Snow-Course and Lake Survey Data for Selected Locations: November 2009

NRCS climate station at Toolik Camp, photo by Jeff Derry.

by

Jeff Derry, Kristie Hilton, Horacio Toniolo, and Michael Lilly

December 2009

Arctic Transportation Networks Project

Report GWS.TR.09.06

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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. 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:

Error! Bookmark not defined. $$SC25 = \frac{AC}{1 + r(T - 25)}$$

where:

SC25 = Specific Conductance at 25°C, in µS/cm

AC = Actual Conductivity, in µS/cm

r = temperature correction coefficient for the sample, in °C

T = temperature of the sample, in °C

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

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).

<u>Millivolt (mV)</u>:

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

<u>Vertical Datum</u>:

"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*.

<u>Horizontal Datum</u>:

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
AAS	Alaska's Arctic Slope
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
cm	centimeters
DO	Dissolved oxygen
DNR	Department of Natural Resources
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

ACKNOWLEDGEMENTS

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Snow-Course and Lake Survey Data for Selected Locations: November 2009

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 10 meteorological stations (including snow-depth, soil temperature, unfrozen soil moisture, precipitation, and wind radiation data), snow depth and density data, water-quality parameters and water quantity measurements on selected lakes and reservoirs.

Snow depth is an important variable with regulatory agencies since tundra travel operations in the Coastal Tundra Area commence once a spatially consistent snow depth of 6 in (15 cm) is maintained. Soil temperatures are equally crucial since 23° F (-5°C) at a depth of 12 in (30 cm) is also a requirement (Bader, 2004). Many meteorological factors determine when these conditions will be met. An established network of meteorological stations and increased snow measurements – both amount collected and number of sites visited – will increase the understanding of the timing and amount of snow distributions and will assist in the development of predictive and management tools.

TRIP OBJECTIVES

The primary goals of the November trip were to collect snow depth and density data (i.e. conduct snow-courses) from Toolik Camp north to the Coast Plain (Figure 1) with some of these sites being co-located with DNR soil and snow sampling locations (Figure 2), install a weather station at 2L-Pad, hold meetings with Department of Natural Resources personnel to discuss snow data collection methods, install water level sensors (pressure transducers) at L9312 station, and obtain lake level survey and physical data from L9312. This data will help resource developers and management agencies evaluate snow conditions in the region. A project workplan was distributed before the trip outlining the sampling schedule (Derry and others, 2009), however, logistical, personnel, and weather constraints may limit the amount of time available in the field for sampling.

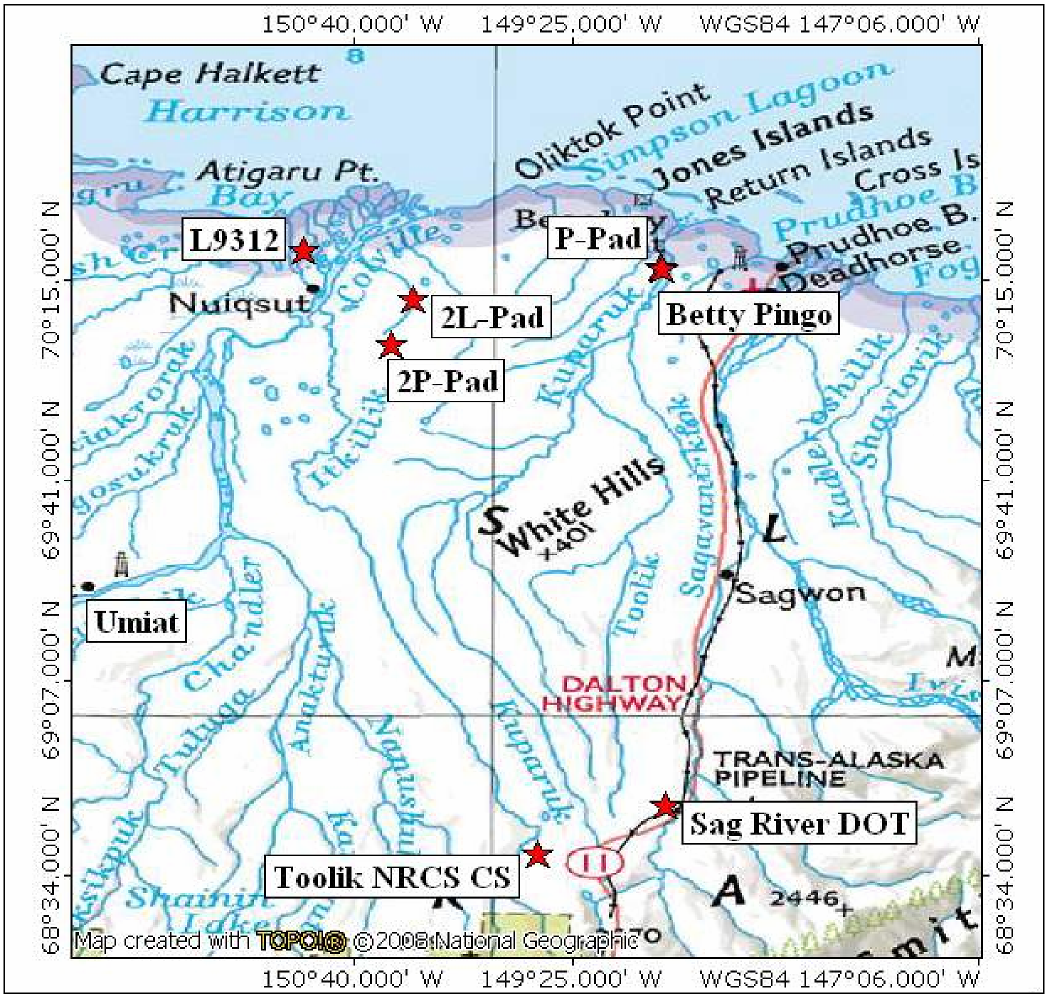

Figure 1. Snow-course locations visited in November by ATN project participants.

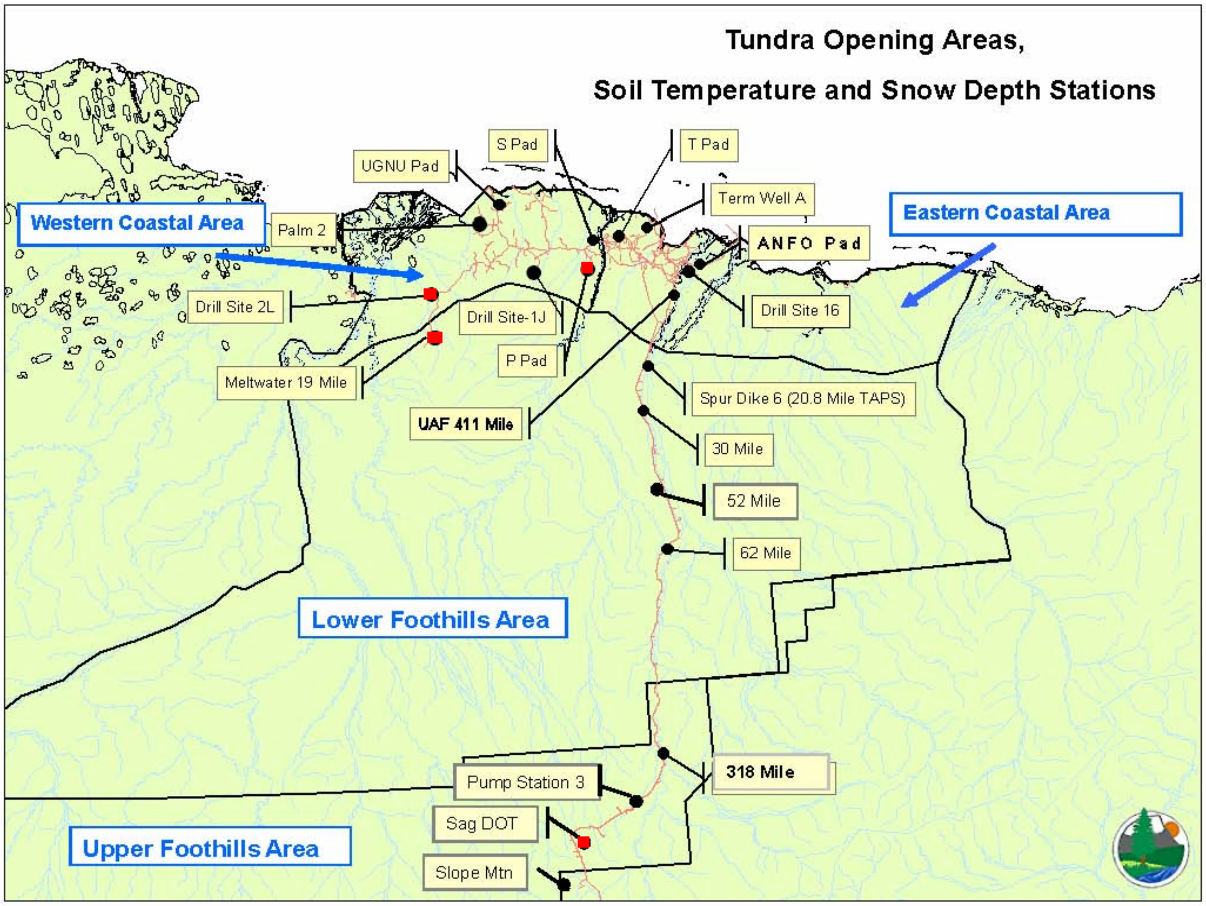

Figure 2. Map of DNR snow and soil temperature sampling sites (DNR, 2009). Sites marked in red were visited by ATN participants during the November field campaign to conduct snow-courses.

PROCEDURES

Small-scale snow depth measurements were conducted in "L" shaped patterns on lake surfaces and/or tundra surfaces at predetermined locations. Snow depth measurements were taken every 3.3 ft (1 m) for 82.0 ft (25 m), then turning 90 degrees, and continuing for another 82.0 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 DNR snow and soil sampling sites to compare sampling methods. The DNR method involves collecting 20 depth measurements along a transect spaced at 1 ft (0.3 m) increments and two density measurements collected with a Federal Sampler. The objective is to determine if the results vary significantly and whether or not the data-sets can be integrated allowing an increased temporal and spatial coverage.

At Lake L9312, a hole was drilled through the ice with a 10-inch diameter ice auger powered by a cordless drill. Physical measurements of 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 taken with a weighted flexible measuring tape. The precision with which physical measurements are reported takes into account field conditions

SELECTED RESULTS

Snow courses were conducted at eight different locations during the November trip with four of these locations being co-located with DNR sampling sites (Table 1).

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

station	elevation ft	north latitude NAD 83	west longitude NAD 83
Meltwater 19	200	70 03.853	150 26.779
DS-2L (ASTAC)	112	70 11.481	150 19.397
P Pad Access	10	70 16.967	148 54.807
Sag River DOT	1630	68 45.686	148 52.746
Betty Pingo (NRCS Site)	10	70 16.772	148 53.741
L9312-Tundra Surface	7	70 19.995	150 56.918
L9312-Lake Surface	7	70 20.008	150 57.083
NRCS Soil Monitoring Site (Toolik Camp)	2362	68 37.366	149 36.598

Results compare well for the four co-located sites (Table 2). The greatest difference in snow depth was at P-Pad where the ATN project method resulted in an average of 6.0 in (15.1 cm) and DNR results averaged 4.3 in (10.9 cm). The average depth for the four locations collected via the ATN method is 6.8 in (17.2 cm) and the DNR average is 6.0 in (15.3 cm), a difference of 0.8 in (2.0 cm), yet the coastal region only reports 5.6 in (14.1 cm) vs. 4.7 in (11.9 cm), respectively. The variability in snow depth and density resulted in no greater difference in SWE estimations between the two methods than 0.3 in (0.8 cm). The standard deviation in snow depth tended to be greater for the ATN method likely since this method collects more than double the amount of depths than the DNR method (50 depths vs. 20 depths).

Table 2. Comparison of average snow depth, density, and SWE at co-located ATN and DNR snow sampling sites.

	Sag River DOT				Meltwater 19				P Pad				DS-2L (ASTAC)			
	GWS		DNR		GWS		DNR		GWS		DNR		GWS		DNR	
	in	cm	in	cm	in	cm	in	cm	in	cm	in	cm	in	Cm	in	cm
depth	10.3	26.3	10.1	25.5	5.1	13.1	4.5	11.4	6.0	15.1	4.3	10.9	5.6	14.2	5.3	13.3
depth standard deviation	1.9	4.9	2.1	5.3	1.8	4.5	1.0	2.5	2.0	5.0	1.0	2.5	1.5	3.9	0.6	1.5
density	0.22		0.23		0.26		0.19		0.19		0.23		0.24		0.21	
SWE	2.3	5.8	2.0	5.0	1.3	3.4	1.0	2.5	1.2	2.9	0.9	2.3	1.3	3.4	1.3	3.2

Snow-course sites visited by ATN personnel (Table 3) show that snow depths are greater to the north by approximately 4.5 in (11.4 cm); this trend is also seen with the DNR data (Appendix B). Deeper snow was measured at L9312 (near Alpine) than at Meltwater 19, DS-2L, P-Pad, and Betty Pingo further to the east (8.9 in (22.7 cm) vs. 5.1 in (13.1 cm), 5.6 in (14.2 cm), 6.0 in (15.1 cm), 6.9 in (17.6 cm), respectively). The average depth of all sites was 6.9 in (17.6 cm) with a density of 0.25. At L9312, the average snow depths on the lake surface were approximately one-third of those reported at the nearby tundra surface. Lake surface snow samples also had a greater density (0.30 vs. 0.24) than the tundra surface samples at this location.

Table 3. Average snow depth, density and SWE for all locations visited by ATN personnel in November.

	Sag River DOT		Meltwater 19		P Pad		DS-2L (ASTAC)		Betty Pingo (NRCS Site)		L9312-Tundra Surface		L9312-Lake Surface		NRCS Soil Monitoring Site (Toolik Camp)	
	in	cm	in	cm	in	cm	in	cm	in	Cm	in	cm	in	cm	in	cm
depth	10.3	26.3	5.1	13.1	6.0	15.1	5.6	14.2	6.9	17.6	8.9	22.7	2.7	6.8	9.9	25.2
density	0.22		0.26		0.19		0.24		0.29		0.26		0.30		0.23	
SWE	2.3	5.8	1.3	3.4	1.2	2.9	1.3	3.4	2.0	5.1	2.3	5.9	0.8	2.0	2.3	5.8

On November 18 at Lake L9312 a water level elevation survey was completed along with the installation of two pressure transducers to record water levels on an hourly time-step. Water levels are higher than they were at this time last year due to a dryer than normal Summer/Fall in 2008 (Figure 3). Current water level conditions are more normal than last year when compared to information going back to 2004.

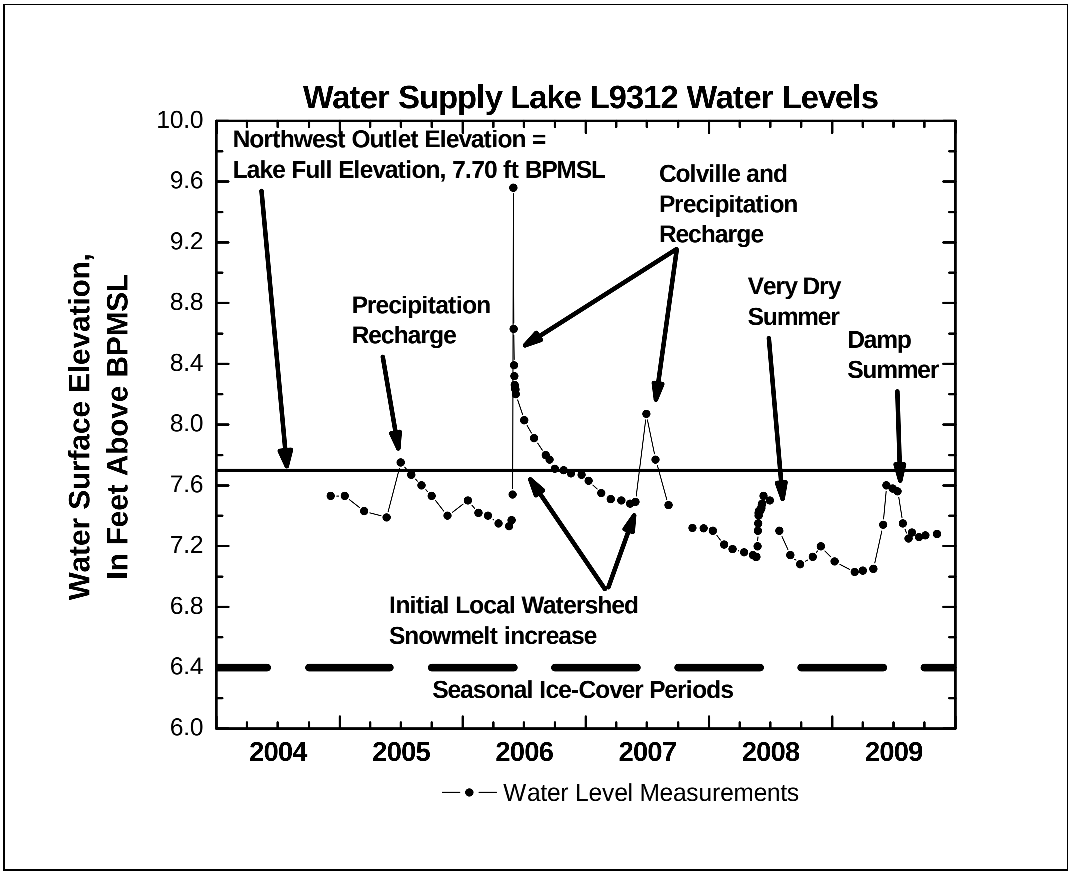

Figure 3. Plot of water level at L9312 through November 18, 2009.

SUMMARY

The November ATN field trip focused on 1) collecting snow depth and density data, and 2) collaboration with DNR personnel on snow data collection efforts at co-located sites. Other accomplishments include the initial installation of a meteorological station at 2L-Pad, the installation of pressure transducers at L9312, and a water level survey with lake ice physical measurements at L9312. Water levels are higher this year at L9312 than the previous year. The collected snow data indicate that snow depths are greater in the southern area of the Central North Slope and lesser towards the Coast. In an east-west direction depths are greater to the west. Data collected compares well between that collected by the ATN project and DNR. Average snow depths are below the minimum 6 in (15 cm) for tundra travel operations. Additional investigations of the timing and amount of snow distributions will help the development of management and predictive tools.

REFERENCES

Bader, H.R. 2004. Tundra Travel Research Project: Validation Study and Management Recommendations. Betula Consulting. 20 pages.

Department of Natural Resources. 2009. Winter Off-road Travel Conditions Monitoring Sampling Protocol. Department of Natural Resources, Division of Mining Land and Water. 4 pages.

Derry, J., Lilly, M.R., and Hilton, K. 2009. A Workplan for Snow Data Collection, Lake Observations and Meteorological Station Maintenance: November 2009. Geo-Watersheds Scientific, Fairbanks, Alaska. 15 pages.

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: **ADNR 2L-Pad**
Survey Purpose: **Determine Snow Depth and SWE**
Date: 11/17/2009 Time: 14:00

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			Weather Observations:	Cold, light conditions good
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:	Snow pack was fairly uniform some slabbing
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Derry, Brent Sheets	

Snow Course Depths (cm)

	1	2	3	4	5
1	12.0	12.0	10.0	11.0	11.0
2	11.0	12.0	19.0	14.0	12.0
3	11.0	8.0	11.0	12.0	10.0
4	12.0	25.0	17.0	23.0	11.0
5	10.0	17.5	16.0	25.0	10.0
6	12.0	14.0	12.0	20.0	10.0
7	17.0	12.0	17.0	15.0	14.0
8	16.0	18.0	13.0	16.0	14.0
9	17.0	14.0	16.0	16.0	20.0
10	12.0	11.0	12.0	15.5	13.0

	(cm)
Average snow depth =	**14.2**
Maximum snow depth =	25.0
Minimum snow depth =	8.0
Standard variation =	3.9

	(inches)
Average snow depth =	**5.6**
Maximum snow depth =	9.8
Minimum snow depth =	3.1
Standard variation =	1.5

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
V4	14	115.4	499.8	0.23	
V3	13	123.1	464.1	0.27	
V2	12	110.0	428.4	0.26	
V1	17	149.2	606.9	0.25	
V5	12	79.2	428.4	0.18	

Average Density = **0.237**
Average Snow Water Equivalent (SWE) = **3.4** cm H2O
Average Snow Water Equivalent = **1.32** inches H2O
Average Snow Water Equivalent = **0.11** feet H2O

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

Data entered by: Jeff Derry Date: 11/19/09
Data QA/QC by: Michael Lilly Date: 11/19/09

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

Project ID:	**ATN Project**	Site Location/Lake ID:	**ADNR 2P-Pad**
Survey Purpose:	**Determine Snow Depth and SWE**	Date: 11/17/2009	Time: 13:00

Location Description:	West of road to 2P-Pad, North of 2P Pad, North of 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			Weather Observations:	Cold, light outside
Latitude:	N 70° 03.853'	Longitude:	W 150° 26.779'	Datum:	NAD83
Elevation:	200 ft	Elevation Datum:	NGVD29	Reference Markers:	none
Drainage Basin:	Kachemach River	Slope Direction:	Flat	Vegetation Type:	Lowland Wet Sedge Tundra
Slope Angle:	Flat	Access Notes:	Truck	Other:	Snowpack uniform to ground, some slabbing
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Derry, Brent Sheets	

Snow Course Depths (cm)

	1	2	3	4	5
1	12.5	9.5	11.0	11.0	14.0
2	11.5	15.5	7.0	18.0	17.0
3	10.0	15.0	14.5	6.5	5.0
4	14.0	15.0	8.5	11.0	13.0
5	12.5	9.5	17.5	13.0	13.0
6	7.0	11.0	16.5	10.0	14.0
7	9.0	19.0	8.0	25.5	19.5
8	13.5	6.5	8.0	22.5	13.0
9	9.0	13.0	19.0	22.0	10.5
10	19.0	13.0	13.0	16.5	10.5

	(cm)
Average snow depth =	**13.1**
Maximum snow depth =	25.5
Minimum snow depth =	5.0
Standard variation =	4.5

	(inches)
Average snow depth =	**5.1**
Maximum snow depth =	10.0
Minimum snow depth =	2.0
Standard variation =	1.8

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
Z4	10	65.5	357.0	0.18	
Z3	19	190.8	678.3	0.28	
Z1	16	173.3	571.2	0.30	
Z5	17	193.7	606.9	0.32	
Z2	13	93.5	464.1	0.20	

Average Density = **0.258**
Average Snow Water Equivalent (SWE) = **3.4** cm H2O
Average Snow Water Equivalent = **1.33** inches H2O
Average Snow Water Equivalent = **0.11** feet H2O

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

Data entered by: Jeff Derry Date: 11/19/09
Data QA/QC by: Michael Lilly Date:11/19/09

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

Project ID: **ATN Project** Site Location/Lake ID: **Betty Pingo**
Survey Purpose: **Determine Snow Depth and SWE** Date: 11/17/2009 Time: 13:00

Location Description:	Near Wyoming gage. At staked snow site. Started east and then went north. Point of beginning is flagged rebar. Vertical snow gauge = Scoured, 0 reading. Snow Depth under Judd = 18,12,14,15,18. Wyoming Gauge = 31 1/8", I think, very hard to see/read.				
Survey objective:	SWE and tundra travel studies and management			Weather Observations:	Cold, Dark
Latitude:	N70°16.772'	Longitude:	W148°53.741'	Datum:	NAD83
Elevation:	34 ft.	Elevation Datum:	NVGD27	Reference Markers:	Re-bar and lathe
Drainage Basin:	Kuparuk River	Slope Direction:	Flat	Vegetation Type:	Lowland Moist Sedge-Shrub Tundra
Slope Angle:	Flat	Access Notes:	Truck	Other:	Hard Crust on most of snowpack
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Derry, Mike Lilly	

Snow Course Depths (cm)

	1	2	3	4	5
1	39.0	11.0	20.0	10.0	22.0
2	13.0	13.0	22.0	12.0	18.0
3	11.0	17.0	28.0	19.0	9.0
4	14.0	20.0	8.0	17.0	19.0
5	13.0	23.0	10.0	10.0	7.0
6	14.0	24.0	11.0	37.0	6.0
7	13.0	20.0	13.0	20.0	18.0
8	12.0	19.0	13.0	23.0	34.0
9	15.0	20.0	8.0	25.0	36.0
10	16.0	14.0	13.0	27.0	26.0

	(cm)
Average snow depth =	**17.6**
Maximum snow depth =	39.0
Minimum snow depth =	6.0
Standard variation =	7.8

	(inches)
Average snow depth =	**6.9**
Maximum snow depth =	15.4
Minimum snow depth =	2.4
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)
zoe1	50	672.4	1785.0	0.38	
zoe4	15	101.5	535.5	0.19	
zoe5	22	202.6	785.4	0.26	
zoe3	26	319.5	928.2	0.34	
zoe2	24	230.8	856.8	0.27	

Average Density = **0.288**
Average Snow Water Equivalent (SWE) = **5.1** cm H2O
Average Snow Water Equivalent = **2.00** inches H2O
Average Snow Water Equivalent = **0.17** feet H2O

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

Data entered by: Jeff Derry Date: 11/22/09
Data QA/QC by: Michael Lilly Date: 11/23/09

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: 11/19/2009 Time: 9:15

Location Description:	On lake surface ~150 yards from L9312 pumphouse.				
Survey objective:	Determine snow depth and density for application to lake recharge studies, and tundra travel management.			Weather Observations:	Dark, cold
Latitude:	N 70° 20.008'	Longitude:	W 150° 57.083'	Datum:	NAD 83
Elevation:	7 ft	Elevation Datum:	BPMSL	Reference Markers:	None, Ice surface
Drainage Basin:	Colville Basin	Slope Direction:	Flat	Vegetation Type:	None, Ice surface
Slope Angle:	Flat	Access Notes:	snowmobile	Other:	Dense snow, drifting, patches of clear ice
Snow Depth Probe Type:		T- probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Derry, Jack (LCMF)	

Snow Course Depths (cm)

	1	2	3	4	5
1	3.0	10.0	1.0	8.0	8.0
2	1.0	13.0	0.5	10.0	10.0
3	1.0	11.0	0.5	11.0	8.0
4	1.0	7.0	7.0	14.0	8.0
5	0.5	7.0	18.0	15.0	3.0
6	4.0	6.0	17.0	13.0	2.0
7	4.0	3.0	15.0	12.0	2.0
8	3.0	2.0	14.0	8.0	0.5
9	5.0	0.5	12.0	12.0	0.5
10	7.0	0.5	10.0	8.0	0.5

	(cm)
Average snow depth =	**6.8**
Maximum snow depth =	18.0
Minimum snow depth =	0.5
Standard variation =	5.2

	(inches)
Average snow depth =	**2.7**
Maximum snow depth =	7.1
Minimum snow depth =	0.2
Standard variation =	2.0

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
E5	5	43.4	178.5	0.24	
E1	10	147.4	357.0	0.41	
E3	26	341.8	928.2	0.37	
E4	16	202.0	571.2	0.35	
E2	5	21.0	178.5	0.12	

Average Density = **0.299**
Average Snow Water Equivalent (SWE) = **2.0** cm H2O
Average Snow Water Equivalent = **0.80** inches H2O
Average Snow Water Equivalent = **0.07** feet H2O

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

Data entered by: Jeff Derry Date: 11/19/09
Data QA/QC by: Michael Lilly Date: 11/19/09

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: 11/19/2009 Time: 9:00

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:	Dark, cold
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:	snowmobile	Other:	Snow pack was fairly uniform, some slabbing
Snow Depth Probe Type:		T-probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Derry, Jack (LCMF)	

Snow Course Depths (cm)

	1	2	3	4	5
1	16.0	10.0	21.0	19.0	21.0
2	22.0	9.0	18.0	18.0	35.0
3	26.0	9.0	19.0	14.0	58.0
4	21.0	15.0	17.0	14.0	56.0
5	47.0	18.0	10.0	10.0	51.0
6	22.0	20.0	19.0	21.0	45.0
7	14.0	29.0	11.0	17.0	47.0
8	15.0	27.0	11.0	11.0	38.0
9	13.0	24.0	29.0	13.0	34.0
10	12.0	17.0	21.0	17.0	32.0

	(cm)
Average snow depth =	**22.7**
Maximum snow depth =	58.0
Minimum snow depth =	9.0
Standard variation =	12.6

	(inches)
Average snow depth =	**8.9**
Maximum snow depth =	22.8
Minimum snow depth =	3.5
Standard variation =	5.0

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
D5	18	197.3	642.6	0.31	
D1	16	110.8	571.2	0.19	
D2	14	93.4	499.8	0.19	
D3	22	205.1	785.4	0.26	
D4	55	671.9	1963.5	0.34	

Average Density = **0.258**
Average Snow Water Equivalent (SWE) = **5.9** cm H2O
Average Snow Water Equivalent = **2.30** inches H2O
Average Snow Water Equivalent = **0.19** feet H2O

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

Data entered by: Jeff Derry Date: 11/19/09
Data QA/QC by: Michael Lilly Date: 11/19/09

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

Project ID: **ATN Project** Site Location/Lake ID: **NRCS Soil Site/Toolik**
Survey Purpose: **Determine Snow Depth and SWE** Date: 11/21/2009 Time: 12:00

Location Description:	Near Tollik Camp and Toolik Lake. Adjacent and south and west of NRCS long-term Climate Station				
Survey objective:	SWE and tundra travel studies and management			Weather Observations:	Cold, Light, Calm
Latitude:	N 68 37.366	Longitude:	W 149 36,598	Datum:	NAD 83
Elevation:	2500 ft.	Elevation Datum:	NGVD27	Reference Markers:	NRCS Station
Drainage Basin:	Toolik Lake	Slope Direction:	East	Vegetation Type:	Upland Shrubby Tussuck Tundra
Slope Angle:	~10 degrees	Access Notes:	Walk from Toolik	Other:	Uniform accumulation
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Derry, Mike Lilly	

Snow Course Depths (cm)

	1	2	3	4	5
1	31.0	23.0	27.0	32.0	18.0
2	22.0	30.0	23.0	39.0	22.0
3	25.0	26.0	24.0	36.0	34.0
4	21.0	15.0	27.0	31.0	21.0
5	25.0	23.0	23.0	24.0	30.0
6	24.0	17.0	22.0	30.0	21.0
7	25.0	26.0	28.0	21.0	21.0
8	24.0	36.0	29.0	23.0	29.0
9	26.0	13.0	15.0	16.0	25.0
10	22.0	27.0	27.0	31.0	28.0

	(cm)
Average snow depth =	**25.2**
Maximum snow depth =	39.0
Minimum snow depth =	13.0
Standard variation =	5.5

	(inches)
Average snow depth =	**9.9**
Maximum snow depth =	15.4
Minimum snow depth =	5.1
Standard variation =	2.2

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
Z2	23	193.1	821.1	0.24	
Z3	24	209.1	856.8	0.24	
Z1	28	262.0	999.6	0.26	
Z5	21	166.3	749.7	0.22	
Z4	21	143.6	749.7	0.19	

Average Density = **0.231**
Average Snow Water Equivalent (SWE) = **5.8** cm H2O
Average Snow Water Equivalent = **2.29** inches H2O
Average Snow Water Equivalent = **0.19** feet H2O

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

Data entered by: Jeff Derry Date: 11/22/09
Data QA/QC by: Michael Lilly Date: 11/23/09

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: **Sag River DOT**
Date: 11/21/2009 Time: 13:00

Location Description:	On Road to DOT garage. Near soil thermistor bore hole. GW-S stays to right (as looking at bore tube) and DNR stays left.				
Survey objective:	SWE and Tundra Travel (Co-located snow survey site with DNR sampling site)			Weather Observations:	Cold, Light, Calm
Latitude:	N 68 45.686	Longitude:	W 148 52.746	Datum:	NAD 83
Elevation:	1640 ft.	Elevation Datum:	NGVD29	Reference Markers:	Soil Thermistor bore hole
Drainage Basin:	Kuparuk	Slope Direction:	Flat	Vegetation Type:	Upland Tussock Tundra
Slope Angle:	Flat	Access Notes:	Truck	Other:	
Snow Depth Probe Type:		T-Handle Probe		Snow-Survey Team Names:	
Snow Tube Type:	Adirondack Snow Tube			Jeff Derry, Mike Lilly	

Snow Course Depths (cm)

	1	2	3	4	5
1	23.0	16.0	21.0	25.0	27.0
2	29.0	21.0	28.0	22.0	35.0
3	30.0	20.0	28.0	19.0	33.0
4	26.0	28.0	29.0	18.0	25.0
5	29.0	23.0	23.0	25.0	31.0
6	33.0	26.0	19.0	31.0	31.0
7	27.0	24.0	26.0	40.0	36.0
8	22.0	25.0	26.0	34.0	31.0
9	26.0	27.0	22.0	27.0	22.0
10	26.0	23.0	23.0	23.0	30.0

	(cm)
Average snow depth =	**26.3**
Maximum snow depth =	40.0
Minimum snow depth =	16.0
Standard variation =	4.9

	(inches)
Average snow depth =	**10.3**
Maximum snow depth =	15.7
Minimum snow depth =	6.3
Standard variation =	1.9

Snow Sample Depths and Weights

Bag #	Snow Depth (cm)	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Organic Plug (cm)
V4	22	175.1	785.4	0.22	
V2	21	166.4	749.7	0.22	
V3	19	163.9	678.3	0.24	
V1	35	221.0	1249.5	0.18	
V5	32	275.8	1142.4	0.24	

Average Density = **0.221**
Average Snow Water Equivalent (SWE) = **5.8** cm H2O
Average Snow Water Equivalent = **2.29** inches H2O
Average Snow Water Equivalent = **0.19** feet H2O

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

Data entered by: Jeff Derry Date: 11/22/09
Data QA/QC by: Michael Lilly Date: 11/23/09

APPENDIX B. DNR SNOW DATA

The following table reports snow information obtained by DNR in November.

DNR Data From Soil and Snow Stations: Snow Depth, Snow Density, and Snow Water Equivalent

Data Collected November 16 - 20

station	*Upper Foothills*																				average	
																					in	cm
Slope Mountain																						
depth (in)	11.0	12.0	9.0	8.0	7.0	8.0	12.0	9.0	6.0	8.0	7.0	10.0	9.0	6.0	9.0	9.0	8.0	8.0	6.0	7.0	8.5	21.5
density (g/cm^3)	0.24	0.18																			0.21	
SWE (in)	1.3	1.2																			1.3	3.2
Sag R. DOT																						
depth (in)	7.0	11.0	10.0	10.0	9.0	10.0	13.0	12.0	7.0	8.0	10.0	10.0	14.0	7.0	14.0	11.0	10.0	10.0	8.0	10.0	10.1	25.5
density (g/cm^3)	0.25	0.22																			0.23	
SWE (in)	2.5	1.4																			2.0	5.0
Pump 3																						
depth (in)	10.0	9.0	11.0	10.0	13.0	11.0	10.0	10.0	12.0	10.0	11.0	12.0	10.0	13.0	10.0	10.0	11.0	11.0	12.0	9.0	10.8	27.3
density (g/cm^3)	0.22	0.23																			0.22	
SWE (in)	2.3	2.6																			2.4	6.1
318 Mile																						
depth (in)	14.0	13.0	11.0	13.0	12.0	8.0	13.0	14.0	14.0	13.0	13.0	13.0	14.0	13.0	14.0	13.0	11.0	15.0	12.0	13.0	12.8	32.5
density (g/cm^3)	0.23	0.21																			0.22	
SWE (in)	2.8	2.7																			2.7	6.9

DNR Data From Soil and Snow Stations: Snow Depth, Snow Density, and Snow Water Equivalent

Data Collected November 16 - 20

station	*Lower Foothills*																				average in	average cm
62 Mile																						
depth (in)	8.0	9.0	9.0	6.0	13.0	10.0	7.0	9.0	5.0	12.0	5.0	7.0	11.0	11.0	10.0	7.0	7.0	7.0	11.0	7.0	8.6	21.7
density (g/cm^3)	0.20	0.18																			0.19	
SWE (in)	1.7	1.4																			1.5	3.9
52 Mile																						
depth (in)	8.0	7.0	10.0	12.0	7.0	12.0	6.0	8.0	12.0	10.0	5.0	5.0	5.0	10.0	8.0	14.0	7.0	9.0	11.0	10.0	8.8	22.4
density (g/cm^3)	0.14	0.16																			0.15	
SWE (in)	1.6	1.2																			1.4	3.6
30 Mile																						
depth (in)	3.0	3.0	4.0	3.0	3.0	2.0	4.0	4.0	4.0	3.0	3.0	3.0	4.0	3.0	4.0	4.0	4.0	5.0	4.0	2.0	3.5	8.8
density (g/cm^3)	0.18	0.13																			0.15	
SWE (in)	0.6	0.5																			0.6	1.4
SpurDike 6-20 Mi																						
depth (in)	6.0	8.0	4.0	8.0	8.0	10.0	6.0	8.0	10.0	8.0	6.0	5.0	7.0	7.0	7.0	9.0	5.0	6.0	8.0	6.0	7.1	18.0
density (g/cm^3)	0.28	0.30																			0.29	
SWE (in)	2.0	1.5																			1.7	4.4
Meltwater 19																						
depth (in)	3.0	4.0	4.0	5.0	5.0	5.0	6.0	4.0	4.0	4.0	4.0	6.0	3.0	6.0	5.0	3.0	6.0	4.0	5.0	4.0	4.5	11.4
density (g/cm^3)	0.15	0.24																			0.19	
SWE (in)	0.7	1.2																			1.0	2.5

DNR Data From Soil and Snow Stations: Snow Depth, Snow Density, and Snow Water Equivalent

Data Collected November 16 - 20

station	*Eastern Coastal Area*																				average	
																					in	cm
UAF 411 mi																						
depth (in)	4.0	3.0	4.0	5.0	4.0	5.0	4.0	3.0	6.0	3.0	4.0	4.0	5.0	5.0	6.0	5.0	4.0	4.0	6.0	6.0	4.5	11.4
density (g/cm^3)	0.25	0.23																			0.24	
SWE (in)	1.5	1.5																			1.5	3.8
P Pad																						
depth (in)	3.0	4.0	4.0	4.0	4.0	3.0	5.0	4.0	4.0	7.0	4.0	4.0	3.0	4.0	6.0	4.0	4.0	4.0	5.0	6.0	4.3	10.9
density (g/cm^3)	0.20	0.26																			0.23	
SWE (in)	1.0	0.8																			0.9	2.3
T Pad																						
depth (in)	4.0	2.0	4.0	2.0	3.0	5.0	4.0	5.0	4.0	4.0	4.0	5.0	4.0	5.0	5.0	3.0	5.0	1.0	5.0	4.0	3.9	9.9
density (g/cm^3)	0.19	0.40																			0.30	
SWE (in)	0.9	1.8																			1.4	3.5
Term Well A																						
depth (in)	4.0	5.0	3.0	5.0	3.0	2.0	4.0	5.0	4.0	4.0	3.0	4.0	4.0	3.0	4.0	4.0	3.0	3.0	3.0	6.0	3.8	9.7
density (g/cm^3)	0.23	0.19																			0.21	
SWE (in)	0.9	0.7																			0.8	2.1
DS 16																						
depth (in)	7.0	7.0	7.0	6.0	5.0	7.0	2.0	7.0	8.0	4.0	7.0	3.0	6.0	6.0	3.0	6.0	4.0	5.0	5.0	3.0	5.4	13.7
density (g/cm^3)	0.50	0.40																			0.45	
SWE (in)	4.0	2.6																			3.3	8.4
ANFO Pad																						
depth (in)	4.0	3.0	3.0	3.0	2.0	4.0	3.0	3.0	2.0	2.0	4.0	2.0	4.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	7.6
density (g/cm^3)	0.47	0.34																			0.40	
SWE (in)	1.4	1.0																			1.2	3.1

DNR Data From Soil and Snow Stations: Snow Depth, Snow Density, and Snow Water Equivalent

Data Collected November 16 - 20

station	*Western Coastal Area*																				average	
																					in	cm
DS-2L (ASTAC)																						
depth (in)	5.0	5.0	5.0	4.0	5.0	4.0	5.0	5.0	5.0	6.0	6.0	5.0	6.0	6.0	6.0	6.0	6.0	5.0	5.0	5.0	5.3	13.3
density (g/cm^3)	0.29	0.13																			0.21	
SWE (in)	1.8	0.8																			1.3	3.2
Palm 2																						
depth (in)	5.0	5.0	4.0	5.0	5.0	6.0	5.0	5.0	5.0	5.0	3.0	5.0	5.0	5.0	5.0	5.0	7.0	4.0	4.0	4.0	4.9	12.3
density (g/cm^3)	0.20	0.22																			0.21	
SWE (in)	0.8	1.3																			1.1	2.7
Ugnu																						
depth (in)	6.0	4.0	3.0	5.0	3.0	5.0	6.0	6.0	5.0	3.0	4.0	4.0	3.0	3.0	4.0	3.0	5.0	3.0	3.0	3.0	4.1	10.3
density (g/cm^3)	0.38	0.17																			0.28	
SWE (in)	1.9	0.7																			1.3	3.3
DS-1J																						
depth (in)	10.0	9.0	5.0	6.0	7.0	9.0	13.0	6.0	6.0	5.0	11.0	7.0	8.0	10.0	5.0	9.0	3.0	5.0	9.0	6.0	7.5	18.9
density (g/cm^3)	0.26	0.32																			0.29	
SWE (in)	1.8	2.7																			2.3	5.7
S Pad																						
depth (in)	4.0	5.0	5.0	6.0	7.0	3.0	5.0	6.0	6.0	6.0	3.0	5.0	6.0	8.0	7.0	4.0	5.0	6.0	7.0	6.0	5.5	14.0
density (g/cm^3)	0.58	0.21																			0.39	
SWE (in)	3.8	0.9																			2.3	6.0

APPENDIX C. L9312 ELEVATION SURVEY FORM

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

Arctic Transportation Networks

Form F-011: Elevation Survey Form

Project ID: **ATN** Site Location/Lake ID: L9312

Survey Purpose: **Water-Level Elevations** Date: 11/18/2009 Time: 17:27

Location:	Lake L9312, located southeast of Alpine pad, survey by pump house benchmarks. Lake ice thickness = 1.58', freeboard = .04', snow depth = 0.04'								
Survey objective:	Determine FWS Elevation.					Weather Observations:	-27°F, Dark.		
Instrument Type:	Leica NA720		Instrument ID:	5482372 (GWS owned)					
Rod Type:	Fiberglass		Rod ID:	Crane Fiber Glass					
Bench Mark Information:						Survey Team Names	Lilly, Derry		
Name	Agency Responsible	Elevation (ft)	Latitude (dd-mm.mmm)	Longitude (ddd-mm.mmm)					
L9312"P"	CP	11.73	N 70 19.995	W 150 56.918					

Station	**BS (ft)**	**HI (ft)**	**FS (ft)**	**Elevation (fasl)**	**Distance (ft)**	**Horizontal Angle**	**Vertical Angle**	**Remarks**
TBM "P"	2.09	13.82		11.73				Top of inlet pipe support
TBM "O"		13.82	2.36	11.46				Top of inlet pipe support. BM Elev=11.46'
99-32-59		13.82	0.73	14.55				Top of Pumphouse SE VSM. BM Elev = 14.55
L9312 WL		13.82	6.56	7.26				
Turn on L9312 WL								
L9312 WL	6.36	13.62		7.26				
99-32-59		13.62	0.93	14.55				
TBM"O"		13.62	2.16	11.46				
TBM"P"		13.62	1.89	11.73				close survey to 0.00'

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 D. LAKE ICE PHYSICAL 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

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	Remarks
11/18/09	17:27	Levels	0.04	10.55	+/- 0.01	1.58'	0.04	7.26		

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