DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

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ALASKA DEPARTMENT OF NATURAL RESOURCES,
DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

HYDROLOGIC INVESTIGATIONS
ATLAS HA-686 (SHEET 2 OF 3)

SURFACE WATER

<u>Runoff</u> -- Runoff is that portion of precipitation that leaves an area as streamflow. Average annual runoff in the Copper River basin ranges from less than 5 in. in the lowland areas to more than 54 in. in the high mountain areas (fig. 8). Annual runoff for the entire basin above Chitina averages 24.8 in., or 37,680 ft^3/s. The runoff values and pattern shown on the map are based on measured and estimated streamflow and on other factors such as estimated evapotranspiration and area-altitude runoff calculations. The map is intended only to delineate the general areal distribution of runoff from the basin and should not be used to estimate the flow of any specific stream.

<u>Stream Types</u> -- The streams draining the Copper River basin can be classified into two general types: nonglacial streams, which drain lowland and low-altitude mountain areas, and glacial streams, which drain the high-altitude mountains.

Streams in the Copper River Lowland areas (fig. 2), have a relatively low gradient and derive their flow from snowmelt and rain. Streamflow is low from September through March, but with the increased solar radiation and warmer temperatures of April and May, flow reaches a peak. This peak results mainly from melting of snow and channel ice. A general recession in flow then takes place during June, July, and August. About 75 percent of the total annual flow occurs during the open-water period, May through September. Squirrel Creek (fig. 9) northwest of Tonsina is an example of a lowland stream.

Low-altitude mountain streams are nonglacial, as their drainage basins lie along the mountain flanks at altitudes too low for glaciers to exist. The Little Tonsina River (fig. 9) typifies such streams. Flow of the Little Tonsina increases due to snowmelt from late April through June and then declines during July, August, and September. About 80 percent of the total annual flow takes place between May and September, the open-water period.

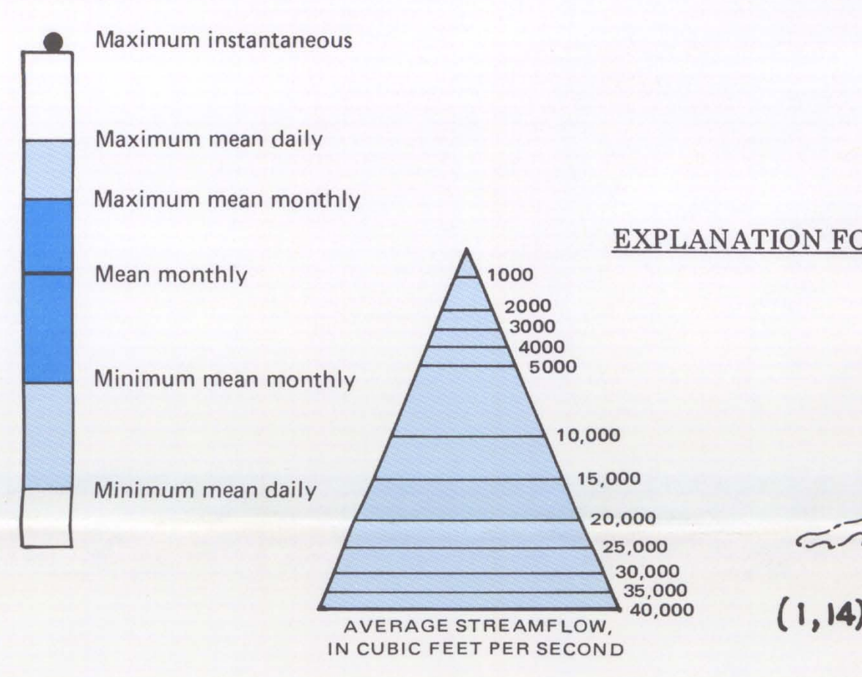
High-altitude mountain streams (glacial) exhibit the greatest seasonal variability of flow. About 88 percent of their total annual flow takes place during the approximately 5-month open-water period (May through September). High flows usually occur in July (fig. 9) when the highest seasonal temperatures cause maximum melting of glacier ice and snow.

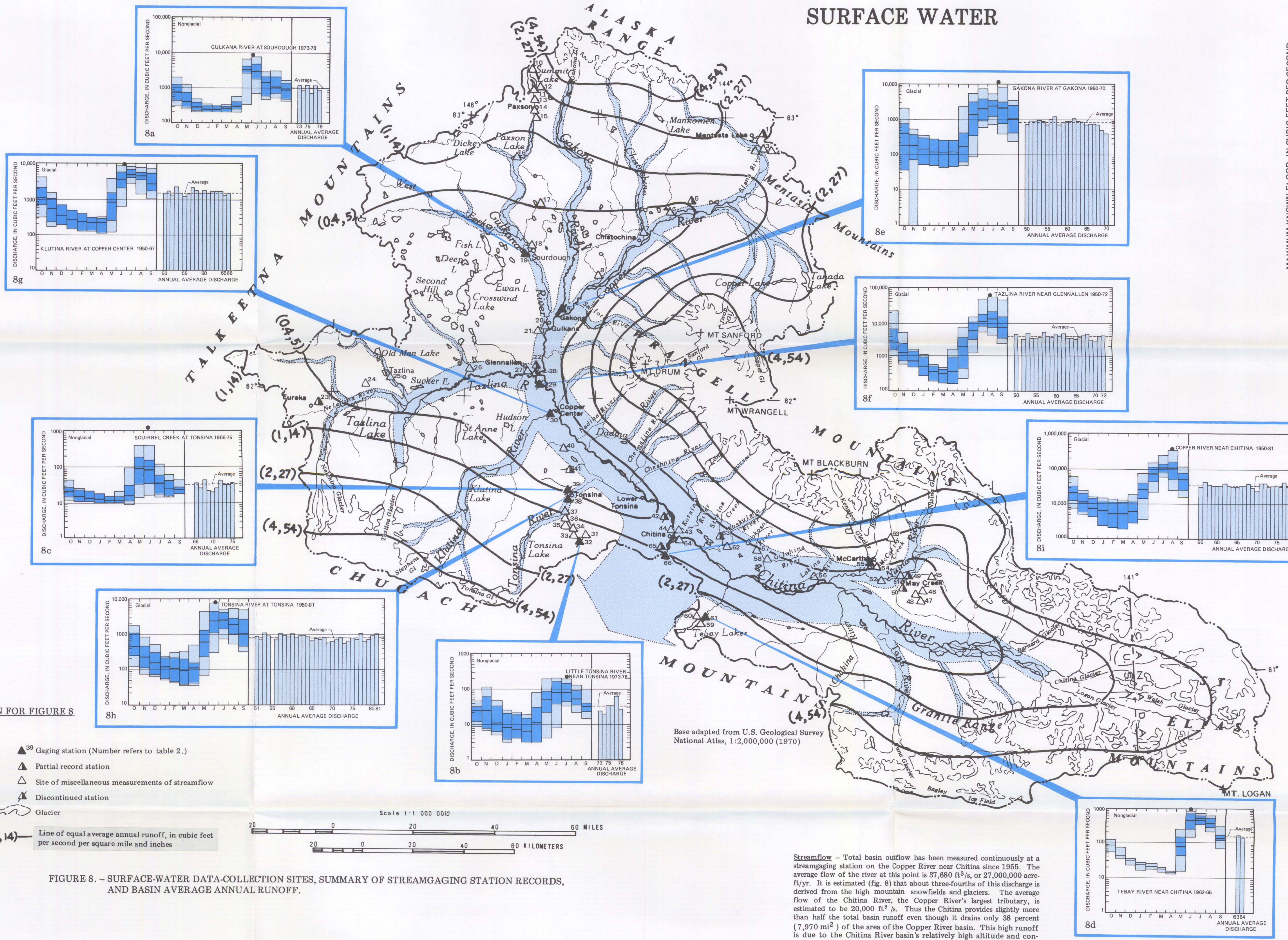
The production of meltwater from a glaciated basin appears to be closely related to annual precipitation. This relation can be seen by comparing the cumulative departure of average annual flow of glacier-fed Tonsina River (fig. 10) to the departure curve of precipitation for the same period (fig. 4).

In the use and management of water, seasonal streamflow variation is of more concern than long-term variation. Streams throughout the basin experience high flows during the spring and summer and low flows during fall and winter. The seasonal and annual variability of streamflow is illustrated in figures 8a-8i. In general, streamflow in the basin shows the greatest variability in mean annual discharge for nonglacial streams and the least in streams affected by glacial meltwater. Glaciers tend to reduce the variation in annual discharge because they release water from ice and firn storage in dry, warm years and store water as snow and firn during cool, wet years. However, during the relatively dry years of 1969-70 even glacial streams experienced the lowest annual average discharge in the period of record (figs. 8e, 8f, 8h, and 8i).

A typical hydrograph of nonglacial streams, such as the Gulkana River (fig. 11), shows sharp May rises during the spring snowmelt, a general recession during the summer months, and a slight increase in streamflow during the early fall rainy period. In contrast, high flow on glacial streams, such as the Tonsina River, coincides with the peak melting of snow and ice in June, July, and August (fig. 11). Rainfall during these same months may produce even higher discharge when the rivers are already high from glacial runoff.

EXPLANATION FOR FIGURES 8a-8i





Base adapted from U.S. Geological Survey National Atlas, 1:2,000,000 (1970)

FIGURE 8. -- SURFACE-WATER DATA-COLLECTION SITES, SUMMARY OF STREAMGAGING STATION RECORDS, AND BASIN AVERAGE ANNUAL RUNOFF.

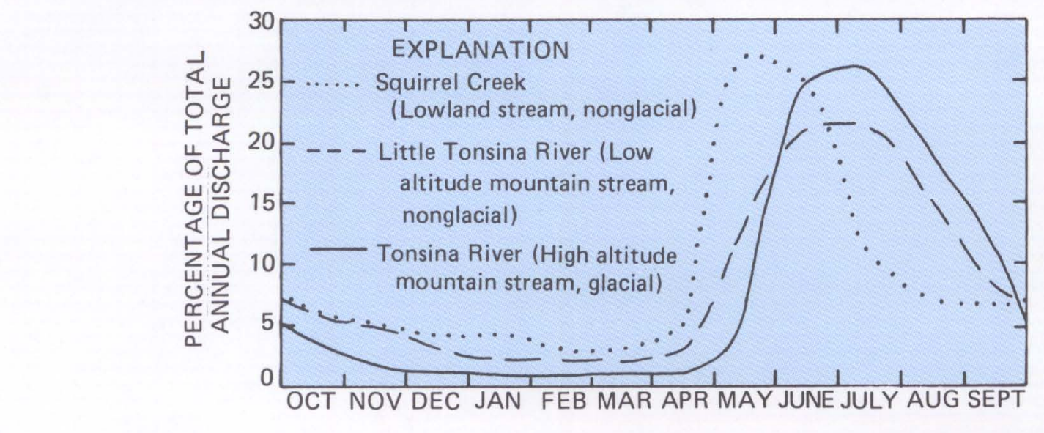


FIGURE 9. -- MEAN MONTHLY DISTRIBUTION OF DISCHARGE OF THREE STREAMS.

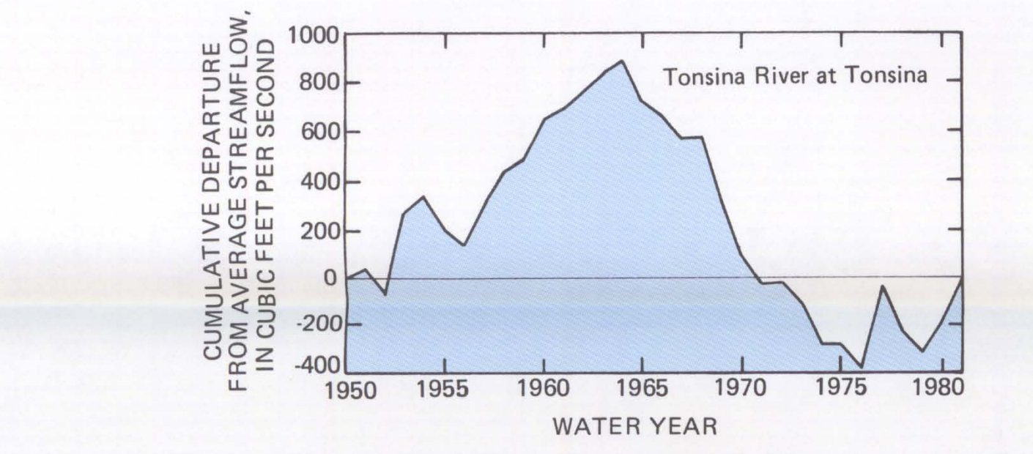


FIGURE 10. -- CUMULATIVE DEPARTURE FROM AVERAGE STREAMFLOW, TONSINA RIVER AT TONSINA.

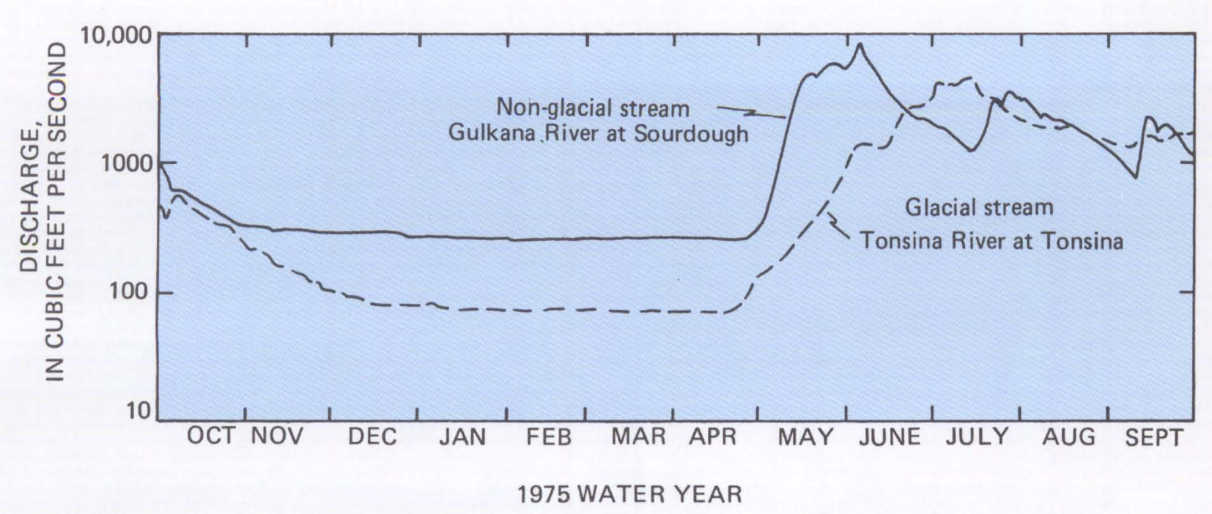


FIGURE 11. -- COMPARISON OF MEAN DAILY DISCHARGE OF A GLACIAL VS. NONGLACIAL STREAM.

TABLE 2. -- SUMMARY OF SURFACE-WATER GAGING STATIONS (G), PARTIAL-RECORD STATIONS (P), AND SITES OF MISCELLANEOUS MEASUREMENTS OF STREAMFLOW (M)

[e - estimated; b - minimum measured discharge; g - glacier-dammed lake breakout; I - intermittent; D - daily]

Map No. (See fig. 8)	Station No.	Stream	Drainage area (mi²)	Period of record water years	Average discharge (ft³/s)	Average discharge Runoff (in/yr)	Maximum observed discharge Date	Maximum Discharge in (ft³/s)	Maximum Discharge in [(ft³/s)/mi²]	Minimum observed discharge Date	Minimum Discharge in (ft³/s)	Minimum Discharge in [(ft³/s)/mi²]	Water quality Chemical	Temperature	Sediment	Biological
1	15198500	Station Creek near Mentasta	15.3	P1970-81	--	--	July 1977	309	20.2	--	--	--	I	I	--	--
2		Slana River	333	M1970-81	e500	e20	Aug. 11, 1971	3,790	--	--	--	--	--	--	--	--
3		Slana Slough	--	M1970-81	--	--	Aug. 11, 1971	1,650	--	--	--	--	--	--	--	--
4		Mabel Creek	--	M1970-81	--	--	--	--	--	--	--	--	--	--	--	--
5	15199000	Copper River Tributary near Slana	4.32	P1963-81	--	--	June 1980	205	47.5	--	--	--	I	I	--	--
6		Indian Creek near Chistochina	113	M1963, 1964	e80	e10	--	--	--	--	--	--	I	I	--	--
7		Chistochina River near Chistochina	610	M1948, 1951, 1952, 1971	e830	e18	Aug. 1971	e40,000	65.6	--	--	--	I	I	--	--
8		Tulsona Creek near Gakona	91.9	M1974, 1977-82	e60	e9	--	--	--	Mar. 30, 1982 July 28, 1982	38	0.41	I	I	--	--
9	15200000	Gakona River at Gakona	620	G1948, 1949-70, P1971-74	866	19	Aug. 10, 1971	10,500	16.9	Mar. 25, 1953	No flow	--	D	D	I	I
10	15200160	Gunn Creek near Paxson	49.6	M1973, 1974	e150	e40	--	--	--	--	--	--	I	I	--	I
11	15200165	Gulkana River near Paxson	75.2	M1973, 1974	e200	e37	--	--	--	--	--	--	I	I	--	I
12	15200170	Fish Creek near Paxson	9.69	M1972-74	e20	e29	--	--	--	--	--	--	I	I	--	I
13	15200190	Gulkana River near Paxson	--	M1973, 1974	--	--	--	--	--	--	--	--	I	I	--	I
14	15200200	Gulkana River near Paxson	--	M1970, 1974	--	--	--	--	--	--	--	--	I	I	--	I
15	15200210	Onemile Creek near Paxson	9.45	M1973, 1974	e14	e20	--	--	--	--	--	--	I	I	--	I
16	15200220	Gulkana River near Paxson	--	M1974	--	--	--	--	--	--	--	--	I	I	--	I
17	15200260	Haggard Creek near Sourdough	13.6	M1973, 1974	e7	e7	--	--	--	--	--	--	I	I	--	I
18	15200270	Sourdough Creek at Sourdough	68.0	M1970-77	e18	e4	May 1972	1,270	18.7	Mar. 29, 1982	0.011	0.00016	I	I	--	I
19	15200280	Gulkana River at Sourdough	1,770	G1973-78	1,063	8.17	June 2, 1977	9,170	5.18	Dec. 6, 1973- Apr. 12, 1974	200	0.11	I	D	I	I
20	15200400	Gulkana River at Gulkana	1,970	M1948, 1949, 1954, 1957, 1959, 1960-62, 1965, 1970, 1971	e1,200	e8	June 3, 1964	16,300	8.27	Mar. 15, 1971	b130	0.066	I	I	I	I
21	15200500	Bear Creek near Gulkana	3.67	M1973, 1974	e2	e7	--	--	--	Apr. 15, 1974	b0.29	0.079	I	I	--	I
22	15201000	Dry Creek near Glennallen	11.4	P1963-81	e3	e4	May 12, 1972	546	47.9	Many days	No flow	--	I	I	--	I
23	15201100	Little Nelchina River Tributary near Eureka	7.81	P1965-81	e2	e4	May 29, 1977	127	16.3	--	--	--	I	I	--	--
24		Cache Creek near Eureka	--	M1970	--	--	--	--	--	--	--	--	I	I	--	--
25		Mendeltna Creek near Glennallen	196	M1970, 1972-76, 1982	e100	e7	--	--	--	Mar. 29, 1982	76.8	0.39	I	I	--	--
26		Tolsona Creek near Glennallen	180	M1948, 1982	e60	e5	--	--	--	Mar. 30, 1982	No flow	--	I	I	--	--
27	15201895	Moose Creek at Glennallen	177	M1948, 1973, 1974, 1982	e70	e5	--	--	--	Apr. 15, 1974	No flow	--	I	I	--	I
28	15201900	Moose Creek Tributary at Glennallen	7.11	P1963-76	e3	e5	May 12, 1972	250	35.2	Many days	No flow	--	I	I	--	--
29	15202000	Tazlina River near Glennallen	2,670	G1949-50, 1951, 1952-72	4,085	20.8	Aug. 14, 1962	g60,700	--	--	--	--	I	I	I	I
30	15206000	Klutina River at Copper Center	880	G1913, 1949-67, P1970	1,686	26.0	June 29, 1953	9,040	10.3	Apr. 1955	110	0.12	D	D	I	I
31		Little Tonsina River	--	M1975	--	--	--	--	--	--	--	--	I	I	--	--
32	15207800	Little Tonsina River near Tonsina	22.7	M1970-71, G1972-78	33.8	20.2	July 20, 1977	214	9.43	Mar. 6-Apr. 26, 1974; Jan. 6-10, 1975	3.0	0.13	I	D	I	I
33		Little Tonsina River	--	M1975	--	--	--	--	--	--	--	--	I	I	--	--
34		Little Tonsina River	--	M1975	--	--	--	--	--	--	--	--	I	I	--	--
35		Little Tonsina River	--	M1975	--	--	--	--	--	--	--	--	I	I	--	--
36		Little Tonsina River	--	M1971, 1975	--	--	--	--	--	--	--	--	I	I	--	--
37		Little Tonsina River	--	M1972	--	--	--	--	--	--	--	--	I	I	--	--
38	15208000	Tonsina River at Tonsina	420	G1950-81	844	27.3	June 17, 1962	8,490	20.2	Mar. 11- Apr. 20, 1974	35	0.083	D	D	I	I
39	15208100	Squirrel Creek at Tonsina	70.5	P1964-65, 1976-77, G1965-75	30.9	5.95	June 1964	1,200	17.0	Apr. 1-10, 1967	9.0	0.13	I	I	I	I
40	15208180	Willow Creek near Copper Center	46.6	M1972, 1973	e20	e6	--	--	--	Apr. 5, 1973	No flow	--	I	I	--	I
41	15208200	Rock Creek near Tonsina	14.3	P1966-81	e6	e6	May 29, 1977	163	11.4	Many days	No flow	--	I	I	--	I
42	15208500	Fivemile Creek near Chitina	13.2	P1963-68	e8	e8	June 1965	412	31.2	--	--	--	--	--	--	--
43		Kotsina River	--	M1913	--	--	--	--	--	--	--	--	--	--	--	--
44		Copper River above Chitina River	12,630	M1960-65, 1982	18,000	e19	--	--	--	Mar. 7, 1960	2,010	0.16	--	--	--	--
45		Dan Creek	--	M1913	--	--	--	--	--	--	--	--	--	--	--	--
46		White Creek	--	M1913	--	--	--	--	--	--	--	--	--	--	--	--
47		Rex Creek	--	M1913	--	--	--	--	--	--	--	--	--	--	--	--
48		Chititu Creek	--	M1913	--	--	--	--	--	--	--	--	--	--	--	--
49	15209000	Chititu Creek near May Creek	30.9	P1973-81	e32	e14	Aug. 7, 1981	970	31.4	--	--	--	I	I	--	--
50	15209100	May Creek near May Creek	10.4	P1973-81	e2	e3	Aug. 7, 1981	168	16.2	--	--	--	I	I	--	--
51		May Creek	--	M1973	--	--	--	--	--	--	--	--	--	--	--	--
52		Nizina River	--	M1913	--	--	--	--	--	--	--	--	--	--	--	--
53		McCarthy Creek	--	M1913	--	--	--	-	--	--	--	--	--	--	--	--
54		McCarthy Creek	75.7	M1975	--	--	July 1, 1975	2,080	27.5	--	--	--	--	--	--	--
55	15210000	McCarthy Creek	78.7	G1913	--	--	June 24, 1913	876	11.1	--	--	--	I	I	--	--
56		Lakina River	--	M1913	--	--	--	--	--	--	--	--	I	I	--	--
57		Gilahina River	--	M1913	--	--	--	--	--	--	--	--	I	I	--	--
58		Chokosna River	--	M1913	--	--	--	--	--	--	--	--	--	--	--	--
59		Tebay River	--	M1950	--	--	--	--	--	--	--	--	--	--	--	--
60		Tebay River Tributary	--	M1950	--	--	--	--	--	--	--	--	--	--	--	--
61	15211500	Tebay River near Chitina	55.4	G1962-65	164	40.3	June 9, 1964	946	17.1	Apr. 27, 1963	b13.4	0.24	I	I	--	--
62		Kuskulana River	--	M1913	--	--	--	--	--	--	--	--	I	I	--	--
63	15211700	Strelna Creek near Chitina	23.8	M1913, P1971-81	e30	e17	June 30, 1977	345	14.5	--	--	--	I	I	--	--
64		Chitina River at mouth	7,970	M1960-65, 1982	e20,000	e34	--	--	--	Mar. 17, 1963	1,200	0.15	I	I	--	--
65	15211900	O'Brien Creek near Chitina	44.8	P1970-81	e58	e18	Aug. 7, 1981	1,940	43.3	Apr. 23, 1976	4.0	0.089	I	I	--	--
66	15212000	Copper River near Chitina	20,600	G1950, 1953, 1955-81	37,680	24.8	Aug. 8, 1981	380,000	18.4	Mar. 1-31, 1956	2,000	0.10	D	D	D	I

<u>Streamflow</u> -- Total basin outflow has been measured continuously at a streamgaging station on the Copper River near Chitina since 1955. The average flow of the river at this point is 37,680 ft^3/s, or 27,000,000 acre-ft/yr. It is estimated (fig. 8) that about three-fourths of this discharge is derived from the high mountain snowfields and glaciers. The average flow of the Chitina River, the Copper River's largest tributary, is estimated to be 20,000 ft^3/s. Thus the Chitina provides slightly more than half the total basin runoff even though it drains only 38 percent (7,970 mi^2) of the area of the Copper River basin. This high runoff is due to the Chitina River basin's relatively high altitude and consequent high precipitation.

Streamflow data have been collected at 10 continuous-recording gaging stations, 10 partial-record stations and 46 miscellaneous measurement sites in the Copper River basin (fig. 8). Information regarding these stations and sites -- such as period of record, drainage area, and streamflow characteristics -- is given on table 2.

The mean annual discharge of ungaged streams in the basin can be estimated using a regression analysis equation developed by Scully and Freethey (1980). The equation is based on data from nearby gaged streams and values for basin characteristics such as drainage area and precipitation. Scully and Freethey concluded that estimates of mean annual discharge of glacial streams and large nonglacial streams (drainage area greater than 100 mi^2) are reliable. However, similarly derived estimates for small nonglacial streams are not reliable.

<u>Flow Duration</u> -- Flow-duration curves are commonly used as a means of expressing the variability of streamflow. The curves show frequency distribution of average daily flows for the period of record and the percent of time any flow is equaled or exceeded. The variability of daily flows is shown for glacial (fig. 12) and nonglacial (fig. 13) streams. Various factors affect flow duration, including melting of snow and glacier ice, glacial outburst flooding, climate, geology, and ground-water inflow.

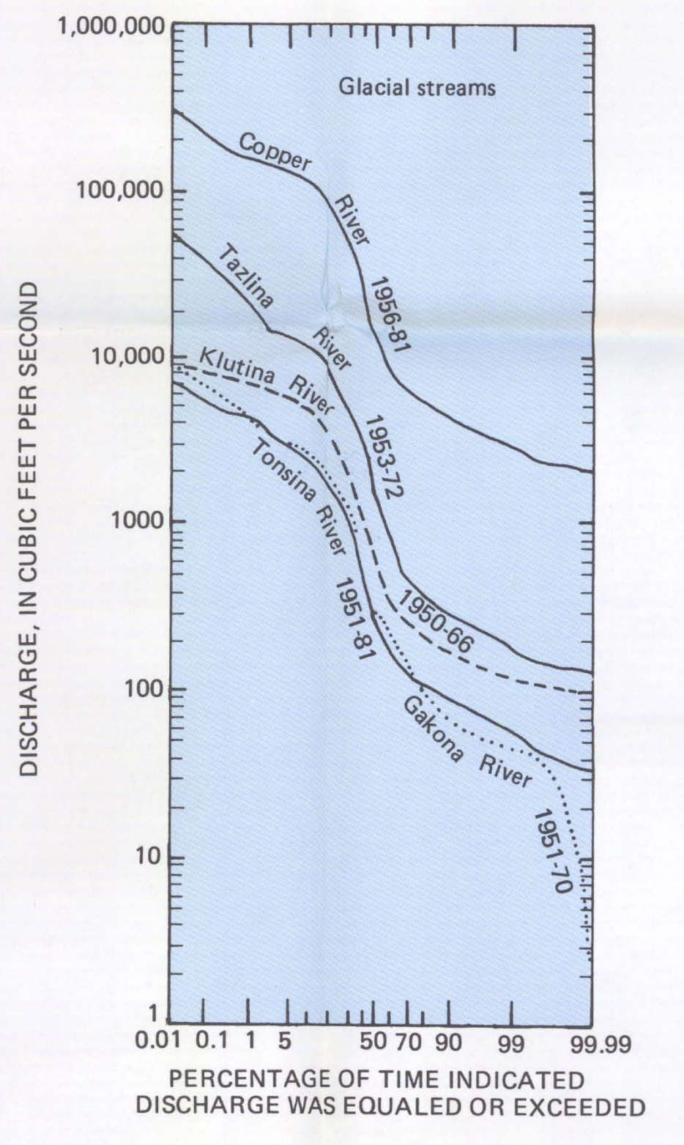


FIGURE 12. -- FLOW-DURATION CURVES FOR FIVE GLACIAL STREAMS.

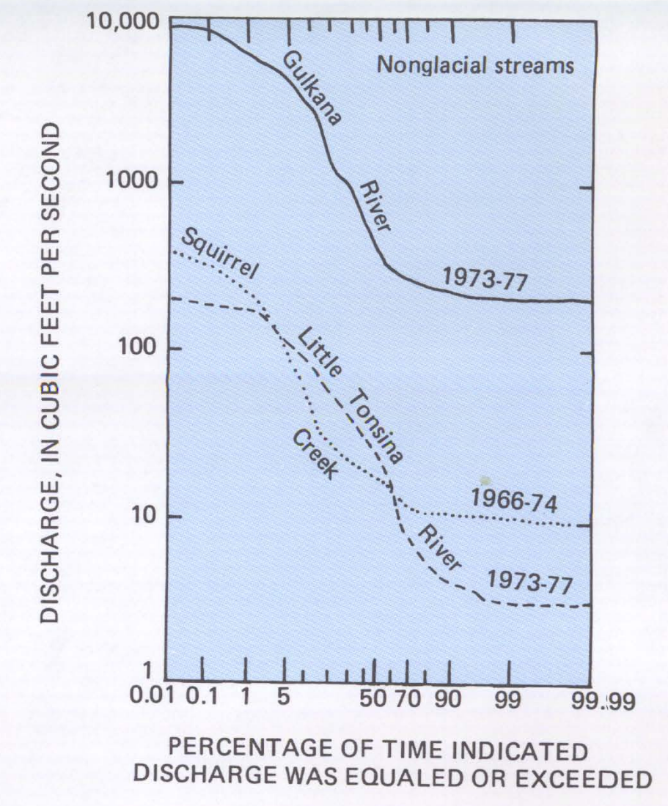


FIGURE 13. -- FLOW-DURATION CURVES FOR THREE NONGLACIAL STREAMS.

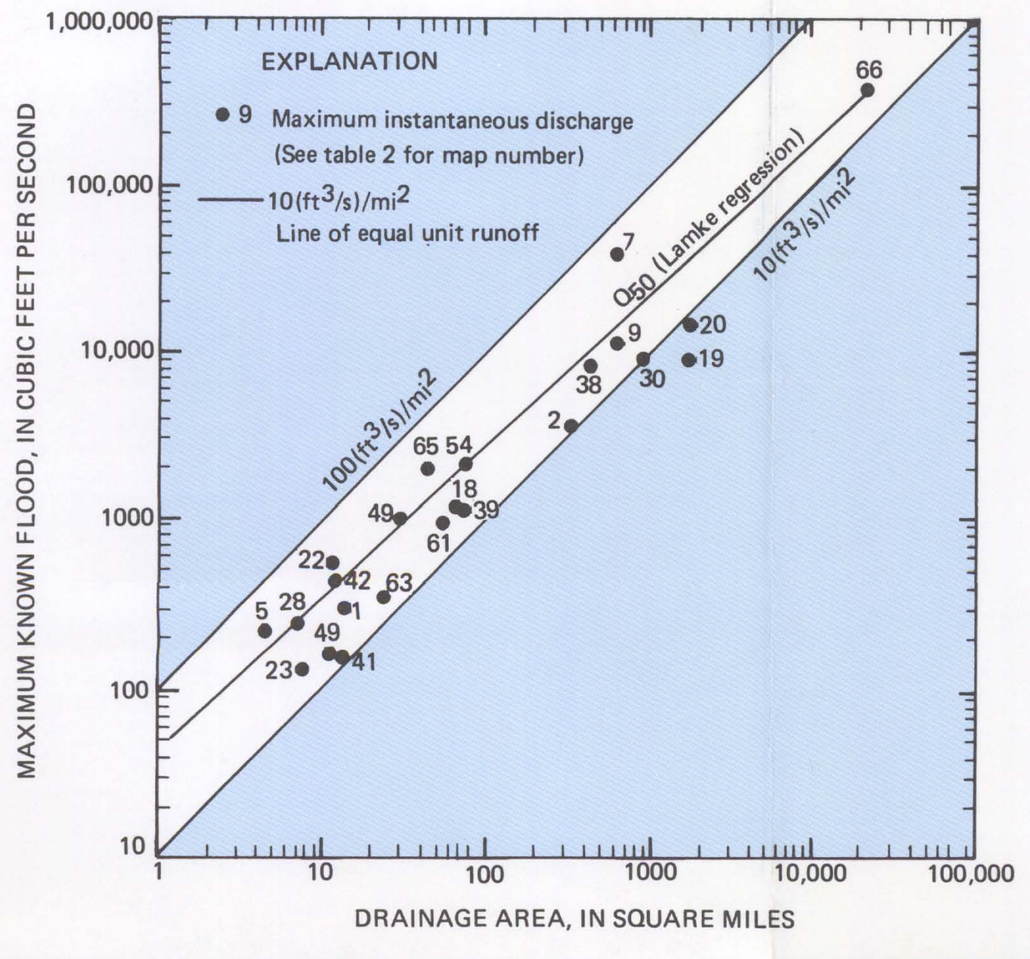


FIGURE 14. -- RELATION BETWEEN MAXIMUM DISCHARGE AND DRAINAGE AREA.

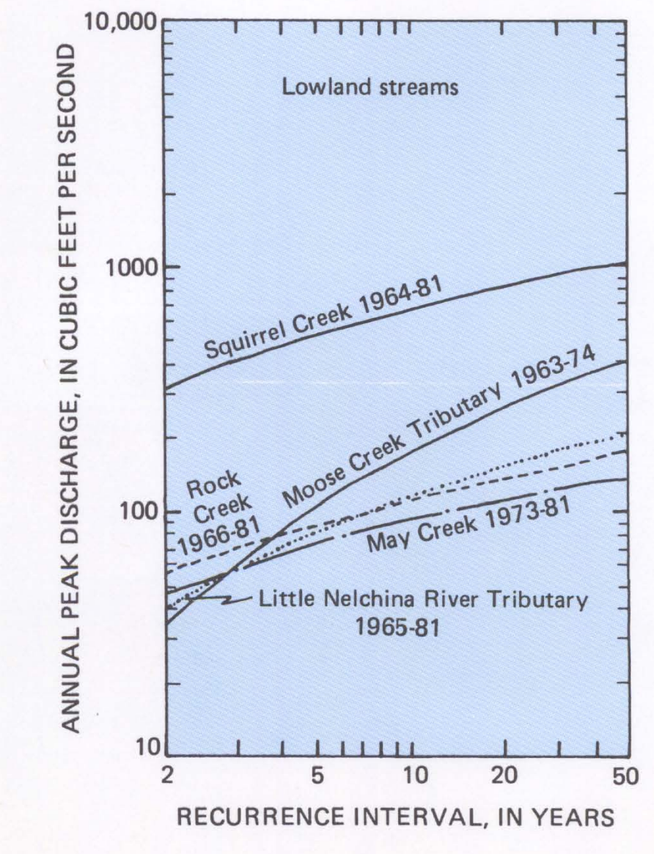


FIGURE 15. -- FLOOD MAGNITUDE AND FREQUENCY FOR SELECTED LOWLAND STREAMS.

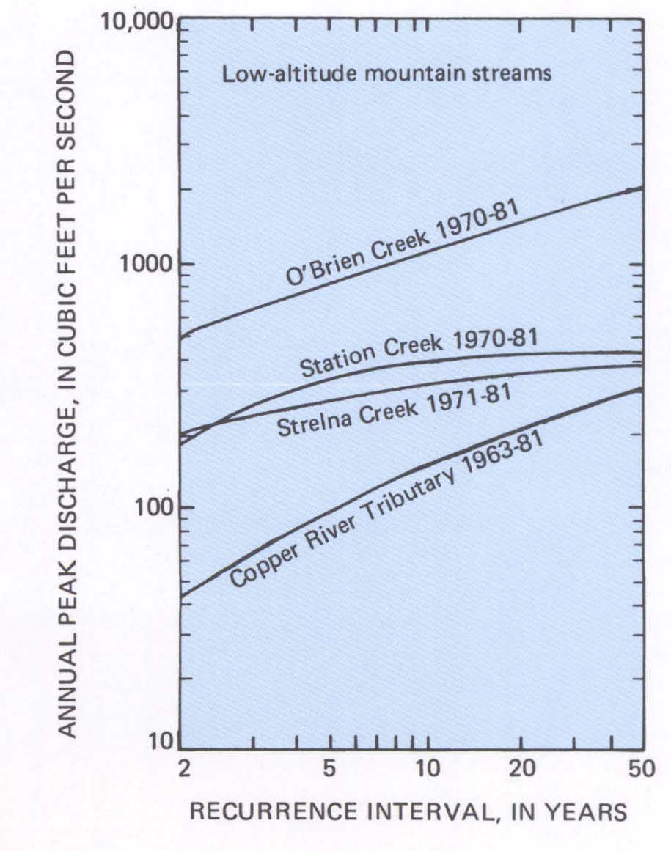


FIGURE 16. -- FLOOD MAGNITUDE AND FREQUENCY FOR SELECTED LOW-ALTITUDE MOUNTAIN STREAMS.

<u>Floods</u> -- Floods on glacial streams coincide with the peak rates of melting of ice and snow in June and July and the rainstorms of late summer and fall. Floods on nonglacial streams in the Copper River Lowland and Gulkana Upland result primarily from snowmelt in the spring and stream overflow in frozen and ice-jammed channels.

The relation of maximum discharge to drainage area for 23 selected streams in the Copper River basin is shown in figure 14. For comparison purposes, a line corresponding to the peak discharge for a 50-yr recurrence interval, computed by the flood-frequency regression equation of Lamke (1979), is also drawn on the graph. Maximum observed instantaneous runoff rates range from 5 $(ft^3/s)/mi^2$ for lowland drainages to 66 $(ft^3/s)/mi^2$ for mountain basins (table 2).

The peak discharges for recurrence intervals from 2 to 50 years for representative lowland, low-altitude mountains, and high-altitude mountains streams are shown in figures 15, 16, and 17. Recurrence interval is the average period of time (in years) within which a flood of specified magnitude will be equaled or exceeded once. For a given recurrence interval, the probability of a flood of specified magnitude occurring in any one year can be estimated. For example, if the recurrence interval of a flood of specified magnitude is 25 years (Q_{25}), the probability that such a flood will occur in any one year is 4 percent (1 chance in 25). For ungaged streams in the study area, the flood discharges for selected recurrence intervals can be estimated using regional flood-flow regression methods given by Lamke (1979).

Comparison of such estimates for a peak discharge that has an average recurrence interval of 50 years (Q_{50}) with the Q_{50} calculated from gaging station records is shown in figure 18. Streams included in the analyses were those for which 10 or more years of gaging station data were available. The analysis and resulting graphs (such as figure 18) indicate that the regression method provides reliable estimates for flood flows only for basins larger than 50 mi^2.

In addition to runoff from rainfall and "normal" melting of snow and ice, several other events or phenomena may lead to flooding in the Copper River basin. These include stream overflow icings (aufeis) and backwater from ice jams, and release of water temporarily dammed by snow or debris slides. Also, of particular concern, are outburst floods associated with glacier-dammed lakes and (or) rapid subglacial melting by volcanic heat (Post and Mayo, 1971). Mt. Wrangell, a glacier-clad volcano, has shown a major increase in heat flux at its summit during the last decade (Benson and Motyka, 1979). Therefore, it appears that the potential for outburst flooding from subglacial thermal activity does exist. This type of flooding has occurred in other areas of the world, including the State of Washington and Iceland. The areas subject to flooding from glacier-dammed lakes and the effects of subglacial thermal activity are shown in figure 19.

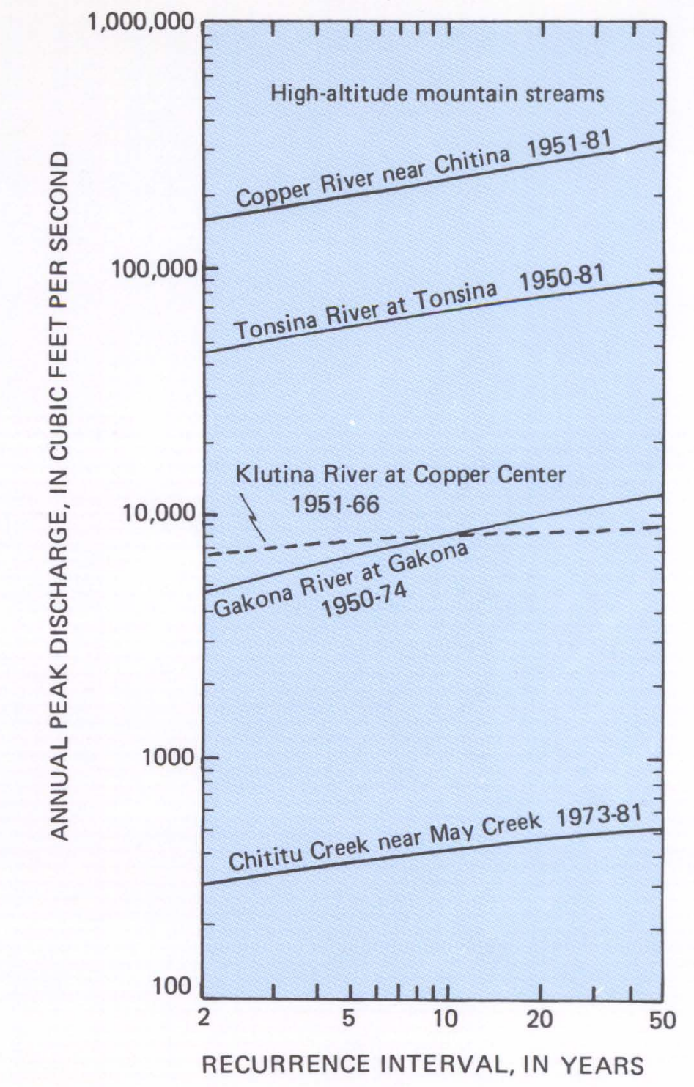


FIGURE 17. -- FLOOD MAGNITUDE AND FREQUENCY FOR SELECTED HIGH-ALTITUDE MOUNTAIN STREAMS.

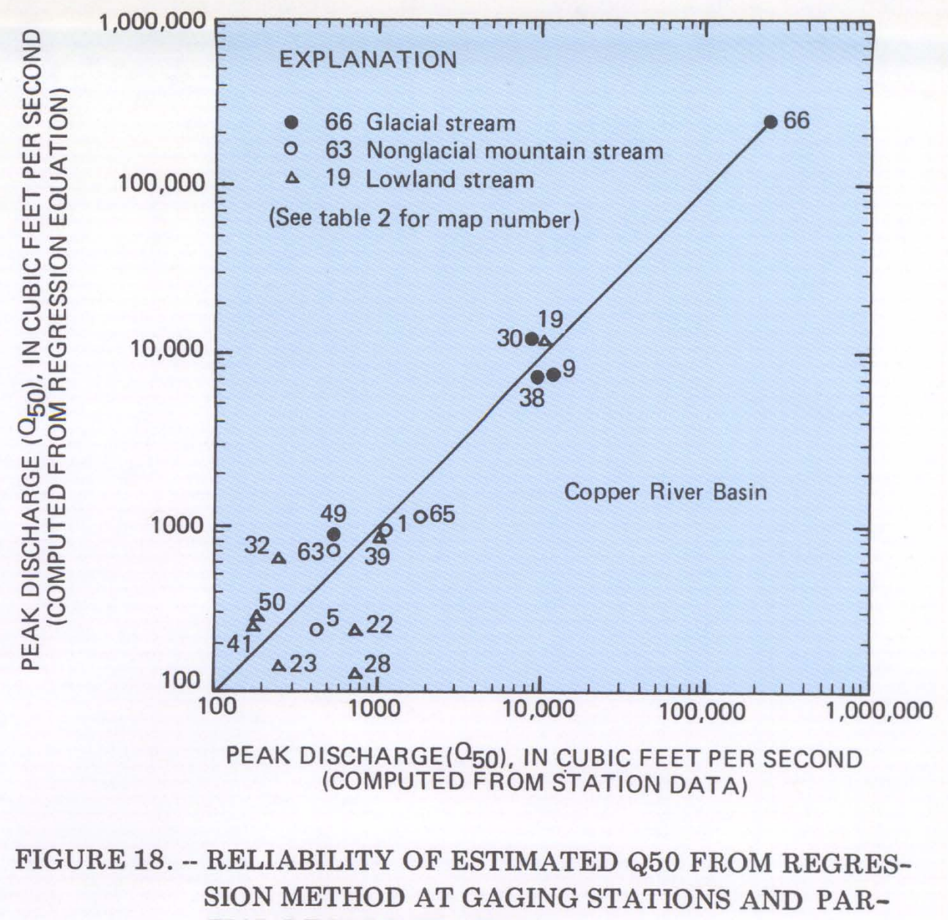


FIGURE 18. -- RELIABILITY OF ESTIMATED Q50 FROM REGRESSION METHOD AT GAGING STATIONS AND PARTIAL-RECORD STATIONS.

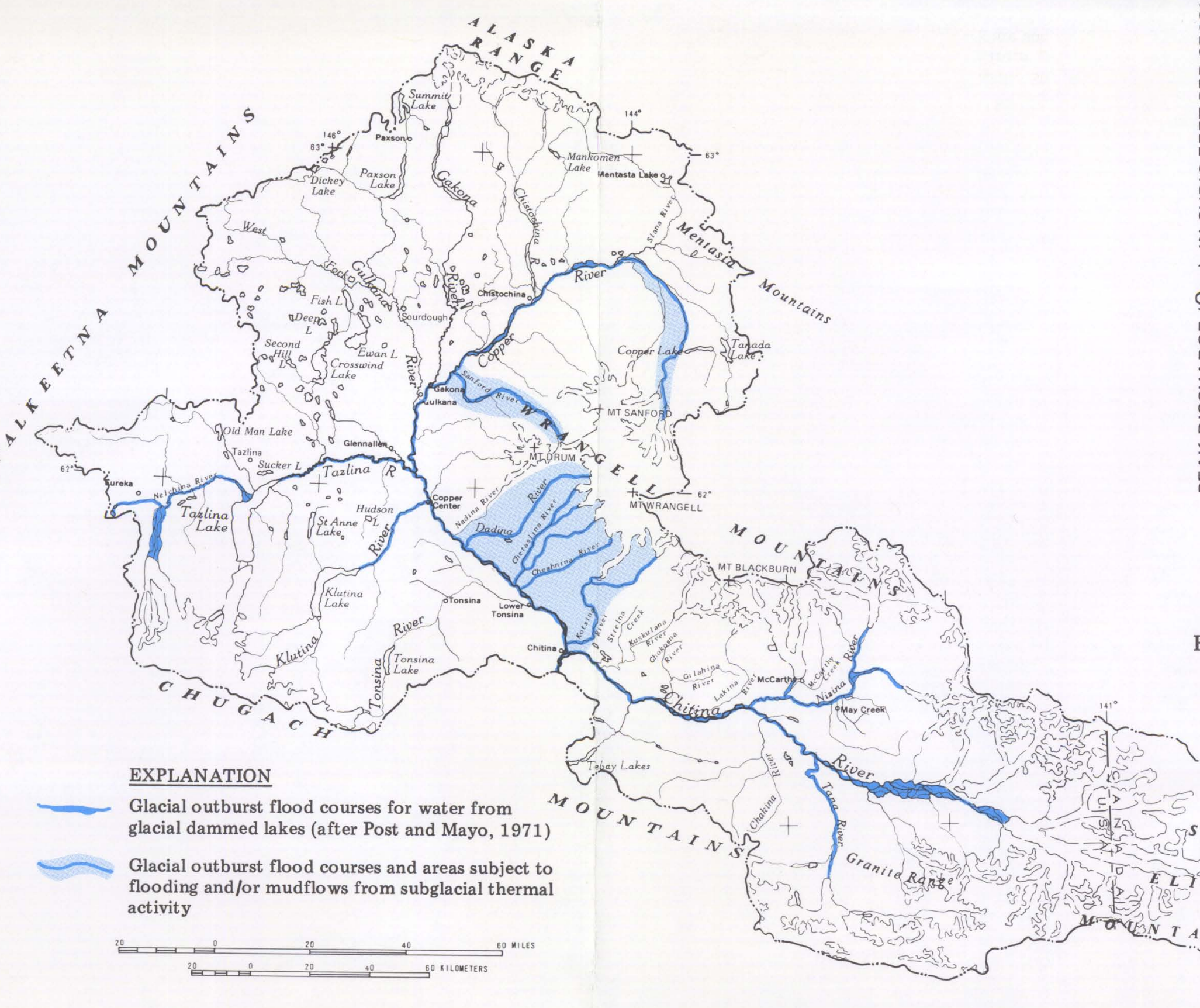


FIGURE 19. -- AREAS SUBJECT TO FLOODING FROM GLACIAL OUTBURSTS.

<u>Low Flow</u> -- Flow in lowland streams is at its minimum during periods of ice cover in late winter (March or April) or during periods of low precipitation in July, August, or September. However, minimum flow in both low-altitude and high-altitude mountain streams occurs during periods of late winter ice cover (March or April). Minimum measured flows of representative streams are listed in table 2. Methods given in Riggs (1972) were used to calculate low-flow frequency characteristics at selected gaging stations and to estimate low-flow characteristics at partial-record stations and miscellaneous measurement sites (table 3). The low-flow analyses were made on a water year basis (October 1 through September 30). Low-flow characteristics for gaging stations with less than 10 years of record and for partial-record stations were estimated by correlation with continuous-record gaging stations for which 10 or more years of record were available.

Accurate estimates of low-flow characteristics at ungaged sites usually cannot be made because low flows are highly dependent on stream-aquifer relationships and on the effects of ice. Acceptable estimates of low-flow characteristics at ungaged sites are possible if a few discharge measurements of base flow are made during summer and winter low-flow periods (Riggs, 1972).

TABLE 3. -- ESTIMATES OF MINIMUM DISCHARGE CHARACTERISTICS

[NF indicates no flow; data through 1981 water year]

Map No. (fig. 8)	Station No.	Station name	Drainage area (mi²)	Annual low flow, in cubic feet per second: 7 consecutive days, recurrence interval, in years: 2	10	20	30 consecutive days, recurrence interval, in years: 2	10	20
9	15200000	Gakona River	620	82	34	27	82	45	39
18	15200270	Sourdough Creek	68.0	0.2	0.2	0.2	0.2	0.2	0.2
19	15200280	Gulkana River	1,770	245	199	187	247	200	188
22	15201000	Dry Creek	11.4	NF	NF	NF	NF	NF	NF
23	15201100	Little Nelchina River Tributary	7.81	NF	NF	NF	NF	NF	NF
25		Mendeltna Creek	196	28	24	22	28	24	22
28	15201900	Moose Creek Tributary	7.11	NF	NF	NF	NF	NF	NF
29	15202000	Tazlina River	2,670	266	197	179	277	206	188
30	15206000	Klutina River	880	185	120	110	185	126	112
32	15207800	Little Tonsina River	22.7	4.4	2.8	2.6	4.7	2.9	2.7
38	15208000	Tonsina River	420	84	57	50	86	58	52
39	15208100	Squirrel Creek	70.5	11	9.3	9.0	11	9.7	9.5
41	15208200	Rock Creek	14.3	NF	NF	NF	NF	NF	NF
44		Copper River above Chitina River	12,630	2,800	1,800	1,600	2,800	1,800	1,600
50	15209100	May Creek	10.4	NF	NF	NF	NF	NF	NF
64		Chitina River at mouth	7,970	1,800	1,200	1,100	1,800	1,200	1,100
65	15211900	O'Brien Creek	44.8	3.0	1.2	1.0	3.0	1.4	1.2
66	15212000	Copper River at Chitina	20,600	4,600	3,000	2,700	4,600	3,000	2,700

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