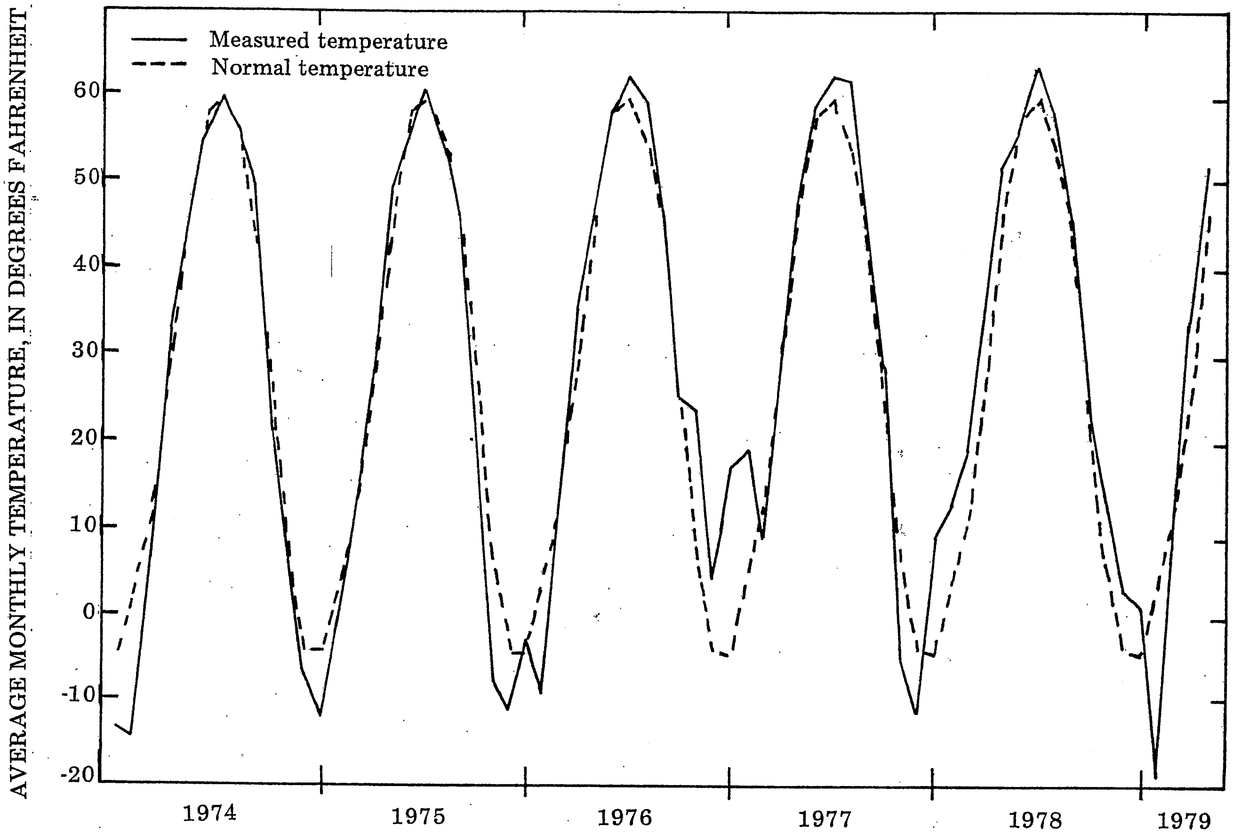


Figure 4.--Comparison of measured monthly average temperature with normal monthly average temperature at Big Delta. Climatological normals based on the period 1941-70 (National Oceanic and Atmospheric Administration, National Climatic Center, 1977).

Landforms in the study area include coalescing alluvial fans, moraines, and river flood plains. Broad alluvial fans of the Gerstle and Delta Rivers coalesce with the fans of small creeks entering the area from the Alaska Range to form a continuous alluvial apron at the base of the range. The Delta-Clearwater area was glaciated in at least three episodes (Péwé and Holmes, 1964). Terminal moraines are present in the Delta and Gerstle River valleys and in the valleys of several small creeks draining the north face of the Alaska Range. Wide flood plains have been formed by the Delta, Gerstle, and Tanana Rivers in the study area.

The Delta-Clearwater area is discontinuously underlain by permafrost. Drillers reported permafrost in five of 14 wells on Fort Greely. The depth of permafrost in the well holes ranged from immediately below seasonally frozen ground to as much as 217 ft below land surface. Permafrost has also been reported in wells near Delta Junction, at the Gerstle River Army Test Site, and along the Alaska Highway in test holes drilled at the Barley Project test plot (fig. 2). The water table is usually reported to lie below the permafrost layer (fig. 5). In many places, shallow permafrost causes poor drainage and wet soils. Farmers in the area report that melting of permafrost causes thermokarst features in some newly cleared fields.

Permafrost is virtually impervious. However, significant quantities of water may flow upward through thawed conduits in otherwise extensive areas of permafrost. Thawed conduits are commonly evident at the land surface as springs, spring-fed ponds, or lakes.

HYDROLOGY

Surface water

The Tanana, Delta, and Gerstle Rivers and Jarvis Creek are glacier fed and have broad, braided streambeds. Jarvis Creek at the Richardson Highway and the Gerstle River at the Alaska Highway are generally frozen solid during the winter little or no flow is present from late fall until early spring. However, area residents report that aufeis (overflow ice) forms near the heads of these rivers during the winter. Aufeis formation indicates ground-water discharge. The Delta River also is frozen solid along much of its length during the winter, but discharges of approximately 30 ft³/s have been measured from springs flowing at its mouth. Discharges measured on the Delta and Gerstle Rivers and Jarvis Creek are listed in table 1.

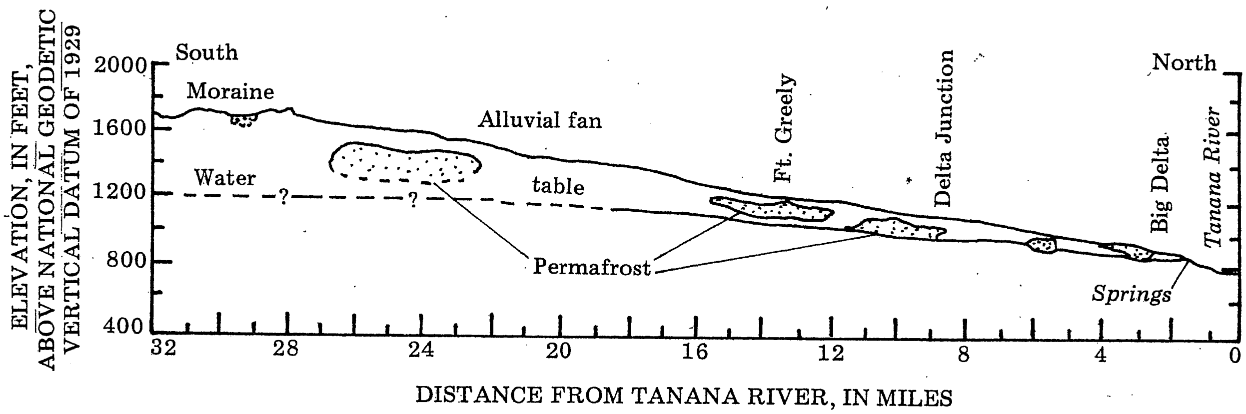


Figure 5.--Schematic drawing of permafrost and ground-water relations in the western Delta-Clearwater area (after Péwé, 1955).

The Tanana River receives relatively warm water from Clearwater Creek and the outlet of Clearwater Lake, which keeps the river open year-round at Big Delta. The Geological Survey maintained a gage on the Tanana River at Big Delta from 1948 to 1957. During the period of record the minimum discharge was 3,720 ft³/s on April 7, 1957; the maximum was 62,800 ft³/s on July 29, 1949. The average flow was 14,950 ft³/s.

Several small creeks entering the study area from the Alaska Range to the south have channels that extend only a short distance from the base of the mountains. Only Sawmill Creek has a channel that reaches as far north as the Alaska Highway. All these creeks appear to cease flowing during the winter, but aufeis in the upper reaches has been reported by local residents.

North of the Alaska Highway, near the toe of the continuous alluvial apron, lies a network of spring-fed creeks (Clearwater, Sawmill, and Granite Creeks), termed the Clearwater Creek network for purposes of this report, and spring-fed Clearwater Lake. Their flows, at specific sites, were measured in this study and are discussed later.

Sawmill and Granite Creeks each have upper and lower reaches that are not hydraulically connected, except possibly during periods of high flow. The upper reaches drain small valleys on Granite Mountain and commonly lose all their flow to the alluvial fan. Flow in the lower reaches heads at spring orifices north of the Alaska Highway.

Table 1.--Discharge measurements of rivers and creeks in the Delta-Clearwater area

	Date	Discharge (ft^3/s)
Gerstle River at Alaska Highway	08-25-1966	452
	09-15-1967	127
Jarvis Creek at Richardson Highway	07-23-1948	561
	09-18-1948	113
	07-07-1949	748
	05-21-1955	172
	05-24-1955	193
	06-07-1955	286
	06-16-1955	266
	06-20-1955	578
	06-23-1955	284
	08-03-1955	683
	08-26-1955	299
	09-30-1955	65
	11-04-1955	0
	01-31-1956	0
	03-02-1956	0
	05-09-1956	320
	06-13-1956	265
	07-21-1956	880
	08-25-1966	254
	09-16-1966	136
	06-15-1967	784
	06-27-1967	493
Delta River 1.8 miles south of Big Delta	08-24-1966	5,130
	10-19-1966	24
	05-17-1967	662
	06-14-1967	7,780
	07-18-1967	9,930
	09-14-1967	2,820
Sawmill Creek 3.0 miles upstream from Granite Creek	08-25-1977	49
Sawmill Creek 0.2 mile upstream from Granite Creek	08-25-1977	209
Granite Creek 0.1 mile upstream from mouth	08-25-1977	53
Clearwater Creek 0.1 mile upstream from Sawmill Creek	08-25-1977	135

Ground Water

Occurrence

The alluvial aquifer system in the Delta-Clearwater area is composed of thick sediments that overlie bedrock. From geophysical information, R. D. Reger (oral commun., 1979) estimated that bedrock is possibly as deep as 2,500 ft between the Delta River and Clearwater Lake, as well as south of Clearwater Lake. The thickness of saturated sediments may be nearly this great. The alluvium has been penetrated by wells to depths of 400 ft at Fort Greely and 549 ft at the Gerstle River Army Test Site.

The alluvial aquifer system may comprise several aquifers separated by leaky confining layers. However, paucity of data precludes dividing it into finer units. In this report, the entire alluvial aquifer system will be treated as a single aquifer with local confinement and will be termed the "alluvial aquifer" or "aquifer". Stratification due to lenticular deposits of silt, sand, and gravel with boulders causes permeability within the alluvial sequence to range widely.

Ground water occurs under confined conditions at Fort Greely (well 50007) and in the Barley Project test plot (wells 51741, 51742, and 51743). Drillers' logs of these and other wells in the area indicate that permafrost does not generally extend into the saturated zone and usually does not act as a confining layer (fig. 5). Silty sediments may locally confine the aquifer; Williams (1970) stated that at Fort Greely it is confined by till of the Delta Glaciation.

The aquifer is unconfined in the vicinity of wells at the Spears Farm (well 51738), near Clearwater Creek (well 51740), and near the Tanana River 18 mi upstream from the Gerstle River (wells 51929, 51930, and 51931).

Recharge to the Ground-Water System

The aquifer is recharged by losing streams along the western, eastern, and southern boundaries of the study area and by infiltration of precipitation.

Jarvis Creek and the Delta River are perched above the aquifer and lose water to it. Nearby wells at Fort Greely and Delta Junction have static water levels as much as 200 ft below the streambeds of these rivers. Waller, Feulner, and Tisdel (1961, p. 123) noted that the gradient of the water table in the vicinity of Fort Greely "indicates that the aquifer receives recharge from the Delta River to the west and probably discharges at the land surface to the northeast, in the Clearwater Lake area." Holmes and Benninghoff (1957) reported that Jarvis Creek loses large quantities of water into its streambed. A series of five discharge measurements made at each of four sites along Jarvis Creek in 1955 show that the seepage losses varied during the summer and with discharge. These seepage measurements indicated water losses as great as 3.5 $(ft^3/day)/ft^2$ of channel. Recharge to the aquifer by these rivers appears to be reflected by seasonal water-level fluctuations discussed in the "Water Levels" section.

Analysis of the study area indicates an unknown, probably substantial, amount of recharge through the streambed of the Tanana River along the eastern boundary of the study area. Three wells near the Tanana River 18 mi upstream from the Gerstle River were drilled to determine whether the reach of the river in this area loses water to the aquifer. Ground-water levels in the wells are approximately 30 ft below river level; thus the river in their vicinity is perched. Additionally, from water-level data collected from these three wells on October 15 and November 16, 1978, and July 19 and September 27, 1979, hydraulic gradients were computed. In October and November 1978 and September 1979, the gradient sloped west-northwest at 3-5 ft/mi; in July 1979 it sloped southwest at about 4 ft/mi. The water-table gradient and the relation of the river level to the ground-water level are evidence that losses from the Tanana River are recharging the aquifer in the reach near the wells.

During an August 1977 aerial reconnaissance, visual estimates of discharge of the Gerstle River indicated a losing reach from the point where the river exits a canyon on Granite Mountain and enters onto the alluvial fan to about 3 mi north of the Alaska Highway bridge. The ground-water level in well 51232 (fig. 2) at the Gerstle River Army Test Site, 3.5 mi south of the Alaska Highway and 1 mi west of the braided section of the river, is about 400 ft below the elevation of the water surface in the river. Seasonal water-level fluctuations of about 13 ft in the well may reflect recharge pulses to the aquifer from this section of the river. No ground-water data have been collected along the lower reaches of the Gerstle River.

Several small creeks draining the north face of the Alaska Range commonly lose all their flow into the ground near the apex of the continuous alluvial apron. In August 1977, during the aerial reconnaissance, the flow in Rhoads, Hajdukovich, Arrow, Cockscomb, and Panoramic Creeks, and the upper reaches of Sawmill and Granite Creeks was estimated at less than 10 ft^3/s each. During the overflight, no flow was observed in these creeks at the Alaska Highway. However, during the spring snowmelt period and during rainstorms in the Granite Mountain area, the discharge in the creeks increases greatly, and the flowing reaches of the streams lengthen in the downstream direction. The volume of ground-water recharge from each of these creeks is directly related to flow because all flow seeps into the ground except possibly during unusual storm events. During summers of 1978 and 1979, local residents reported flow in Sawmill Creek at the Alaska Highway bridge after a few heavy rains. On June 20, 1979, a flow of 5.2 ft^3/s was measured at the bridge; two days later the streambed was reported dry. The dry streambed of the upper reach of Sawmill Creek extends nearly as far north as the spring orifice at the head of the lower reach. During periods of extremely high runoff, surface flow in the upper and lower reaches of Sawmill Creek could conceivably connect; this could alter both the flow and the quality of water in the spring-fed creek network.

Discharge from the Ground-Water System

Water is discharged from the aquifer by springs in the northern and western parts of the study area. The major discharge areas are along the Clearwater Creek network, at Clearwater Lake, and at springs near the mouth of the Delta River. Ground water also discharges to the surface from the hydrologic system as spring-flow into the swampy areas near the Tanana River along the northern boundary of the study area and discharges out of the study area as subsurface flow beneath the beds of the Tanana and Delta Rivers near Big Delta.

The Clearwater Creek network is almost entirely spring fed. The major spring orifice in the network is at the head of Sawmill Creek. A flow of 50 ft^3/s was measured 0.2 mi downstream from this orifice in August 1977. Seepage measurements along Sawmill Creek in August 1977 showed a gain of 158 ft³/s along 2.8 mi of channel. Discharges measured along the spring-fed creeks are shown in table 1. Discharge from May 1977 to July 1979 at the gaging station on Clearwater Creek near Delta Junction is illustrated by the hydrograph in figure 6.* Streamflow shows little variation; discharge ranged from 650 to 773 ft³/s during the period of record. An aerial reconnaissance in December 1977 showed Clearwater Creek and the lower reach of Sawmill Creek were unfrozen, except for shore ice, along their lengths. The inflow of relatively warm ground water keeps these creeks open during the winter months, although the shore ice may be as thick as 2 ft.

Clearwater Lake also is almost entirely spring fed. A discharge of 463 ft³/s was measured at the outlet of Clearwater Lake in September 1977. This is probably some measure of the ground-water discharge into the lake, but flow at the lake outlet is affected by changes in the volume of water stored in the lake, which is related to lake level. The rate at which ground water discharges to the lake also probably varies with the changing level of the lake surface. High-water marks on vegetation and rocks along the shores indicate that the lake level can fluctuate several tenths of a foot; the fluctuations may be related to the stage in the Tanana River. During the winter, ice covers the lake surface except where spring-flow maintains open water.

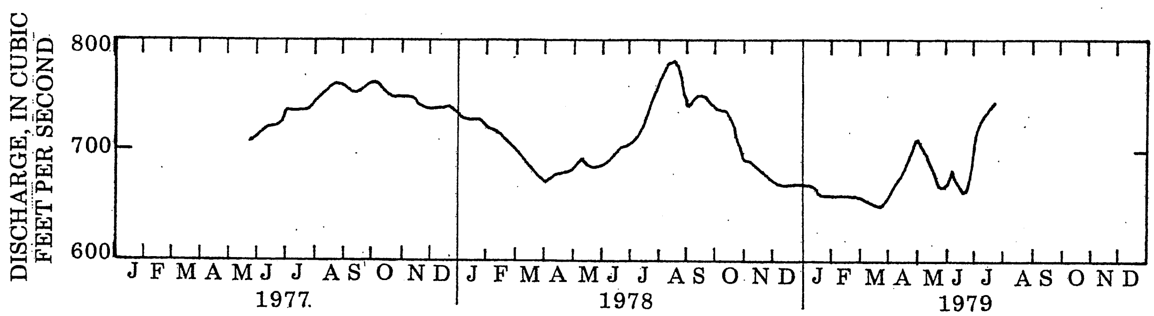


Figure 6.--Discharge hydrograph of Clearwater Creek at gaging station 15477500.

Several perennial springs occur at the mouth of the Delta River. Total discharge of these springs has been measured at about 30 ft³/s in March of 1975, 1976, and 1977.

The year-round ground-water discharge rate from the hydrologic system in the study area is estimated to exceed 1,200 ft³/s. This figure may be conservative because the discharge of Clearwater Creek at its mouth should be larger than at the gage, due to presumed spring inflow along the 7-mi reach downstream of the gage. Additionally, the reach of the Tanana River along the northern boundary of the study area receives significant but unmeasured seepage.

Aquifer Characteristics

Field-determined values of the transmissivity and storage are not available for the aquifer in the Delta-Clearwater area. A pumping test was attempted on the

*Three surface-water sites in the Delta-Clearwater area have U.S. Geological Survey downstream-order station numbers. They are listed in table A at the back of the text along with their corresponding latitudes and longitudes.

production well (51741) in the Barley Project test plot, but the resulting data could not be analyzed without ambiguity.

The presence of silty sediments in many areas may cause some sections of the aquifer to have relatively low transmissivity. However, the hypothesized large thickness of the alluvium and the presence of lenses of sand and gravel probably result in an overall high transmissivity for the alluvial aquifer. Well yields in the area are as high as 1,500 gal/min from a well formerly used to produce cooling water for the now-abandoned nuclear powerplant reactor at Fort Greely.

Water Levels

Ground-water data are available from some sections of the study area. Around the population centers of Big Delta, Delta Junction, and Fort Greely, wells and data are abundant; elsewhere, data are sparse. The potentiometric surface is more than 400 ft below land surface near the front of the Alaska Range, 150-200 ft near Fort Greely, 50-100 ft near Delta Junction, and less than 10 ft near Clearwater Creek, Clearwater Lake, and Big Delta. Waller, Feulner, and Tisdel (1961) reported that the potentiometric surface near Fort Greely sloped in a northeasterly direction at about 11 ft/mi from September through November 1959. Additional data compiled for this study show that the potentiometric surface across most of the study area slopes northward at gradients ranging from about 1 to 25 ft/mi; however, in some areas it slopes northeast and in others northwest.

Ground-water levels fluctuate in response to seasonal recharge pulses to the aquifer from river and stream channel losses and from precipitation. Residents in Delta Junction have reported fluctuations as great as 50 ft/yr in domestic wells. Hydrographs of four observation wells (figs. 7-10) show the seasonal trends clearly. All the hydrographs have a similar, roughly sinusoidal trace. The hydrograph for the Fort Greely well (fig. 7), which includes 4 years of continuous recorder data, shows that water levels are lowest in late May or early June. River ice breaks up in April or May, and the recharge pulse begins; the ground-water level rises until it reaches a peak in October. At this time the rivers freeze and recharge ceases. The ground-water level then recedes until May or June, when recharge begins again. However, silt may clog the streambed gravel and reduce permeability during much of the summer. Recharge may take place largely during periods of high flow when scouring and shifting of channels occur. Low and high water levels in the Spears Farm irrigation well (fig. 8) and the Geological Survey's Tanana test well (fig. 9) also occur in June and October, respectively. The lowest water level in the Barley Project well (fig. 10) was in July; the highest was in December.

The water levels recorded in the Fort Greely well during 1978 and 1979 are the highest for the 16 years of record. They may reflect delayed ground-water recharge from 1975, 1976, and 1977 (fig. 3) when summer rainfall was greater than normal at the Big Delta FAA station (National Oceanic and Atmospheric Administration, 1974-1979). Other ground-water levels measured during this study may also be above normal.

Hydrologic Flow

The hypothesized ground-water flow system is shown in figure 11. Data are insufficient to justify more than a gross conceptual model. The aquifer discharges at the Clearwater Creek network, at Clearwater Lake, and also at the mouth of the

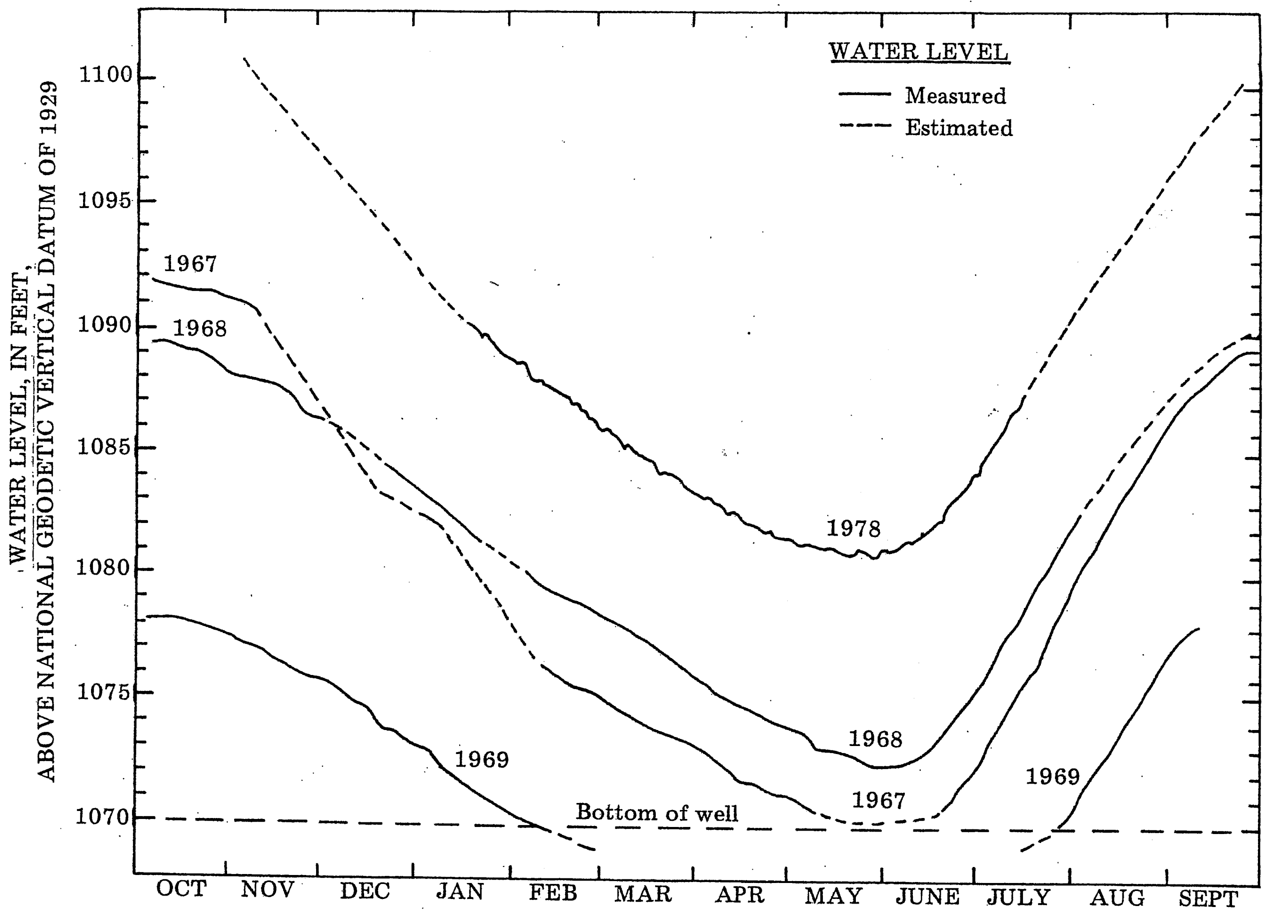


Figure 7.--Hydrograph of well 50007, Fort Greely No. 7.

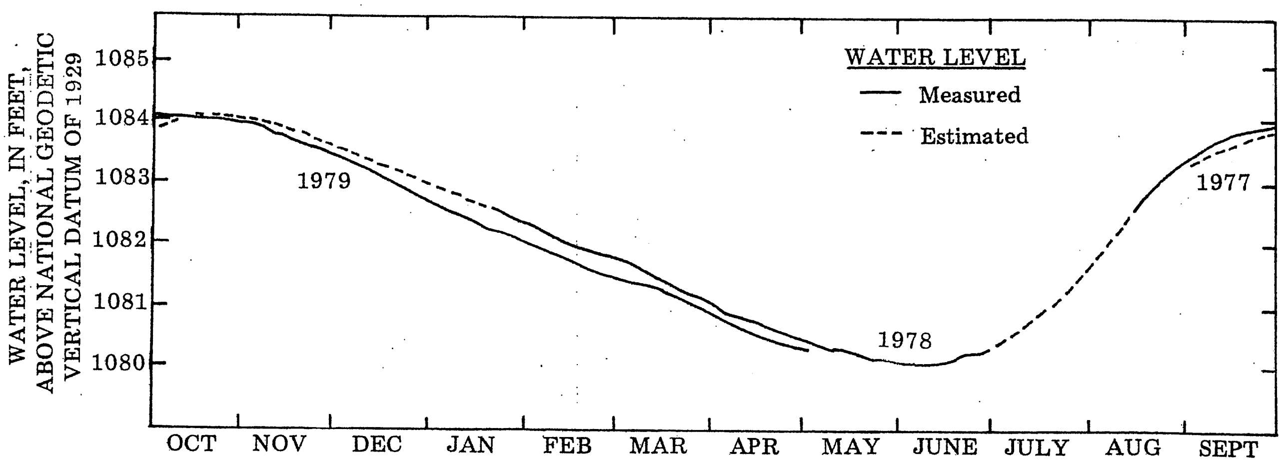


Figure 8.--Hydrograph of well 51738, Spears Farm.

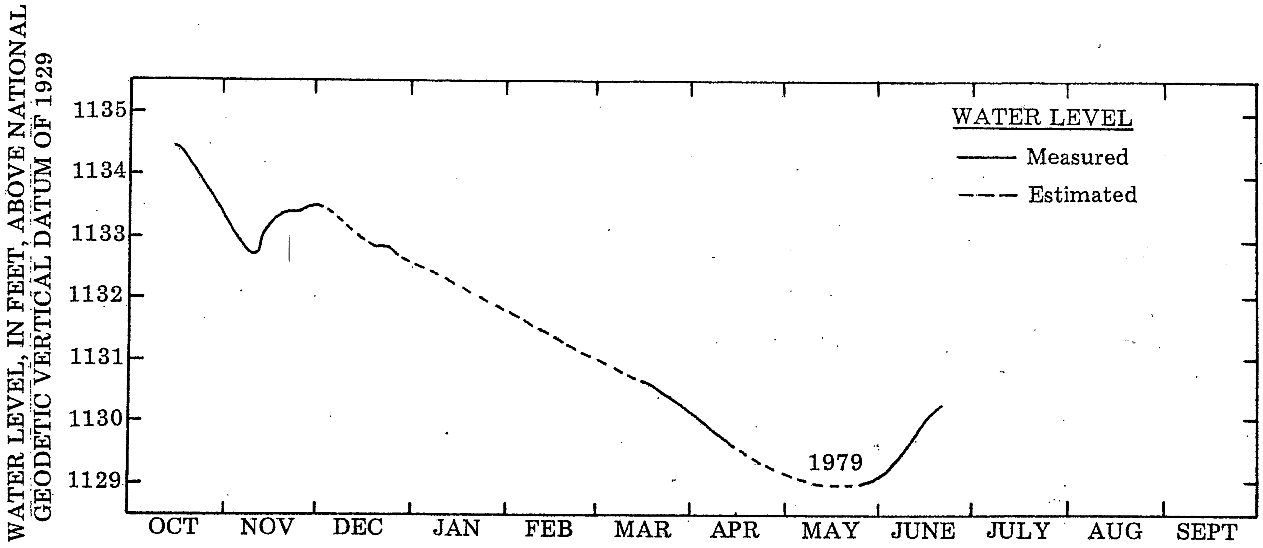


Figure 9.--Hydrograph of well 51930, U.S. Geological Survey Tanana Test Well No. 1.

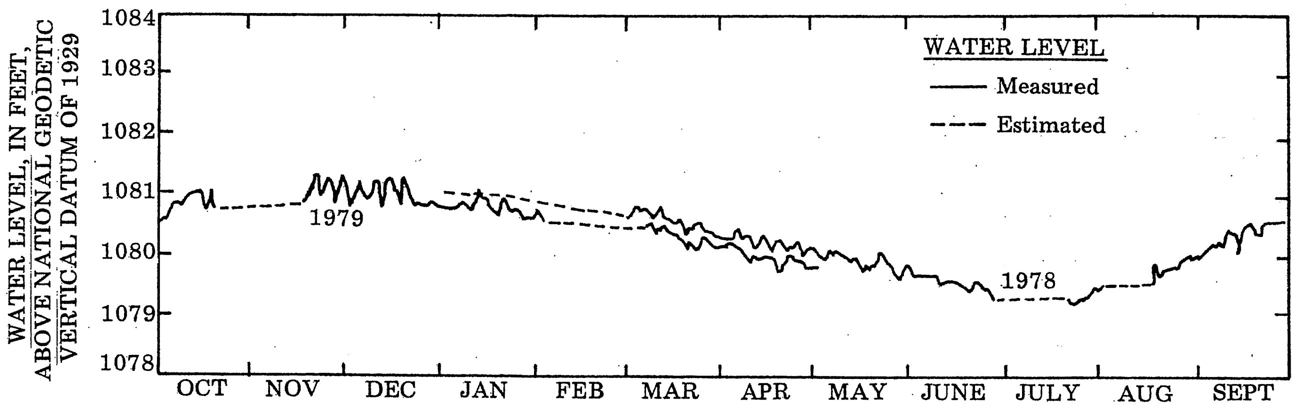
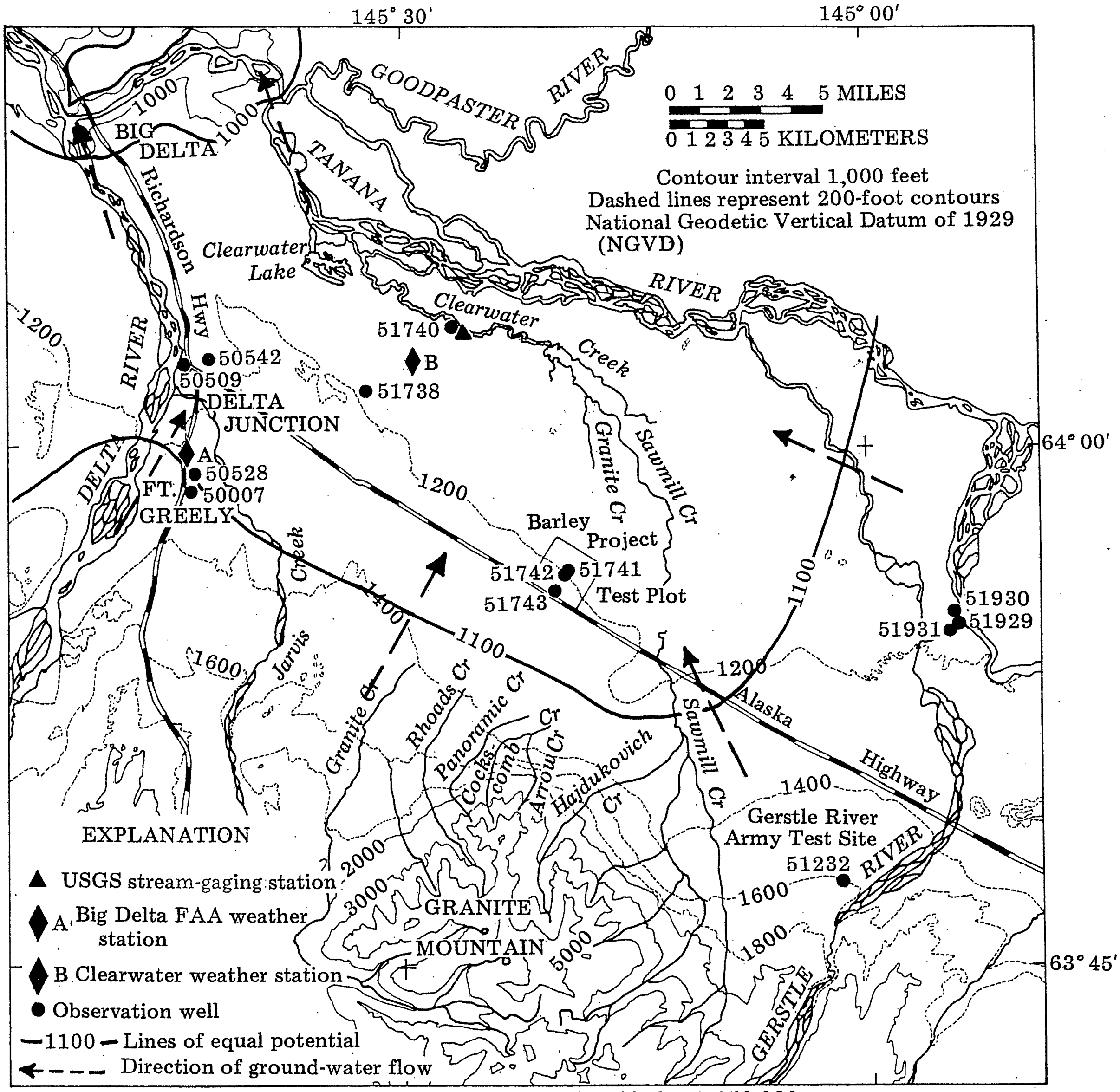


Figure 10.--Hydrograph of well 51743, Barley Project No. 3.

Delta River. The potentiometric surface indicates that ground water recharged by the Delta River and Jarvis Creek flows northeast toward Clearwater Lake. Ground water recharged by the Tanana River along the eastern boundary of the study area, the Gerstle River, and the small creeks draining the north face of the Alaska Range flows toward the Clearwater Creek spring network.

Changes to the land surface during agricultural development may alter the thickness and areal extent of permafrost and affect ground-water/surface-water relationships and, ultimately, flow. Permafrost is an effective barrier to the downward migration of water and water-borne pollutants. However, because downward infiltration is impeded, greater amounts of precipitation may run off as overland flow in areas underlain by permafrost than in permafrost-free areas. This surface runoff, especially in newly cultivated areas, may contribute sediment and topically applied agricultural chemicals to surface-water bodies downslope. As the permafrost level is lowered under tilled fields and elsewhere, surface runoff may decrease as ground-water infiltration increases.



Base from U.S. Geological Survey Mt. Hayes and Big Delta, Alaska, 1:250,000

Figure 11.--Hypothesized hydrologic flow system.

Water Quality

Surface Water

Water-quality analyses are available for 13 surface-water sites in the Delta-Clearwater area. Representative analyses are given in table 2. Complete data are published elsewhere in reports of the Geological Survey; references are given in the following table.

References for U.S. Geological Survey water-quality analyses (WSP - Water-Supply Paper; AK 75-1 and similar abbreviations - Water-Data Report for the given water year.)

Site name	Publication	Page no.
Tanana R at Big Delta 64°09'20" 145°51'00"	WSP 1372 WSP 1466 WSP 1486 WSP 1570 AK-75-1 AK-79-1	184-186, 244 187-190, 238 221 117 331 318
Clearwater Cr nr Delta Jct 64°03'22" 145°26'16"	AK-77-1 AK-78-1 AK-79-1	189 219 223-225
Sawmill Cr 3.0 mi above Granite Cr nr Delta Jct 63°59'48" 145°14'49"	AK-77-1	305
Jarvis Cr nr Delta Jct 64°01'25" 145°43'25"	WSP 1372 WSP 1466 WSP 1486 AK-74-1 AK-75-1 AK-79-1	244 238 222 312 341 318
Granite Cr 0.1 mi above Sawmill Cr nr Delta Jct 64°01'22" 145°18'07"	AK-77-1	306
Tanana R 18 mi above Gerstle R nr Delta Jct 63°55'00" 144°53'55"	AK-79-1	317
Clearwater Lk nr Big Delta 64°05'10" 145°36'00"	AK-79-1	328

Site name	Publication	Page n
Gerstle R nr Big Delta 63°49'00" 144°55'00"	WSP 1372 WSP 1466 WSP 1486 WSP 1500 WSP 1570 AK-79-1	244 235 220 95 116 317
Sawmill Cr nr Big Delta 63°53'55" 145°13'45"	WSP 1372 AK-79-1	244 290, 31
Sawmill Cr 0.2 mi above Granite Cr nr Delta Jct 64°01'23" 145°17'43"	AK-77-1	306
Clearwater Cr 0.1 mi above Sawmill Cr nr Delta Jct 64°02'54" 145°20'14"	AK-77-1	305
Clearwater Lk outlet nr Delta Jct 64°06'23" 145°36'00"	AK-77-1	306
Delta R nr Big Delta 64°07'35" 145°50'00"	WSP 1486 WSP 1500 WSP 1570 AK-75-1 AK-79-1	222 95 117 342 318

Predominant ions in the surface water are calcium and bicarbonate. Percentages of milliequivalents per liter of calcium, magnesium, sodium plus potassium, chloride, sulfate, and carbonate plus bicarbonate for samples collected at selected