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Hydrologic Data and a Proposed Water-Quality Monitoring Network for the Kobuk River Basin, Gates of the Arctic National Park and Preserve, and Kobuk Valley National Park, Alaska

By TIMOTHY P. BRABETS

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CONVERSION FACTORS, VERTICAL DATUM, AND WATER-QUALITY INFORMATION

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
ton	0.9072	megagram

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

××°F = (1.8 × °C) + 32

VERTICAL DATUM

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

ABBREVIATED WATER-QUALITY UNITS

Chemical concentration and water temperature are given only in metric units. Chemical concentration in water is given in milligrams per liter (mg/L) or micrograms per liter (µg/L). Milligrams per liter is a unit expressing the solute mass per unit volume (liter) of water. One milligram per liter is equivalent to 1,000 micrograms per liter. For concentrations less than 7,000 milligrams per liter, the numerical value is about the same as for concentrations in parts per million. Specific conductance is given in microsiemens per centimeter (µS/cm) at 25°C.

MAPPING SOURCES:

Base map modified from U.S. Geological Survey 1:63,360 State base maps.

U.S. Geological Survey Digital Line Graphs published at 1:250,000 and 1:63,360.

Publication projection is Albers Equal Area.

Standard parallels are 55°00′ and 65°00′, central meridian–154°00′, latitude of projection origin 50°00′.

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By Timothy P. Brabets

Abstract

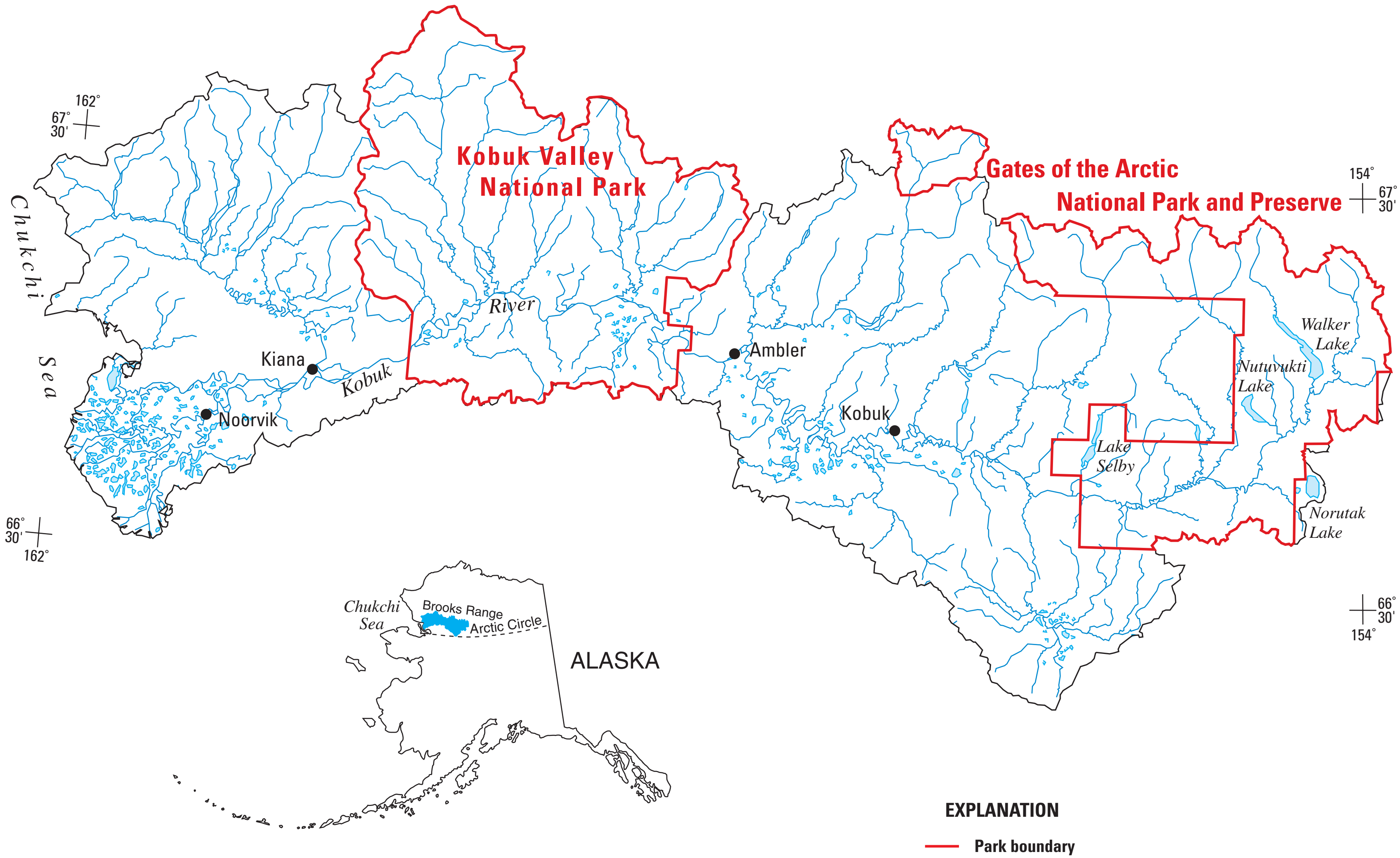
Located in northwestern Alaska, the Kobuk River drains a watershed of approximately 12,300 square miles. Two national parks are located in the basin: the entire Kobuk Valley National Park and and a portion of Gates of the Arctic National Park and Preserve. Reconnaissance-type water-quality data collected on the Kobuk River and some of its tributaries indicate that the water is of a calcium to calcium-magnesium-bicarbonate type. To design a representative water-quality monitoring network, a geographical information system (GIS) of the Kobuk River Basin was created. The GIS was used with a statistical technique, cluster analysis, to stratify the Kobuk River Basin into different regions. Potential water-quality monitoring sites were then selected from these regions.

INTRODUCTION

The Kobuk River Basin has an area of approximately 12,300 mi^2 and is located in northwestern Alaska, just north of the Arctic Circle (fig. 1). Originating in the central and eastern Brooks Range, the Kobuk River flows westward for more than 300 miles before it enters the Chukchi Sea (fig. 1). Four villages are located along the main stem of the Kobuk River, and abandoned mining camps and settlements are scattered throughout the basin.

Kobuk Valley National Park (KVNP) (fig. 1) is approximately 2,700 mi^2 in area and is contained entirely within the Kobuk River Basin. The portion of Gates of the Arctic National Park and Preserve (GANPP) commonly referred to as the “boot” covers approximately 2,000 mi^2, contains several large lakes (Selby, Nutuvukti, and Walker), and is located in the eastern part of the basin. In both parks, trees approach their northern limit; forest and tundra meet, creating a mosaic of forest and open tundra. Thousands of caribou funnel through mountain passes and cross the Kobuk River on their spring and fall migrations. Salmon and Arctic char migrate to spawning grounds within the parks. Native people have hunted, fished, and lived along the Kobuk River for at least 12,500 years, and the subsistence use of resources of the Kobuk River Valley continues into the present.

One of the most significant natural changes occurring in the Kobuk River Basin is climate warming. Air-temperature records from 1961–90 indicate a warming trend on the order of 1.4°F (0.78°C) per decade at latitudes where the Kobuk River is located (Chapman and Walsh, 1993). Much of the Kobuk River is underlain by permafrost, and if the permafrost melts, the upper layers of soil will become drier and well aerated. Even if permafrost remains as temperatures increase, the shallow soils that thaw and freeze each year (the active layer) thaw more deeply and develop a thicker unsaturated zone. Soil microbes increasingly oxidize the organic carbon sequestered in the soils. This increased respiration releases carbon, in the form of dissolved carbon, into streams and the atmosphere.



Base map modified from U.S. Geological Survey 1:63,360 State base maps
U.S. Geological Survey Digital Line Graphs published at 1:250,000 and 1:63,360
Publication projection is Albers Equal Area
Standard parallels are 55°00' and 65°00', central meridian -154°00', latitude of projection origin 50°00'

Figure 1. Location and extent of the Kobuk River Basin, Gates of the Arctic National Park and Preserve, and Kobuk Valley National Park, Alaska.

Changes in dissolved organic carbon (DOC) could affect all trophic levels of stream aquatic communities that rely on DOC as a food source.

Private lands totaling about 150 mi^2, selected under the provisions of the Alaska Native Claims Settlement Act (ANCSA), are located in KVNP and the portion of GANPP that is part of the Kobuk River Basin. In addition, a right-of-way access route to the Ambler Mining District along the eastern portion of the Kobuk River was reserved in the creation of GANPP. These private lands may be developed, possibly altering the runoff and water-quality characteristics of nearby streams and rivers.

Water-quality and quantity information is needed on the Kobuk River to monitor possible future climate change and potential development. By collecting and analyzing data before development takes place, park managers will have a baseline with which to compare future impacts. Proper data reduction and analysis can help ensure that the correct data have been collected, determine whether more or different types of data collection are needed, and indicate trends in water quality and whether these trends are occurring naturally or by human activity. To date, a water-quality monitoring plan has not been developed for the Kobuk River Basin.

Purpose and Scope

This report (1) summarizes the hydrologic data that have been collected in the Kobuk River Basin and (2) proposes a conceptual water-quality monitoring network for the streams and rivers of KVNP and GANPP. Only previously existing data were used in this study. Since the portion of the Kobuk River downstream of the western boundary of KVNP is outside both national parks (fig. 1), this area was not included in the analysis; the remaining portion of the Kobuk River Basin used in this study was approximately 9,500 mi^2.

The operation of a water-quality monitoring network would also include collection of continuous streamflow data from a subset of the water-quality monitoring sites and limnology data from a subset of the lakes in KVNP and GANPP. Identification of potential gaging sites and lakes was beyond the scope of this study. However, La Perriere (1999) studied a number of lakes in GANPP that are located in the Kobuk River Basin and developed a monitoring plan for these lakes.

PHYSICAL SETTING

Located in the central and eastern Brooks Range in northwestern Alaska, the Kobuk River Basin has a continental climate with short, warm summers, and long, very cold winters. Precipitation ranges from 15 to 40 inches, with an average of 21 inches for the entire basin (fig. 2). Average basin elevation for the Kobuk River Basin is about 1,300 feet and ranges from approximately 0 to 11,400 feet (fig. 3). The topography of the basin consists of low, generally rolling mountains (35 percent), plains and lowlands (29 percent), moderately high rugged mountains (21 percent), and plateaus and highlands of rolling topography and gentle slopes (15 percent) (fig. 4).

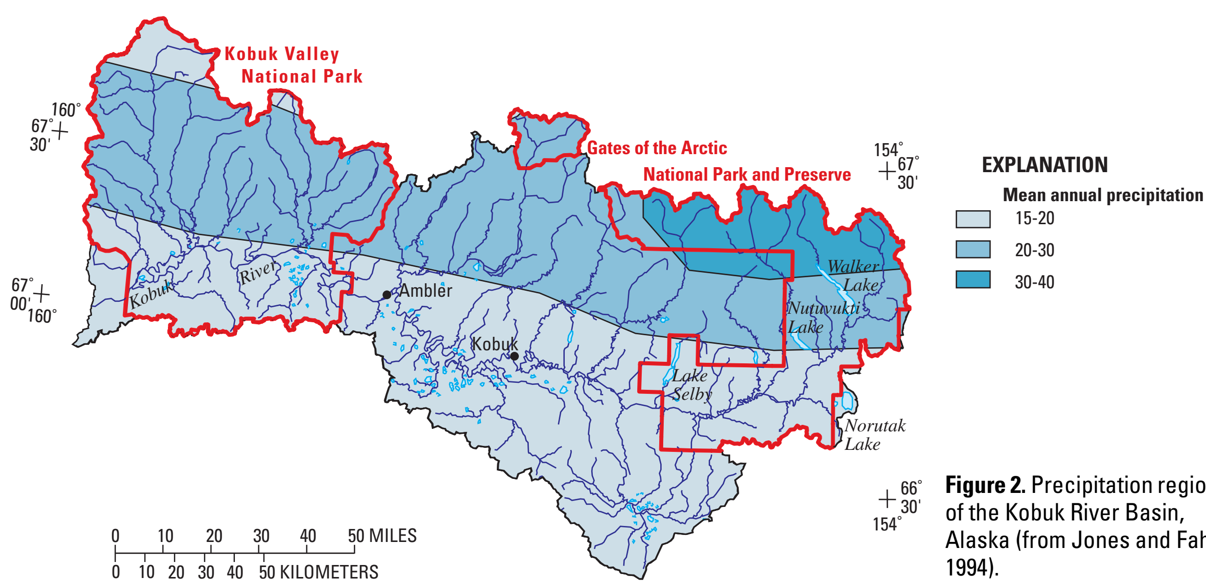


Figure 2. Precipitation regions of the Kobuk River Basin, Alaska (from Jones and Fahl, 1994).

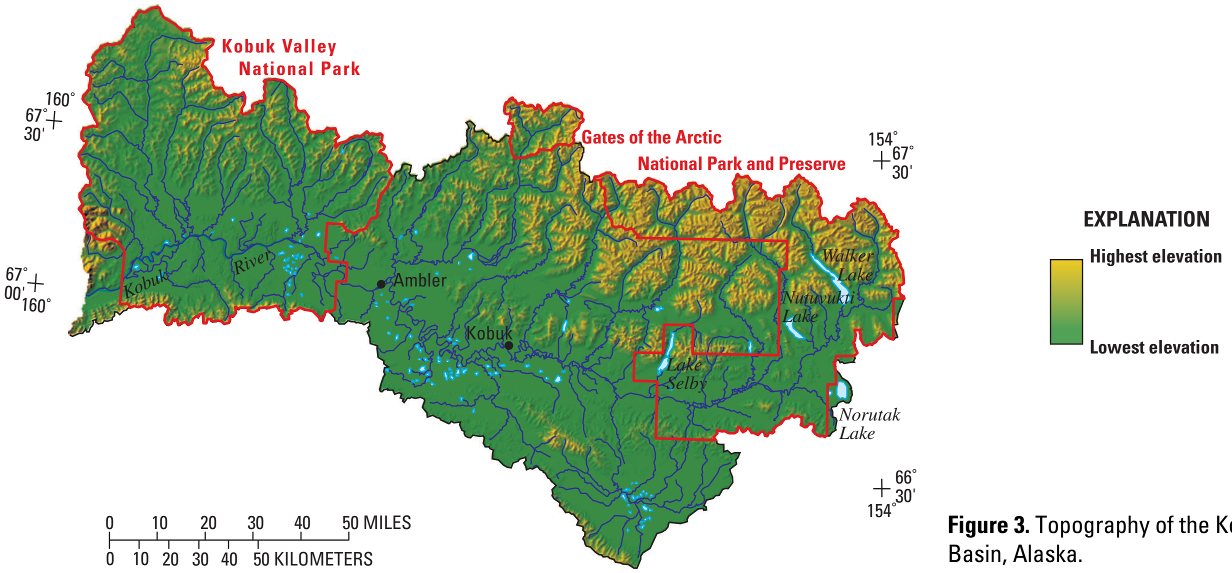


Figure 3. Topography of the Kobuk River Basin, Alaska.

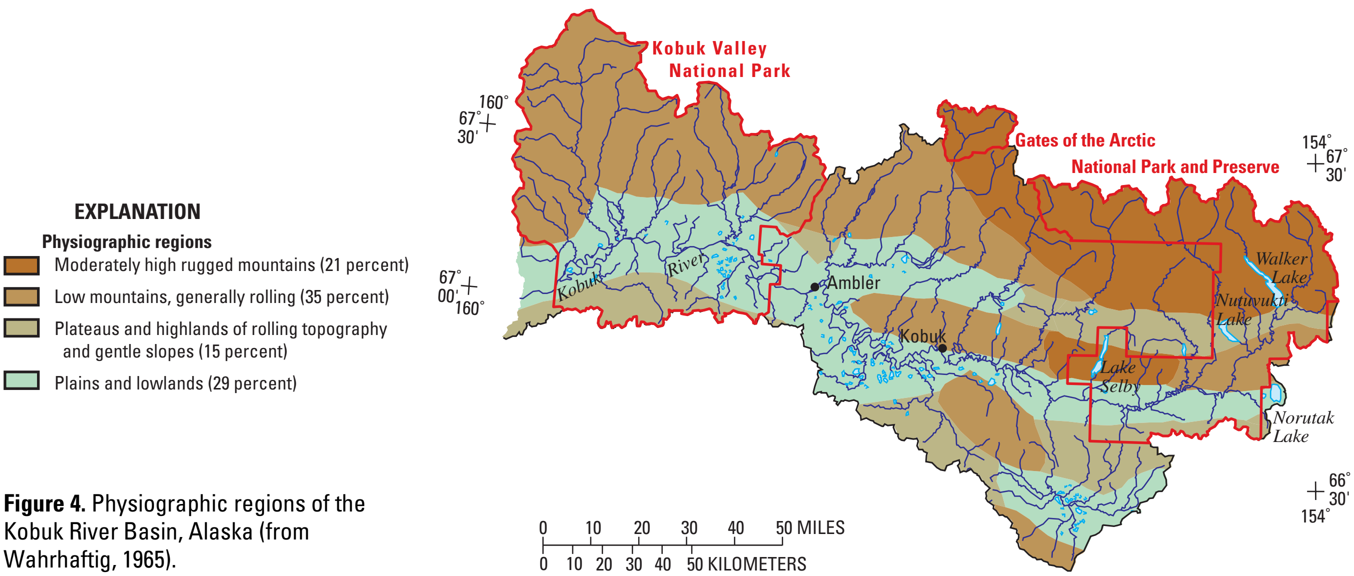


Figure 4. Physiographic regions of the Kobuk River Basin, Alaska (from Wahrhaftig, 1965).

Land cover categories for the Kobuk River Basin consist primarily of tall and low shrub (31 percent), dry or moist herbaceous (31 percent), needleleaf forest (26 percent), and dwarf shrub (10 percent) (fig. 5). Tall and low shrubs consist of willows and alders, dry or moist herbaceous plants consist of sedges, needleleaf forests consist of white and black spruce, and dwarf shrubs consist of plants less than 0.6 feet that are predominantly dwarf birch.

The geology of the Kobuk River Basin is composed primarily of Mesozoic sedimentary rocks (31 percent), Mesozoic volcanic rocks (15 percent), Paleozoic sedimentary rocks (32 percent), and Precambrian rocks (18 percent) (fig. 6). Mesozoic sedimentary rocks consist of shale, sandstone, conglomerate, bentonite, clay, and coal. Mesozoic volcanic rocks consist of basalt, diabase, diorite, gabbro, chert, and dunite. Paleozoic rocks consist of shale, sandstone, chert, conglomerates, and quartzite. Precambrian rocks consist of quartz-mica schist, mafic greenschist, calcareous schist, chloritic schist, phyllite, and quartzite.

Much of the Kobuk River Basin (83 percent) is underlain by continuous permafrost (fig. 7). A mass of material is considered to be permafrost if it has a temperature continually at or below 32°F (0°C) for 2 or more years (Ferrians, 1965). Permafrost has a very low permeability and commonly acts as a barrier to infiltration and as a confining layer to aquifers. Because permafrost is a barrier to infiltration, the likelihood of flash floods is greater in streams draining permafrost areas.

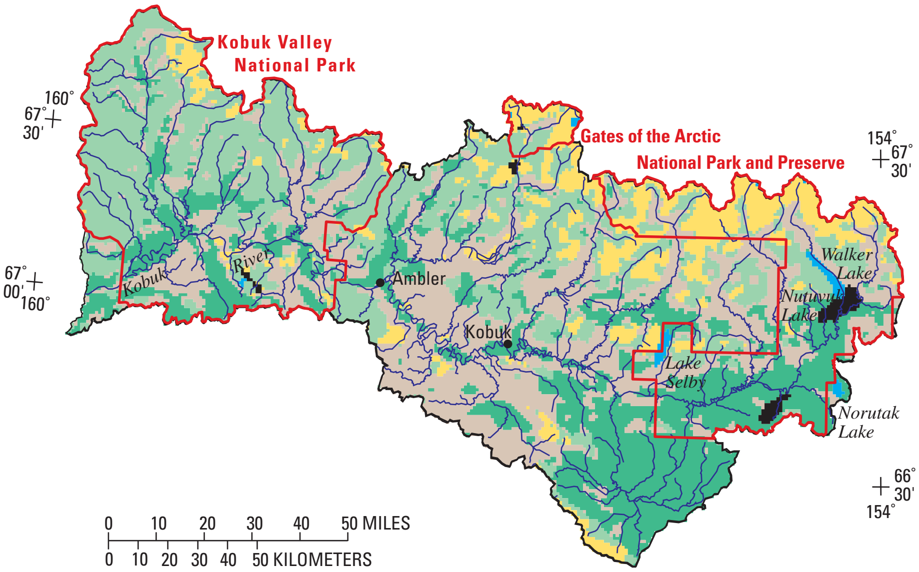


Figure 5. Land cover of the Kobuk River Basin, Alaska (from Alaska Geospatial Data Clearinghouse, 1998).

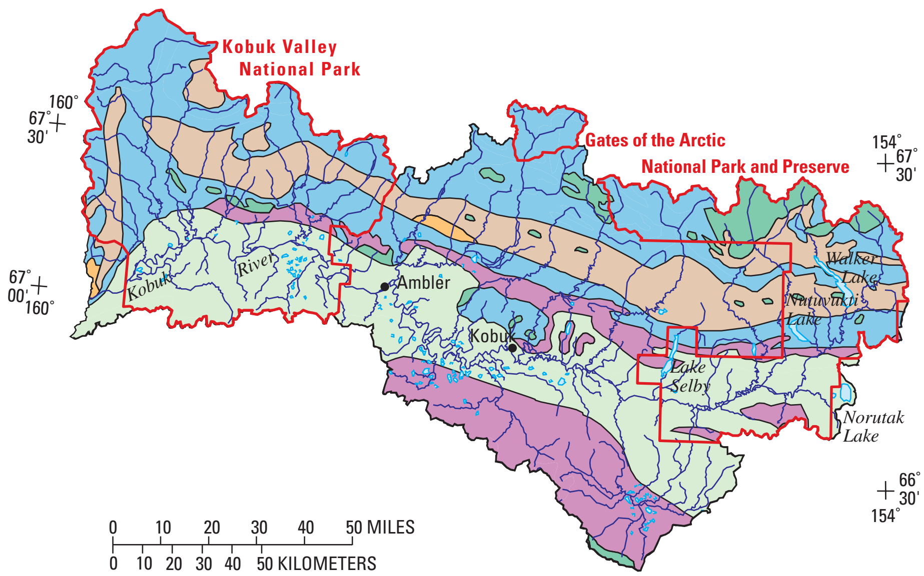


Figure 6. Geology of the Kobuk River Basin, Alaska (from Silbererling and others, 1994).

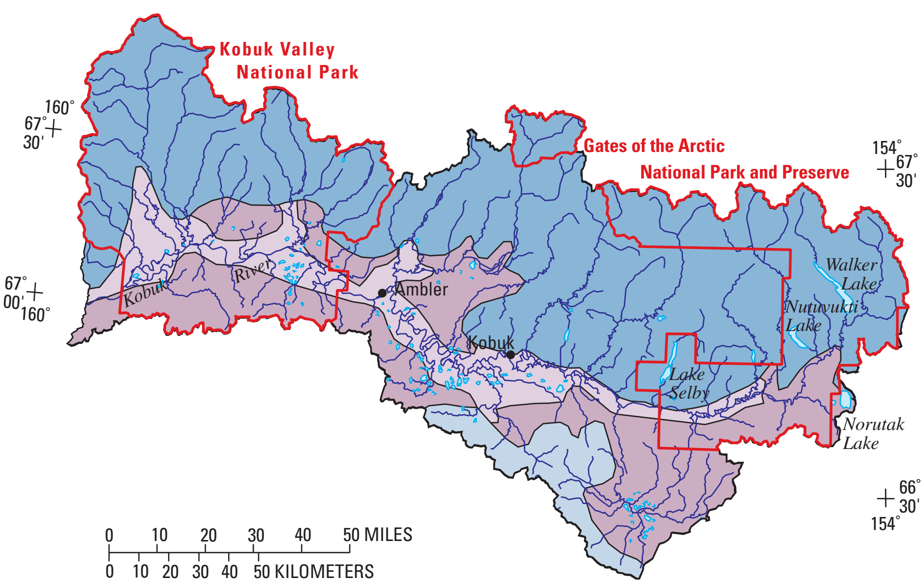


Figure 7. Permafrost regions of the Kobuk River Basin, Alaska (from Ferrians, 1965).

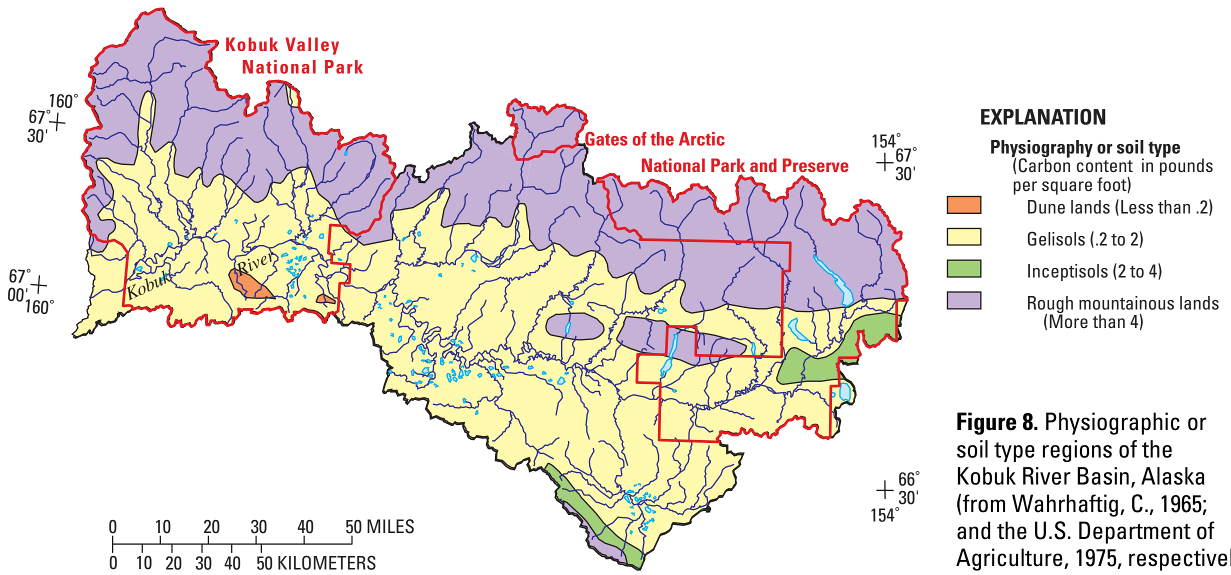


Figure 8. Physiographic or soil type regions of the Kobuk River Basin, Alaska (from Wahrhaftig, C., 1965; and the U.S. Department of Agriculture, 1975, respectively).

Because the Kobuk River Basin is dominated by permafrost, most of the soils are classified as gelisols (fig. 8). These are soils that have permafrost within about 40 inches of the soil surface and (or) have gelic materials within about 40 inches of the soil surface and have permafrost within about 80 inches. A suborder of the gelisol soils known as histic pergelic cryaquepts have thick accumulations of organic matter on the soil surface, commonly in the form of a mat of slightly or partly decomposed mosses, sedges, and associated plants. Because the mat is effective insulation against summer heat, the permafrost table in these soils is normally very shallow. The upper part of the soil that thaws each summer and refreezes each winter, known as the active layer, is almost constantly saturated during the thaw period. These soils contain varying amounts of carbon, ranging from less than 0.2 lb/ft^2 to more than 4 lb/ft^2 (fig. 8). The total amount of carbon held in the soil of the Kobuk River Basin is estimated to be approximately 36 million tons (National Resource Conservation Service, 2000).

SURFACE WATER

Flow characteristics of the Kobuk River are similar to those of other large Arctic rivers in Alaska and can be illustrated by flow records from the Kobuk River at Ambler (site 29, fig. 9, fig. 10) and the Kobuk River near Kiana (site 37, fig. 9, fig. 11). Late October to late May is a period of relatively low flow. In late May, when the snowpack has reached melting stage, flow in the Kobuk River begins to increase rapidly. Most of the runoff from the basin occurs during June as the water from snowmelt enters the river. For the remainder of the summer, July through September, flow fluctuates depending on the amount of precipitation. In October, flow begins to decrease with the onset of winter and the process repeats itself.

The average annual flow for the Kobuk River near Ambler has ranged from 5,839 ft^3/s to 14,890 ft^3/s for the period 1966–78 (table 1). Average annual flow for the Kobuk River near Kiana has ranged from 10,020 ft^3/s to 24,960 ft^3/s for the period 1977–99 (table 1). Peak discharges at the Kobuk River at Ambler have ranged from 30,000 ft^3/s to 95,000 ft^3/s and at the Kobuk River near Kiana from 45,000 ft^3/s to 161,000 ft^3/s (table 1). Some peaks were the result of ice jams that occurred during breakup. Large volumes of water are released when the ice jams fail.

In addition to the continuous flow records near Ambler and near Kiana, discharge data have been collected at 35 additional sites in the Kobuk River Basin (fig. 9, table 2). Most of the flow measurements were made on reconnaissance trips during the summer of 1979 and the winter of 1980 (Childers and Kernodle, 1983) and in 1994 (Deschu and others, 1999). Childers and Kernodle noted that frequent, heavy rains occurred during the middle and latter part of August 1979, and thus streamflow was probably higher than normal.

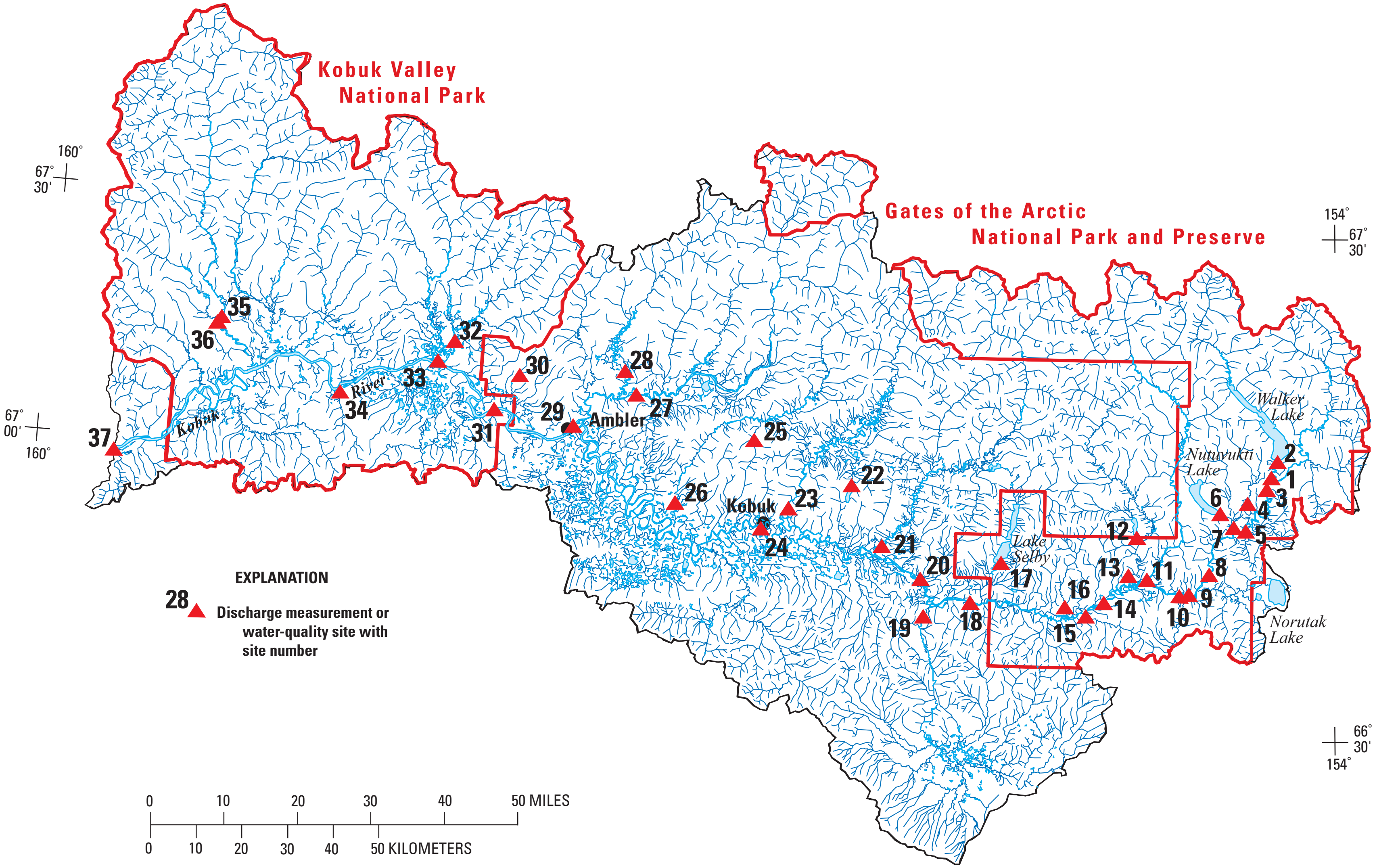


Figure 9. Locations of discharge measurements and water-quality sampling sites in the Kobuk River Basin, Alaska.

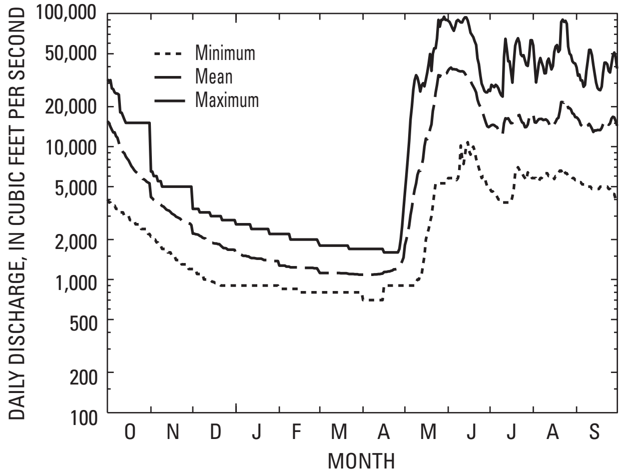


Figure 10. Flow statistics for the Kobuk River at Ambler, Alaska, 1965–78.

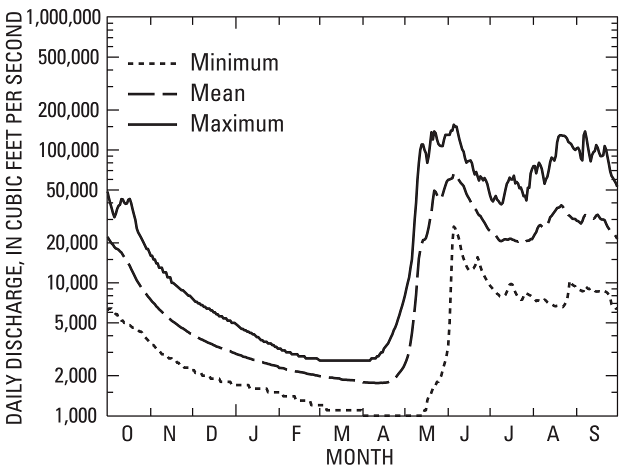


Figure 11. Flow statistics for the Kobuk River near Kiana, Alaska, 1976–99.

Unit runoff for the Kobuk River tributaries ranged from 0.1 $ft^3/s/mi^2$ to 12.2 $ft^3/s/mi^2$. Data from both reconnaissance trips indicated that most major tributaries draining from high relief areas had higher unit runoff than tributaries draining the lower relief areas (table 3). For example, the Pah River, which drains a lowland area of 956 mi^2, had a unit runoff of only 0.48 $ft^3/s/mi^2$. Other tributaries, which drain high relief areas, had unit runoff greater than 2.0 $ft^3/s/mi^2$.

WATER QUALITY

Water-quality data are available for the Kobuk River at Ambler for 1967–77, from the Kobuk River near Kiana for 1975–81, and from the reconnaissance trips in 1979 (Childers and Kernodle, 1983) and 1994 (Deschu and others, 1999).

Table 1. Average and peak discharges for the Kobuk River at Ambler and near Kiana, Alaska

[ft^3/s, cubic foot per second; --, no data]

Water year	Average discharge (ft^3/s)		Peak discharge (ft^3/s)	
	Ambler	Kiana	Ambler	Kiana
1966	8,675	--	63,900	--
1967	13,340	--	81,500	--
1968	9,601	--	94,000	--
1969	5,839	--	35,900	--
1970	6,220	--	[1]55,000	--
1971	9,203	--	[1]95,000	--
1972	9,025	--	[1]90,000	--
1973	14,890	--	93,600	--
1974	8,532	--	64,200	--
1975	8,760	--	66,700	--
1976	6,045	--	36,600	--
1977	7,279	10,020	39,100	69,300
1978	7,742	12,450	[1]30,000	48,000
1979	--	20,380	--	109,000
1980	--	18,050	--	99,600
1981	--	13,940	--	77,200
1982	--	18,360	--	152,000
1983	--	13,640	--	82,000
1984	--	12,900	--	80,700
1985	--	15,130	--	146,000
1986	--	17,120	--	141,000
1987	--	11,370	--	[1]45,000
1988	--	13,590	--	[2]84,000
1989	--	22,410	--	151,000
1990	--	13,260	--	[1]130,000
1991	--	15,870	--	[1]120,000
1992	--	12,220	--	161,000
1993	--	19,470	--	139,000
1994	--	24,960	--	138,000
1995	--	12,080	--	[1]110,000
1996	--	13,080	--	142,000
1997	--	10,640	--	[1]66,000
1998	--	20,130	--	103,000
1999	--	13,270	--	70,000
2000	--	--	--	--

[1]Maximum daily discharge.
[2]Estimated.

Table 2. Discharge measurement and water-quality sampling sites in the Kobuk River Basin, Alaska

[USGS site ID, U.S. Geological Survey site identification number; *, asterisk indicates water-quality sampling site]

Map number (figure 9)		Site	USGS site ID	Drainage area (square miles)
1		Kobuk River above Walker Lake outlet	6701371542036	285
2	*	Walker Lake outlet	6703291541849	178
3	*	Kobuk River below Walker Lake	6657471542148	285
4	*	Meandering tributary	6657221542545	43.0
5	*	Red Bog tributary	6655031542904	28.8
6		Nutuvukti Lake outlet	6657191543550	29.0
7	*	Nutuvukti Lake tributary	6655031543038	69.4
8	*	Kobuk River above Lower Kobuk Canyon	6650061543900	714
9	*	Beaver Pond tributary	6647301544550	6.70
10	*	Norutak Hills tributary	6647371544712	22.5
11	*	Reed River near mouth	6649251545731	364
12		Minakokosa Lake outlet	6654231550044	33.0
13	*	Beaver Creek	6649021550223	282
14		Kobuk River above Sulakpoatokvik Creek	6646361551018	1,560
15	*	Tributary near Bear Island	6645121551606	52.8
16	*	Akpelik Creek	6645041552137	37.3
17		Selby Lake outlet	6651041554104	113
18		Kobuk River below Selby River	6646181555000	2,000
19	*	Pah River near mouth	6644301560348	956
20		Killak River near mouth	6648541560500	42.0
21		Mauneluk River near mouth	6652401561645	573
22		Kollioksak Lake outlet	6659431562631	6.00
23	*	Kogoluktuk River near mouth	6656421564506	626
24	*	Kobuk River above Kobuk	6654121565306	4,170
25	*	Ruby Creek at Bornite	6704361565612	13.0
26		Shungnak River near mouth	6656471571903	213
27		Ambler River above Redstone River	6709181573223	716
28		Redstone River near Ambler	6712011573605	211
29	*	Kobuk River at Ambler	15744000	6,570
30		Jade Creek near Ambler	6710491580747	57.0
31	*	Kobuk River below Jade Creek	6706351581451	6,720
32		Akillik River above Hunt River	6714221582805	303
33		Hunt River near Ambler	6711541583242	646
34	*	Kavet Creek at mouth	6707241590130	25.0
35	*	Salmon River above Kitlik River	6715121593858	515
36	*	Kitlik River near Kiana	6714301594006	98.0
37	*	Kobuk River near Kiana	15744500	9,520

Table 3. Discharge measurements at sites in the Kobuk River Basin, Alaska

[ft^3/s/ cubic foot per second; $ft^3/s/mi^2$, cubic foot per second per square mile]

Map number (figure 9)	Site	Date	Discharge (ft^3/s)	Unit discharge ($ft^3/s/mi^2$)
1	Kobuk River above Walker Lake outlet	8-11-79	1,090	3.82
2	Walker Lake outlet	8-11-79	1,160	6.52
		6-14-94	[1]2,000	11.2
3	Kobuk River below Walker Lake	6-15-94	[1]5,000	17.5
4	Meandering tributary	6-15-94	200	4.65
5	Red Bog tributary	6-16-94	10	0.34
6	Nutuvukti Lake outlet	8-14-79	47	1.62
7	Nutuvukti Lake tributary	6-16-94	260	3.75
8	Kobuk River above Lower Kobuk Canyon	8-13-79	2,380	3.33
10	Norutak Hills tributary	6-17-94	37	1.64
11	Reed River near mouth	8-15-79	1,640	4.51
		6-18-94	[1]2,000	5.49
12	Minakokosa Lake outlet	8-14-79	88	2.70
13	Beaver Creek	6-18-94	[1]1,700	6.03
14	Kobuk River above Sulakpoatokvik Creek	8-16-79	6,930	4.45
15	Tributary near Bear Island	6-19-94	29	0.55
16	Akpelik Creek	6-19-94	114	3.06
17	Selby Lake outlet	8-16-79	332	2.94
18	Kobuk River below Selby Lake	8-17-79	7,240	3.62
19	Pah River near mouth	8-17-79	458	0.48
20	Killak River near mouth	8-18-79	92	2.19
21	Mauneluk River near mouth	8-18-79	2,980	5.20
22	Kollioksak Lake outlet	8-18-79	.5	0.08
23	Kogoluktuk River near mouth	8-19-79	2,540	4.06
		4-02-80	63	0.10
24	Kobuk River above Kobuk	8-24-79	21,900	5.25
		4-02-80	1,240	0.30
25	Ruby Creek at Bornite	8-21-79	80	6.15
26	Shungnak River near mouth	8-23-79	1,520	7.14
27	Ambler River above Redstone River	8-19-79	5,030	7.03
28	Redstone River near Ambler	8-22-79	1,100	5.21
30	Jade Creek near Ambler	8-22-79	150	2.63
31	Kobuk River below Jade Creek	8-28-79	50,800	7.56
32	Akillik River above Hunt River	8-22-79	3,700	12.2
33	Hunt River near Ambler	3-28-80	164	0.24
34	Kavet Creek	8-29-79	55	2.20
35	Salmon River above Kitlik River	8-23-79	4,400	8.54
36	Kitlik River near Kiana	8-23-79	851	8.68

[1]Estimated.

Most of the data consist of field parameters (pH, water temperature, specific conductance, and dissolved oxygen) and major ions (tables 4 and 5). Some trace-element data are available for the Kobuk River near Kiana.

The trilinear diagram in figure 12 (Piper, 1944) indicates that the water chemistry of the Kobuk River at Ambler is of a calcium to calcium-magnesium-bicarbonate type. High correlations exist between the concentrations of major ions (table 4) and specific conductance (table 5). Conductance is inversely correlated with discharge, indicating that concentrations of these constituents become more dilute with increasing discharge.

Analysis of water-quality samples from the Kobuk River near Kiana indicates the same type of water as found upstream at Ambler (fig. 13, table 6).

Table 4. Water-quality summary for the Kobuk River at Ambler, Alaska

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter]

Constituent	Number of samples	Minimum	Median	Maximum
pH	15	6.7	7.7	8.4
Specific conductance (µS/cm)	28	59	150	212
Water temperature (°C)	30	0.0	4.8	19.0
Hardness (mg/L as $CaCO_3$)	15	28	79	110
Calcium (mg/L)	15	9.0	25	34
Magnesium (mg/L)	15	1.3	4.0	5.9
Potassium (mg/L)	15	0.2	.5	1.3
Sodium (mg/L)	15	0.3	1.0	2.1
Alkalinity (mg/L)	14	28	71	100
Chloride (mg/L)	15	0.0	0.4	1.0
Fluoride (mg/L)	15	0.0	0.1	0.2
Silica (mg/L)	15	1.1	3.3	6.8
Sulfate (mg/L)	15	0.0	11	17

Table 5. Correlation matrix of specific conductance, instantaneous discharge, and concentrations of major ions for the Kobuk River at Ambler, Alaska

[Number of samples = 15; degrees of freedom = 13; correlation coefficient greater than or equal to 0.51 is significant at the 95 percent confidence limit]

Constituent	Specific conductance	Instantaneous discharge	Calcium	Magnesium	Potassium	Sodium	Alkalinity	Chloride	Fluoride	Silica	Sulfate
Specific conductance	1.00										
Instantaneous discharge	-0.87	1.00									
Calcium	0.99	-0.88	1.00								
Magnesium	0.98	-0.83	0.96	1.00							
Potassium	0.73	-0.54	0.70	0.73	1.00						
Sodium	0.89	-0.68	0.88	0.86	0.79	1.00					
Alkalinity	0.98	-0.83	0.98	0.97	0.74	0.86	1.00				
Chloride	-0.03	0.11	-0.03	-0.04	-0.23	0.01	-0.01	1.00			
Fluoride	0.24	-0.13	0.26	0.14	0.34	0.40	0.19	-0.02	1.00		
Silica	0.86	-0.73	0.86	0.85	0.62	0.88	0.87	-0.01	0.11	1.00	
Sulfate	0.81	-0.86	0.79	0.76	0.53	0.72	0.70	-0.22	0.41	0.63	1.00

The corner ***A*** coresponds to 100 percent Mg in the cation triangle, 100 percent (Ca+Mg), 0 percent (Na+K); 100 percent alkalinity, 0 percent (SO4 +Cl) in the quadrilateral.

The corner ***B*** is 100 percent SO4 in the anion triangle, 100 percent (Na+K), 0 percent (Ca+Mg); 100 percent (SO4 +Cl), 0 percent alkalinity in the quadrilateral.

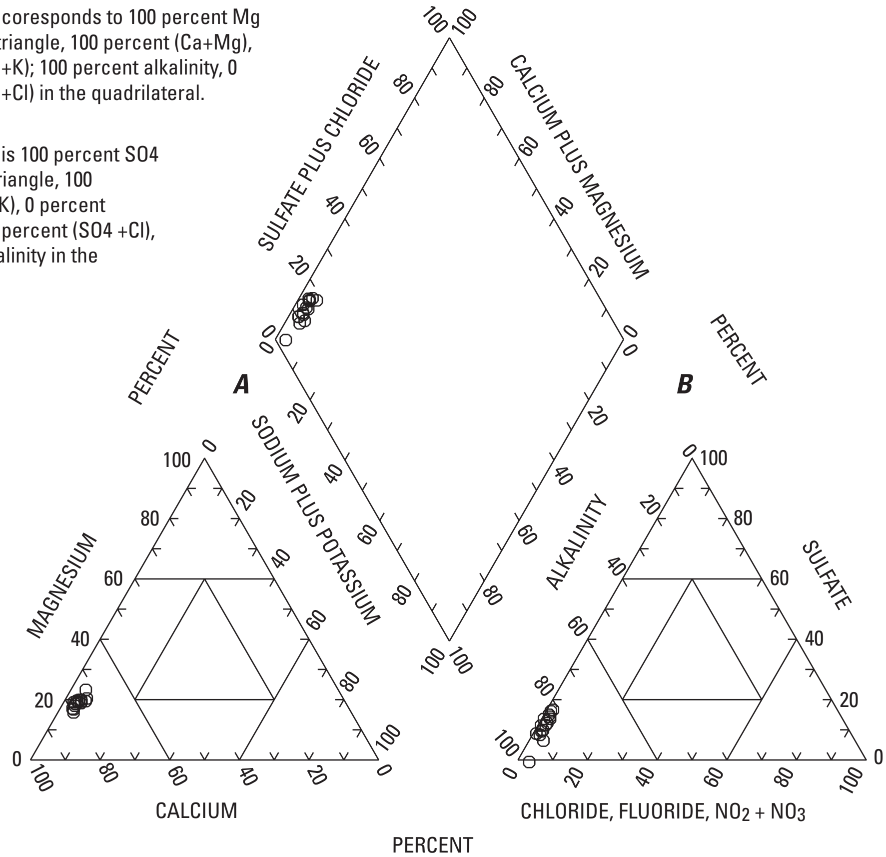


Figure 12. Water chemistry of the Kobuk River at Ambler, Alaska.

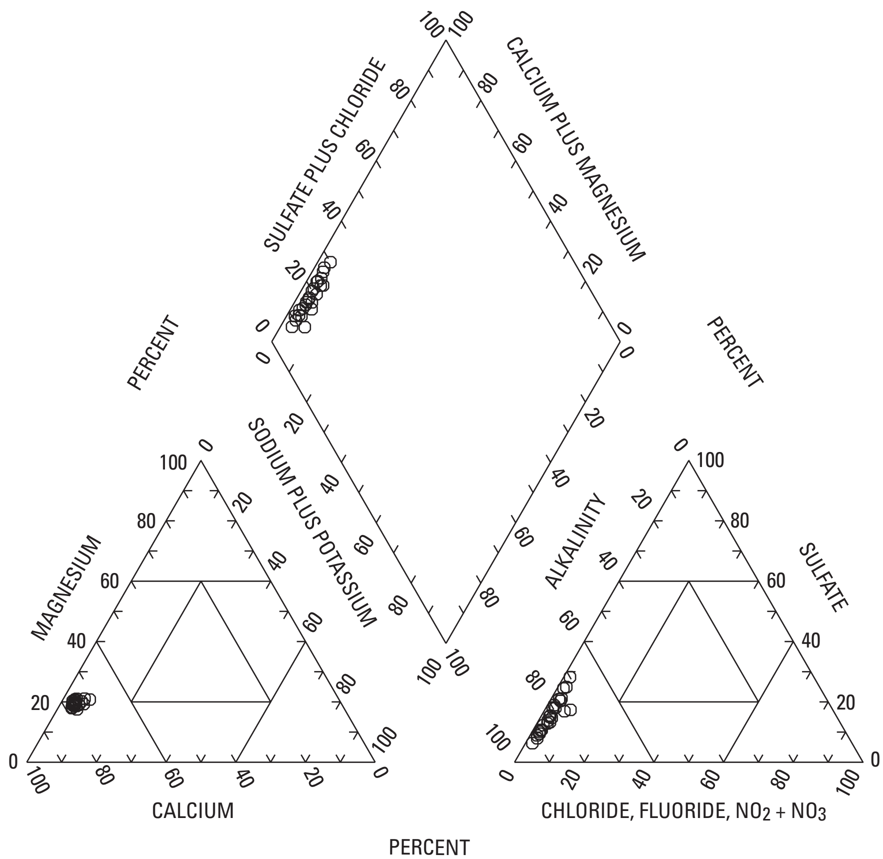


Figure 13. Water chemistry of the Kobuk River near Kiana, Alaska.

Table 6. Water-quality summary for the Kobuk River near Kiana, Alaska

[µS/cm, microsiemens per centimeter at 25 degrees Celsius; °C, degrees Celsius; mg/L, milligrams per liter; µg/L; micrograms per liter]

Constituent or property	Number of samples	Minimum	Median	Maximum	Non-detections
PROPERTIES					
pH	25	6.2	7.1	8.0	0
Specific conductance (µS/cm)	26	85	157	205	0
Water temperature (°C)	27	0.0	4.5	16.0	0
Hardness (mg/L as $CaCO_3$)	26	41	79	110	0
MAJOR IONS					
Calcium (mg/L)	26	13	25.0	34	0
Magnesium (mg/L)	26	2.1	4.1	6.3	0
Potassium (mg/L)	26	0.2	0.5	2.2	0
Sodium (mg/L)	26	0.6	0.9	2.5	0
Alkalinity (mg/L)	26	30	66	110	0
Chloride (mg/L)	26	0.1	0.6	2.9	0
Fluoride (mg/L)	19	0.1	0.1	0.1	4
Silica (mg/L)	26	2.2	3.4	6.1	0
Sulfate (mg/L)	25	4.4	13.0	27.0	0
NUTRIENTS					
Total nitrogen, NO_2 + NO_3 (mg/L)	25	0.09	0.17	1.6	0
Total nitrogen as N (mg/L)	24	0.09	0.46	2.5	0
Total nitrogen as NO_3 (mg/L)	24	0.40	2.0	11.0	0
CARBON					
Organic carbon, Dissolved (mg/L)	8	2.5	7.4	15.0	1
Organic carbon, suspended (mg/L)	6	0.3	0.6	0.8	2
Organic carbon, total (mg/L)	14	0.5	2.6	10.0	0
SELECTED TRACE ELEMENTS					
Arsenic, total (µg/L)	16	1	1	9	0
Copper, dissolved (µg/L)	12	2	6	32	4
Copper, suspended (µg/L)	12	5	7	41	2
Copper, total (µg/L)	12	5	13.5	50	3
Iron, dissolved (µg/L)	16	30	90	450	0
Iron, suspended (µg/L)	8	190	350	3,200	0
Iron, total (µg/L)	16	250	430	3,300	0
Lead, dissolved (µg/L)	12	2	6	11	3
Lead, suspended (µg/L)	11	8	17	32	4
Lead, total (µg/L)	11	7	18	38	4
Manganese, total (µg/L)	16	20	30	110	0
Zinc, dissolved (µg/L)	11	6.0	20	90	5
Zinc, suspended (µg/L)	10	10	30	470	6
Zinc, total (µg/L)	14	10	30	560	2

Similar to the Kobuk River at Ambler, dissolved constituents from the Kobuk River near Kiana are correlated to specific conductance and inversely correlated with discharge (table 7). Two trace elements, iron and manganese, and suspended sediment are somewhat correlated with discharge (table 8). Iron and zinc are correlated with suspended sediment.

Water samples collected during the reconnaissance trips in August 1979 and June 1999 provide a good "snapshot" of the water quality of the Kobuk River Basin. Water temperatures during the time of sampling ranged from 5.2°C to 17.5°C (table 9). Stream sampling sites near lake outlets had the warmest water. Concentrations of dissolved oxygen ranged from 7.5 mg/L to 13.5 mg/L. Values of pH ranged from 6.2 to 7.9, and specific conductance of water ranged from 45 µS/cm to 235 µS/cm. Major-ion analysis of water samples collected at some of the sites (table 10) indicated that most waters sampled are of the calcium-magnesium to calcium-bicarbonate type (fig. 14).

Table 7. Correlation matrix of specific conductance, instantaneous discharge, and concentrations of major ions for the Kobuk River near Kiana, Alaska

[Number of samples = 26; degrees of freedom = 24; correlation coefficient greater than or equal to 0.39 is significant at the 95 percent confidence limit]

Constituent	Specific conductance	Instantaneous discharge	Calcium	Magnesium	Potassium	Sodium	Alkalinity	Chloride	Fluoride	Silica	Sulfate
Specific conductance	1.00										
Instantaneous discharge	-0.86	1.00									
Calcium	0.92	-0.90	1.00								
Magnesium	0.89	-0.87	0.97	1.00							
Potassium	0.32	-0.39	0.52	0.61	1.00						
Sodium	0.45	-0.50	0.60	0.70	0.78	1.00					
Alkalinity	0.84	-0.82	0.92	0.88	0.47	0.58	1.00				
Chloride	0.22	-0.32	0.27	0.31	0.18	0.03	0.21	1.00			
Fluoride	-0.27	0.18	-0.23	-0.34	-0.14	-0.51	-0.14	0.01	1.00		
Silica	0.78	-0.68	0.84	0.86	0.44	0.64	0.85	0.04	-0.37	1.00	
Sulfate	0.21	-0.19	0.11	0.16	-0.14	0.14	0.04	-0.07	-0.44	0.05	1.00

Table 8. Correlation matrix of iron, manganese, zinc, and suspended sediment concentrations and instantaneous discharge for the Kobuk River near Kiana, Alaska

[Number of samples = 14; degrees of freedom = 12; correlation coefficient greater than or equal to 0.53 is significant at the 95 percent confidence limit]

Constituent	Iron	Manganese	Zinc	Suspended sediment	Instantaneous discharge
Iron	1.00				
Manganese	0.87	1.00			
Zinc	0.34	0.08	1.00		
Suspended sediment	0.78	0.53	0.81	1.00	
Discharge	0.89	0.79	0.14	0.63	1.00

Table 9. Field properties measured at sites in the Kobuk River Basin, Alaska

[ft^3/s, cubic foot per second; mg/L, milligram per liter; °C, degrees Celsius; µS/cm, microsiemens per centimeter at 25°C; NTU, nepthelometric turbidity unit; --, not measured; <, less than]

Map number (figure 9)	Site	Date	Discharge (ft^3/s)	Dissolved oxygen (mg/L)	pH	Specific conductance (µS/cm)	Turbidity (NTU)	Water temperature (°C)
1	Kobuk River above Walker Lake outlet	8-11-79	1,090	--	7.7	175	0.25	10.5
2	Walker Lake outlet	8-11-79	1,160	--	7.9	130	0.18	14.5
		6-14-94	[1]2,000	--	7.7	153	<0.20	5.2
3	Kobuk River below Walker Lake	6-15-94	[1]5,000	--	7.7	137	<0.20	6.0
4	Meandering tributary	6-15-94	200	--	6.9	77	1.5	7.0
5	Red Bog tributary	6-16-94	10	--	6.2	181	1.6	12.1
6	Nutuvukti Lake outlet	8-14-79	47	--	6.8	65	0.35	17.5
7	Nutuvukti Lake tributary	6-16-94	260	--	6.9	64	0.50	11.1
8	Kobuk River above Lower Kobuk Canyon	8-13-79	2,380	--	7.9	160	0.35	14.0
9	Beaver Pond tributary	6-17-94	--	--	7.2	179	0.80	7.4
10	Norutak Hills tributary	6-17-94	37	--	7.5	148	34.0	8.2
11	Reed River near mouth	8-15-79	1,640	--	7.2	110	0.30	9.5
		6-18-94	[1]2,000	--	7.5	105	1.00	7.5
12	Minakokosa Lake outlet	8-14-79	88	--	7.7	70	0.35	16.0
13	Beaver Creek	6-18-94	[1]1,700	--	7.4	108	1.0	7.7
14	Kobuk River above Sulakpoatokvik Creek	8-16-79	6,930	--	7.3	135	0.45	10.5
15	Tributary near Bear Island	6-19-94	29	--	7.1	124	0.30	6.6
16	Akpelik Creek	6-19-94	114	--	7.2	62	<0.20	5.6
17	Selby Lake outlet	8-16-79	332	--	7.5	85	0.30	17.0
18	Kobuk River below Selby River	8-17-79	7,240	--	7.5	135	0.30	13.0
19	Pah River near mouth	8-17-79	458	--	7.1	80	0.85	13.5
20	Killak River near mouth	8-18-79	92	13.5	6.5	55	0.50	7.5
21	Mauneluk River near mouth	8-18-79	2,980	--	7.4	155	0.65	9.0
22	Kollioksak Lake outlet	8-18-79	0.5	7.5	6.2	45	2.0	13.5
23	Kogoluktuk River near mouth	8-19-79	2,540	11.8	7.3	180	0.85	9.0
24	Kobuk River above Kobuk	8-24-79	21,900	11.0	7.3	165	0.20	12.0
25	Ruby Creek at Bornite	8-21-79	80	11.6	7.5	235	0.20	6.5
26	Shungnak River near mouth	8-23-79	1,520	12.9	7.6	127	0.40	11.0
27	Ambler River above Redstone River	8-19-79	5,030	11.4	7.9	170	0.40	10.0
28	Redstone River near Ambler	8-22-79	1,100	12.1	7.0	100	0.50	8.0
28	Kobuk River at Ambler	8-27-79	--	11.3	7.5	150	2.0	8.5
30	Jade Creek near Ambler	8-22-79	150	12.2	6.8	62	0.40	6.5
31	Kobuk River below Jade Creek	8-28-79	50,800	11.6	7.7	145	0.70	9.0
32	Akillik River above Hunt River	8-22-79	3,700	11.8	6.9	95	0.80	7.0
34	Kavet Creek at mouth	8-29-79	55	11.3	7.8	220	3.5	8.0
35	Salmon River above Kitlik River	8-23-79	4,400	11.8	7.5	185	0.60	7.5
36	Kitlik River near Kiana	8-23-79	851	11.6	6.5	55	0.15	7.5
37	Kobuk River near Kiana	8-30-79	--	11.1	7.5	230	0.30	9.0

[1]Estimated.

Table 10. Major ion concentrations at sites in the Kobuk River Basin, Alaska

[fig., figure; --, no data; <, less than]

Map number (fig. 9)	Site	Date	Constituent (milligrams per liter)								
			Calcium	Magnesium	Sodium	Potassium	Chloride	Sulfate	Fluoride	Silica	Dissolved solids
2	Walker Lake outlet	8-11-79	23	2.5	0.6	1.1	0.2	11	0.1	2.0	70
		6-14-94	22	3.1	0.52	1.2	0.3	8.6	--	--	--
3	Kobuk River below Walker Lake	6-15-94	21	2.8	0.40	0.9	<0.1	7.0	--	--	--
4	Meandering tributary	6-15-94	11	1.6	0.41	<0.5	0.3	6.0	--	--	--
5	Red Bog tributary	6-16-94	23	7.8	3.5	<0.5	0.5	6.5	--	--	--
7	Nutuvukti Lake tributary	6-16-94	6.9	1.9	0.6	<0.5	0.3	6.0	--	--	--
8	Kobuk River above Lower Kobuk Canyon	8-13-79	26	2.9	0.7	0.9	0.3	14	0.1	2.1	82
9	Beaver Pond tributary	6-17-94	32	5.4	1.3	0.6	0.2	8.5	--	--	--
10	Norutak Hills tributary	6-17-94	17	5.5	2.0	<0.5	0.2	14	--	--	--
11	Reed River at mouth	8-15-79	17	1.9	0.9	0.7	0.1	13	0.2	2.7	55
		6-18-94	13	2.0	0.73	0.7	0.2	8.0	--	--	--
13	Beaver Creek	6-18-94	15	2.2	0.55	<0.5	<0.1	10	--	--	--
15	Tributary near Bear Island	6-19-94	13	6.2	2.0	<0.5	<0.2	4.5	--	--	--
16	Akpelik Creek	6-19-94	6.2	2.2	1.2	<0.5	<0.1	3.0	--	--	--
19	Pah River near mouth	8-17-79	11	2.9	2.1	0.2	0.5	6.4	0.1	6.1	5.1
23	Kogoluktuk River near mouth	8-19-79	29	4.0	0.9	1.0	0.3	26	0.1	2.9	104
24	Kobuk River above Kobuk	8-24-79	27	3.7	0.8	0.7	0.2	23	0.1	3.4	95
25	Ruby Creek at Bornite	8-21-79	37	6.2	0.5	<0.1	0.4	17	0.1	3.0	130
31	Kobuk River below Jade Creek	8-28-79	29	4.5	0.50	0.3	0.3	15	0.1	2.5	86
34	Kavet Creek at mouth	8-29-79	40	4.8	1.6	0.3	0.5	4.5	0.1	6.4	128
35	Salmon River above Kitlik River	8-23-79	33	7.6	0.7	0.1	0.3	51	0.1	2.7	136
36	Kitlik River near Kiana	8-23-79	7.4	1.4	0.5	<0.1	0.1	11	0.1	2.6	29

WATER-QUALITY MONITORING NETWORK

Factors to be used in designing a water-quality monitoring network for the Kobuk River Basin and for KVNP and GANPP include the optimal number and placement of sites, types of constituents to sample, frequency of sampling, time of sampling, and cost. The latter factor directly affects the number of sampling sites that can be included in the network. It is unknown when and how much funding will be available for water-quality monitoring of the Kobuk River Basin in the two national parks and thus how many sites are possible; however, the primary goal of this study was to identify *potential* monitoring sites. The following guidelines were used: (1) sites and corresponding watershed area should be entirely within either KVNP or GANPP, (2) sites should represent the different physical characteristics found in the parks, (3) a spatial distribution should be obtained, and (4) specific sites requested by the National Park Service should be included in the monitoring network.

Classification Analysis

Cluster analysis was developed as a means of classifying objects into homogeneous groups on the basis of some measure or set of measures describing the objects.

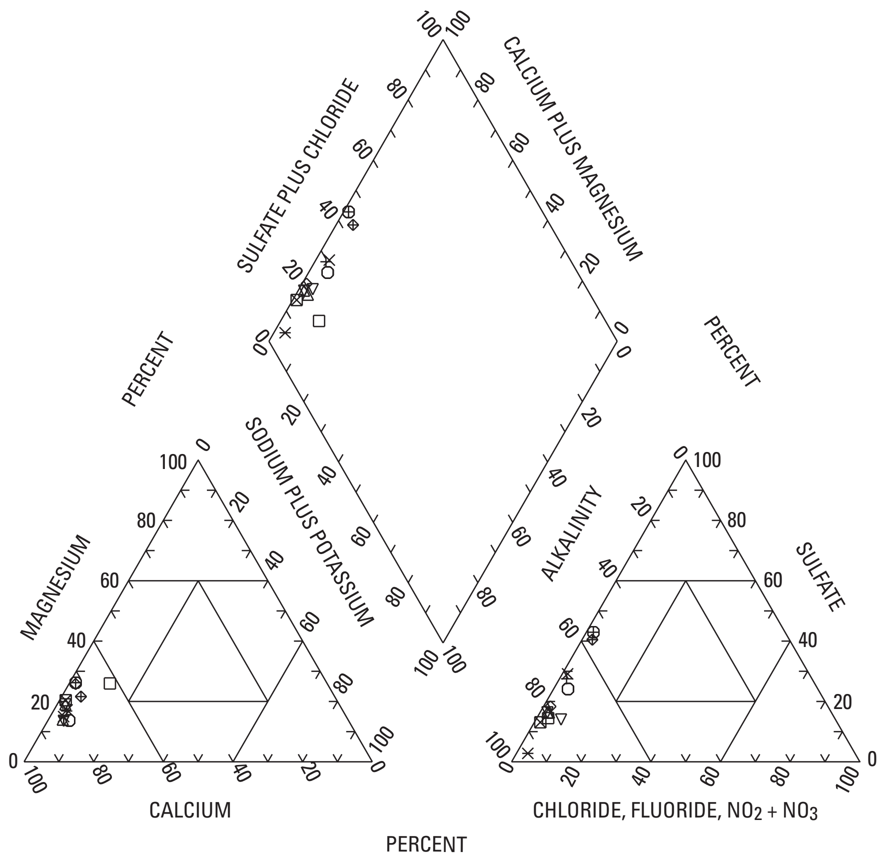


Figure 14. Water chemistry in samples collected basinwide on reconnaissance trip of 1979.

Classification analysis is a multivariate statistical technique that separates data into groups or clusters that are both homogeneous and distinct from other groups (Davis, 1986). For this study, the classification analysis was done using Geographic Information Systems (GIS) techniques. In using GIS techniques, different coverages are stacked on top of each other and then an isocluster function is used to identify the clusters. The isocluster function uses a *k*-means clustering approach, in which *k* points characterized by *m* variables are designated (either by the user or arbitrarily by the program) as initial centroids. The number of observations are calculated, and the closest or most similar observations are clustered with the nearest centroids. New centroids are then calculated and the process iterates exactly like a hierarchical procedure. This clustering method divides candidate basins into groups by maximizing the between-cluster variation and minimizing the within-cluster variation.

Groupings of clusters were evaluated to determine which one provided the most practical and common-sense environmental framework. To determine whether the clusters were good in terms of their separability, a dendrogram was constructed. Dendrograms order the clusters relative to each other using the multidimensional distance separating the classes in attribute space. A good cluster should have little overlap between the clusters in multivariate space. If the dendrogram indicates clusters with identical means, the clusters are often combined. After any classes are combined, the cells were classified as to their "most likely cluster." The Arc/INFO function "classprob" calculates for each cell the probability of the cell belonging to each cluster. The cell is then assigned to the class with the highest probability.

The following GIS coverages composed the initial data set:

- **Soil and Carbon Regions, figure 8** (National Resources Conservation Service, 2000): The carbon map indicates areas where carbon is stored. Due to climate warming, the permafrost will melt and the active layer will grow. Additional dissolved organic carbon will likely enter streams and rivers.
- **Permafrost Regions, figure 7** (Ferrians, 1965): Permafrost acts as a barrier to infiltration. However, if the permafrost melts, infiltration will increase, resulting in a higher ground-water component. Changes in runoff characteristics would affect water quality.

- **Geology, figure 6** ××(Silbererling and others, 1994): Water-quality characteristics of surface water are strongly affected by the type and age of rock.
- **Vegetation (Land Cover) figure 5** (Alaska Geospatial Data Clearinghouse, 1998): Land cover influences a number of hydrologic factors, such as snow accumulation, soil moisture depletion, surface runoff, infiltration, and erosion. Different types of vegetation have different rates of interception. The amount of interception is important because it determines the amount of particles and dissolved carbon that is washed off the leaves, thus affecting soil and water chemistry.
- **Physiographic Regions, figure 4** (Wahrhaftig, C., 1965): These regions represent the topographic features of the region. For example, topographic regions that are steep basins will most likely have more runoff than regions that are flat.
- **Precipitation Regions, figure 2** (Jones and Fahl, 1994): The amount of precipitation affects the amount of runoff from a particular basin. Loads of particular water-quality constituents are dependent on the amount of runoff.

The variables for each GIS coverage were "scaled" to give each coverage equal weight (table 11). For example, precipitation regions were assigned a value of 1, 2, or 3, representing 15–20, 20–30, and 30–40 inches (low to high) of precipitation respectively. Although somewhat crude, the variables can be considered continuous. The data are not normal and various transformations of the data could not correct this problem. However, the cluster analysis was still done to help serve as a visualization tool in combining all the information from the different GIS coverages.

A principal component analysis (PCA) was run on the GIS data before the cluster analysis. The purpose of the PCA was to transform the data into a new set of variables. These new variables are not correlated with each other and explain a percentage of the variance of the data. The first principal component explains most of the variance of the data. Each succeeding principal component explains more of the remaining variance. Based on the PCA, the precipitation and permafrost coverages did not account for a significant amount of the variance, probably because these two coverages (fig. 2 and fig. 7) overlap with (or are similar to) the physiographic-regions coverage (fig. 4). Thus, the PCA helped eliminate the redundancy of data, and it was not necessary to use the precipitation and permafrost coverages in the cluster analysis.

Table 11. Values assigned to different units of geographic information system coverages

[lb/ft^2, pounds per square foot; >, greater than]

Value	Represents	Remarks
	CARBON (figure 8)	
1	No carbon present	Lowest carbon
2	0 to 2 lb/ft^2	
3	2 to 6.5 lb/ft^2	
4	6.5 to 13 lb/ft^2	
5	> 13 lb/ft^2	Highest carbon
	GEOLOGY (figure 6)	
1	Cenozoic volcanic rocks	Youngest rocks
2	Mesozoic sedimentary rocks	
3	Mesozoic volcanic rocks	
4	Mesozoic intrusive rocks	
5	Paleozoic sedimentary rocks	
6	Precambrian rocks	Oldest rocks
	PERMAFROST (figure 7)	
1	Continuous—high rugged mountains	No infiltration
2	Continuous—lowland areas	
3	Discontinuous—mountains	
4	Discontinuous—lowlands	Highest infiltration
	PHYSIOGRAPHIC (figure 4)	
1	High rugged mountains	Steepest slope
2	Low mountains	
3	Rolling hills	
4	Plains	Flat areas
	PRECIPITATION (figure 2)	
1	15–20 inches	Lowest precipitation
2	20–30 inches	
3	30–40 inches	Highest precipitation
	VEGETATION (figure 5)	
1	Needleleaf	Highest interception
2	Tall shrub	
3	Dwarf shrub	
4	Moist herbaceous	Lowest interception

The initial cluster analysis indicated seven clusters (fig. 15). These clusters formed two major clusters that indicated a north-south division of the Kobuk River Basin (fig. 16). A comparison of the six GIS coverages makes the north-south division apparent. For example, the northern portion of the Kobuk River Basin consists of mountainous terrain, whereas the southern portion consists of plains and lowlands. The northern portion of the Kobuk Basin has higher precipitation and is dominated by Paleozoic sedimentary rocks, while the southern portion of the Kobuk Basin has lower precipitation and is dominated by Mesozoic sedimentary rocks. Thus, it is felt that the cluster analysis provided reasonable guidance when the information from all the GIS coverages was combined.

As another check on the cluster results, a limited comparison can be made among the water-quality data that have been collected on the tributaries to the Kobuk River (table 10). Values of silica are significantly higher at sites 19 and 34 on Pah River and Kavet Creek, located in cluster region 2, than at the sites that are located in cluster region 1. At sites 5, 9, 10, and 15 on Red Bog tributary, Beaver Pond tributary, Norutak Hills tributary, and Bear Island tributary, respectively, streams that drain areas in cluster region 2, values of magnesium are higher than in some streams located in cluster region 1.

These comparisons might be another indication that the stratification of the Kobuk River Basin is reasonable. Once a sufficient data amount has been collected, another technique that could be used to test the stratification is Multiple Discriminant Analysis (MDA). MDA is a procedure in which data are assigned a probability of being in a particular region. Low probabilities would indicate that the water-quality monitoring network should be reviewed and possibly revised.

Site Selection

Using the results of the cluster analysis and the selection criteria listed in the first paragraph of the "Water-Quality Monitoring Network" section as guides, potential water-quality sites were identified. The selection process consisted of identifying potential watersheds in the northern section of the Kobuk River Basin (cluster region 1) and the southern section of the Kobuk River Basin (cluster region 2). Once a potential watershed was identified, an ArcView extension, the Watershed Delineator, was used to compute the basin area. Use of the Watershed Delineator permitted a quick and accurate means of determining the size of the watershed upstream from the potential monitoring site. The corresponding basin characteristics were computed once the area was determined.

Since factors such as access to a potential site and hydraulic and mixing characteristics are unknown, many potential sites were selected (fig. 17, table 12).

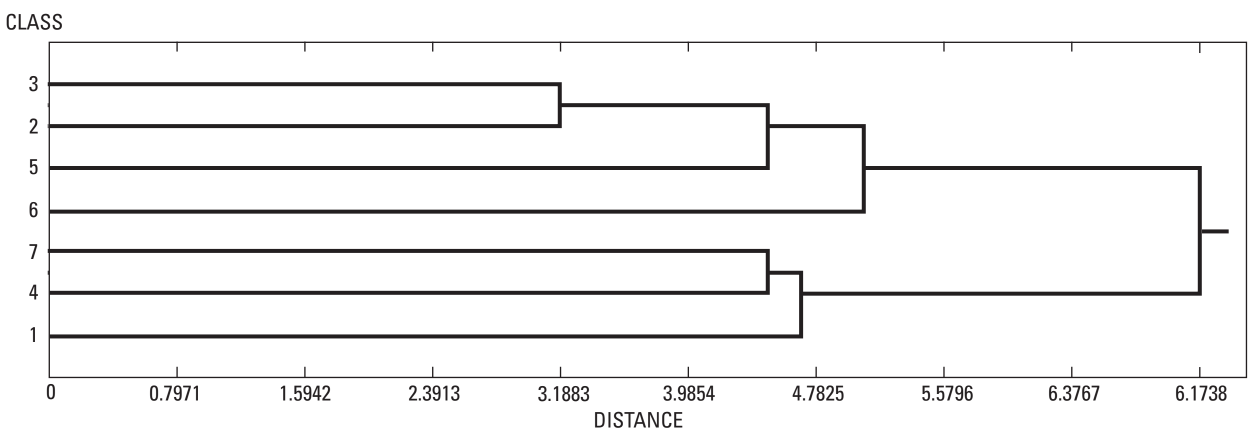


Figure 15. Dendrogram of the cluster regions of the Kobuk River Basin, Alaska.

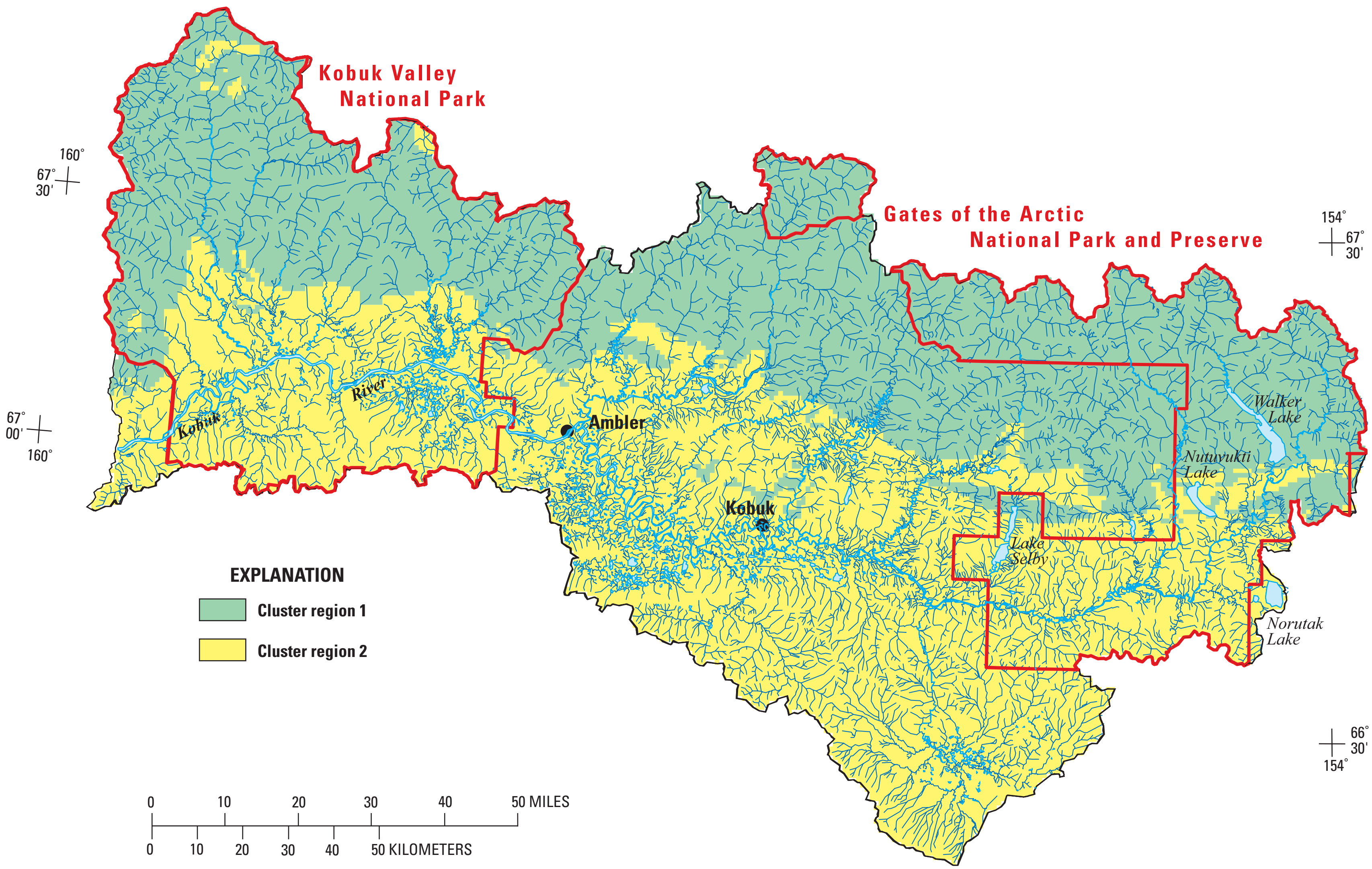


Figure 16. Cluster regions of the Kobuk River Basin, Alaska.

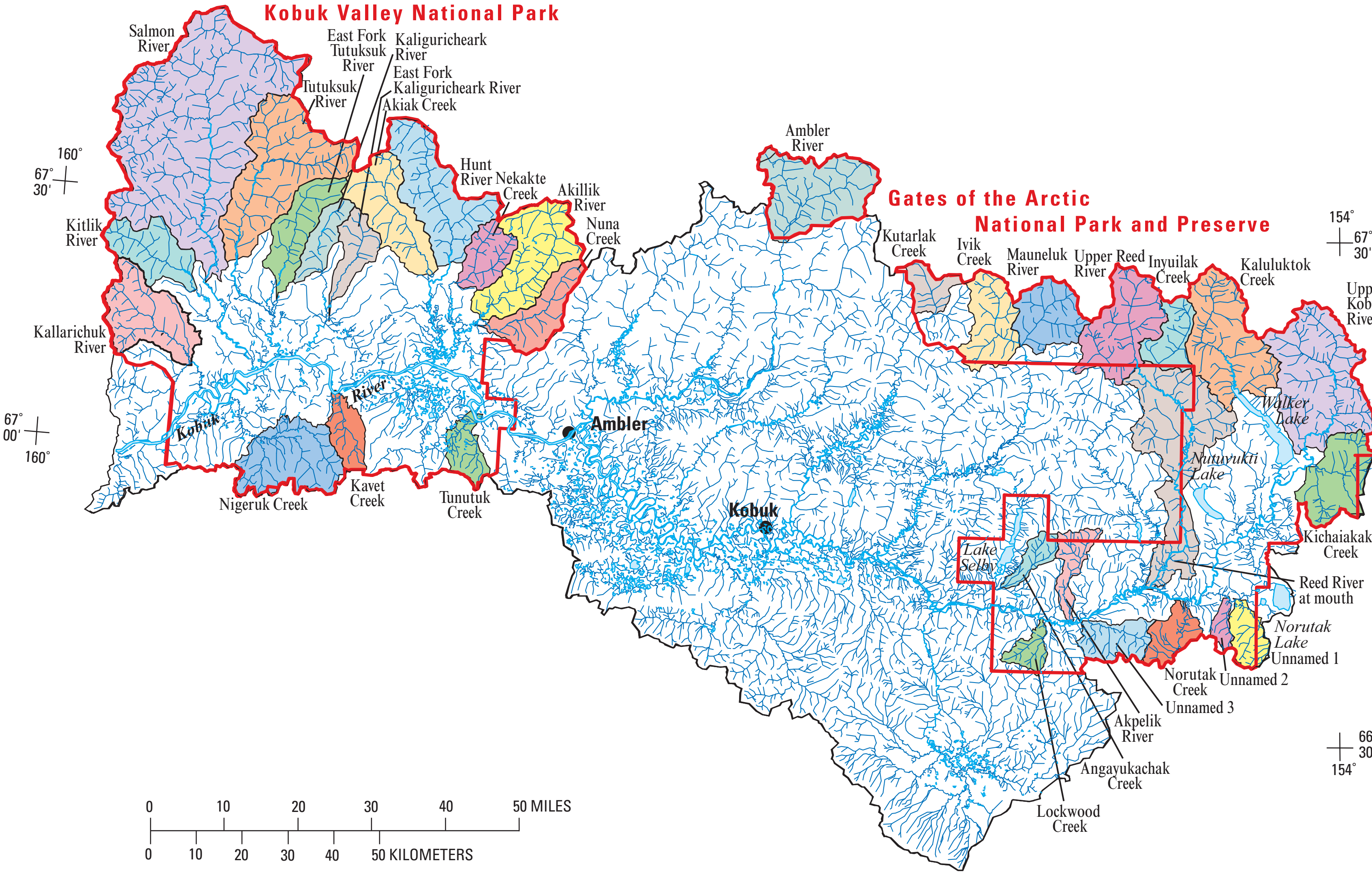


Figure 17. Potential watersheds for water-quality monitoring sites in the Kobuk River Basin, Alaska.

Table 12. Potential watersheds for monitoring sites in the Kobuk River Basin, Alaska

[mi^2, square miles; in, inches; lb, pounds; #, number]

Potential watershed	Area (mi^2)	Cluster region	Precipitation (in)	Slope (degrees)	Physiography[1]	Geology[2]	Land cover[3]	Permafrost[4]	Carbon (lb)
GATES OF THE ARCTIC NATIONAL PARK AND PRESERVE									
Ambler River	134	1	25	23	R	P	D	M	36.5
Kutarlak Creek	32.2	1	25	24	R	P	T	M	0
Ivik Creek	75.6	1	29	26	R	P	D	M	0
Mauneluk River	71.1	1	30	25	R	P	D	M	0
Upper Reed River	113	1	30	25	R	MI	D	M	0
Reed River at mouth	364	1,2	24	14	R	PR	T	M	3,780
Inyuilak Creek	45.4	1	30	23	R	PR	D	M	0
Kaluluktok Creek	146	1	30	24	R	PR	D	M	0
Upper Kobuk River	191	1	28	23	R	P	T	M	0
Kichaiakaka Creek	84.7	1	24	24	R	P	T	M	2,800
Akpelik Creek	34.8	2	17	16	R	MS	N	M	1,130
Norutak Creek	34.8	2	17	8	P	MS	N	L	1,490
Lockwood Creek	13.3	2	17	11	P	MS	N	L	559
Unnamed Creek #1	37.8	2	17	7	P	MV	N	L	1,640
Unnamed Creek #2	45.6	2	17	8	P	MS	N	L	2,000
Unnamed Creek #3	22.4	2	17	11	P	MS	N	L	920
Angayukachak Creek	24.2	2	17	15	P	MS	DR	M	660
KOBUK VALLEY NATIONAL PARK AND PRESERVE									
Nuna Creek	67.5	1	25	13	L	P	DR	M	650
Akillik River	126	1	25	16	L	P	DR	M	1,220
Nekakte Creek	48.2	1	25	16	L	PR	DR	M	466
Hunt River	141	1	24	17	L	P	DR	M	1,530
Akiak Creek	101	1	24	17	L	PR	DR	M	1,090
Kaliguricheark River	37.6	1	25	17	L	PR	DR	M	471
East Fork Kaliguricheark River	43.6	1	25	15	L	PR	DR	M	548
Tutuksuk River	196	1	24	18	L	PR	DR	M	2,240
East Fork Tutuksuk River	72.3	1	25	18	L	PR	DR	M	946
Salmon River	508	1,2	22	14	L	P	DR	M	6,370
Kitlik River	70.5	1	25	14	L	P	DR	M	1,930
Nigeruk Creek	111	2	17	14	Pl	MS	N	L	4,870
Kallarichuk River	102	2	19	24	L	P	DR	M	3,500
Kavet Creek	38.0	2	17	10	Pl	MS	N	L	497
Tunutuk Creek	35.8	2	17	4	P	MS	N	L	1,180

[1]**Physiography:R**, Moderately high rugged mountains; **P**, Plains and lowlands; **Pl**, Plateaus and highlands of rolling topography and gentle slopes; **L**, Low mountains, generally rolling.

[2]**Geology: P**, Paleozoic sedimentary rocks; **MI**, Mesozoic intrusive rocks; **PR**, Precambrian rocks; **MS**, Mesozoic sedimentary rocks; **MV**, Mesozoic volcanic rocks.

[3]**Land cover vegetation: D**, Dwarf shrub; **T**, Tall and low shrub; **N**, Needleleaf forest; **DR**, dry or moist herbaceous.

[4]**Permafrost:M**, Mountainous areas underlain by continuous permafrost; **L**, Lowland areas underlain by continuous permafrost.

The size of the basins ranged from 35.8 to 196 mi^2 in KVNP and from 13.3 to 364 mi^2 in GANPP. Most of the basins are located entirely in cluster region 1 or 2, with only a few overlapping both regions. Sites in cluster region 1 would generally be in areas considered rugged and steep, having minimal soils and carbon, and underlain by continuous permafrost. Sites in cluster region 2 would generally be in areas considered plains or lowlands, consisting of soils with varying amounts of carbon, covered by needleleaf forests, and underlain by moderately thick to thin permafrost.

SUMMARY AND CONCLUSIONS

This report summarizes available water-quality and water-quantity data for the Kobuk River Basin and presents a method to identify future water-quality monitoring sites located in the Kobuk River Basin and within Gates of the Arctic National Park and Preserve and Kobuk Valley National Park. Specific findings are:

1. The average discharge of the Kobuk River near Kiana ranged from 10,020 to 24,960 ft^3/s from 1977 to 1999. Most of the flow in the Kobuk River occurs between late May and October.

2. Based on historical water-quality data, the water of the Kobuk River and its tributaries is considered a calcium to calcium-magnesium-bicarbonate type water.

3. A statistical technique, cluster analysis, was used to stratify the Kobuk River Basin into two distinct regions based on physical characteristics of the basin such as the amount of carbon, vegetation (land cover), and geology. Potential water-quality monitoring sites were then chosen from these two regions.

4. The geographic information system (GIS) coverages used for this study are at a large scale and lack some detail. In addition, some of the coverages, such as permafrost and geology, were mapped over 30 years ago and may have changed. If more recent maps and smaller-scale maps become available, the cluster analysis should be redone to determine if there are other distinct regions in the Kobuk River Basin.

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Cover photograph:
View of the Kobuk River Basin near Kiana, Alaska. (Photograph by Richard Kemnitz, U.S. Geological Survey, July 10, 1988.)