

Ice thickness on lakes and reservoirs is another important measurement related to Arctic transportation networks. Adequate ice thickness must exist before save travel over ungrounded ice (not frozen to bottom of lake or reservoir) can be conducted. In most cases, for lakes over 7 feet (2.1 m) deep, an end-of-season ice thickness of 7 ft (2.1 m) is assumed for the North Slope.

This is a conservative seasonal ice thickness that is rarely measured, but has provided a safe management approach in lack of supporting data for seasonal ice thicknesses over the North Slope and over time. Ice thickness data collected by the ATN project and others will be used to help develop better management approaches associated with water use and North Slope lakes and reservoirs.

TRIP OBJECTIVES

The November field effort was primarily focused on conducting snow-courses, lake measurements, and verification of meteorological station operations. Snow sampling was performed at co-located ADNR and ATN project sampling sites (see Figure 1). In addition to the standard snow-course measurements that will be continued from the spring season, additional measurement techniques were developed to address both the varying methods of measuring snow depth on the North Slope and the adequacy of current measurement standards. Concurrent with these activities, 2L-Pad meteorological station was upgraded with a remote Campbell Scientific CC640 camera.

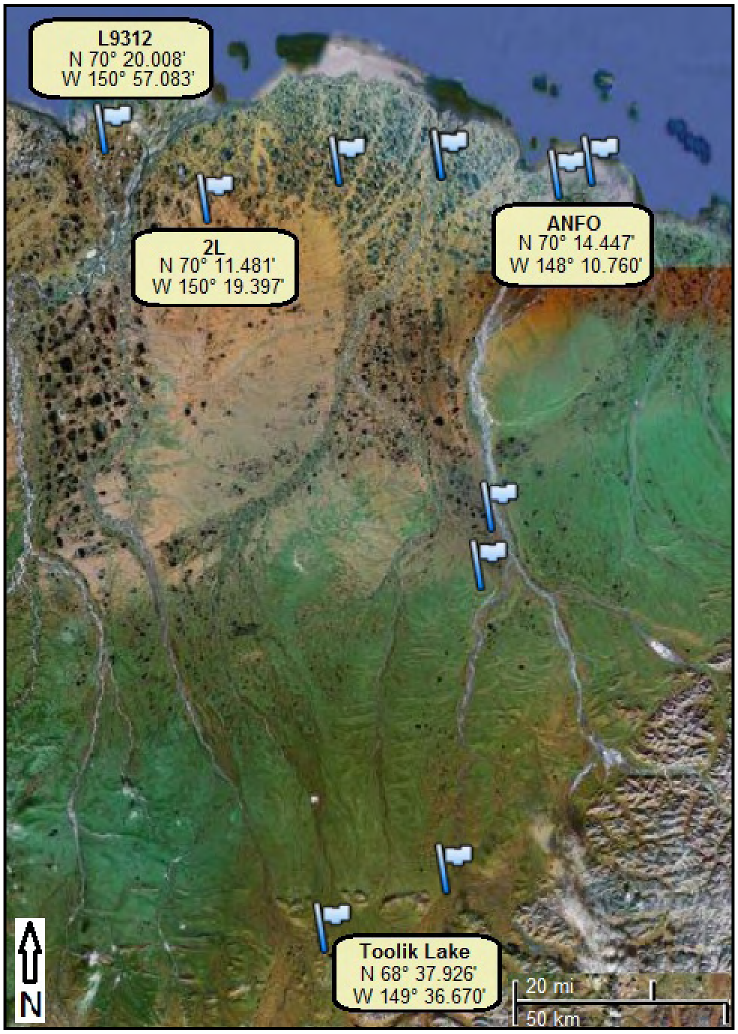

Figure 1. Snow-course locations visited in November 2010 are labeled.

A workplan was published prior to the November field campaign containing a site-by-site list of objectives (Murray et al. 2010). Project accomplishments include the following:

1. Central Kuparuk
    - Conducted snow courses and additional snow measurements to test snow measurement approaches
    - 2L station maintenance and upgrades – installed Campbell Scientific CC640 camera and camera lens heater

2. L9312
    - Conducted snow courses at L9312 on tundra and lake ice surface and addition snow measurements to test snow measurement approaches
    - L9312 station maintenance (update datalogger operating system)
    - Measured lake ice parameters

3. Kuparuk Area
   - Conducted snow courses at Kuparuk area sites and additional snow measurements to test snow measurement approaches

4. Toolik
   - Conducted snow courses on lake ice surface and addition snow measurements to test snow measurement approaches
   - Measured lake ice parameters

PROCEDURES

ATN's standard snow-depth measurements were conducted in "L" shaped patterns on lake surfaces and/or tundra surfaces at predetermined locations according to ATN snow measurement methods (Derry et al. 2009). Snow-depth measurements were taken with a T-handle probe approximately every 3.3 ft (1 m) for 82 ft (25 m), then turning 90 degrees, and continuing for another 82 ft (25 m). Snow samples were also collected for density measurements with an Adirondack snow sampler. Five densities were collected at each location and averaged to establish a representative density. A number of sampling sites are co-located with ADNR snow and soil sampling sites to compare sampling methods. The ADNR method has been changed, and it now involves collecting 20 depth measurements along a transect spaced at 5 meter increments with a meter long ruler and 5 density measurements collected with a Federal Sampler (Derry et al. 2009). The intent of co-located sites is to provide data for ADNR and ATN project staff to compare measurement methods at representative sites.

In order to better address this comparison, ATN project members have also incorporated performing snow course measurements with a ruler similar to that used by ADNR. At various sites and times throughout the season, ATN will measure snow depths with both the T-handle probe and the ruler to compare the precision of each technique on both tundra and lake ice surfaces.

Two other measurement practices are being integrated into ATN's practices throughout this winter season. ATN recommends the "L-transect" method, which involves a 50 meter transect with a right angle at the halfway point. To further test the validity of this method, a straight-line

100 meter transect is performed with snow depths measured at both 0.5 meter and 1 meter increments. This strategy is used to analyze the difference in the overall snow depth at a site by comparing the standard procedure with a larger sample size. The other new measurement practice is to collect snow depths from nearby roads adjacent to access sites to help determine if the snow-measurement sites are outside the influence of the roads. There is some concern that the depth of snow at some sampling locations is affected by drifting and depletion zones caused by the raised roads throughout the oil fields. Collecting snow-depth measurements across both sides of a road adjacent to the sampling sites over the course of the winter season will be used to address this issue.

At Lake L9312 and Toolik Lake, holes were drilled through the ice with a gas powered, 10-inch diameter ice auger. Water depth (lake bottom to water surface), freeboard (water surface to top of ice), ice thickness (bottom of ice to top of ice), and snow depth (top of ice to top of snow, measured at the hole where snow was cleared to drill) were measured after the hole was drilled. Water depth was measured with a flexible tape, and freeboard and ice thickness was measured with a folding tape. Snow depth was measured with the same T-handle probe that is used for snow courses.

SELECTED RESULTS

Snow course measurements were conducted at only five different locations during the November trip due to increased time spent for winter season planning and winter-storm conditions (Table 1). Eleven sites have been chosen for this winter season, several of which are co-located with ADNR sites (see Figure 2).

Table 1. November snow sampling locations, locations in bold indicate site is co-located with ADNR snow and soil temperature sampling sites.

Station	Elevation Ft	North Latitude NAD 83	West Longitude NAD 83
2L-Pad	112	70° 11.481'	150° 19.397'
ANFO 2	27	70° 14.447'	148° 10.760'
L9312 - Lake Surface	7	70° 20.008’	150° 57.083’
L9312 - Tundra Surface	7	70° 19.995’	150° 56.918’
Toolik Lake (Toolik Camp)	2,362	68° 37.926'	149° 36.670'

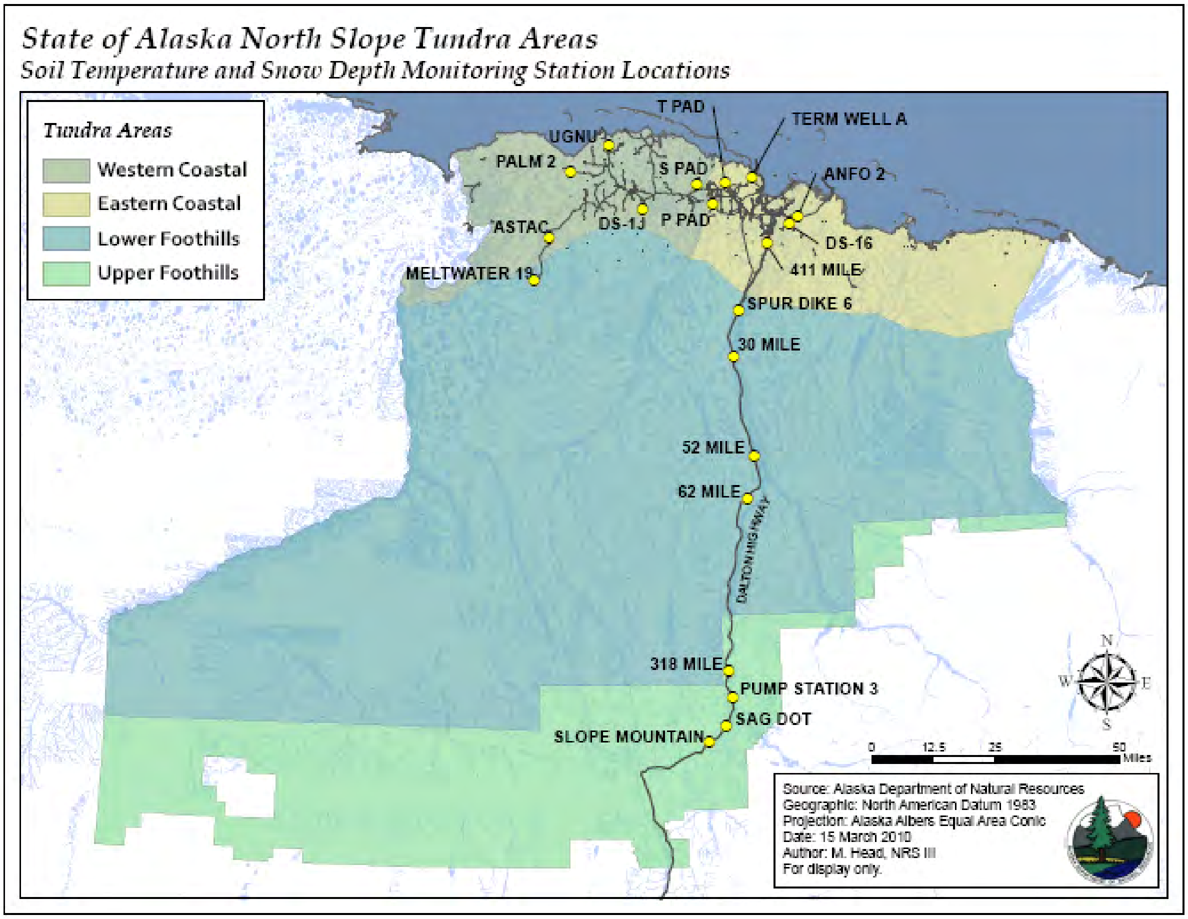

Figure 2. Map of ADNR snow and soil temperature sampling sites (ADNR, 2010).

Table 2 provides a summary of the snow data collected at the sampling sites visited in November. Sites were sampled in all areas except for the Lower Foothills. Individual snow forms can be found in Appendix A.

The November trip was the first effort to compare the multiple snow measurement techniques. At several of the sites, snow depths were collected according to the techniques previously described. Because so few sites were visited during the November trip, only a small sample size of the various measurement methods was able to be collected. Therefore, no conclusions about the efficacy of the measurement techniques should be drawn based on this month's results. Future field trip efforts will continue the data collection utilizing these methods, and new measurement questions will also be addressed.

Table 2. Summary of snow depth, density and SWE values from sites visited by ATN personnel in November.

	ATN Snow Data Collected in November				
	Snow Depth		Density	SWE	
	cm	in	g/cm^3	cm	in
Eastern Coastal Area					
ANFO 2	24.4	9.6	0.2	4.8	1.9
Western Coastal Area					
DS-2L (ASTAC)	21.60	8.50	0.20	4.40	1.73
L9312 - Tundra Surface	23.90	9.40	0.23	5.50	2.16
L9312 - Lake Surface	12.40	4.90	0.25	3.10	1.23
Upper Foothills Area					
Toolik Lake	12.6	4.9	0.18	2.3	0.9

Note: Above is ATN collected data but separated according to ADNR regions

Table 3 compares the results of the snow depth measurements that were obtained during the November trip utilizing the different techniques by ATN, LCMF, and ADNR at overlapping sampling sites. LCMF personnel have experience performing the “L” transect measurements from the previous spring season field trips and are accompanied by ATN staff. It is also important to note that ADNR did not collect data at the same time as ATN and LCMF, so the resulting differences in depths may be affected by wind and snow events occurring between relative sampling events.

Table 3. Average depth values collected with multiple techniques by ATN, LCMF, and ADNR personnel in November.

Snow Depth Data Collected in November (cm)					
	Method				
Site	**ATN "L"**	**LCMF "L"**	**ATN 100m**	**ATN Ruler**	**ADNR**
ANFO 2	24.4	--	--	--	19.3
DS-2L	21.6	--	23.3	--	22.3
L9312- Tundra	23.9	27.7	25.5	--	--
L9312- Lake	12.4	10.9	7.8	--	--
Toolik Lake	12.6	--	--	11.5	--

Field observations are helpful tools to describe the data displayed in Table 3. When comparing ATN's to LCMF's "L" transect, it was noted that the LCMF staff member used greater force when probing through the snow to reach the tundra surface than the ATN member. Also, while the two were measuring snow depth approximately 10 feet apart, LCMF seemed to cross through greater snow drifting than ATN. Both variables, in addition to uneven tundra surface, can likely account for the difference in the resulting snow depth. On the L9312 surface, there is also a noticeable difference in average snow depths according to Table 3. While measuring depths with the "L" transect and 100 meter transect, different snow patterns were observed. Because of the relatively small area covered with the "L" pattern, there was less snow cover variation recorded than in the 100 meter transect. The 100 meter transect covered a straight line path towards the center of the lake. Over the distance, more bare ice was recorded than during the "L" transect, which is likely the reason for the smaller snow depth average.

SUMMARY

During the November ATN trip, objectives focused on snow depth and density measurements. New questions have been raised to ensure accurate snow-sampling measurements are being collected. This trip is only the first that will address these questions, so they cannot adequately be answered with the results gathered during the November trip. Lake and ice depth measurements were taken along with a lake level survey, and at 2L-Pad Met station, a camera was installed to capture changes in snow and tundra conditions. The images are available online with other station data.

The collection of snow and lake information related to Arctic transportation networks will help the development of regulatory and user management tools and forecast modeling tools. These tools will help manage increasing resource development and variation of natural conditions in extreme Arctic climates.

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APPENDIX A. SNOW SURVEY FORMS

The following forms report the snow survey information obtained during field sampling.

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID:	**ATN Project**	Site Location/Lake ID:	**ANFO2**
Survey Purpose:	**Determine Snow Depth and SWE**	Date: 11/14/2010	Time: 17:30

Location Description:	Off road to the North. Near Duck Island gravel pit. Close to PVC pipe.. GWS stays to right (as looking at pipe) and DNR stays left.				
Survey objective:	SWE and Tundra Travel (Co-located snow survey site with DNR sampling site)			Weather Observations	~ -2F, 1- mph winds
Latitude:	N 70° 14.460'	Longitude:	W 148° 10.800'	Datum:	NAD 83
Elevation:	27 ft.	Elevation Datum:	NGVD29	Reference Markers:	Black PVC pipe
Drainage Basin:	Sagavanirktok River	Slope Direction:	Flat	Vegetation Type:	Upland Tussock Tundra
Slope Angle:	Flat	Access Notes:	Truck	Other:	soft snow, no voids or slabs
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray, Michael Lilly	

Snow Course Depths (cm)

	1	2	3	4	5
1	17.0	25.0	20.0	22.0	21.0
2	20.0	23.5	15.5	24.0	27.0
3	20.0	24.5	18.5	25.0	28.0
4	26.0	25.0	16.0	34.0	33.0
5	22.0	24.0	23.0	27.5	31.0
6	21.0	24.0	24.0	27.0	26.0
7	24.5	33.0	21.0	27.0	32.0
8	23.0	26.0	22.0	24.0	29.0
9	26.0	24.0	19.0	21.0	30.0
10	24.5	24.0	21.0	23.0	31.0

	(cm)
Average snow depth =	**24.4**
Maximum snow depth =	34.0
Minimum snow depth =	15.5
Standard deviation =	4.3

	(inches)
Average snow depth =	**9.6**
Maximum snow depth =	**13.4**
Minimum snow depth =	**6.1**
Standard deviation =	**1.7**

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
F1	24	154.0	856.8	0.18	
F5	18	107.1	642.6	0.17	
F4	26	219.5	928.2	0.24	
F2	28	202.6	999.6	0.20	
F3	23	167.0	821.1	0.20	

Average Density = **0.198**
Average Snow Water Equivalent (SWE) = **4.8** cm H2O
Average Snow Water Equivalent = **1.90** inches H2O
Average Snow Water Equivalent = **0.16** feet H2O

SWE = avg. snow depth*(density snow/density water)

Data entered by: Michael Lilly Date:11/14/10
Data QA/QC by: Jeff Murray Date: 11/15/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID:	**ATN Project**	Site Location/Lake ID:	**ADNR 2L-Pad**
Survey Purpose:	**Determine Snow Depth and SWE**	Date: 11/18/2010	Time: 14:20

Location Description:	West of road between 2L-Pad and 2N-Pad, near soil thermistors. GWS measures to right (as looking at bore tube from road) and DNR measures to left.				
Survey objective:	Co-located snow survey site with DNR sampling site, tundra travel studies and management. Snow depth comparison between ATN personnel			Weather Observations:	20s F, windy, overcast
Latitude:	N 70° 11.481'	Longitude:	W 150° 19.397'	Datum:	NAD83
Elevation:	112 ft	Elevation Datum:	NGVD29	Reference Markers:	Just northeast of weather station
Drainage Basin:	Miluveach River	Slope Direction:	Flat	Vegetation Type:	Lowland Wet Sedge Tundra
Slope Angle:	Flat	Access Notes:	Truck	Other:	strong surface layer, hoar frost beneath
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray	

Snow Course Depths (cm)

	1	2	3	4	5
1	18.0	17.0	21.0	46.0	21.5
2	21.0	21.0	19.0	43.0	15.0
3	18.5	26.0	16.0	39.0	9.0
4	15.0	22.5	16.5	36.0	24.0
5	20.0	23.5	16.0	26.0	25.0
6	28.0	23.5	17.0	19.0	17.0
7	27.0	19.0	26.0	24.0	19.5
8	26.0	15.0	19.5	18.0	12.5
9	24.0	13.0	19.0	12.0	14.0
10	22.0	24.0	27.0	16.0	20.0

	(cm)
Average snow depth =	**21.6**
Maximum snow depth =	46.0
Minimum snow depth =	9.0
Standard deviation =	7.3

	(inches)
Average snow depth =	**8.5**
Maximum snow depth =	**18.1**
Minimum snow depth =	**3.5**
Standard deviation =	**2.9**

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
9Q	14	65.6	499.8	0.13	
5Q	16	112.3	571.2	0.20	
P1	22	173.4	785.4	0.22	
8Q	18	140.1	642.6	0.22	
P4	23	207.6	821.1	0.25	

Average Density = **0.204**
Average Snow Water Equivalent (SWE) = **4.4** cm H2O
Average Snow Water Equivalent = **1.73** inches H2O
Average Snow Water Equivalent = **0.14** feet H2O

SWE = avg. snow depth*(density snow/density water)

Data entered by: Jeff Murray — Date: 11/19/10
Data QA/QC by: K. Hilton — Date: 12/1/2010

Arctic Transportation Networks Project

Form F-012: Snow Survey Form

Project ID:	**ATN Project**	Site Location/Lake ID:	**ADNR 2L-Pad (100m)**
Survey Purpose:	**Determine Snow Depth and SWE**	Date: 11/18/2010	Time: 14:20

Location Description:	West of road between 2L-Pad and 2N-Pad, near soil thermistors. GWS measures to right (as looking at bore tube from road) and DNR measures to left.				
Survey objective:	Co-located snow survey site with DNR sampling site, tundra travel studies and management. Snow depth comparison between ATN personnel			Weather Observations:	20s F, windy, overcast
Latitude:	N 70° 11.481'	Longitude:	W 150° 19.397'	Datum:	NAD83
Elevation:	112 ft	Elevation Datum:	NGVD29	Reference Markers:	Just northeast of weather station
Drainage Basin:	Miluveach River	Slope Direction:	Flat	Vegetation Type:	Lowland Wet Sedge Tundra
Slope Angle:	Flat	Access Notes:	Truck	Other:	strong surface layer, hoar frost beneath
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray	

Snow Course Depths (cm)

	1	2	3	4	5	6	7	8
1	38.0	20.0	27.0	31.0	14.0	24.0	22.5	17.0
2	43.0	22.0	28.0	33.0	19.5	25.0	21.5	16.0
3	39.0	26.0	28.0	28.0	22.0	24.0	27.5	13.0
4	37.5	18.0	28.0	30.0	17.0	30.0	26.0	19.0
5	36.0	20.0	27.0	24.0	22.0	33.0	25.0	13.0
6	35.0	20.5	30.0	29.0	12.0	24.0	20.0	14.0
7	34.0	22.5	33.5	30.0	15.0	21.0	26.0	13.0
8	32.0	19.0	31.5	23.0	13.0	14.0	12.0	14.0
9	38.0	19.5	30.0	29.0	19.0	13.0	15.0	16.0
10	38.0	20.0	25.0	35.0	18.0	15.0	16.0	12.0
11	36.0	19.0	22.0	36.0	36.0	20.0	21.0	19.0
12	40.0	14.0	20.0	37.0	29.0	19.0	18.0	30.0
13	39.0	15.0	19.0	37.5	32.0	20.0	15.0	25.0
14	36.5	21.0	23.0	22.0	27.0	15.0	13.0	32.0
15	29.0	20.0	21.0	14.0	24.0	18.0	22.0	37.0
16	37.0	22.5	18.0	14.0	27.0	15.0	23.0	30.0
17	35.0	25.0	15.0	16.0	24.0	14.0	22.0	30.0
18	35.0	27.0	19.0	13.0	23.5	17.0	21.5	20.0
19	35.0	20.0	24.0	20.0	23.0	19.0	25.0	19.0
20	35.0	22.0	24.0	12.0	25.5	19.0	20.0	25.0
21	30.0	27.5	17.0	17.5	19.5	19.0	21.5	29.0
22	32.0	28.0	14.0	16.0	20.0	14.0	24.0	28.0
23	15.0	29.0	27.0	16.0	21.0	15.0	23.0	22.0
24	18.0	29.0	23.0	13.5	14.0	11.0	20.0	26.0
25	24.0	28.5	20.0	15.0	22.0	19.0	17.0	26.0

	(cm)		(inches)
Average snow depth =	**23.3**	Average snow depth =	**9.2**
Maximum snow depth =	43.0	Maximum snow depth =	**16.9**
Minimum snow depth =	11.0	Minimum snow depth =	**4.3**
Standard deviation =	7.3	Standard deviation =	**2.9**

Data entered by: Jeff Murray　　Date: 11/19/10

Data QA/QC by: K. Hilton　　Date: 12/1/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID: **ATN**
Survey Purpose: **Determine snow depth, SWE**

Site Location/Lake ID: **L9312 - Lake Surface**
Date: 11/16/2010 Time: 12:00

Location Description:	On lake surface ~150 yards east from L9312 pumphouse.				
Survey objective:	Determine snow depth and density for application to lake recharge studies, and tundra travel management.			Weather Observations	Cold, Clear, Windy
Latitude:	N 70° 19.995'	Longitude:	W 150° 56.918'	Datum:	NAD 83
Elevation:	7 ft	Elevation Datum:	BPMSL	Reference Markers:	Lathe
Drainage Basin:	Colville Basin	Slope Direction:	Flat	Vegetation Type:	None, Ice surface
Slope Angle:	Flat	Access Notes:	Snow Machine	Other:	Packed snow, Areas of bare ice
Snow Depth Probe Type:		T- probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray, Jack Tiepelman (LCMF)	

Snow Course Depths (cm)

	1	2	3	4	5
1	5.0	2.0	16.5	15.0	23.0
2	7.0	1.0	13.0	21.0	24.0
3	7.0	4.0	9.0	21.5	27.0
4	8.0	1.0	9.0	20.0	26.0
5	2.0	3.0	8.5	18.5	23.0
6	1.0	6.5	5.0	18.0	15.0
7	6.0	14.0	5.0	20.5	14.0
8	5.0	10.0	4.0	22.0	16.5
9	5.0	13.0	6.0	22.5	20.0
10	7.0	14.0	10.0	24.0	19.0

	(cm)
Average snow depth =	**12.4**
Maximum snow depth =	27.0
Minimum snow depth =	1.0
Standard variation =	7.8

	(inches)
Average snow depth =	**4.9**
Maximum snow depth =	**10.6**
Minimum snow depth =	**0.4**
Standard variation =	**3.1**

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
BB1	6	46.5	214.2	0.22	
AA1	5	54.2	178.5	0.30	
AA4	6	42.2	214.2	0.20	
M2	20	230.2	714.0	0.32	
BB2	10	78.7	357.0	0.22	

Average Density = **0.252**
Average Snow Water Equivalent (SWE) = **3.1** cm H2O
Average Snow Water Equivalent = **1.23** inches H2O
Average Snow Water Equivalent = **0.10** feet H2O

SWE = avg. snow depth*(density snow/density water)

Data entered by: Jeff Murray Date: 11/17/10
Data QA/QC by: Kristie Hilton Date: 12/1/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID:	**ATN**	Site Location/Lake ID:	**L9312 - Lake (100m)**
Survey Purpose:	**Determine snow depth, SWE**	Date: 11/16/2010	Time: 12:20

Location Description:	On lake surface ~150 yards east from L9312 pumphouse.				
Survey objective:	Determine snow depth and density for application to lake recharge studies, and tundra travel management.			Weather Observations:	Cold, Clear, Windy
Latitude:	N 70° 19.995'	Longitude:	W 150° 56.918'	Datum:	NAD 83
Elevation:	7 ft	Elevation Datum:	BPMSL	Reference Markers:	Orange stakes
Drainage Basin:	Colville River	Slope Direction:	Flat	Vegetation Type:	None, Ice surface
Slope Angle:	Flat	Access Notes:	Snow Machine	Other:	Packed snow, Areas of bare ice
Snow Depth Probe Type:		T-probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray, Jack Tiepelman (LCMF)	

Snow Course Depths (cm)

	1	2	3	4	5	6	7	8
1	8.0	2.0	2.0	12.0	13.0	5.5	5.0	12.0
2	9.0	5.0	2.0	7.0	14.0	8.0	6.0	11.0
3	7.0	7.0	3.0	8.0	17.0	8.0	5.0	9.0
4	5.0	9.0	4.0	8.0	22.0	7.0	6.0	5.0
5	7.0	8.0	4.0	9.0	18.0	7.0	6.0	5.0
6	7.0	6.0	5.0	8.0	19.0	11.0	5.0	5.0
7	5.0	13.0	4.0	8.0	13.5	10.0	4.0	4.0
8	6.0	14.0	5.5	8.0	16.0	10.0	3.0	3.0
9	4.0	12.5	6.0	8.0	16.0	4.0	5.0	11.0
10	5.0	17.0	5.0	8.0	18.0	5.0	9.0	16.0
11	2.0	14.0	4.0	7.0	18.0	6.0	8.0	17.0
12	1.0	17.0	2.0	7.0	18.0	8.0	11.0	17.0
13	3.0	15.0	3.0	6.0	17.0	11.0	10.0	15.0
14	5.0	9.0	2.0	10.0	16.0	12.0	8.0	12.0
15	7.5	11.0	3.0	4.0	16.0	9.0	13.0	7.0
16	7.0	11.0	3.0	19.0	16.0	7.0	13.0	4.0
17	8.0	12.0	1.0	17.0	13.0	6.0	11.0	0.0
18	6.0	9.0	1.0	11.0	11.0	2.0	10.0	0.0
19	4.0	6.0	1.0	11.0	7.0	4.0	9.0	4.0
20	3.0	5.0	3.0	10.0	9.0	1.0	9.0	11.0
21	2.0	4.0	7.0	6.0	9.0	2.0	10.0	5.5
22	2.0	4.0	7.0	5.0	5.0	3.0	12.0	7.0
23	6.0	3.0	6.0	5.0	5.0	3.0	12.0	8.0
24	4.0	3.0	8.0	8.0	4.0	3.0	12.0	6.0
25	2.0	2.0	10.0	6.0	4.0	3.0	13.0	5.0

	(cm)		(inches)
Average snow depth =	**7.8**	Average snow depth =	**3.1**
Maximum snow depth =	22.0	Maximum snow depth =	**8.7**
Minimum snow depth =	0.0	Minimum snow depth =	**0.0**
Standard variation =	4.6	Standard variation =	**1.8**

Data entered by: Jeff Murray 11/17/2010
Data QA/QC by: Kristie Hilton 12/1/2010

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID:	**ATN**	Site Location/Lake ID:	**L9312 - Lake (LCMF)**
Survey Purpose:	**Determine snow depth, SWE**	Date: 11/16/2010	Time: 11:45

Location Description:	On lake surface ~150 yards east from L9312 pumphouse (conducted by LCMF).				
Survey objective:	Determine snow depth and density for application to lake recharge studies, and tundra travel management.			Weather Observations.	Cold, Clear, Windy
Latitude:	N 70° 20.008'	Longitude:	W 150° 57.083'	Datum:	NAD 83
Elevation:	7 ft	Elevation Datum:	BPMSL	Reference Markers:	Lathe
Drainage Basin:	Colville Basin	Slope Direction:	Flat	Vegetation Type:	None, Ice surface
Slope Angle:	Flat	Access Notes:	Snow Machine	Other:	Packed snow, Areas of bare ice
Snow Depth Probe Type:		T- probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jack Tiepelman (LCMF), Jeff Murray	

Snow Course Depths (cm)

	1	2	3	4	5
1	4.0	2.0	13.0	7.0	22.0
2	6.0	2.0	15.0	8.0	20.0
3	8.0	5.0	8.0	10.5	17.0
4	7.0	1.0	9.0	16.5	14.5
5	4.0	1.0	8.0	22.0	15.0
6	1.0	6.0	6.0	21.0	13.0
7	6.0	14.5	5.5	20.0	14.0
8	6.0	10.0	4.0	19.0	17.0
9	7.0	12.0	5.0	19.0	22.0
10	6.0	14.5	5.0	20.5	24.5

	(cm)
Average snow depth =	**10.9**
Maximum snow depth =	24.5
Minimum snow depth =	1.0
Standard variation =	6.7

	(inches)
Average snow depth =	**4.3**
Maximum snow depth =	**9.6**
Minimum snow depth =	**0.4**
Standard variation =	**2.6**

Data entered by: Jeff Murray — Date: 11/17/10
Data QA/QC by: Kristie Hilton — Date: 12/1/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID:	**ATN**	Site Location/Lake ID:	**L9312 - Tundra**
Survey Purpose:	**Determine snow depth, SWE**	Date: 11/16/2010	Time: 11:15

Location Description:	On tundra on staked course, adjacent and north of L9312 weather station.				
Survey objective:	Determine snow depth and density for application to lake recharge studies, and tundra travel management.			Weather Observations:	Cold, Clear, Windy
Latitude:	N 70° 19.995'	Longitude:	W 150° 56.918'	Datum:	NAD 83
Elevation:	7 ft	Elevation Datum:	BPMSL	Reference Markers:	Orange stakes
Drainage Basin:	Colville River	Slope Direction:	Flat	Vegetation Type:	Lowland Wet Sedge Tundra
Slope Angle:	Flat	Access Notes:	Snow Machine	Other:	Soft, Some surface layering
Snow Depth Probe Type:		T-probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray, Jack Tiepelman (LCMF)	

Snow Course Depths (cm)

	1	2	3	4	5
1	21.0	15.0	22.0	52.0	17.0
2	24.0	11.0	20.0	45.0	25.0
3	21.0	11.0	19.0	39.0	34.0
4	17.0	11.0	18.0	29.0	32.0
5	19.0	13.0	22.0	27.0	36.0
6	19.0	12.0	19.0	25.0	39.0
7	23.0	15.0	21.0	26.5	38.0
8	18.0	18.0	40.0	19.0	30.0
9	15.0	15.5	47.0	23.0	13.0
10	12.0	19.0	49.0	17.0	22.0

	(cm)
Average snow depth =	**23.9**
Maximum snow depth =	52.0
Minimum snow depth =	11.0
Standard variation =	10.6

	(inches)
Average snow depth =	**9.4**
Maximum snow depth =	**20.5**
Minimum snow depth =	**4.3**
Standard variation =	**4.2**

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
F2	35	269.4	1249.5	0.22	
F4	39	289.0	1392.3	0.21	
F3	30	270.5	1071.0	0.25	
F1	36	368.5	1285.2	0.29	
F5	28	184.2	999.6	0.18	

Average Density = **0.229**
Average Snow Water Equivalent (SWE) = **5.5** cm H2O
Average Snow Water Equivalent = **2.16** inches H2O
Average Snow Water Equivalent = **0.18** feet H2O

SWE = avg. snow depth*(density snow/density water)

Data entered by: Jeff Murray — Date: 11/17/10
Data QA/QC by: Kristie Hilton — Date: 12/1/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID: **ATN** Site Location/Lake ID: **L9312 - Tundra (100m)**
Survey Purpose: **Determine snow depth, SWE** Date: 11/16/2010 Time: 12:20

Location Description:	On tundra on staked course, adjacent and north of L9312 weather station.				
Survey objective:	Determine snow depth and density for application to lake recharge studies, and tundra travel management.			Weather Observations.	Cold, Clear, Windy
Latitude:	N 70° 19.995'	Longitude:	W 150° 56.918'	Datum:	NAD 83
Elevation:	7 ft	Elevation Datum:	BPMSL	Reference Markers:	Orange stakes
Drainage Basin:	Colville River	Slope Direction:	Flat	Vegetation Type:	Lowland Wet Sedge Tundra
Slope Angle:	Flat	Access Notes:	Snow Machine	Other:	Soft, Some surface layering
Snow Depth Probe Type:		T-probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray, Jack Tiepelman (LCMF)	

Snow Course Depths (cm)

	1	2	3	4	5	6	7	8
1	20.0	24.0	25.0	16.0	18.0	19.0	33.0	27.0
2	19.0	19.0	32.0	20.0	15.0	17.0	32.0	21.0
3	22.0	23.0	38.0	22.0	15.0	16.0	32.0	12.0
4	26.0	26.0	40.0	21.0	19.0	18.0	30.0	24.0
5	12.0	22.0	40.0	23.0	30.0	18.0	34.0	27.0
6	12.0	25.0	38.0	23.0	37.0	22.0	30.0	20.0
7	24.0	32.0	39.0	25.0	42.0	21.0	28.0	18.0
8	24.0	30.0	35.5	30.0	41.0	22.0	31.0	18.0
9	25.0	39.0	33.0	34.0	38.0	25.0	25.0	21.0
10	30.0	31.0	28.0	29.0	37.0	27.0	31.0	23.0
11	36.0	38.0	23.0	21.0	35.0	27.0	23.0	19.0
12	36.0	33.0	19.0	19.0	30.0	28.0	22.0	18.0
13	34.0	28.0	16.0	14.0	29.0	27.0	20.0	18.0
14	47.0	35.0	18.0	16.0	9.0	27.0	18.0	12.0
15	45.0	42.0	13.0	31.0	17.0	26.0	15.0	17.0
16	48.0	42.0	20.0	31.0	13.0	23.0	18.0	23.0
17	41.0	34.0	13.0	27.0	18.0	15.0	23.0	20.0
18	41.0	34.0	24.0	28.0	27.0	20.0	24.0	24.0
19	35.0	38.0	28.0	27.0	28.0	21.0	23.0	22.0
20	35.0	36.0	38.0	23.0	29.0	20.0	22.0	23.0
21	34.0	32.0	39.0	15.0	26.0	16.0	22.0	31.0
22	34.0	37.0	41.0	13.0	24.0	18.0	22.0	30.0
23	29.0	19.0	28.0	15.5	22.0	21.0	25.0	30.0
24	25.0	11.0	16.0	17.0	19.0	13.0	25.0	31.0
25	26.0	15.0	12.0	14.0	19.0	13.0	28.0	26.0

	(cm)		(inches)
Average snow depth =	**25.5**	Average snow depth =	**10.0**
Maximum snow depth =	48.0	Maximum snow depth =	**18.9**
Minimum snow depth =	9.0	Minimum snow depth =	**3.5**
Standard variation =	8.2	Standard variation =	**3.2**

Data entered by: Jeff Murray Date: 11/17/10
Data QA/QC by: Kristie Hilton Date: 12/1/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID: **ATN** Site Location/Lake ID: **L9312 - Tundra (LCMF)**
Survey Purpose: **Determine snow depth, SWE** Date: 11/16/2010 Time: 11:30

Location Description:	On tundra on staked course, adjacent and north of L9312 weather station (conducted by LCMF).				
Survey objective:	Determine snow depth and density for application to lake recharge studies, and tundra travel management.			Weather Observations	Cold, Clear, Windy
Latitude:	N 70° 19.995'	Longitude:	W 150° 56.918'	Datum:	NAD 83
Elevation:	7 ft	Elevation Datum:	BPMSL	Reference Markers:	Orange stakes
Drainage Basin:	Colville River	Slope Direction:	Flat	Vegetation Type:	Lowland Wet Sedge Tundra
Slope Angle:	Flat	Access Notes:	Snow Machine	Other:	Soft, Some surface layering
Snow Depth Probe Type:		T-probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jack Tiepelman (LCMF), Jeff Murray	

Snow Course Depths (cm)

	1	2	3	4	5
1	22.0	17.0	37.0	40.0	35.0
2	19.5	23.0	33.0	34.0	34.0
3	21.0	16.5	35.0	35.0	36.0
4	22.0	26.0	23.0	36.0	28.0
5	38.0	27.0	22.0	23.5	16.0
6	45.0	24.5	27.0	22.0	20.0
7	19.0	21.0	20.0	17.0	34.0
8	19.0	24.5	19.0	25.0	35.0
9	20.0	20.0	38.0	33.0	42.0
10	17.5	27.0	37.0	35.0	43.0

	(cm)
Average snow depth =	**27.7**
Maximum snow depth =	45.0
Minimum snow depth =	16.0
Standard variation =	8.2

	(inches)
Average snow depth =	**10.9**
Maximum snow depth =	**17.7**
Minimum snow depth =	**6.3**
Standard variation =	**3.2**

Data entered by: Jeff Murray Date: 11/17/10
Data QA/QC by: Kristie Hilton Date: 12/1/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID:	**ATN Project**	Site Location/Lake ID:	**Toolik Lake Site 4**
Survey Purpose:	**Determine Snow Depth and SWE**	Date: 11/19/2010	Time: 13:30

Location Description:	Toolik Lake. Site #4. Near center of lake.				
Survey objective:	SWE and tundra travel studies and management. Standard L-Transect			Weather Observations:	20s F, windy, Overcast
Latitude:	N 68° 37.926'	Longitude:	W 149° 36.670'	Datum:	NAD 83
Elevation:	2500 ft.	Elevation Datum:	NGVD27	Reference Markers:	none
Drainage Basin:	Toolik Lake	Slope Direction:	none	Vegetation Type:	None. Lake Ice
Slope Angle:	none	Access Notes:	Snow Machine	Other:	Soft, consistent throughout
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray	

Snow Course Depths (cm)

	1	2	3	4	5
1	12.5	9.0	16.0	9.0	15.0
2	8.5	9.0	14.0	11.0	15.0
3	11.0	7.5	13.0	11.0	16.0
4	7.0	9.0	13.0	11.5	16.0
5	7.0	13.0	12.0	11.0	17.0
6	7.5	15.0	12.0	11.0	19.0
7	7.0	17.0	10.0	12.0	22.0
8	9.5	17.0	9.0	12.0	22.0
9	8.0	17.5	8.0	14.0	22.0
10	5.0	18.5	6.0	14.0	19.0

	(cm)
Average snow depth =	**12.6**
Maximum snow depth =	22.0
Minimum snow depth =	5.0
Standard deviation =	4.3

	(inches)
Average snow depth =	**4.9**
Maximum snow depth =	**8.7**
Minimum snow depth =	**2.0**
Standard deviation =	**1.7**

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
F5	8	43.9	285.6	0.15	
F4	8	72.8	285.6	0.25	
BB2	11	59.3	392.7	0.15	
P1	14	92.9	499.8	0.19	
9Q	18	108.7	642.6	0.17	

Average Density = **0.183**
Average Snow Water Equivalent (SWE) = **2.3** cm H2O
Average Snow Water Equivalent = **0.90** inches H2O
Average Snow Water Equivalent = **0.08** feet H2O

SWE = avg. snow depth*(density snow/density water)

Data entered by: Jeff Murray — Date: 11/19/10
Data QA/QC by: Kristie Hilton — Date: 12/1/10

Arctic Transportation Networks Project
Form F-012: Snow Survey Form

Project ID: **ATN Project**
Survey Purpose: **Determine Snow Depth and SWE**

Site Location/Lake ID: **Toolik Lake Site 4 (Ruler)**
Date: 11/19/2010 Time: 13:40

Location Description:	Toolik Lake. Site #4. Near center of lake.				
Survey objective:	SWE and tundra travel studies and management. L-Transect with Ruler to compare with ADNR's sampling method.			Weather Observations:	20s F, windy, Overcast
Latitude:	N 68° 37.926'	Longitude:	W 149° 36.670'	Datum:	NAD 83
Elevation:	2500 ft.	Elevation Datum:	NGVD27	Reference Markers:	none
Drainage Basin:	Toolik Lake	Slope Direction:	none	Vegetation Type:	None. Lake Ice
Slope Angle:	none	Access Notes:	Snow Machine	Other:	Soft, consistent throughout
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Murray	

Snow Course Depths (in)

	1	2	3	4	5
1	4.75	2.75	5.75	3.50	5.75
2	4.00	3.00	2.25	4.50	5.75
3	3.00	3.00	4.50	4.25	6.00
4	2.50	3.50	4.75	4.00	6.00
5	2.50	3.75	4.50	4.00	6.50
6	2.50	5.00	4.25	4.00	7.20
7	2.50	6.25	4.00	4.25	8.00
8	3.00	6.00	3.25	4.25	8.25
9	3.00	6.50	3.00	5.00	8.00
10	1.75	6.50	2.25	5.25	7.00

	(inches)
Average snow depth =	**4.5**
Maximum snow depth =	8.3
Minimum snow depth =	1.8
Standard deviation =	1.7

	(cm)
Average snow depth =	**11.5**
Maximum snow depth =	**21.0**
Minimum snow depth =	**4.4**
Standard deviation =	**4.2**

Depths measured to nearest 1/4 inch

Data entered by: Jeff Murray Date: 11/19/10
Data QA/QC by: Kristie Hilton Date: 12/1/10

APPENDIX B. ADNR SNOW DATA

The following tables report snow information measured by ADNR staff. ADNR snow measurement methods prior to 11/15/10 recorded snow depths to the nearest 1-inch increment. Snow depths were recorded to the nearest 0.25-inch. Depth measurements were taken with a construction-scale metal ruler at 20 locations spread out over an approximate 300 foot transect. Density measurements were taken with a Federal Sampler at 5 locations.

Eastern Coastal Management Area

P Pad (N 70.282, W 148.912)																						average		
Date																						g/cm^3	in	cm
	depth (in)	7	7	7	15	6	6	6	5	5	11	6	7	6	10	9	9	9	7	10	7		7.75	19.69
11/1/2010	density (g/cm^3)	0.11	0.14	0.168	0.134	0.2																0.12		
	SWE (in)	0.96	0.78	1.092	0.938	1.597																	1.07	2.73

Eastern Coastal Management Area

T Pad (N 70.345, W 148.801)																						average		
Date																						g/cm^3	in	cm
	depth (in)	8	8	6	10	7	6	8	7	5	10	8	5	9	9	10	8	7	12	5	8		7.80	19.81
11/1/2010	density (g/cm^3)	0.12	0.13	0.104	0.106	0.124																0.13		
	SWE (in)	0.91	0.79	0.677	0.739	0.745																	0.77	1.96

Eastern Coastal Management Area

Term Well A (N 70.363, W 148.569)																						average		
Date																						g/cm^3	in	cm
	depth (in)	4	4	5	5	3	6	7	6	5	4	6	4	6	6	6	5	6	4	4	5		5.05	12.83
11/1/2010	density (g/cm^3)	0.21	0.19	0.124	0.224	0.101																0.20		
	SWE (in)	1.98	1.33	0.931	2.016	0.605																	1.37	3.48
	depth (in)	7	13	8.25	5.5	4.25	6.25	11	5.5	5	6	5.5	5.25	11	6.5	6.5	6.75	5.5	5.5	5.5	11		7.04	17.88
11/15/2010	density (g/cm^3)	0.40	0.21	0.298	0.184	0.272																0.30		
	SWE (in)	2.38	1.24	1.937	0.873	2.583																	1.80	4.58

Eastern Coastal Management Area

DS 16 (N 70.222, W 148.256)																						average		
Date																						g/cm^3	in	cm
	depth (in)	9	9	9	9	10	9	9	9	8	9	8	9	10	10	9	12	11	12	11	11		9.65	24.51
11/1/2010	density (g/cm^3)	0.17	0.15	0.176	0.148	0.142																0.16		
	SWE (in)	1.77	1.75	1.663	1.628	1.343																	1.63	4.14
	depth (in)	8	8	7	6	7.25	12	9	8	10.75	9.5	10.75	10	7.75	10	6.5	8.5	10.5	11.5	11.25	13.5		9.29	23.59
11/15/2010	density (g/cm^3)	0.25	0.25	0.255	0.233	0.224																0.25		
	SWE (in)	1.48	2.28	1.913	1.398	1.288																	1.67	4.25

Eastern Coastal Management Area

ANFO Pad (N 70.241, W 148.180)																						average		
Date																						g/cm^3	in	cm
	depth (in)	10	8	9	10	9	7	8	9	8	9	9	8	7	8	9	7	9	7	8	8		8.35	21.21
11/1/2010	density (g/cm^3)	0.18	0.12	0.195	0.158	0.194																		
	SWE (in)	1.17	1.08	1.855	1.498	1.742																		
	depth (in)	7	5.5	5.5	8	8	5	7	9	9	11.25	10	6.75	9.75	9.5	5.25	9	7	5	4.25	10.25		7.60	19.30
11/15/2010	density (g/cm^3)	0.27	0.73	0.12	0.204	0.206																0.50		
	SWE (in)	1.61	4.35	0.542	1.174	1.649																	1.87	4.74

Upper Foothills Management Area																								
Slope Mountain (N 68.718, W 149.015)																						average		
Date																						g/cm^3	in	cm
11/2/2010	depth (in)	6	9	10	5	10	6	7	7	7	11	7	7	9	10	6	7	7	8	8	6		7.65	19.43
	density (g/cm^3)	0.135	0.164	0.182	0.169	0.15																0.99		
	SWE (in)	0.74	1.23	1.003	1.182	0.976																	1.03	2.61
11/18/2010	depth (in)	15	8.75	16.75	13	13	12	14.5	10	8.5	17.75	10	11.5	19	9.5	14	6.5	10.5	9	8.5	12.5		12.01	30.51
	density (g/cm^3)	0.205	0.182	0.257	0.248	0.13																0.19		
	SWE (in)	2.662	1.687	2.882	2.109	0.618																	1.99	5.06

Upper Foothills Management Area																								
Sag River DOT (N 68.761, W 148.879)																						average		
Date																						g/cm^3	in	cm
11/2/2010	depth (in)	9	8	9	8	6	8	11	11	9	8	10	10	9	8	7	8	7	9	8	8		8.55	21.72
	density (g/cm^3)	0.11	0.11	0.128	0.116	0.092																0.11		
	SWE (in)	0.95	0.96	0.958	0.814	0.739																	0.88	2.24
11/18/2010	depth (in)	7.5	11.5	8.5	7.5	7	8	5.5	5	5.5	7.5	6.75	6	10.5	8.75	7	7	8	6.75	3.75	3.5		7.08	17.97
	density (g/cm^3)	0.243	0.172	0.164	0.19	0.1																0.21		
	SWE (in)	1.264	1.12	1.426	0.498																		1.08	2.74

Upper Foothills Management Area																								
Pump Station 3 (N 68.843, W 148.820)																						average		
Date																						g/cm^3	in	cm
11/2/2010	depth (in)	8	8	8	8	9	9	8	9	8	9	9	9	9	8	9	9	9	8	9	9		8.60	21.84
	density (g/cm^3)	0.14	0.13	0.135	0.122	0.127																0.13		
	SWE (in)	1.17	1.00	1.079	0.914	1.079																	1.05	2.66
11/18/2010	depth (in)	10.5	6.75	10.25	7	6.5	10	8.5	6.5	8	7.5	10.5	8.5	8	8	7	7.75	6.5	6.5	9.5	10.25		8.20	20.83
	density (g/cm^3)	0.15	0.137	0.193	0.127	0.145																0.14		
	SWE (in)	0.972	1.027	1.494	0.701	0.945																	1.03	2.61

Upper Foothills Management Area																								
318 Mile (N 68.922, W 148.850)																						average		
Date																						g/cm^3	in	cm
11/2/2010	depth (in)	9	9	8	9	8	8	8	9	8	10	8	8	7	7	10	8	10	8	8	8		8.40	21.34
	density (g/cm^3)	0.10	0.09	0.101	0.113	0.108																0.09		
	SWE (in)	0.82	0.84	0.958	1.02	0.976																	0.92	2.34
11/18/2010	depth (in)	9	9.75	13	11.25	12.25	10.75	7	6	6.5	9.25	12.75	4.25	11	12	8.5	6	10	7.5	5	10.25		9.10	23.11
	density (g/cm^3)	0.15	0.25	0.18	0.33	0.13																0.20		
	SWE (in)	1.78	2.67	1.24	3.43	1.37																	2.10	5.33

Lower Foothills Management Area																								
62 Mile (N 69.422, 148.659)																							average	
Date																						g/cm^3	in	cm
10/21/2010	depth (in)	7	10	10	9	9	10	9	10	12	12	11	12	10	9	12	8	8	12	6	10		9.80	24.89
	density (g/cm^3)	0.17	0.13	0.162	0.135	0.122																0.15		
	SWE (in)	1.72	0.99	1.295	1.144	1.285																	1.29	3.27
11/2/2010	depth (in)	12	13	13	16	16	11	13	15	9	9	10	7	12	14	11	10	13	15	17	9		12.25	31.12
	density (g/cm^3)	0.12	0.11	0.136	0.088	0.098																0.12		
	SWE (in)	2.01	1.67	1.288	1.055	1.027																	1.41	3.58

Lower Foothills Management Area																								
52 Mile (N 69.547, W 148.606)																							average	
Date																						g/cm^3	in	cm
10/21/2010	depth (in)	9	8	10	11	11	10	6	8	8	7	7	9	8	10	10	8	12	10	10	7		8.95	22.73
	density (g/cm^3)	0.10	0.12	0.125	0.109	0.099																0.11		
	SWE (in)	0.85	0.93	1.127	0.873	0.89																	0.94	2.38
11/18/2010	depth (in)	8.5	8	5	12	9	11.5	10.75	3.25	4.5	9	11	12.5	10	6	9.5	15.25	8.25	11	6.75	10.7		9.12	23.17
	density (g/cm^3)																							
	SWE (in)																							

Lower Foothills Management Area																								
30 Mile (N 69.839, W 148.758)																							average	
Date																						g/cm^3	in	cm
10/21/2010	depth (in)	2	3	4	1	1	1	2	2	2	2	3	3	1	4	2	1	1	4	3	1		2.15	5.46
	density (g/cm^3)																							
	SWE (in)																							
11/18/2010	depth (in)	5	4	4	4.5	9	4.5	7.25	5.25	3.75	4.25	5.75	8	3.25	6.75	3.25	4.75	2.5	2	4.5	9.75		5.10	12.95
	density (g/cm^3)																							
	SWE (in)																							

Lower Foothills Management Area																								
Spur Dike 6 - 20 Mile (N 69.975, W 148.709)																							average	
Date																						g/cm^3	in	cm
10/21/2010	depth (in)	6	3	4	5	6	2	4	3	2	2	3	3	5	4	4	3	5	6	3	3		3.80	9.65
	density (g/cm^3)																							
	SWE (in)																							

Lower Foothills Management Area																								
Meltwater 19 (N 70.065, W 150.448)																							average	
Date																						g/cm^3	in	cm
10/21/2010	depth (in)	7	8	11	11	7	9	9	10	8	9	7	7	11	10	9	9	11	11	8	9		9.05	22.99
	density (g/cm^3)	0.17	0.22	0.191	0.24	0.211																0.20		
	SWE (in)	1.12	2.06	1.525	2.044	1.9																	1.73	4.39
11/1/2010	depth (in)	8	8	12	9	6	8	4	4	6	9	8	6	5	8	12	6	3	6	14	5		7.35	18.67
	density (g/cm^3)	0.18	0.21	0.246	0.172	0.218																0.20		
	SWE (in)	1.10	1.38	2.336	1.034	2.075																	1.58	4.02
11/17/2010	depth (in)	10.25	13.75	16	6	6.5	16	8.25	5	10.5	6	14.5	10.5	12	5.25	12	8	10.75	5.25	13.5	9		9.95	25.27
	density (g/cm^3)	0.388	0.208	0.24	0.342	0.308																0.30		
	SWE (in)	4.363	0.782	1.082	2.391	2.618																	2.25	5.71

Western Coastal Management Area																								
DS-2L-ASTAC (N 70.235, W 150.452)																							average	
Date																						g/cm^3	in	cm
11/3/2010	depth (in)	6	5	7	6	10	5	5	7	7	6	9	8	6	7	7	5	9	6	5	9		6.75	17.15
	density (g/cm^3)	0.08	0.22	0.144	0.173																	0.15		
	SWE (in)	0.37	1.52	0.721	1.213																		0.96	2.43
11/17/2010	depth (in)	9.5	10.75	15.5	13.2	8	10	7	8	5.75	5.25	7.75	9.25	12.25	8.25	13	6.5	6.75	5.75	7	6.25		8.79	22.31
	density (g/cm^3)																							
	SWE (in)																							

Western Coastal Management Area																								
Palm 2 (N 70.384, W 150.138)																							average	
Date																						g/cm^3	in	cm
11/3/2010	depth (in)	5	7	7	7	7	8	5	8	10	7	5	6	8	8	7	9	4	7	5	7		6.85	17.40
	density (g/cm^3)																							
	SWE (in)																							

Western Coastal Management Area																								
Ugnu (N 70.458, W 149.809)																							average	
Date																						g/cm^3	in	cm
11/3/2010	depth (in)	6	7	7	11	5	5	6	8	6	6	5	6	7	5	5	5	6	6	6	5		6.15	15.62
	density (g/cm^3)																							
	SWE (in)																							
11/17/2010	depth (in)	6	10	7.75	5	4	6.5	13	9.75	7.25	9.25	11	13	13.5	8	13.75	12.75	7	9	7.75	6.5		9.04	22.96
	density (g/cm^3)	0.32	0.32	0.331	0.309	0.266																0.32		
	SWE (in)	2.32	3.03	2.401	1.776	2.065																	2.32	5.89

Western Coastal Management Area																								
S Pad (N 70.342, W 149.048)																							average	
Date																						g/cm^3	in	cm
11/3/2010	depth (in)	10	8	6	8	5	4	5	3	5	4	3	5	4	5	12	6	5	7	5	6		5.80	14.73
	density (g/cm^3)																							
	SWE (in)																							
11/16/2010	depth (in)	5.75	7	5.5	5.5	4.5	6	5	6	5	5	5	6	5	5.75	4.75	11.25	6.75	7	12	11		6.49	16.48
	density (g/cm^3)	0.18	0.19	0.287	0.253	0.3																0.18		
	SWE (in)	1.08	1.07	2.295	1.773	1.876																	1.62	4.11

APPENDIX C. ADNR SNOW DATA SUMMARY

The following table reports a summary of snow information obtained by ADNR staff.

	Oct 21-22			Nov 1-5			Nov 15-19		
	Depth (in)	Density (g/cm^3)	SWE (in)	Depth (in)	Density (g/cm^3)	SWE (in)	Depth (in)	Density (g/cm^3)	SWE (in)
Eastern Coastal Area									
ANFO Pad	--	--	--	8.4	--	--	7.6	0.50	1.9
DS 16	--	--	--	9.7	0.16	1.6	9.3	0.25	1.7
UAF 411 mi	--	--	--	--	--	--	--	--	--
Term Well A	--	--	--	5.1	0.20	1.4	7.0	0.30	1.8
P Pad	--	--	--	7.8	0.12	1.1	--	--	--
T Pad	--	--	--	7.8	0.13	0.8	--	--	--
Area Averages	N/A	N/A	N/A	7.7	0.15	1.2	8.0	0.35	1.8
Western Coastal Area									
S Pad	--	--	--	5.8	--	--	6.5	0.18	1.6
DS-1J	--	--	--	--	--	--	--	--	--
UGNU Pad	--	--	--	6.2	--	--	9.0	0.32	2.3
Palm 2	--	--	--	6.9	--	--	--	--	--
DS-2L (ASTAC)	--	--	--	6.8	0.15	1.0	8.8	--	--
Area Averages	N/A	N/A	N/A	6.4	0.15	1.0	8.1	0.25	2.0
Lower Foothills Area									
SpurDike 6-20 Mi	3.8	--	--	--	--	--	--	--	--
30 Mile	2.2	--	--	--	--	--	5.1	--	--
52 Mile	9.0	0.11	0.9	--	--	--	9.1	--	--
62 Mile	9.8	0.15	1.3	12.3	0.12	1.4	--	--	--
Meltwater 19	9.1	0.20	1.7	7.4	0.20	1.6	10.0	0.30	2.3
Area Averages	6.8	0.15	1.3	9.8	0.16	1.5	8.1	0.30	2.3
Upper Foothills Area									
318 Mile	--	--	--	8.4	0.09	0.9	9.1	0.20	2.1
Pump 3	--	--	--	8.6	0.13	1.1	8.2	0.14	1.0
Sag R. DOT	--	--	--	8.6	0.11	0.9	7.1	0.21	1.1
Slope Mountain	--	--	--	7.7	0.99	1.0	12.0	0.19	2.0
Area Averages	N/A	N/A	N/A	8.3	0.33	1.0	9.1	0.19	1.6

APPENDIX D. ELEVATION SURVEY FORMS

The following form reports the elevation survey information obtained during field sampling.

Arctic Transportation Networks

Form F-011: Elevation Survey Form

Project ID:	**ATN Project**	Site Location/Lake ID:	L9312
Survey Purpose:	**Water-Level Elevations**	Date: 11/16/2010	Time: 12:45

Location:	Lake L9312, located southeast of Alpine pad, survey by pump house benchmarks							
Survey objective:	Determine FWS Elevation.					Weather Observations:		
Instrument Type:	Leica NA720		Instrument ID:	5482372 (GWS owned)		Cold, Overcast, Slight breeze		
Rod Type:	Fiberglass		Rod ID:	Crane Fiber Glass				
Bench Mark Information:						Survey Team Names		
Name	Agency Responsible	Elevation (ft)	Latitude (dd-mm.mmm)	Longitude (ddd-mm.mmm)		Jeff Murray, Jack (LCMF)		
L9312"P"	CP	11.73	na	na				

Station	**BS (ft)**	**HI (ft)**	**FS (ft)**	**Elevation (fasl)**	**Distance (ft)**	**Horizontal Angle**	**Vertical Angle**	**Remarks**
TBM "P"	0.800	12.53		11.73				Top of inlet pipe support
TBM "O"		12.530	1.100	11.43				Top of inlet pipe support. BM Elev=11.44'
99-32-59		12.530	-2.000	14.53				Top of Pumphouse SE VSM. BM Elev = 14.53
L9312 WL		12.530	5.140	**7.39**				
L9312 Ice		12.530	4.980	7.55				
Turn on L9312 Ice								
L9312 Ice	4.93	12.480		7.55				
L9312 WL		12.480	5.09	7.39				**WL = 7.39**
99-32-59		12.480	-2.040	14.52				
TBM"O"		12.480	1.060	11.42				
TBM"P"		12.480	0.760	11.72				close survey to 0.01'

Abbreviations: backsight, BS; degrees, dd; feet, ft; feet above mean sea level, fasml; foresight, FS; height of instrument, HI; minutes, mm; seconds, ss; BP Mean Sea Level, BPMSL

APPENDIX E. LAKE HYDROLOGICAL MEASURMENTS

The following form reports physical measurements pertaining to lake ice obtained during field sampling.

Arctic Transportation Networks Project

FORM F-005: WATER-LEVEL MEASUREMENT FORM

Lake or Site ID: **L9312**

Local Number: Survey ID

ABBREVIATIONS
BOI, bottom of ice
Calib, used to calibrate PT
IS, ice surface
LB, lake bottom
LS, land surface
MP, measuring point
N/A, not available
WS, water surface

All measurements in feet, unless noted

	NAD83	
Elevation (ft)	Latitude (dd-mm.mmm)	Longitude (dd-mm.mmm)
7.00	N 70° 19.995'	W 150° 56.918'

Vertical-Datum Corrections, reference survey notes in site folders

Date	MP ID	MP Elevation (feet above BP Sea Level)	
3/26/2004	"P"	11.61	
1/16/2006	"P"	11.73	(BM elevation adjusted)

Date	Time	Method	Snow Depth	Total Depth IS to LB	Estimated Error	Ice Thickness (IS to BOI)	Freeboard (IS to WS)	WS Elevation	IS Elevation
11/16/10	12:45	Tape/Levels	0.41'	10.83'	+/- 0.01'	1.9'	0.16'	7.39'	7.55'

Collected Data Values

Lake-Full Elevation = measured at staff gage or near vertical benchmark after lake outflow ceased following spring snowmelt

Freeboard (FB) = Height of ice level over water level in open hole

Ice Thickness (IT) = Measured distance between top and bottom of ice

Total Depth (TD) = Measured distance from water surface to lake bottom

Estimated Error = Field estimate of water level measurement error

Calculated Values

Ice Surface (IS) Elevation = Water Elevation + Freeboard

Ice Bottom (IB) Elevation = Ice Surface Elevation - Ice Thickness

Arctic Transportation Networks Project

FORM F-005: WATER-LEVEL MEASUREMENT FORM

Lake or Site ID: **Toolik Lake**

Local Number: Survey ID NAD83

All measurements in feet, unless noted

Elevation (ft)	Latitude (dd-mm.mmm)	Longitude (dd-mm.mmm)
2382 ft.	N 68° 37.926'	W 149° 36.670'

Vertical-Datum Corrections, reference survey notes in site folders

ABBREVIATIONS

BOI, bottom of ice
Calib, used to calibrate PT
IS, ice surface
LB, lake bottom
LS, land surface
MP, measuring point
N/A, not available
WS, water surface
WD, water depth

Date	Time	Method	Snow Depth	Total Depth IS to LB	Estimated Error	Ice Thickness (IS to BOI)	Freeboard (IS to WS)	WD	Latitude (dd-mm.mmm)	Longitude (dd-mm.mmm)
11/19/10	13:30	Tape	0.41'	38.40'	+/- 0.01	1.45'	0.00'	38.40'	N 68° 37.926'	W 149° 36.670'

Collected Data Values

Lake-Full Elevation = measured at staff gage or near vertical benchmark after lake outflow ceased following spring snowmelt
Freeboard (FB) = Height of ice level over water level in open hole
Ice Thickness (IT) = Measured distance between top and bottom of ice
Total Depth (TD) = Measured distance from water surface to lake bottom
Estimated Error = Field estimate of water level measurement error

Calculated Values

Ice Surface (IS) Elevation = Water Elevation + Freeboard
Ice Bottom (IB) Elevation = Ice Surface Elevation - Ice Thickness