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RECONNAISSANCE SNOW SURVEYS OF THE NATIONAL PETROLEUM RESERVE IN ALASKA, APRIL 1977 AND APRIL-MAY 1978

By Charles Sloan, Dennis Trabant, and William Glude

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For use of those readers who may prefer to use inch-pound units rather than metric units, the conversion factors for the terms used in this report are listed below:

Multiply metric units	by	to obtain inch-pound units
centimeter (cm)	3.393	inch (in.)
meter (m)	3.281	foot (ft)
cubic meter (m^3)	35.31	cubic foot (ft^3)
kilogram (kg)	2.205	pound (lb)
square kilometer (km^2)	0.3861	square mile (mi^2)

RECONNAISSANCE SNOW SURVEYS OF THE NATIONAL PETROLEUM RESERVE IN ALASKA, APRIL 1977 AND APRIL-MAY 1978

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ABSTRACT

Reconnaissance snow surveys of the National Petroleum Reserve in Alaska were made in April 1977 and April-May 1978 to ascertain general snow charactersitcs and distribution patterns. Thirty-nine sites in 1977 and forty-one sites in 1978 were sampled to determine snow depth, density, structure, and snow-soil interface temperature. In addition, snow surface wind indicators were examined over most of the National Petroleum Reserve in Alaska.

In April and early May of two consecutive years, the snow cover in the National Petroleum Reserve in Alaska was thin, wind-packed, and virtually continuous. The depth and water equivalent of the snow generally increased with altitude and with distance from the coastal plain. Snow depth on tundra ranged from less than 0.20 meters (m) near the coast to more than 0.90 m in parts of the Brooks Range. Snow density was relatively high in areas where wind slab was developed throughout the snow pack, and lower where there was less wind slab. In 1977, the coastal plain showed the greatest wind slab development and higher densities, averaging 310 kilograms per cubic meter (kg/m^3) on tundra, while the mountains and foothills had less wind slab and lower densities, averaging 270 kg/m^3. In 1978, with more local variation, snow density on the coastal plain averaged 330 kg/m^3 on tundra and averaged 310 kg/m^3 in the mountains and foothills. Water equivalent of the snowpack in 1977 ranged from less than 0.10 m in the coastal areas to more than 0.25 m in the Brooks Range, and averaged nearly 0.12 m on tundra for the entire area. Water equivalent of the snowpack averaged more than 0.13 m in 1978.

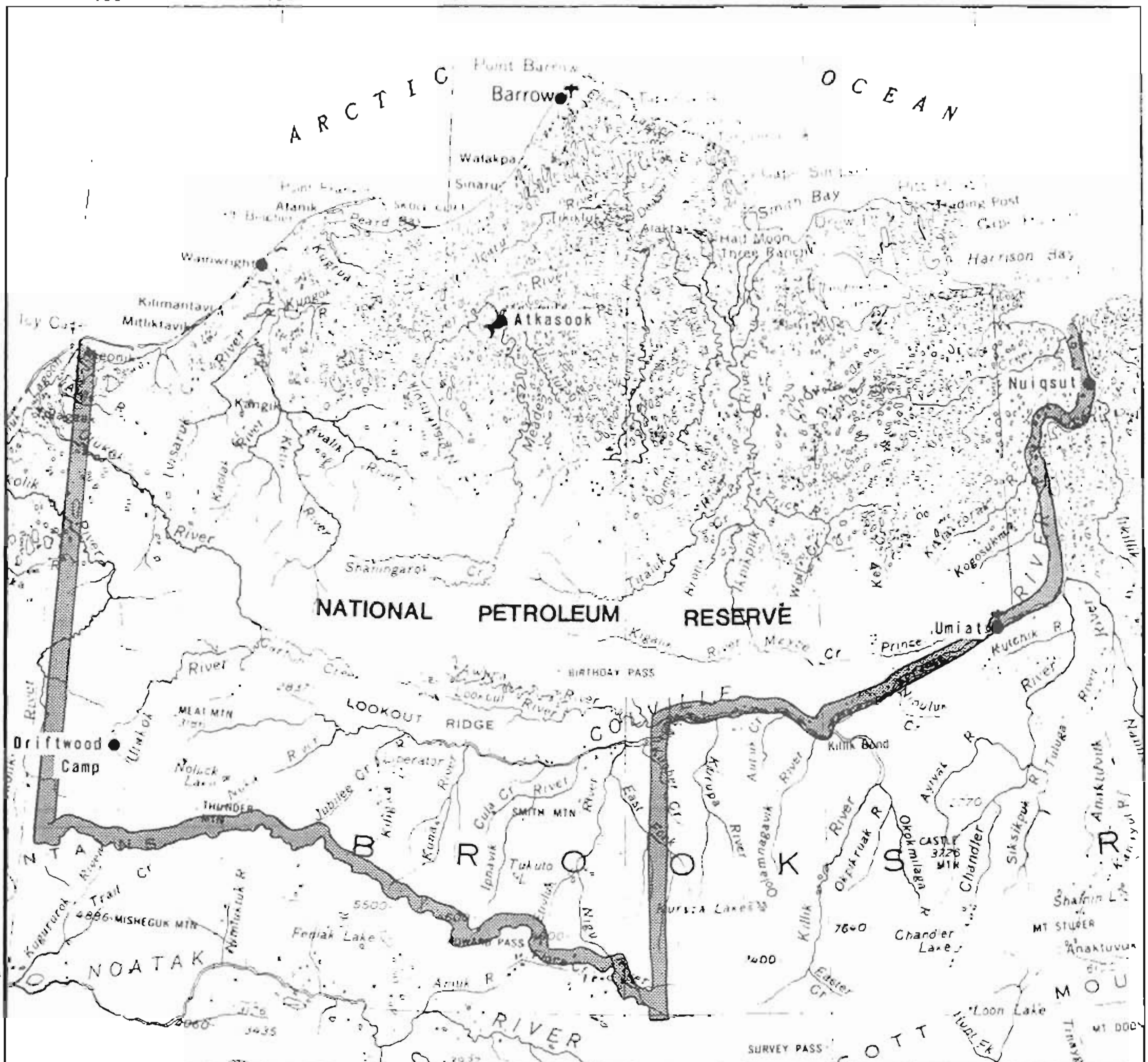
Snow-soil interface temperatures in 1977 ranged from about -20°C on the coastal plain, where the snowpack was thin and ambient air temperatures were low, to about -5°C in the mountains and foothills where the snowpack was thicker and ambient air temperatures higher.

INTRODUCTION

The National Petroleum Reserve in Alaska (NPRA), on the Arctic Slope between Point Barrow and the Brooks Range and generally west of the Colville River (fig. 1), covers some 96,000 square kilometers (km^2). The Naval Petroleum Reserves Production Act of 1976 transferred jurisdiction of the Reserve from the Department of the Navy to the Department of the Interior. Section 105(c) of the act directs the Department of the Interior to conduct a study to determine resource values and their best uses; section 105(b) calls for a study to be made of the economic and environmental consequences of potential development, production, transportation, and distribution of petroleum from the reserve. Both 105(b), the Environmental Assessment, and 105(c), the Land Use Study, require basic information on the physical environment including climate.

Climatic data in NPRA are available for only a few stations. Wind, temperature, and precipitation data have been recorded at Barrow since 1948 and at Umiat from 1948 to 1953. Only precipitation and temperature data have been collected at Wainwright. Other stations near the reserve where miscellaneous climatic data have been gathered include Barter Island, Cape Lisburne, Point Lay, Oliktok, and Anaktuvuk Pass (Selkregg, 1975).

Recently, an attempt has been made to improve the catch efficiency of precipitation gages in the area by installing a type of snow fence on precipitation gages at Meade River and Barrow. These shielded gages, commonly called Wyoming Precipitation Gages (fig. 2), have been shown to have a catch which approaches the true precipitation.



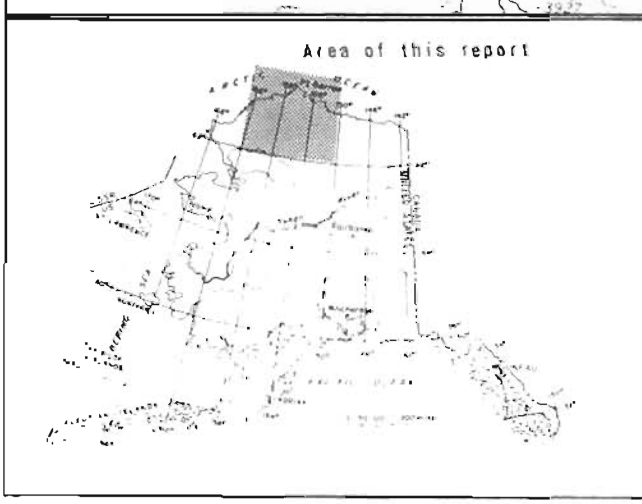


Figure 1.--Location of NPRA in Alaska.

Wyoming Precipitation Gages are also installed at Barter Island, Point Hope, Prudhoe Bay, on the Kavik and Jago Rivers, and at several sites along the Alaska pipeline route.

Figure 2.--Wyoming Precipitation Gage at Toolik River, near TAPS pipeline east of NPRA, showing snow fence surrounding standard precipitation can.
Photo by Soil Conservation Service

NPRA is snow covered for about 8 months of the year, generally from October through May. Snow courses have not been established on the Arctic Slope, except at Anaktuvuk Pass. Snow may fall in any month of the year, but rain is common during the summer months of June through August. On the basis of scanty information, it appears that slightly more precipitation falls as rain than as snow in NPRA.

Snowmelt during the spring breakup period is the principal source of water for lakes and streams in NPRA. Snow is a manageable resource for water supplies, as well as a construction material for winter roads and airstrips. Snow provides a protective cover for the underlying tundra that facilitates seismic exploration and winter travel.

permit sampling after the major winter snow accumulation and before the spring thaw. The 1977 survey was done between April 18 and 26, and the 1978 survey was done from April 17 to May 6. Tentative sampling sites were selected on the basis of map studies to provide a representative distribution over the reserve, but weather conditions actually determined which sites were visited. Landing and takeoff capabilities of the aircraft used were also factors in final site selection. A fixed-wing aircraft on skis with nonretractable wheels used in 1977 experienced great difficulty in taking off from deep snow; an aircraft with retractable ski-wheels used later in that survey was found to be much more efficient, and that type of aircraft was used again in 1978.

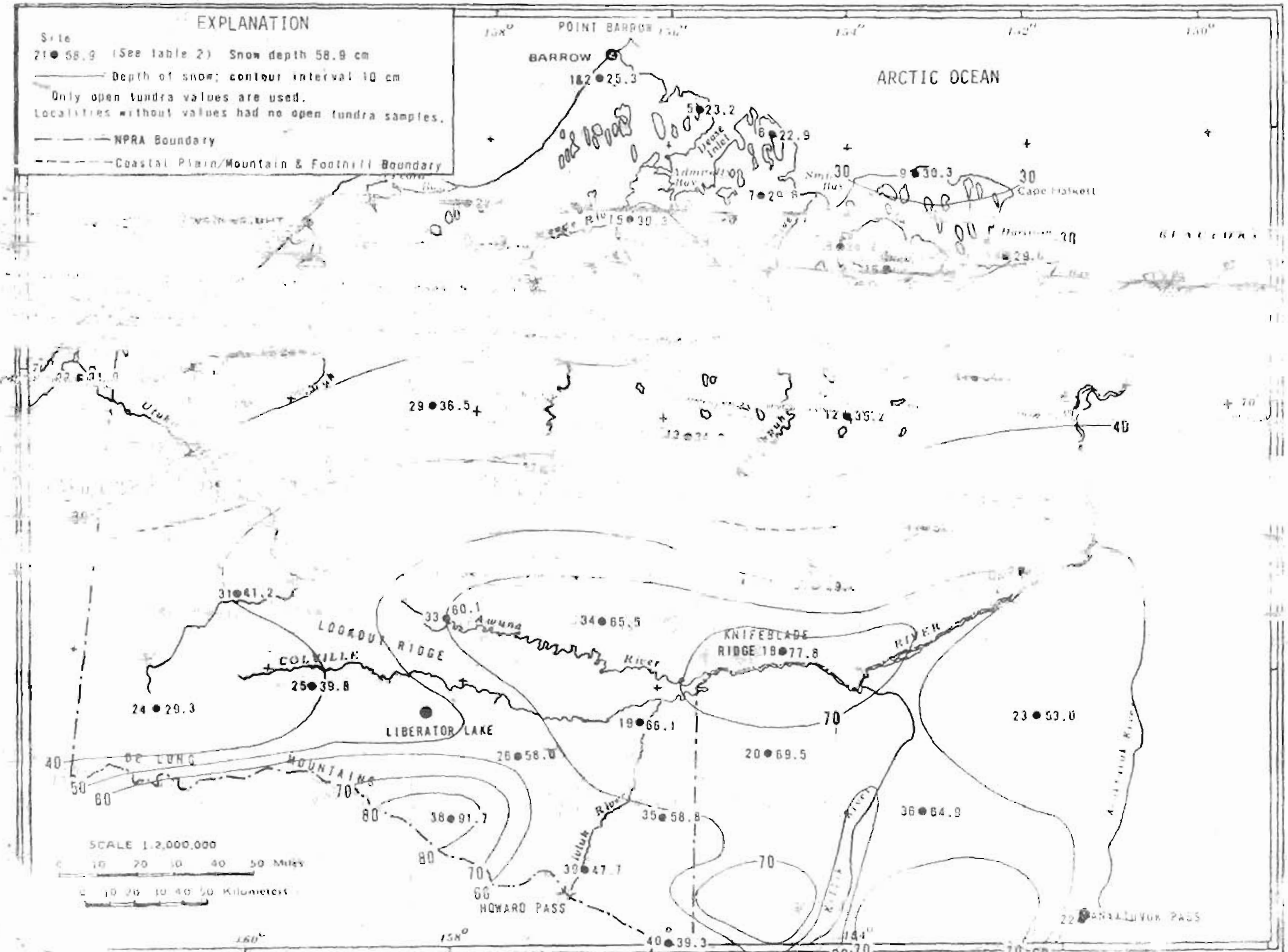
Sampling was done primarily on open tundra, that is, tundra of low relief and without significant obstructions to the wind. Both ground and snow surfaces were usually irregular. Tussocks and clumps of vegetation up to 0.40 m high and frost polygons with some ridges more than 0.50 m high made it difficult to obtain accurate snow depth measurements. Each site was probed at approximately 40 points in a

Table 2.--[illegible] snow survey [illegible], NPRA, April-May 197[illegible]

Site no.	Location N. lat	W. long	Name	Approx. altitude (m above MSL)	Site Description	Date
1	[illegible]	[illegible]	[illegible]		Lake ice	[illegible]
2	71°15'	156°46'	Emaiksoun L	12	Coastal plain tundra	[illegible]
[illegible]	[illegible]	[illegible]	Atkasook	18	High center polygon tundra	4-13
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	4-19
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Coastal plain tundra	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	69°56'	155°44'	NW of Oumalik Lake	[illegible]	Coastal [illegible]	[illegible]
[illegible]	[illegible]	[illegible]	Topagoruk R	24	Coastal plain tundra	[illegible]
[illegible]	70°43'	156°24'	Lower Meade R	[illegible]	Coastal plain tundra	[illegible]
16	70°33'	153°37'	Teshekpuk L	2	Lake ice	4-
17	69°36'	153°14'	Square L	159	Tundra-edge of coastal plain	4-2[illegible]
18	69°09'	154°45'	Knifeblade Ridge	341	Gentle hillside tundra	4-25
19	68°52'	156°09'	Colville R at Etivluk R	329	Rolling upland tundra	4-25
[illegible]	[illegible]	154°5[illegible]'	Between Kurupa R and Heather C	[illegible]	Rolling upland tundra	[illegible]
[illegible]	69°24'	152°11'	Umiat	213	Ridgetop tundra	4-2[illegible]
[illegible]	68°09'	151°44'	Anaktuvuk Pass (Soil Conservation Service snow course)	640	Willows next to airstrip	5-3
[illegible]	[illegible]	152°09'	Aiyak Mesa	259	Broad valley tundra	[illegible]
[illegible]	[illegible]	161°0[illegible]'	S of Driftwood	457	Broad basin tundra	5-3

Table 2.--*Reconnaissance snow survey data, NPRA, April-May 1978*--Continued.

Site no.	Location N. lat	Location W. long	Name	Approx. altitude (m above MSL)	Site description	Date	Depth (m)	Density (kg/m³)	Water equiv. (m)	Basal snowpack temp. (°C)
25	68°57'	159°31'	Reynard C	503	Rolling upland tundra	5-3	0.40	356	0.14	-12.0
26	68°43'	157°26'	N of Monument Ridge	442	Rolling upland tundra	5-3	0.58	323	0.19	- 9.0
27	69°59'	162°15'	Mouth of Utukok R	24	Coastal plain tundra	5-4	0.21	334	0.07	-12.0
28	70°10'	159°53'	Kuk R	34	Coastal plain tundra	5-4	0.26	351	0.09	-12.5
29	70°01'	158°27'	Avalik R	55	Coastal plain tundra	5-4	0.36	337	0.12	-12.0
30	69°39'	160°43'	Utukok R N of Avingak C	101	Tundra-edge of coastal plain	5-4	0.33	323	0.11	-11.0
31	69°16'	160°23'	Utukok R N of Archimedes Ridge	244	Broad basin tundra	5-4	0.41	331	0.14	-10.5
32	69°47'	157°16'	Upper Meade R	76	Tundra-edge of coastal plain	5-5	0.40	267	0.11	-11.0
33	69°14'	158°13'	Upper Awuna R	351	Rolling upland tundra	5-5	0.60	295	0.18	- 9.0
34	69°14'	156°31'	Birthday Pass	363	Broad ridgetop tundra	5-5	0.65	292	0.19	- 8.0
35	68°31'	155°53'	Iteriak C W of Iyotuk Hills	533	Broad basin tundra	5-5	0.59	265	0.16	- 7.0
36	68°32'	153°22'	Verdant C	594	Broad basin tundra	5-5	0.65	289	0.19	- 5.0
37	69°23'	154°25'	NE of Howard Hill	213	Broad ridgetop tundra	5-5	0.50	316	0.16	-10.0
38	68°29'	158°05'	Upper Kuna R	668	Broad basin tundra	5-6	0.92	348	0.32	- 8.0
39	68°19'	156°42'	Howard Pass	564	Broad basin tundra	5-6	0.48	350	0.17	- 8.0
40	68°03'	155°52'	Nukatpiat Mtn	914	Tundra-bench above Nigu R	5-6	0.39	321	0.13	- 6.0
41	67°53'	153°04'	Nigu R/Alatna R Pass	899	Valley bottom tundra	5-6	0.57	266	0.15	- 6.0



1978 snow depth.

Table 3.--*Comparison of 1977 and 1978 snow survey data.*

Open tundra was used as a standard environment for comparison. Different snow accumulation environments were also sampled at some sites and are included under "overall". The boundary between coastal plain and mountain and foothill zones as used in this report is shown on all of the maps except figure 1.

1977	Open tundra only			Overall
	Coastal plain 17 sites	Mountain and foothill 17 sites	All tundra 34 sites	46 sites with willow, drift and over-ice values
Average depth (m) (standard deviation)	0.27 (.11)	0.55 (.15)	0.41 (.19)	0.44 (.25)
Average density (kg/m³) (standard deviation)	312 (41)	272 (29)	292 (40)	291 (49)
Average water equivalent (m) (standard deviation)	.08 (.04)	.15 (.05)	.12 (.06)	.13 (.08)
Basal temperature (°C) (standard deviation)	-15.3 (1.9)	-10.6 (2.8)	-13.1 (3.3)	-12.4 (3.9)

1978	Open tundra only			Overall
	Coastal plain 18 sites	Mountain and foothill 20 sites	All tundra 38 sites	41 sites with willow and lake values
Average depth (m) (standard deviation)	0.29 (.05)	0.56 (.15)	0.43 (.18)	0.42 (.18)
Average density (kg/m³) (standard deviation)	332 (34)	307 (36)	319 (36)	325 (44)
Average water equivalent (m) (standard deviation)	.10 (.02)	.17 (.05)	.14 (.05)	.14 (.05)
Basal temperature (°C) (standard deviation)	-12.6 (1.9)	-9.1 (2.4)	-10.8 (2.8)	-10.4 (3.2)
Percentage of depth hoar in snow pack. (standard deviation)	39.5 (16.9)	45.2 (11.1)	42.6 (14.0)	40.8 (16.3)

Along the coast, where wind action is intense, tundra grasses protruded through much of the thin snow cover (fig. 6). Most of the lake surfaces were about 20 percent free of snow in 1977, though they were less than 5 percent snow-free in 1978. River channels which

Figure 6.--Tundra grasses protruding through thin snow cover on coastal plain near Kokolik River at site 4; April 19, 1977. View is to the west.

parallel the prevailing east-northeasterly wind direction were generally blown clear of snow in both years. Those channels with sandy or silty beds commonly had dark areas of windblown dirt extending across the snow up to a few hundred meters downwind from the channels. Farther south on the coastal plain, the snow cover was more continuous. Wind action appeared to be less and most lakes and river banks were snowy, though many streambeds contributed large quantities of windblown sand and silt to the nearby snow.

On a more local scale, snow accumulation patterns were strongly influenced by drifting. Surface irregularities, including tussocks, polygons, and vegetation clumps, as well as the more obvious lake and stream banks and larger terrain features, affected the drift patterns.

Topographic features such as polygon ridges, about 0.30 m to 1 m high, and other low undulations in the tundra surface appeared to be the most significant influences on drifting snow accumulation on open

Figure 7.--Snowdrift about 5 meters high on the east bank of the Kokolik River near site 4; April, 1977.

coastal plain tundra. Smaller scale topographic features such as tussocks or ridges less than about 0.30 m high were generally covered. Large-scale topographic features such as high riverbanks or lakeshores are certainly important traps for drifting snow, but do not occupy a large area on the coastal plain.

The largest drifts observed in 1977 extended from the east banks of lakes and streams (fig. 7). The drifts had accumulated on the lee shore with respect to the prevailing winds. Drifts on the west shore were observed to be smaller; in most instances, the western drifts had less than half the volume of the eastern drifts.

In some places, thinner snow cover on the tundra above the western bank indicated that the saltation load carried by the wind was almost completely deposited below the top of the lee bank and that a new load was picked up from the tundra above the western bank.

Although drifts do not cover a large percentage of the reserve, they may be important to runoff because the depths and densities indicate that a significant amount of water is stored in them. As an example, a drift on the east shore of a lake near the Kukpowruk River (1977 site 2, table 1) was estimated to contain about 50,000 m^3 of water. It covered an area estimated to be 915 m long by 130 m wide and had an average depth of 1.06 m. If the drift at 1977 site 2 and another one on the bank of the Kokolik River (1977 site 4) are compared with the adjacent tundra sample sites, the drifts are 91 percent thicker than snow cover on tundra, and the snow is 23 percent denser. Although the two localities represent too small a sampling to be statistically significant, they do serve to illustrate the water-storage capabilities of drifts.

Snow cover over ice on both lakes and rivers was generally thin except in the bank drifts. At the five 1977 sites (3, 11, 18, 19 and 33, table 1) where snow depths over lake or river ice were measured, the average depth was 0.26 m. This is substantially less than the average depth of 0.44 m overall and 0.41 m on tundra in 1977. At 1977 sites 3, 11 and 33, snow depths over lake and river ice were compared with snow depth over tundra; snow over ice was about half as deep as snow over tundra. In the two 1978 sites (1 and 2; 8 and 16; table 2) where snow depths on lake ice and adjacent tundra were compared, snow over ice was about two-thirds as deep as snow over tundra.

Vegetation also had a pronounced influence on local snow accumulation patterns. In particular, stands of willow protected snow from the wind and may have trapped some windblown snow. Of six 1977 sites sampled in willows (3, 19, 26, 34, 35, and 39; table 1), the average snow depth was 0.60 m, about 41 percent deeper than the average snow depth on tundra. At the two 1977 sites (3 and 39) where snow in a willow stand and over adjacent tundra or ice were compared, snow in the willows was approximately twice as deep as that on the tundra or ice. Tundra grasses also help hold winter snow from the wind. In the spring, though, these emergent grasses may be important in increasing the rate of snow ablation because of their greater heat absorption. These grasses were estimated to protrude in less than 2 percent of the tundra area with thin snow cover.

Snow Density

Snow density on tundra in 1977 averaged 290 kg/m^3. It was relatively high in the coastal zone where the snow cover was thin and wind slab was well developed. Density decreased inland, where the snow had less wind slab. Density was higher again in some localities in the mountains where the snow was deep, due to settling and poorly developed depth hoar. Coastal plain snow densities on tundra averaged 310 kg/m^3, and in the mountains and foothills, densities averaged 270 kg/m^3.

Densities at the low end of the measurement range occurred in tall willow stands, whereas high densities were measured in larger drifts (sites 19 and 2; table 1).

Average snow density in 1978 was higher than in 1977. The average density on tundra was 320 kg/m^3, with averages of 330 kg/m^3 for the coastal plain and 310 kg/m^3 for the mountains and foothills. The difference between the coastal plain and the mountain and foothill snow densities was not as great in 1977, and there was more local variation, but the pattern of density distribution was much the same.

Water Equivalent

Average water equivalent is determined by multiplying average snow depth by average density, the latter expressed as a percentage of an equivalent volume of water. The average water equivalent of snow measured on tundra in NPRA was 0.12 m in 1977 and 0.14 m in 1978.

The water equivalent pattern measured in 1977 was similar to the pattern for snow depth (figs. 4 and 8; tables 1 and 3). Water equivalent ranged from less than 0.10 m near the coast to more than 0.25 m in the mountains. A zone of lower density and reduced snow depth in the inland portion of the coastal plain was noted; a low water equivalent of 0.04 m was measured over tundra on the middle reaches of the Kokolik River (site 4). On the coastal plain, the water equivalent of snow was more uniform than was the snow depth. Snow cover on the coast was dense but thin, whereas snow cover inland was less dense, but thicker; therefore measurements of water equivalent exhibited less overall variation than measurements of snow depth. Water equivalent averaged about 0.08 m in 1977 for the coastal plain and about 0.15 m for the mountains and foothills.

The 1978 water equivalent was generally higher (fig. 9; tables 2 and 3), particularly in the mountains and foothills. Coastal plain water equivalents on tundra averaged about 0.10 m, and mountain and foothill water equivalents averaged about 0.17 m. Despite significant local differences as discussed in snow depth and density sections of this report, the overall water equivalent pattern was much the same as in 1977.

Snowpack Temperature

The snow-surface temperatures measured in 1977 averaged -8.2°C and ranged from 0°C to -16°C. Surface temperature was closely related to ambient air temperature and showed much variability. Snow-surface and ambient air temperatures were highest near the Anaktuvuk River. Snow-surface temperatures measured in 1978 were higher than in 1977, averaging -6.8°C and ranging from approximately 0°C to -17°C.

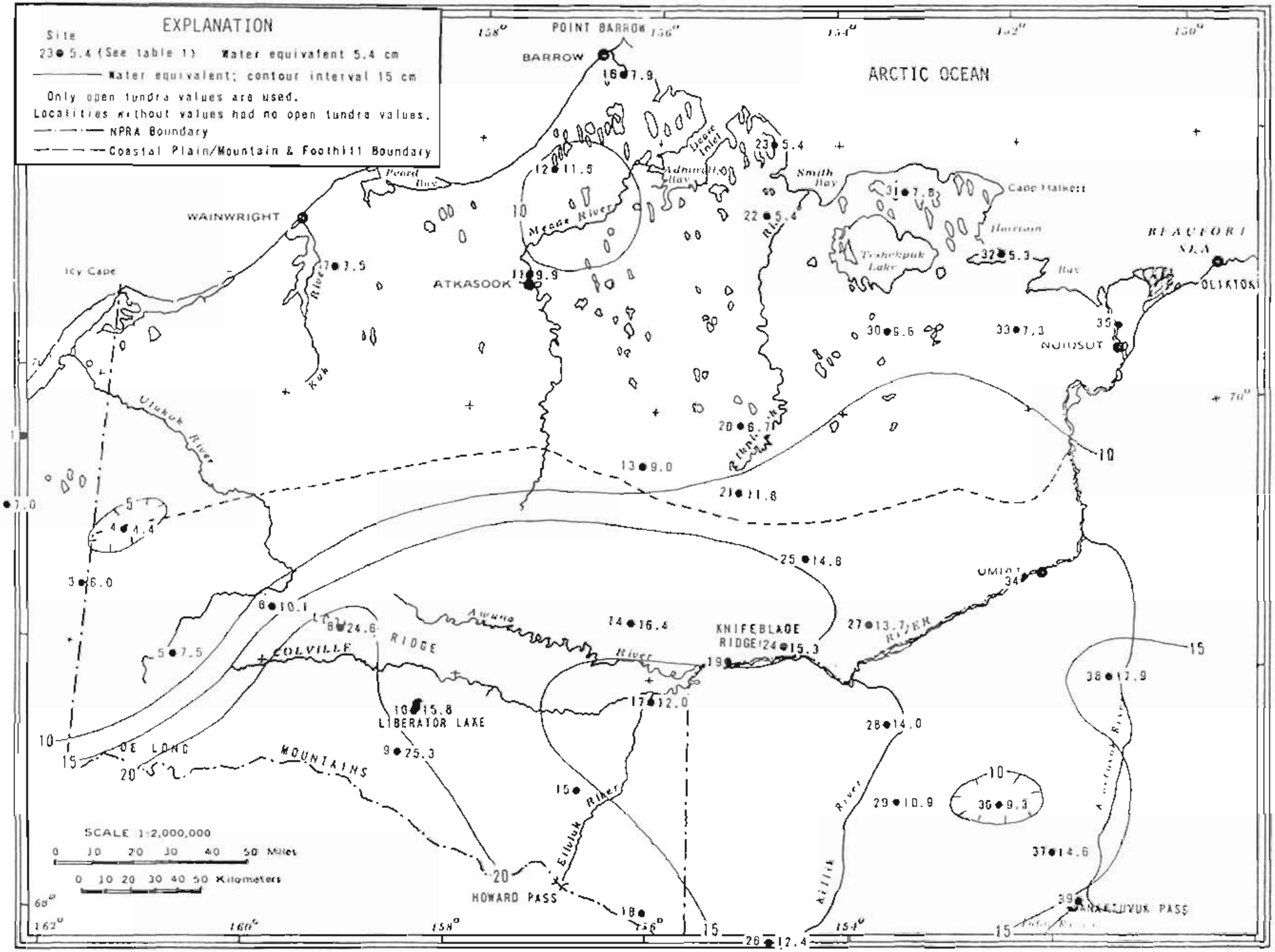


Figure 8.--1977 water equivalent.

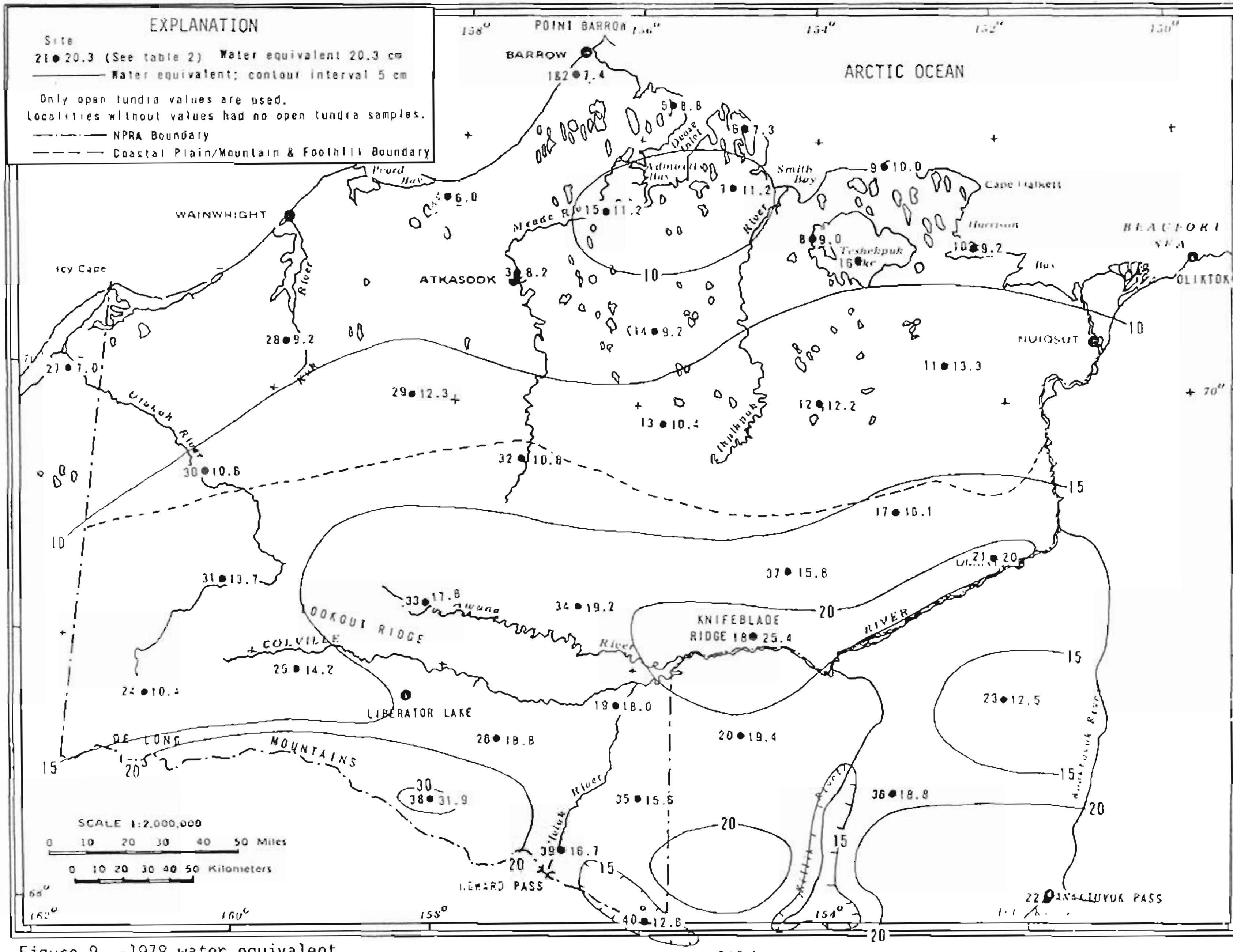


Figure 9.--1978 water equivalent.

Temperatures at the snow-soil interface (basal snowpack temperatures) averaged -13.1°C on tundra in 1977. Basal temperatures were lowest to the north and west, along the coast, and higher to the south and east. The range over soil was from -20°C at Point Lay (site 1; table 1) to -5°C near the Anaktuvuk River (site 38). On the coastal plain the average was -15°C on tundra, and in the mountains and foothills it averaged -10.6°C. Basal snowpack temperatures over ice were measured at sites 2, 3, 4, 11, 18, 19, and 33. They averaged -7°C and ranged from -18°C on the Kokolik River (site 3) to -2°C, also on the Kokolik (site 4). Basal snowpack temperatures over ice seemed to reflect the presence or absence of water below, being higher over water and lower over solidly frozen lakes and streams.

In 1978, basal snowpack temperatures on tundra were higher, averaging -10.4°C (tables 2 and 3). The coastal plain temperatures averaged -12.6°C and in the mountains and foothills averaged -9.1°C. The range was from -16°C at site 10 (Kogru) to 0°C at site 22 (Anaktuvuk Pass). No temperature measurements were made over ice in 1978.

Snow Structure

In April 1977, snow in coastal areas consisted of surface hoar less than 0.01 m thick over approximately equal thicknesses of dense wind slab and underlying depth hoar. Surface hoar is a deposit of thin ice crystals formed as a result of radiational cooling of a surface and is also known as hoar frost. Depth hoar is an increase in grain size and an overall decrease in the strength of the ice skeleton within the snowpack caused by temperature gradient induced water vapor transfer. Farther inland, where snow was deeper and wind less active, the wind slab was less prevalent and depth hoar did not develop to as great a thickness. This was generally true in both the foothills and the Brooks Range. However, thicker wind slab was present locally in passes and other wind channels.

In April-May 1978, the surface hoar in coastal areas was absent. The snow consisted of sastrugi-surfaced wind slab over depth hoar. On coastal plain tundra the snow consisted of 60.5 percent wind slab and 39.5 percent depth hoar by thickness, compared with an overall average of 42.7 percent depth hoar (table 3). As in 1977, the wind slab was generally less prevalent in the mountains and foothills than in the coastal plain. The only mountain and foothill sample sites which had sastrugi were site 21 (table 2), on a ridge north of Umiat, and site 24, in a broad basin south of Driftwood. Many localities in the foothills had 0.01 to 0.02 m of large (up to 0.01-m diameter) undisturbed stellar crystals on the surface. In contrast to 1977, depth hoar in 1978 was thicker in the mountains and foothills than on the coastal plain. Depth hoar thickness was 45.2 percent of the mountain and foothill snowpack (table 3).

Three distinct crusts were noted in the snowpack in 1978. A middle crust was not always present, but an upper crust relatively close to the surface and a lower crust directly or not far above the depth hoar were generally present. The crusts were usually coarse granular snow, ice layers, or granular snow over an ice layer. In some places, they appeared as zones of ice lenses or multiple thin wind crusts.

The snow stratigraphy is significant as a record of winter weather patterns and because it is the major factor which determines mechanical properties and stability of the snow. Accurate interpretation of snow stratigraphy, however, would require more detailed studies. Correlations of snow layers between sites were much more tenuous in the highly wind-affected coastal plain snowpack than in the mountains and foothills.

Wind Indicators

Due to the dominance of wind as a factor affecting both distribution and structure of snow on the Arctic Slope, wind indicators on the snow surface were noted in 1977 and re-examined in 1978. The patterns for both years were grossly similar, though many northwest-southeast marks were visible in 1977 that did not appear in 1978. A map (fig. 10) was compiled from the 1978 results.

The northeasterly to east-northeasterly prevailing wind on the coastal plain showed up well in snow-surface patterns, as did the opposing southwesterly to west-southwesterly storm wind. (See Benson, 1969, and Benson and others, 1975, for discussion of wind effects on Arctic Slope snow cover.) Both winds were deflected along the mountains and foothills to form an east-west flow. The storm wind indicators were far less apparent in most areas than those of the prevailing wind.

There was a strong wind flow from the south over the Brooks Range, particularly in the broad valleys and rolling mountains between Howard Pass and the eastern end of the DeLong Mountains. Southerly wind indicators from this area were evident in the foothills north of the Colville River. In the rugged mountains east of Howard Pass, southerly winds were channeled by the Nigu and Killik River valleys, resulting in thin snow cover. The thin snow appeared to be due both to wind erosion and transport of snow and to warm (chinook) winds. In early May 1978, the upper Nigu and Killik valleys were mostly snow-free.

Since snow-surface wind indicators are produced by wind transport of snow, their development depends on wind duration, as well as wind speed. Therefore, the wind indicators are an index of wind intensity. The corrugated surface of the coastal plain, with its well-developed sastrugi and drifts, is considered to indicate a high wind intensity.

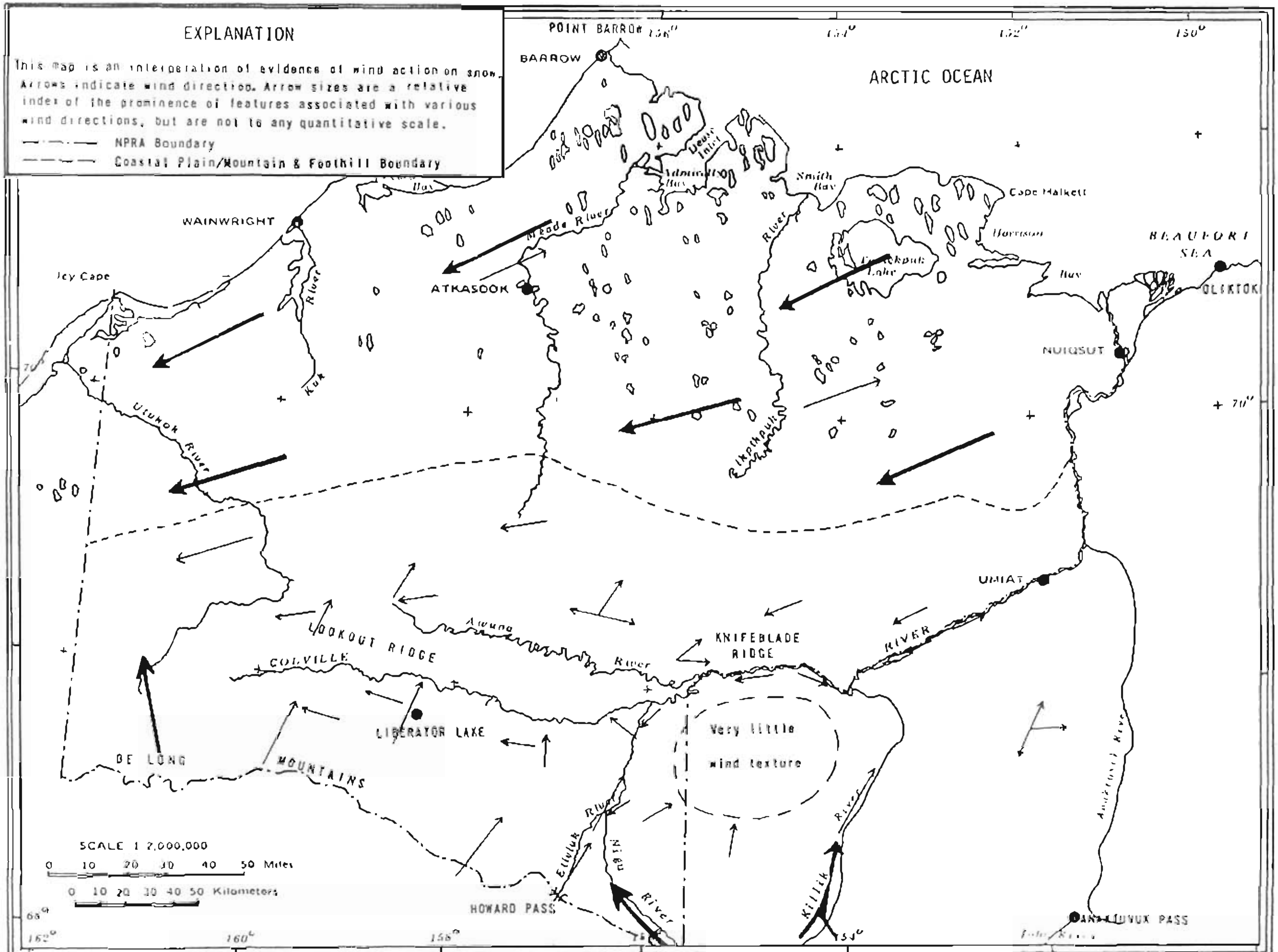


Figure 10.--1978 wind directions indicated by snow surface features.

Sastrugi were present throughout the coastal plain and locally in the mountains and foothills, most notably in the upper Utukok River area (fig. 10). Wind intensity was probably also high in areas where wind action had removed the snow down to bare ground. The most prominent of these areas were the upper Nigu and Killik River valleys. In a wide area of the middle Utukok River there were less pronounced indications of wind scour. The eastern edge of this moderately high wind intensity area appeared to grade near Liberator Lake into the moderate wind intensity zone characteristic of the foothills. The foothills area just south of the Colville River and from the Etivluk River to the Killik River appeared to be a zone of unusually low wind intensity in comparison with most areas observed. The high mountains south of this area may shelter it somewhat and divert south winds down the Nigu-Etivluk and Killik River drainages.

REMOTE SENSING

Landsat and National Oceanic and Atmospheric Administration (NOAA) weather satellite imagery was examined for information regarding snow cover conditions for NPRA in 1977. Quantitative estimates of snow cover were not attempted from the image analysis, but several patterns of snow distribution could be distinguished. Lakes near Teshekpuk Lake and Cape Halkett were easily distinguished on the 1:1,000,000-scale Landsat images of March 23 and 26, 1977. The lakes were relatively free of snow (fig. 11).

Streams on the coastal plain, such as the Meade, Topagoruk, Oumalik, Chipp, and Ikpikpuk Rivers, are conspicuous on March 27, 1977 (fig. 12), because of windblown sediment from exposed banks. The Landsat image of May 15, 1975 (fig. 13), shows ridges such as Meat Mountain in the upper reaches of the Utukok and Kokolik Rivers blown partly free of snow, suggesting intense wind action and thin snow cover.

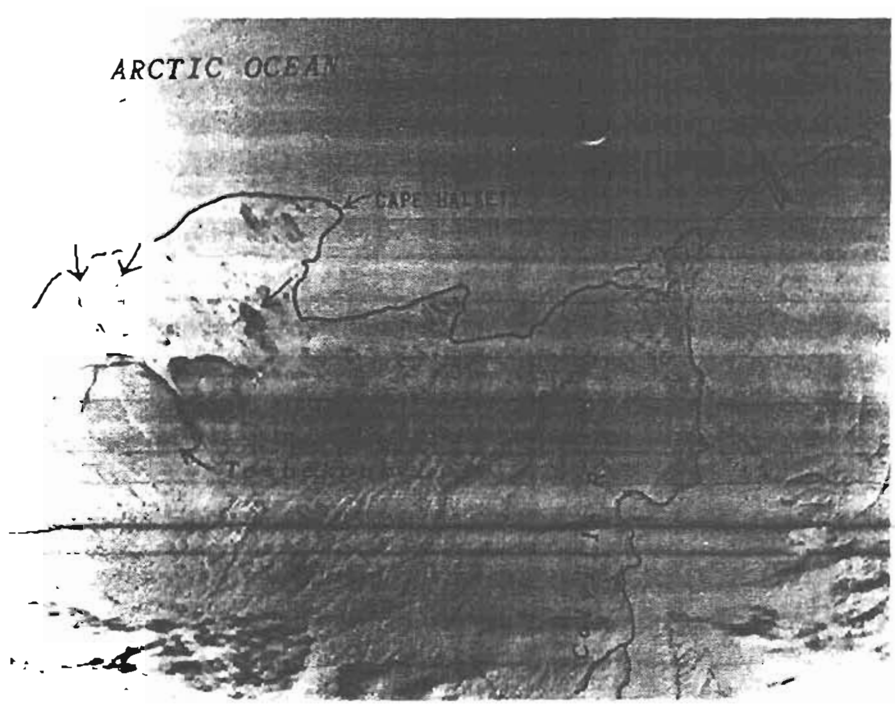


Figure 11.--Thin, wind-eroded snow cover on frozen lakes (indicated by arrows) in vicinity of Teshekpuk Lake, Landsat image E2791-21062, March 23, 1977.

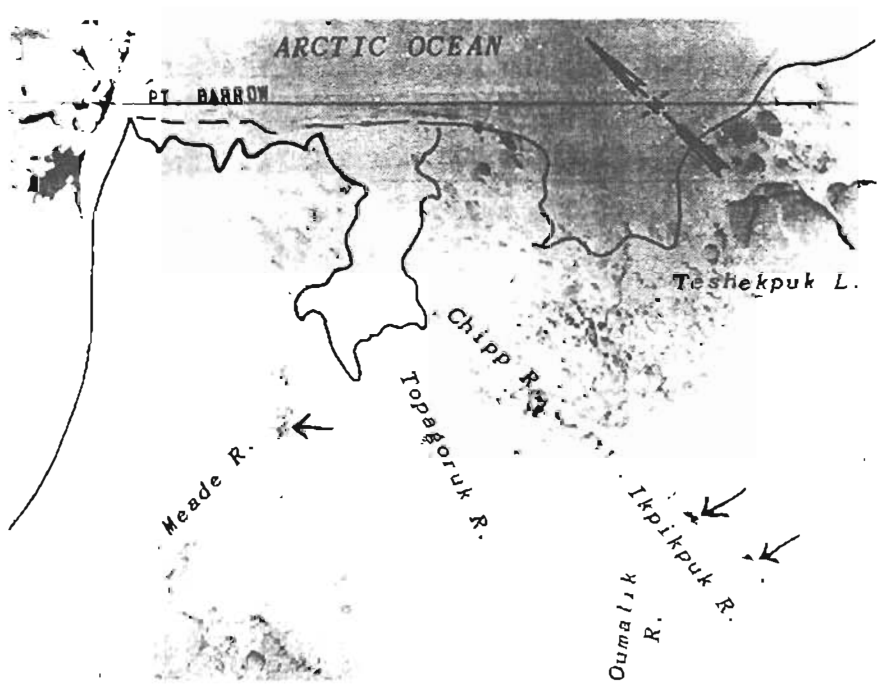


Figure 12.--Sediment (dark areas, indicated by arrows) on coastal plain rivers that are exposed by winds and blown across the snow. Landsat image E2794-21233, March 26, 1977; approximate width of image is 150 kilometers.

Figure 13.--Wind-eroded snow on ridges (arrows) in upper Utukok River drainage basin. Landsat image E2113-21572 of May 15, 1975; approximate distance across photo is 160 kilometers.

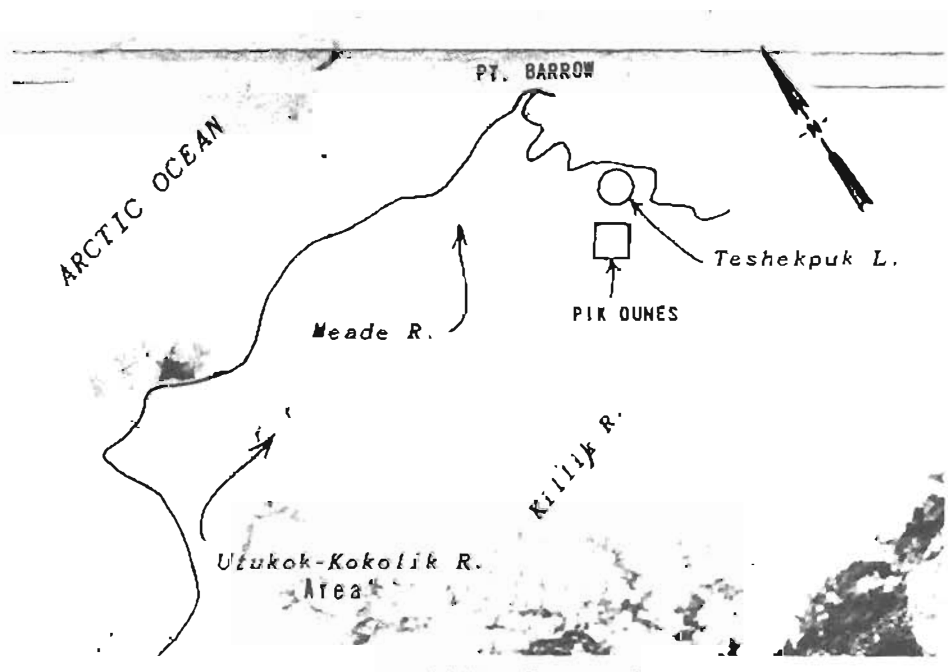


Figure 14.--NOAA satellite image, April 27, 1977, showing sediment at Pik Dunes and along coastal plain rivers.

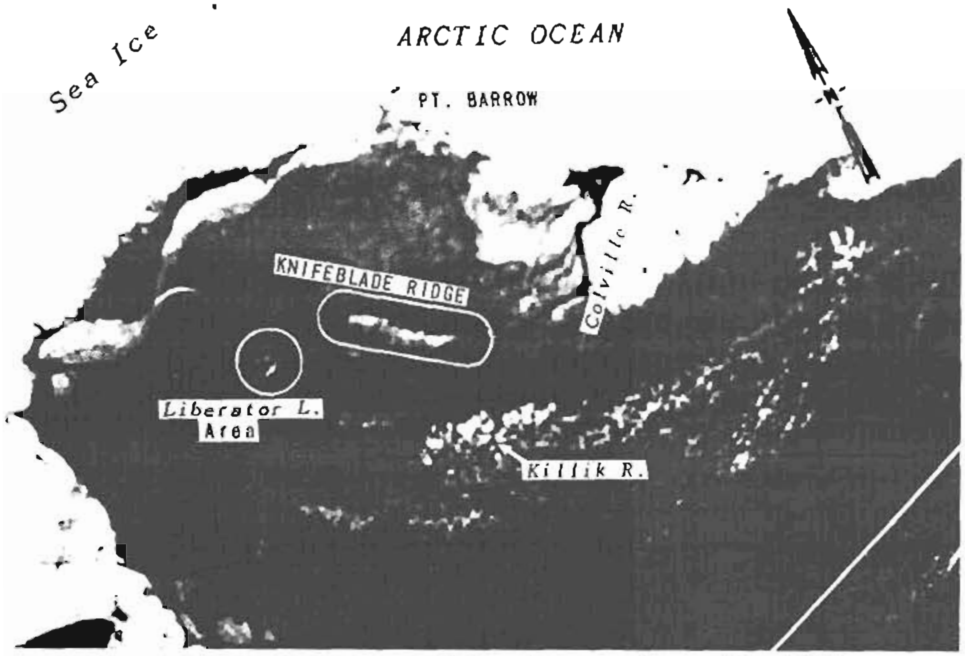


Figure 15.--NOAA satellite image, June 11, 1976, showing remnants, of snow cover after most snow has melted.

The scale of NOAA satellite imagery is not uniform throughout the image but is approximately an order of magnitude smaller than Landsat imagery and shows a large part of Alaska in one scene. A scene from April 27, 1977 (fig. 14), shows windblown sediment along stream channels from the Meade to Colville Rivers on the coastal plain, as well as in the Pik Dunes area south of Teshekpuk Lake. The thin snow cover on Teshekpuk Lake is also discernible. Also readily apparent are the wind-eroded thin snow areas in the Killik River valley and the snow-free ridges in the headwaters of the Ukukok and Kokolik drainage basins. A scene from June 11, 1976 (fig. 15), when snowmelt was far advanced, shows areas where snow persists. These include the high mountains on either side of the Killik River valley, Knifeblade Ridge, and the area in the DeLong Mountains southwest of Liberator Lake. These areas correspond in a general way with the areas of deepest snowpack found during the 1977 snow survey.

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