PERMAFROST AND GROUND-WATER CONDITIONS
IN THE
GLENNALLEN AREA, ALASKA

By

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This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

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INTRODUCTION

This report is an outgrowth of permafrost and geologic field studies now in progress in the southeastern Copper River basin, Alaska and is in response to inquiries for information on permafrost and ground-water conditions. Various private and governmental groups have encountered severe differential settlement of building foundations on permafrost, and consequent maintenance problems. Settlement and expansion of communities in the area also have been retarded by the apparent lack of a ready and large source of potable water. The information below is presented to make available data on permafrost and ground-water conditions for the benefit of those undertaking construction projects in the area.

Location.--The Glennallen area is in the southeastern portion of the Copper River Basin, in southeastern Interior Alaska. It lies near the center of Alaska's network of highways at the junction of the Glenn (mile 189) and Richardson (mile 115) Highways (fig. 1). It is approximately midway between Gulkana, 12 miles to the north, and Copper Center, 15 miles to the south. The general area discussed lies east of Moose Creek, north of the Tazlina River, west of the Copper River and includes the northern boundary of the Gulkana Civil Aeronautics Airstrip at mile 119 of the Richardson Highway. The village of Glennallen in the Moose Creek valley is about 2 miles to the west of the junction of the Glen and Richardson Highways.

Methods of study.--The study is a part of a study of the Quaternary geology of the southeastern Copper River basin initiated in June 1954. Field traverses made along the Copper River and its major tributaries, adjacent to the highways, and spot checks elsewhere, provide the basis for the geologic setting described in this report. Locally test holes were hand-augered and soil-moisture samples were taken (fig. 1 and table 2). In poorly accessible areas, the interpretation of aerial photographs has been necessary to extrapolate to similar terrain and geologic units known elsewhere. Many conclusions were reached with the aid of data resulting from cooperative studies in progress by the Geological Survey and the Alaska Road Commission in nearby areas. These studies are based on numerous 20-foot auger test holes from which samples were collected and run for soil-moisture determinations and particle-size analyses. Soil temperatures have been measured in these test holes at weekly intervals for more than a year.

Personnel and acknowledgments.--John R. Watson of the Alaska Road Commission played a large part in the collection of general permafrost information in the Glennallen area. The Geophysics Branch of the Geological Survey provided most of the temperature-recording cables and converted some of the temperature records to degrees centigrade. Water analyses were made by the Quality of Water Laboratory, U. S. Geological Survey, Palmer, Alaska, and by the Anchorage laboratory of the Alaska District, Corps of Engineers, U. S. Army. Numerous local residents were helpful in providing well data and other information.

GEOGRAPHY

Topography.--The Copper River basin, ranging from 500 to over 4,000 feet above sea level, is an intermontane basin rimmed by peaks of the Chugach, Alaska, Talkeetna, and Wrangell mountains, which rise as high as 7,000 to 16,500 feet. The terrain of the basin can be divided into two physiographic sub-units: 1) the rolling, hummocky Copper River basin piedmont surface, with scattered bedrock hills and numerous lakes, ranges from 2,000 to 4,000 feet above sea level in the northern, western, and southern part of the area, and 2) the Copper River basin trough extends in a crescentic arc along the north, west, and south sides of the Wrangell Mountains and drops from an elevation of 2,000 feet at the north end to 500 feet near Chitina at the south end. South of Chitina, the Copper River cuts a deep canyon across the axis of the Chugach Mountains and empties into the Pacific Ocean.

The Copper River basin trough is generally flat and lacks the hummocky, rolling character of the piedmont surface. In the floor of both the piedmont and trough, the Copper River and its principal tributaries have cut canyons as much as three miles wide, and as deep as 500 feet at the escarpment between the two.

The Glennallen area, lies within the Copper River basin trough approximately at an elevation of 1,500 feet. The western part of the report area, sloping slightly to the south, is very flat, and local relief does not exceed 5 feet except where the surface is incised by Moose Creek which has cut a valley 50 to 200 feet beneath the general surface. The eastern margin drops sharply to the 250- to 300-foot-deep canyon of the Copper River. Dry creek, flowing across the northern part of the area, has incised a 50- to 200-foot channel into the trough floor.

Drainage.--Most of the Glennallen area is generally poorly drained by seepage in broad swales little more than 2 feet deep. The slope is southward toward Moose Creek and the Tazlina River and approximates only 50 feet per mile. A heavy vegetation mat restricts surface runoff, and subsurface drainage is restricted by fine-grained sediments and by permafrost at shallow depths; the result is local ponding of water in channels and minor depressions. The eastern margin of the area has a much more pronounced slope and drains to the east into the Copper River. Few areas of standing water are encountered, but locally the vegetation and the silty soil are saturated. The importance of surface drainage to stabilization of building foundations will be discussed under local problems in construction on permafrost.

Vegetation.—Aside from the organic mat of moss, grasses, low bush cranberry, and other low brush types, three types of vegetation cover the Glennallen area: (1) Alder and willow, growing in tangled masses 4 to 10 feet in height, cover the gentle depressions of swales and old drainage channels and resemble broad swaths cut through the spruce forest. (2) White spruce cover parts of the slope on the eastern half of the area and form small, isolated clumps or islands in the western half. These trees are 20 to 30 feet tall and 1 to 2 feet in diameter. (3) Stunted black spruce are dominant along the margins of the drainage channels and other poorly drained areas over the greater part of the area. A few small stands of tall birch-aspen-balsam poplar grow along the Richardson Highway south of the junction, along Dry Creek, and on the flat gravel terraces adjoining the Copper River. Clearing for construction purposes does not appear to present problems except for the difficulty of access to timbered areas on swampy terrain.

Climate.—The central Copper River region has a typical arctic continental weather regime with mild to warm summers and severe winters (U.S. Weather Bureau, 1954). Periods in the winter during which daily minimum and maximum temperatures range between 50° and 20° F. below zero occur occasionally and may last two weeks or more. In summer, daily maximum temperatures usually range from 60° to 70° F. but occasionally reach peaks in the high eighties. Although daily minimums average in the low forties, freezing temperatures have been recorded for every month of the year, though not during the same year. The average date of the last spring freeze is June 5 and that of the first freeze in the fall is August 12, giving a general frost-free period of about 67 days. The mean maximum temperature is 37.3° F. and mean minimum is 16.6°F. The mean annual temperature is 27.2°F. The mean annual precipitation is 11.7 inches and the mean annual snowfall is 48.6 inches, though there is seldom more than 2 feet of snow on the ground at any one time.

GEOLOGY

The terrain, geology of the unconsolidated deposits, and foundation materials of the Copper River basin are related to Pleistocene and Recent events. Glaciers from the Chugach, Wrangell, Talkeetna and Alaska Ranges repeatedly invaded the basin, perhaps at times filling it and flowing across the divides to the north, west, east and south. Such extensive glaciation has resulted in the deposition of large thicknesses of coarse glacial boulder clays (till) and coarse outwash gravel and sand on the piedmont surface, with finer till and outwash interbedded with lake deposits in the basin trough. During the last major glacial advance, glaciers emanating in the Chugach, Wrangell and Alaska Ranges pushed out into the basin as valley glaciers and, coalescing locally, formed large ice lobes over portions of the pediment and trough. Glacier-free areas in the lower part of the basin were covered by an extensive lake or series of glacier-segmented lakes which resulted in the accumulation of lake silts, clay and pebbly silt. The complicated interfingering of lake deposits with glacial till and outwash sand and gravel reflects the great fluctuation of glacier and lake margins. A little more than 4,600 years ago (Rubin and Suess, p. 445). the basin trough, essentially as it is today is presumed to have become exposed with the lowering and retreat of glaciers blocking drainage outlets and the rapid draining of the lake or lakes. Since that time, the Copper River and its major tributaries have carved 200-to 550-foot canyons into the trough sediments, which are of unknown thickness. Between river valleys, muskeg and marsh remnants of once larger lakes are perched on poorly drained silts and boulder clays, which generally comprise the upper 20 feet of the trough surface in the Glennallen area.

A composite geologic section made up of drill logs and river bluff sections (fig. 2) in and adjacent to the report area (fig. 1) would show the following:

	Approximate thickness	Material
Top	20 feet	Pro-glacial lake silt and clay with pebbles. Locally mantled with loess (wind blown silt) or channelled by thin sandy or gravelly fill.
	75	Glacial boulder clay or till with lenses of sand and gravel.
	30 feet	Glacial outwash gravel and sand.
	40-60 feet	Glacial boulder clay or till.
	15-30 feet	Gray sand, silt, and gravel.
	30-45 feet	Laminated silt and sand; locally varved silt.
	30 feet	Outwash gravel and sand; locally water bearing.
	5 feet	Pink silty rubble.
	70 feet	Coarse gravel and sand; water bearing.
	80 feet	Glacial clay or till.

The deposits are indicative of a nearly continual glacial or proglacial environment. The most recent agents active upon the surface, and still continuing, are wind (deposition of silt from river bluffs and bars) and water (local channelling, with possible concentration of lag sands and gravel).

GROUND WATER

Ground water in the Glennallen area is generally at depths greater than 200 feet and is characteristically hard and has a salty taste (location of wells shown in figure 1 and water analyses in table 1). It is generally confined under artesian pressure beneath fine-grained material and/or permafrost.

Description of wells and quality of water.--

1. The shallowest continuously flowing well (No. 1 in figure and table 1) was drilled to a depth of 65 feet by the Catholic Mission Society of Alaska. It is on a low terrace of the Copper and Tazlina Rivers, 5 miles south of the junction of the Glenn and Richardson Highways. This artesian water is very hard and is high in dissolved solids, sodium, and chloride.

2. The Alaska Road Commission has drilled 2 wells, 180 (No. 4) and 205 (No. 3) feet deep respectively, 2 1/2 miles west of the highway junction in the Moose Creek flood plain and has encountered potable water. However, it is relatively hard and has a moderate dissolved-solids content necessitating some treatment.

3. The Civil Aeronautics Administration has drilled 2 wells at the Gulkana Airfield, to 330 and 433 feet (No. 6) respectively. Water was encountered in each but proved unsuitable in quality, and it finally was decided to develop a water supply from a higher horizon. The 433-foot well was plugged below 293 feet (No. 6) at which point, a limited supply of water is available. The quality is fairly good but the water must be treated.

4. The Alaska District Corps of Engineers, recently drilled a well to a depth of 354 feet (No. 7) 1/3 of a mile west of Mile 119 on the Richardson Highway. Chemical analyses show that the water below 330 feet is entirely unsuitable for domestic uses, the chloride and dissolved-solids contents being extremely high (W. M. Knoppe, written communication, January 1955). The well was abandoned, as the water did not clear after 120 hours of continuous pumping at 100 gallons per minute (table 1).

5. During World War II a small Army camp was located beside Dry Creek where it is crossed by the Richardson Highway. Reportedly, it was supplied by good water from two 200-foot wells drilled beside the creek. This water was hauled, and later piped, to the CAA airfield until the deep well there was plugged and a water supply obtained from the 293 foot depth. However, no drill logs, analyses, or other data are available for an evaluation of the quality of the water. The wells are now clogged with pumping equipment and debris.

6. Gateway Lodge, 1/2 mile north of the junction of the Glenn and Richardson Highways, has had 3 wells drilled. Two were to depths of approximately 150 feet, where drilling was discontinued owing to breakage of the casing in one well and loss of drill tools in the other. The third well, not now in use, was drilled to 321 feet (No. 5) and yielded hard water, high in chloride and dissolved solids.

7. The well supplying the Territorial Police office and quarters at Glennallen is drilled into the Moose Creek valley at a point near one of the largest tributaries of Moose Creek. The well is about 90 feet deep (oral communication, Rev. Vincent Joy, July 1955) and the water is superior in quality to that of the Alaska Road Commission wells. Even so, it is noticeably harder and more highly mineralized than the chlorinated water supply of Anchorage.

8. A number of shallow wells have been dug in the flood plain of Moose Creek at Glennallen and near marshes on the trough floor west of Glennallen. Most of these wells were unsuccessful, but several reportedly yield satisfactory amounts of water for the single user throughout the year. Several others may be pumped during the summer and fall months, but they dry up during the winter and spring. Water from one 12-foot well, at Glennallen Lodge 3 miles west of Moose Creek, flows the year around with sufficient quantity for dishwashing, gasoline station, and other non-cooking and non-drinking purposes. Such wells are generally from 10 to 20 feet deep and apparently tap "swamp water" or surface water seepage in drainageways from the trough surface. Water from shallow wells in this area, as elsewhere in Alaska (Alter, 1950a, 1950b, and unpublished report 1/), is frequently subject to contamination from sewage emanating from open-cribbed cesspools (see page 17) and from surface wastage such as gasoline and oil seeping down to water perched on permafrost.

In addition to the wells listed above, various attempts have been made to locate water (a) in Recent terrace deposits of the Copper and Tazlina Rivers (No. 2 and 8) and (b) under the flood plains of these rivers (No. 9). Attempts were abandoned when it was discovered that the ground water was saline (25,000 ppm of dissolved solids) even at river level.

Proposals to construct water-intake systems through which water would be drawn from the Copper and Tazlina Rivers have been deferred, temporarily at least, because of (a) ice conditions on the rivers during breakup; (b) difficulty of maintaining a continuous flow past an open intake system in ephemeral channels of a braided river such as the Copper River; (c) settling treatment made necessary by the high sediment load of the Copper River and, to a lesser extent, the Tazlina River; (d) possible inflow of saline ground water even into a below-river intake system; (e) in some instances, the long horizontal and vertical pumping necessary to transport the water from the river level to the point of use; and (f) the difficulty of keeping water pipes unfrozen over a great distance during the winter months.

It appears that the best possibilities of tapping large quantities of potable ground water would lie in drilling 180-to 250-foot wells adjacent to Dry Creek or Moose Creek.

1/ Alter, A. J., 1950, Water-supply problems in low-temperature areas: Mimeo. rept. distributed at the 1st Alaska Sci. Conf., Washington, D. C., 13 p.

PERMAFROST

Distribution.--Until recently the southern half of the Copper River basin was considered to be in the sporadic zone of permafrost (Benninghoff, 1952, p. 35; Péwé, 1954, p. 317; Nikiforoff, 1928, p. 75; Hopkinds, Karstrom, and others, 1955, p. 116). New data, including those collected for the present study, show that it may be considered with the discontinuous zone. Excluding the lower terraces of the major river systems, permafrost has been found in all areas where construction activity or the search for water made it possible to obtain subsurface data. The hand augering done in the Glennallen area did not permit complete determination of either the presence of depth of permafrost, but drill records and other data leave little doubt that it underlies the entire trough surface in the Glennallen area from near the surface to depths greater than 100 feet. In undisturbed ground, or under road beds constructed over the vegetation mat, its upper limit is 1 to 6 feet beneath the surface, depending on the amount and types of vegetation, type of materials, thickness of snow cover, and direction of exposure. It is exposed in most north- and west-facing river bluffs and generally contains considerable amounts of ground ice.

Description.--Among the properties of permafrost affecting economic development in this region are: (1) temperature, (2) thickness, (3) moisture (ice) content of the ground, and (4) type, size, and depth of ground ice. In discussing these properties of the permafrost underlying the Glennallen area, data from permafrost studies made within a 15-mile radius are liberally drawn upon. Conditions vary so little between the study sites and the townsite that comparisons may be made with a reasonable degree of assurance.

(1) Temperature.--Subsurface temperature data collected during the past year and a half indicate that the temperature of the permafrost in this area averages between -0.5° C. (31.1°F.) and -2.0° C. (27.4°F.) at depths between 10 and 30 feet, or within the zone of annual seasonal temperature change in permafrost. Incomplete temperature data from beneath the zone of annual seasonal temperature change indicate a permafrost temperature of approximately -1° C. (30.2°F.). In a road bed abandoned in 1951 the thawing of permafrost, in ground on which the snow cover is no longer removed has proceeded to a depth of only 16 feet in 15 years. Seasonal frost penetration extends to a depth of approximately 10 feet under these conditions. The present climate apparently is sufficiently cool to maintain the permafrost level and temperature unless the thermal regimen is disturbed by natural or human-induced changes.

(2) Thickness.--Where encountered in river bluffs, permafrost extends from near the surface to depths of 150 to 250 feet, or until the exposure is obliterated by slope debris. Drill logs of water wells report its presence to depths of 100 to 200 feet. Few reliable drill logs record the bottom of permafrost at depths less than 100 feet.

(3) Moisture (ice) content of the ground.--Soil samples collected from drilling done for permafrost studies in the Glennallen area had a moisture or ice content averaging between 30 and 60 percent relative to the weight of the dry soil. Moisture varied from a minimum of 3 percent in coarse road fill to a maximum of 1,042 percent in a blue-gray lake clay. The average moisture content of materials in place is approximately 50 percent, or one-third the weight of the total sample. Eight random samples taken from shallow test holes near the junction

of the Glenn and richardson Highways (fig. 1 and table 2) averaged 38.8 percent moisture. In general, near-surface samples (presumably in the zone of seasonal frost) have lower moisture contents than samples taken at depth in permafrost. Moisture content appears to be lower, and the upper limit of permafrost to lie deeper, in silt and sand under cotton-wood aspen stands.

(4) Type, size, and depth of ground ice.--Types of ground ice are difficult to determine from well cuttings, but in the Glennallen area finely segregated ice crystals disseminated through the ground appear to be the dominant type. The distribution of disseminated ground ice crystals is generally uniform, probably because of the homogeneity of the enclosing soil materials over wide areas. Only a few ice lenses up to 2 feet thick have been recognized from churn drilling. Exposures in river section in the lower part of the basin, however, revealed ice in the form of veinlets, lenses, wedges, and irregular masses up to 15 feet thick, extending over 100 feet laterally, at depths from 10 to 150 feet. No data are available on the depth at which large ground ice masses are most likely to occur. Areas of polygonal ground, frost mounds, thermokarst pits, and other surface manifestations of ground ice masses are rare.

LOCAL PROBLEMS IN CONSTRUCTION IN PERMAFROST

Permafrost conditions throughout the area studied are similar to those in the Glennallen area. The following paragraphs review causes of some of the difficulties encountered by various groups in constructing and maintaining several types of structures in this area.

Instability of foundation materials.--As shown in the generalized geologic section, the region is immediately underlain primarily by fine-grained deposits--dominantly silt and clay, which are subject to extreme effects of frost action (Muller, 1945, p. 64; Beskow, 1935, p. 28, 52). Locally, where the clay and silts have been eroded, glacial boulder clays (till) are exposed at the surface. With the exception of a few large boulders in the till, the composition of the materials is nearly the same. Thin layers of fine gravel and sand may be locally interbedded; this does not affect the over-all frost-susceptibility of these deposits when used as foundation materials for construction purposes. Fine-grained materials are characterized by marked heaving upon freezing if they contain any significant amount of moisture. Spring and summer thaws will result in loss of volume, but a building heaved by frost action will seldom return to its previous position when the ground thaws. When permafrost in these materials is thawed, considerable settlement may result because of the high ice content relative to the void space in fine-grained materials. Their nature of fluid flow when saturated reduces their stability and bearing capacity upon the thaw of either seasonal frost or permafrost. Without a detailed permafrost study of a construction site, it is impossible to predict the amount of settlement to be expected because of the great number of highly variable and indeterminable factors (Tsytovitch and Sumgin, 1937). Even after thorough consideration of the data collected in such a study, it would be difficult to predict successfully the precise amount of settlement. However, a practical evaluation of the anticipated settlement could be made for engineering purposes.

Drainage.--The importance of surface drainage with regard to frost action and permafrost has not been adequately considered in designing road and building foundations. A foundation that has become saturated with water because of poor surface drainage is subject to considerable frost heave during the winter and consequent settlement in the spring and summer. Of those buildings in the Glennallen area that were constructed on poorly drained silts and boulder clays, almost all have been affected by such heave and settlement of their foundations. Unless a practicable surface drainage program is worked out for the construction area, the serious effects of severe seasonal frost-action on wet foundation materials must be anticipated. Poor surface, and hence subsurface, drainage also produces differential thaw of underlying permafrost and rapid deterioration of foundations, the result being that doors will not close, windows and window frames are cracked, and maintenance costs are continual and high.

Cesspools.—Community and individual cesspools have caused rapid and differential thaw of permafrost and settlement of surrounding buildings. As downward percolation of water is prohibited by the permafrost table, cesspools in permafrost areas are of the open-crib design to allow for lateral seepage. Sewage water from this seepage collects in natural depressions in the permafrost table under buildings and accelerates thawing action. If a building is on piling, the water will tend to percolate downward along the piles, destroying the adfreezing strength between piles and permafrost unless preventive action is taken. When fine-grained foundation materials containing permafrost have a moisture content as high as 50 percent by weight and the ice is melted, complete destruction of the building may result in time (Liverovsky and Morozov, 1941, p. 36).

Utilidors.—Because of the lack of a ready source of potable ground water and the need for treatment of available water, individual wells are not always economically practicable and a central water-supply source would be necessary for large-scale expansion. A system of utilidors would be required to carry water from source to user and also to carry sewage from source to disposal area. The Alaska Road Commission at Glennallen uses a below-ground circulating -hot-water utilidor system. At the points where heated utilidors enter and leave the buildings, differential thaw of permafrost has taken place and the buildings have settled. The Civil Aeronautics Administration investigated on above-ground heated utilidor system to carry water from the Army Dry Creek wells to the Airfield station and found the cost to be prohibitive (John Lynn, C. A. A. Station Manager, Gulkana; oral communication, July 1955). However, the Alaska Communication System now uses such a system for its buildings at Glennallen.

Basements.—Basements have proved to be an additional cause of differential thaw and settlement because of heat exchange between basement and surrounding ground. Resultant depressions in the permafrost table become collection points for drainage of relatively warm sewage water and subsurface runoff, and thawing is further accelerated. Even when structures are built above the ground, solar absorption along the south side of the building causes considerable differential thaw unless adequate air space and insulation under the building are provided.

CONCLUSIONS

Ground water.—In the Glennallen area, ground water is available at a depth of 300 to 400 feet beneath the trough floor. It is commonly under considerable hydrostatic pressure because impervious strata of perma frost or glacial clays, or a combination of both lie above the ground water horizon. The water is high in dissolved solids (1,055 to nearly 25,000 ppm in available analyses) and chloride (230 to nearly 8,000 ppm). It is usually extremely hard, ranging from 240 to 15, 500 ppm. The hardness and the high content of sodium chloride make the water undesirable for domestic use.

Two areas may possibly yield potable water. They are the Moose Creek and Dry Creek flood plains, where seepage of creek water has apparently resulted in a local reservoir of fairly good ground water at a depth of approximately 200 feet. This water may require some treatment. No other sources of good water are known.

Permafrost.--In designing structures to be erected on permafrost in Arctic and sub-Arctic regions, the possibility of differential settlement of foundations must be taken into account. The thawing of ice-rich permafrost under a foundation will result in differential settling and may result in destruction of the building. Seasonal frost heaving and settling also have adverse effects--more marked and more serious when foundations materials are fine-grained, unconsolidated, and wet, as they are in the Glennallen area. With that in mind attempts have been made to so design and construct buildings that they would remain stable despite any shifting of the foundation and would withstand strain on any structural member under which unequal thawing of permafrost might take place. Unfortunately, the methods of construction involved in such designs are extremely costly and often prove inadequate when used.

Where permafrost is taken into consideration, basic construction principles usually follow either the active or the passive method (Muller, 1945 p. 26; Tsytovitch and Sumgin, 1937; and Liverovsky and Morozov, 1941, p. 105). The former is based on the principle of complete elimination of permafrost from the area before construction is begun and upon the premise that once it has been eliminated, it will not return. This method is generally reserved for areas in which permafrost is relatively thin, temperatures are above -1.0°C., ice masses are either lacking or are present in small quantities, and foundation materials are relatively coarse grained. In the passive method, used on colder, thicker permafrost with considerable ice content and where foundation materials range from fine sand to clay, the permafrost is utilized as part of the foundation and every effort is made to preserve it. Other factors, such as type of structure, temperature regime of the structure, air temperature and drainage conditions at the site, are also important and may sway the decision for or against any one type of construction. Design for and construction of large scale projects should be preceded by intensive permafrost studies and studies of other site conditions in order that the correct choice may be made between the active and passive methods.

In the Glennallen area permafrost is somewhat marginal in temperature--between -0.5° C. and -2.0° C.--but it has a moderate to high ice content and extends from near the surface to considerable depths (Nichols and Watson, 1955). The area is characterized by fine-grained deposits, highly susceptible to frost action, and by very poor surface and subsurface drainage. Marginal temperatures point to the use of the active method while the type of foundation materials, ice content of the permafrost, and other factors favors the use of the passive method, indicating that difficulties may be encountered with the use of either.

For this reason it seems best to locate structures and roads, where practicable, on areas that are devoid of permafrost, such as some of the permafrost-free terraces of the Copper River.

The question arises as to why settlement problems appear to be excessive in the Glennallen area in contrast to those encountered in areas such as Fairbanks. Comparisons have been made with other areas in Alaska where, although there are many examples of the destructive nature of permafrost with regard to structures, there are as many or more buildings apparently not affected. Some of the more obvious reasons may be, 1) the light snow cover in the Glennallen area permits deeper penetration of seasonal frost and retards degradation of the permafrost table, 2) permafrost temperatures here are more marginal and hence it is more difficult to use the passive construction method, 3) permafrost here is consistently thick and continuous, less readily permitting the active construction method or location on non-permafrost areas, 4) the homogeneity of ice content here results in settlement nearly everywhere the permafrost table is reduced, whereas relatively "dry" permafrost in local areas elsewhere may be reduced without a significant reduction in volume of the ground, 5) few areas are so consistently underlain by highly frost-susceptible materials, and 6) longer experience in larger, established towns and centers of population, and hence a greater amount of data, allows more adequate planning.

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TABLE 1

CHEMICAL ANAYLSES OF GROUND WATER IN THE GLENNALLEN AREA, ALASKA

Well No.	Sample No.	Owner	Location [1]	Date collected	Depth (feet)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium & potassium (Na & K)	Carbonate & Bicarbonate (CO_3 & HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Nitrate (NO_3)	Dissolved solids (ppm)	Total hardness as $CaCO_3$ (ppm)	Spec. conductance (micromhos at 25°C)
						(Chemical constituents in parts per million)											
1	1	Catholic Mission	Mouth of Tazlina R.	7-54	90	43	2.1	126	41	695	1,270	1	650	1	2,180	483	3,730
2	2	Catholic Mission	Mouth of Tazlina R.	6-55	20	-	-	230	61	226	273	90	650	-	-	825	2,780
3	3	A. R. C.	Glennallen	7-50	205	40	.32	-	-	-	304	1	63	3.4	-	276	661
4	4	A. R. C.	Glennallen	7-50	180	40	.12	-	-	-	300	2	32	2.8	-	238	550
5	5	Gateway Lodge (Dykes)	0.5 mi. N. of highway junction	8-51 2/	321	47	.14	693	204	429	290	15	2,300	3.5	3,830	2,570	7,380
5	6	Gateway Lodge (Dykes)	0.5 mi. N. of highway junction	8-51 3/	321	44	.08	681	206	491	280	-	2,400	-	3,960	2,550	7,350
6	7	C. A. A.	Gulkana	1945	433	-	-	4,780	984	2,710 (calculated)	84	5	15,400	-	24,400	1,600 (calculated)	-
6	8	C. A. A.	Gulkana	7-50	293	42	.86	-	-	-	266	28	230	4.6	-	465	1,370
6	9	C. A. A.	Gulkana	1-55	293	-	-	-	-	-	-	-	625	-	1,060	-	-
7	10	C. E.	Near Gulkana	12-54	354	19	2.2	1,900	520	1,190	53	0	6,470	-	10,200	6,880	-
7	11	C. E.	Near Gulkana	1-19-54 4/	354	-	-	-	-	-	-	-	7,800	-	13,300	-	-
7	12	C. E.	Near Gulkana	1-29-55 5/	354	-	-	-	-	-	-	-	6,320	-	12,500	-	-
8	13	Brenwick	Copper & high Tazlina R. terrace	7-11-55	34	-	-	153	37	8.7	254	250	60	.3	634	534	1,030
9	14	Seep on public land	Copper R. floodplain	7-20-55	Surface	-	-	2,080	392	670	226	60	5,680	-	8,990	6,800	16,400

Samples Nos. 9, 11, and 12 analyzed by U. S. Army, Corps of Engineers, Alaska District, Anchorage, Alaska.
All other analyses by U. S. Geological Survey, Quality of Water Branch, Palmer, Alaska.

Compiled by Donald R. Nichols,
U. S. Geological Survey, 1955.

Abbreviations: A. R. C. -Alaska Road Commission
C. A. A. -Civil Aeronautics Administration
C. E. -Corps of Engineers, U. S. Army

1/ See map for location of wells.
2/ After first pumping test.
3/ After 3 hours of pumping.
4/ After 24 hours pumping at 100 gallons per minute.
5/ After 72 hours pumping at 100 gallons per minute.

TABLE 2

GROUND CONDITIONS IN THE GLENNALLEN AREA*

Test Hole	Depth (feet)	Vegetation	Terrain	Condition of ground surface	Type of frost	Percentage of moisture relative to weight of soil materials
a	1.0	Black spruce	Flat	Wet	Seasonal frost	58.8
a	2.0	Black spruce	Flat	Wet	Seasonal frost	25.2
a	3.5	Black spruce	Flat	Wet	Permafrost	44.8
b	1.8	Alder and willow	Drainage channel	Standing water	Seasonal frost	25.1
c	4.7	Alder and willow	Drainage channel	Standing water	Permafrost (?)	43.2
d	3.0	Black spruce	Flat	Wet	Permafrost (?)	42.3
e	2.0	White spruce	Flat	Dry	Seasonal frost	32.1
f	2.8	Alder and willow	Drainage channel	Standing water	Permafrost (?)	38.8
g	5	Aspen and cottonwood	Flat	Moist	Unfrozen	No sample taken
g	6	Aspen and cottonwood	Flat	Moist	Seasonal frost	No sample taken
g	8	Aspen and cottonwood	Flat	Moist	Unfrozen	No sample taken
g	11.5	Aspen and cottonwood	Flat	Moist	Permafrost	No sample taken
h	5	Black spruce	Flat	Wet	Permafrost	No sample taken

*Samples collected June 7, 1955
Location of test holes shown on map, Figure 1.

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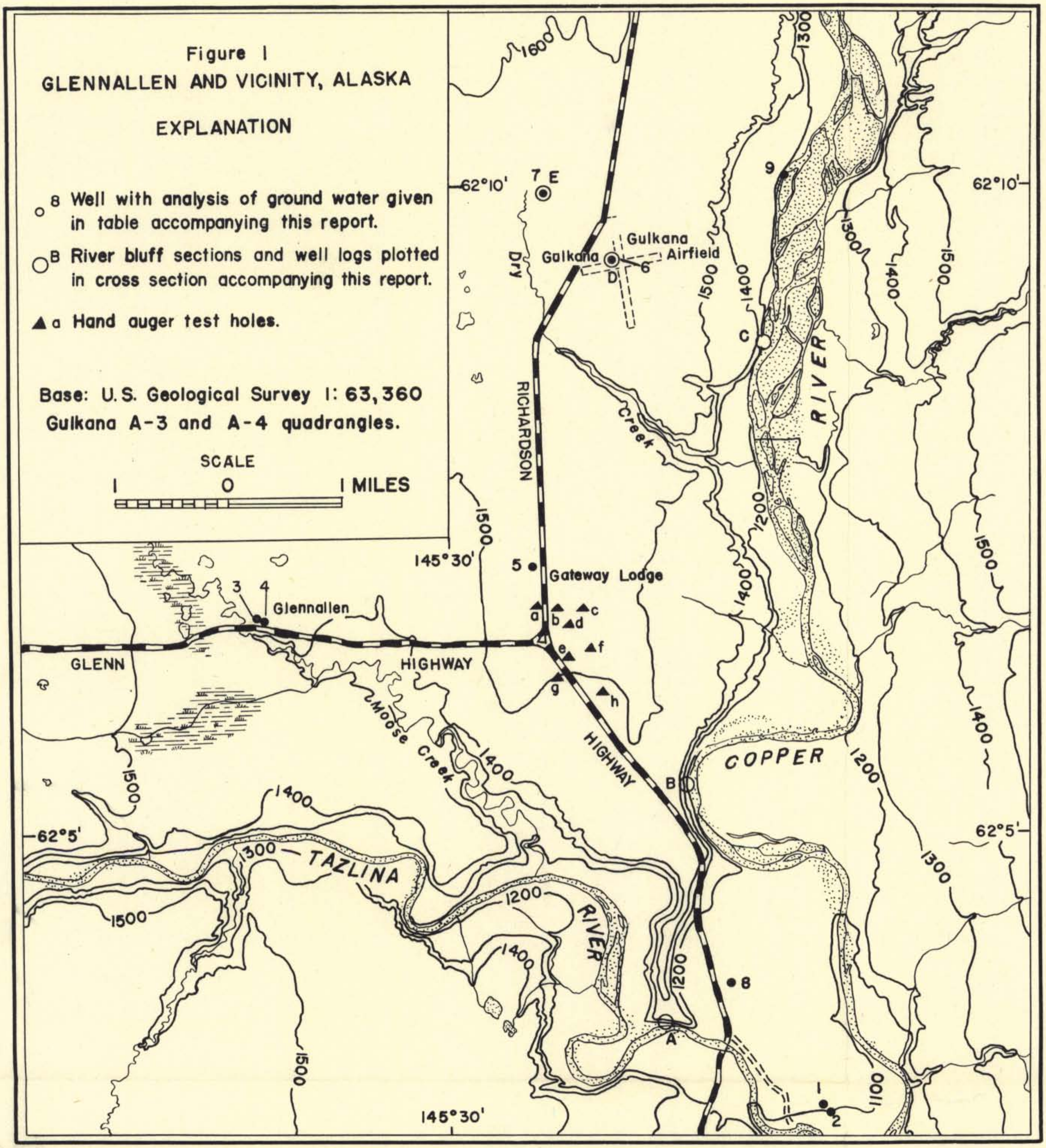
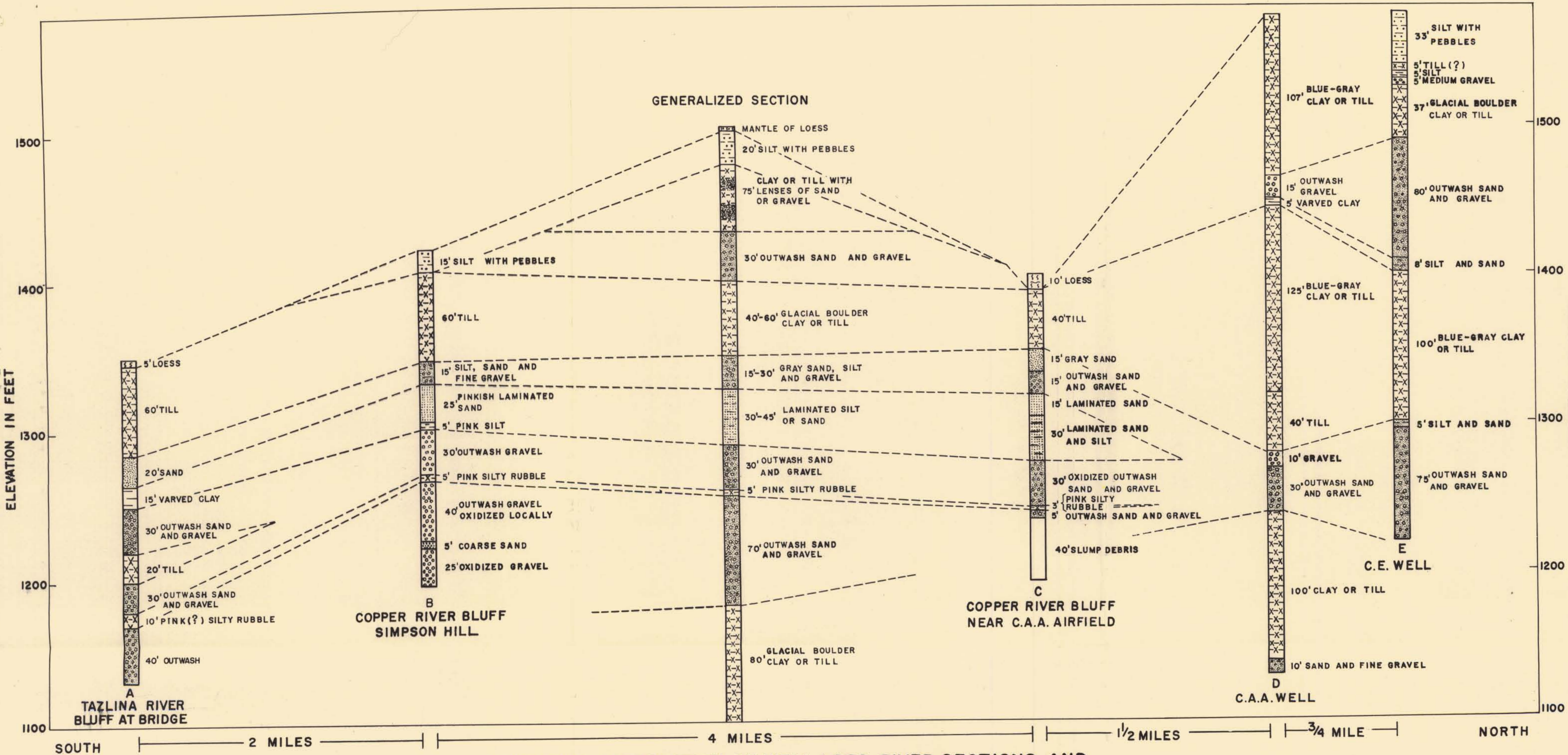


Figure 1
GLENNALLEN AND VICINITY, ALASKA
EXPLANATION
8 Well with analysis of ground water given in table accompanying this report.
B River bluff sections and well logs plotted in cross section accompanying this report.
a Hand auger test holes.
Base: U.S. Geological Survey 1: 63,360
Gulkana A-3 and A-4 quadrangles.
SCALE
1 0 1 MILES
62°10'
62°10'
62°5'
62°5'
145°30'
145°30'
Gulkana
Gulkana Airfield
Dry
Creek
RICHARDSON
HIGHWAY
Gateway Lodge
Glennallen
GLENN
HIGHWAY
Moose Creek
TAZLINA
RIVER
COPPER
RIVER
1600
1500
1400
1300
1200
1100

Fig. 2



TENTATIVE CORRELATION OF WELL LOGS, RIVER SECTIONS, AND GENERALIZED SECTION IN GLENNALLEN AREA