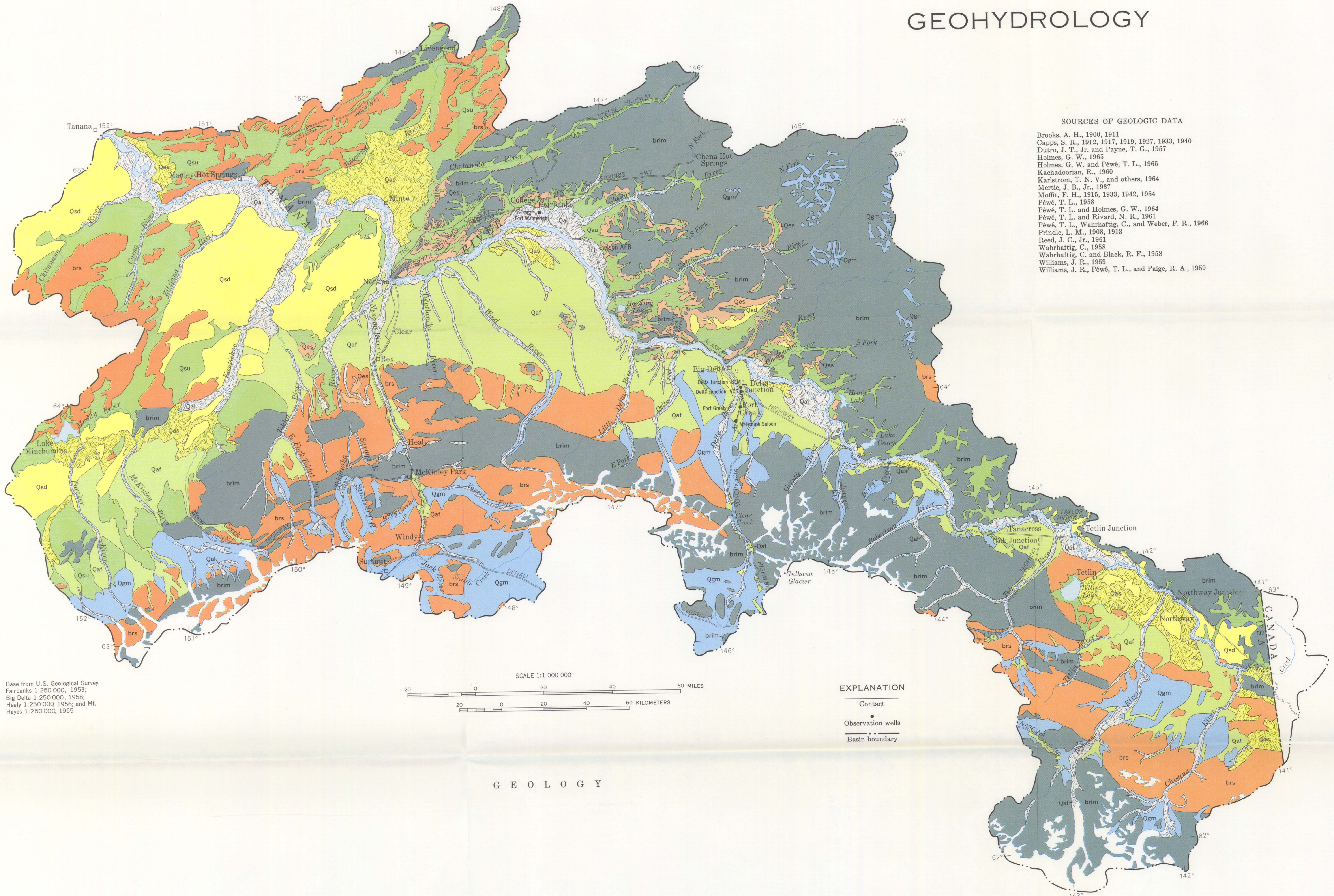
GEOHYDROLOGY



G E O L O G Y

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GEOLOGIC HISTORY

The geologic framework of the Tanana basin is similar to that of the western conterminous United States. The Alaska Range can be compared to the Sierra Nevada of California; north of Alaska Range, the uplands, mountains, and alluvium-floored lowlands are geologically similar to the intermontane plateaus of western North America. Rocks ranging in age from Precambrian to Holocene record alternating marine invasion, volcanism, mountain building, erosion, and sedimentation (table below). The development of most of the present landscape and erosion and deposition of the unconsolidated sediments took place in the Quaternary Period of the Cenozoic Era.

Era	Duration of Era, in millions of years	Summary of events
Cenozoic	63	Continuing orogenic activity, intrusive, or extrusive volcanism, advance and retreat of glaciers, formation and thawing of permafrost, formation and erosion of sand dunes and loess deposits, and filling of basins with fluvial sediments
Mesozoic	167	End of major marine invasion, extensive orogenic activity with implacement of major batholiths, deposition of clastic and volcanic rocks in basins
Paleozoic	370	Extensive marine deposition, some orogenic activity, and minor igneous intrusion
Precambrian	2,700	Complex history of marine deposition and orogenic activity

GEOLOGIC FORMATIONS AND THEIR WATER-BEARING PROPERTIES

The mountains surrounding the basin generally consist of folded, faulted, and metamorphosed sedimentary and igneous rocks including slate, schist, gneiss, argillite, marble, and greenstone. Deposited on, and subsequently folded and faulted with the basal metamorphic complex, are limestone, sandstone, shale, conglomerate, chert and volcanic rocks. Igneous rocks were intruded into the metamorphic and sedimentary complex. Information on the water-bearing properties of the rocks is very limited. The bedrock generally is dense and compact; however, fractures due to faulting, folding, and weathering have imparted secondary permeability to these rocks. For this report the entire bedrock section is grouped into two units: sedimentary bedrock (brs) and igneous metamorphic (brim), all of pre-Quaternary age. Their areal distribution is shown on the geologic map and their water-bearing properties are summarized in the explanation.

Virtually all of the Tanana basin is mantled by unconsolidated Quaternary deposits either in the form of glacial, alluvial, eolian, or colluvial sediments. Near Minto approximately 2,000 feet of unconsolidated sediments have been found by test drilling. Their areal distribution is shown on the geologic map and their water-bearing properties are summarized in the explanation.

MAP EXPLANATION AND SUMMARY OF UNITS

Map unit	Lithology	Landforms and occurrence	Surface drainage, infiltration, and permeability	Probable ground-water conditions
Qal Flood-plain alluvium	Well-stratified to lenticular silt, sand, and gravel. Ice content low. Gravel and sand near mountains grading to sand and silt away from mountains.	Forms alluvial flood plains and low terraces of the Tanana River and major tributaries.	Surface drainage poor to moderate because of low relief; infiltration moderate to good, except where covered by silt or underlain by permafrost; permeability moderate to good.	Ground-water availability good because of extensive saturated thickness and abundant recharge. Yields of 1,000 to 3,000 gpm (gallons per minute) generally available from depths of less than 200 feet. Static water levels less than 50 feet, but depth to permeable sediments as great as 400 feet.
Qaf Alluvial fans	Well-stratified to lenticular gravel and sand with silt. Ice content low. Upper part consists of poorly stratified silt and silty sand with moderate to high ice content.	Forms broad coalescing fans along the north flank of the Alaska Range and small fans in the mountain valleys. Apexes of fans commonly dissected to form high terraces.	Surface drainage moderate to good; infiltration moderate to good; permeability moderate to good.	Ground-water availability good because of extensive saturated thickness and abundant recharge. Yields up to 3,000 gpm generally available from depths less than 200 feet. Locally, the depth to water is greater than 400 feet near the mountain fronts or in the deeply dissected fans of the major streams, and recharge is limited in the areas furthest removed from major streams.
Qas Alluvial silt and sand	Well-stratified to lenticular silt, sand, and minor amounts of gravel. Upper part consists of poorly stratified silt, silty sand, and peat. Ice content moderate to high.	Forms flood plains and low terraces characteristic of the subsiding areas near Minto and Northway.	Surface drainage poor because of low relief; infiltration poor because of silt and permafrost; permeability poor to moderate.	Ground-water availability poor to moderate because of low permeability. Unit grades to more permeable sediments at depths greater than 100 feet. Yields up to 1,000 gpm generally available from depths less than 200 feet.
Qes Eolian silt	Massive, homogeneous silt and minor amounts of clay and fine sand. No permafrost except in poorly drained areas.	Forms deposits covering bedrock uplands, common on the north side of the Tanana River.	Surface drainage good; infiltration moderate to good; permeability poor.	Ground-water availability poor because of limited saturated thickness and low permeability. Unit generally less than 200 feet thick.
Qsd Sand dunes	Well-sorted eolian sand and silt. Permafrost absent or at considerable depth.	Forms longitudinal and parabolic dune fields near the Kantishna River and near Northway.	Surface drainage good on slopes, poor in depressions; infiltration moderate to good, except where covered by silt or underlain by permafrost; permeability poor to moderate.	Ground-water availability assumed to be poor to moderate because of limited saturated thickness and recharge. Unit generally less than 200 feet thick.
Qsu Undifferentiated alluvial, colluvial, or eolian sand and silt	Massive, poorly- to well-sorted silt, sand, and peat. High ice content.	Forms alluvial and colluvial fans and valley fills consisting of reworked sediments. Blankets uplands in southwest area of map. Common in tributaries debouching from the Yukon-Tanana Upland and in the Kantishna River region.	Surface drainage poor because of low relief; infiltration poor because of silt and permafrost; permeability poor.	Ground-water availability poor because of low permeability. Unit generally less than 200 feet thick.
Qgm Glacial moraines	Heterogeneous mixture of silt, sand, and gravel. Permafrost ranges from low ice content in coarse material to high ice content in fine material.	Forms hummocky terrain extending beyond glacial valleys which dissect the Alaska Range. Scattered, extensively weathered, deposits in the Yukon-Tanana Upland.	Surface drainage good on slopes, poor in depressions; infiltration and permeability ranges from poor to good depending on soil texture and permafrost.	Ground-water availability poor to moderate because of limited saturated thickness and low permeability. Unit generally less than 400 feet thick.
brs Sedimentary bedrock	Poorly- to well-consolidated sandstone, limestone, shale, and gravel conglomerate and interbedded coal and clay. Generally covered with thick deposits of rubble, talus, and colluvium. Low ice content.	Forms low, rounded hills, linear ridges, and mountains in the Yukon-Tanana Upland and the Alaska Range.	Surface drainage good; infiltration poor to moderate; primary permeability poor, secondary permeability in faults and fractures poor to moderate.	Unit has no wells. Ground-water availability assumed equal to or better than for igneous and metamorphic bedrock.
brim Igneous and metamorphic bedrock	Igneous and metamorphic rocks well-consolidated, dense, commonly fractured and faulted. Mantled by moderate to thick deposits of weathered bedrock and colluvium. Low ice content.	Forms low, rounded to steep hills and mountains in the Yukon-Tanana Upland and the Alaska Range.	Surface drainage good to excellent; infiltration poor to moderate; primary permeability poor, secondary permeability in faults and fractures poor to moderate.	Ground-water availability poor to moderate because of limited saturated thickness and low permeability. Yields less than 50 gpm at depths from 100 to 200 feet.

PERMAFROST

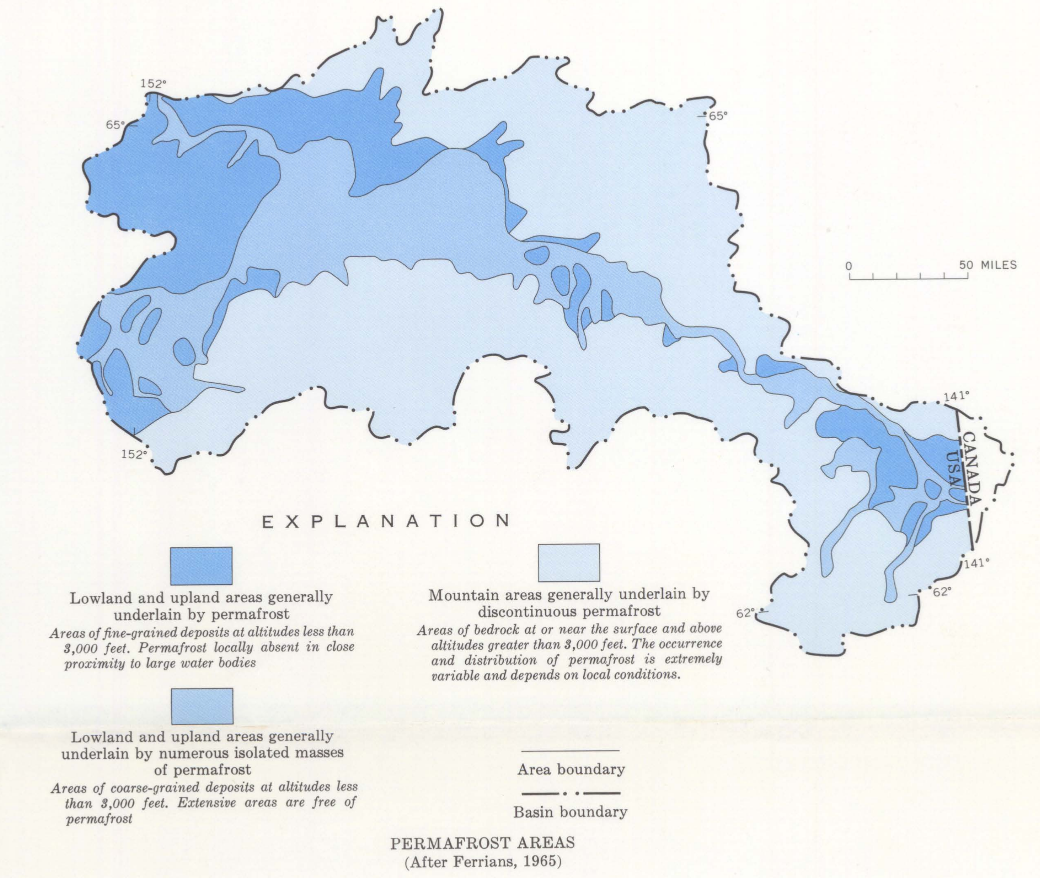
The Tanana basin is entirely within the discontinous permafrost zone of Alaska (Hopkins and others, 1955, p. 116.) Although the perennially frozen ground is discontinous, frozen areas outnumber unfrozen areas.

"Permanently frozen ground or permafrost is defined as a thickness of soil or other superficial deposit, or even of bedrock, at a variable depth beneath the surface of earth in which temperature below freezing has existed continually for a long time (from two to tens of thousands of years). Permanently frozen ground is defined exclusively on the basis of temperature, irrespective of texture, degree of induration, water content, or lithologic character" (Muller, 1945, p. 3).

The primary prerequisite for the formation of permafrost is that of mean annual air temperature below freezing. The exact temperature requirements are not defined but probably range from 24°F. to 30°F. (Brown, R. J. E., 1963). Within similar temperature zones favorable for the formation or preservation of permafrost, other environmental factors such as subsurface drainage and surface insulation, affect the distribution of permafrost (Hopkins and others, 1955, p. 117). Ferrians (1965) prepared a permafrost distribution map of Alaska. The Tanana basin part of that map is reproduced at the right.

In the Tanana basin, the most continuous permafrost areas have high ice content and are found in poorly drained areas of fine-grained sediments. The sporadic permafrost areas have the lowest ice content and are found in well-drained areas of coarse sediment or bedrock. Permafrost generally does not form, or has melted, below large bodies of water.

The distribution of permafrost in depth is even more variable than the areal distribution and appears to be controlled by sediment texture, ground-water circulation, geothermal gradient, and surface topography. Limited subsurface data indicate that permafrost bodies are lenticular and discontinous. Maximum observed depth of permafrost in the Tanana basin is 265 feet near Fairbanks.



PERMAFROST AREAS
(After Ferrians, 1965)

OCCURRENCE OF GROUND WATER

Ground water in the Tanana basin occurs under unconfined and artesian conditions. Unconfined ground water generally is found in unconsolidated alluvium in the valleys and in fractured bedrock beneath high slopes and ridges. Artesian conditions generally occur in the lower slopes where permeable beds are confined by permafrost or by impermeable sedimentary beds. Along the lower hillslopes, flowing artesian wells are common. The schematic section illustrates ground-water conditions in the Fairbanks area.

The most important source of ground water is seepage from streams, and, to a much lesser degree, direct infiltration of precipitation. The greatest depth of precipitation falls in areas underlain by bedrock; consequently, most of the precipitation runs off. In areas where streams leave the mountains and cross the fans, the water table is generally deep, and much water percolates downward through permeable material. The area of major recharge is along the south side of the valley where the major rivers (see sheet 3) cross alluvial fans.

Because the greatest percentage of runoff is from glacial streams having low variability of annual flow, large annual variations in recharge are not likely to occur unless the climate changes. Channel losses in Jarvis Creek average 10 cfs (cubic feet per second) or 6.5 mgd (millions of gallons per day) per linear mile of channel (see graph, sheet 3). Records of streamflow are not available on Jarvis Creek to evaluate the volume of seepage contributed to ground water. Three years of records of streamflow near the mouth of the Tok River are available; annual runoff at the gaging station is equivalent to approximately 4 inches per year. From the runoff map (sheet 3) annual runoff at point of origin is estimated to be 9 inches. The difference in runoff values is accounted for as channel loss, estimated to be 220 mgd. The quantity of direct recharge from precipitation is not known, but probably is small relative to influent seepage from streams.

The direction of regional ground-water flow generally parallels surface drainage. In areas where influent tributaries debouch from the Alaska Range, ground-water mounds form under the channels and the water flows away from the axis of the tributary. The water-table slope is generally less than the land-surface slope but in a similar direction. The relationship of ground-water and land-surface slopes near Delta Junction is illustrated in section A–A′ drawn parallel to the flow direction.

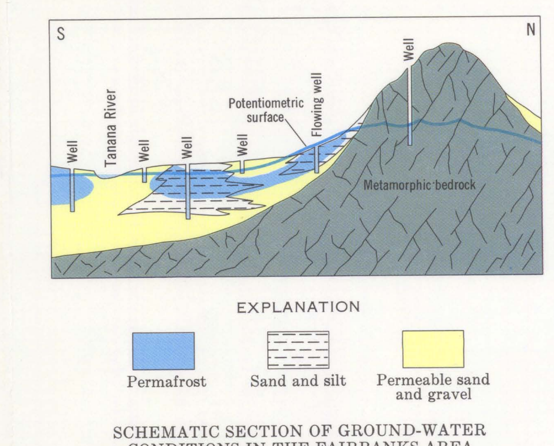
Water-level fluctuations in the Tanana basin are related principally to seasonal changes in recharge and discharge and range from a few inches to more than 50 feet per year. The seasonal fluctuation patterns are illustrated by the hydrographs of five wells. The greatest fluctuation has been recorded in wells near Delta Junction (hydrographs). The distance of the observation wells from influent streams largely controls the time and magnitude of seasonal changes. Wells within an immediate area of recharge, such as at Delta Junction Alaska Communication System (section A–A′ and hydrographs) have large fluctuations. On flood plains and low terraces where the ground water is shallow, the surface streams alternately gain and lose in flow. Water-level fluctuations in flood plains and low terraces show more correlation with surface-water stage than with local precipitation as shown by the record of the observation well at Fort Wainwright at Fairbanks (hydrographs and comparison graph). The fluctuations also are more variable than those in wells on alluvial fans. Water-level fluctuations in bedrock respond to snowmelt and precipitation recharge, but the changes usually are small.

Only locally have ground-water withdrawals affected water levels. Most noticeable effects are in areas of bedrock and alluvium with restricted recharge, such as in the residential part of the hills north of Fairbanks.

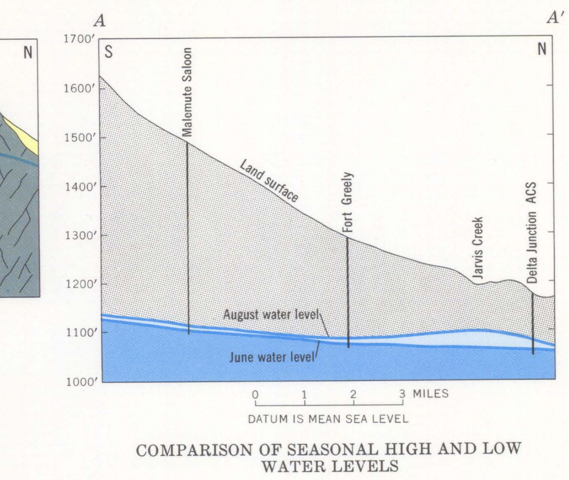
Most of the ground water moves out of the basin by underflow through alluvium and by contributing to streamflow. Only a small part of the ground-water discharge is by pumping from wells (less than 15 mgd) and evapotranspiration in the present stage of development of the basin.

Permafrost affects and is affected by the hydrology. As permafrost is virtually impermeable, it restricts recharge, discharge, and movement of ground water, creates artesian conditions, and limits storage capacity. As an impermeable substratum, it prevents infiltration from runoff and creates lakes and swamps. Permafrost is a form of water storage. Little is known concerning the volume in storage and changes of storage as permafrost in the Tanana basin.

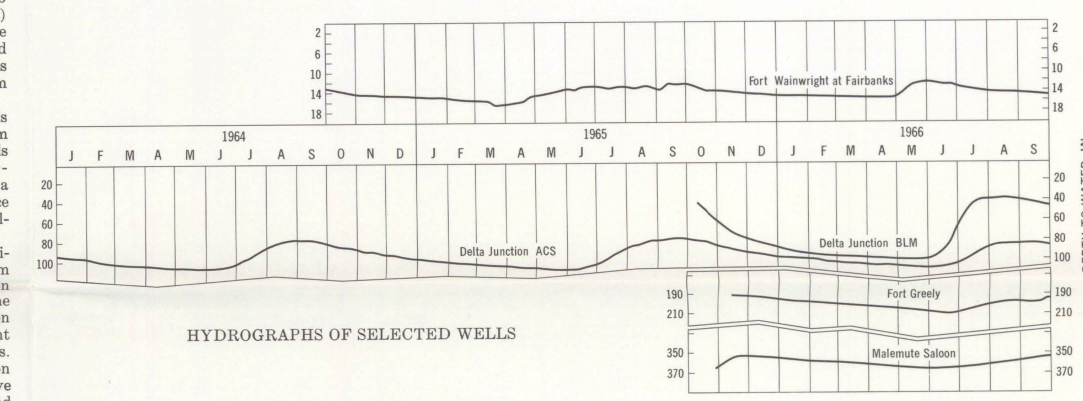
Conversely the thermal effects of water exert a dominant control on the permafrost regimen. Deeper lakes and rivers and the circulation of ground water cause the degradation of permafrost and limit its distribution both vertically and areally.



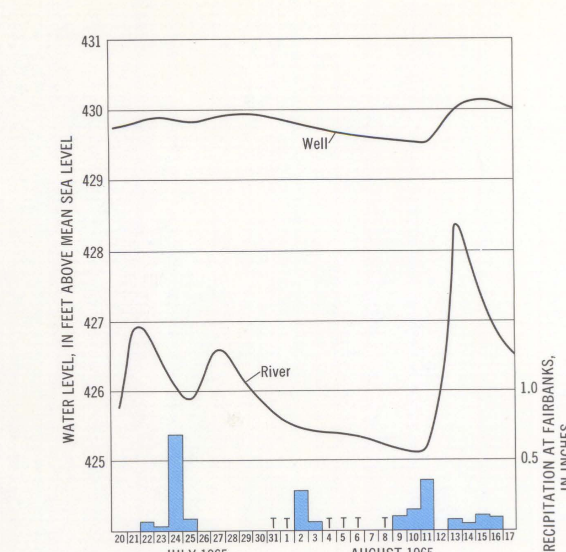
SCHEMATIC SECTION OF GROUND-WATER CONDITIONS IN THE FAIRBANKS AREA



COMPARISON OF SEASONAL HIGH AND LOW WATER LEVELS



HYDROGRAPHS OF SELECTED WELLS



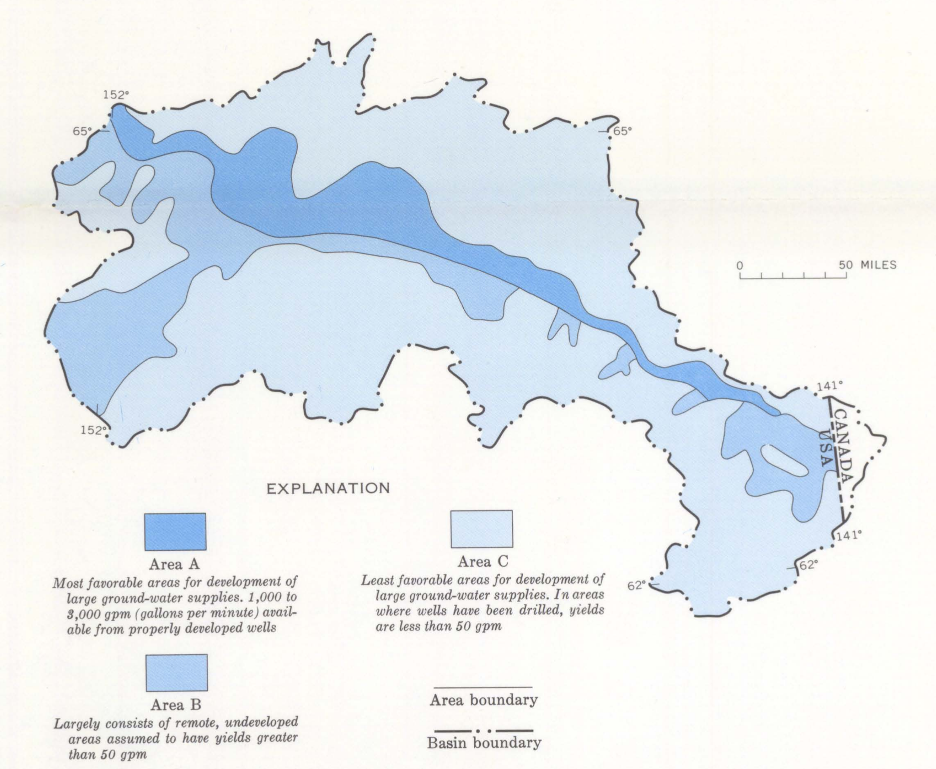
COMPARISON OF THE STAGE OF CHENA RIVER AT FAIRBANKS A NEARBY WELL RECORD, AND PRECIPITATION

AVAILABILITY OF GROUND WATER

The map at the right illustrates the general availability of ground water within the Tanana basin. The most favorable area of development, A, is in the alluvium and glacial outwash of the Tanana River and its major tributaries. Yields from 1,000 to 3,000 gpm (gallons per minute) from depths of less than 200 feet are commonly available from properly developed wells. The maximum recorded depth to water-bearing sediments because of overlying impermeable silt is 427 feet and because of permafrost is 265 feet. Both wells are in the Fairbanks area. The static water levels after well completion were less than 20 feet from the land surface.

Area B includes coarse and fine alluvium in areas of limited recharge. The area is largely undeveloped, but from the meager data available it appears that yields greater than 50 gpm could be developed at depths less than 500 feet. In the upper Tanana basin, near Northway, where the area has had limited development, wells are less than 300 feet deep and yields are less than those of area A. Along the flanks of the Alaska Range, in the central part of the basin, geologic mapping indicates that the sediments are coarse. However, meager ground-water data indicate that the depth to water is commonly greater than 300 feet and that the ground-water supplies may be small because of the limited recharge. In the lower Tanana basin, the ground-water availability is inferred entirely from the geologic maps.

Area C includes the sedimentary, igneous, and metamorphic bedrock complexes. Extensive development of this unit has occurred only in the Fairbanks area. Yields are less than 50 gpm from wells that range in depth from less than 50 to more than 550 feet.



GROUND-WATER AVAILABILITY

HYDROLOGIC RECONNAISSANCE OF THE TANANA BASIN, CENTRAL ALASKA

By
G. S. Anderson

1970