Snow Survey Data for the Kuparuk Foothills Hydrology Study: Spring 2006

Snow survey sampling in Brooks Range, K. Irving

by

Douglas Kane, Sveta Berezovskaya, Ken Irving,

Robert Busey, Robert Gieck, Molly Chambers,

Amanda Blackburn, and Michael Lilly

July 2006

Kuparuk Foothills Hydrology Project

Report No. INE/WERC 06.06

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DISCLAIMER

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CONVERSION FACTORS, 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, stream flow was reported in cubic feet per second (cfs) followed by the approximate value in cubic meters per second (m^3/s) in parentheses.

Physical 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:

$$°F = 1.8(°C) + 32$$

Millivolt (mV):

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

Vertical Datum:

In this report, "sea level" 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.

Abbreviations, Acronyms, and Symbols

AC	Actual conductivity
ADOT&PF	Alaska Department of Transportation and Public Facilities
ASTM	American Society for Testing and Materials
atm	atmospheres
C	Celsius
DO	Dissolved oxygen
DVM	digital voltage multi-meter
e-tape	electric tape
F	Fahrenheit (^oF).
ft	feet
GWS	Geo-Watersheds Scientific
GWSI	USGS Ground-Water Site Inventory
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
NWIS	National Water Information System
ORP	oxygen-reduction potential
ppm	parts per million
QA	quality assurance
QC	quality control
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

This project was funded by grant ADN #2562123, Alaska Department of Transportation and Public Facilities. Field coordination was provided by BP Exploration (Alaska) Inc. Alaska and the Department of Natural Resources provided background data in the study area.

Snow Survey Data for the Kuparuk Foothills Hydrology Study: Spring 2006

INTRODUCTION

Snowcover on the Arctic Slope of Alaska lasts up to nine months a year. Water contained in snowpack ensures that snowmelt is a major hydrological event each year. Peak discharge resulting from snowmelt is the highest for many rivers on the North Slope, particularly for the largest basins like the Colville, Sagavanirktok, and Kuparuk Rivers. Rivers flowing into the Beaufort Sea drain a large area that extends from the Brooks Range through the Northern Foothills and across the Coastal Plain before discharging into the Arctic Ocean. The data on water content of snowpack at the end-of-winter have been collected in the basins of the Central Alaskan Arctic. Snow depth, snow water equivalent (SWE) and snow density have been measured at numerous sites from the Continental Divide (south) to the Arctic Ocean (north) in the Kuparuk River basin (Figure 1, Tables 1, 2, 3). Ablation curves were determined from \snowpack measurements during melt on a south-north transect along the Dalton Highway and on the Prudhoe Bay oil field.

SAMPLING METHOD

The snowpack water equivalent (SWE) is estimated using double sampling method. Double sampling refers to the measurement of the snowpack by measuring the depth at a number of points and measuring the snow water equivalent (plus the depth) at a smaller number of points.

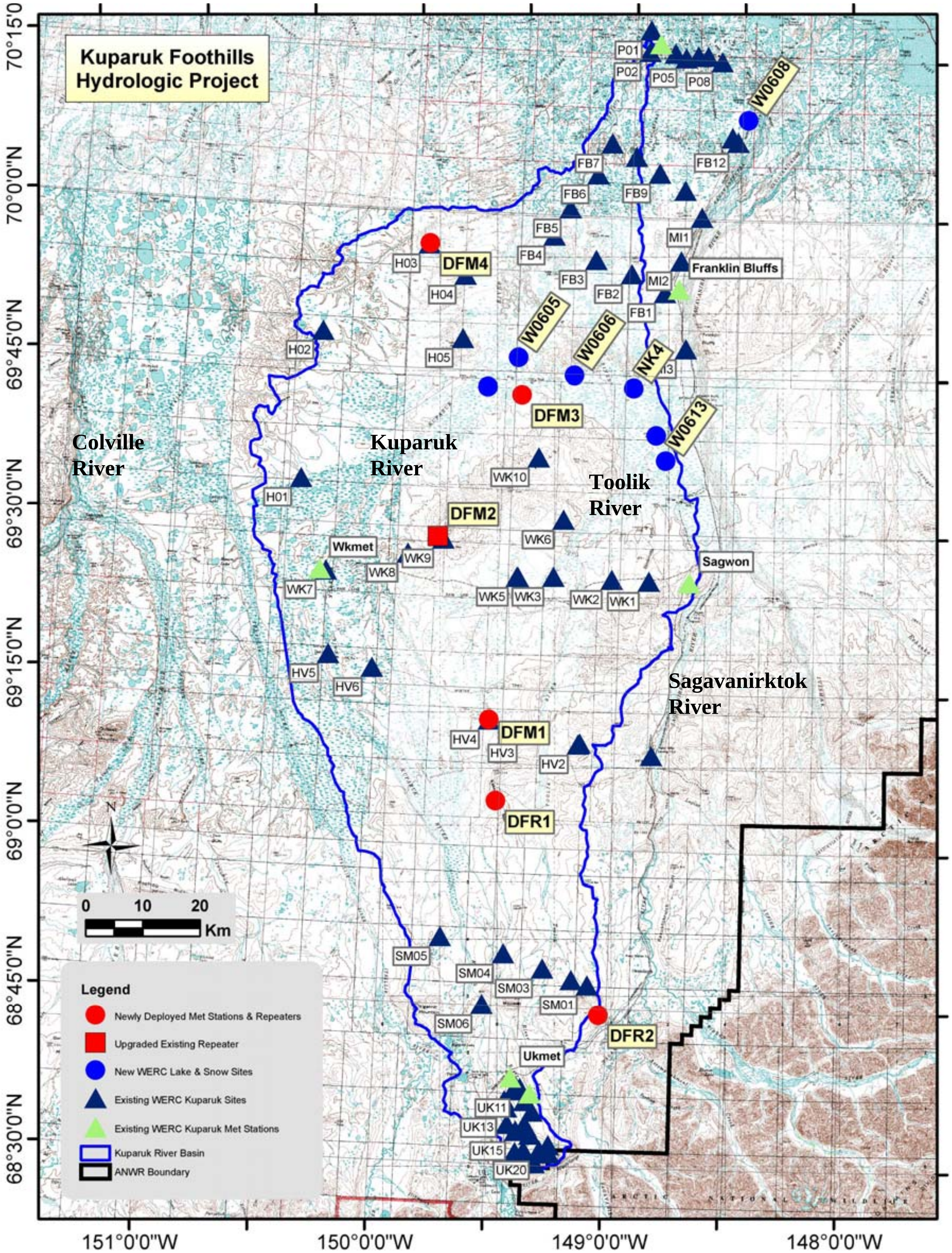

Figure 1. Study area and lake location map for the Kuparuk Foothills Region, North Slope, Alaska, with snow survey sites and meteorological stations.

The approach we use is to measure the snow depth at 50 points along an L-shaped transect with measurements spaced approximately every meter. Twenty-five depth measurements are made on each leg of the L; this strategy is used to account for the presence of snowdrifts in the area of measurement. The directions of measurement are chosen randomly. Five SWE measurements (and accompanying five depths) are taken at each site; from these measurements the density (mass/volume) of the snowpack is determined. Then using this density, with the 50 depth measurements, a new average estimate of the SWE is obtained. This combination of measurements yields an optimal estimate of the average snowpack water equivalent having lower time cost and lower variance, over a larger area, than is possible by measuring just five SWE values (Rovansek et al, 1993).

Snow depth is measured with a T-shaped snow probe. Snow density is sampled with the Adirondack Fiberglass snow sampler (cross-sectional area is 35.7 cm^2) (Woo, 1997). To obtain site average SWE, mean density (from 5 measurements) is multiplied by mean snow depth (50 measurements). Averages of snow depth and SWE measurements taken at each site are listed in Tables 4, 5, 6.

Table 1. Coordinates of mountain snow survey sites in the headwaters of the Kuparuk River.

№	ID	ELEV	LAT	LON
		m	*NAD83*	*NAD83*
1	UK05	1021	68.5200	-149.227
2	UK06	1050	68.5199	-149.262
3	UK14	1027	68.5638	-149.411
4	UK16	1045	68.5207	-149.373
5	UK17	1109	68.5007	-149.411
6	UK19	1115	68.5037	-149.289
7	UK20	1024	68.5247	-149.269

Table 2. Coordinates of foothills snow survey sites in and adjacent to the Kuparuk River Basin.

№	ID	ELEV	LAT	LON
		m	*NAD83*	*NAD83*
1	UK01	912	68.5849	-149.306
2	UK02	834	68.6010	-149.338
3	UK03	827	68.5639	-149.335
4	UK04	908	68.5335	-149.231
5	UK07	848	68.5489	-149.311
6	UK08	968	68.5222	-149.338
7	UK09	763	68.6241	-149.379
8	UK10	801	68.6173	-149.384
9	UK11	796	68.6215	-149.360
10	UK12	904	68.6007	-149.425
11	UK13	937	68.5899	-149.416
12	UK15	951	68.5540	-149.373
13	UK18	981	68.5187	-149.328
14	Ukmet	778	68.6374	-149.404
15	SM01	732	68.7879	-149.087
16	SM02	680	68.7956	-149.158
17	SM03	651	68.8122	-149.284
18	SM04	612	68.8336	-149.456
19	SM05	568	68.8565	-149.733
20	SM06	609	68.7521	-149.539
21	Happy Valley	314	69.1519	-148.839
22	HV1	365	69.1682	-149.155
23	HV2	353	69.1667	-149.162
24	HV3	386	69.1816	-149.390
25	HV4	308	69.2007	-149.558
26	HV5	179	69.2937	-150.284
27	HV6	218	69.2756	-150.087
28	Wkmet	159	69.4259	-150.342
29	WK1	218	69.4265	-148.872
30	WK2	226	69.4278	-149.038
31	WK3	174	69.4291	-149.298
32	WK4	203	69.4269	-149.461
33	WK5	197	69.4269	-149.457
34	WK6	195	69.5199	-149.262
35	WK8	173	69.4576	-149.953
36	WK9	401	69.4826	-149.797
37	WK10	214	69.6173	-149.384
38	Sagwon	275	69.4262	-148.691
39	H02	172	69.8020	-150.384
40	IB	897	68.6134	-149.318

Table 3. Coordinates of coastal plain snow survey sites in and adjacent to the Kuparuk River Basin.

№	ID	ELEV	LAT	LON
		m	*NAD83*	*NAD83*
1	West Dock	5	70.3602	-148.570
2	Franklin Bluffs	71	69.8886	-148.775
3	FB1	71	69.8828	-148.839
4	FB2	64	69.9108	-148.992
5	FB3	58	69.9316	-149.156
6	FB4	52	69.9676	-149.351
7	FB5	42	70.0113	-149.283
8	FB6	38	70.0667	-149.160
9	FB7	32	70.1160	-149.101
10	FB8	34	70.0960	-148.987
11	FB9	34	70.0710	-148.878
12	FB10	40	70.0451	-148.758
13	FB11	21	70.1294	-148.548
14	FB12	20	70.1227	-148.521
15	P01	12	70.2955	-148.937
16	P02	15	70.2614	-148.940
17	P03	11	70.2744	-148.891
18	P04	12	70.2601	-148.821
19	P05	15	70.2532	-148.772
20	P06	12	70.2562	-148.670
21	P07	12	70.2566	-148.716
21	P08	12	70.2486	-148.604
22	MI1	48	70.0032	-148.679
23	MI2	60	69.9336	-148.768
24	MI3	90	69.7950	-148.736
25	H01	113	69.5687	-150.448
26	H03	124	69.9467	-149.920
27	H04	77	69.9000	-149.750
28	H05	90	69.8000	-149.750
29	L19	16	70.1568	-148.475
30	L30	73	69.7255	-149.626
31	L31	73	69.7730	-149.492
32	L32	91	69.7482	-149.237
33	L34	116	69.6576	-148.858
34	NK4	101	69.7307	-148.966
35	WC1	127	69.6179	-148.812
36	WK7	137	69.4243	-150.315

Table 4. Results of snow survey 2006 for mountain sites: snow depth, snow density and snow water equivalent

№	ID	DATE	SWE		SNOW DEPTH		SNOW DENSITY	
			cm	*in*	*cm*	*in*	*kg/m3*	*slug/ft3*
1	UK05	4/24/06	9.9	3.9	37.9	14.9	260	0.504
2	UK06	4/24/06	3.4	1.3	22.7	8.9	150	0.291
3	UK14	4/24/06	9.7	3.8	48.4	19.1	200	0.388
4	UK16	4/24/06	-	-	12.6	5.0	-	-
5	UK17	4/26/06	5.0	2.0	16.7	6.6	300	0.582
6	UK19	4/24/06	5.9	2.3	28.1	11.1	210	0.407
7	UK20	4/24/06	6.2	2.4	22.8	9.0	270	0.524
	Average		6.7	2.6	27.0	10.6	232	0.450

SPATIAL DISTRIBUTION OF SNOW SURVEY SITES

Snow survey sites are chosen to represent snow characteristics over a wide range of vegetation and terrain conditions within the domain. The total elevation range within the Kuparuk River basin is sea level to 4800 ft (0 to1464 m). Snow water equivalents are measured at elevations from sea level to 3674 ft (0 to ~1120 m) in the Kuparuk River basin (Tables 1, 2, 3). Sites with missing data could not be visited due to weather.

Liston and Sturm (2002) mentioned that there are two distinctly different snow regimes across the Kuparuk basin, uplands and coastal. Using this knowledge, snow sites over the research domain are classified over the coastal plain (Table 3) and uplands (i.e. foothills and mountains). The coastal sites are the sites located below elevation isoline of 500 ft (152 m) and those above are referred as uplands sites. Uplands snow sites are, in turn, separated to the foothills and mountains based on surrounding topography (Tables 1, 2). Elevation is not representative, because in the mountains regions most of the snow survey sites are located in the valley bottoms that can be safely accessed by helicopter (Figure 1).

Table 5. Results of snow survey 2006 for foothills sites: snow depth, snow density and snow water equivalent.

№	ID	DATE	SWE		SNOW DEPTH		SNOW DENSITY	
			cm	*in*	*cm*	*in*	*kg/m3*	*slug/ft3*
1	UK01	4/26/06	8.9	3.5	47.1	18.5	190	0.369
2	UK02	4/26/06	8.3	3.3	41.4	16.3	200	0.388
3	UK03	4/26/06	4.3	1.7	28.4	11.2	150	0.291
4	UK04	4/24/06	3.2	1.2	12.6	5.0	250	0.485
5	UK07	4/24/06	4.5	1.8	22.6	8.9	200	0.388
6	UK08	4/26/06	4.3	1.7	21.6	8.5	200	0.388
7	UK09	4/26/06	6.4	2.5	32.1	12.6	200	0.388
8	UK10	4/26/06	9.5	3.7	39.6	15.6	240	0.466
9	UK11	4/26/06	8.6	3.4	48.0	18.9	180	0.349
10	UK12	4/26/06	4.7	1.9	21.5	8.5	220	0.427
11	UK13	4/24/06	9.1	3.6	45.4	17.9	200	0.388
12	UK15	4/24/06	8.4	3.3	36.5	14.4	230	0.446
13	UK18	4/26/06	2.8	1.1	14.1	5.6	200	0.388
14	Ukmet	4/26/06	11.9	4.7	56.9	22.4	210	0.407
15	SM01	4/24/06	5.6	2.2	33.2	13.1	170	0.330
16	SM02	4/24/06	6.8	2.7	32.2	12.7	210	0.407
17	SM03	4/24/06	13.8	5.4	52.9	20.8	260	0.504
18	SM04	4/26/06	11.4	4.5	57.2	22.5	200	0.388
19	SM05	4/26/06	12.1	4.8	60.7	23.9	200	0.388
20	SM06	4/26/06	10.8	4.2	49.0	19.3	220	0.427
21	Happy Valley	4/27/06	16.7	6.6	69.6	27.4	240	0.466
22	HV1	4/29/06	10.1	4.0	47.9	18.9	210	0.407
23	HV2	4/29/06	7.2	2.8	37.9	14.9	190	0.369
24	HV3	4/29/06	16.6	6.6	64.0	25.2	260	0.504
25	HV4	4/29/06	11.5	4.5	45.8	18.0	250	0.485
26	HV5	4/24/06	11.4	4.5	60.2	23.7	190	0.369
27	HV6	4/24/06	12.1	4.8	46.7	18.4	260	0.504
28	Wkmet	4/24/06	7.5	3.0	41.8	16.5	180	0.349
29	WK1	5/4/06	6.1	2.4	30.3	11.9	200	0.388
30	WK2	5/4/06	12.7	5.0	55.0	21.7	230	0.446
31	WK3	5/4/06	3.2	1.3	22.9	9.0	140	0.272
32	WK4	5/4/06	10.2	4.0	42.5	16.7	240	0.466
33	WK5	5/4/06	21.3	8.4	88.6	34.9	240	0.466
34	WK6	5/4/06	7.9	3.1	44.1	17.4	180	0.349
35	WK8	5/4/06	12.5	4.9	51.9	20.4	240	0.466
36	WK9	5/4/06	3.3	1.3	19.6	7.7	170	0.330
37	WK10	5/4/06	7.1	2.8	37.6	14.8	190	0.369
38	Sagwon	4/27/06	5.9	2.3	32.9	13.0	180	0.349
39	IB	4/25/06	9.6	3.8	39.2	15.5	246	0.477
	Average		8.9	3.5	41.8	16.5	209	0.406

Table 6. Results of snow survey 2006 for coastal plain sites: snow depth, snow density and snow water equivalent.

№	ID	DATE	SWE		SNOW DEPTH		SNOW DENSITY	
			cm	*in*	*cm*	*in*	*kg/m3*	*slug/ft3*
1	West Dock	4/24/06	8.9	3.5	30.7	12.1	290	0.563
2	Franklin Bluffs	4/27/06	10.3	4.0	44.6	17.6	230	0.446
3	FB1	4/25/06	10.0	3.9	39.9	15.7	250	0.485
4	FB2	4/25/06	8.7	3.4	43.3	17.0	200	0.388
5	FB3	4/25/06	11.7	4.6	39.0	15.4	300	0.582
6	FB4	4/25/06	8.8	3.5	35.3	13.9	250	0.485
7	FB5	4/25/06	7.2	2.8	30.1	11.9	240	0.466
8	FB6	4/25/06	7.5	2.9	34.0	13.4	220	0.427
9	FB7	4/25/06	10.6	4.2	46.3	18.2	230	0.446
10	FB8	4/25/06	18.7	7.4	60.4	23.8	310	0.602
11	FB9	4/25/06	9.0	3.5	28.9	11.4	310	0.602
12	FB10	4/25/06	13.2	5.2	41.4	16.3	320	0.621
13	FB11	4/25/06	7.4	2.9	22.5	8.9	330	0.640
14	FB12	4/25/06	8.0	3.2	34.8	13.7	230	0.446
15	P01	4/26/06	6.3	2.5	28.5	11.2	220	0.427
16	P02	4/26/06	6.3	2.5	36.9	14.5	170	0.330
17	P03	4/26/06	12.0	4.7	37.5	14.8	320	0.621
18	P04	4/26/06	5.8	2.3	32.4	12.8	180	0.349
19	P05	-	-	-	-	-	-	-
20	P06	4/26/06	4.9	1.9	21.5	8.5	230	0.446
21	P07	-	-	-	-	-	-	-
22	P08	4/26/06	7.9	3.1	34.5	13.6	230	0.446
23	MI1	4/26/06	6.8	2.7	29.4	11.6	230	0.446
24	MI2	4/26/06	11.2	4.4	44.9	17.7	250	0.485
25	MI3	4/26/06	9.8	3.8	42.5	16.7	230	0.446
26	H01	4/25/06	11.1	4.4	46.1	18.1	240	0.466
27	H02	-	-	-	-	-	-	-
28	H03	4/25/06	11.1	4.4	41.1	16.2	270	0.524
29	H04	4/25/06	7.1	2.8	39.6	15.6	180	0.349
30	H05	4/25/06	11.3	4.4	45.1	17.8	250	0.485
31	L19	5/1/06	11.7	4.6	40.4	15.9	290	0.563
32	L30	5/1/06	11.8	4.7	51.4	20.2	230	0.446
33	L31	5/1/06	12.6	5.0	52.7	20.7	240	0.466
34	L32	5/1/06	6.7	2.6	35.4	13.9	190	0.369
35	L34	5/1/06	8.4	3.3	40.0	15.7	210	0.407
36	NK4	5/1/06	8.3	3.3	37.8	14.9	220	0.427
37	WC1	5/4/06	7.6	3.0	42.4	16.7	180	0.349
38	WK7	5/4/06	14.8	5.8	67.2	26.5	220	0.427
	Average		9.5	3.8	39.4	15.5	243	0.471

SNOW DEPTH AND SNOW WATER EQUIVALENT

Snowpack water equivalent distribution is highly heterogeneous over the area. On local scale of few hundred of meters, it results from interaction between vegetation, terrain and wind-blowing snow redistribution. It also varies on a regional scale of several tens to hundred of kilometers, in response to regional precipitation, air temperature, humidity and wind gradients (Liston and Sturm, 2002).

Average coastal plain densities (0.471 slug ft^{-3} / 243 kg m^{-3}) are slightly higher than both foothill (0.404 slug ft^{-3} / 208 kg m^{-3}) and mountain (0.450 slug ft^{-3} / 232 kg m^{-3}) snow densities (Tables 4, 5, 6).

Coastal plain average snow water equivalent is 3.8 in (9.5 cm), and snow depth average is 15.5 in (39.4 cm). Foothills average snow water equivalent is 3.5 in (8.9 cm), and snow depth average is 16.5 in (41.9 cm). Mountains average snow water equivalent (3.0 in / 7.5 cm) and snow depths (10.6 / 27.0 cm) are generally lower than those at the coast and foothills.

These data show a general SWE increase towards the coast. Such regional trend differs from south-north variations of the Kuparuk basin SWE observed in 1995, 1996 and 1997 by Liston and Sturm (2002). Because of the extreme local snow-depth variability found in the exposed and sheltered areas, they used only intermediate (flat or gentle slopes) sites to determine regional trends. These trends were similar each year with the highest snow accumulation in uplands.

Due to complex terrain and wind interaction in uplands, a simple average from point observations in mountains shown in Table 4 is not recommended to represent the aerial SWE estimates. The reason for that is the location of the most mountains sites are in the valley bottoms. The north-south trending valleys of the Brooks Range are subjected to strong katabatic winds that contribute to blowing snow redistribution and sublimation processes. Liston and Sturm (2004) suggested that reduced snow cover in these areas is thought to be the result of these strong winds flowing through the valley towards north.

Please, refer to work plan 2006 (snow data analysis section) that contains detailed description of methods and models to quantify realistically the spatial snow water equivalent distribution in the domain before onset of ablation.

ABLATION PATTERN

Snowmelt in spring 2006 was an average event in terms of timing (Figure 2); comparing it to 22 years of data at Imnavait Creek, the event started about one or two days earlier than the average. At all sites, except Happy Valley the snowpack was about 20 % lighter than average. The measurement site at Happy Valley had about twice the SWE as all the other sites, therefore melt lasted longer and it was also the last site to finish ablation. Initiation of melt at the Happy Valley site started about the same time as other sites and the neighboring site (Sagwon) had both the lowest SWE and was also the first to complete ablation. The daily melt rates were similar to other years.

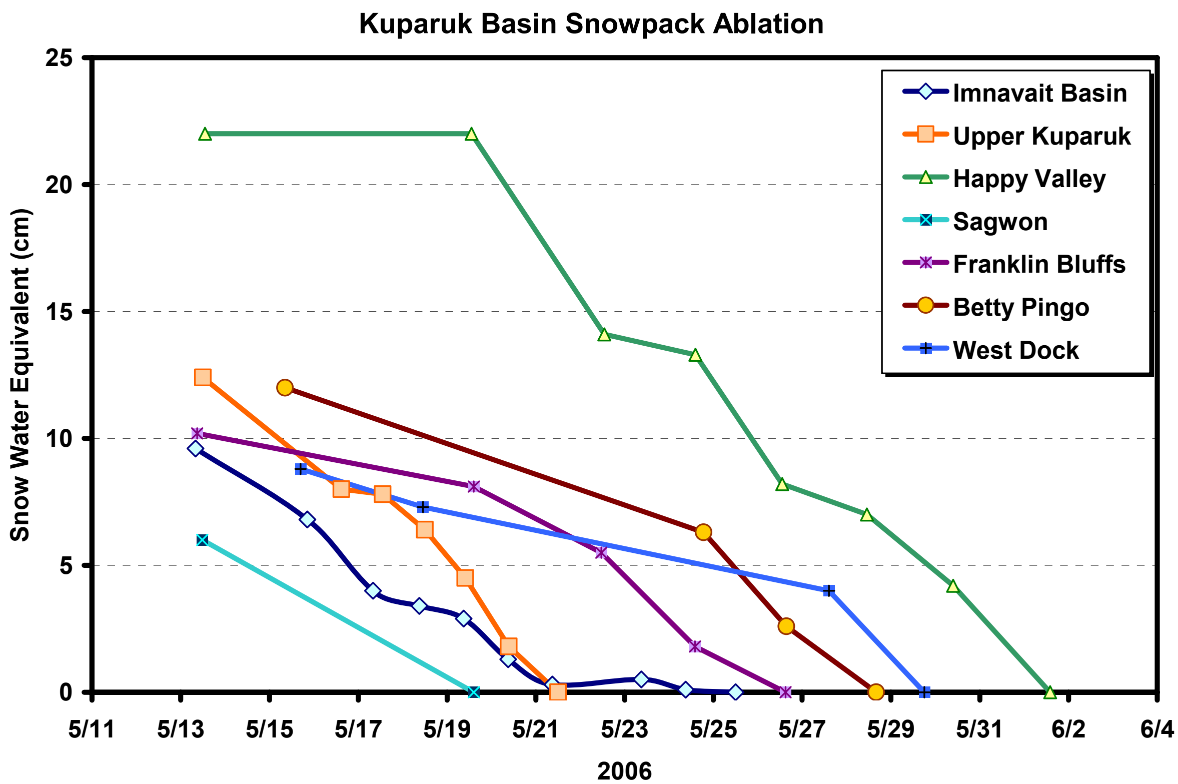

Figure 2. Kuparuk River snowpack ablation along the Dalton Highway and Prudhoe Bay oil field.

SUMMARY

The 2006 snow data survey is considered to be a base dataset for successful estimation of basin wide maximum snowpack water content before melt. In this region no other ground snow information is otherwise available. Compiled dataset will also be used as input into hydrological models for runoff estimation of both gauged and ungauged watersheds. This pattern of snow distribution, with the coastal plain having the highest SWE, was quite similar between the Sagavanirktok River / Bullen Point area and this study. In general, the snowpack was lighter than average and snowmelt was average for this region.

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