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The Joint Federal-State Land Use Planning Commission for Alaska

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The University of Alaska.
Arctic Environmental Information and Data Center

Alaska Regional Profiles

Arctic Region

State of Alaska

Jay S. Hammond
Governor

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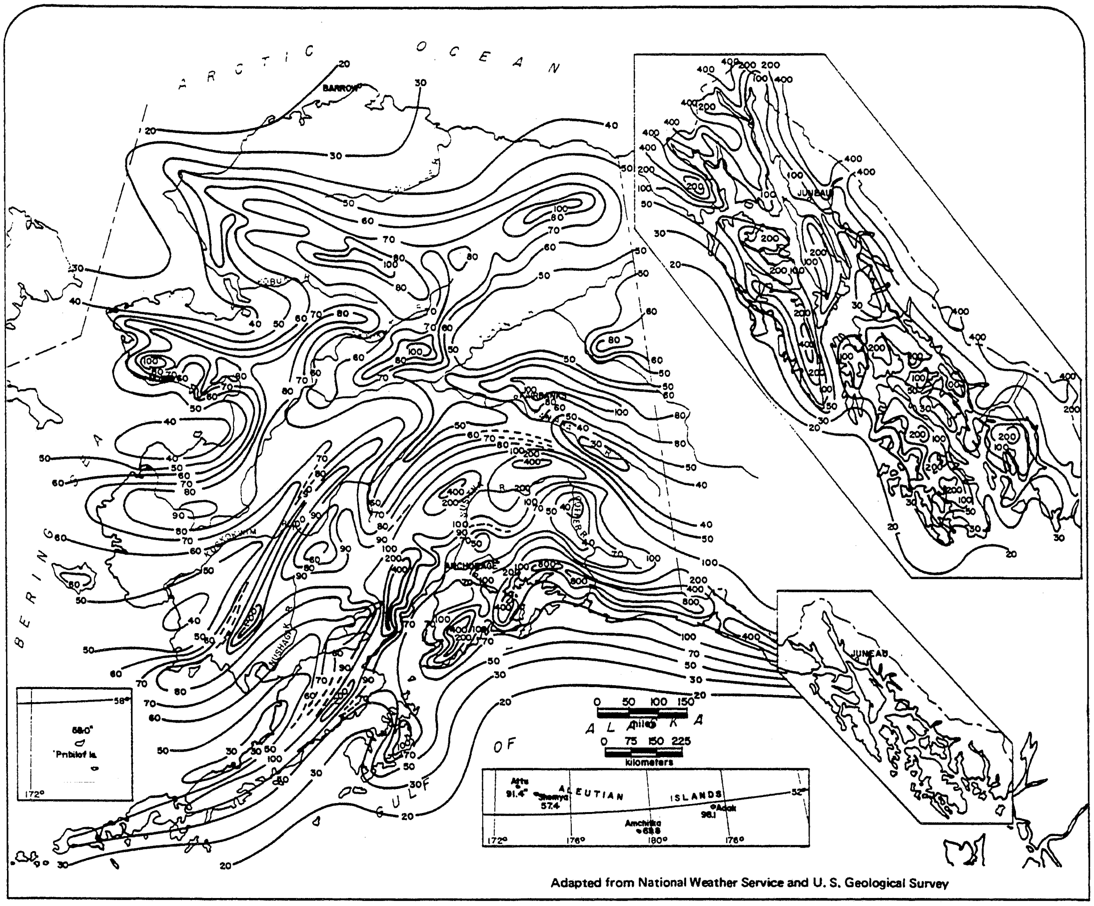

Figure 5

Snowfall Distribution in Inches

Precipitation values include the water equivalent of the snow.

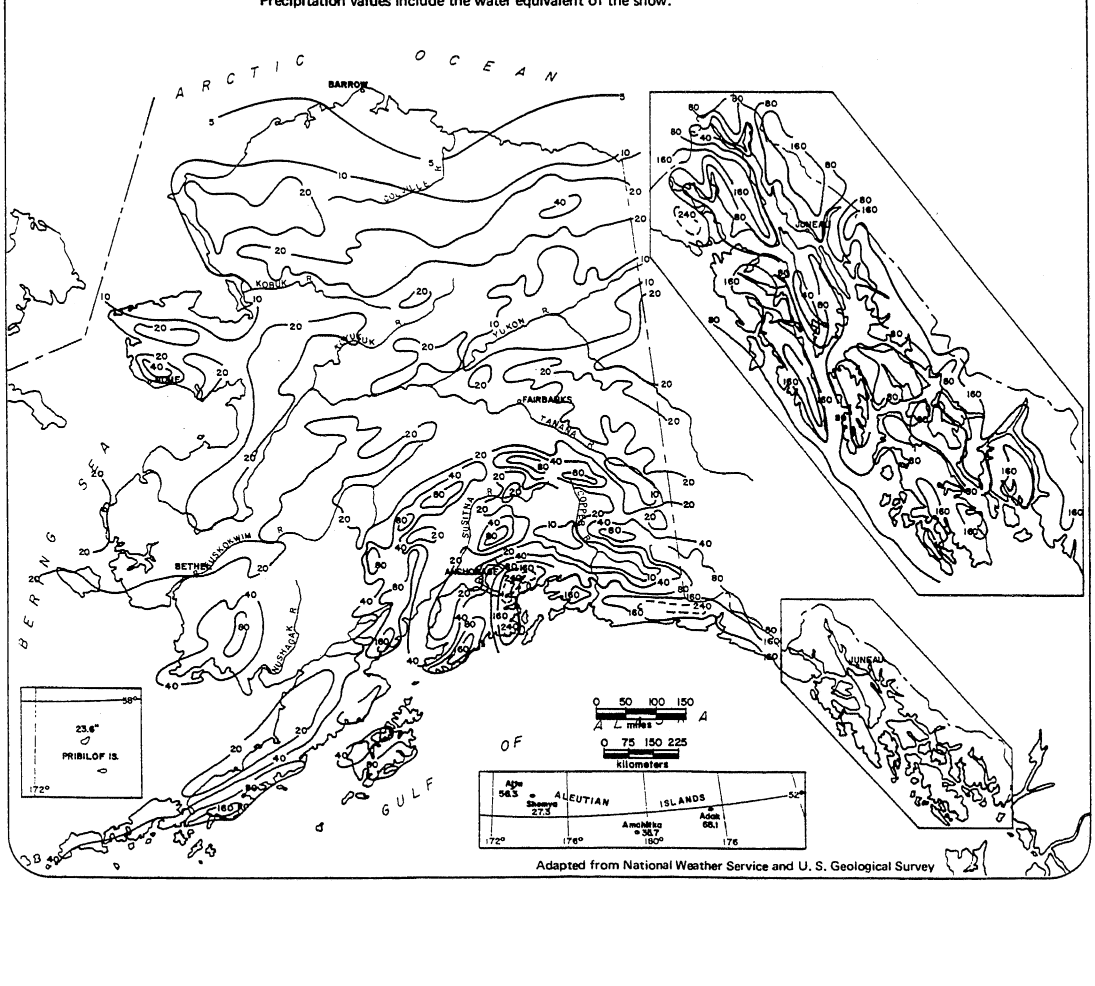

Figure 6

Mean Annual Precipitation Distribution in Inches

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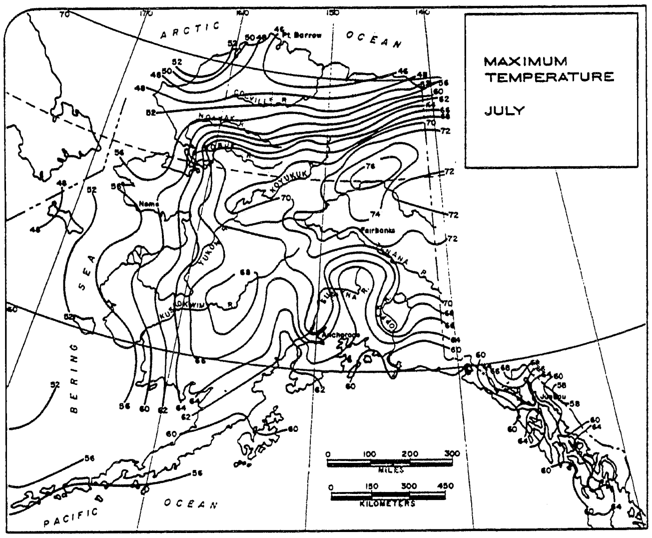
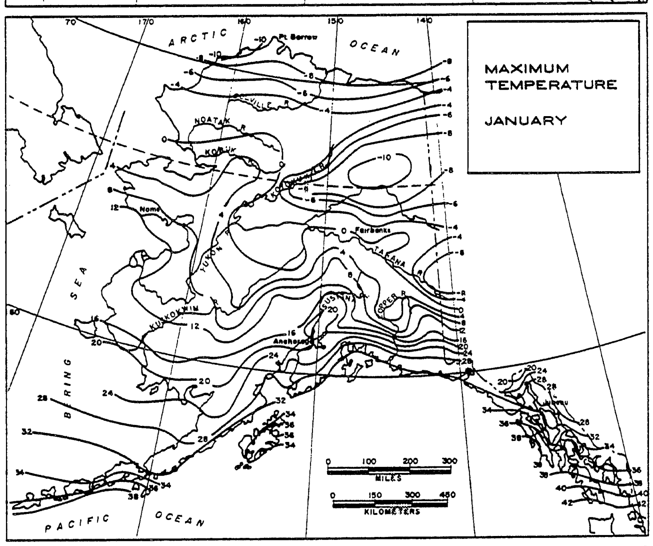
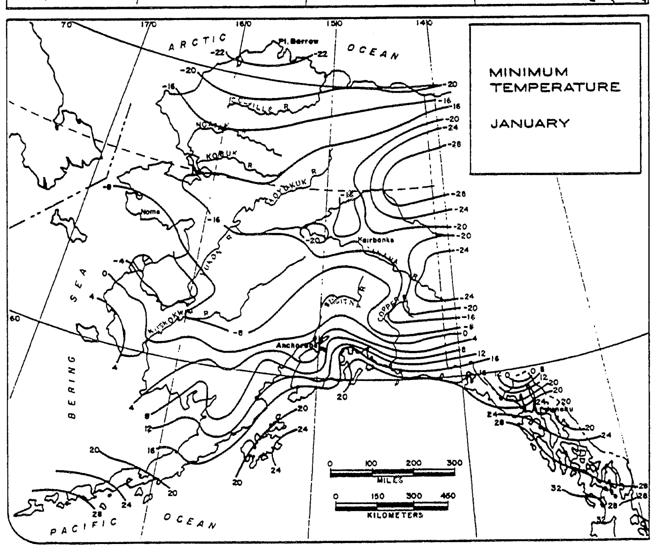
Temperature

Temperature patterns appear in Figures 7 through 10. The range of more than 100 degrees F between summer high and winter low temperatures in the Interior is characteristic of the Continental Zone, just as a range of only about 40 degrees F is typical of the Maritime Zone to the south. The National Weather Service, the official weather reporting and recording agency of the federal government, reported 100 degrees F at Fort Yukon on June 27, 1915, as the highest recorded temperature in the state. The lowest recorded temperature was minus 80 degrees F at Prospect Creek, about 25 miles southeast of Bettles, on January 23, 1971.

In general, temperature patterns shown are representative since the map scale makes it impossible to show them individually. The variety of terrain in Alaska creates **microclimates** or small areas where temperature, precipitation, or both will vary from that of the surrounding area. For example, **summer frost** in interior Alaska varies in frequency from one location to another but correlates most closely with elevation. Sites at higher elevations have greater frost frequency and cannot be shown on a small scale map.







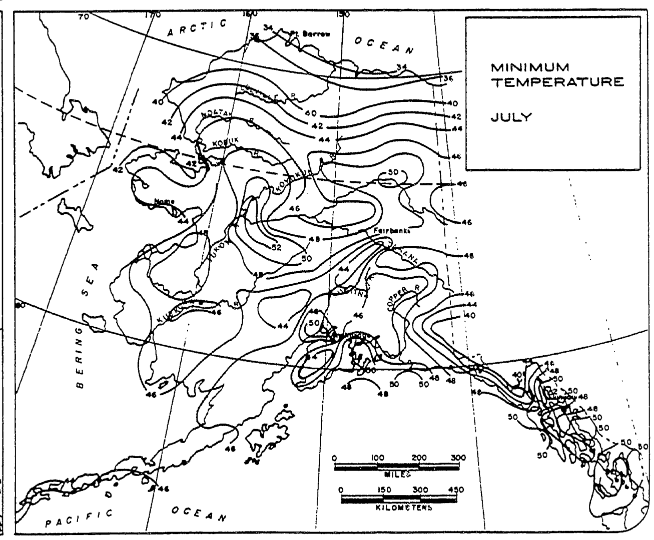


Figure 7 **Mean Maximum Temperature Distribution, July**

Figure 8 **Mean Maximum Temperature Distribution, January**

Figure 9 **Mean Minimum Temperature Distribution, January**

Figure 10 **Mean Minimum Temperature Distribution, July**

Degree Days

Degree days measure the departure of mean daily temperature from a given standard, one degree day for each degree of departure above or below the standard during the day. The standard for heating degree days is 65 degrees F, for freezing and thawing, 32 degrees F. Degree days are usually accumulated over a period of time or season.

By using the temperature pattern data of an area, **thermal loads** can be measured over a period of time, usually one year. **Heating, freezing,** and **thawing** loads are often measured in degree days per year.

Heating degree days measured below 65 degrees F provide information for calculating the annual fuel requirement for a heated building. The freezing degree days measured below 32 degrees F provide a basis for calculating the depth of annual ground freezing or ice thickness, while the thawing degree days measured above 32 degrees F provide a measure of ground thaw during spring.

Freezing Degree Days

For design purposes, freezing degree days of 1,000 more than the mean (Figure 11) will approximate an extreme that can be expected once in a 10-year period (Johnson, Hartman 1969). North of the Bering Strait, lines of equal freezing degree days at the coast are linear with values farther inland reflecting winter conditions. A curved pattern shows the influence of the unfrozen sea in the central and southern Bering Sea. The southern limit of isolated permafrost falls close to 2,000 freezing degree days on the Alaska Peninsula. A general relationship is not apparent between freezing degree days and other permafrost conditions.

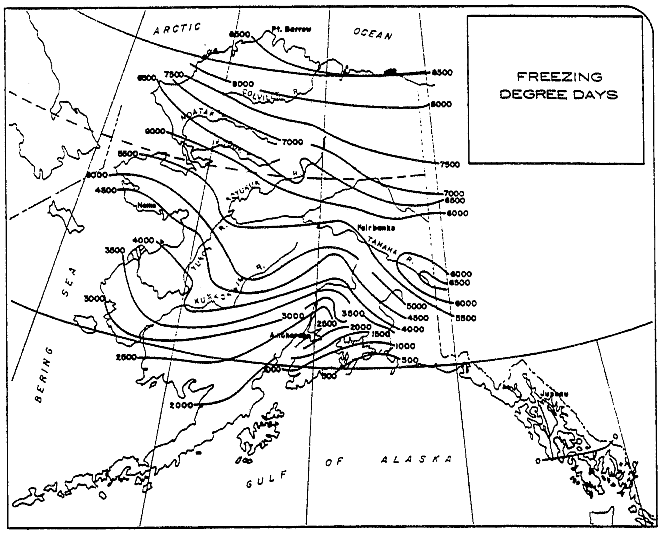
Thawing Degree Days

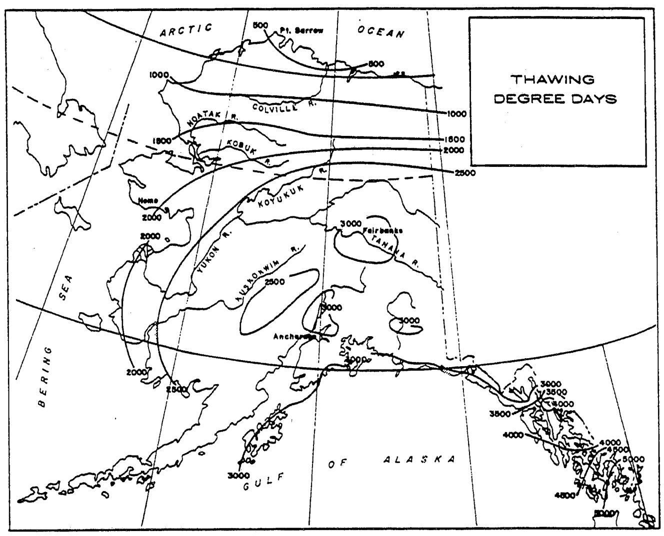
The presence of permafrost depends on thawing as well as freezing. Thawing degree days (Figure 12) also measure summer duration and temperatures. Areas with lower values of thawing degree days than freezing degree days tend to have some permafrost. Areas with low thawing degree days and high freezing degree days are candidates for continuous permafrost.

The uniformity of thawing degree days in interior Alaska is caused by higher summer temperatures, which compensate for longer thawing seasons farther south. It results in a fairly uniform type of forest cover, except where altitude reduces the length of the growing season for forest species. For design purposes in Alaska, thawing degree days which are 300 degrees greater than shown will occur approximately once every 10 years.

Heating Degree Days

Home heating begins when the air temperature is near 65 degrees F. Mean temperatures below 65 degrees accumulate heating degree days (Figure 13). When the mean temperature for a particular day is above 65 degrees, cooling degree days are measured. For design purposes the addition of 500 heating degree days for the Aleutian Islands and Southeast Alaska and 1,000 for the remainder of the state to the values shown on the chart for these areas will approximate one occurrence every 10 years.





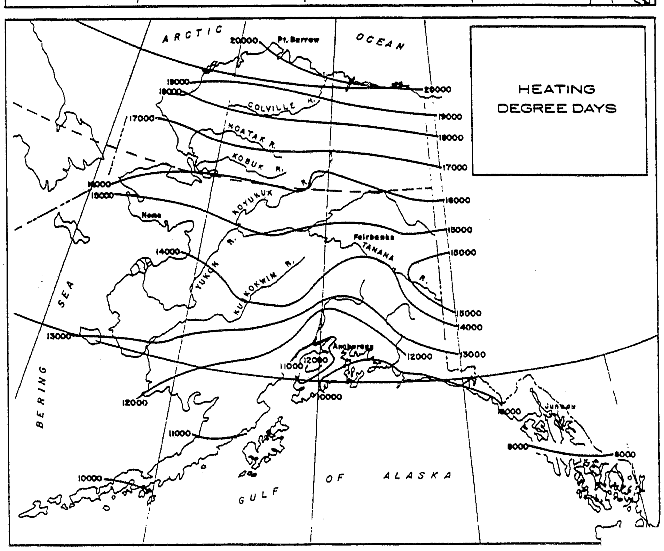


Figure 11 Annual Freezing Degree Day Distribution

Figure 12 Annual Thawing Degree Day Distribution

Figure 13 Annual Heating Degree Day Distribution

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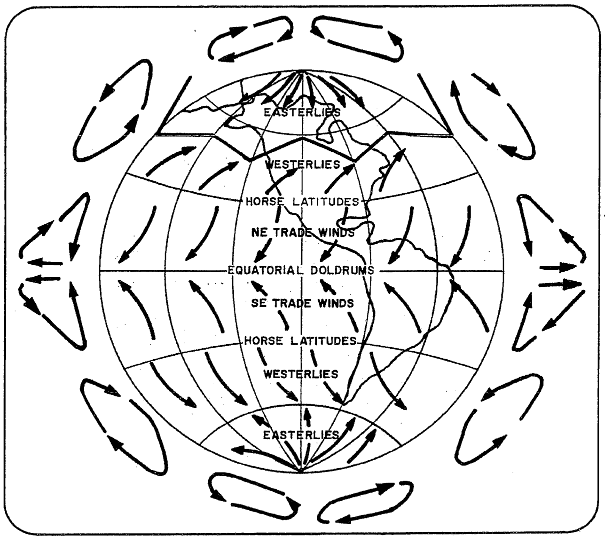
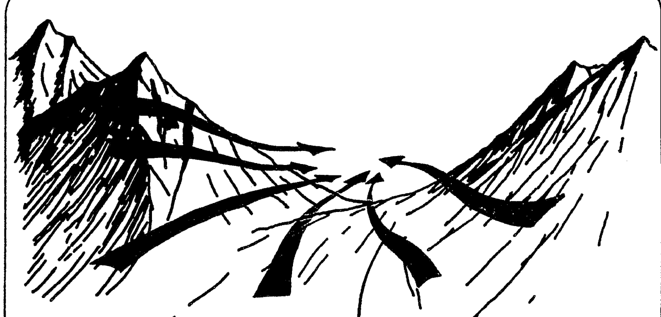


Figure 14 **Global Wind Circulation Pattern**



Air flowing through narrow gaps, such as mountain valleys, is accelerated. The more severe the restriction, the greater the acceleration.

Figure 15 **Wind Channeling**

WIND SPEED	COOLING POWER OF WIND EXPRESSED AS "EQUIVALENT CHILL TEMPERATURE"																				
MILES PER HOUR	TEMPERATURE (°F)																				
CALM	40	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-60
	EQUIVALENT CHILL TEMPERATURE																				
5	35	30	25	20	15	10	5	0	-5	-10	-15	-20	-25	-30	-35	-40	-45	-50	-55	-65	-70
10	30	20	15	10	5	0	-10	-15	-20	-25	-35	-40	-45	-50	-60	-65	-70	-75	-80	-90	-95
15	25	15	10	0	-5	-10	-20	-25	-30	-40	-45	-50	-60	-65	-70	-80	-85	-90	-100	-105	-110
20	20	10	5	0	-10	-15	-25	-30	-35	-45	-50	-60	-65	-75	-80	-85	-95	-100	-110	-115	-120
25	15	10	0	-5	-15	-20	-30	-35	-45	-50	-60	-65	-75	-80	-90	-95	-105	-110	-120	-125	-135
30	10	5	0	-10	-20	-25	-30	-40	-50	-55	-65	-70	-80	-85	-95	-100	-110	-115	-125	-130	-140
35	10	5	-5	-10	-20	-30	-35	-40	-50	-60	-65	-75	-80	-90	-100	-105	-115	-120	-130	-135	-145
40	10	0	-5	-15	-20	-30	-35	-45	-55	-60	-70	-75	-85	-95	-100	-110	-115	-125	-130	-140	-150
WINDS ABOVE 40 HAVE LITTLE ADDITIONAL EFFECT.	LITTLE DANGER					INCREASING DANGER (Flesh may freeze within 1 min.)						GREAT DANGER (Flesh may freeze within 30 seconds)									
	DANGER OF FREEZING EXPOSED FLESH FOR PROPERLY CLOTHED PERSONS																				

Figure 16 **Equivalent Wind Chill Temperatures**

Wind

Rotation and uneven heating of the earth's surface combine to create a model global circulation pattern shown in Figure 14 (Miller, Thompson 1970). These combined forces create three major circulation cells between the equator and the pole. Heated air at the equator rises and moves north, then gradually turns east at a latitude of 30 degrees under the influence of the earth's rotation. Air accumulates, creating high pressure at the surface. To equalize this pressure, air flows outward from the high toward the south as **northeasterly trade winds** and northeastward as **prevailing westerlies.** Cold air from the Arctic flows southwest and meets the warmer moist air moving north. Again air accumulates, this time at the earth's surface where it is forced upward by temperature gradient effect. This air mass divides in the upper atmosphere, part flowing north and part south, completing the circulation of the three cells. This last zone of upward moving air varies between 50 and 60 degrees latitude and provides the conditions for storms that form in the northern and western Pacific Ocean and move eastward to the south of the Aleutian Island chain into the Gulf of Alaska.

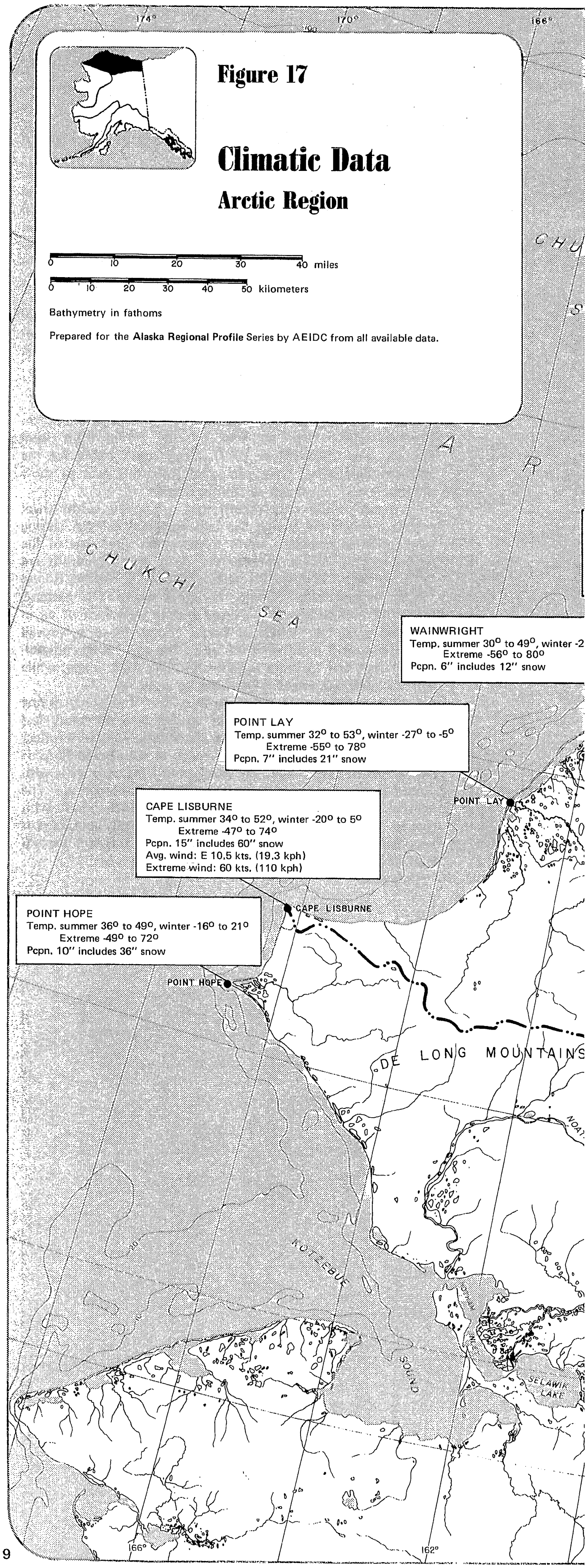
The earth's atmosphere is broken into numerous high and low pressure cells. These relate to certain types of weather. High pressure usually indicates improving or good weather; low pressure, deteriorating or stormy weather. Movements of air or wind are commonly related to tangible weather events but actually result from fluctuations in air pressure. Air in a high pressure cell flows toward a low pressure cell, creating **wind** movement. The speed of moving air is related to the difference in pressure over a given distance; the greater the pressure difference, the greater the wind speed.

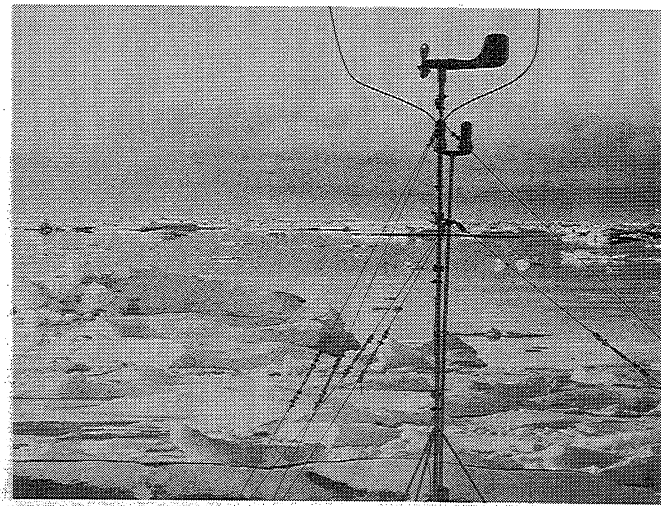
Wind Channeling

Wind speeds may also increase by channeling (Figure 15). Water provides a good example of this channeling effect. In a wide channel water may flow at a speed of five knots. If the channel narrows, the speed of the current increases in order to carry an equal volume of water in an equal amount of time. Wind reacts in the same way. Valleys and mountain passes form narrow channels. The best example of this in the Arctic Region is the Killik River valley. Observers flying over the valley in winter often report that strong winds have swept the ground bare of snow. Sheltered areas nearby are still covered with snow. Other examples of this are Anaktuvuk Pass and the Chandler River valley. Wind speeds in these special areas may double or triple.

Chill Temperature

The human body or any body warmer than the surrounding air, loses heat to the air. The rate of loss depends on the barriers to **heat loss,** such as clothing, insulation, and air. Air at body temperature reduces the loss to zero. Heat loss continues in changing air that is lower than body temperature. The rate depends on temperature differential and rate of change. Even a light wind results in an increased rate of heat loss. A strong wind can produce a rate loss greater than the body can replace it, resulting in a lowering of body temperature. The relationship between body heat loss and wind speed has been developed and is shown in graphic form in Figure 16. Proper clothing protects the body from extreme cold and wind.




Courtesy of Naval Arctic Research Laboratory

Arctic Climate

Arctic weather sharply contrasts with weather in other parts of Alaska. Average temperatures are cold, and persistently strong winds blow over the northern half of the area. Although the terrain is continuously wet in summer and dotted with lakes, the amount of precipitation is low. Therefore, except at higher elevations, the region is classified as a desert—a desert of frozen land.

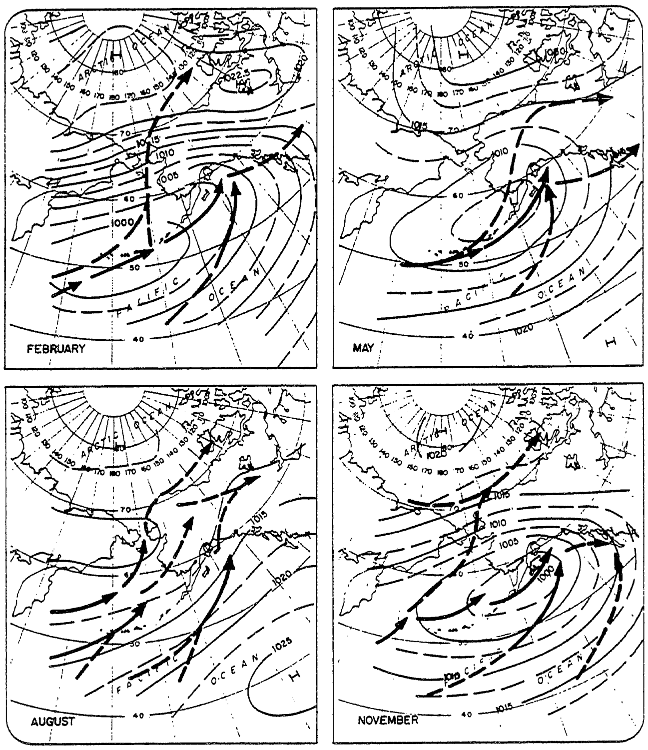
In the Arctic weather is critically important to man. At times, wind and temperature make outdoor activities difficult or impossible. The primary mode of transportation, flying, depends heavily on weather conditions. Surface transportation is restricted to a limited road system during warm months but increases when the tundra is frozen and snow-covered.

The Arctic Region and the Arctic Climatic Zone are geographically the same. Despite the proximity of the offshore icepack to land for at least 10 months of the year, the Arctic Ocean and Beaufort Sea have a modifying effect on coastal temperatures. On the southern extremity of the region the Brooks Range affects both temperature and precipitation. Surface winds are relatively strong along the coast but weaken and become more variable further inland. In the mountains wind speeds accelerate as they are channeled through north-south oriented passes (Figure 15).

The nine locations shown in Figure 17 are the only stations that provide weather data for the immense Arctic Region. Only at these locations have temperature and precipitation data been consistently recorded and summarized. Wind data are available only for Barrow, Umiat, Cape Lisburne, and Kaktovik (Barter Island). Because of the small amount of usable data for Oliktok, the figures shown for that station do not necessarily represent average conditions.

During exploratory oilwell drilling, observations were made at a number of locations near Prudhoe Bay. These records, which included information relating to aviation weather, did not include daily values of high and low temperature and precipitation. The data were not routinely summarized, therefore, although the locations of the observation points are shown on Figure 17, basic weather data are not shown for these sites. With the exception of Oliktok, a military Dewline station, data from the weather stations shown in Figure 17 are available from the National Climatic Center, Federal Building, Asheville, North Carolina 28801 and the Arctic Environmental Information and Data Center, University of Alaska, Anchorage.

Five stations on the coast from Barrow southeastward provide adequate data coverage for that portion of the coastal region. The remainder of the region is inadequately covered by weather reporting stations. Therefore, the sparsity of data stations requires that a great deal of subjective analysis be used to portray regional climatic patterns.



Primary Storm Track
Secondary Storm Track
—1015— Sea Level Pressure in Millibars (mb)

Lines called isobars connect points of equal surface pressure. Units of pressure are recorded in millibars rather than inches of mercury in order to better show very small changes in pressure. One millibar is approximately 0.03 inches of mercury. The area of high pressure found in the upper center of each of the four charts is a semipermanent pressure condition. Period of record is 40 years.

Adapted from National Weather Service charts.

Figure 18 **Average Storm Tracks and Sea Level Pressure Patterns for Four Months of the Year**

Weather conditions along the coast are reasonably represented by the conditions at Barrow and Barter Island, except fog which differs seasonally between the two locations. Since terrain is flat and most storms move west to east, all areas are affected in much the same way.

Inland from the coast, weather conditions are more locally variable. Umiat, in the foothills of the Brooks Range at the bend of the Colville River, is the only inland station with significant data. Sporadic data are available from Sagwon and more recently from pipeline construction camps along the trans-Alaska pipeline route. Inland surface winds are lighter and slightly more variable in direction. Temperatures have a greater range than along the coast, but precipitation is about the same.

Weather conditions at Anaktuvuk Pass are greatly influenced by local terrain and are therefore unique to that location. For example, as surface winds are channeled through the pass, they become quite strong at times.

Mean Storm Tracks and Storm Frequency

During World War II historical weather maps of the northern hemisphere were prepared for the period from 1899 through June 1939 (Klein 1957). Mean storm tracks for the northern hemisphere were computed from this data to show the source and movement of storm centers.

August is the only month that a primary storm track crosses through the Bering Sea into northwest Alaska. During other months secondary storm tracks affect some part of the Arctic Region. Storm patterns for 4 of the 12 months are shown in Figure 18. Mean pressure patterns (U.S. Weather Bureau 1952) are superimposed onto the storm tracks. The patterns for all 12 months show an average east to west flow of air in the Arctic. Surface winds at Barter Island, however, prevail from the west 3 months of the year. The small scale climatology of that area permits locally prevailing west winds, while large scale air movement is from east to west.

With a primary storm track into the Arctic only during August, the annual frequency of storms is considerably less than in other parts of Alaska. The statistics in Figure 19 reflect the percentage frequency of occurrence in days or portions of days averaged over 40 years of record for geographic areas with dimensions of 5 degrees latitude by 10 degrees longitude. The highest frequency of occurrence is during summer months with August the highest. However, even the frequency in August is low, especially when compared to the Bristol Bay and western Gulf of Alaska regions.

Whiteout in the Arctic.

Joseph C. LaBelle

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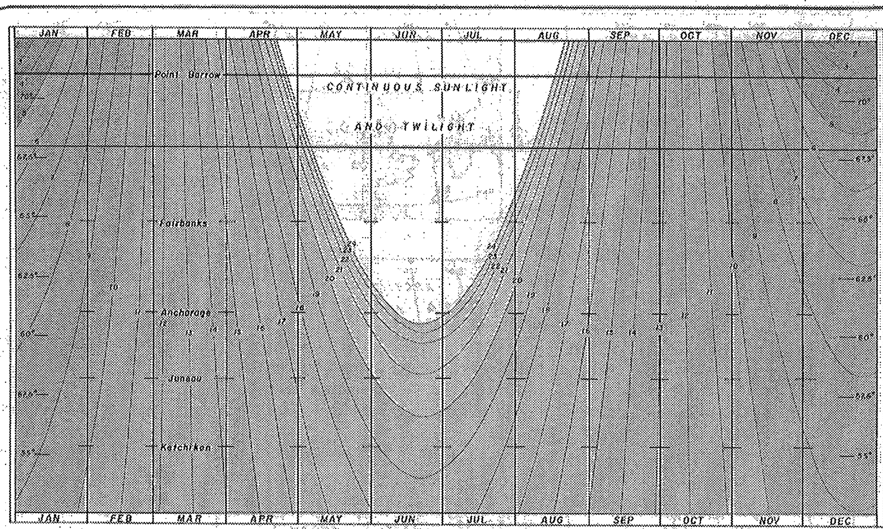

The curved lines are labeled in hours and represent the combined hours of sunlight and civil twilight for different latitudes and months of the year. Hours of darkness can be estimated by computing the difference between the value of the line and the total of 24 hours. The latitude locations of the villages in the Arctic are indicated by a solid horizontal line.

Source: Environmental Atlas of the Greater Anchorage Area Borough, Alaska, L. Selkregg et al, 1972.

Figure 20 Sunlight and Darkness

Solar Radiation of Sunlight and Heat

Latitude and the season of the year determine the length of each day at a particular location (Figure 20). In the north days are longer in summer and shorter in winter than at more southerly latitudes. Twilight marks the beginning of darkness or sunlight.

The three twilight terms in use are civil, nautical, and astronomical. **Civil twilight,** the term most frequently used, is the time of day when the sun is below the horizon by 6 degrees or less. **Nautical twilight** represents the range between 6 and 12 degrees below the horizon, and **astronomical twilight** is between 12 and 18 degrees below the horizon (American Meteorological Society 1959). Beyond 18 degrees sunlight no longer results from bending the sun's rays, but is reflected light such as from the moon. At the end of civil twilight visibility is drastically reduced affecting most outdoor activities.

The sun rises at Barrow at 1:06 a.m. on May 10th and does not set again until August 2nd at 11:51 p.m. with an elapsed time of 84 days, 21 hours, and 3 minutes (U. S. Naval Observatory). Actually, darkness ceases with the beginning of civil twilight at 1:03 a.m. on April 23rd and does not begin again until the end of twilight at 11:59 p.m. on August 19th. The total elapsed time without complete darkness is 118 days, 22 hours, and 56 minutes. The sun sets in Barrow at 12:50 p.m. on November 18th and does not rise again until January 24th at 11:51 a.m. with an elapsed time of 66 days, 23 hours, and 1 minute. However, a short period of twilight or indirect sunlight occurs during each of these days, ranging from 2 hours and 58 minutes in December to slightly more than 6 hours in November and January. Although the sun does not appear above the horizon for almost 67 days, approximately 12½ days of twilight occur at daily intervals of varying length.

Summer in the arctic foothills.

Courtesy of ARCO

Temperature

The Arctic receives most of its heat energy during summer. The decrease of heat energy in fall and winter is gradual at southern latitudes, but is dramatically rapid at extreme northern latitudes. Decreases in temperature follow the same pattern, especially after heat energy from the surface to the atmosphere exceeds the incoming heat from the atmosphere to the surface. Then, temperatures in the Arctic are influenced by air flow which periodically carries warmer air to the north.

In the Arctic the heat energy balance becomes negative—more outgoing than incoming—in September, compared to mid-October for southern Alaska. From September until the end of December both maximum and minimum temperatures drop rapidly. A slight warming trend occurs in most of the region in January. Temperatures reach their lowest point in February, move upward beginning in late March, and rise rapidly from April to July. The heat energy balance becomes positive again in late March or early April. Figure 23 shows average maximum and minimum temperatures and extreme temperatures for locations where data are available.

February is the coldest month at all stations except Anaktuvuk, where January is the coldest (Environmental Data Service, U. S. Department of Commerce, various dates). Average minimums range from about minus 35 degrees F (minus 37 degrees C) along the foothills of the Brooks Range to approximately minus 25 degrees F (minus 32 degrees C) along the north and northwest coast to minus 20 degrees F (minus 29 degrees C) along the extreme southwestern coast. July is the warmest month in the region. Average Fahrenheit maximums range from the mid- to low 60s along the foothills to the mid-40s along the north coast to the mid-50s along the southwestern coast. Summer minimum temperatures drop below freezing in all areas but average below freezing at only three of the seven observation sites. Extreme temperatures, both warmest and coldest, occur in the foothills or mountain areas.

In the Arctic, chill temperature values are more important to biologic systems than the free air temperature. Cold winter temperatures coupled with strong winds produce chill temperatures that require extreme precautions before outdoor activity is conducted. Figure 24 reflects chill temperatures for each degree and mile per hour of wind. This detailed interpolation of equivalent chill temperature is presented in addition to Figure 16 since this climatic condition is so important to man's occupancy and use of the land.

The frequencies of occurrence of chill temperatures at three locations are presented in Figure 25. Barrow is used to represent the area from the coast inland approximately 50 miles, Umiat for the interior beyond 50 miles, and Cape Lisburne for the western coastal area.

Figure 23 Temperature Averages and Extremes

Average maximums, minimums, and extremes have been combined on a single chart for the nine available observation locations. This allows comparisons between stations and shows the rapid temperature changes that occur during spring and fall months. Because only one to five years of record are available for Oliktok, the information presented for this station does not allow long-term averaging.

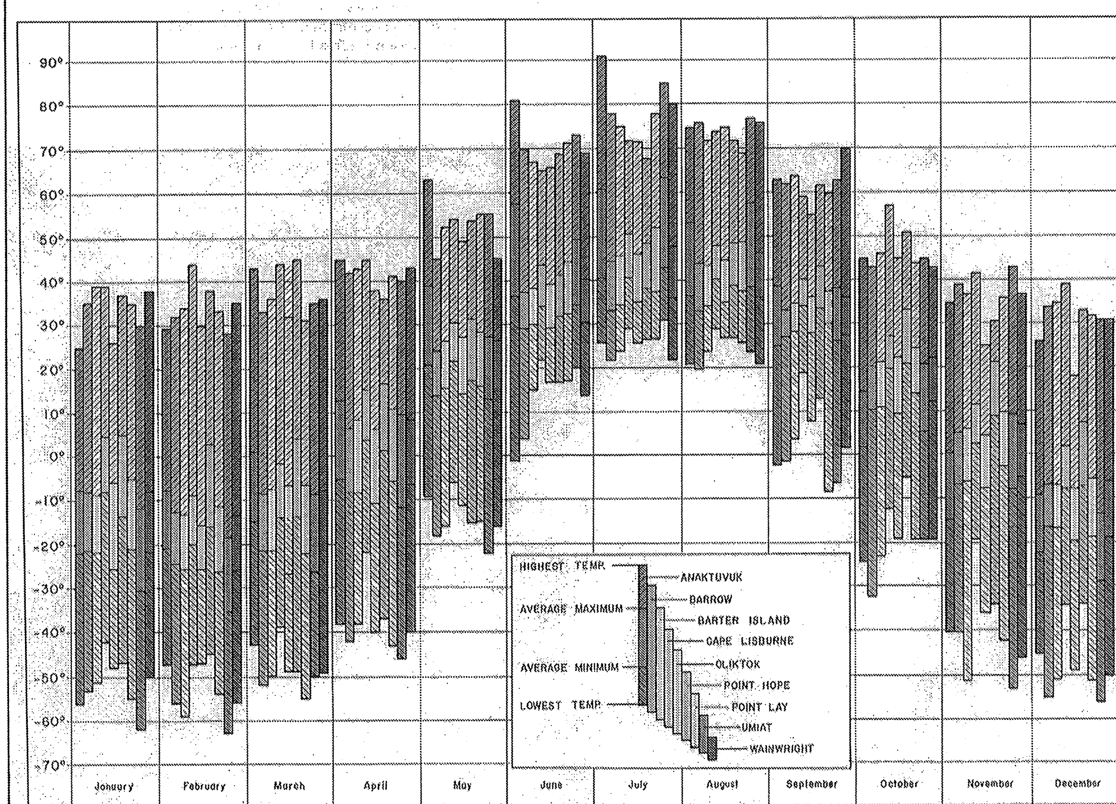

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Figure 24 Cooling Power of Wind Expressed as "Equivalent Chill Temperature"

LITTLE DANGER (temperatures 0 to -15) — INCREASING DANGER (temperatures -16 to -35)

Wind \ Temperature	0	-1	-2	-3	-4	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35
5	-5	-6	-7	-8	-9	-10	-11	-12	-13	-14	-15	-16	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40
6	-8	-9	-10	-11	-12	-13	-14	-15	-17	-18	-19	-20	-21	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-39	-40	-41	-42	-43	-44	-45
7	-11	-12	-13	-14	-15	-16	-17	-19	-20	-22	-23	-24	-25	-26	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-41	-42	-43	-45	-46	-47	-48	-49	-50
8	-14	-15	-16	-17	-18	-19	-21	-22	-23	-25	-27	-28	-29	-30	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	-41	-42	-43	-45	-47	-48	-50	-51	-52	-53	-54	-55
9	-17	-18	-19	-20	-21	-22	-24	-26	-27	-29	-31	-32	-33	-34	-35	-36	-37	-38	-39	-40	-41	-42	-43	-44	-45	-46	-47	-49	-51	-53	-55	-56	-57	-58	-59	-60
10	-20	-21	-22	-23	-24	-25	-27	-29	-31	-33	-35	-36	-37	-38	-39	-40	-41	-42	-43	-44	-45	-46	-47	-48	-49	-50	-52	-54	-56	-58	-60	-61	-62	-63	-64	-65
11	-22	-23	-24	-25	-26	-28	-30	-32	-34	-35	-37	-38	-39	-40	-41	-42	-43	-44	-45	-47	-48	-49	-50	-51	-52	-53	-55	-57	-59	-61	-62	-63	-64	-65	-66	-68
12	-24	-25	-26	-27	-29	-31	-33	-34	-35	-37	-39	-40	-41	-42	-43	-44	-45	-47	-48	-50	-51	-52	-53	-54	-55	-56	-58	-59	-61	-63	-64	-65	-66	-67	-69	-71
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14	-28	-29	-30	-33	-35	-37	-39	-40	-41	-42	-43	-44	-45	-46	-47	-48	-49	-52	-54	-56	-57	-58	-59	-60	-61	-62	-63	-64	-65	-66	-68	-69	-71	-73	-75	-77
15	-30	-32	-34	-36	-38	-40	-41	-42	-43	-44	-45	-46	-47	-48	-49	-50	-52	-54	-56	-58	-60	-61	-62	-63	-64	-65	-66	-67	-68	-69	-70	-72	-74	-76	-78	-80
16	-31	-33	-35	-37	-39	-41	-42	-43	-44	-45	-46	-47	-49	-50	-51	-52	-54	-56	-58	-59	-61	-62	-64	-65	-66	-67	-68	-69	-70	-71	-72	-74	-75	-77	-79	-81
17	-32	-34	-36	-38	-40	-42	-43	-44	-45	-46	-47	-48	-50	-52	-53	-54	-56	-58	-60	-61	-62	-64	-66	-67	-68	-69	-70	-71	-72	-73	-74	-76	-77	-78	-80	-82
18	-33	-35	-37	-39	-41	-43	-44	-45	-46	-47	-48	-49	-51	-52	-54	-56	-58	-60	-61	-62	-63	-65	-67	-69	-70	-71	-72	-73	-74	-75	-76	-78	-79	-80	-82	-83
19	-34	-36	-38	-40	-42	-44	-45	-46	-47	-48	-49	-50	-52	-54	-56	-58	-60	-61	-62	-63	-64	-66	-68	-70	-72	-73	-74	-75	-76	-77	-78	-80	-81	-82	-83	-84
20	-35	-37	-39	-41	-43	-45	-46	-47	-48	-49	-50	-52	-54	-56	-58	-60	-61	-62	-63	-64	-65	-67	-69	-71	-73	-75	-76	-77	-78	-79	-80	-81	-82	-83	-84	-85
21	-37	-38	-40	-42	-44	-46	-47	-48	-49	-50	-52	-54	-56	-58	-60	-61	-62	-63	-64	-66	-67	-68	-70	-72	-74	-76	-78	-79	-80	-81	-82	-83	-84	-85	-86	-87
22	-39	-40	-42	-44	-46	-47	-48	-49	-50	-52	-54	-56	-57	-59	-61	-62	-63	-64	-66	-68	-69	-70	-72	-74	-76	-77	-79	-80	-81	-83	-84	-85	-86	-87	-88	-89
23	-41	-42	-43	-45	-47	-48	-49	-50	-52	-54	-56	-58	-59	-60	-62	-63	-64	-66	-68	-70	-71	-72	-74	-76	-77	-78	-80	-81	-82	-84	-86	-87	-88	-89	-90	-91
24	-43	-44	-45	-47	-48	-49	-50	-52	-54	-56	-58	-59	-60	-61	-62	-63	-65	-67	-69	-71	-73	-74	-76	-77	-78	-79	-81	-82	-84	-86	-88	-89	-90	-91	-92	-93
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28	-48	-49	-50	-51	-52	-53	-55	-57	-59	-61	-63	-64	-65	-66	-67	-68	-70	-72	-74	-76	-78	-79	-80	-81	-82	-84	-85	-87	-89	-91	-93	-94	-95	-96	-97	-98
29	-49	-50	-51	-52	-53	-54	-56	-58	-60	-62	-64	-65	-66	-67	-68	-69	-71	-73	-75	-77	-79	-80	-81	-82	-83	-84	-86	-88	-90	-92	-94	-95	-96	-97	-98	-99
30	-50	-51	-52	-53	-54	-55	-57	-59	-61	-63	-65	-66	-67	-68	-69	-70	-72	-74	-76	-78	-80	-81	-82	-83	-84	-85	-87	-89	-91	-93	-95	-96	-97	-98	-99	-100
31	-51	-52	-53	-54	-55	-56	-58	-60	-62	-64	-65	-66	-68	-69	-70	-71	-73	-75	-76	-78	-80	-81	-83	-83	-84	-86	-88	-90	-92	-94	-96	-97	-98	-99	-100	-101
32	-52	-53	-54	-55	-56	-57	-59	-60	-62	-64	-65	-67	-69	-70	-71	-72	-74	-76	-77	-78	-80	-82	-83	-85	-86	-87	-89	-91	-93	-95	-97	-98	-99	-100	-101	-102
33	-53	-54	-55	-56	-57	-58	-60	-61	-62	-64	-65	-67	-69	-71	-72	-73	-75	-76	-77	-79	-80	-82	-84	-86	-87	-88	-90	-92	-94	-96	-98	-99	-100	-101	-102	-103
34	-54	-55	-56	-57	-58	-59	-60	-62	-63	-64	-65	-67	-69	-71	-73	-74	-76	-77	-78	-79	-80	-83	-85	-87	-88	-89	-91	-93	-95	-97	-99	-100	-101	-102	-103	-104
35	-55	-56	-57	-58	-59	-60	-61	-62	-63	-64	-65	-67	-69	-71	-73	-75	-76	-77	-78	-79	-80	-83	-86	-88	-89	-90	-92	-94	-96	-98	-100	-101	-102	-103	-104	-105
36	-56	-57	-58	-59	-60	-61	-62	-63	-64	-65	-66	-68	-70	-71	-73	-75	-76	-78	-79	-80	-81	-82	-83	-84	-87	-91	-93	-95	-97	-99	-101	-102	-103	-104	-105	-106
37	-57	-58	-59	-60	-61	-62	-63	-64	-65	-66	-67	-68	-70	-72	-74	-75	-76	-79	-80	-81	-82	-83	-85	-88	-90	-92	-94	-96	-98	-100	-102	-103	-104	-105	-106	-107
38	-58	-59	-60	-61	-62	-63	-64	-65	-66	-67	-68	-69	-71	-73	-74	-75	-76	-80	-81	-82	-83	-84	-86	-88	-91	-93	-95	-97	-99	-101	-103	-104	-105	-106	-107	-108
39	-59	-60	-61	-62	-63	-64	-65	-66	-67	-68	-69	-70	-71	-73	-74	-75	-78	-81	-82	-83	-84	-85	-87	-89	-92	-94	-96	-98	-100	-102	-104	-105	-106	-107	-108	-109
40	-60	-61	-62	-63	-64	-65	-66	-67	-68	-69	-70	-71	-72	-73	-74	-75	-78	-79	-82	-83	-85	-87	-89	-91	-93	-96	-97	-99	-101	-103	-105	-106	-107	-108	-109	-110

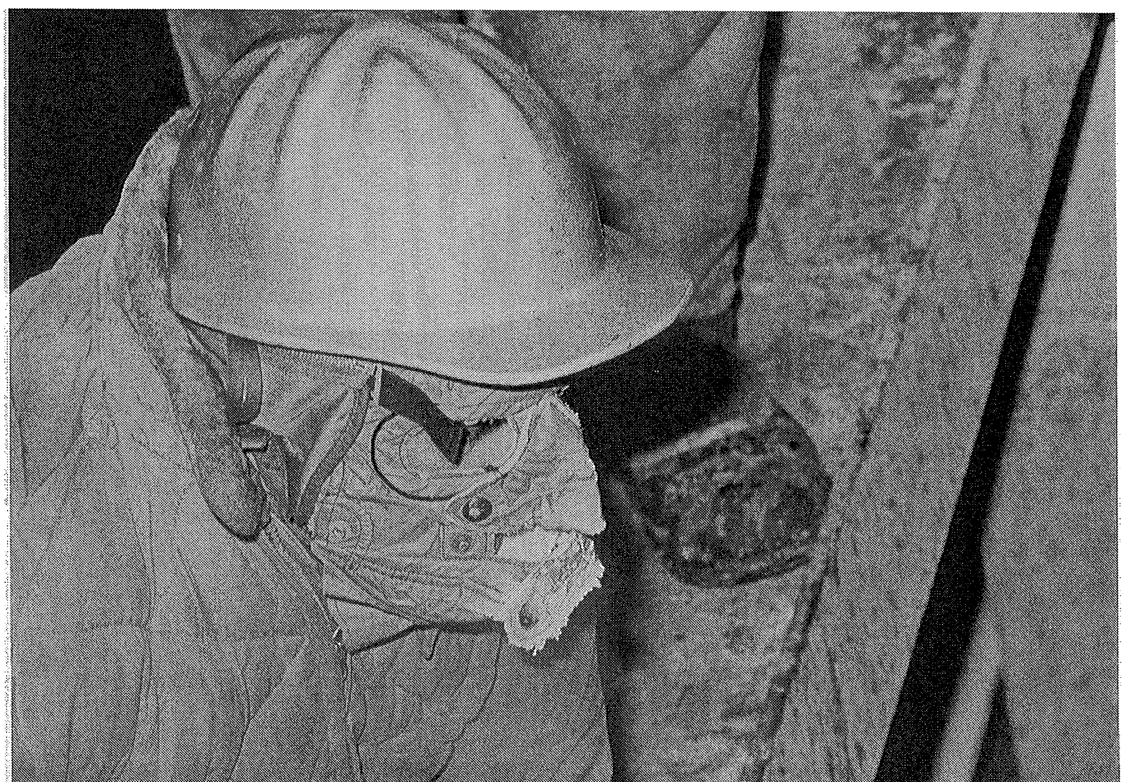
INCREASING DANGER
Exposed flesh may freeze within one minute.

GREAT DANGER
Exposed flesh may freeze within thirty seconds.

The chill temperature for each Fahrenheit degree and mile per hour of wind was interpolated from the Equivalent Wind Chill Temperature Chart, Figure 16. Temperatures of zero and colder are critical in the Arctic because of moderately strong surface winds.

Wind speeds are in MPH, Temperature °F.

Adapted from U.S. Air Force, Arctic Aeromedical Laboratory and Scientific Services, 11th Weather Squadron



Grossmann-Granger Productions, Courtesy of ARCO

RCA Comments
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Data summaries are available only from these three locations. For most planning purposes Barrow is considered representative of the north arctic coast, Cape Lisburne of the western and northwestern coast, and Umiat of the interior plains and foothills.

Period of records: Barrow—20 years, Cape Lisburne —14 years, Umiat—8 years.

Adapted from U.S. Air Force, Air Weather Service.

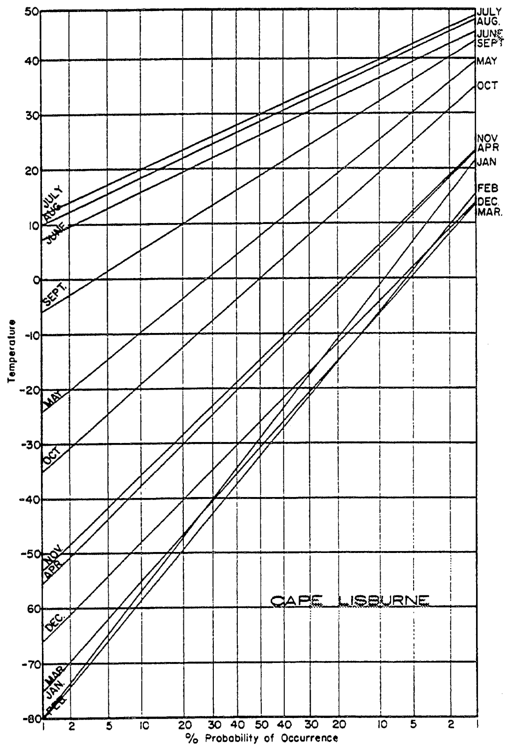
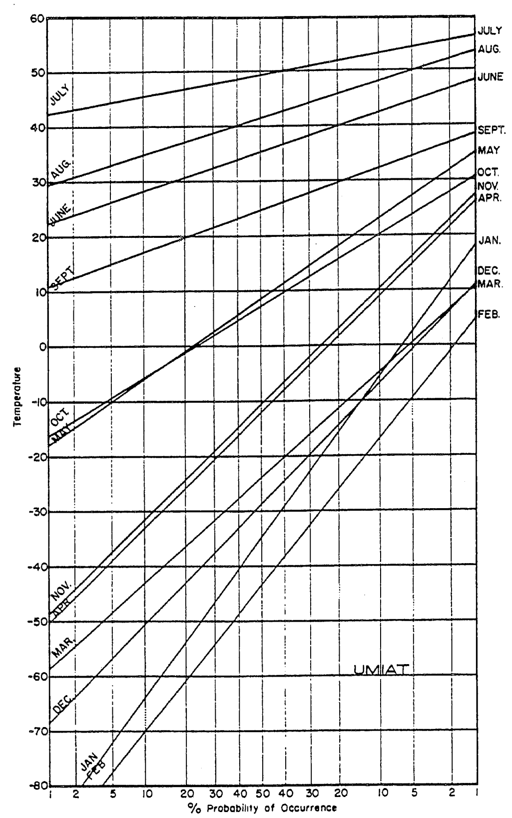
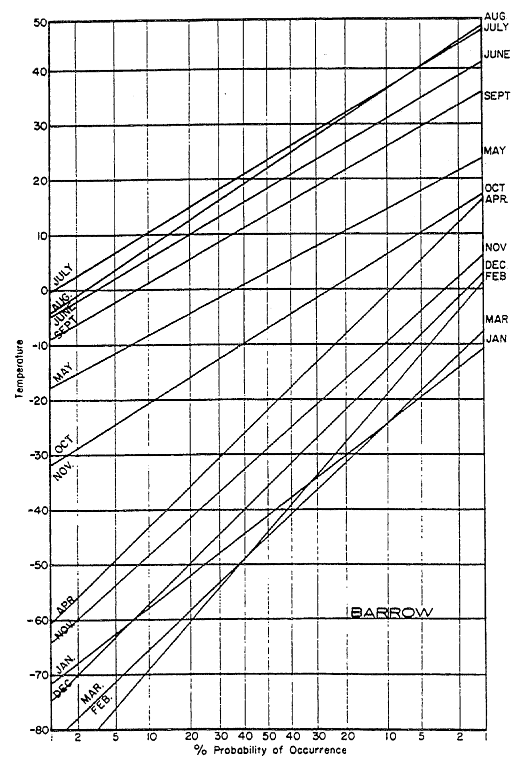


Figure 25 Frequency of Occurrence of Chill Temperatures at Barrow, Cape Lisburne, and Umiat.





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Precipitation

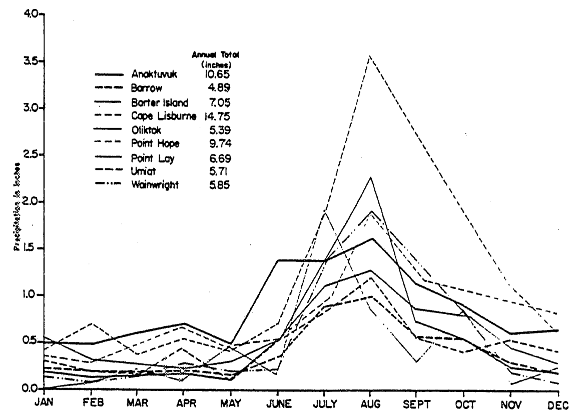
Annual precipitation amounts depend on many climatic interrelationships such as global weather patterns, terrain of the surrounding area, and air temperature. Annual precipitation amounts in the Arctic are generally low (Environmental Data Service, U. S. Department of Commerce, various dates). Any exception can be explained by special conditions affecting one or more of the three factors mentioned above.

Global weather patterns, partially presented in Figure 18, show major storm tracks. During all months except August the major storm track in Alaska is along and to the south of the Aleutian Island chain, Alaska Peninsula, and into the Gulf of Alaska. There are many minor storm tracks. One pushes storms in a west to east movement along the Alaskan coastal Arctic from the Soviet Arctic or north through the Bering Sea to the Alaskan Arctic. During August the south to north movement of storms through the Bering Sea becomes a major storm track producing the Arctic's largest monthly precipitation amounts.

Terrain can increase precipitation amounts whenever moist air is forced up a mountain slope. The moisture in the air cools and condenses and then falls to earth as rain or snow. Without this mechanical lift precipitation may not develop.

Air temperature controls how much moisture the air holds as a vapor or gas. Regardless of other factors, extremely cold air can contain only very small amounts of water vapor. The result is low precipitation.

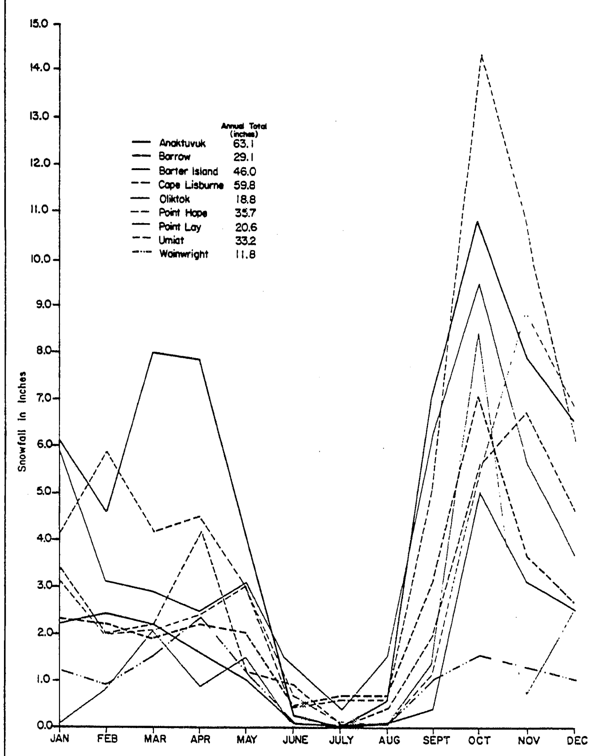
Precipitation in the Alaskan Arctic varies considerably with location. Heaviest amounts occur in the highest elevations of the Brooks Range where the average annual amounts vary from 40 or more inches in the eastern glacial area to about 10 inches in parts of the central portion. In the coastal and foothill areas amounts range from 7 to less than 5 inches. Most precipitation occurs during summer as rain (Figure 26). Areas with the heaviest snowfall correspond to those with the most total precipitation. Average annual snowfall amounts range from an estimated 100 inches in the eastern Brooks Range to only 12 inches along the northwest coast (Figure 27). The two data stations with the heaviest annual precipitation are both influenced by terrain. Figure 28 shows the frequency of occurrence of precipitation.



The line graph plot of the nine data stations shows the distribution of precipitation through the year, showing clearly the comparatively heavy precipitation that occurs in late summer and early fall. Period of record is 8 to 20 years.

Adapted from the National Oceanic and Atmospheric Administration Environmental Data Service.

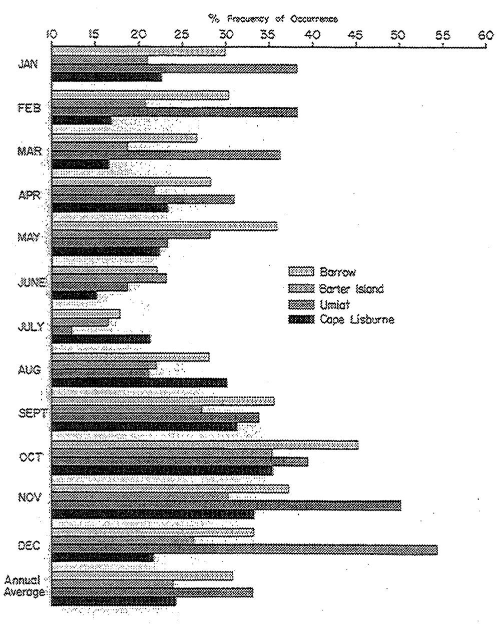
Figure 26 Average Monthly and Annual Precipitation



In contrast to the single period in August when most precipitation occurs, the snowfall pattern shows a primary peak in October and a secondary peak in spring which varies from February to May. Period of record is 8 to 20 years.

Adapted from the National Oceanic and Atmospheric Administration Environmental Data Service.

Figure 27 Average Monthly and Annual Snowfall



Precipitation data are available for only the four locations shown. Without regard to intensity or rate of fall, this chart gives the frequency of occurrence of any type of precipitation. For example, the value of 30 for Barrow in January means that 30 percent of the time, some type of precipitation was occurring. Period of record is 8 to 20 years.

Adapted from the U.S. Air Force, Air Weather Service.

Figure 28 Percentage Frequency of Occurrence of Precipitation

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Wind

Temperature differences determine pressure differences in the atmosphere. Cold air is denser and heavier than warm air. Since a cold air mass has higher surface pressure than a warm air mass, air movement (wind) flows from the cold to warm air as long as a pressure differential exists; the greater the difference, the faster the flow. Horizontal pressure differences are the most important, but differences in vertical gradient can also have an effect on the horizontal wind speed. Figure 14, showing the global air flow, pictures a major down motion of air in the Arctic. This downdraft results in a piling up of air that creates an area of high pressure centered approximately 600 miles north of the Alaska arctic coast (Figure 18). Air continually flows south from this area of higher pressure as a north wind. By the time it reaches the Alaska coast its direction is between northeast and east because of the rotation of the earth, which turns a flow of air to the right in the northern hemisphere.

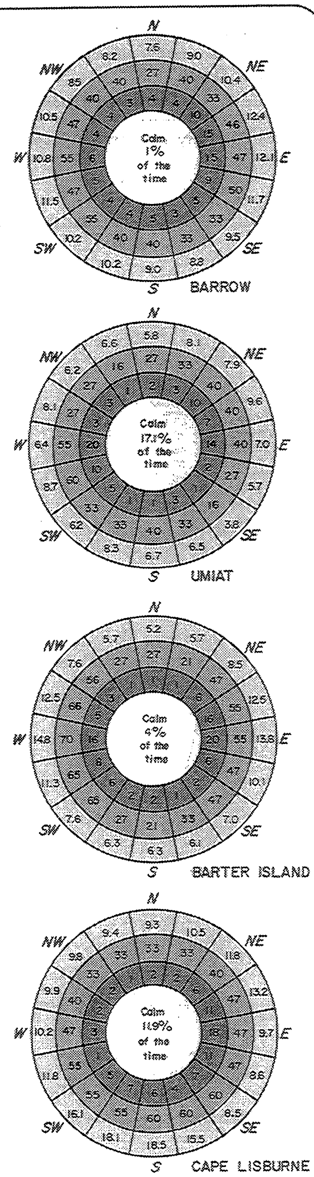
Surface wind speeds along the coast are persistent and strong compared to those in more interior regions (Air Weather Service, U. S. Air Force, various dates). Calm conditions are recorded at Barrow only 1 percent of the time, while Umiat in the foothills, has calm conditions 17 percent of the time. By comparison, the city of Fairbanks in the interior basin of Alaska, is calm 21 percent of the time. Arctic coastal wind speeds of 30 to 50 knots are common during winter months. Usually, damage will not occur if buildings are designed for strong winds. However, structural damage has occurred when wind generated storm tides carried water into some of the coastal villages or when wave action eroded beaches.

Strong winds can cause other problems. A whiteout condition, when neither shadows, horizon, nor clouds are discernible, can result from blowing snow. Senses of depth and orientation are lost, and only very dark, nearby objects can be seen. Often, guide ropes are necessary to move from one place to another. Strong winds also can stop all aviation traffic because of turbulence and runway drifts. Although they can occur in the mountains, strong winds are usually restricted to specific locations where valleys or mountain passes channel the wind, drastically increasing its speed.

Detailed wind information is shown in Figure 29. Wind direction is predominantly easterly at coastal stations and evenly divided between east and west at Umiat. Considering all locations and directions, the strongest average wind speeds have been recorded at Cape Lisburne. The directions associated with these speeds are SSE through SW and do not include the prevailing direction. This indicates that the wind blows from these directions only when conditions favor strong winds, such as storms or an intense high pressure system in interior Alaska.

Prevailing wind directions (Figure 30) are usually the primary determinant of runway and landing strip orientations. In the coastal Arctic they generally lie east to west. Variable terrain, particularly in the foothills and near mountains, may channel the wind in other directions and dictate otherwise.

Figure 29 Detailed Wind Data



Wind speed and direction data are available for only the four locations shown. The figures in the inner circle show the predominance of the general east to west flow of air along the arctic coast. In none of the four locations are the strongest winds associated with prevailing directions. Period of record is 8 to 20 years.

Average wind speed for direction noted

Extreme wind for direction noted.

Percentage frequency of occurrence of wind direction.

Wind speeds are in knots.

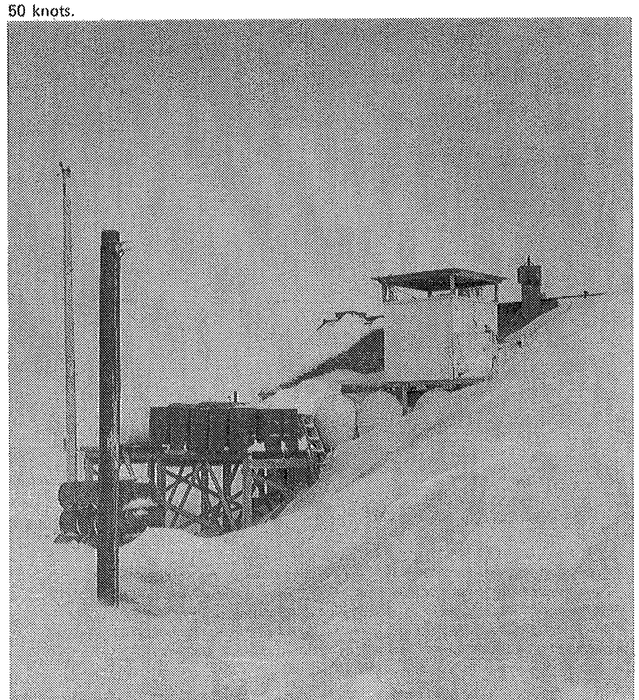
Figure 30 Mean Monthly Wind Speed and Prevailing Direction

(Speed in knots)

Station	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annl
Barrow	10.3 ENE	9.9 E	9.9 ENE	10.0 ENE	10.5 ENE	10.1 E	10.2 E	11.0 E	11.2 E	11.8 ENE	11.8 ENE	9.9 ENE	10.6 ENE
Barter Island	12.7 E	12.8 W	12.0 W	11.1 E	10.7 E	9.8 E	10.3 ENE	11.3 E	13.2 E	13.1 E	12.4 E	11.5 W	11.5 E
Umiat	6.1 W	6.6 W	4.9 W	6.0 W	7.2 E	7.6 E	6.2 E	5.7 E	5.8 E	4.5 E	5.9 W	5.6 W	6.0 W/E
Cape Lisburne	11.6 ESE	9.8 ESE	10.1 E	10.0 E	9.7 E	8.2 E	10.1 E	10.0 E	10.8 ENE	13.0 ENE	12.8 E	10.4 E	10.5 E

Source: U. S. Air Force, Air Weather Service

Snowdrifts caused by winds that often reach 30 to 50 knots.



Courtesy of National Weather Service

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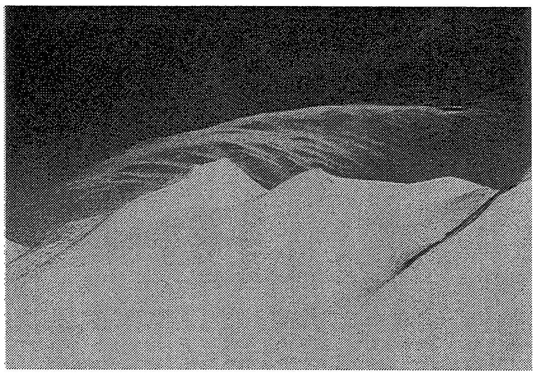
Detailed Weather Conditions

Average annual sky cover conditions differ only slightly between the four data locations (Air Weather Service, U. S. Air Force, various dates). Divided into monthly increments, these differences become slightly more significant. Seasonal trends are similar for all stations. Where total cloudiness influences operational planning, the data in Figure 31 will be useful.

Snow depth data must be applied with caution. Even though these data are compiled and presented in Figure 32, their value is greatly reduced since wind continuously moves the snow from one area to another. Also, there are areas where snow is packing and developing a hard crust. Measurements made at a single or even several locations will not necessarily give an accurate picture of general conditions.

Obstructions to vision are yet another planning consideration (Figure 33). An obstruction to vision is a condition that reduces visibility to six miles or less. In the Arctic, particularly along the coast, the most persistent and significant of these is fog, which occurs often enough to be a hazard. Along the coast the occurrence of fog increases drastically as soon as open water begins to appear in May or June and continues into early October. Statistics on heavy fog, a reduction to visibility of one-quarter mile or less, are available for Barrow and Barter Island (Figure 34). In the interior portion of the Arctic, fog occurs most frequently in winter. Warm summer temperatures in this area reduce fog occurrences. Smoke and haze occur so infrequently that they have a negligible effect on visibility. Blowing snow, however, is a serious hazard.



Wind flows across a mountain ridge. The lenticular cloud appears to be stationary, but it is actually dissipating on the leeward side at the same time it is forming on the windward side. Joseph C. LaBelle

March occurrence of fog over an open lead.

Joseph C. LaBelle, AEIDC

Figure 31 Sky Cover

Categories Below Are Tenths of Total Sky Cover

Month	0-3	4-5	6-7	8-9	10	0-3	4-5	6-7	8-9	10	0-3	4-5	6-7	8-9	10	0-3	4-5	6-7	8-9	10
J	42	5	7	8	38	53	4	4	5	34	43	5	5	6	41	36	7	9	9	3
F	44	6	6	7	37	50	4	5	6	35	46	5	6	7	36	48	7	8	9	28
M	42	6	7	10	35	46	5	6	9	34	40	6	7	10	37	45	7	9	10	29
A	35	5	7	10	43	41	4	5	8	42	31	5	8	10	46	29	8	8	12	43
M	14	3	4	8	71	14	2	3	6	75	19	3	5	8	65	19	4	6	10	61
J	15	5	6	13	61	13	4	5	10	68	15	6	9	15	55	18	6	9	17	50
J	16	6	7	15	56	13	5	6	14	62	19	6	10	17	48	12	5	8	17	58
A	10	4	6	14	66	5	2	3	8	82	11	4	7	13	65	7	3	6	15	69
S	12	4	5	10	69	5	2	2	6	85	11	3	5	9	72	8	3	5	13	71
O	15	4	4	8	69	11	3	4	8	74	18	3	6	7	66	9	4	7	12	68
N	27	4	5	8	56	21	4	5	7	63	20	5	5	7	63	18	6	9	10	57
D	39	5	6	7	43	40	4	4	6	46	36	5	5	6	48	37	6	7	8	42
Yr	25	5	6	10	54	26	4	4	8	58	26	5	6	9	54	23	6	8	12	51
	Barter Island					Barrow					Umiat					Cape Lisburne				

Figure 32 Depth of Snow on Ground

Month	Trace or less	1- 3 inches	4- 6 inches	7-12 inches	13-24 inches	25-36 inches	37-48 inches	Trace or less	1- 3 inches	4- 6 inches	7-12 inches	13-24 inches	25-36 inches	37-48 inches	Trace or less	1- 3 inches	4- 6 inches	7-12 inches	13-24 inches	25-36 inches	37-48 inches	Trace or less	1- 3 inches	4- 6 inches	7-12 inches	13-24 inches	25-36 inches	37-48 inches	Month
J			9	31	37	21	2			20	55	25						49	51			3	3	5	37	54	1		J
F			2	17	56	18	7			2	48	50						18	82			1	6	4	23	46	18	3	F
M			1	19	47	20	13				50	50						50	50				4	5	29	36	26		M
A			6	29	29	26	10				50	50					7	49	32	12			2	12	27	40	21		A
M		8	14	25	38	13	2		1	14	55	30			13	4	32	38	13			23	24	9	24	13	7		M
J	49	26	7	10	6	2		51	30	6	11	2			79	18	3					83	14	2	1				J
J	99	1						94	6						100							100							J
A	98	2						90	10						100							99	1						A
S	78	15	2	2	3			52	38	10					86	14						86	10	4					S
O	18	20	34	20	8			12	51	24	13				12	42	44	2				24	29	20	18	8	1		O
N		4	26	46	24				9	44	43	4				13	30	57	8				9	25	31	32	1	2	N
D			16	40	35	9				33	57	10					11	49	40				9	9	41	38	34		D
YR	29	6	10	20	23	9	3	29	9	12	32	18			32	7	11	26	23	1		35	9	8	19	22	7	*	YR
	Barter Island							Barrow							Umiat							Cape Lisburne							

*Less than .5

Figure 33 Obstructions to Vision

	Fog				Blowing Snow				Smoke and/or Haze				Percentage Observations with Obstructions to Vision			
	Barter Is.	Barrow	Umiat	Cape Lisburne	Barter Is.	Barrow	Umiat	Cape Lisburne	Barter Is.	Barrow	Umiat	Cape Lisburne	Barter Is.	Barrow	Umiat	Cape Lisburne
J	6.9	12.5	14.5	8.1	20.2	13.7	6.2	15.9	.1	.5	.8	.0	26.6	24.7	19.8	21.9
F	8.0	13.1	15.7	10.5	22.3	12.6	8.7	11.3	.1	.3	.7	.1	29.2	25.3	23.2	20.0
M	9.7	7.9	12.4	11.7	16.8	10.0	2.0	10.6	.1	.2	.0	.2	24.9	17.3	14.3	20.5
A	11.8	9.3	13.7	13.5	11.5	7.8	3.6	9.9	.2	.2			22.7	16.7	17.2	20.9
M	25.1	17.4	14.1	16.6	3.3	4.0	.4	2.1	.0	.0		.0	27.5	21.0	14.3	17.9
J	26.6	26.4	8.3	22.8	.1	.5			.1	.0	.0	.1	26.7	26.9	8.3	22.8
J	25.3	25.9	6.6	18.6					.0		1.0	.3	25.3	25.9	7.6	18.9
A	31.5	25.5	9.5	18.8		.0			.1	.0		.3	31.6	25.5	9.5	18.9
S	26.6	17.7	13.4	11.3	1.9	.7	.3	.5	.0		.0	.0	28.3	18.2	13.7	11.8
O	13.5	13.0	15.9	5.2	10.4	7.7	1.9	7.8	.2	.0			22.6	20.9	18.1	12.7
N	9.8	10.5	15.0	4.4	17.6	16.3	5.1	14.3	.1	.0	.0	.2	25.0	26.0	19.6	18.5
D	8.0	10.4	13.4	6.1	16.6	13.5	5.8	13.0	.1	.1	.5	.1	23.7	22.5	18.4	18.2
Yr	17.0	15.8	12.7	12.3	9.9	7.2	2.8	7.1	.1	.1	.3	.1	26.1	22.6	15.3	18.6

Note: The detailed weather conditions presented in Figures 31, 32, and 33 are all average percentage frequency of occurrence values, based on hourly observations. A particular value represents the amount of the total time during that month that an event occurred. For example, in August on Barter Island fog is present as an obstruction to vision 31.5 percent of the time, or out of 744 total hours, fog was present for 234 hours. To qualify as an obstruction to vision, visibility must be reduced to six miles or less. Period of record is 8 to 20 years.

Adapted from U.S. Air Force, Air Weather Service.

Figure 34 Days with Heavy Fog

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annl
Barrow	2	2	1	3	8	12	13	12	5	4	3	2	65
Barter Island	2	1	1	3	7	12	15	16	10	4	2	1	75

Note: The statistics for this chart were compiled by noting the occurrence of heavy fog on a daily rather than hourly basis. Heavy fog, defined as fog reducing visibility to one-quarter mile or less, must occur at some time during a day to establish a day with heavy fog. Period of record is 25 years.

Source: National Oceanic and Atmospheric Administration, Environmental Data Service.

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Aviation Weather

Aviation weather information is extremely important in the Arctic. Lack of surface transportation makes aviation the prime mode of transport to the region and between villages. Some information related to general flying conditions in the Arctic is shown in Figures 38 and 39. Official, current weather information can be obtained from flight service stations at Barrow and Deadhorse.

The data application discussion assumes that average weather conditions at Barrow and Barter Island reasonably represent the coastal area between them. This does not mean that ceiling, visibility, and wind conditions associated with a particular storm in the Barrow area are also going to affect Barter Island the same way two days later. Both storm track and intensity may vary enough to result in completely different conditions at Barter Island. The average of all these storm conditions provides the similarity. Average ceiling and visibility conditions are reflected in Figure 38 (Air Weather Service, U. S. Air Force, various dates).

If a flight cannot land at its destination, the possibilities of landing at alternate fields in the same general area can be evaluated in several ways (Searby 1971). In a study of six locations near the Prudhoe Bay oil explorations, weather observations were taken hourly throughout the day. First, the total time that each location met a set criteria was established to determine if, during the interval of one year, certain stations experienced better weather than others (Figure 39). Second, if one station was experiencing particular conditions, circumstances at the other six stations at the same time needed to be known (Figure 39). Results from the latter part of the study indicate that weather conditions vary considerably from site to site during specific periods, making it possible to select an alternate landing field nearby. Results from one year of data do not guarantee that conditions will be the same during future years, but they are adequate for long range operational plans.

Figure 38 Ceiling and Visibility

Station	Visibility (in miles) ≥3	≥1½	≥1	≥¾	≥½	≥¼	≥0	Ceiling (in feet)	Station	Visibility (in miles) ≥3	≥1½	≥1	≥¾	≥½	≥¼	≥0
Barrow	58	59	60	61	62	62	62	≥ 1,800	Barter Island	61	63	64	65	66	68	68
	61	63	64	64	65	66	66	≥ 1,500		64	66	68	68	70	71	72
	65	67	68	69	69	70	71	≥ 1,200		67	69	71	72	73	74	75
	69	72	73	74	75	76	76	≥ 1,000		70	73	75	76	78	79	80
	71	74	75	76	77	78	78	≥ 900		71	74	76	77	79	80	81
	74	77	79	79	80	81	82	≥ 800		73	76	79	80	81	83	84
	77	80	81	82	83	84	84	≥ 700		74	78	80	82	83	85	86
	79	83	84	85	86	87	88	≥ 600		76	80	82	84	85	87	88
	82	86	88	89	90	91	92	≥ 500		77	81	84	86	88	89	91
	84	88	90	91	93	94	94	≥ 400		78	82	86	87	89	91	92
	85	89	92	93	95	96	97	≥ 300		78	83	87	88	91	93	95
	85	90	92	93	96	98	99	≥ 200		78	83	87	89	92	95	97
	85	90	92	94	96	98	100	≥ 100		78	83	87	89	92	96	98
	85	90	92	94	96	98	100	≥ 0		78	83	87	89	92	96	103
Umiat	74	75	76	76	76	76	76	≥ 1,800	Cape Lisburne	65	67	68	68	68	69	69
	77	79	79	80	80	80	80	≥ 1,500		73	75	76	77	77	77	77
	81	83	84	84	84	84	84	≥ 1,200		77	80	81	82	82	83	83
	85	87	88	88	89	89	89	≥ 1,000		80	83	85	81	86	86	87
	86	88	90	90	90	90	90	≥ 900		82	85	87	87	88	88	88
	87	90	91	91	91	92	92	≥ 800		84	87	89	90	91	91	91
	88	91	93	93	93	94	94	≥ 700		85	89	91	92	93	93	93
	89	93	94	94	95	95	95	≥ 600		86	91	93	94	94	95	95
	90	93	95	95	96	96	97	≥ 500		87	92	94	95	96	96	97
	90	94	96	96	97	97	98	≥ 400		88	92	95	96	97	98	98
	91	94	96	97	98	98	98	≥ 300		88	93	96	97	98	99	99
	91	94	97	97	98	99	99	≥ 200		88	93	96	97	98	99	100
	91	95	97	97	98	99	100	≥ 100		88	93	96	97	98	99	100
	91	95	97	97	98	99	100	≥ 0		88	93	96	97	98	99	100

Data is presented for all months and all hours. A ceiling exists when the sky is more than half covered with clouds. Due to the cumulative nature of this presentation, it is possible to determine the percentage frequency of occurrence for any given limit of ceiling or visibility separately, or in combination of ceiling and visibility. The totals progress to the right and downward. The frequency of occurrence of a particular ceiling height may be determined independently by referring to totals in the extreme right hand column for each station. The frequency of occurrence of a particular visibility range may be determined independently by referring to the horizontal row of totals at the bottom of each station grid. The percentage frequency for which the station was meeting or exceeding any given set of minima may be determined from the figure at the intersection of the appropriate ceiling column and visibility row.

Data compiled by U. S. Air Force, Air Weather Service

O. Eugene Cot

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National Marine Fisheries Service

Lakes and streams provide food year-round. Here a woman of Lapp ancestry fishes through a hole in the ice. Laplanders were originally brought to Alaska to develop reindeer herding as a source of food and income and many intermarried with Alaska Natives.

Lake and River Ice

Observation and recording of freezeup and breakup dates on rivers and lakes in the region began more than 20 years ago. Although there are some gaps in these data, Figures 34 and 35 present all that are available. Since river water moves, river freezeup dates are later than those of lakes, breakup dates are earlier, and the days that ice is safe for men and vehicles are fewer. The ice-free season falls approximately between these dates. As soon as the temperature remains above freezing, ice melts much more quickly than it forms when the temperature drops below freezing.

Figure 35 gives average beginning and ending freezeup dates of the ice season for selected lakes and rivers. Locations of these observational sites are found in Figure 18. Ice observations are not available for other locations in this region.

Alaska's lakes and rivers are important transportation and recreation resources year-round. In summer a high percentage of airplanes is equipped with floats, which allows them to land close to most otherwise inaccessible areas. Floats are exchanged for skis in winter. For surface transportation, these water bodies often must be bridged, which requires knowledge of ice conditions for engineering design and construction.

Figure 34
Freezing Temperatures for Selected Locations

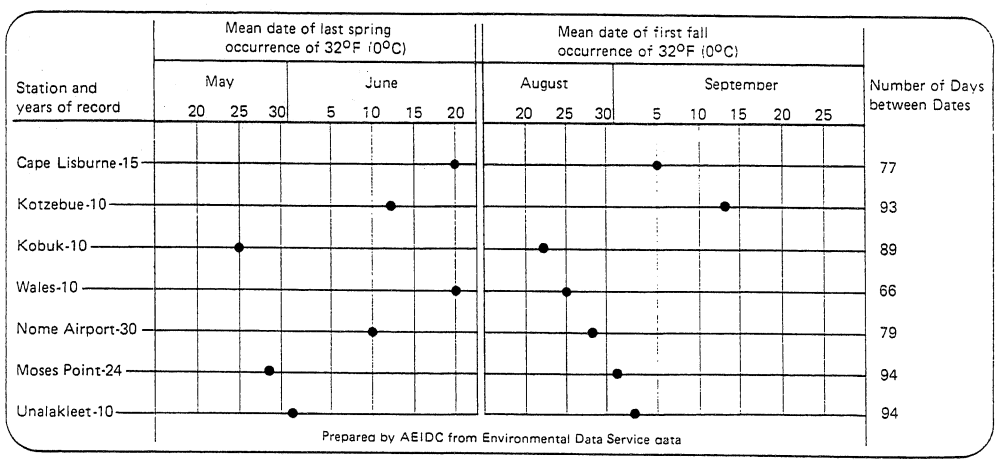
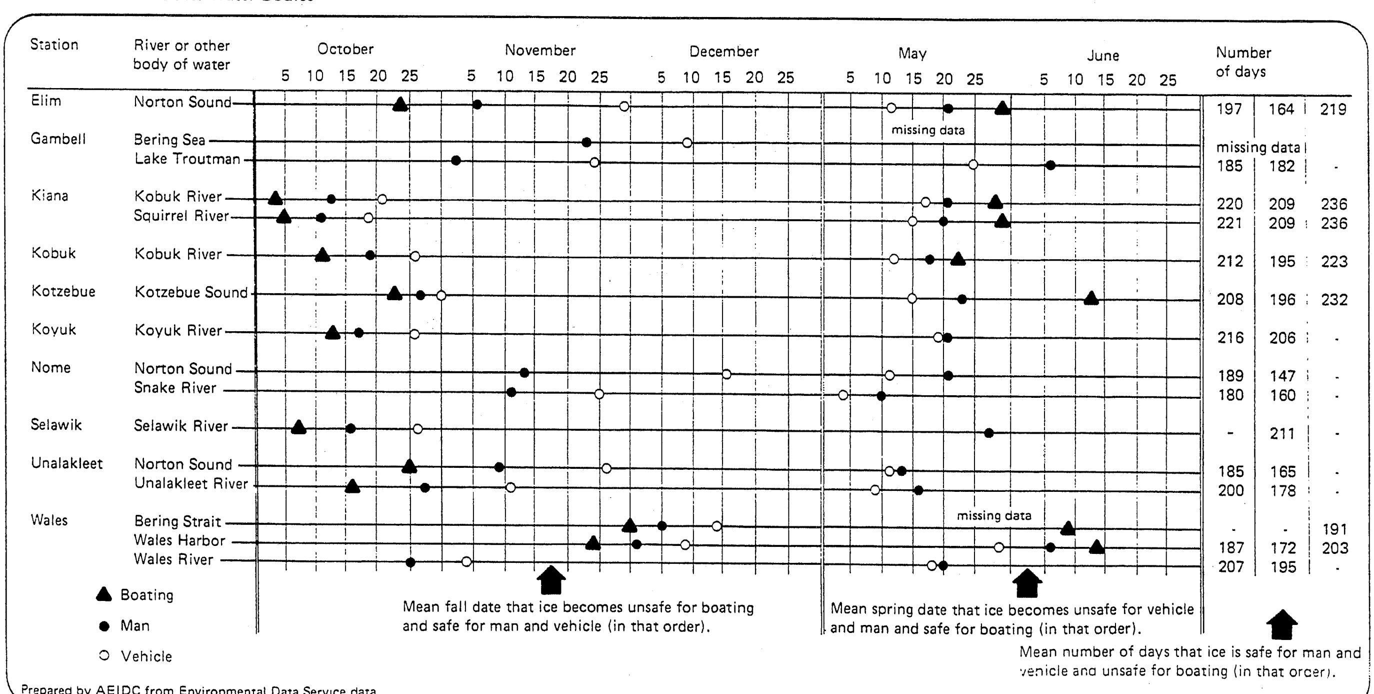


Figure 35
Freezeup and Breakup Dates for Selected Rivers and Other Water Bodies



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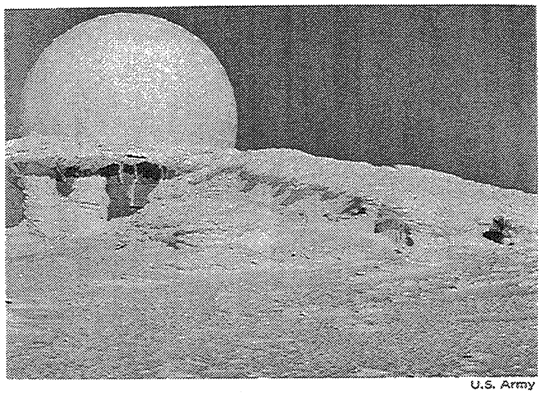
Detailed Weather Conditions

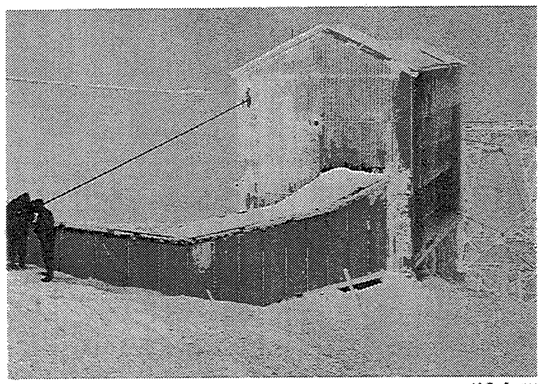
The detailed weather information in Figure 36 is particularly useful for community planning. Engineers need to know the maximum amount of precipitation that could occur during a specific time period to design an adequate drainage system. Budgeting for snow removal from city streets, highways, and airports requires knowledge of both average and extreme snowfall amounts as well as how often it is likely to snow each winter. The water equivalent of snow on the ground can be applied in flood forecasting. Accurate snow depth measurements are complicated by drifting. Even taking several samples and averaging them does not produce a value that can be applied a short distance away, so the data on snow depth must be used cautiously.

Obstructions to vision, conditions that reduce visibility to six miles or less, are another planning consideration. The data show fog as the most common obstruction in summer and blowing snow as the most frequent obstruction in midwinter at most locations. Data on heavy fog, defined as a reduction of visibility to one-quarter mile or less, are presented for Kotzebue, Nome, and Unalakleet. The seasonal trend for heavy fog is similar for all three locations. Smoke and haze present significant problems when forest fires occur in the Kobuk valley.

Average annual sky conditions differ slightly among the six stations shown in Figure 36. All have the least cloudiness in winter and the most in late summer. Northeast Cape and Tin City, the locations more exposed to oceanic influences, tend to have more cloudiness than Unalakleet and Kotzebue.



U.S. Army



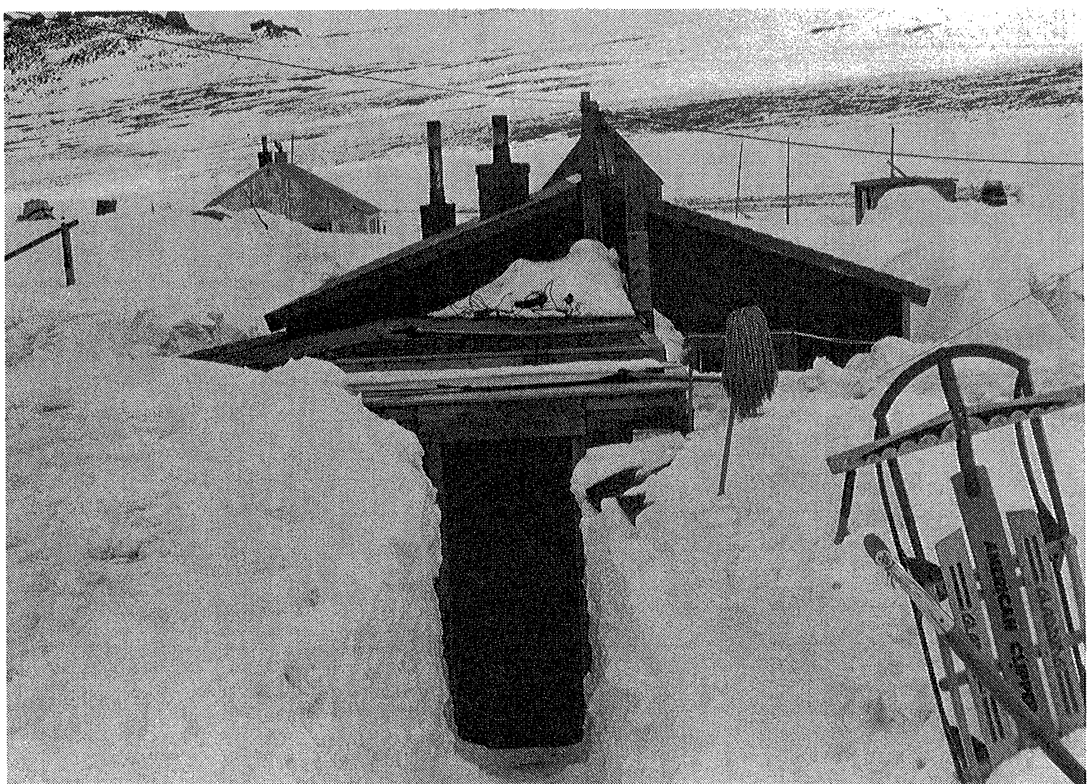
U.S. Army

The effects of wind are clearly displayed in these photos of Northeast Cape.

Top: Extremely fine water droplets that exist at temperatures below freezing have been blown against the building, almost covering it with rime ice. In the foreground, the wind blowing from left to right has sculpted the snow, leaving miniature drifts on the leeward side of hard-crusted areas of snow protruding above its normal level.

Center: The wind direction is into the picture. The loose snow has been blown away, leaving the sculptured appearance. The buildup on the tower, building, and cable is either rime ice or heavy wet snow.

Bottom: Winds on the Bering Strait coast pile snow in deep drifts around buildings. In this area near Wales, which averages only about 40 inches of snow a year, snowdrifts well over six feet deep are adjacent to ground swept clear of snow by the wind.



C.D. Evans

and after melting, leaves behind irregular mounds or ridges of sediments extending along the beach as much as several miles. Some of those with ice cores may originally be up to six feet high but shrink to two feet when the core melts. Others have been observed up to five feet high with no ice cores.

Deposits are often destroyed by the first storm waves. In some cases they persist by being pushed above the normal reach of waves, by growth of the beach, or because close pack ice retards wave erosion. Deposition from ice push probably never amounts to more than 10 percent of the sediments above sea level, generally ranging between 1 and 2 percent. Ice carries sediments and drops them when it melts, possibly accounting for up to 3 percent of the deposition near shore.

Though not quantitatively significant, sand and pebbles up to 0.4 inches long have been observed floating freely in the sea. Only flat, tabular particles float; spherical particles sink. The floating particles commonly gather in patches or rafts, although they also float singly. Surface tension has been described as the mechanism of floating. At most, only 20 to 25 pounds of material per hour has been observed passing any given point.

Applied Geology

Geologic maps serve as a basis for describing the origin, age, and physical character of earth materials; they also can show the application of geologic knowledge to man's use of the land. **Applied geology maps** are designed to show many different land characteristics, such as type and distribution of foundation material, gravel resources, mineral resources, and location of potential energy sources. The applied geology chart (Figure 70), when used in conjunction with the geologic map (Figure 65), reflects the basic engineering characteristics of each geologic unit. It can serve as a guide to planners and developers as to what types of problems to expect and what types of investigations should be carried out to insure safe and economical development.

The chart or the geologic map is not intended to serve as a source for estimating reserves or detailing the precise uses for which particular deposits are most suited. More detailed site investigations, such as are found in studies done by LaBelle (1973, 1974), Davidson, Roy and Associates (1959), and Lounsbury and Associates (1973), are required. The chart and map serve primarily as guides so planners can determine which areas deserve further consideration and study.

Special Geologic Conditions Affecting the Arctic Region

Permafrost and erosion are primary geologic phenomena to be considered in the development of the Arctic Region. Their effects have far-reaching impact on man's occupancy and use of land. Earthquakes and volcanism are insignificant processes in the Arctic Region.

Figure 71 shows the seismic zones of Alaska as interpreted by the U. S. Army Corps of Engineers. The only seismic activity reported in the Arctic between 1955 and 1964 occurred in the Chukchi Sea, where four earthquakes with a magnitude greater than 6.0 were recorded.

Figure 70 Generalized Engineering Characteristics of Surficial Deposits

Qa
Qf – **Sand and gravel—coarse-grained deposits**
- Good foundation material
- Relatively easy to excavate
- Generally well-drained
- Source of sand and gravel for construction
- Not frost susceptible

Qm – **Mixed coarse- and fine-grained deposits—Till**
- Generally high in silt content, especially near surface
- Generally poor foundation material, except where locally high in gravel and sand content
- Poorly drained
- High in ice content, especially in silts
- Often becomes unstable if thawed; may cause differential settlement of foundations
- Difficult to excavate
- Frost susceptible

Qc
Qe — **Sand—medium-grained deposits**
- Fair to good foundation material
- Relatively easy to excavate
- Generally well-drained
- Source of sand for construction
- Not seriously frost susceptible

Qe
Ql — **Silt and Clay—fine-grained deposits**
- Generally poor foundation material
- If thin, it can be removed or filled over prior to construction
- Poorly drained
- Unstable during earthquakes; may cause landslides along bluffs or differential settlement.
- High ice/water content
- Will become unstable if thawed; may cause differential settlement of foundations
- Generally poor fill material
- Frost susceptible

– **Peat—organic surface material**
- Poor foundation material
- Poorly drained
- Commonly removed or filled over prior to construction
- Contains high percentage of ice/water

– **Bedrock**
- Generally suitable for foundations
- Somewhat difficult to excavate
- Hard and resistant but commonly fractured
- Generally steep slopes in mountains make development difficult
- Can be quarried and crushed for construction material

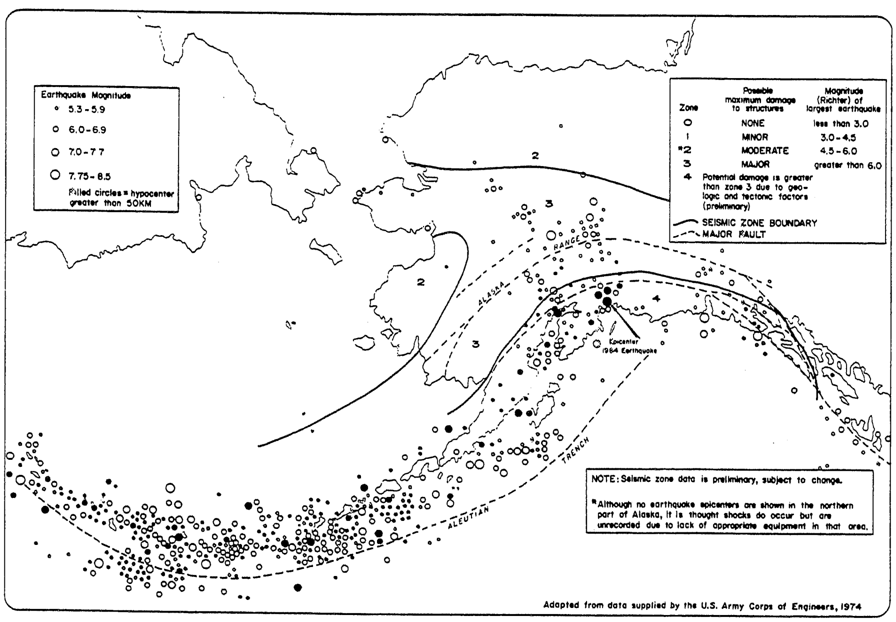


Figure 71 Seismic Zone Map of Alaska

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Permafrost

A lump of frozen gravel from below the permafrost table compared to unfrozen gravel.

Robert Lewellen

Permafrost is any earth material, such as soil or bedrock, that has remained below 32 degrees F (0 degrees C) at least from one winter through the next. This is the minimum duration of permafrost; much has been in existence for tens of thousands of years.

Permanently frozen ground prevails throughout most of Alaska, ranging from less than a foot in depth at the southern margin to 1,300 feet at Barrow and 2,000 feet at Prudhoe Bay (Figure 72). Local variations in thickness, areal extent, and permafrost temperature depend on differing thermal properties of earth materials and on local differences in climate, topography, vegetation, geology, hydrology, and rate of heat flow within the earth. In many places these local variations mask the regional southward decrease in areal extent and thickness and southward increase in permafrost temperatures. Areas around large water bodies and thermal springs are generally free of permafrost because of increased amounts of heat flow in the ground. The shape of the permafrost and subpermafrost tables reflect the presence of these features and large-scale surface topography (Figure 73).

The **permafrost table** is the upper boundary of permanently frozen ground. The area above it is called the **suprapermafrost layer**. The **active layer** is that part of the suprapermafrost zone that freezes in winter and thaws in summer. When winter freezing does not extend all the way down to the permafrost table, an unfrozen layer remains between the permafrost and the frozen active layer. Such unfrozen ground surrounded by frozen ground is known as **talik** (Figure 74). Groundwater trapped in taliks may be stored under great hydrostatic pressure. If disturbed, springs may burst to the ground surface and freeze, producing a thick and often widespread ice sheet or ice mound called *aufeis*. This process is known as **icing.** Since water deposits tend to reduce temperature fluctuations from season to season, thawing usually reaches deeper in drier materials. Permafrost thickness is **aggrading** as it thickens and **degrading** as it thins.

Shading and insulation of the ground surface favor the formation and continuation of permafrost which in turn influences vegetative types, engineering structures, and groundwater resources. Permafrost limits the rooting depths of plants, prevents infiltration of water downward through surficial materials, and forces surface runoff. Surface drainage often accumulates in depressions where peaty materials form, creating a continuously wet environment which promotes marsh and tundra development. This vegetative blanket insulates and preserves the permafrost layer, increasing its freezing depth. Disruption of the vegetative cover destroys the fragile thermal balance of the underlying permafrost resulting in thaw, subsidence, and erosion. Snow cover also limits heat transfer between the air and ground which affects permafrost distribution.

In the Arctic permafrost temperatures reflect seasonal variations to a depth of approximately 70 to 100 feet. Below that depth permafrost is at its coldest, warming gradually thereafter with depth until it passes 32 degrees F (0 degrees C), indicating the subpermafrost boundary (Figure 75). Ground ice is up to nearly 80 percent of the volume of the upper 10 to 15 feet of the ground (Figure 76).

Several types of geomorphic features are produced by permafrost and frost action.

Thermokarst Topography

Thermokarst topography consists of mounds, sink holes, tunnels, caverns, short ravines, lake basins, and circular lowlands. Local melting of ground ice and the subsequent settling of the ground creates this uneven topography, so it is most common where massive ice formations such as ice wedges and thick segregated ice exist. Melting can result from the disturbance or removal of vegetation or by a warming trend in climate. Even small disturbances, such as a vehicle driven across the tundra, can create thermokarst features.

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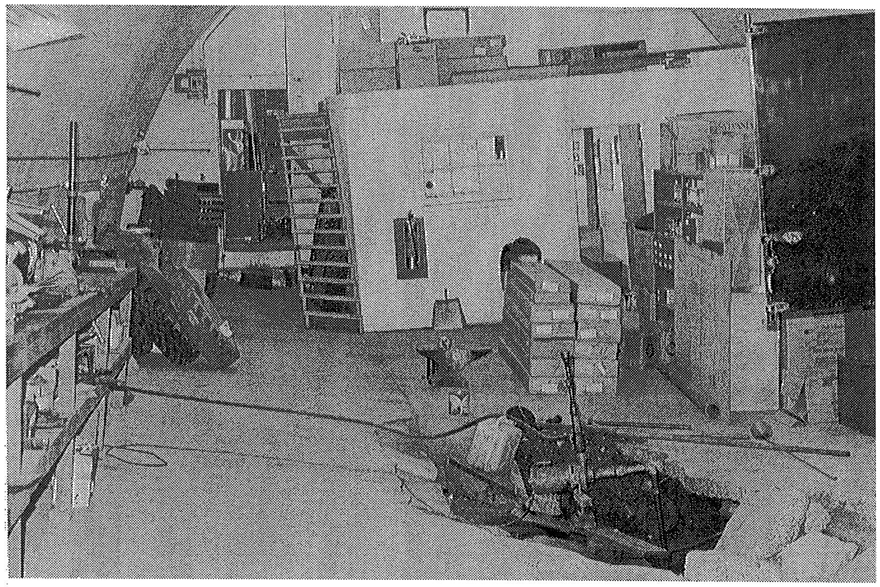
Engineering Considerations

The widespread occurrence of permafrost requires special engineering considerations for the design, construction, and maintenance of structures and facilities. Permafrost degradation is primarily related to the insulation qualities of the surface layers and the ice content of the frozen ground beneath. Sensitivity is great in the north, where the surface organic layer is thinnest and soil ice content is highest.

The engineering limitations associated with permafrost are not the same for rock type or sediment. Frozen bedrock with ice in its crevices will present few, if any, construction or maintenance problems. Well-drained, coarse sediments such as gravel, may contain little or no ice, even though they are frozen. Here again, few, if any problems occur. Although saline water in sediments may be below 32 degrees F (0 degrees C), it may remain liquid because of its lower freezing point.

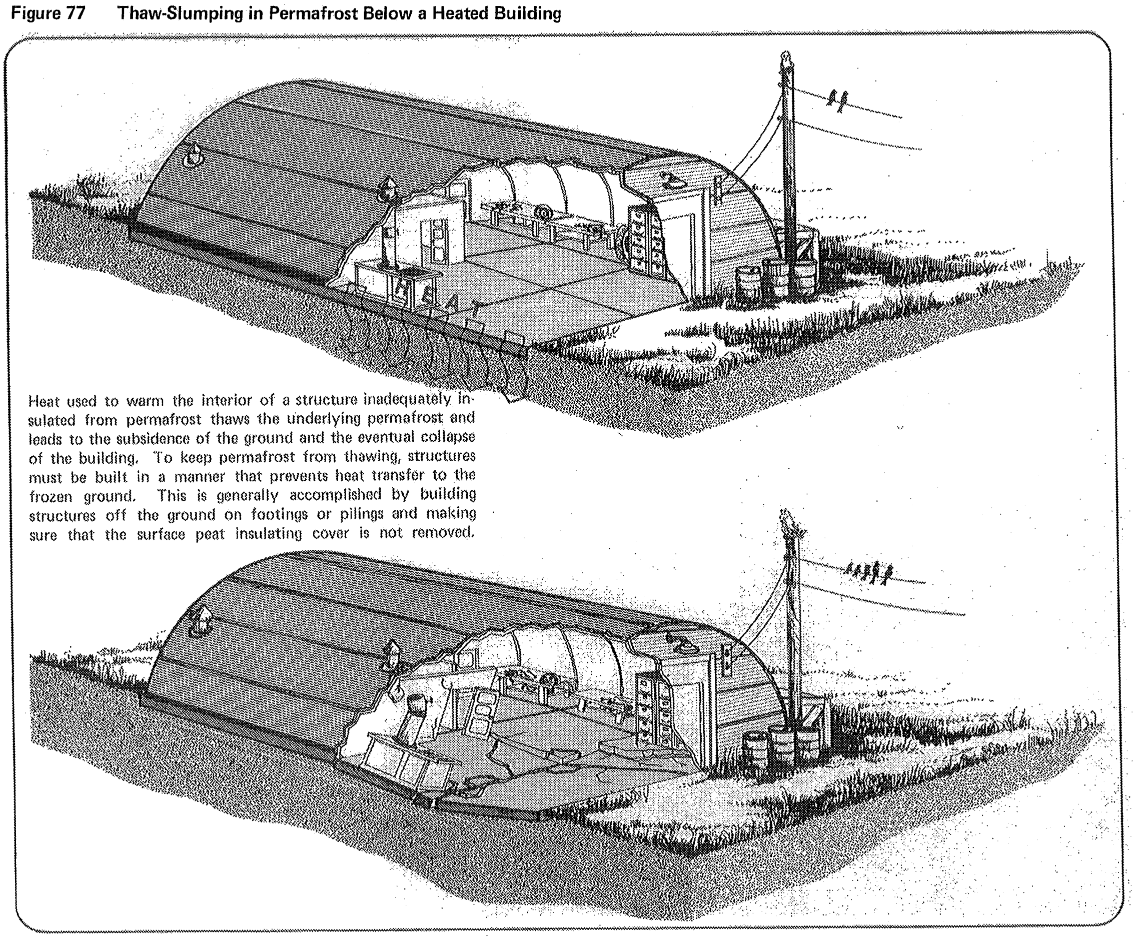
Major engineering problems arise when permafrost occurs in poorly drained, fine-grained sediments. These sediments contain large amounts of ice. Disruption of these deposits results in a change in the thermal balance which causes the ice to melt (Figure 77). Thawing produces excessive wetting and plasticity which makes the sediments unstable. This results in icings, frost heaves, slumping and subsidence of the ground surface, and in many cases, the sediments flow laterally or downslope. During winter the active layer freezes downward from the ground surface to the permafrost table. In fine-grained materials especially, the formation and resulting expansion of ice causes frost heaving. Thawing of permafrost and cycles of freezing and thawing in the active layer causes extensive damage to highways, railroads, airstrips, and other facilities. Computer models are being used to predict the interaction of permafrost and man-made structures. This may reduce construction and maintenance costs.

Lack of sufficient insulation below this utilities building at Barrow allowed heat from the structure to thaw the permafrost below. Slumping resulted in severe damage to the structure.



Robert Lewellen

Figure 77 Thaw-Slumping in Permafrost Below a Heated Building



Heat used to warm the interior of a structure inadequately insulated from permafrost thaws the underlying permafrost and leads to the subsidence of the ground and the eventual collapse of the building. To keep permafrost from thawing, structures must be built in a manner that prevents heat transfer to the frozen ground. This is generally accomplished by building structures off the ground on footings or pilings and making sure that the surface peat insulating cover is not removed.

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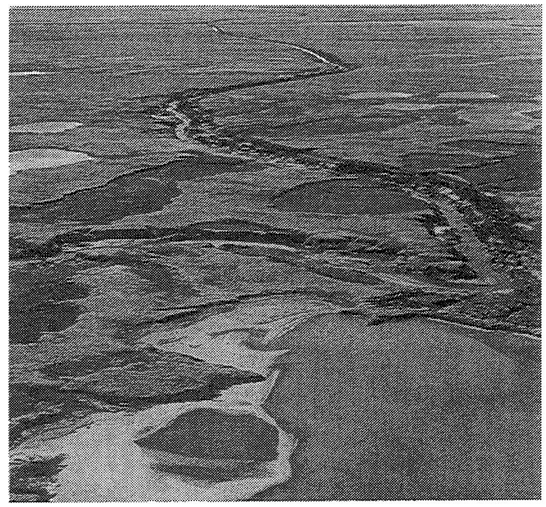
The best approach to construction in the Arctic is to preserve the permafrost by enhancing the natural insulative cover to prevent thawing of frozen sediments. Roads and airfields must be built on insulated basements that are thick enough to limit thawing of the underlying frozen ground (Figure 78). Structures must either be built on similar gravel pads or footings or be raised on pilings that allow air circulation beneath the structure. Self-refrigerated pilings are now being used at some locations to maintain frozen ground temperatures (Long 1973).

Gas, oil, and power utilities must either be raised on elevated utilidors, laid upon gravel basements, or buried and insulated enough to prevent thawing and degradation of permafrost.

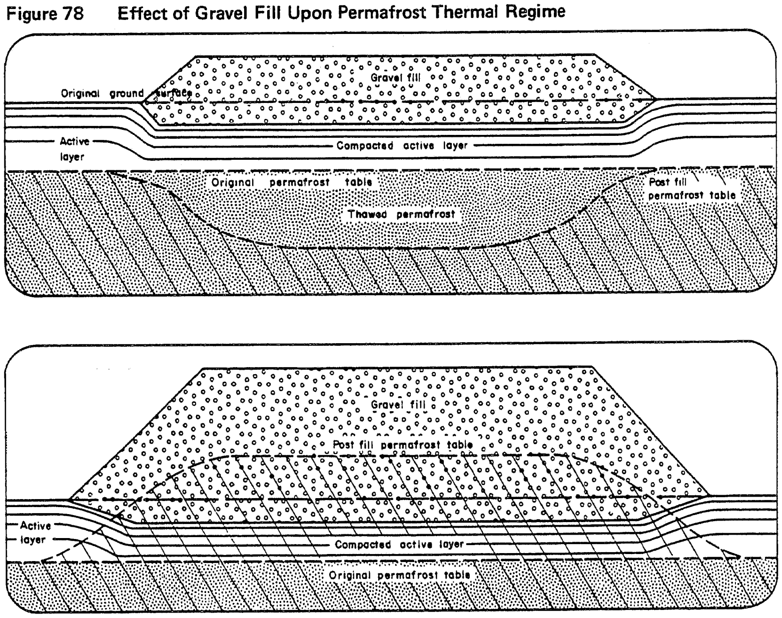
Gravel is in short supply in much of the Arctic, and even in areas of plentiful supply, removal can cause damage to the land. Experiments with artificial fill materials such as wood, styrofoam, sulfur foams, and the new rigid and flexible polyurethane foams, used in conjunction with gravel to form insulating basements and pads, have proved to be satisfactory in many instances.



During the late 1940s or early 1950s a trail was bladed east of the Colville delta in winter. Numerous summer thaws since then have slumped and flooded the trail so badly that it has formed a stream, draining several tundra lakes in its path.

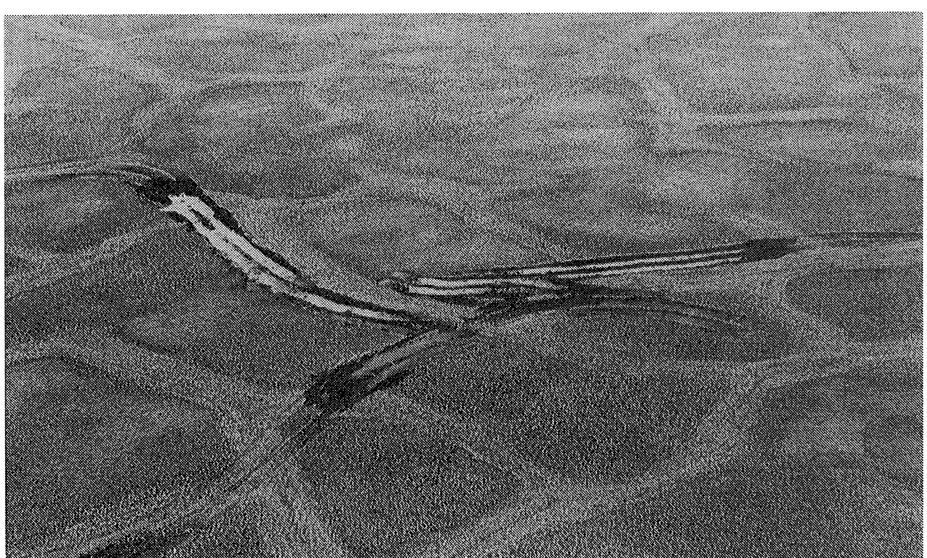
C. D. Evans, U.S. Fish and Wildlife Service

Figure 78 Effect of Gravel Fill Upon Permafrost Thermal Regime



An example of a clean, properly constructed oil drilling pad, located near the mouth of the Itkillik River. A thick gravel pad and runway complex prevented permafrost degradation during drilling operations.

Joseph C. LaBelle, AEIDC



Joseph C. LaBelle, AEID

Rolligon tracks on the tundra near Cape Simpson. Driving vehicles on the tundra in summer often results in destruction of the insulating vegetative cover. Permafrost below can then melt, flooding the track.

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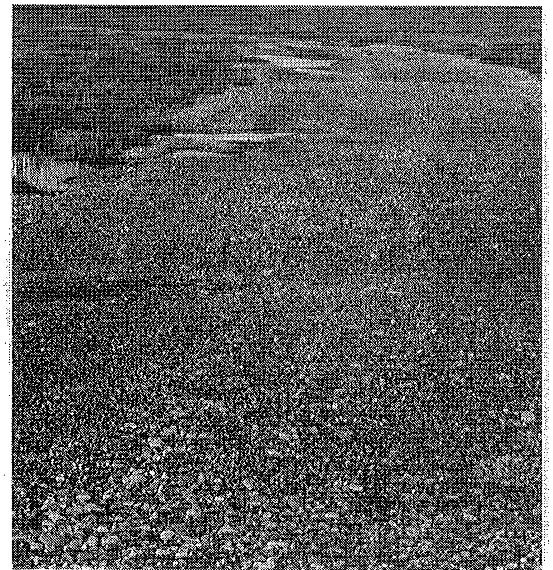
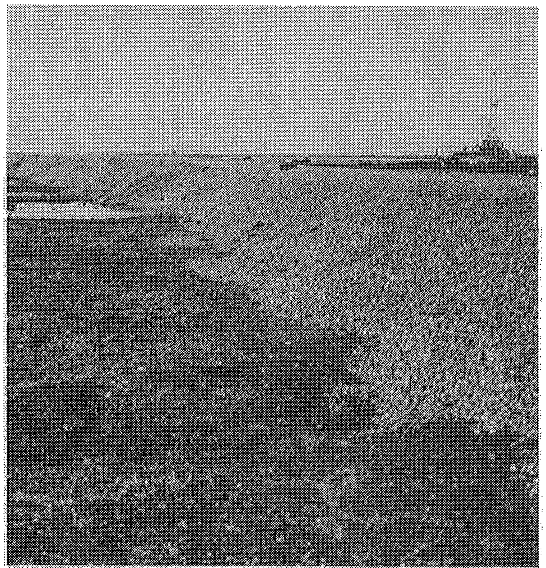
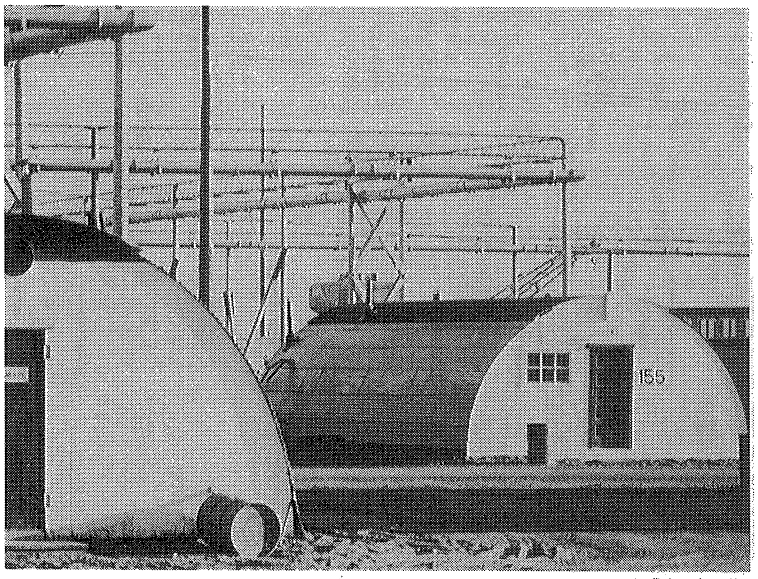


Joseph C. LaBelle, AEIDC



Robert Lewellen



Robert Lewellen

Joseph C. LaBelle, AEIDC

Top left: Gravel roadbeds of sufficient thickness will prevent permafrost thaw. If the bed is too thin, as seen here at an oil pad west of Sagwon, ice wedges melt beneath the road, resulting in slumping and flooding.

Top right: Gravel road near Prudhoe Bay is about three to four feet thick, enough to prevent permafrost thaw slumping.

Center left: Raising gas utilidors above the ground, as here at the Naval Arctic Research Laboratory near Barrow, avoids difficult excavation in frozen ground and prevents permafrost degradation.

Center right: Steel mesh over thick gravel runways, as used at the Naval Arctic Research Laboratory near Barrow, provides the surface strength necessary for heavy aircraft traffic.

Bottom: Installing pilings in permafrost near Prudhoe Bay. Raising buildings on piles allows air circulation beneath the building, preventing permafrost thaw.

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Floods

Extensive severe flooding, especially in the larger stream channels, occurs during spring breakup between May and early July. Ice jams increase the height of the floodwater, especially in downstream reaches. When spring flow begins, it overflows the massive ice that is still frozen to the channel bed. Flooding extends for considerable distances, often up to several miles on each side of the stream (Figure 87). Flooding subsides as the ice is released from the stream bed and carried downstream and out to sea. Often, large blocks of ice are left stranded on beaches and bars where they quickly melt and disappear.

Tundra flooding is common during the snowmelt season. Because of the extremely flat terrain, drainage is slow and sluggish. Melting snow often pools temporarily behind unmelted snow berms, hardpacked winter snow roads, and other minor obstructions. Local flooding, especially bothersome in populated areas, occurs until snowmelt is complete and the waters can drain away.

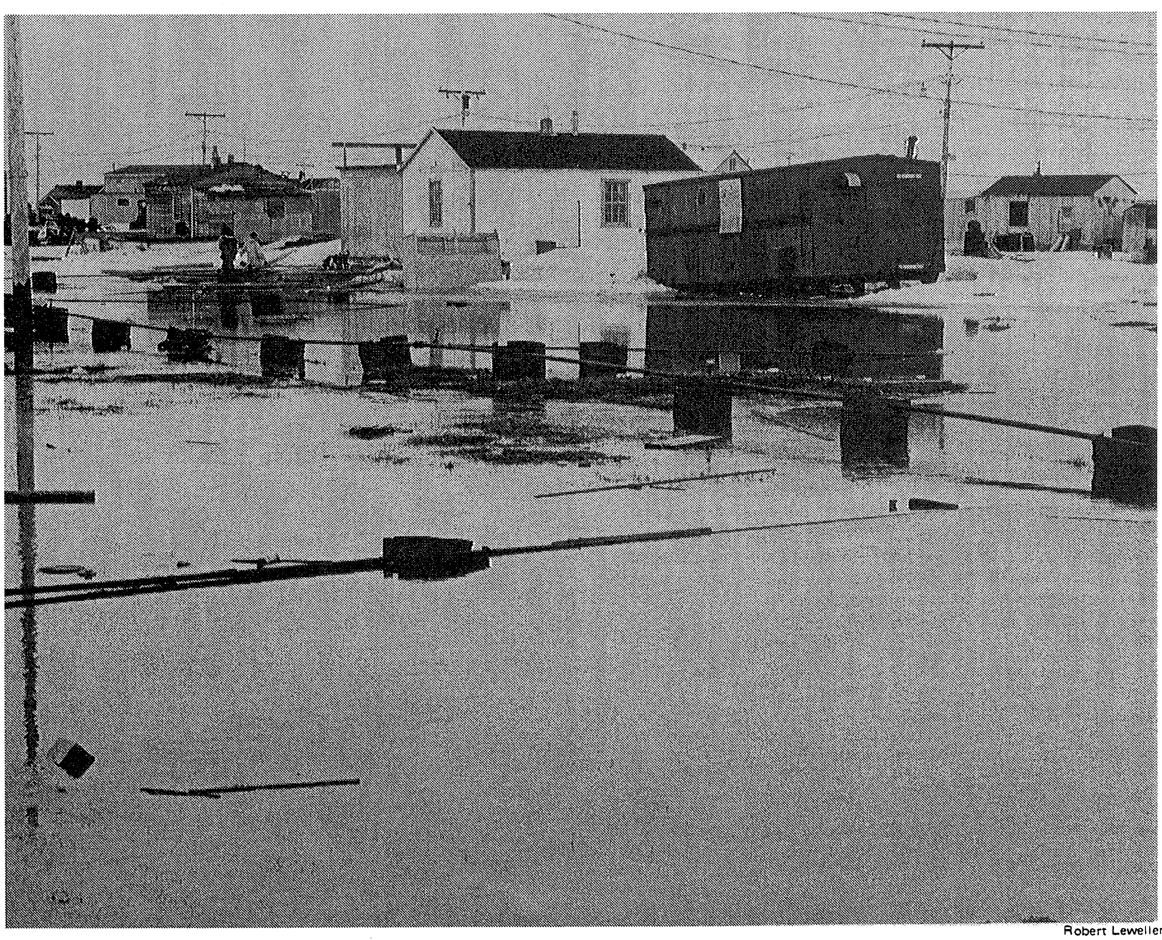
Intense, long periods of rainfall can cause general flooding and swollen streams. This is not a normal yearly occurrence because of low precipitation in the Arctic, however, floods from August rains have been extensive, perhaps once every 15 to 20 years. In winter, flooding is locally caused by the growth of large icings that cover some river floodplains to heights that often exceed open channel flood stages.

During late fall, storm surges often cause significant flooding and damage along coastal areas. At that time, ice may be far enough offshore to allow northwest winds a long fetch of open sea. The winds can develop high waves and a storm surge tide that inundate coastal areas. A storm of this type occurred in October 1963; the worst in Eskimo memory and considered a once in two hundred years occurrence. Extensive flooding and damage were sustained at the village of Barrow and the Naval Arctic Research Laboratory.

Beach erosion, most extensive during coastal storms but known to be a continual process, often is responsible for local flooding of coastal communities and installations. Studies have shown this process to be accelerated by removal of beach gravel for local construction.

Several alternatives are available to assist in flood protection and prevention, including construction of levees and bank stabilization. Stream overflow is apparently not a significant problem at present because no communities are built within stream flood areas. As most villages depend on the sea for their economic base, development away from the coast is not an alternative, especially in the west arctic subregion. Local protection works appear to be the major means to stop beach erosion and storm flooding.

Snowmelt flooding in the village of Barrow.



Robert Lewellen

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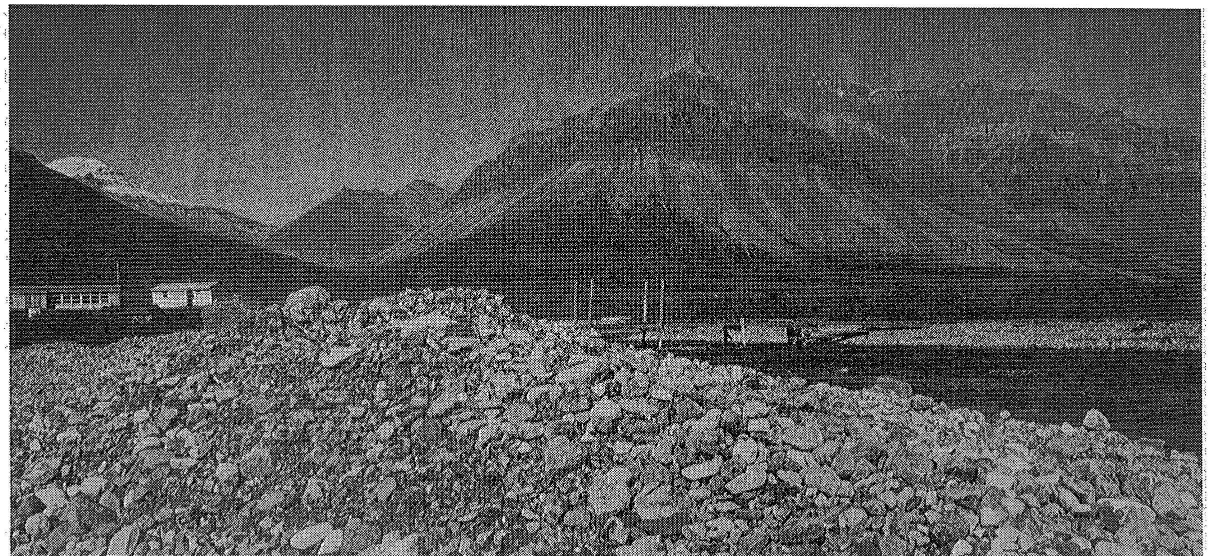
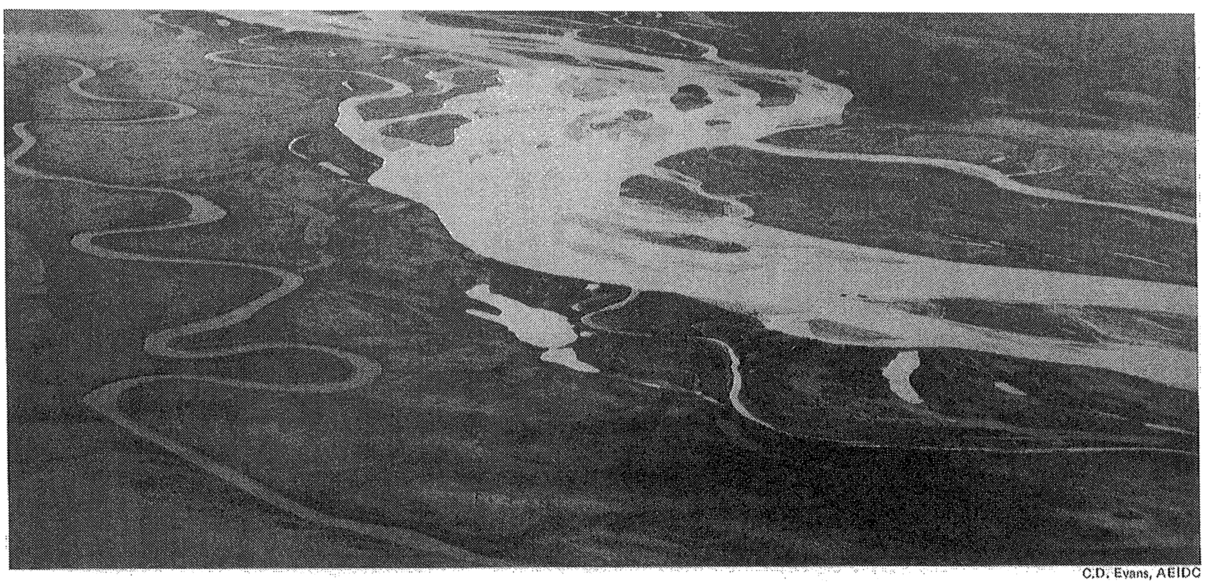


Local flood protection—a stone levee in Anaktuvuk. Marilyn Warren

Colville River during breakup flooding.

H.J. Walker, Louisiana State University

Runoff reaches a peak just after breakup in June and recedes to lower flow throughout the rest of the summer. Colville River.



C.D. Evans, AEIDC

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Economy

The overall economy of the Arctic Region is a combination of monetary, barter, and subsistence factors. Particularly since the post war period of exploration on Naval Petroleum Reserve No. 4 (Pet 4), the indigenous people of the region have participated more in an evolving cash economy. The harvest of fish and wildlife has continued to be extremely important (Figure 134). Evidence indicates that in some localities this take has actually increased over the post war period. Despite subsistence harvest levels and an increasing monetary economy, the Arctic Region remains depressed. This is reflected in the region's share of state total gross receipts as shown in Figure 137 for 1972. More recent data is unavailable, but will doubtless show an increase since the renewal of Prudhoe Bay oil field and pipeline development and production activities. Employment figures will also reflect this situation.

Employment, Work Force, and Unemployment

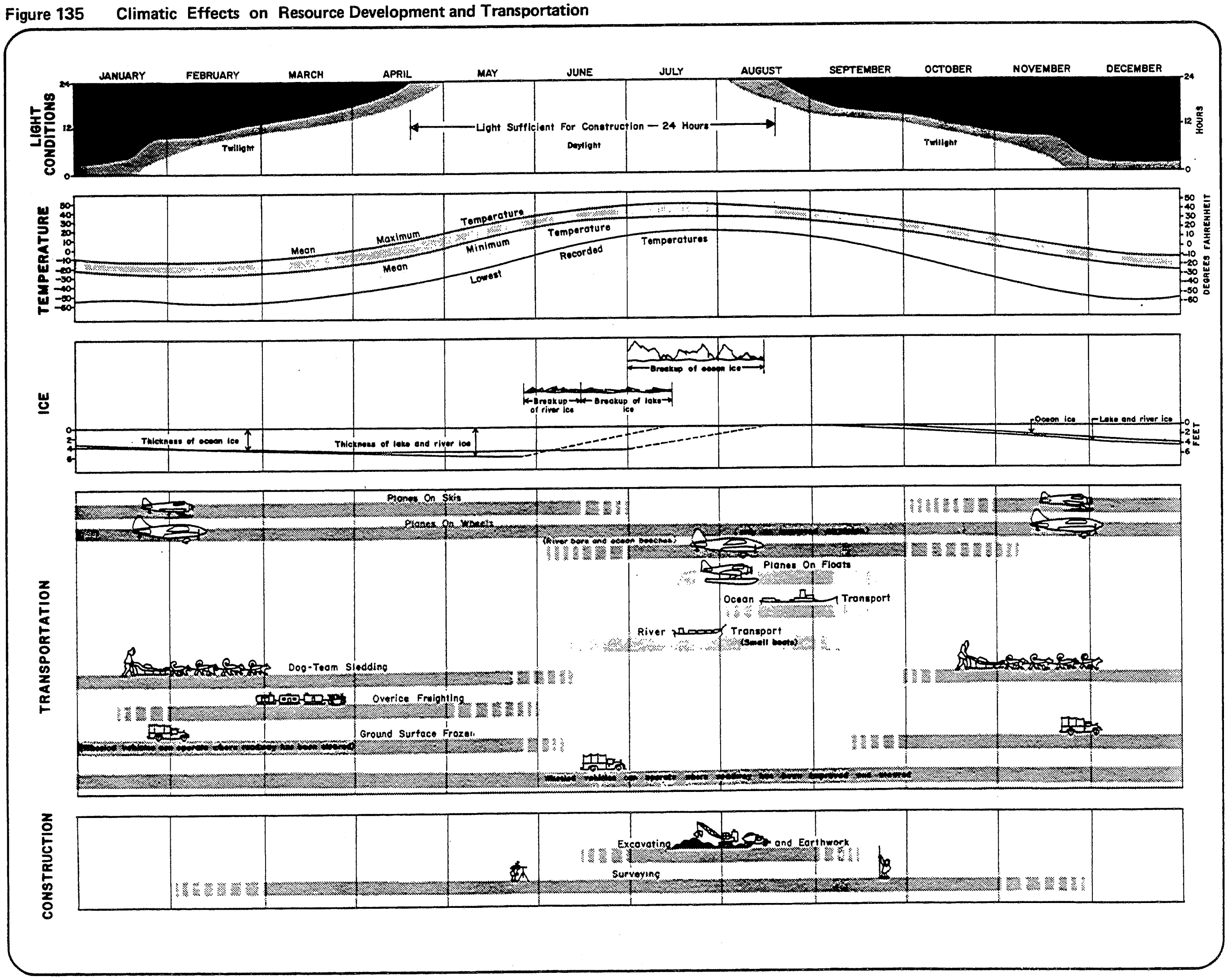
The remote, sparsely populated Arctic Region accounted for only 1.2 percent of the state's workforce in 1973, based on a count of workers by place of employment, and for a .9 percent of the state's labor force, which represents a count of workers by place of residence for the same year (Figure 139). Seasonality of work is reflected in the employment figures. In the northernmost area, severe winter weather curtails most outdoor activity (Figure 135). This situation may be altered somewhat with oil pipeline activity continuing throughout even the coldest winter months.

Figure 134 Average Annual Estimates of Subsistence Harvest Based on 1969-1973 Data—Arctic Region

Community	Population[1]	Mammals	Wildfowl (in pounds)	Fish	Total	Per Capita Harvest
Anaktuvuk Pass	97	156,555	540	3,950	161,045	1,660
Barrow	1,901	1,284,550	7,600	61,550	1,353,700	711
Kaktovik	107	91,500	2,300	15,000	109,300	1,012
Point Hope	369	537,600	19,300	40,000	596,900	1,618
Wainwright	308	469,455	1,200	2,840	473,495	1,542

(1) Figures represent Eskimo population in 1970.
Source: Joint Federal-State Land Use Planning Commission for Alaska, 1974.

Figure 135 Climatic Effects on Resource Development and Transportation



Barrow

State of Alaska, Division of Tou

Transportation

Transportation modes into and within the Arctic Region are perhaps the most underdeveloped in the nation. The residents depend almost exclusively on air transport for intervillage and interregional passenger and freight movement but only a few communities are served by scheduled airlines (Figure 160). A system of historic winter trails exists, but is only used occasionally today. Roads are nonexistent except for the recently completed Fairbanks to Prudhoe Bay service road and roads within villages and the Prudhoe Bay development complex (Figure 162).

Courtesy of ARCO

The new and the old way to travel in the Arctic.

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Figure 161 Distances in Miles Between Selected Communities on the Alaska Highway System

	Alaska Boundary	Anchorage	Circle	Delta Junction	Eagle	Fairbanks	Glennallen	Haines	Haines Jct., Yukon	Homer	Livengood	Palmer	Paxson	Portage	*Prudhoe Bay	Seward	Tok	Valdez
Alaska Boundary		421	463	201	242	298	232	364	205	648	380	373	274	469	776	550	93	347
Anchorage	421		523	340	503	358	189	785	626	227	440	40	259	48	836	129	328	304
Circle	463	523		262	545	165	413	827	668	750	223	483	343	571	643	652	370	528
Delta Junction	201	340	262		283	97	151	565	406	567	179	292	81	388	575	469	108	266
Eagle	242	503	545	283		380	314	606	447	730	462	455	356	551	858	632	175	429
Fairbanks	298	358	165	97	380		248	662	503	585	82	389	178	406	478	487	205	363
Glennallen	232	189	413	151	314	248		596	437	416	330	141	70	237	726	318	139	115
Haines	364	785	827	565	606	662	596		159	1012	744	737	638	833	1140	914	457	711
Haines Jct., Yukon	205	626	668	406	447	503	437	159		853	585	578	479	674	981	755	298	552
Homer	648	227	750	567	730	585	416	1012	853		667	267	486	179	1063	172	555	531
Livengood	380	440	223	179	462	82	330	744	585	667		400	260	488	560	569	287	445
Palmer	373	40	483	292	455	389	141	737	578	267	400		211	88	867	169	280	256
Paxson	274	259	343	81	356	178	70	638	479	486	260	211		307	656	388	181	185
Portage	469	48	571	388	551	406	237	833	674	179	488	88	307		884	81	376	352
*Prudhoe Bay	776	836	643	575	858	478	726	1140	981	1063	560	867	656	884		965	683	841
Seward	550	129	652	469	632	487	318	914	755	172	569	169	388	81	965		457	433
Tok	93	328	370	108	175	205	139	457	298	555	287	280	181	376	683	457		254
Valdez	347	304	528	266	429	363	115	711	552	531	445	256	185	352	841	433	254	

*Presently used only for trans-Alaska pipeline construction traffic. Not open to public use.

Adapted from State of Alaska, Department of Highways.

Figure 162 Existing Transportation System