UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WATER RESOURCES OF THE JUNEAU AREA, ALASKA

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Prepared in Cooperation with the City
and Borough of Juneau

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ERRATA SHEET

Please make the following corrections on the report "Water Resources of the City and Borough of Juneau, Alaska" by J. A. McConaghy and W. N. Bowman. Thank you.

J. A. McConaghy

1. Inside title page - change to agree with outside title.
2. List of illustrations, figure 6 - under heading "page" add "pocket".
3. Page 2, line 24 - "93.75 inches downtown", should read "93.75 inches at Mendenhall Glacier."
4. Page 20, figure 7 - Note that scale on left is out of registery on all four parts. Scales should be shifted upward about 0.25 inches.
5. Page 23, line 11 - "5 inches less than ..." should read "5 inches more than...."
6. Page 46, figure 20 - delete "or cubic feet per day" from title.
7. Page 55, right diagram - "10 C.F.S. (64 M.G.D.)", should read "10 C.F.S. (6.4 M.G.D.)".
8. Page 55, left diagram - "Storage required = 52,000 Ac. ft...", should read "Storage required = 32,000 Ac. ft..."

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Water Resources of the Juneau Area, Alaska

By J. A. McConaghy and W. N. Bowman

SUMMARY

CHAPTER 1 - THE LAND, THE PEOPLE, AND WATER-RESOURCES DEVELOPMENT

- The City-Borough of Juneau is in the Southeastern Panhandle region of Alaska about 900 miles northwest of Seattle, Wash.
- Glaciation has been the dominant process in shaping the landforms in the area.
- The 1968 special census indicated that the rural areas are experiencing a more rapid growth rate than are the cities of Juneau and Douglas.
- In 1970, the population of the City-Borough was 13,556.
- The estimated 1970 water demand is about 5 mgd (million gallons per day).

CHAPTER 2 - HOW AND WHERE WATER IS FOUND

- Juneau's water is classified into three categories--atmospheric, surface, and subsurface.
- Surface water includes not only water in the ocean, rivers, lakes, and ponds but also water frozen in glaciers and snow.
- The major streams have gradients ranging from 200 to 600 feet per mile, and the smaller streams commonly have gradients of 1,000 feet per mile.
- Fractured bedrock and unconsolidated permeable materials that overlie bedrock are the two types of ground-water reservoirs in the study area. Both types of aquifers contain ground water under water-table and artesian conditions.

- Bedrock yields small quantities of water from fractures, and presence of fractures decreases with depth. Sand and gravel deposits are the only geologic units capable of yielding large quantities of water.
- The volume of the major aquifers in the study area is about 1.5 cubic miles; 20 percent of which is water. An estimated 100 billion gallons of fresh water is stored in these aquifers.
- During the winter, temperature controls the runoff from both glacial and nonglacial streams.
- During the summer, runoff of nonglacial Montana Creek mirrors the precipitation rates.
- Almost 90 percent of the annual runoff from glacial Mendenhall River occurs during the summer; 50 percent of the annual runoff might be derived from melting of the glacier.
- During September 1968, 10 inches of precipitation in Mendenhall Valley caused the water table to rise more than 5 feet.

CHAPTER 3 - WHERE WATER COMES FROM

- Water in the Juneau area is derived generally from precipitation. The mean annual precipitation recorded at altitudes below 90 feet in the study area ranges from 54.62 at the airport to 93.75 inches downtown.
- Precipitation data at altitudes above 90 feet are sparse, but one study indicated that at 3,400 feet on Mount Juneau the annual precipitation might be 285 inches.
- Another study indicated that the annual precipitation at an an altitude of 4,000 feet on the Juneau ice cap is about 100 inches.
- The highest average monthly precipitation rates in the City-Borough occur in the fall when regional storms dominate, and the lowest occur in late spring when local storms are more prevalent.
- The greatest cumulative excess in precipitation during the

period of record in the study area occurred during the 1958-64 period, and the greatest cumulative deficiency occurred during the 1949-51 period.

CHAPTER 4 - WHERE THE WATER GOES

- Water is removed from the City-Borough by evapotranspiration, streamflow, and ground-water underflow.
- The only quantitative data available indicates that streamflow in the City-Borough is related directly to the rate and volume of precipitation and to basin size. Direct runoff increases from about 50 percent of the precipitation recorded at altitudes below 90 feet during a 1-inch storm to about 125 percent during a 5-inch storm. That relation implies higher rates and volumes of precipitation at altitudes above 90 feet--altitudes where no precipitation records are available.
- Total outflow of fresh water through streams during the month of greatest flow averages about 15 times the total during the month of least flow.
- The low flow of many streams is derived from drainage of ground water; but when streamflow is high, surface water recharges the aquifer.

CHAPTER 5 - CHEMICAL AND PHYSICAL PROPERTIES OF WATER

- Chemical analyses of 301 water samples from the City-Borough show that most of the samples are the calcium bicarbonate type, although several ground-water samples were classified as the sodium bicarbonate type.
- Only 5.5 percent of the ground-water samples and no surface-water samples exceeded the Public Health Service's recommended upper limit of 500 mg/l (milligrams per liter) dissolved solids (milligrams of dissolved material per liter of water).
- No samples in the City-Borough exceeded 10 mg/l nitrate concentration, which is well below the recommended upper limit of 45 mg/l.
- With the exception of iron content, most of the fresh water

in the study area is of excellent chemical quality, although some of it may be corrosive to metals because of the low dissolved-solids content.

- None of the streams sampled in the City-Borough has a high sediment concentration.
- Only a few ground-water supplies have been classified as unsafe because of possible pathogenic pollution.

CHAPTER 6 - METHODS OF DEVELOPING AND MANAGING THE WATER RESOURCES OF THE CITY-BOROUGH

- The hydrologic system must respond in a way that is consistent with the water-budget equation:

$$\text{Inflow} = \text{Outflow} \pm \text{Changes in storage}$$

- A management program that causes a hydrologic imbalance by continual withdrawal in excess of inflow will result in eventual depletion of the water.
- A continuation and extension of the present program of data collection will provide the City-Borough water managers with the information required to develop a water budget for each source area.
- Specific programs should be designed to collect data that will describe the hydrologic changes caused by community development.
- Because most of the City-Borough is still in an early phase of water utilization, water managers have the time now to formulate plans for the protection and utilization of the water resources.
- One possible way to meet future water demands in the City-Borough would be to install a pipeline system to collect available water from streams. The overall average of water available from such a system in the study area is about 5 cfs (cubic feet per second) per mile.
- Another possible way to meet future water demands is storage facilities on streams. Studies indicate that during the 1967-68 period, storage would have been required on Herbert River for any continuous demand in excess of 100 cfs.

- A public water-supply system utilizing four wells in the upper Mendenhall Valley has been proposed to meet an estimated demand of 2,000 gpm (gallons per minute) by 1980. Careful planning, testing, and management will be required in the design, location, and development of these wells to prevent undesirable effects on the hydrologic system.
- The well field in the Last Chance Basin will be placed under greater demands as the population increases. Present data indicate that the field is capable of supporting additional wells.
- Water demand in the Lemon Creek and Salmon Creek valleys will eventually be great enough to require central water systems. These systems can be supplied by ground water.

CHAPTER 7 - FUTURE STUDY NEEDED

- The lower Mendenhall Valley may contain thick gravel deposits that are deltaic in origin. These could prove to be a major fresh ground-water reservoir.
- Exploratory drilling to bedrock may be the only method presently available to determine if deltaic deposits are present in the lower Mendenhall Valley because of subsurface clay lenses that preclude the use of surface geophysical methods.
- The estimated maximum depth to bedrock is 700 feet below land surface.
- Exploratory drilling should also be considered in other valleys to locate aquifers for local water needs.
- Discharge water from the powerplant on Salmon Creek may be a potential source for public supply.
- All lakes in the area should be evaluated as potential water-supply sources.
- Desalination technology may eventually advance to the point that sea water could be used as a water-supply source for the City-Borough. Long-range plans should include continuing evaluation of this resource.

CHAPTER 1

The Land, The People, and Water-Resources Development

The City and Borough of Juneau is in the Southeastern Panhandle region of the State of Alaska about 900 miles northwest of Seattle and about 75 miles east of the open Pacific Ocean. The City-Borough trends northwest-southeast and extends from about 57°49' to 58°58' north latitude and from 133°05' to 134°53' west longitude (dashed boundary on figure 1).

No highways or railroads connect the City-Borough with other areas: air and sea transportation constitute the only access.

Although the present landforms of the area are the result of many geologic processes, glaciation has been the dominant process. The major valleys and channels (fig. 2) were excavated during the last ice age. The Mendenhall Glacier, which is fed by the Juneau Ice Field, provides excellent contemporary examples of landforms resulting from Alpine glaciation. Among the most prominent landforms are the rugged mountains that parallel the Gastineau Channel and rise to heights of more than 3,500 feet in distances of less than 2 miles from the shore. The Mendenhall Valley, Eagle-Herbert Rivers area, and Lemon Creek Valley are the only large flatlands in the study area. The ruggedness of the topography largely confines the habitable areas to altitudes of less than 200 feet.

The 1968 special census indicated that 12,853 people were living in the City-Borough: 6,007 in the city of Juneau, 1,152 in the city of Douglas, and 5,694 in the rural areas. Of those in the rural areas, 3,300 were in the Mendenhall Valley, 980 were in the Auke Bay area, and 470 were in the Lemon Creek Valley. The other 944 were distrib-

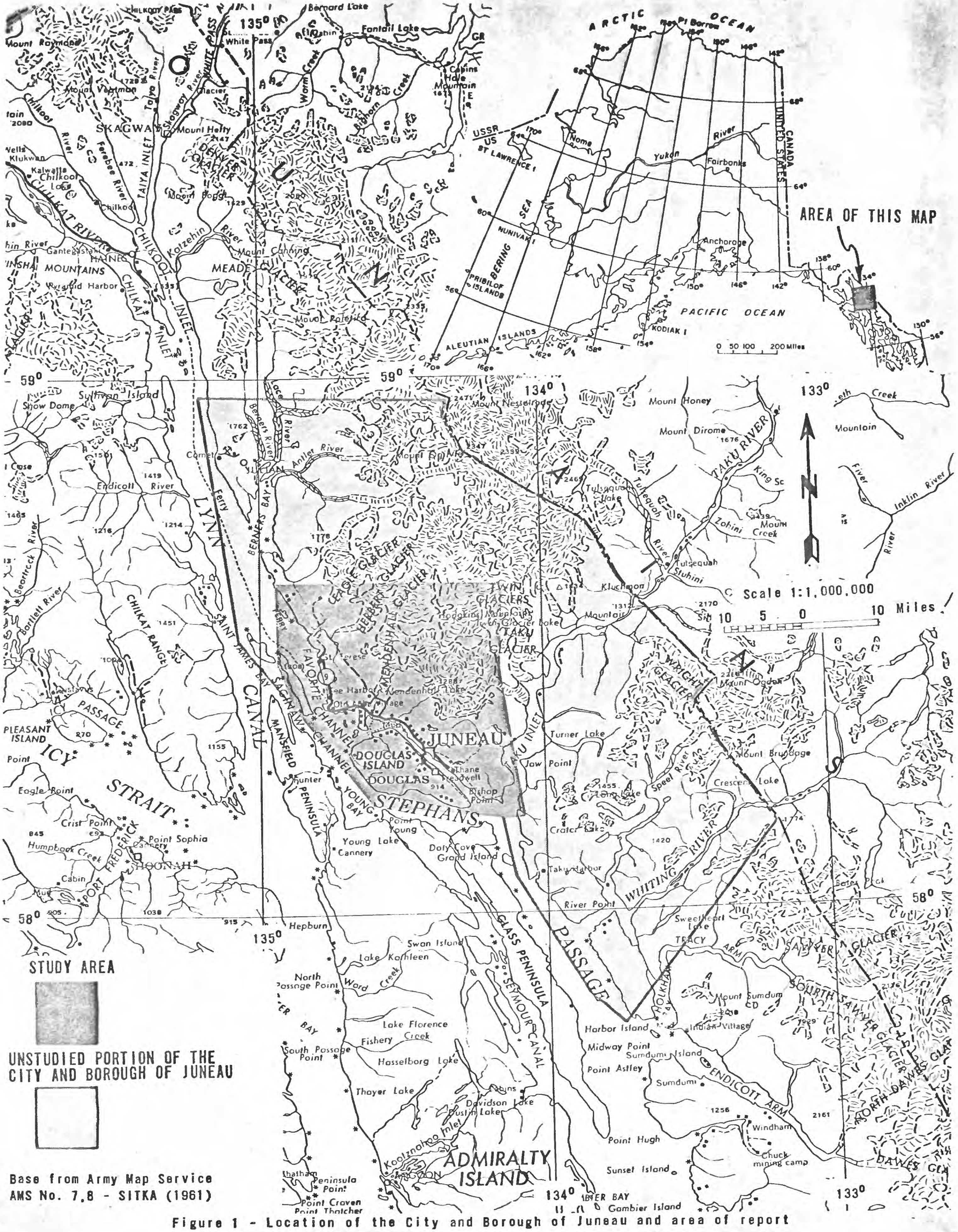


Figure 1 - Location of the City and Borough of Juneau and area of report

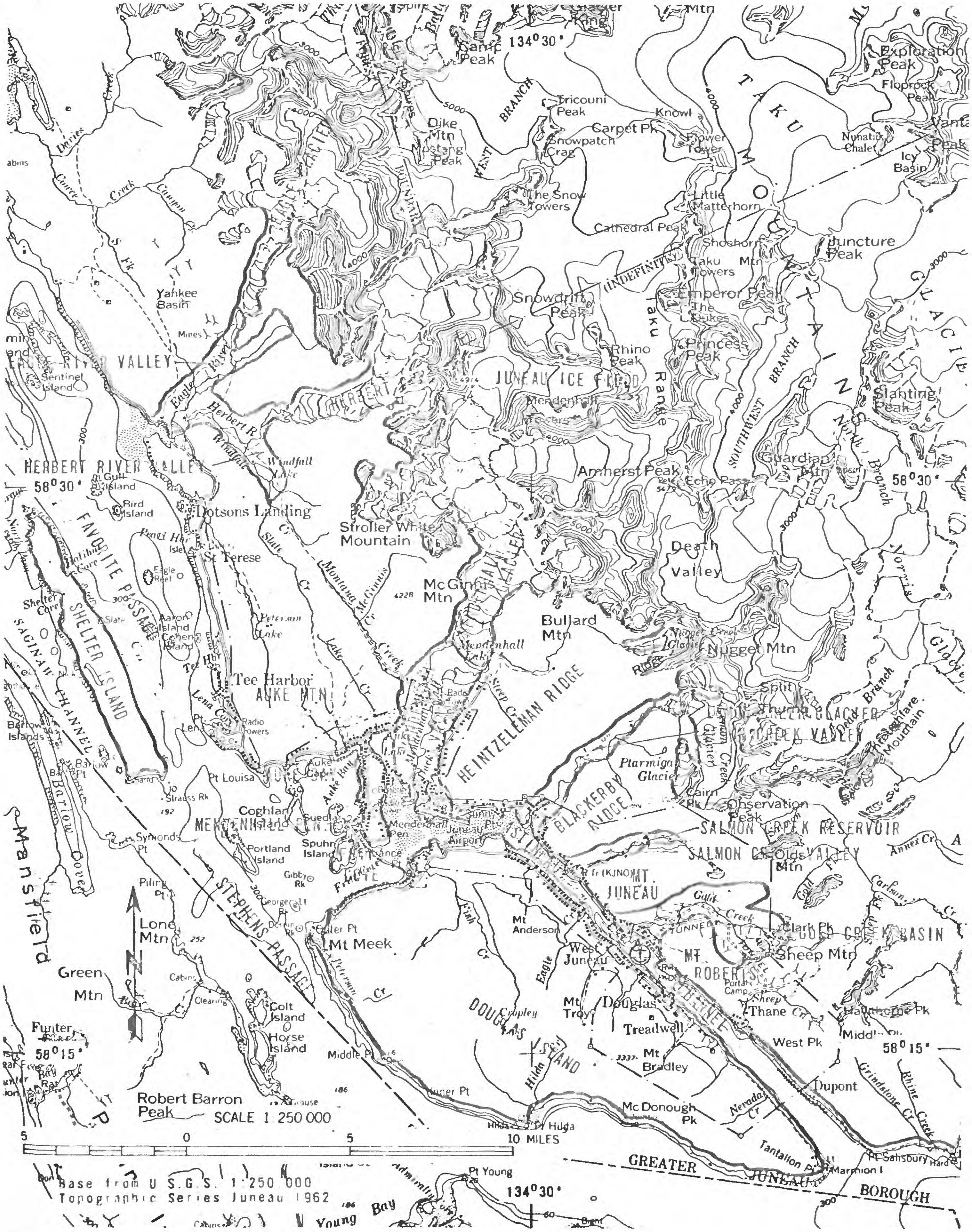


Figure 2 - Principal land forms in the project area.

uted along the roads throughout the rest of the study area. The 1970 census indicated a total population of 13,556. population of the City-Borough has grown slightly more than 3.7 times between 1900 and 1970. As indicated in figure 3, this growth has not been constant. However, with the exception of the 1920 census, each census has recorded an increase. Figure 3 shows that the population trend has shifted to the rural areas, and that in 1968 more than 44 percent of the total population lived outside the city limits of Juneau and Douglas. The city of Juneau has had continued growth since 1910; however, the 1968 special census indicates that this trend may have reversed. The population of the city of Douglas declined between 1910 and 1940, but has increased since then. Since closing of the mines in 1944, the major activities have centered around tourism, government, local services, and fishing. None of these are large users of water. However, recent announcements of a large forest-products plant to be built at Berners Bay and a mill for processing low-grade iron ore near Port Snettisham indicate that industrial use of water will increase.

The history of water-resource development in the City-Borough is short. The early settlers undoubtedly took all their domestic water from the nearest stream. Some of them diverted water from the stream for mining or power, but the water was returned to the stream nearby. Later water demand was great enough to cause construction of interbasin diversion facilities such as the Treadwell ditch (fig. 6). The Treadwell ditch conveyed water from Upper Fish Creek to the mine and mill southeast of Douglas; the ditch is presently unused. At present the city of Douglas makes the only interbasin diversion of water. However, future community growth might make extensive systems for collection of surface water feasible. Water is generally available for such systems.

In 1959 on the basis of an engineering report by Cornell, Howland, Hayes, and Merryfield (1957, unpublished report), the city of Juneau embarked on a program of exploratory drilling along Gold Creek about 1 mile from town. This led to the drilling and development of two wells that were reported to flow about 1,000 gpm when drilled.

Figure 4 shows the City-Borough's estimated domestic water needs by area on the basis of the 1968 census and on the assumed per capita use of 200 gpd (gallons per day). Assuming that other needs equal this figure, the present (1970) water demand is about 5 mgd or 8 cfs.

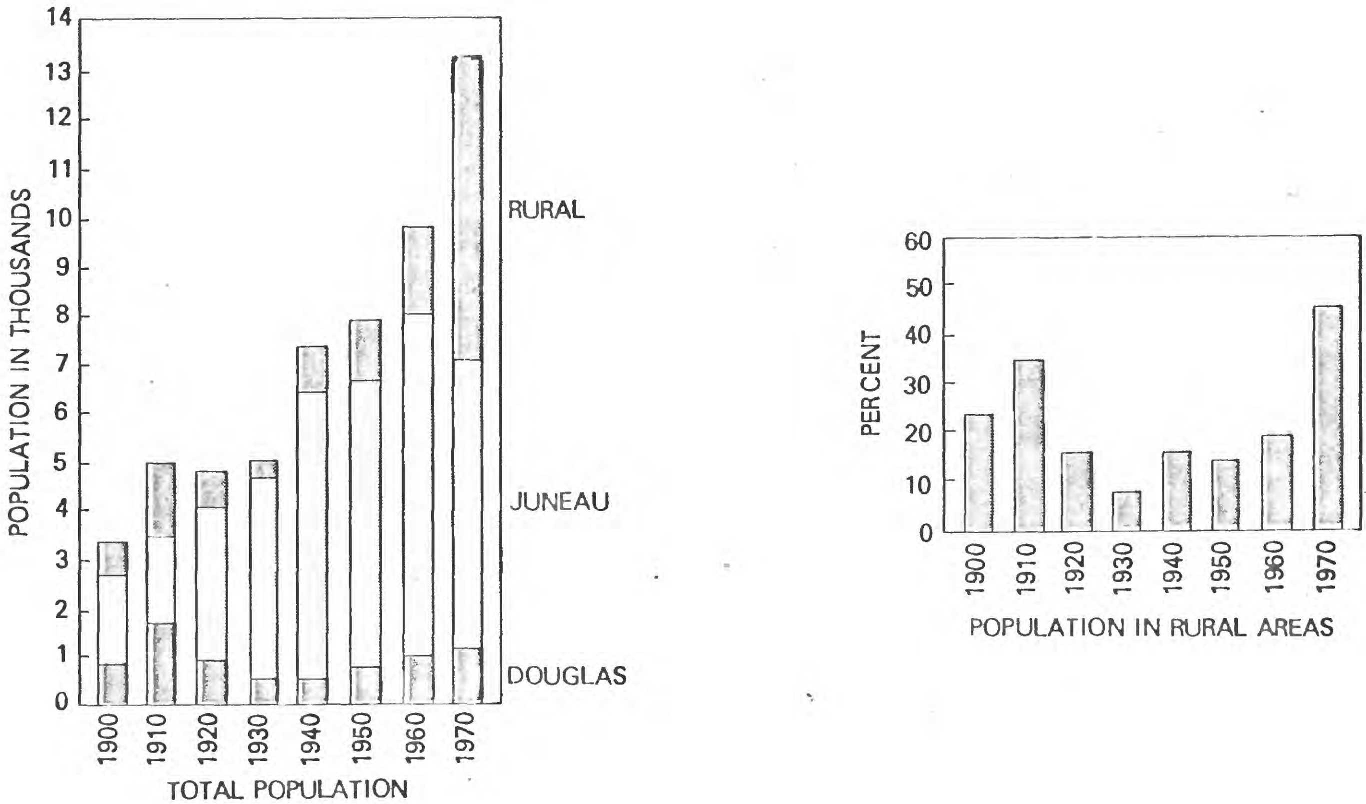
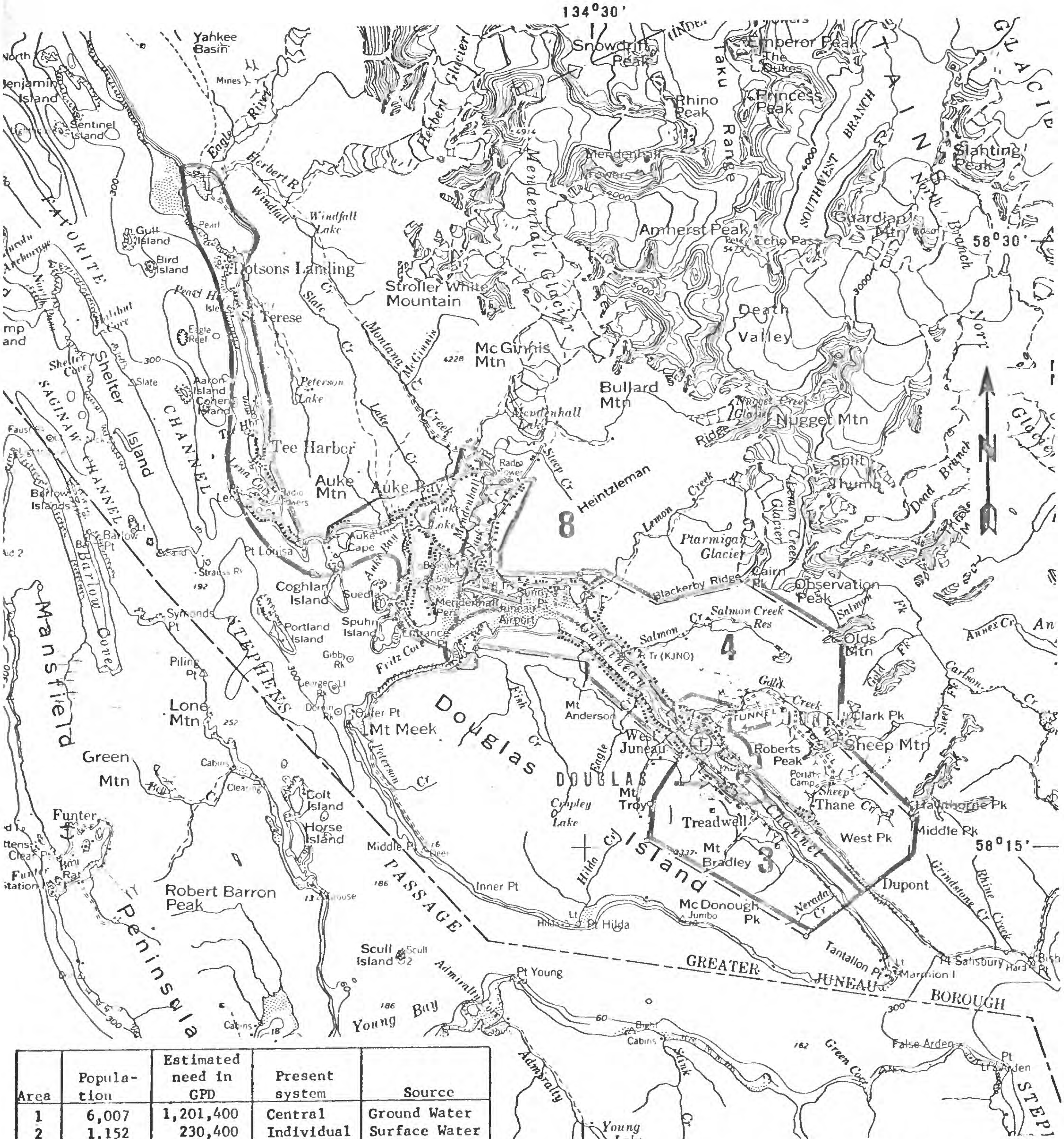


Figure 3 - Population trends in the City - Borough



Area	Population	Estimated need in GPD	Present system	Source
1	6,007	1,201,400	Central	Ground Water
2	1,152	230,400	Individual	Surface Water
3	487	97,400	Individual	Ground Water
4	819	163,800	Individual	Ground Water
5	468	93,600	Individual	Ground Water
6	2,593	518,600	Central & Individual	Ground Water
7	1,219	243,800	Individual	Ground Water
8	108	21,600	Individual	Ground Water

Base from U.S.G.S. 1:250,000
Topographic Series JUNEAU 1962

Figure 4 - Population Distribution in 1966 and Water Use by area showing present sources of water

CHAPTER 2

How and Where Water Is Found

The City-Borough has an almost limitless supply of water from the Pacific Ocean. Although ocean water is economically important to the area for recreation and fishing, this report is concerned mainly with fresh water. Precipitation is the source of all fresh water in the City-Borough. In some of the bays and in the lower reaches of most streams emptying into them, the fresh and salty water mix to produce brackish water.

Water has been classified into three general categories: atmospheric water, surface water, and subsurface water. The general relations between these waters under natural conditions are summarized in figure 5.

Atmospheric water, expressed commonly in terms of relative humidity, changes continually depending upon air temperature and other factors. In the City-Borough, approximately 25 percent of the precipitation evaporates from the land surface or is transpired by plants soon after it falls. The amounts that percolate and run off are highly variable because of the geology and topography; perhaps 25 percent percolates into the zone of saturation and 50 percent enters the streams as direct runoff.

Surface water includes not only water in the ocean, rivers, lakes, and ponds, but also water frozen in glaciers and snow. Streams in the City-Borough respond rapidly to precipitation, but the annual discharge is very consistent. Because nearly impermeable bedrock is at the surface in much of the area, most of the precipitation runs off rather than

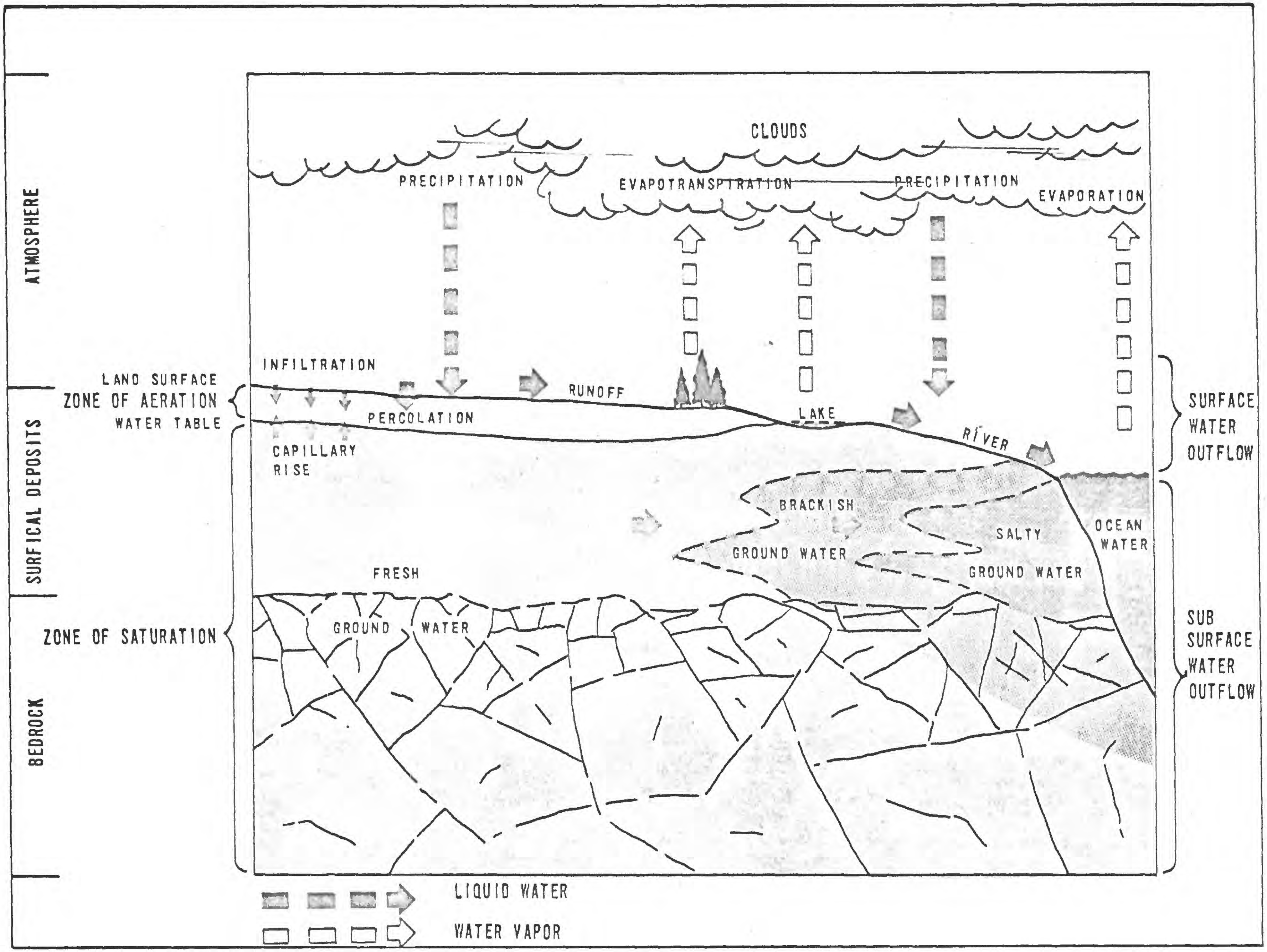


Figure 5 - Flow diagram of the hydrologic system under natural conditions

percolating downward to become subsurface water. The major streams have gradients ranging from 200 to 600 feet per mile. The smaller streams commonly have gradients of 1,000 feet per mile. Locations of stream basins, discharge data, and quality-of-water determinations are contained in the basic-data report (McConaghy, 1969). Characteristics of gaged streams are given in table 1 of this report. Most surface water in the City-Borough is stored in lakes and ice. With the exception of the Salmon Creek Reservoir, which is a dammed stream, the larger lakes were formed by glacial action during the last ice age. The extent of lakes, glaciers, and streams is shown on the hydrogeologic map (fig. 6). Most of the smaller lakes, particularly those in the Mendenhall Valley, are water-table lakes (lakes in which the water level coincides with adjacent ground-water levels).

The City-Borough is underlain by two general rock types: metamorphic bedrock and unconsolidated surficial deposits. The distribution and water-bearing properties of these materials are shown in figure 6, which is a generalization of a geologic map by R. D. Miller (written commun., 1967) of the U.S. Geological Survey.

The underlying bedrock is composed of dense metamorphic rock that contains water only in fractures. Well yields are generally limited to only a few gallons per minute. Bedrock is not a potential source of public-supply water; however, it is a valuable source of water for individual supplies. In areas colored gray in figure 6, bedrock is the only source of ground water; in areas of other colors, it may be the principal source if the overlying material is thin or drained. Historically, individual supplies have been used in rapidly developing areas until central supply systems could be constructed..

The surficial deposits consist of gravel, sand, silt, and clay. Gravel is one of the best deposits for yielding water. Sand is also a good producer of water, although the interstices are small. Clay and silt are the poorest sources of water because the particles and interstices are very small; these minute pores hold water tenaciously and release it slowly. The permeable surficial deposits in figure 6 are further subdivided on the basis of their position. Raised deposits tend to be drained, and consequently yield no water to wells. Deposits near the mouths of rivers tend to have water of poor quality, because of intrusion of salt water. Thick sections of saturated permeable material are capable of yielding several hundred gallons per minute to properly constructed wells.

Ground water occurs under two distinctly different conditions--water table and artesian. Ground water under water-table conditions sometimes is referred to as unconfined ground water, and the aquifers in which it occurs commonly are called unconfined aquifers. Similarly, artesian ground water and the aquifers in which it occurs commonly are referred to as confined ground water and confined aquifers, respectively.

Ground water in the uppermost part of the zone of saturation is under water-table conditions throughout most of the study area, but artesian conditions are found where the saturated deposits are overlain and confined by silty and clayey layers of low permeability. No extensive confining layers exist in the presently developed ground-water reservoirs of the City-Borough, but numerous local clay and silt layers in the upper glacial aquifers confine the underlying water under pressure. The pressure is sufficient near the Mendenhall River and Gold Creek to cause wells that penetrate the clay to flow at the land surface.

Although the confining layers are of sufficiently low permeability to restrict the flow of water through them, they are not completely impermeable. Therefore, at many places ground water flows slowly through confining layers from one more permeable layer to another. Moreover, some of the confining layers have been breached by ancient erosional channels, which were later filled with material of moderate to high permeability. In such areas, moderately large amounts of water may flow vertically through these more permeable materials.

The major fresh ground-water reservoirs (the unconsolidated rock materials saturated with fresh ground water that are shown in yellow in figure 6) range in thickness from zero, where bedrock is exposed at the land surface, to about 700 feet in the Mendenhall Valley. The volume of the major aquifers in the study area is about 1.5 cubic miles; approximately 20 percent of which is filled with water. Therefore, perhaps 100 billion gallons of fresh ground water are stored in these deposits, not all of which is available for use. The availability of water depends on the thickness and water-bearing properties of the materials penetrated by wells.

Away from the coastal areas, ground water (that part of the subsurface water beneath the water table) is generally fresh. However, it may become progressively more salty in the seaward direction and at depth depending upon the hydraulics of the fresh water-salt water contact. Near the lower end of most major valleys in the City-Borough, fresh ground water and ocean water are hydraulically interconnected. The position of the interface between fresh water and salt water is determined largely by differences in the densities and hydraulic heads of the waters as salty ground water moves landward and mixes with the fresh water that is flowing upward and seaward. Wells drilled near the landward edge of the interface would yield water that is usable, but it would have higher-than-average mineral content. Here, heavy pumping of the well would substantially shorten its useful life because of intrusion of salt water from the interface to the well. In the Mendenhall, Herbert, and Eagle River valleys, bodies of fresh water may underlie bodies of salty water.

Ground water is discharged principally by subsurface outflow to the sea and by seepage to streams, but small amounts of ground water are also discharged by pumping and evapotranspiration. Changes in ground-water levels represent changes in the amount of ground water in storage, which reflects the differences between recharge and discharge. Ground-water outflow tends to remain nearly constant from month to month; consequently, ground-water levels tend to rise when recharge is above normal and decline when recharge is below normal.

The relationship between precipitation, streamflow, and ground-water storage is shown in figure 7. This figure illustrates that during the winter months temperature is the controlling factor in runoff from both nonglacial Montana Creek and glacial Mendenhall River because variation in precipitation is not mirrored in the runoff. During the summer months, the runoff from Montana Creek mirrors the precipitation and hence is not temperature dependent. By contrast, the effect of higher temperature on glacial melt is dramatic throughout the summer and masks the runoff due to precipitation in Mendenhall River basin. The annual runoff from Mendenhall River is more than twice that of Montana Creek. Almost 90 percent of the runoff from

Mendenhall River occurs during the summer, indicating that glacial melt accounts for a substantial amount of the total flow. The hydrograph of the Borough test well (fig. 7) illustrates that ground-water levels in Mendenhall Valley respond also to precipitation. During September 1968, 10 inches of precipitation caused the water table to rise more than 5 feet.

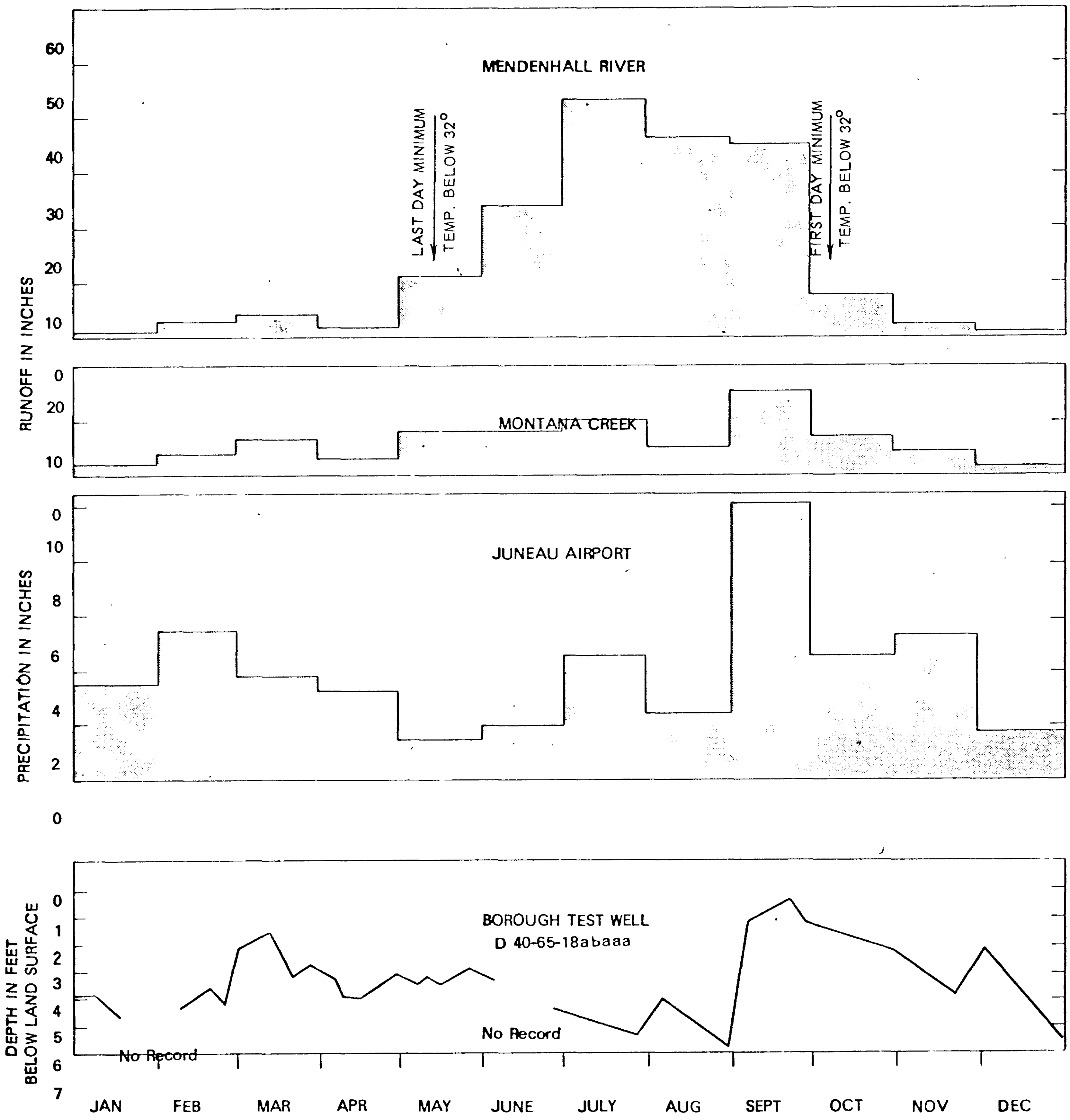


Figure 7.--Hydrographs for 1968 showing comparison between precipitation, surface water, and ground water near Mendenhall Glacier.

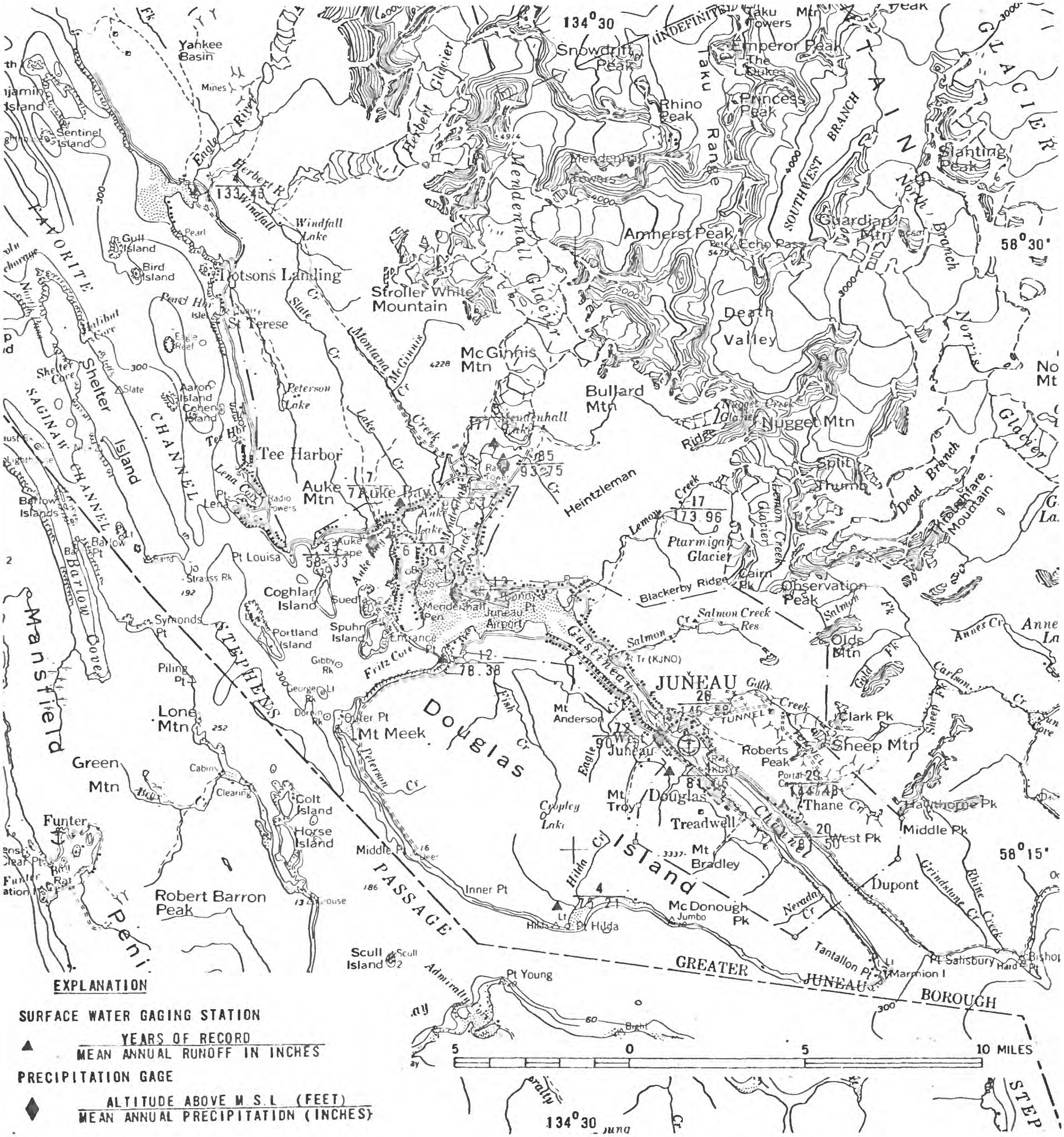
CHAPTER 3

Where Water Comes From

Figure 8 shows that the mean-annual precipitation for stations below 90 feet altitude ranges from 54.62 inches to 93.75 inches. Fragmentary data from high-altitude stations indicate that precipitation increases rapidly with increased altitude as an air mass rises over the initial mountain front; precipitation then declines as the air mass moves over the ice field. Murphy and Schamach (1965, p. 1) measured approximately 285 inches of precipitation a year at an altitude of 3,400 feet on Mount Juneau. A. E. Helmers (oral commun., 1969) indicates that precipitation at an altitude of 4,000 feet on the ice cap is about 100 inches a year.

Mean-annual runoff in inches provides an estimate of mean-annual precipitation less evapotranspiration losses. Because precipitation is greater at high altitudes, the runoff will be greater than that from precipitation observed at a station near sea level. Precipitation data at altitudes above 90 feet in the study area are sparse.

The effect of altitude on precipitation is clearly demonstrated by comparison of records on precipitation at Juneau and on runoff at the Sheep Creek gage (fig. 9). The Sheep Creek gage is about 630 feet above mean sea level, and the mean basin altitude is 1,900 feet above mean sea level. Although close correlation between the records at Juneau and at Sheep Creek is evident, the average runoff above Sheep Creek gage is 60 inches greater than precipitation at Juneau. Figure 9 shows also the relationship between mean altitude of the basin and runoff for selected streams in the City-Borough and indicates that sea-level precipitation data are not meaningful for use in basins



Base from USGS 1:250,000 Topographic series - Juneau 1962

Figure 8 - Locations of stream gages and weather stations showing variation of precipitation, runoff, and length of records.

having a mean altitude greater than about 2,000 feet. A high degree of variability is shown in the runoff from basins having a mean altitude greater than 2,000 feet. For example, Carlson Creek has about 50 percent more runoff than does Gold Creek, which is approximately the same mean altitude. This discrepancy might be explained by the different orientation of Carlson Creek basin and its proximity to the ice field. Another partial explanation might be that the stations have various periods of record. For example, the mean-annual runoff for Sheep Creek during 1951-67 is about 5 inches less than that during the full period of record (1946-69). Obviously, more data on high-altitude precipitation and runoff will be required before streamflow of various basins can be correlated and a meaningful water budget can be prepared for the City-Borough as a whole.

Although it varies widely, the highest average monthly precipitation occurs in the fall when regional storms dominate, and the lowest occurs in late spring when local storms are more prevalent. The maximum monthly precipitation recorded in Juneau was 25.87 inches in November 1936 in contrast to the minimum monthly precipitation of 0.25 inches in July 1915. The maximum monthly precipitation recorded at the Juneau Airport was 13.29 inches in October 1952, and the minimum monthly precipitation was 0.27 inches in April 1948.

Juneau has continuous precipitation records since 1912; the airport has continuous records from 1944 (fig. 10). As shown in figure 10a, the total precipitation in the city of Juneau ranged from 119.48 to 62.06 inches; at the airport it ranged from 68.11 to 37.80 inches. Figure 10b shows the distribution of precipitation in the study area and the similarity of seasonal variation in precipitation at the two stations. The slope of the graph showing cumulative departure from average precipitation in the Juneau area (fig. 10c) indicates whether precipitation in a given year was above or below average. An upward slope to the right

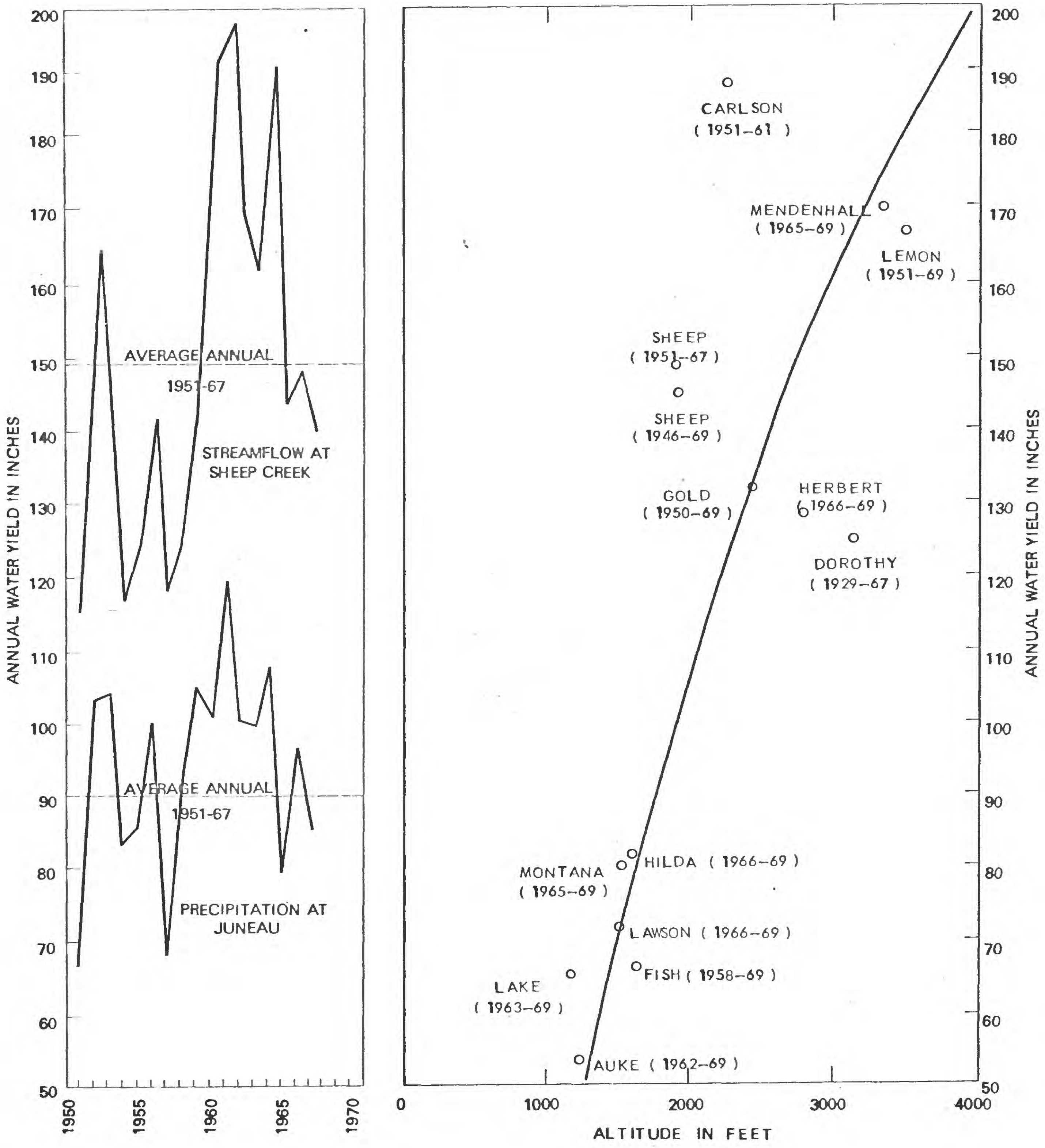


Figure 9 - Comparisons of annual runoff with mean basin altitude and of precipitation at Juneau with runoff from Sheep Creek Basin.

indicates above-average precipitation, and a downward slope to the right indicates below-average precipitation. A change in slope is also significant. The greatest excess occurred between 1958 and 1964; the largest deficiency occurred between 1949 and 1951.

The probability that a given amount of precipitation will occur in any single year can be estimated from figure 10d. For example, the chances are that 80 percent of the time (8 out of every 10 years) the annual precipitation will be equal to or greater than 70 inches at Juneau and equal to or greater than 40 inches at the airport. On the other hand, the chances are that 20 percent of the time (2 out of every 10 years) the annual precipitation will be equal to or greater than 105 inches at Juneau and equal to or greater than 65 inches at the airport. The chances against the annual precipitation being less than 40 inches or greater than 130 inches in Juneau are about 100 to 1. At the airport, the chances are about 100 to 1 against the annual precipitation being less than 30 inches or greater than 90 inches.

Since 1967 there has been a rather persistent shortage of precipitation, but the shortage is not expected to have any permanent effect on ground-water levels. Records show that climatic changes during the period of record are insignificant; consequently, both surface-water records and ground-water records can be extended with a fair degree of confidence.

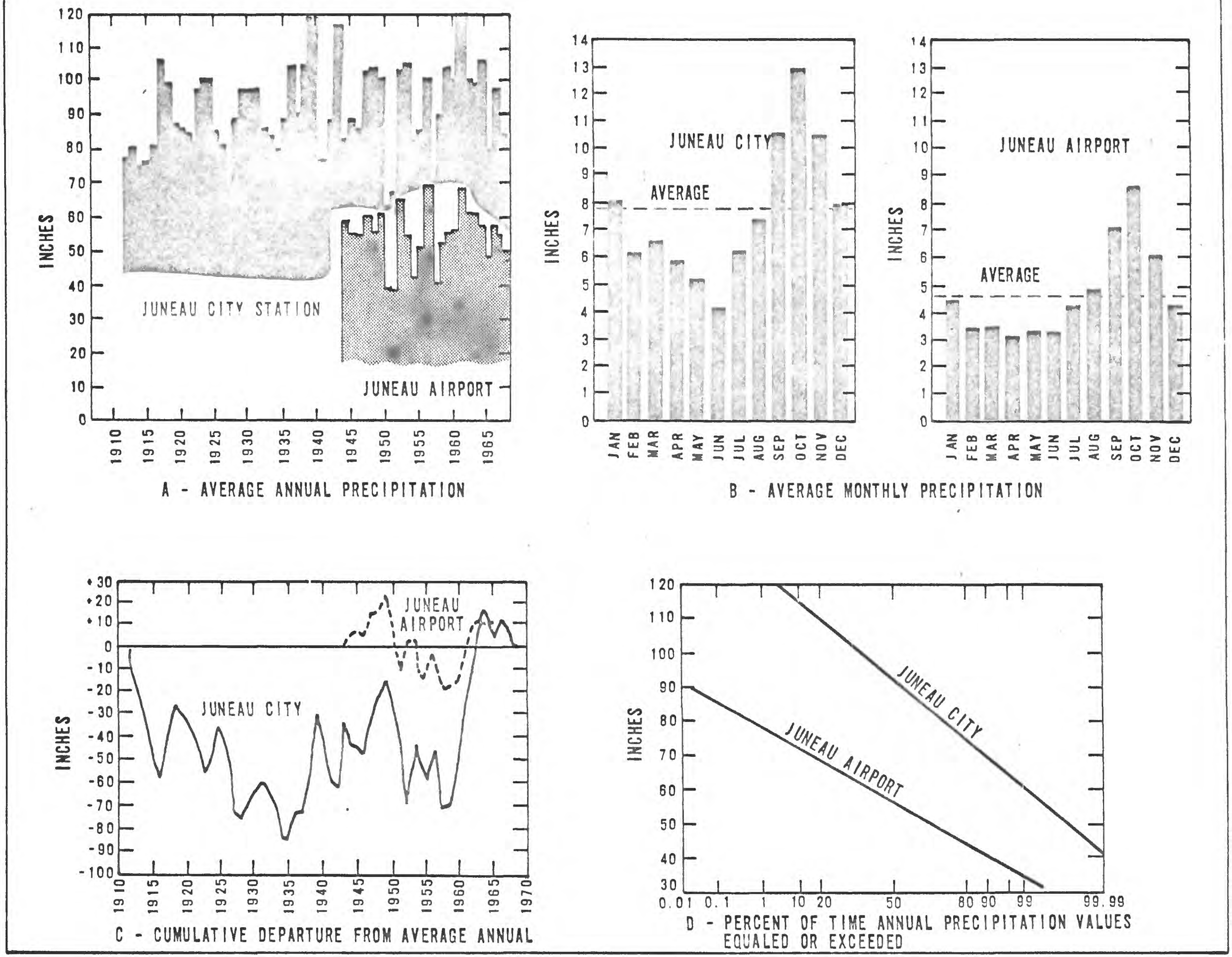


Figure 10 - Relation of precipitation at Juneau to precipitation at Juneau Airport

CHAPTER 4

Where the Water Goes

Water is removed from the City-Borough by evapotranspiration, streamflow, and ground-water underflow.

The term evapotranspiration refers to all the natural processes by which water on and beneath the land surface is returned to the atmosphere as water vapor. The major elements of evapotranspiration in the study area are (a) evaporation of precipitation soon after it falls, (b) evaporation from glaciers and permanent or semipermanent surface-water bodies, and (c) transpiration by plants of soil moisture and of ground water.

Sufficient data are not available in the Juneau area to evaluate directly evapotranspiration of precipitation with a high degree of accuracy. However, Patric and Black (1968) developed empirical estimates based mainly on National Weather Service data. Their estimates of annual potential evapotranspiration in the Juneau area ranged from 17.79 inches to 21.89 inches and averaged 20.35 inches. Patric (1966) determined also that 25 percent of the total precipitation in areas of mature coniferous forest never reached the ground. Patric's potential evaporation was water loss from fully vegetated land surfaces always abundantly supplied with soil moisture. During the 6 months that Patric collected data, only 72.5 percent of gross rainfall reached the ground under the forest.

Streams flowing to the sea represent another major element of fresh-water discharge from the hydrologic system in the study area. Analysis of streamflow records gives reliable information on floods, total flow, maximum flow, minimum flow, and time duration of flow. Estimates of flow characteristics of ungaged streams can be made also by making statistical comparisons with long-term records on comparable streams, checked by spot-discharge measurements on the ungaged streams. Long-term streamflow records from a network of gaging stations are fundamental to such studies. Continuous streamflow records, ranging from about 3 to 28 years, are available for the 11 streams shown in figure 8. Stations on these streams were established at points sufficiently upstream from the ocean so that the records would not be affected by tidal fluctuations. Records are also available from Carlson and Dorothy Creeks, which are not in the project area but are near enough to provide applicable data. Neither of these stations is in operation at the present time.

Discharge of many streams in the City-Borough is related directly to precipitation. The increased streamflow caused by a storm is logically called direct runoff, and can be estimated from a stream hydrograph (fig. 11). This figure also summarizes the relation between precipitation and direct runoff in the 11 gaged streams during 6 selected storms. The data indicate that direct runoff increases from about 50 percent of the precipitation recorded at altitudes below 90 feet during a 1-inch storm to about 125 percent during a 5-inch storm. This seeming excess of 25 percent reflects lack of precipitation records at altitudes higher than 90 feet.

For the major streams in the study area, monthly flows are normally greatest in early summer and least in late winter. Data indicate that the total outflow of fresh water during the month of greatest flow averages about 15 times the total during the month of least flow. The long-term monthly flow characteristics of selected streams are shown in figure 12. Basic data on these and other gaged-stream basins are included in table 1.

Discharge of any stream depends primarily on the size of its basin, although other factors are undoubtedly influential. Figure 13 shows the relation of stream discharge

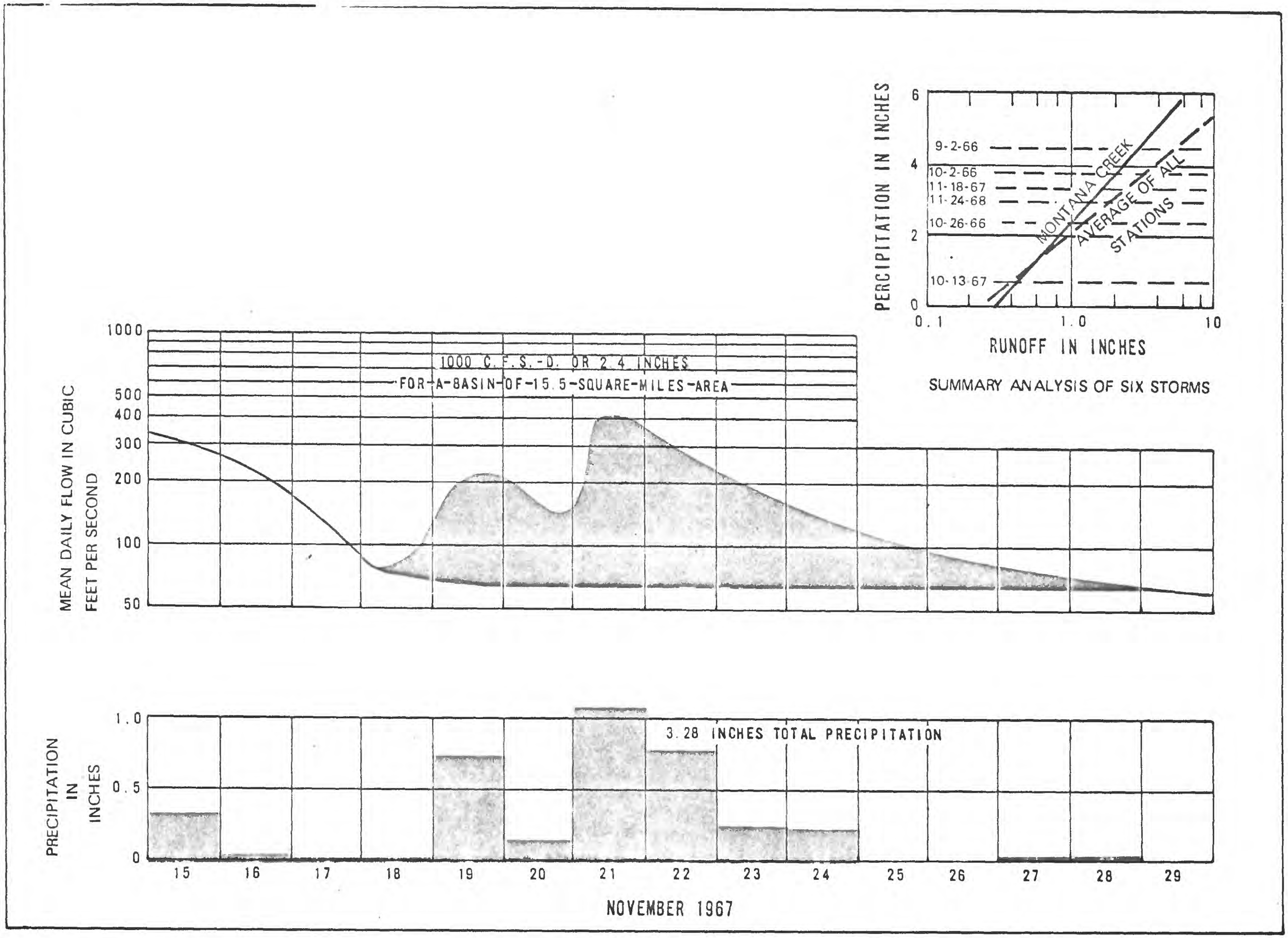


Figure 11.--Relation of precipitation to direct runoff for selected storms recorded at Juneau airport

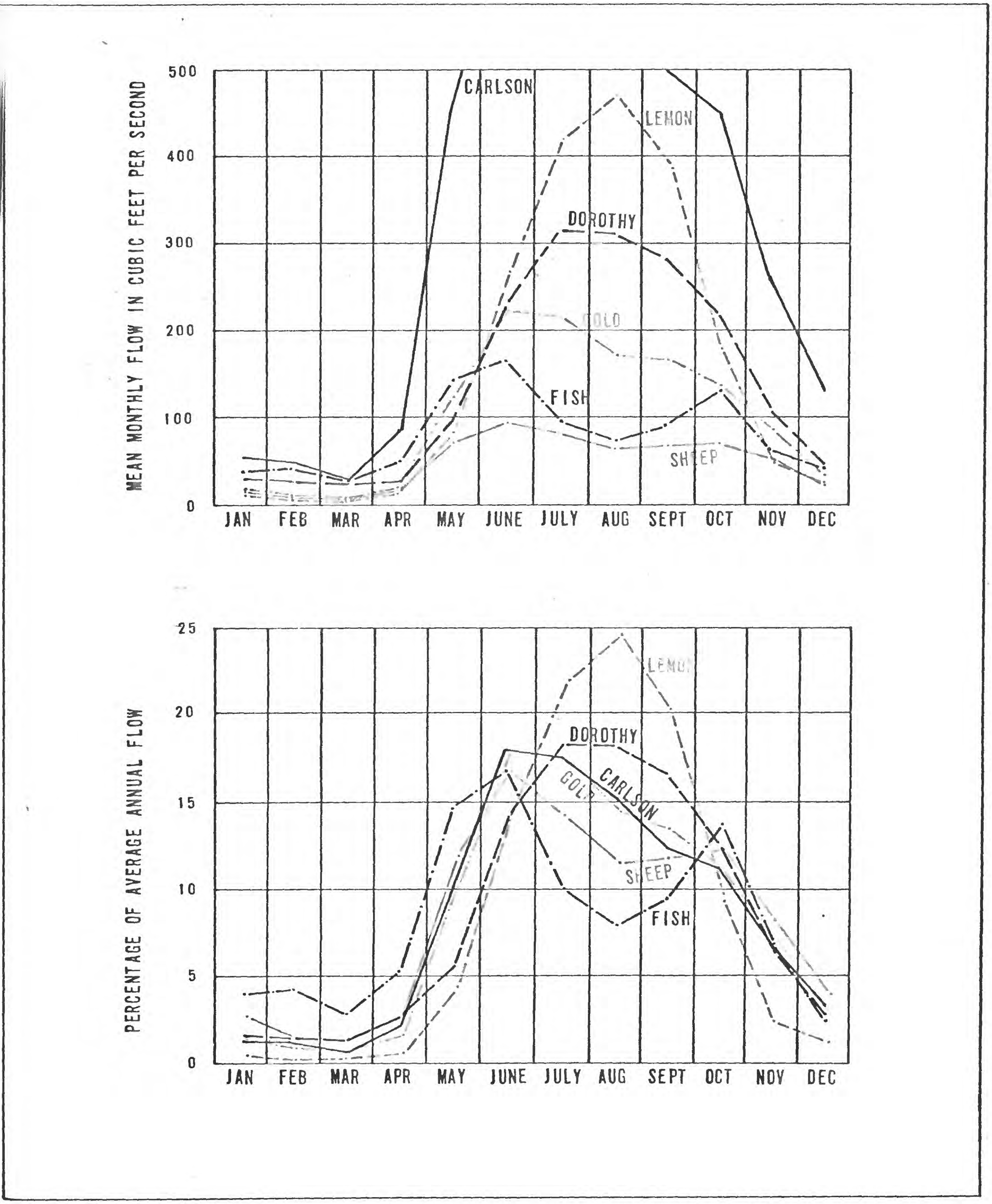


Figure 12 - Long-term monthly flow characteristics of selected streams in the City-Borough

Table 1.--Basin description of gaged streams.

Name of stream	Number (fig. 8)	Latitude	Longitude	Drainage area (square miles)	Mean basin altitude (feet above mean sea level)	Gage altitude (feet above mean sea level)	Stream length (miles)	Main channel slope (feet per mile)
Herbert River	A	58°31'26"	134°47'40"	56.9	2,790	5	16.2	393.4
Lake Creek	B	58°23'40"	134°37'50"	2.50	1,170	75	3.6	555
Montana Creek	C	58°23'53"	134°36'34"	15.5	1,500	75	7.6	264
Mendenhall River	D	58°25'05"	134°32'40"	85.1	3,260	60	18.3	291.5
Auke Creek	E	58°22'56"	134°38'10"	3.96	1,200	69.1	3.6	536
Lemon Creek	F	58°23'30"	134°25'15"	12.1	3,430	650	5.3	500
Fish Creek	G	58°19'50"	134°35'20"	13.6	1,600	17	6.9	289
Gold Creek	H	58°18'25"	134°24'05"	9.76	2,400	245	4.9	541
Lawson Creek	I	58°17'05"	134°24'40"	2.98	1,530	75	3.7	556
Sheep Creek	J	58°16'30"	134°18'50"	4.57	1,900	629.8	3.4	232
Hilda Creek	K	58°13'38"	134°29'50"	2.62	1,580	30	4.3	500
Carlson Creek	-	58°19'00"	134°10'15"	24.3	2,200	130	8.5	219
Dorothy Creek	-	58°13'40"	134°02'25"	15.2	3,100	350	8.5	234

Name of stream	Lake area (percent)	Forest area (percent)	Glacier area (percent)	Record high discharge (cubic feet per second)	Record low discharge (cubic feet per second)	Years of record	Average discharge (cubic feet per second)	Runoff (inches)
Herbert River	1.8	36.9	58	6,280	15	4	523	133.41
Lake Creek	.0	70.0	.0	980	0	7	13.2	71.70
Montana Creek	.0	64.5	3.2	1,920	5	5	101.3	88.75
Mendenhall River	3.5	9.4	66	9,020	25	6	1,114	177.77
Auke Creek	.0	48	.0	348	.02	10	17.8	61.04
Lemon Creek	.0	4	67	2,800	--	18	155	173.96
Fish Creek	.0	72	.0	2,120	1.0	12	78.5	78.38
Gold Creek	.0	29	8	2,650	.0	17	107	148.88
Lawson Creek	.0	81.9	.0	565	.27	4	17.9	81.57
Sheep Creek	.0	44	2.0	840	.0	31	48.6	144.42
Hilda Creek	.0	59.5	.0	400	.60	4	14.5	75.16
Carlson Creek	.0	68	10	5,100	--	10	340	190.01
Dorothy Creek	15	13	16	1,780	6	38	143	127.76

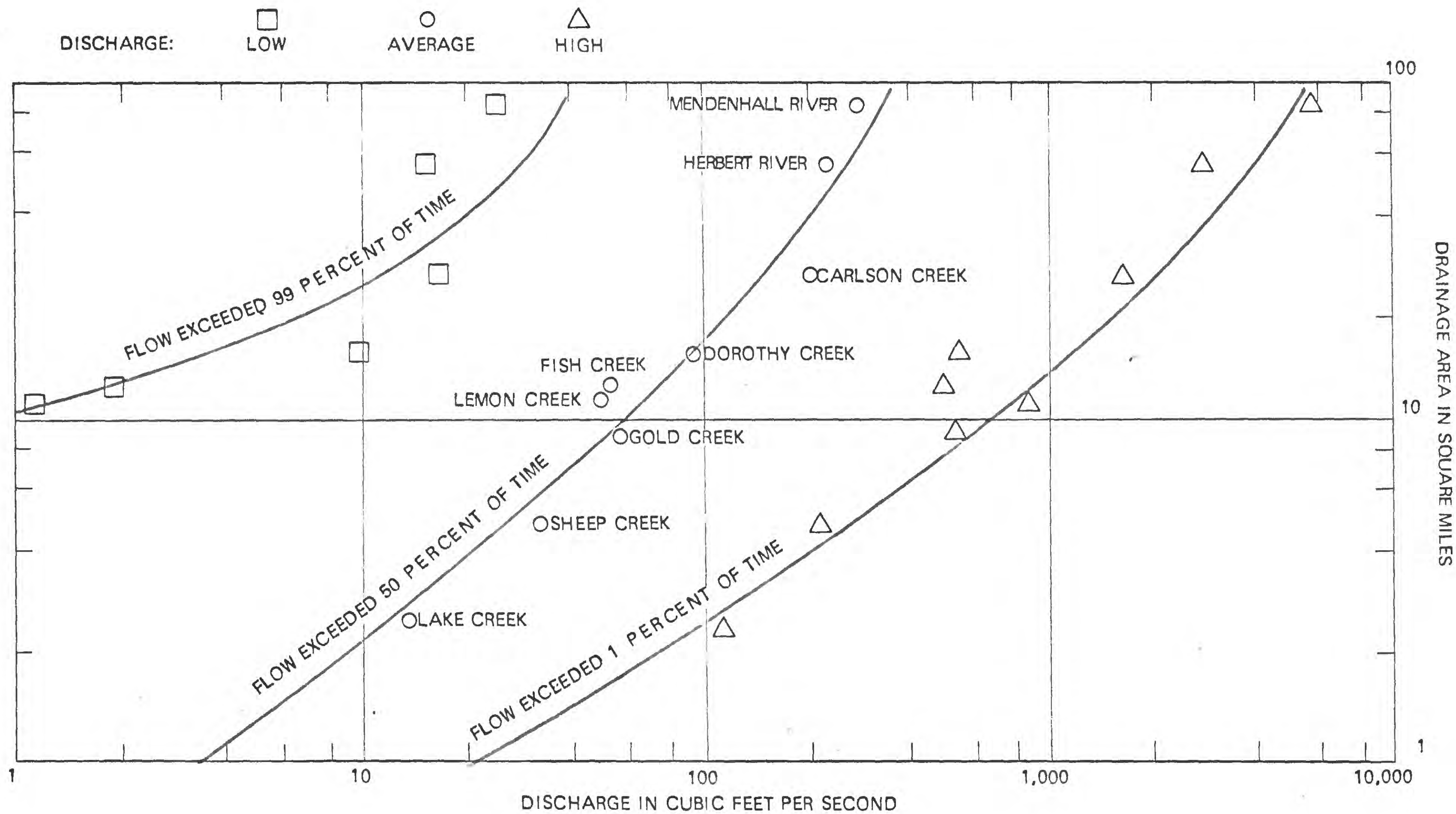


Figure 13.--Relation of streamflow to basin size.

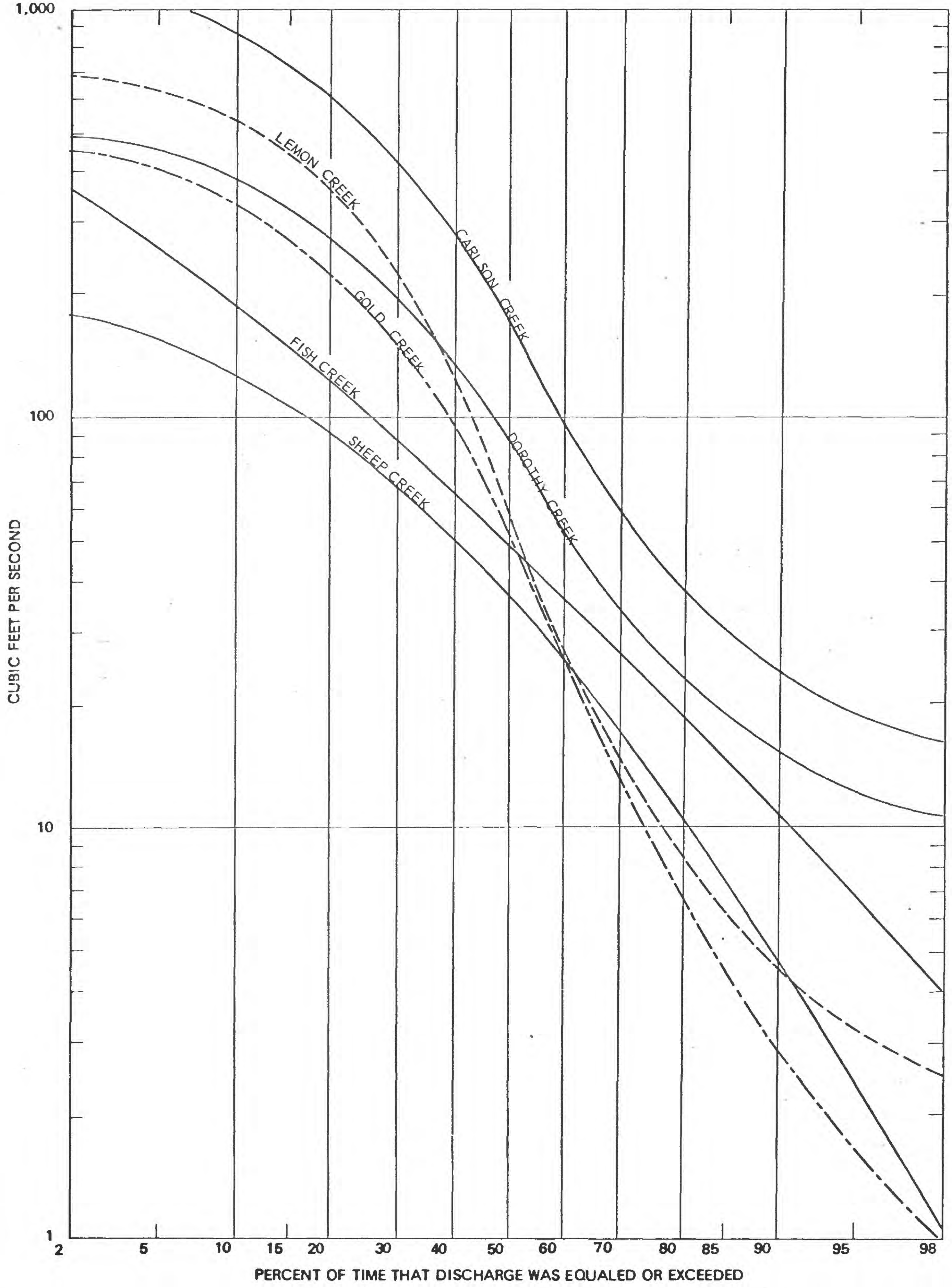


Figure 14.--Flow duration of selected streams in the City-Borough.

to basin size. The regression curves show high-, average-, and low-discharge relation. High flow is generally proportional to average flow regardless of basin size. But low flow of small basins is disproportionately low because such basins generally lack the ground-water reservoirs, which provide the base flow of larger streams.

Use of a surface-water resource either for supply or for waste disposal requires an understanding of flow variation from year-to-year. Such an understanding is required also to anticipate floods. Because streams respond to precipitation, which is a random but statistically predictable phenomenon, statistical methods may be used to predict flow variation. The probability that a given flow condition will be equaled or exceeded during a stated time interval is commonly shown by flow-duration curves such as those shown in figure 14. For example, Gold Creek can be expected to have a mean daily flow of more than 1 cfs about 98 percent of the time and can be expected to have a mean daily flow of more than 460 cfs only 2 percent of the time or once every 50 years. Because the flow-duration curve considers all flow at the gaging station for the period of record, longer records enable more accurate predictions; 25 years of record are usually considered adequate for flood-frequency and low-flow analyses.

The low flow of many streams is derived from drainage of ground water; but when flow in the streams is high, surface water generally recharges the aquifer. The aquifers are also recharged by infiltration of precipitation. Sufficient data are not available to estimate directly the quantity of ground-water recharge in the study area; however, indirect estimates of ground-water recharge indicate that under natural conditions, recharge might be 25 percent of total precipitation in the larger basins.

Ground water is in constant motion beneath the surface, flowing from areas of higher to areas of lower hydraulic head. Most of the water that reaches the water table in the

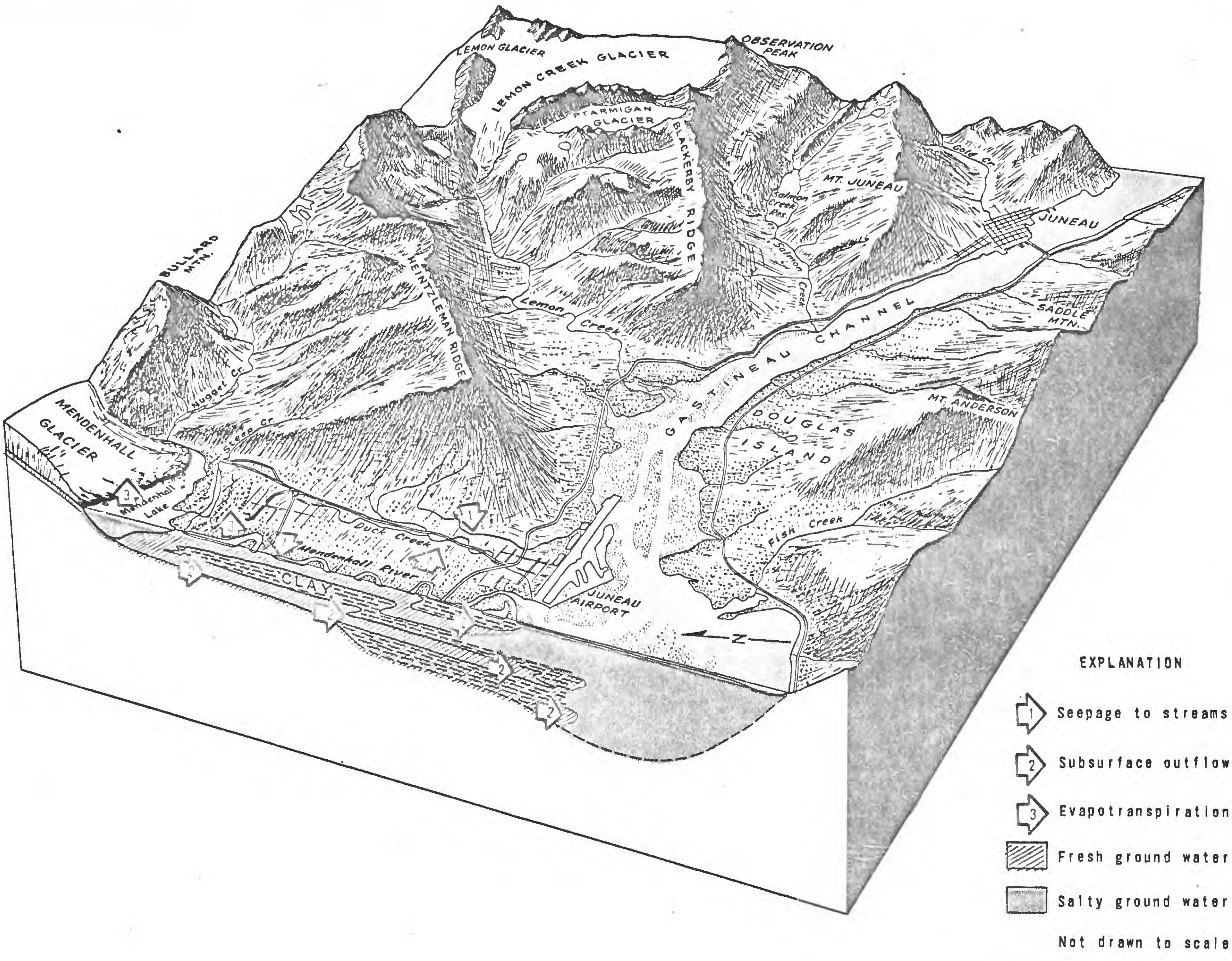


Figure 15 - Ground-water movement and discharge under natural conditions.

City-Borough moves laterally through the surficial deposits and ultimately discharges into streams or into salt-water bodies bordering the study area (fig. 15). Some of the water, however, moves laterally to ponds or swamps and subsequently evaporates. Under unconfined conditions, the water table is a subdued replica of the land surface. Hence, the horizontal direction of ground-water movement in the study area is mainly toward the ocean. Under natural conditions, the rate of ground-water flow in the horizontal direction through the more permeable materials in the study area ranges from a few feet to perhaps a few hundred feet per year. The flow in the vertical direction is on the average much slower--probably on the order of a hundred times slower--because of the many relatively impermeable layers in the strata through which the water has to flow. Accordingly, much of the fresh water presently being discharged from the ground-water system has been moving through the system for many years.

Operation of large-capacity wells will change the direction and rate of ground-water movement locally. Their operation may cause water from different areas to flow toward the well and perhaps eventually result in obtaining water of differing quality. The probable long-term effect of the well on ground-water movement should be considered before the well is drilled.

CHAPTER 5

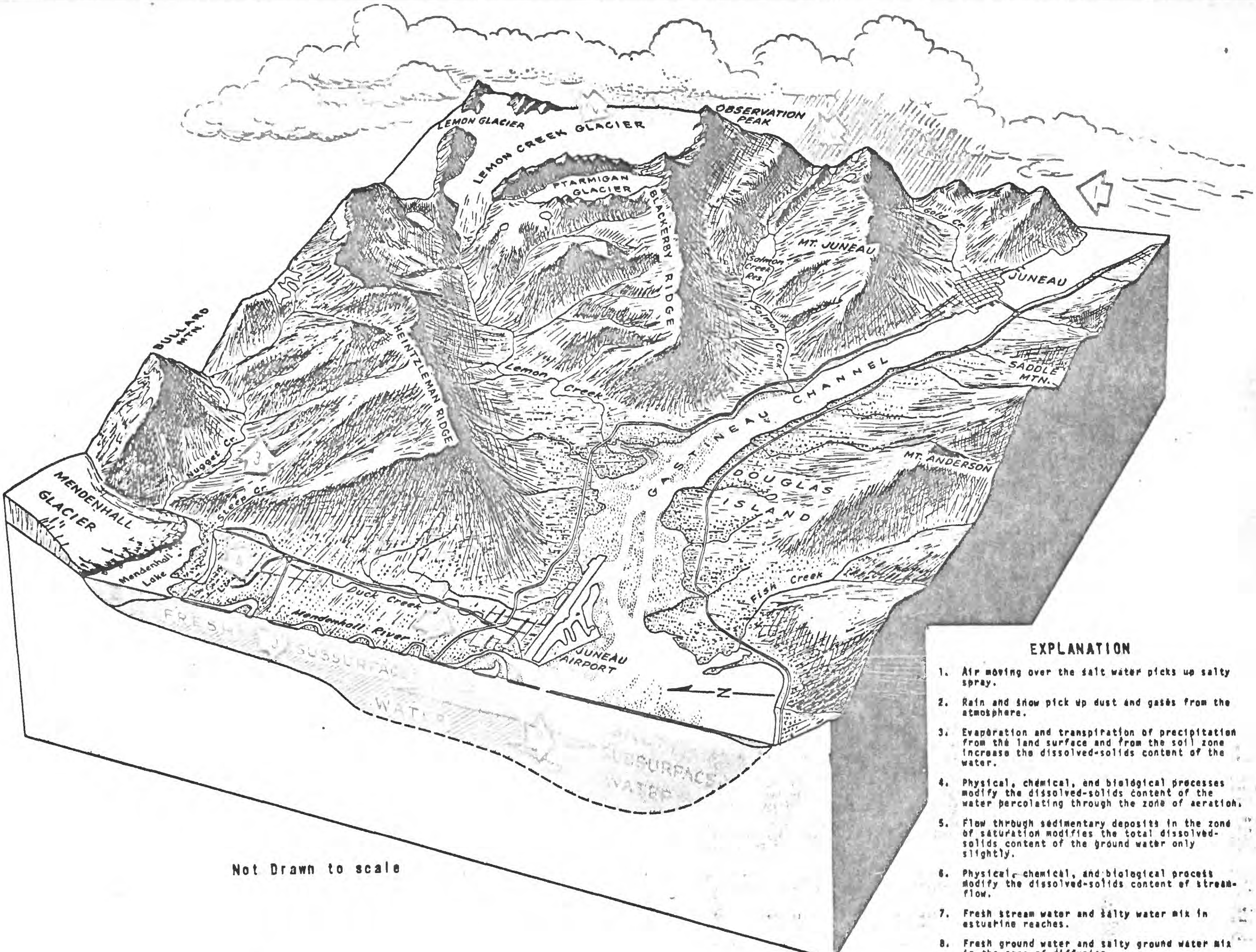
Chemical and Physical Properties of Water

Water in nature is never pure but always contains some dissolved and suspended impurities, which even when present in relatively small amounts may limit or even prevent its use. Consequently, the kinds and quantities of impurities are important in water-resource appraisals.

All rock minerals are, at least to some extent, soluble in water. Solution generally increases with time and contact. Consequently, the dissolved-solids content commonly increases as water moves through the hydrologic system. The general flow pattern in the hydrologic system and related water-quality features under natural conditions are shown in figure 16. Some changes in quality related to the activities of man are discussed in Chapter 6.

Most chemical properties of water are related to quantities of substances that are in solution, even though these may be small. One of the common measurement units previously used in Juneau area reports is parts per million (ppm) dissolved-solids content, which is the number of parts, by weight, of dissolved material in 1 million parts of the solution containing the dissolved material. Current practice is to express concentration in milligrams per liter, which is numerically equivalent to parts per million where concentrations are less than 7,000 mg/l.

Chemical analyses of 301 water samples from the study area are tabulated in a previously released basic-data report (McConaghy, 1969). The analyses in that report are believed to be generally representative of the natural range in the chemical quality of the fresh water, although some may indicate contamination by the activities of man. In order to generalize about water-quality variations, both



EXPLANATION

1. Air moving over the salt water picks up salty spray.
2. Rain and snow pick up dust and gases from the atmosphere.
3. Evaporation and transpiration of precipitation from the land surface and from the soil zone increase the dissolved-solids content of the water.
4. Physical, chemical, and biological processes modify the dissolved-solids content of the water percolating through the zone of aeration.
5. Flow through sedimentary deposits in the zone of saturation modifies the total dissolved-solids content of the ground water only slightly.
6. Physical, chemical, and biological process modify the dissolved-solids content of streamflow.
7. Fresh stream water and salty water mix in estuarine reaches.
8. Fresh ground water and salty ground water mix in the zone of diffusion.

Figure 18 - Changes in the chemical quality of water under natural conditions.

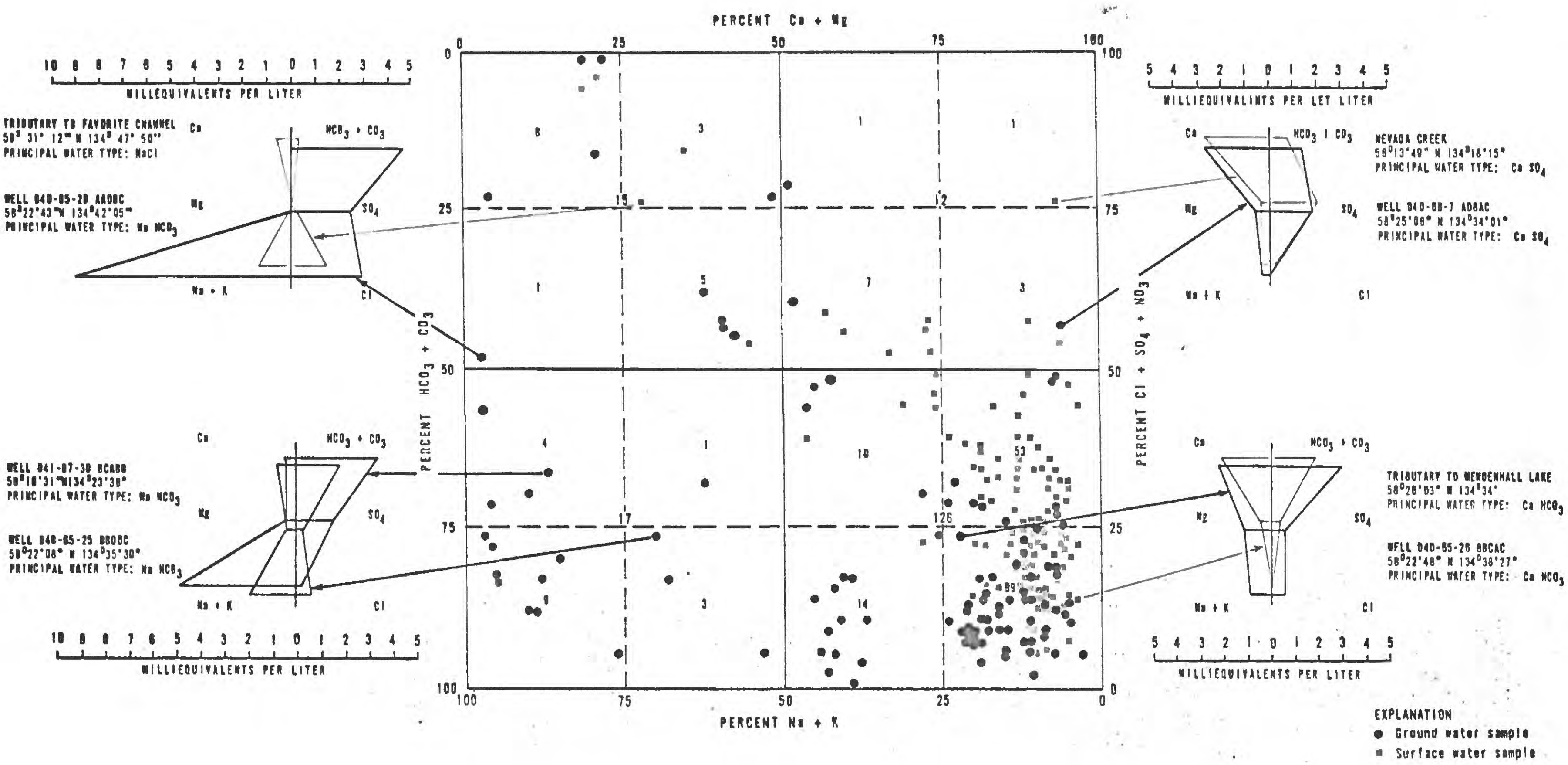


Figure 17 - Comparitive analysis of 220 selected water samples from the City-Borough.
Numerals indicate number of analyses in sector

classification into types and graphical presentation are necessary.

In the City-Borough, precipitation probably has very low dissolved-solids concentrations (10 mg/l or less); surface-water samples have intermediate dissolved-solids concentrations--generally less than 100 mg/l; and the ground-water samples have the highest dissolved-solids concentrations--generally more than 100 mg/l. These concentrations illustrate the progressive increase that might be expected in dissolved-solids content as the water moves through the hydrologic cycle.

Different waters are commonly classified by the concentration ratios of principal ions. Figure 17 shows two graphic methods of comparing water-quality data. On the four pattern diagrams near the edges of figure 17, the lengths of the horizontal lines are related to the concentrations of the ions indicated. The diagrams show that individual samples have chemical characteristics that are distinctive. The large scatter diagram in the center of the figure summarizes all water samples analyzed through 1969. It shows that most water in the area is of the calcium bicarbonate type. The sodium bicarbonate type water is soft, and its presence indicates that the rocks may be functioning as a natural water softener that exchanges sodium ions for calcium ions.

One noteworthy feature of the analyses is the very low dissolved-solids content--ranging from 7 to 296 mg/l--of all fresh surface-water samples; the commonly recommended limit for the dissolved-solids content of potable water supplies for human consumption is 500 mg/l (U.S. Public Health Service, 1962, p. 7). The range of dissolved solids for all samples is shown in figure 18. The ground water generally contains somewhat higher concentrations of dissolved solids than the surface water. The uncontaminated ground-water samples in the City-Borough ranged from 20 to 936 mg/l; however, only about 5 percent of the ground-water samples exceeded 500 mg/l dissolved-solids concentrations.

A common manifestation of low dissolved-solids content is the tendency for the water to be corrosive. Corrosion is a chemical action by which a metal changes to a more stable compound through chemical reaction; thus, steel forms iron oxide or rust. Water having a low dissolved-solids content generally is not in equilibrium with its iron-carrying capacity. Consequently, it corrodes the metal and tends to take more iron into solution. If the water is corrosive, the problem can be reduced by choice of metals used or by treatment or both. Waters of the City-Borough are probably corrosive to most iron alloys with the ground waters being somewhat more corrosive than the surface waters.

Nitrate is generally present in ground water at concentrations of 5 mg/l or less. Higher concentrations may or may not indicate septic pollution but are always cause for suspicion. Nitrate in water sometimes is hazardous to babies, the maximum allowable being 45 mg/l. As can be seen from figure 18, the maximum concentration in any water in the Juneau area was less than 10 mg/l and the mean less than 1 mg/l. Hence, as indicated by nitrates, the water now used in the City-Borough is probably free from pollution.

Except for some high iron concentrations, the constituents shown on the accompanying graphs indicate the water is of excellent chemical quality. The iron content of a few samples of ground water in the City-Borough is above the 0.3 mg/l limit recommended for public supply use (U.S. Public Health Service, 1962, p. 42). Water having an iron content in excess of 0.3 mg/l commonly stains plumbing fixtures, cooking utensils, and laundry unless it is specially treated before use. It has no sanitary significance. Where undesirable iron concentrations are found, it may be more economical to treat the water than to explore for a more satisfactory source.

One of the more favorable characteristics of ground water is that it generally contains very little sediment.

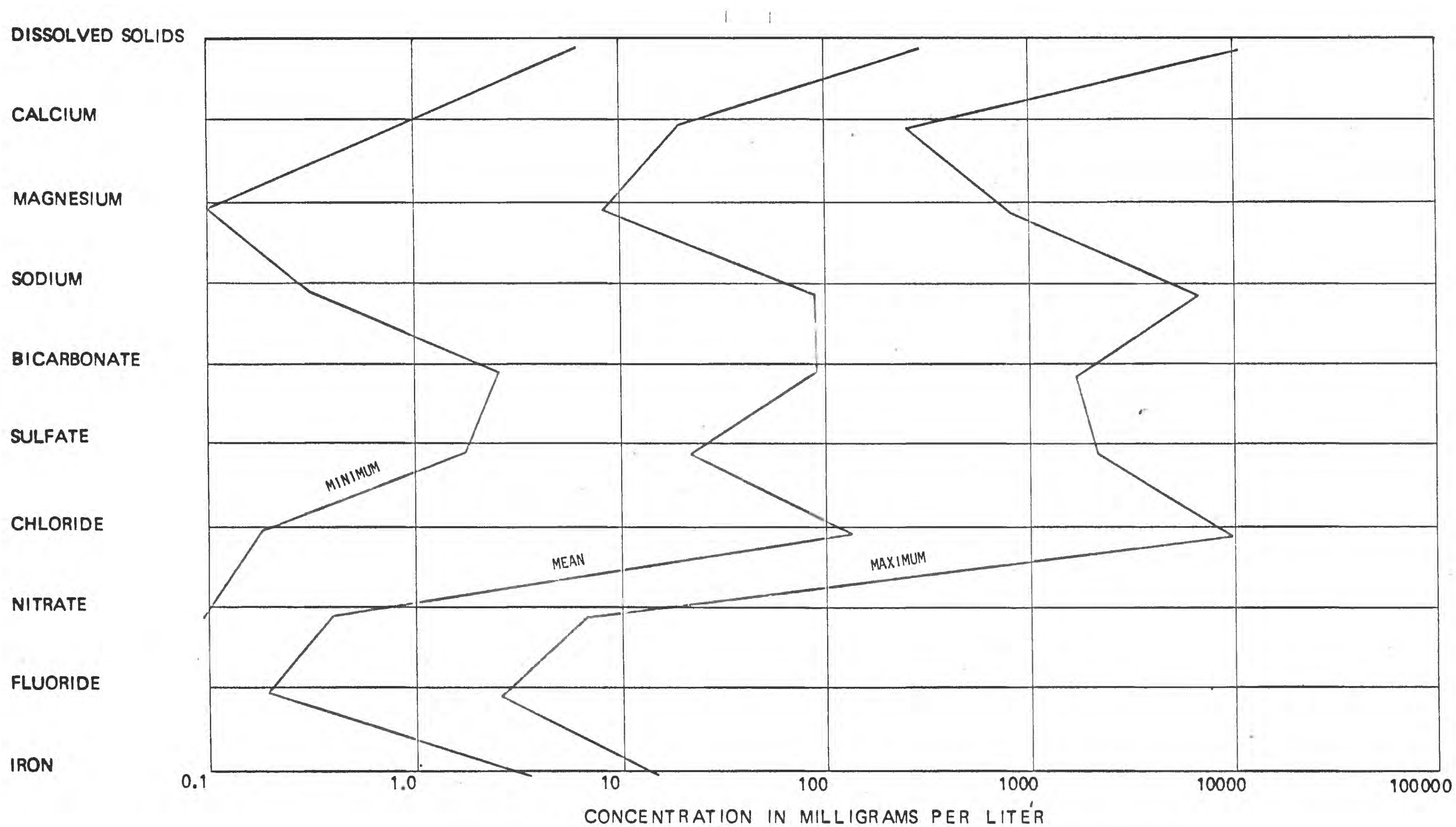


Figure 18.--Range of selected constituents in the water samples from the City-Borough.

However, improperly completed wells can produce water containing considerable sediment.

Surface water rather commonly carries undesirable loads of sediment that must be removed by filtration. The quantity of sediment carried depends on the erodability of the streambed and the velocity of the stream. Surface water may also contain glacial flour. Determination of weight and volume of sediment is necessary for solution of engineering problems such as the expected useful life of natural or artificial reservoirs and the filling of harbors and ship channels. The distribution and amount of sediment can also be informative in explaining geologic processes.

Numerous sediment samples have been taken at various discharge rates to determine the sediment concentration and discharge relationship of selected streams in the City-Borough. A summary of the relationships found (fig. 19) shows that sediment-concentration increase is consistent with increased discharge. None of the streams carried high sediment concentrations when sampled. Fish Creek is unusual in the uniformity of its sediment concentrations. The relatively higher concentration of sediment shown in Lake Creek is a reflection of large quantities of landslide debris in upper reaches of the stream that were observed by D. A. Brew (oral commun., 1968).

The weight of volume of sediment carried by selected streams can be determined from figure 20. For example, figure 19 shows that when Sheep Creek is flowing 100 cfs, the sediment concentration will be about 13 mg/l and figure 20 shows that the stream will discharge about 4 tons per day.

Organic material that is detrimental to water quality consists mainly of decomposed vegetable matter (which causes discoloration) and bacteria (which may be a health hazard). Although organic material occurs in both ground water and surface water, it is much more prevalent in the latter. Generally organic material is readily removed by proper treatment. However, if organic concentrations are high, alternate sources may be desirable.

Analyses for organic contamination of water in the City-Borough are made by the State Health and Welfare Department. According to Mr. Norris Johnson (oral commun., 1969), only a few ground-water supplies have been classified as unsafe. Most of these obtain water from well-point sources and the high organic content indicates local pollution.

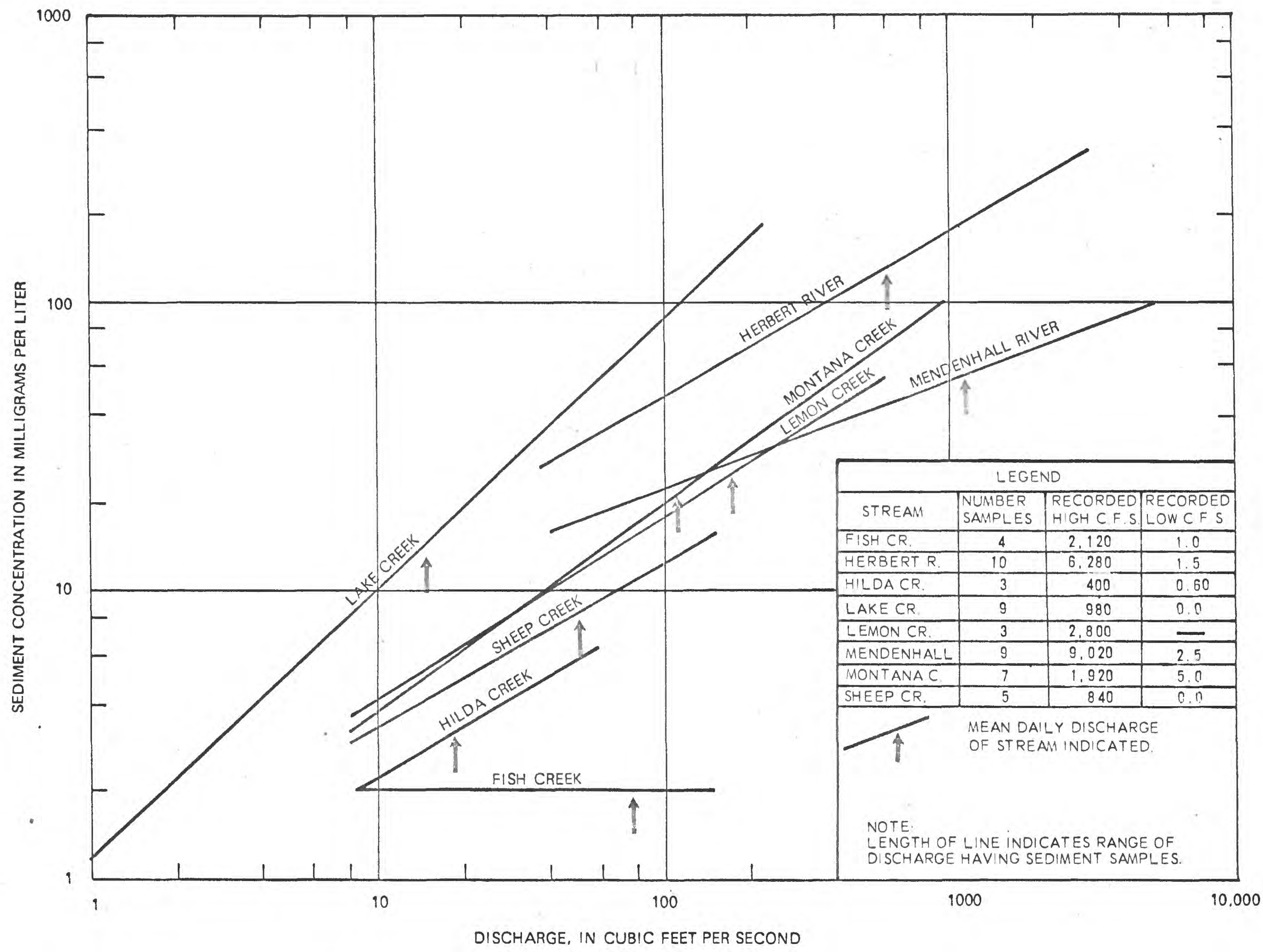


Figure 19-Relationship of suspended-sediment concentration to discharge of selected streams

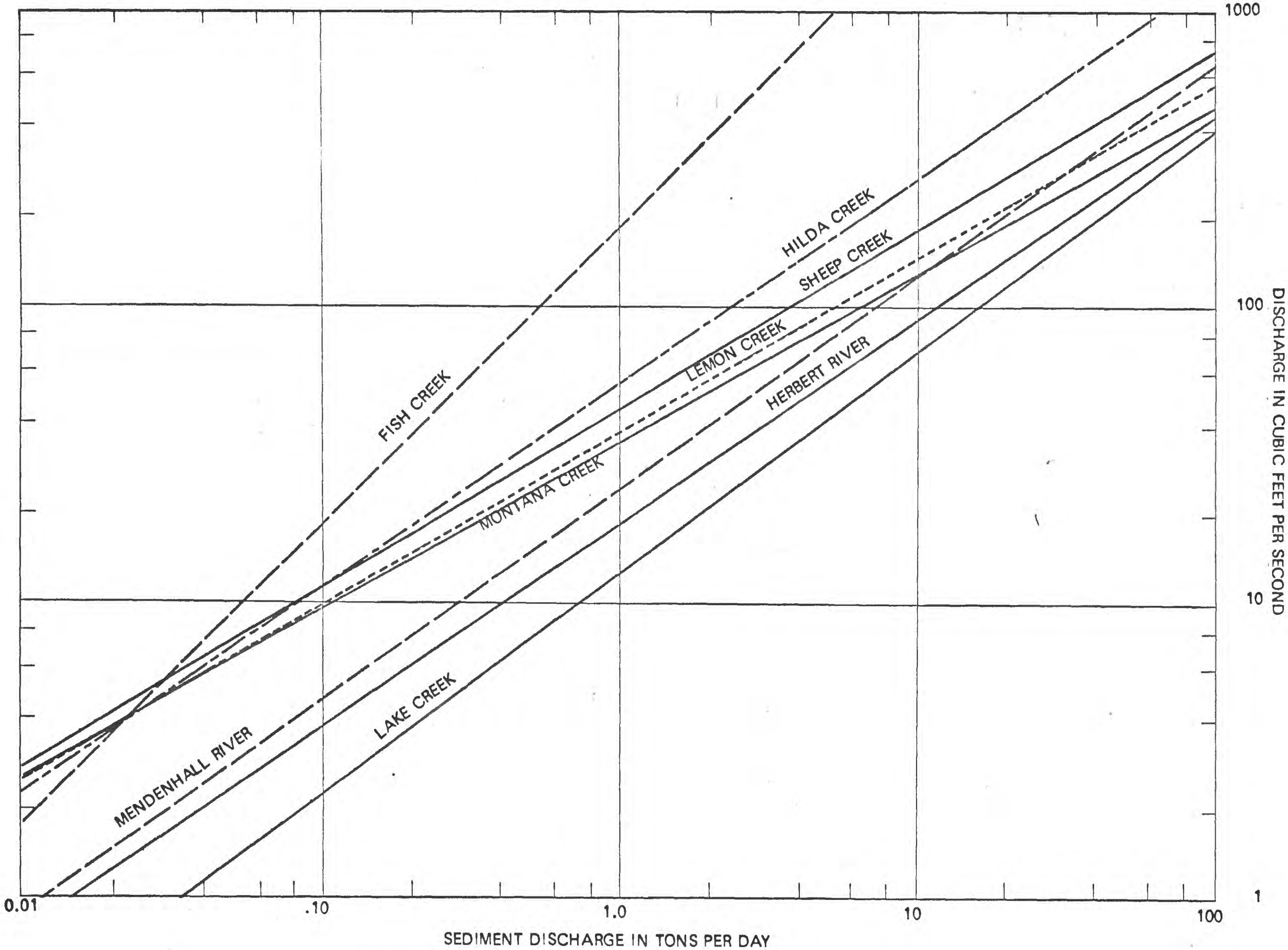


Figure 20.--Sediment discharge in tons per day or cubic feet per day for selected streams at various discharges.

CHAPTER 6

Methods of Developing and Managing the Water Resources of the City - Borough

People concerned with developing and managing the water resources of the area are interested in the relationship between components of the hydrologic system.

This system must respond in a way that is consistent quantitatively with the overall water-budget equation:

$$\text{Inflow} = \text{Outflow} \pm \text{Changes in Storage}$$

where inflow is precipitation and outflow is evapotranspiration of surface water and ground water, subsurface outflow of ground water, streamflow discharging to salt water, and flow of springs. A management program that causes a hydrologic imbalance by continual withdrawal in excess of inflow will result in eventual depletion or deterioration of the fresh water. If one of the management objectives is to use the fresh water in a way that will not result in depletion, increased consumptive use will have to be balanced by increased inflow from precipitation and a net increase in storage (such as artificial recharge) or by a reduction of natural outflow (such as subsurface flow of ground water or streamflow discharge to salt water). If, however, the concept of temporary overdraft is incorporated into a management program, the number of choices increases markedly. For example, increased net ground-water withdrawals can be accomplished in a coastal area if the decision is made to tolerate (a) declining ground-water levels, (b) landward movement of salty ground water, (c) decreased streamflow, or (d) a combination of these factors.

Although the total volume of fresh water-saturated sediments in the Juneau area is small, they probably contain enough water to provide a water supply capable of satisfying current needs while sound long-range water-management plans are being formulated. During this period, wells can be drilled at convenient and suitable locations and can be pumped at rates that might cause temporary overdrafts, if necessary.

Because effective management of the area's water resources depends on the concepts of a water budget, a program of data collection should be continued. Present data are not adequate to provide a base for future water management. The hydrologic cycle (fig. 5) should be defined for each basin to be managed. As water supplies are developed, resource managers should require detailed water-use records on all diversions, pumpage, and storage changes. Because most proposed community developments affect the hydrologic system, specific programs should be designed to collect data that will describe hydrologic changes caused by development.

Present public-supply sources of water have been described by Wyller-Killewich-Van Doren and Hazard (1967, p. II-1 to III-2). Figure 4 shows that most of the City-Borough's present water supply is derived from ground water. The ultimate water system will probably be supplied by both surface water and ground water. Conjunctive use of the resource will permit much greater latitude in the decisions that future water managers must make. For example, a conjunctive-use system would allow water use from streams until flow became insufficient or until high flow caused excessive turbidity. Then the system could increase utilization of water from wells. During winter, when streamflow is low, the ground water is 5 to 10 degrees warmer and would tend to keep the distribution system from freezing. If needed, artificial recharge of the ground-water body using excess surface water near the well field could compensate for temporary overdraft in places where artificial recharge can be effectively used.

Some methods of management will result in salvaging only small quantities of natural stream discharge or will cause only a slight increase in ground-water recharge. Other methods of management, however, will result in salvaging much of the natural stream discharge and also will induce substantial quantities of additional ground-water recharge. The yield of the hydrologic system in the latter case will be many times larger than that in the former case.

The choices usually are to use surface water, to use ground water, or to use varying proportions of each. Before making this choice the water manager must consider the following differences:

Surface Water	Ground Water
1. Availability is highly dependent on seasonal variations in precipitation.	1. Availability is influenced only slightly by seasonal variations in precipitation. Aquifers are generally widespread and store large quantities of water.
2. Withdrawals are limited largely by the perennial supply owing to the small amount of storage.	2. Withdrawals may exceed the perennial supply substantially for extended periods according to the amount of water in storage.
3. Most, if not all, of the perennial supply can be withdrawn from a single point within the system.	3. Only a small part of the perennial supply can be withdrawn from a single point.
4. The rate of transmission of water from place-to-place within the system is rapid.	4. The rate of subsurface transmission of water from place-to-place is comparatively slow.
5. Annual temperature variations are large.	5. Annual temperature variations are small. The temperature is approximately the same as the mean annual air temperature.
6. Removal of silt, and chlorination before use may be required.	6. No treatment, except softening or iron removal, is required.
7. Large evaporation loss occurs from water in storage.	7. Evaporation loss is insignificant.

Because most of the City-Borough is still in an early phase of water utilization, water managers have the time now to formulate plans for the development of central water and sewer systems that will allow the optimum use of the area's water resources. The Mendenhall Valley probably contains aquifers that have never been tapped. Proper well spacing will prevent local overdevelopment. Pollution of the ground water could probably be avoided by proper zoning ordinances.

Several major alternative methods of developing and managing the water resources of the City-Borough are possible. The final selection of one or more water-management plans doubtless will be guided by economic, political, sociological, and other factors, in addition to hydrologic factors. However, an evaluation of factors other than hydrologic is beyond the scope of this report. The remainder of this chapter discusses the possibility of obtaining water by collection of water from small streams, by construction of a well field in the Mendenhall Valley, and by increased utilization of ground water from other basins.

One possible way to meet water demands in the future would be to install a pipeline system to collect water from diversion structures on small streams in the area. Figure 21 shows such a system of collection lines that could be constructed outward from centers in Juneau, Douglas, Hilda Creek, the airport, and Tee Harbor. The quantities of water available from these streams are those shown on page 60 and 61 of the basic-data report (McConaghy, 1969), which are discharge measurements made at times of relatively low flow. Figure 22 shows the average gain in cubic feet per second per linear mile of collection pipeline radiating along present highways from the centers indicated. The overall average for these hypothetical collection lines is about 5 cfs per mile. Based on water gain per mile of pipeline, Juneau is probably the most desirable place to consider such a scheme, whereas the Hilda Creek area is the least desirable.

Figure 21 - Map of Juneau Area Showing Location of Possible Collection Lines for Surface Water

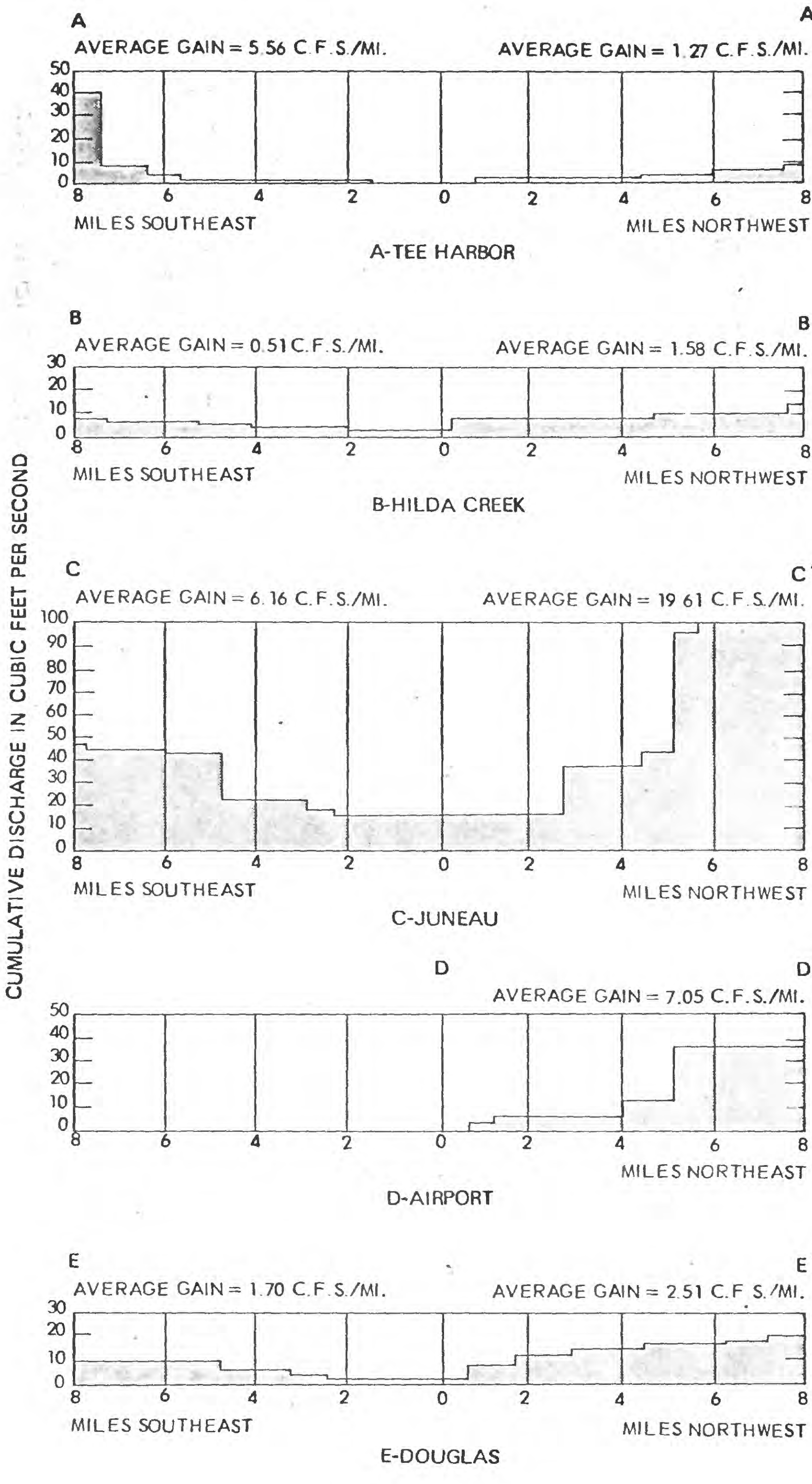


Figure 22--Cumulative surface-water low flow available to radiating collection systems.

The foregoing discussion has shown that adequate water for domestic use of public supply is available in several streams. However, before water is diverted from any stream, other water uses should be considered. For example, in each stream a different minimum discharge is required for salmon migration and spawning. Furthermore, the timing of migration may vary between streams; consequently, each stream must be considered separately.

Where flow in a stream is not always adequate to meet anticipated demand, some storage of water may be desirable. One method of determining storage requirements is by analysis of mass-flow diagrams such as those in figure 23. These diagrams are graphs that show the cumulative monthly streamflow. The slope of such a graph at any point is proportional to the average streamflow at indicated time. Anticipated water-use demand is the slope of dashed lines on the diagrams. Where the demand slope is greater than the supply slope, storage is required. On the figure, the area between the two lines is a graphic expression of the amount of storage required to maintain the desired supply during the period of streamflow deficiency.

The two mass-flow diagrams in figure 23 are representative of the two types of streams in the City-Borough. Diagrams for glacial streams, such as Herbert River, show well-defined steps caused by abnormally high summer discharge rates. Diagrams for nonglacial streams, such as Lawson Creek, show much more uniform streamflow. The Herbert River diagram shows that storage would have been required in 1967 and 1968 for any demand in excess of about 100 cfs. A sustained supply of 500 cfs would be possible after construction of a 150,000 acre-foot reservoir; a sustained supply of 200 cfs would require a 32,000 acre-foot reservoir.

Construction of a public water-supply system in the upper Mendenhall Valley was proposed by Wyller-Killewich-Van Doren and Hazard (1967, p. V1-1). They estimate that, by 1980,

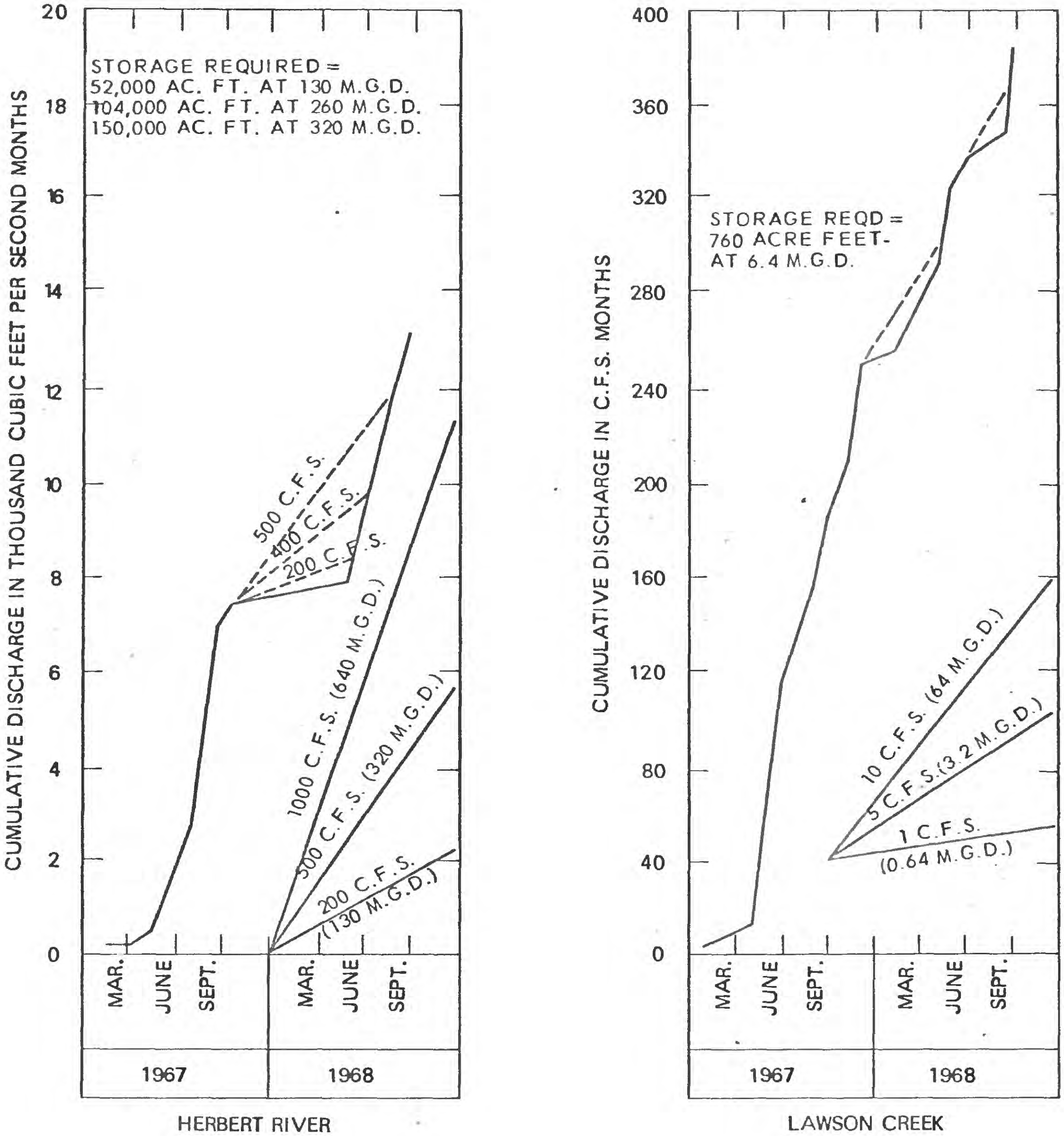


Figure 23--Mass-flow diagrams for Herbert River and Lawson Creek

peak daily demand for the area outside of Juneau and Douglas will be equivalent to 2,000 gpm; they propose four wells to meet this need. Similar demand by the year 2000 is expected to be more than 9,000 gpm. Presumably 18 wells would then be required to supply the demand. Properly designing and locating these wells for optimum use and anticipating their effect on each other and on the hydrologic system require careful planning and management.

Data are not sufficient to predict completely the long-term effects of the proposed well field. Available data should be used to construct a preliminary analog model that can be modified as new data are obtained during development of the well field. Such a model can be as complex or as simple as the available data and the requested information warrant. Possible sources of contamination must also be considered as the well construction and testing program proceeds.

Testing of each new well in the proposed well field is a critical part of construction. In addition to determining the degree of development of the well, the test also has other purposes. A proper test allows selection of the most efficient pump, the ideal operation schedule, and the optimum spacing of new wells that will tap the same water-bearing formation. The test also enables calculation of expected water levels near the well after any period of pumping and indicates the source of the water. The latter helps to avoid contamination by salt water or by water from other undesirable sources and to predict the effects of hydrologic boundaries. Adequate test data are not yet available for the Juneau area but should be obtained as the area's water resources are developed.

The well field in the Last Chance Basin will be placed under greater demands as the population within Juneau increases or if water from the city system is made available to the area outside the city limits. Present data indicate that the aquifer is adequate for current needs and that the aquifer would adequately supply water to additional production wells if they are properly spaced.

The water needs in the Lemon and Salmon Creek valleys will eventually require a central water system that can be supplied by ground water.

If the population density and industrial developments increase markedly along the Gastineau Channel, a water system utilizing additional ground water from the Last Chance Basin and the Lemon and Salmon Creek valleys would probably be able to meet the water needs. These sources could be supplemented by surface water from Sheep and Lawson Creeks.

Because the availability of fresh-water sources will become critical as water demand increases, the sources will need to be protected from pollution.

CHAPTER 7

Future Study Needed

A continuing hydrologic program is needed in the Juneau area. This program, divided into several studies, should be composed of several work elements that are described below.

First of all, the expansion of the basic hydrologic data-collection program is needed. Because a relatively long record is required (in some cases more than 10 years), the data-collection network should be expanded to meet foreseeable needs as soon as practical. This long-term data and that acquired by continued operation provides a base for evaluation of changes in the hydrologic system and suggests alternatives needed in management. Adverse changes can often be minimized by early detection and correct action. Emphasis should be given to those areas that have more potential for urbanization and to those that may contain potential sources of water supply. The formulation of realistic policies and regulations by the City-Borough at this time can do much to assure orderly development and control of Juneau's water resources.

Another pressing need is further definition of the geology of the lower Mendenhall Valley. R. D. Miller (written commun., October 8, 1969) indicated that the thick gravel deposits of Montana Creek are deltaic in origin and older than some of the material in the Mendenhall Valley. If a remnant of these gravel deposits exists in the Mendenhall Valley, it could prove to be a major fresh ground-water reservoir. Clay lenses may preclude the use of surface geophysical methods for the detection of underlying aquifers. Until an exploratory test hole is drilled to bedrock, the presence or absence of a major potable water-bearing zone in the deepest part of the valley will remain mere speculation. If such a zone were to be discovered, it could cause major changes in water-resources development in the City-Borough. Present geophysical data indicate that the test hole would reach bedrock about 700 feet below land surface.

A more complete description of the geohydrology of other major valleys is also needed. This would require additional field study and test drilling. These studies would serve to define the boundaries of surficial materials and thus delineate principal aquifers.

The flow of Salmon Creek is artificially controlled by operators of the powerplant. Discharge water from the powerplant has potential as a public-supply source, but evaluation of this source was not feasible during this investigation. Study of power-production records could give a preliminary estimate of water availability if the discharge cannot be measured continuously under the proposed continuing project.

All lakes should be evaluated for their potential as water-supply sources, and also for their recreational value. The evaluation should consider the effects of pollution resulting from any change in use.

The rapid development of desalination technology is resulting in progressively lower prices for manufactured fresh water. Costs are expected to show a gradual decline. As the cost of treatment approaches the cost of water from conventional sources, sea water in the City-Borough may become a valuable resource. Long-range plans should include the continuing evaluation of the sea-water resource and the steps necessary to protect it from pollution. This study should involve observation of current flow patterns and quality of sea water.

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