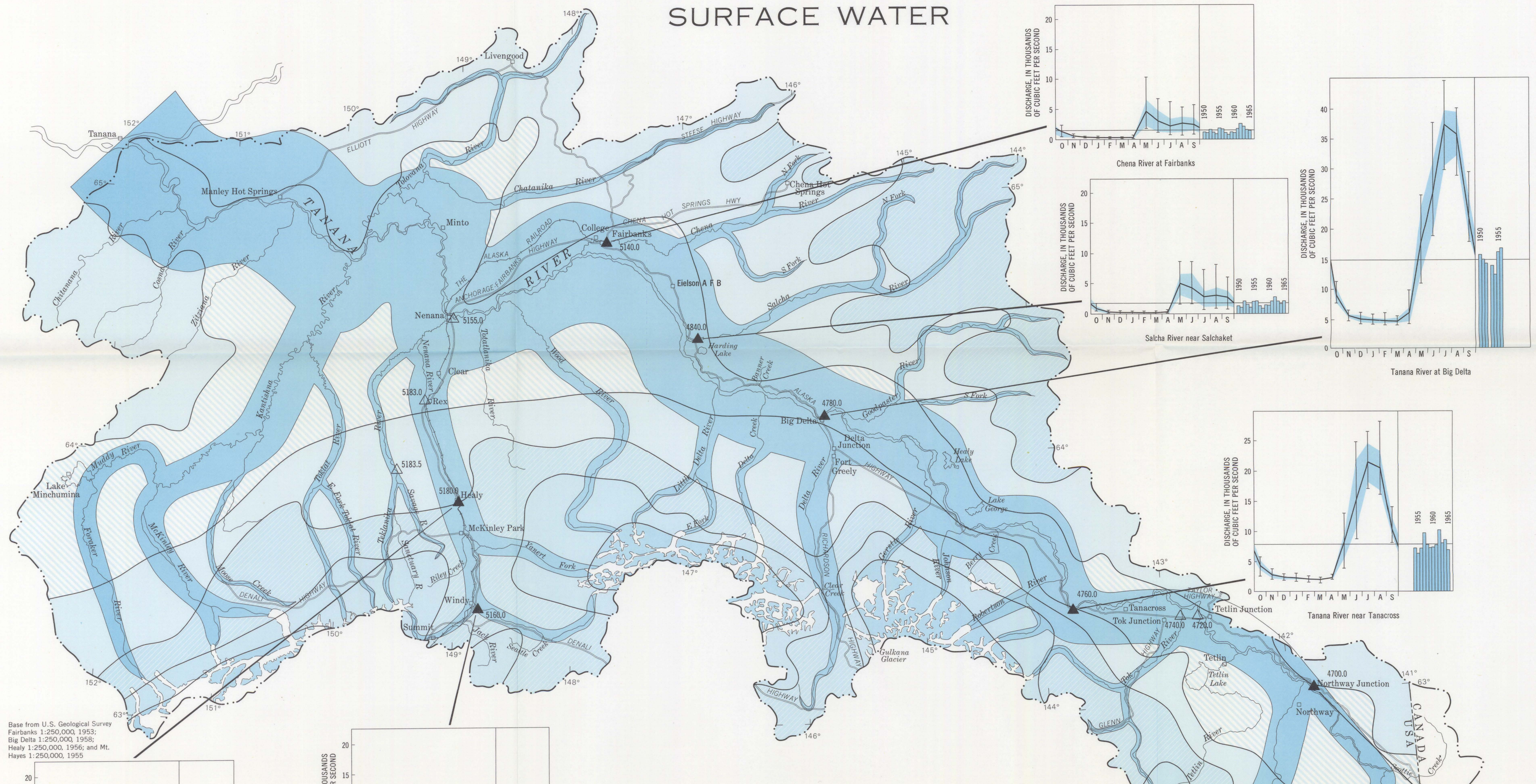
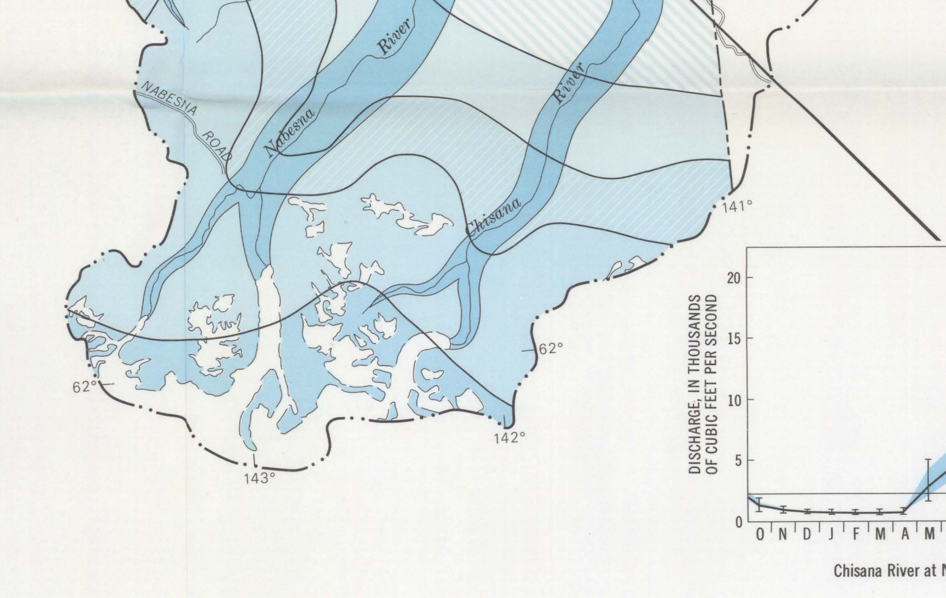
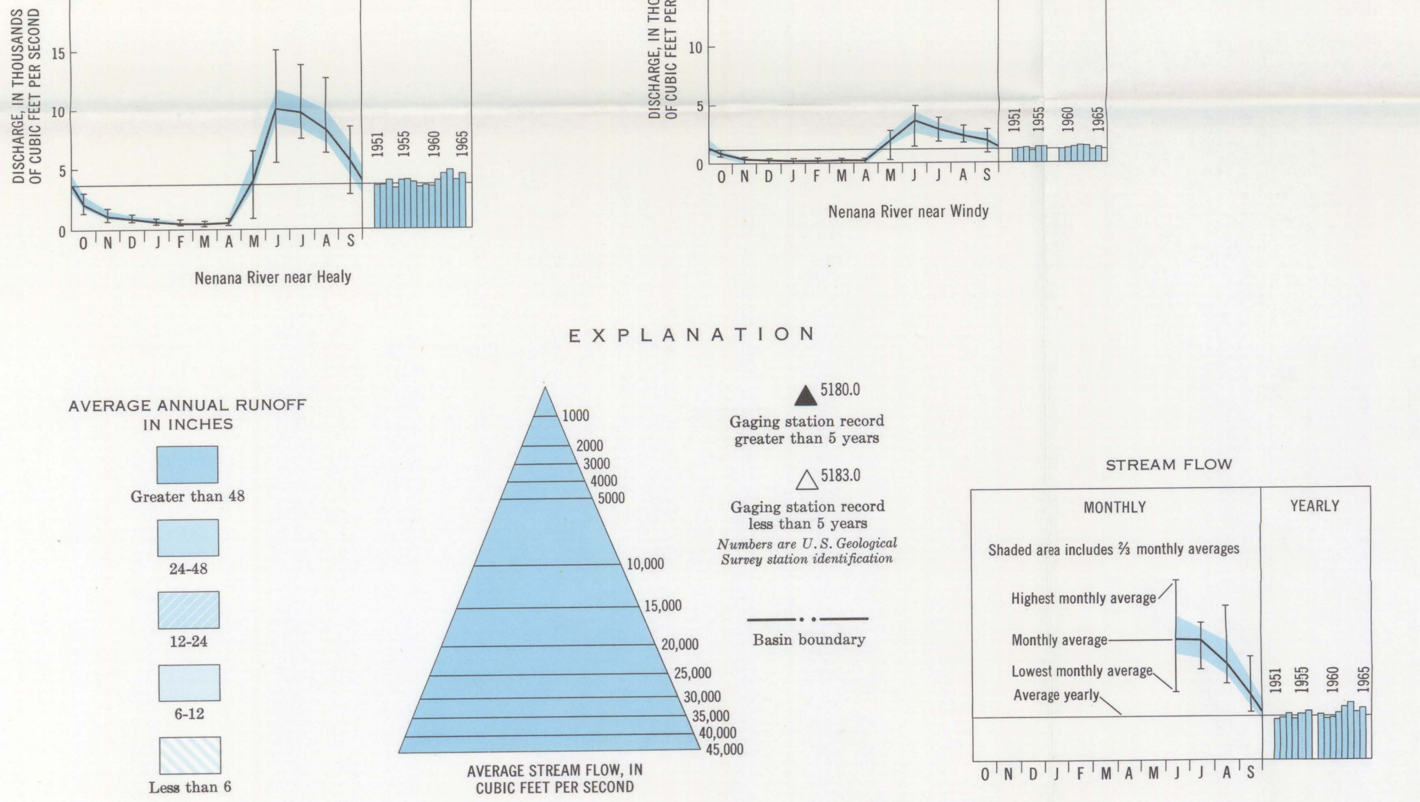
SURFACE WATER

A

B

COMPARISON PHOTOGRAPHS OF THE LOWER END OF GULKANA GLACIER, CENTRAL ALASKA RANGE, ALASKA

West Gulkana Glacier in background. View to west from altitude of 4,650 feet above sea level (after P. V. Sellmann, written commun., 1962)

A. Gulkana Glacier extending to the crest of the lateral moraines. Photographed by Fred Moffit, 1910 (U.S. Geological Survey photographs No. 423-424)

B. Ice-free lower valley previously occupied by Gulkana Glacier. Photographed by Troy L. Péwé, July 12, 1952 (U.S. Geological Survey photographs No. 666-668)

RUNOFF

Runoff is defined as that part of precipitation that leaves an area as streamflow. It includes melt water from glaciers so the time lag between precipitation and runoff may be hundreds or thousands of years. In the Tanana basin, measured average annual runoff ranges from 10 to 26 inches. Runoff from basins in the Alaska Range, not tributary to the Tanana River, is as much as 51 inches.

The runoff map portrays average annual runoff by altitude zones and the average streamflow. Average runoff is expressed on the map in terms of inches per year. When expressed in inches, runoff represents average depth at place of origin. The longest streamflow records span 17 years and form the base period used in this report. Where possible, shorter records were adjusted to the longer time period. On ungaged basins average streamflow has been estimated.

The runoff map was constructed by a trial-and-error process of apportioning measured streamflow and the estimated ground-water underflow throughout the basin, assuming that precipitation tends to increase and evapotranspiration tends to decrease with altitude. Other environmental factors such as geology, permafrost, vegetation, and lake or ice storage were introduced as variables related to elevation distribution. Thus, area-altitude distribution provides an index to quantify altitude zones of assumed homogeneous runoff characteristics. A set of values was assumed to be satisfactory when estimated and measured runoff values were comparable at gaging stations. Altitude zones of assumed constant local runoff were drawn with the aid of altitude contours. The runoff values are real only in the sense that they satisfy an inferred hydrologic model and provide the best fit for apportioning the measured streamflow throughout the basin. Thus, the map is useful in comparison of runoff with climatic or geologic characteristics of the area and in grossly delineating the geographic distribution of water in the basin. The map is not intended to provide a means for estimating the flow of any specific stream.

The greatest contribution of runoff to the Tanana River is from the Alaska Range from areas above 5,000 feet. This is a rather gross simplification of a complex process because some precipitation above 5,000 feet is transported in the solid state by wind or glaciers to lower altitudes before it melts and becomes runoff. Runoff from areas above 5,000 feet having perennial ice and snow is estimated to average 84 inches; runoff from subareas having minor amounts of perennial ice and snow may be as low as 24 inches.

In the 3,000 to 5,000-foot altitude (generally between tree line and snowline) average runoff approaches 100 percent of precipitation or 12 to 24 inches. From 3,000 feet to valley bottom runoff is approximately 60 percent of precipitation or 8 to 12 inches. The works by Ellsworth and Davenport (1915) and Dingman (1966a, 1966b) support runoff values in these ranges.

In the poorly drained low-relief areas of the valley bottoms, average annual runoff from direct precipitation is presumed to be 0 to 8 inches. Maximum runoff would be from snowmelt; little runoff results from rain. Lowest runoff is from the areas of lakes and swamps where evapotranspiration is high. It is reasonable to assume that water losses from lakes and swamps are higher than precipitation, and they are losing part of the inflow from higher altitudes.

SUMMARY OF SURFACE-WATER GAGING-STATION RECORD
Data from published and unpublished records of the U.S. Geological Survey

Map number	Stream	Drainage area in square miles	Period of record	Average flow: Cfs	Average flow: Runoff in inches	Maximum stage and discharge: Date	Maximum stage and discharge: Gage height in feet	Maximum discharge: Cfs	Maximum discharge: Cfs per square mile	Minimum monthly average discharge: Date	Minimum discharge: Cfs	Minimum discharge: Cfs per square mile
4700.0	Chisana River at Northway Junction	3,280	July 1949 to Sept. 1965	2,336	9.6	June 28, 1964	13.18	12,000	3.66	Jan. and Mar. 1956	590	0.180
4760.0	Tanana River near Tanacross	8,550	June 1953 to Sept. 1965	7,938	12.6	June 19, 1962	11.65	39,100	4.57	Mar. 1956	1,400	0.164
4780.0	Tanana River at Big Delta	13,500	Sept. 1948 to Sept. 1952 Oct. 1953 to Sept. 1957	14,950	15.0	July 29, 1949	23.57	62,800	4.65	Mar. 1957	4,054	0.300
4840.0	Salcha River near Salchaket	2,170	Oct. 1948 to Sept. 1965	1,766	11.0	June 23, 1956 May 2 or 3, 1960	16.13 19.6	36,500 ———	16.8 ——	Mar. 1953	60	0.028
5140.0	Chena River at Fairbanks	1,980	Oct. 1948 to Sept. 1965	1,503	10.3	May 21, 1948 May 11-14, 1937	14.17 15.9	24,200 ———	12.2 ——	Feb. 1953 and Mar. 1958	120	0.061
5160.0	Nenana River near Windy	710	June 1950 to Sept. 1956 Oct. 1958 to Sept. 1965	1,239	23.7	June 15, 1962 May or June 1964	9.84 10.20	11,900 ———	16.8 ——	Feb. 1953	110	0.155
5180.0	Nenana River near Healy	1,910	Oct. 1950 to Sept. 1965	3,682	26.2	June 15, 1962	12.51	39,000	20.4	Mar. 1959	339	0.177
4720.0	Tanana River near Tok Junction	6,800	May 1950 to Sept. 1953	——	——	————	——	———	——	———	——	———
4740.0	Tok River near Tok Junction	930	Oct. 1951 to Sept. 1954	——	——	————	——	———	——	———	——	———
5155.0	Tanana River at Nenana	27,500	May 1962 to Sept. 1965	——	——	June 16, 1962 May 1948	14.51 15.9	117,000 Exceeded 135,000	4.2 ——	——— ———	—— ——	——— ———
5183.0	Nenana River near Rex	2,450	Oct. 1964 to Sept. 1965	——	——	————	——	———	——	———	——	———
5183.5	Teklanika River near Lignite	489	Oct. 1964 to Sept. 1965	——	——	————	——	———	——	———	——	———

WATER BALANCE

A generalized water balance for the Tanana basin is given in the table below.

Altitude zone	Area: Square miles	Area: Percent of basin area	Precipitation Acre-feet x 10^6	Evapotranspiration loss[1] Acre-feet x 10^6	Runoff: Acre-feet x 10^6	Runoff: Percent of total basin runoff
<1,000	12,000	27	8.0	6.3	1.7	5
1-3,000	20,000	46	14.9	7.7	7.2	24
3-5,000	8,000	18	7.7	0.4	7.3	24
>5,000	4,000	9	[2]14.2	Minor	14.2	47
Total	44,000	100	44.8	14.4	[3]30.4	100

[1]Calculated from precipitation minus runoff
[2]Includes an estimated 1.4 x 10^6 acre-feet long-term ice storage loss
[3]Includes an estimated 3.7 x 10^6 acre-feet of ground-water underflow

Below 5000 feet precipitation is obtained from climatic station record; above 5,000 feet it is inferred to approximate the estimated runoff. The volume of runoff is obtained from the runoff map. Evapotranspiration is derived as the difference between precipitation and runoff. From this water balance, it is estimated that in the Tanana basin, 32 percent of the annual precipitation is lost by evapotranspiration. This estimate is quite low compared to pan evaporation data from the University Experiment Station where losses are twice as much as concurrent precipitation (see sheet 1). Potential evapotranspiration determined by the Thornthwaite and Mather (1957) method agrees quite closely with pan evaporation at the University Experiment Station (Dingman, 1966a) and with unpublished results obtained by the U.S. Forest Service (J. H. Patric, written commun., 1966).

The estimate of evapotranspiration in the table above compares more favorably with other water-balance inventories in the basin. From Dingman's study (1966a) of a small basin near Fairbanks, about 76 percent of summer precipitation was removed by evapotranspiration from that basin. Ellsworth and Davenport (1915, p. 64) inferred that less than 40 percent of the annual precipitation was lost, principally by evapotranspiration, in the Yukon Basin above Eagle. The Corps of Engineers (1951, p. 19) estimated that about 20 percent of the annual precipitation in the Yukon-Tanana Upland was lost, principally by evapotranspiration, within the upland.

Year-to-year gains or losses in the lake, ground water, and permafrost or glacial-ice parts of the hydrologic cycle are included in the values of the water-balance table; the proportions of their individual contributions are poorly defined. Data from Gulkana Glacier show a general storage loss since 1875 (Péwé, 1965, p. 5). The earliest known photographs of Gulkana Glacier were taken by Moffit of the U.S. Geological Survey in 1910; Moffit's photographing station was reoccupied by Péwé of the U.S. Geological Survey in 1952. Both photos are referenced to the runoff map. It is estimated that net loss of ice may contribute about 5 percent of the Tanana basin yield. This estimate, admittedly crude, is based on the long-term photographic record, on water-budget studies of Gulkana Glacier, and on patterns of runoff.

The water balance in the table above is dynamic in the sense that it considers the net water volume moving through the hydrologic cycle. It does not include the large volume of water more or less permanently stored in lakes, ground water, or ice within the Tanana basin.

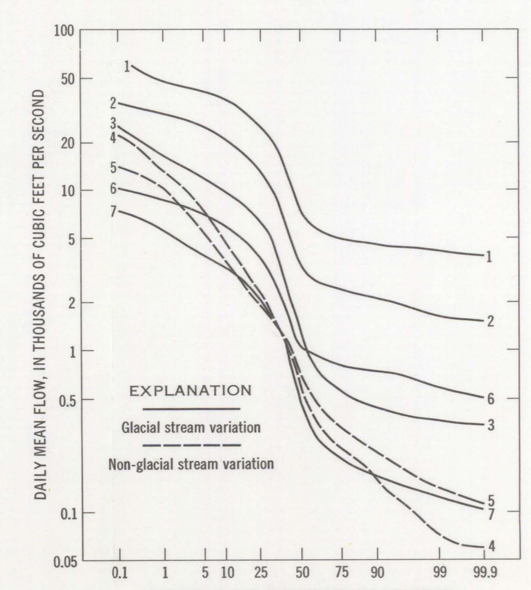
STREAMFLOW

The average streamflow of the Tanana River near its mouth is estimated as 37,000 cfs (cubic feet per second). Approximately 85 percent of this discharge originates in the Alaska Range; approximately 50 percent of the discharge is contributed by four tributaries from the south side, the Kantishna, Nenana, Nabesna, and Delta Rivers. Approximately 15 percent of the total basin discharge originates in the Yukon-Tanana Upland and is concentrated in four main tributaries, the Salcha, Tolovana, Chena, and Goodpaster Rivers.

Streamflow in the Tanana basin shows the greatest variability in nonglacial streams and the least variability in glacial streams. The Chena River (nonglacial) ranged from 47 to 173 percent of the average annual flow (16-year average); the Nenana River (glacial) at Healy ranged from 86 to 123 percent of the average annual flow (14-year average). For comparison, 15 years of concurrent precipitation records at the University Experiment Station show that annual precipitation ranged from 60 to 151 percent of the average for the period. The rather small variability of the glacial streams is caused by the regulatory effect of ice storage.

With respect to water-resource management problems, the seasonal streamflow variation is of more concern than the long-term variation. Streams throughout the basin experience high flows during the spring and summer and low flows during fall and winter. Streamflow on nonglacial streams, such as the Salcha River (see graph on runoff map), shows sharp May rises during the spring snowmelt, a general recession during the summer months, and a slight increase during the early fall rainy period. Maximum streamflow on glacial streams coincides with the peak melting of glaciers in June and July as illustrated by the graph for the Tanana River at Big Delta (runoff map). Large base flows occur in drainage basins with extensive ground-water storage, thus the minimum monthly flow of the Tanana River at Big Delta has been about 30 percent of the average flow (runoff map). In contrast the base flows are extremely small on those streams with limited ground-water storage, such as the Salcha River whose record indicates the minimum monthly flow of about 5 percent of the average flow (runoff map).

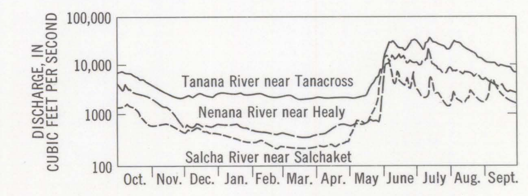
A common way of expressing the variability of streamflow is by use of flow-duration curves shown below. The flow-duration curve is a frequency distribution of the average daily flows for the period of record and shows the percent of time that any flow was equaled or exceeded. Flow-duration curves do not show the chronological sequence, nor are the extreme events adequately described. Geology and climate exert strong influences on the variability of daily streamflows in the basin. The range of flows in streams unaffected by glacier or groundwater storage shows a wide distribution represented by nearly straight and steeply sloping lines, such as 4 and 5. Glacial streams having well-sustained flow during the summer have flatly sloping lines of high flows with an abrupt transition to winter conditions as shown by lines 1, 2, 3, 6, and 7. Main-stem stations, with well-sustained ground-water discharge during the winter, have flatly sloping graphs at low flows as shown by lines 1, 2, and 6.



VARIABILITY OF DAILY FLOWS FOR STREAMS AT GAGING STATIONS DURING PERIOD OF RECORD

1. Tanana River at Big Delta, 2. Tanana River near Tanacross, 3. Nenana River near Healy, 4. Salcha River near Salchaket, 5. Chena River at Fairbanks, 6. Chisana River at Northway Junction, 7. Nenana River near Windy

To better illustrate the time sequence of daily flow, hydrographs of three stations for the water year 1964 are shown below. The Salcha



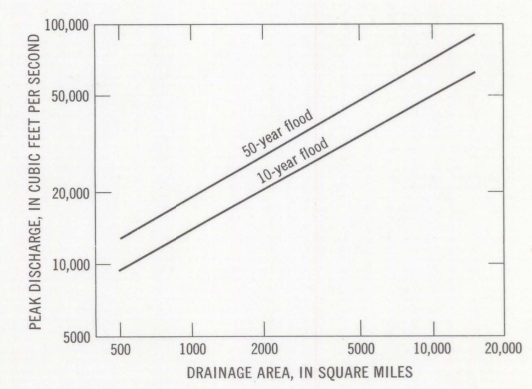
DAILY STREAMFLOW, 1963-64, FOR SELECTED STREAMS

Tanana River near Tanacross, mainstem; Nenana River near Healy, glacial; and Salcha River near Salchaket, nonglacial

River, a nonglacial stream, has a relatively low winter flow with a sharp spring rise associated with snowmelt. After the spring runoff, streamflow is flashy and variable depending on the nature of summer rains. In contrast, the Nenana River, a glacial stream, has a rapid rise in the spring with the high flows maintained through the summer months by glacial melt. The main-stem Tanana near Tanacross has a well-sustained winter flow and a high, somewhat variable, summer flow.

The magnitude and frequency of floods in the Tanana basin are not well known because streamflow records are short and the density of gaging stations is low. Also, local floods can occur in remote areas without economic loss and may pass unnoticed.

Maximum floods for gaging stations to water-year 1965 were presented in the summary of surface-water records.[1] Berwick, Childers, and Kuentzel (1964) have prepared curves (see graph below) for the probability of floods on streams in the Tanana basin with drainage areas larger than 500-square miles.



RELATIONSHIP BETWEEN THE PEAK DISCHARGE FOR THE 10 AND 50-YEAR FLOODS AND THE DRAINAGE AREA OF THE BASIN

[*Modified from Berwick, Childers, and Kuentzel, 1964*]

The graph above presents the relationship between the peak discharge for 10-and 50-year floods and the drainage area of the basin. The 10-and 50-year floods denote the recurrence interval of the corresponding discharges which can be expected to be equaled or exceeded at least once during that period of time. This means that a 10-or 50-year flood has a 10-percent or 2-percent chance, respectively, of occurring in any year.

Since 1963, the Alaska flood frequency analysis has included crest-stage partial-record station data for basins smaller than 50-square miles. Measured floods on small basins have had unit discharges much higher than those referred to in the summary of surface-water gaging-station record.

In the Tanana basin, floods commonly occur in the spring from snowmelt or in late summer from rain. The most severe flooding should be expected from rain concurrent with rapid snowmelt. Floods are aggravated during the early spring when the channel is constricted with ice.

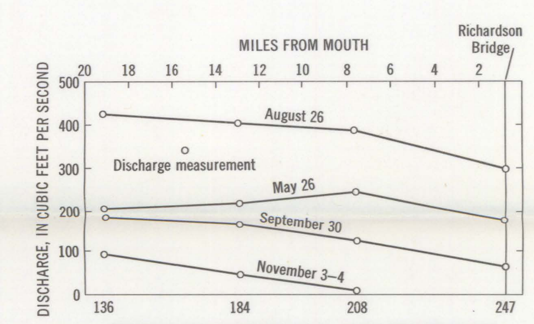
Available data do not adequately describe minimum flow characteristics of the Tanana basin. The problem is similar to flood-frequency analysis in that streamflow records are limited in time and space. A further complication is that winter streamflow records are not reliable because of the complexity of stream-ice formation and its control of the flow regimen.

Ellsworth and Davenport (1915) discussed the character of low flow during the summer in the Yukon-Tanana Upland. They found that the minimum weekly average discharge of basins smaller than 500-square miles ranged from 0.018 to 0.470 cfs per square mile and averaged between 0.1 and 0.2 cfs per square mile. Summer low flows generally occurred during the first part of August. It was their opinion that basins smaller than 400-square miles would not have sufficient discharge to maintain a free channel in winter. Freezing would be so severe that most streamflow would be converted to aufeis.[2] Exceptions would occur where the stream was adequately supplied with ground water or fed by thermal-spring discharge.

Streams can also cease to flow in the winter because of losses due to influent seepage. Jarvis Creek is typical of many streams that lose water by influent seepage. Streamflow is relatively well sustained in the headwater area in the Alaska Range, but channel losses are large in the lower reach on the alluvial fan. Near its mouth, Jarvis Creek is dry during the winter (see graph below).

[1]Does not include the flood of August 1967 (Childers and Meckel, 1967).

[2]*aufeis*, (Ger.) also called *naleds* (Russ.), *flood-plain icings* or "*glaciers*" are accumulations of ice formed by freezing of successive outflows of water from ground seepages, springs, and streams and rivers which freeze to the bottom. In the northern latitudes the resulting masses of ice can achieve large dimensions, both in thickness and areal extent, as they may be composed of a large percentage of the total winter flow.



SURFACE-WATER LOSSES ALONG JARVIS CREEK, 1965

HYDROLOGIC RECONNAISSANCE OF THE TANANA BASIN, CENTRAL ALASKA

By
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1970