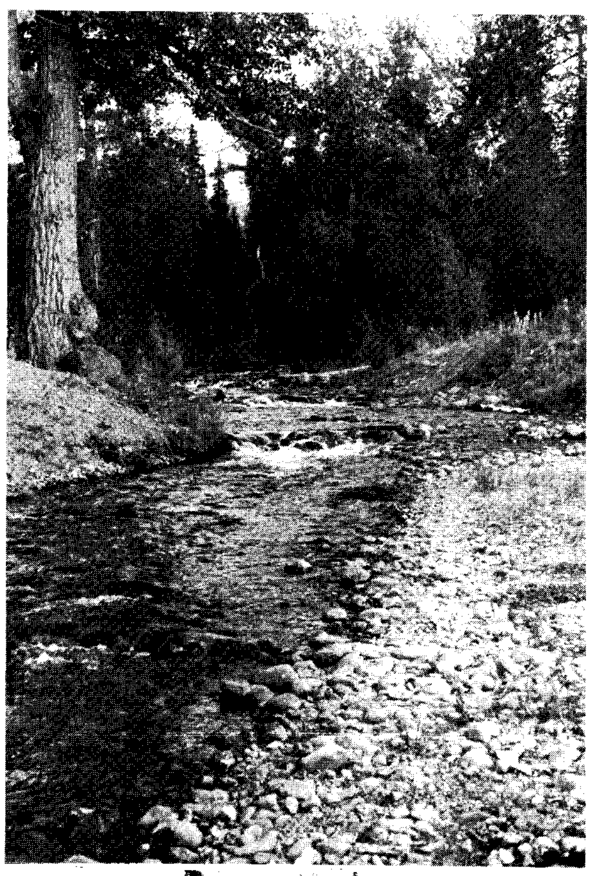
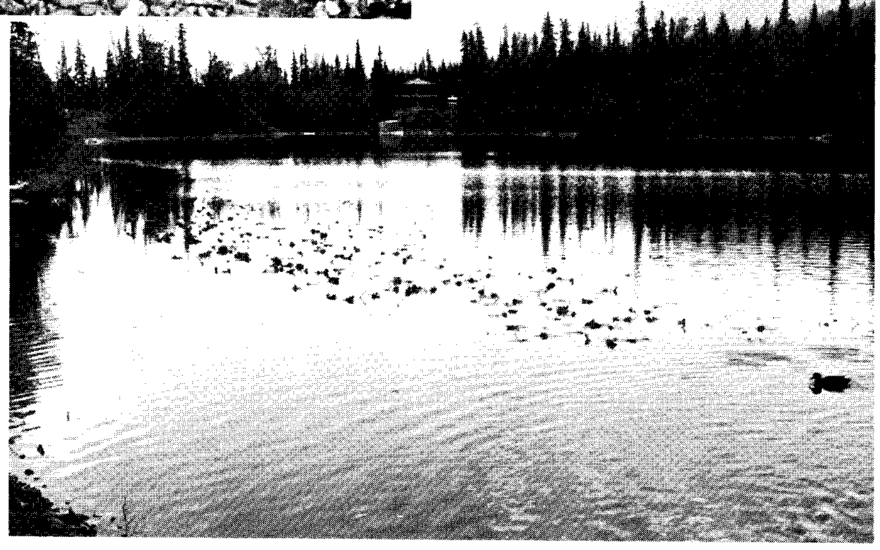
HYDROLOGY FOR LAND-USE PLANNING: THE HILLSIDE AREA, ANCHORAGE, ALASKA

OPEN-FILE REPORT 75-105
Prepared by the U.S.Department of the Interior, Geological Survey in cooperation with the Greater Anchorage Area Borough.





UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
Water Resources Division
218 E Street
Anchorage, AK 99501

September 1, 1976

Memorandum

To: Distribution

From: District Chief, WRD, Anchorage, AK

Subject: PUBLICATIONS - Errata for U.S. Geological Survey Open-File Report 75-105

Enclosed are errata sheets for Figures 28 and 30 of the subject report "Hydrology for Land-Use Planning: The Hillside Area, Anchorage, Alaska," by L. L. Dearborn and W. W. Barnwell. You may wish to insert them in your copy of the report.

Harry Hulsing

Enclosures

ROUTING AND TRANSMITTAL SLIP		ACTION
1 TO *(Name, office symbol or location)* Mrs. Mary Tailleur	INITIALS / DATE	CIRCULATE / COORDINATION
2 Technical Data Unit Alaskan Geology Branch U.S. Geological Survey	INITIALS / DATE	FILE / INFORMATION
3 345 Middlefield Road Menlo Park, CA 94025	INITIALS / DATE	NOTE AND RETURN / PER CON-VERSATION
4	INITIALS / DATE	SEE ME / SIGNATURE

REMARKS

Attached are the three copies of open-file report 75-105 per your request.

There are two changes to be made on your office copy.

Appendix A-4, page 44
The last line Parameter should be pH.

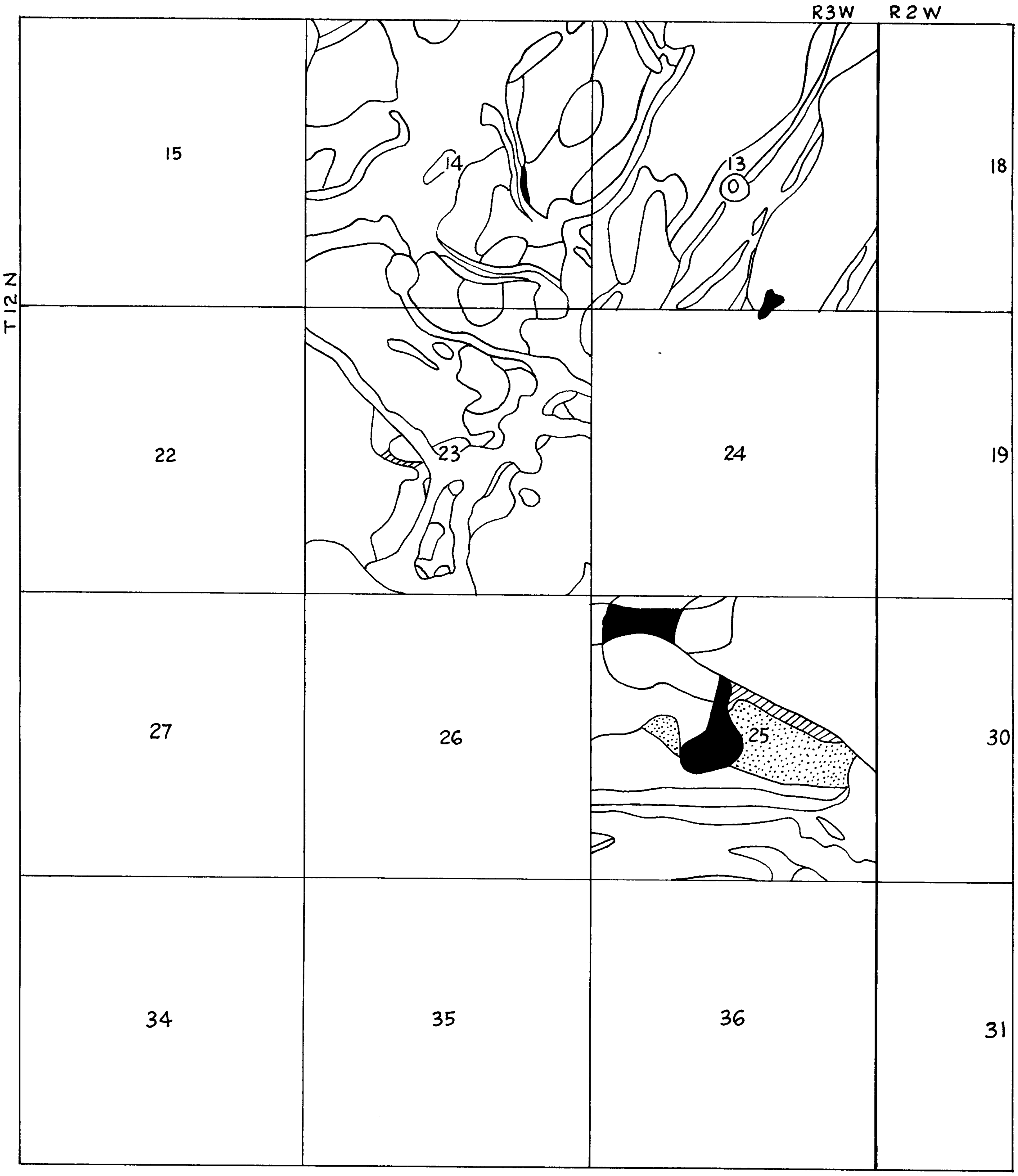
Appendix A-5, page 45
Column heading Nitrate NO_3 should have "as N" removed.

Helen Robson
USGS, WRD, Anchorage

Do NOT use this form as a RECORD of approvals, concurrences, disapprovals, clearances, and similar actions.

FROM *(Name, office symbol or location)*	DATE
	PHONE

OPTIONAL FORM 41
AUGUST 1967
GSA FPMR (41CFR) 100-11.206
GPO : 1967 O—300-455 (8-H) 5041-101



ERRATA

Figure 28.--Relative susceptibility of water resources to pollution by liquid waste disposal.

HYDROLOGY FOR LAND-USE PLANNING: THE HILLSIDE AREA, ANCHORAGE, ALASKA

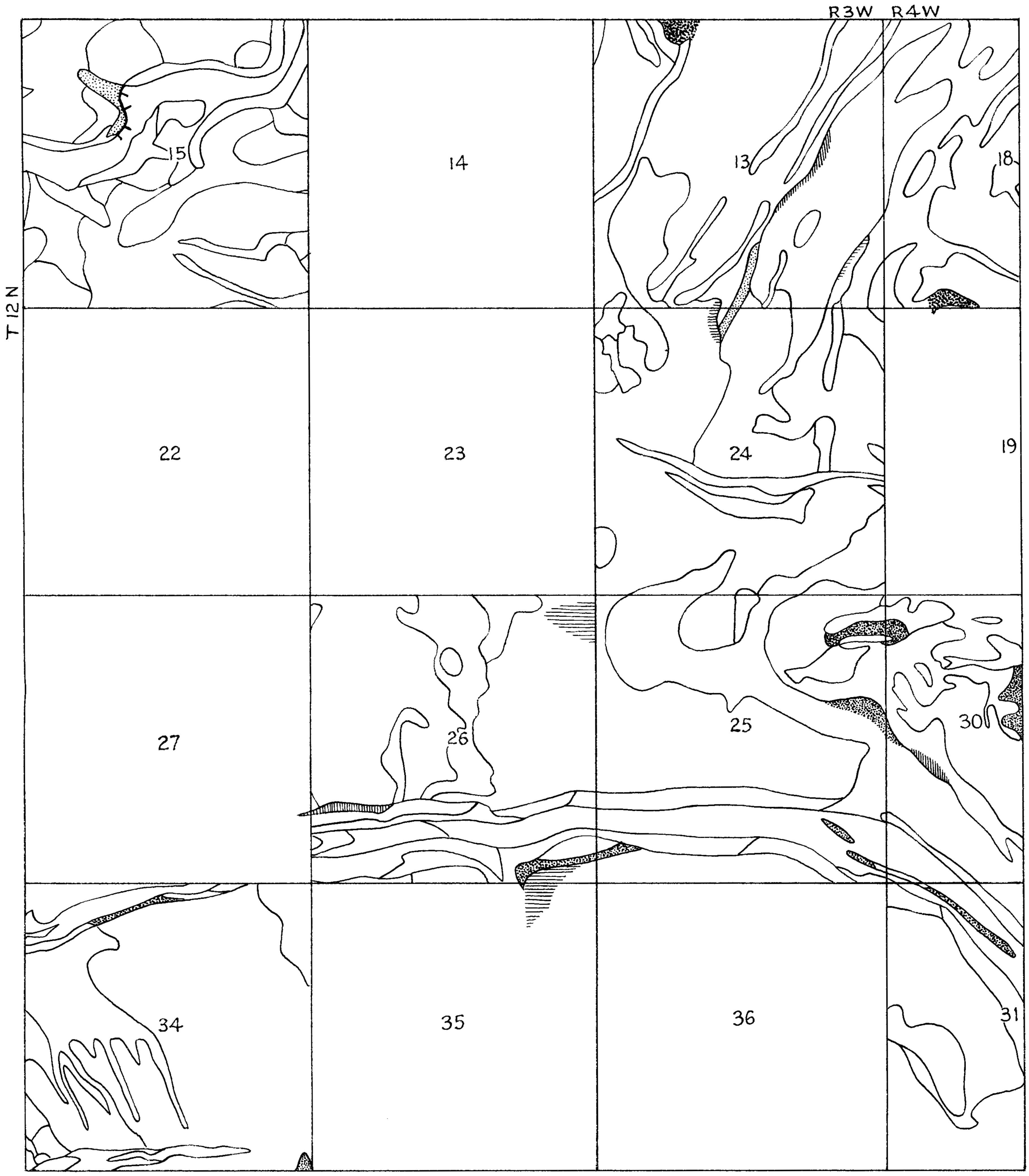
By Larry L. Dearborn and William W. Barnwell

Open-File Report: 75-105, 1975

Changes on page 28 of report.

Relative susceptibility of streams, lakes and shallow ground water to pollution from septic-tank systems.

Change to purple - High   Change to blue - Low   Change to white - Very Low



ERRATA
Figure 30.--Generalized landslope and sediment thickness near mountain front.
HYDROLOGY FOR LAND-USE PLANNING: THE HILLSIDE AREA, ANCHORAGE, ALASKA
By Larry L. Dearborn and William W. Barnwell
Open-File Report: 75-105, 1975

Changes on page 30 of report

LANDSLOPE UNITS

Change to light blue--less than 5 percent

Change to dark blue--15-25 percent

Change to lavendar--5-15 percent

Change to pink--25-45 percent

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

HYDROLOGY FOR LAND-USE PLANNING: THE HILLSIDE AREA, ANCHORAGE, ALASKA

By

Larry L. Dearborn and William W. Barnwell

Prepared in cooperation with the
Greater Anchorage Area Borough

OPEN-FILE REPORT
75-105

Anchorage, Alaska
1975

GREATER ANCHORAGE AREA BOROUGH
3500 EAST TUDOR ROAD
ANCHORAGE, ALASKA 99507

PLANNING DEPARTMENT

C L E A N A I R * C L E A N W A T E R * A C L E A N C O M M U N I T Y

The Hillside area study by the U.S. Geological Survey was made at a critical time during the development of the comprehensive land-use plan and during a time when basic zoning decisions are being made in the Hillside area.

The first major use by the Borough of the findings of this study was in the development of a preliminary comprehensive plan. In preparing this plan, a technique was used whereby four population alternatives were presented to the residents and landowners of the area. These alternatives represented a range from the least amount of development one could realistically expect to the highest degree of development predicted on the basis of population projections. In formulating these alternatives, particularly ones depicting a high degree of development, a number of questions pertaining to hydrologic limitations of the land were raised. For example, what housing density can the land support if the decision is made not to extend sewers and public water into the area? This question can be answered only through knowledge of the area's total water balance, land-drainage characteristics, and the suitability of the land to safely accomodate septic-tank systems. This kind of information is contained in the Hillside report and can be used in current and future planning.

This report clearly demonstrates that a large physiographic area of land must be examined as a unit rather than as a number of small, unrelated parcels. The Hillside is a prime example of an area that is truly interrelated in that any decisions regarding housing density or land use in one part of the community will almost surely have an impact on another.

William H. Beaty

William H. Beaty
Director of Planning
Greater Anchorage Area Borough

CONTENTS

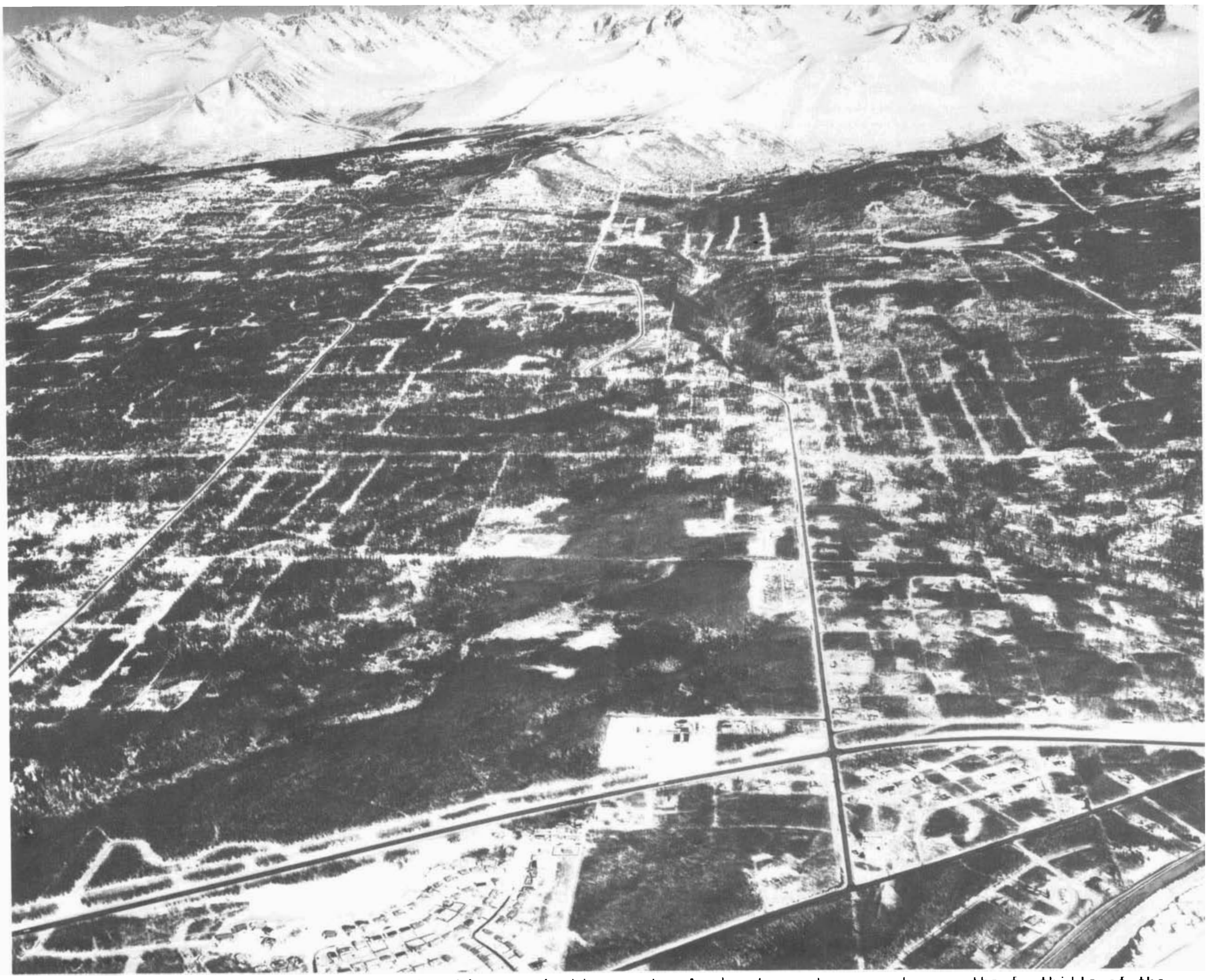
ILLUSTRATIONS

ILLUSTRATIONS

TABLES

FACTORS FOR CONVERTING ENGLISH UNITS TO INTERNATIONAL SYSTEM (SI) UNITS

Multiply English units	By	To obtain SI units
feet (ft)	.3048	metres (m)
miles (mi)	1.609	kilometres (km)
square miles (mi^2)	2.590	square kilometres (km^2)
gallons per minute (gal/min)	.06309	litres per second (l/s)
million gallons per day (Mgal/d)	.04381	cubic metres per second (m^3/s)
acres	.004047	square kilometres (km^2)
inches (in)	25.4	millimetres (mm)
cubic feet per second (ft^3/s)	.02832	cubic metres per second (m^3/s)
gallons (gal)	3.785	litres (l)



Frontispiece.-- 1972 aerial view of the Hillside area looking east. As development encroaches on the foothills of the Chugach Mountains, water supply, drainage, and waste disposal may become critical problems.

ABSTRACT

Rapid residential growth of the Hillside area, Anchorage, Alaska, may cause depletion of aquifers and a change in quality of water resources as a result of extensive development of small-lot tracts. Ground-water yields are low and may be locally inadequate for single family requirements where wells produce from bedrock in the eastern Hillside region. At lower altitudes single family water requirements of 3 to 10 gallons per minute or 0.2 to 0.6 litre per second usually can be obtained, but aquifers capable of being pumped at larger yields for public supplies are uncommon. However, in a few localities, wells do produce 40 to 300 gallons per minute or 2.5 to 19 litres per second from sand and gravel aquifers lying within thick sequences of glacial till. Streamflow within the Hillside area is inadequate as a significant source of water for public supply. Springs, swamps, and water-logged surficial sediments in the Hillside area are mainly caused by hilly terrain and low permeability of surficial materials.

The relative vulnerability of streams, lakes, and ground water to pollution caused by the discharge of liquid waste, particularly from onsite sewage-disposal systems, is moderate to high in about half the study area. At higher altitudes contamination of bedrock aquifers may occur if discharge of liquid wastes is not regulated. The deep sedimentary aquifers at lower altitudes are less susceptible to contamination. However, shallow ground-water bodies may become polluted by discharge of sewage effluent and, consequently, some deep wells may be contaminated by seepage down the outside of casings or through leaky casing joints and underground seals.

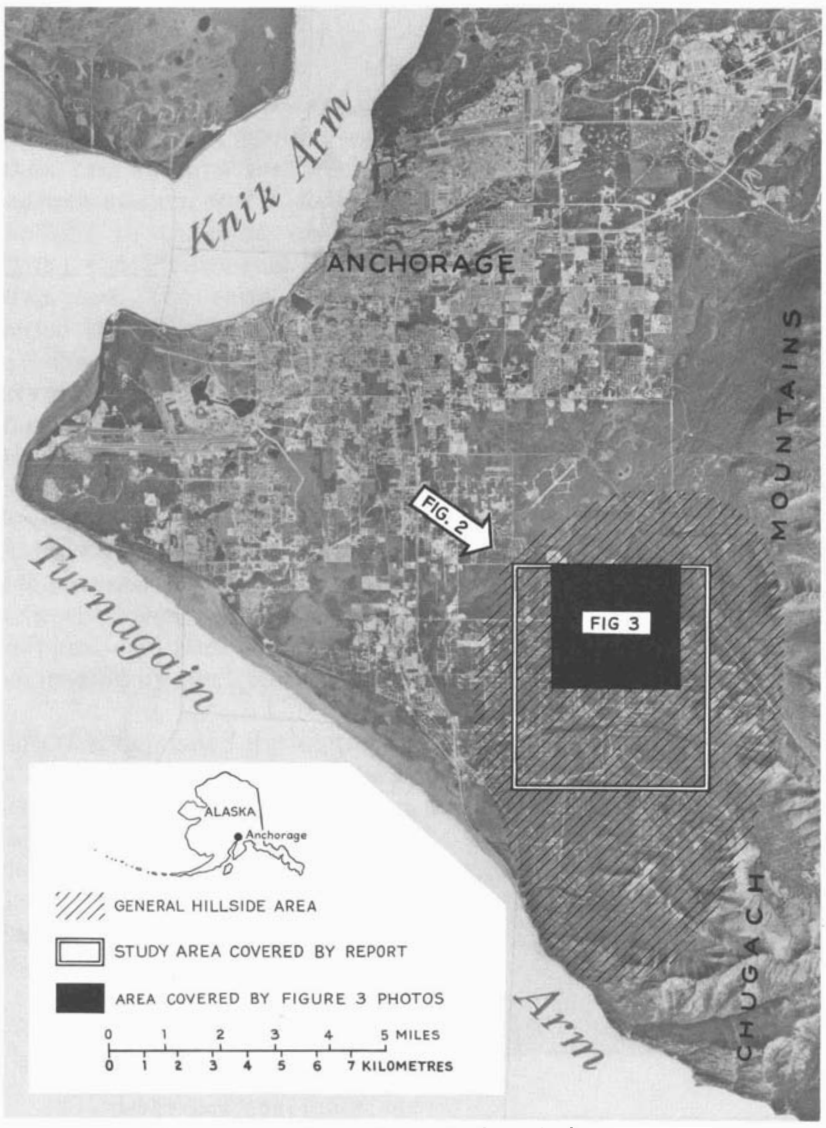


Figure 1.-- Location of the study area.
Photograph courtesy of North Pacific Aerial Surveys Inc.

INTRODUCTION

This report describes the hydrology of an area locally known as the Hillside area, a rapidly growing suburban community about 8 mi (13 km) southeast of the city of Anchorage (fig. 1). The general Hillside area consists of westward-sloping land that is bordered by Turnagain Arm on the south and west and by the Chugach Mountains on the east (fig. 2). The area is currently being subdivided into residential lots. According to the Greater Anchorage Area Borough, the population of the Hillside area may reach 15,000 people by 1985, or approximately three times its current population (Paul Carr, oral commun., 1973). A perspective on the impact of the current rate of development in the area can be gained from aerial photographs (fig. 3) which show the intensity of subdivision growth from 1965 to 1974.

The Greater Anchorage Area Borough, faced with long-range water and land-management decisions, requested that the U.S. Geological Survey study the water situation of the Hillside area as part of an ongoing cooperative program. The study began in 1971 with the following objectives:

1. To determine the water-supply potential within the Hillside area.

2. To define existing or potential drainage problems related to land development.

3. To determine the susceptibility of the water resources to pollution by liquid-waste disposal.

The study consisted largely of a literature search, compilation, and interpretation of existing data. The study was concentrated within the 14 mi^2 (36.3 km^2) shown in figures 1 and 2. This report presents an interpretation of the current information on water resources.

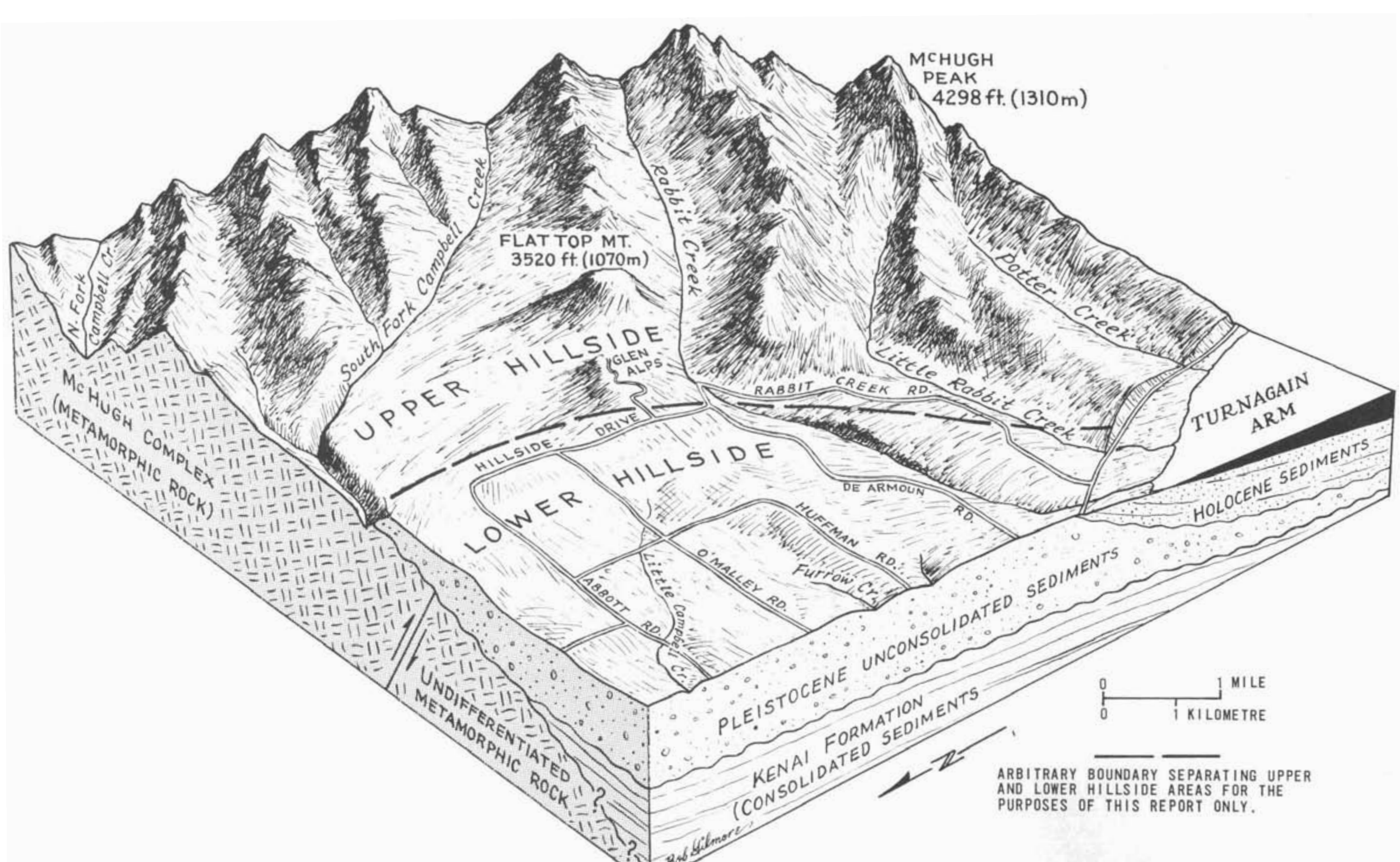
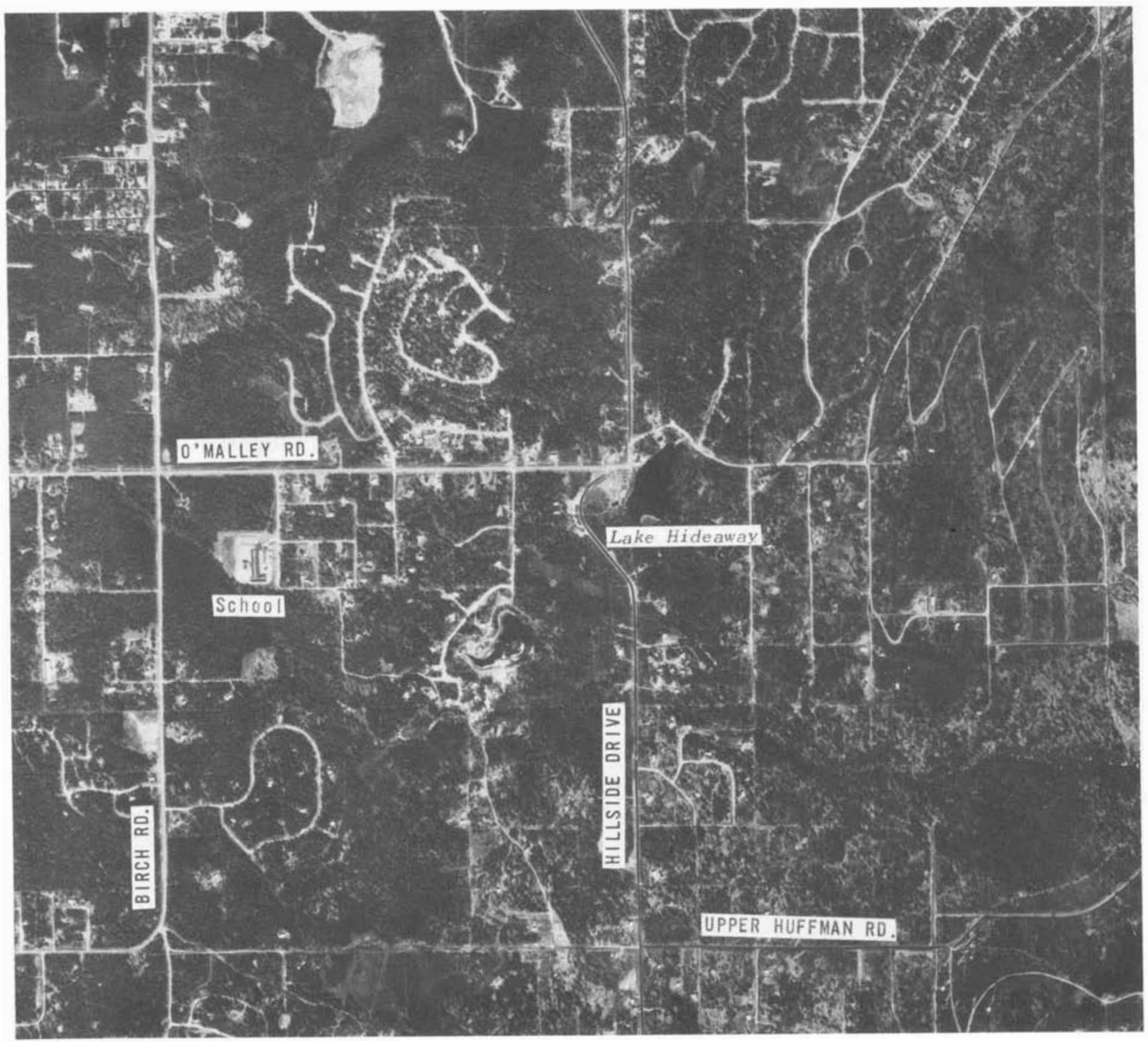


Figure 2.-- Block diagram of the Hillside area showing physical setting, viewed looking southeast from Spenard.



N

May 21, 1974

Photograph courtesy of
North Pacific Aerial Surveys Inc.

0 1000 2000 FEET
0 200 400 600 METRES

In 9 years the density of houses has more than tripled in this area. In lower photograph very few homes surround Lake Hideaway; in upper photograph many septic systems are located relatively close to the shallow lake. Continued small-tract development where springs and seeps are common will add to the potential for serious drainage problems. An altitude drop of approximately 1000 ft (300m) from east to west further complicates most modifications of natural runoff.

N

May 16, 1965

Photograph courtesy of
Air Photo Tech Inc.

0 1000 2000 FEET
0 200 400 600 METRES

Figure 3.-- Suburban development in a northern sector of the Hillside area.

THE RELATION OF WATER TO THE GEOLOGIC SETTING

The availability of ground water and the distribution of streams, lakes, and swamps are largely the result of glacial processes. The bedrock and unconsolidated sediments of the Anchorage plain and foothills to the east were covered by several glacial advances during the Pleistocene Epoch, from 10,000 to about 2 million years ago. The early Pleistocene glacial ice masses repeatedly buried the Hillside area to an altitude of at least 3,300 ft (1,000 m) above the present sea level. During the last major glacial advance (Wisconsin), about 20,000 years ago, ice flowed southward through the Upper Cook Inlet basin and covered the Anchorage plain and foothills to an altitude of about 800 ft (240 m). This southward-flowing ice mass was joined by a glacier flowing west through Turnagain Arm. The two ice masses coalesced in the vicinity of what is now Huffman Road. During this advance, bedrock and older unconsolidated marine and glacial sediments were scoured by the erosive force of moving ice and redeposited. Sediments that were not eroded were tightly compacted by the tremendous weight of the ice mass.

Materials deposited during the Wisconsin Glaciation make up most of the surficial sediments in the Hillside area. The composition and distribution of the glacier-related deposits vary greatly with depth and lateral distance (figs. 4, 5, and 6). Most of the unconsolidated glacial sediments contain poorly sorted rock particles ranging in size from clay to boulders and have low permeability. These deposits are commonly called till.

During and following the retreat of the Wisconsin ice mass, melt-water streams moved great quantities of detrital material. In part, the modern topography and surface drainage of the Hillside area are a direct result of flow in melt-water runoff channels that bordered glacial lobes or issued from glacier termini as the ice mass retreated. The streams flowing through the area today occupy some of these relatively young alluvial channels.

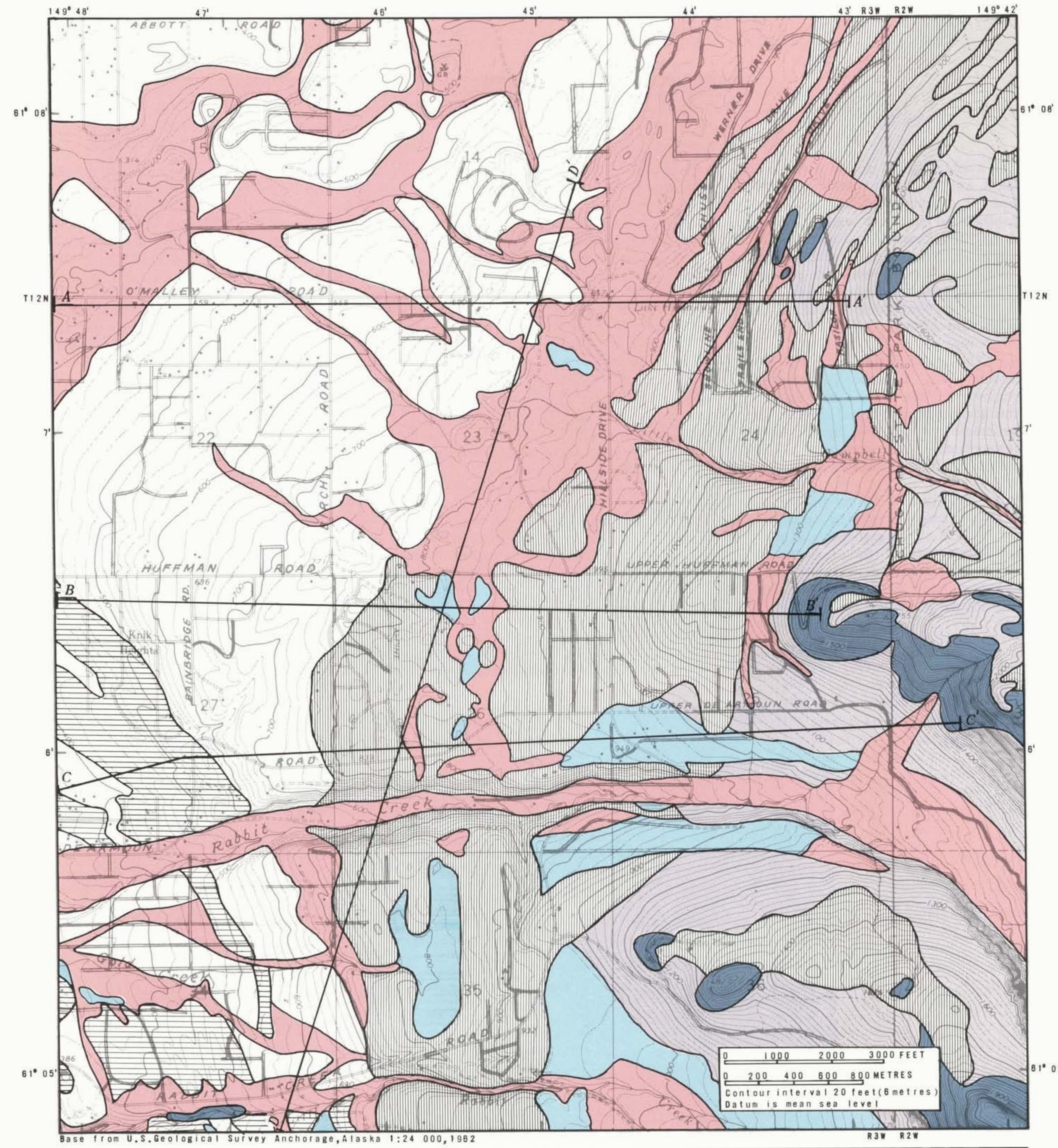
The thick and extensive morainal deposits (see fig. 5 and table 1) apparently resisted erosion by melt-water runoff. Few drainage channels cross the moraines, and swamps and ponds are scattered among the hummocks and low hills of the morainal areas.

Subsurface deposits composed of stream-laid sand and gravel are of great hydrologic significance to the area. They yield most of the ground water pumped by wells. These deposits lie within and between till layers.

Older basement rocks, or bedrock, underlie the unconsolidated deposits or are exposed locally in the easternmost part of the Hillside area. The bedrock consists of conglomerate, limestone, silty sandstone, argillite, and volcanic rocks. Generally, these rocks are metamorphosed and are hard and dense except where extensively fractured or weathered at their contact with overlying sediments or at the land surface.

Figure 4.-- Typical depositional environment at terminus of large alpine glacier.

Rock fragments deposited directly from melting ice are angular and have a wide range in fragment size. However, in outwash streams silt and clay particles are washed from the mixed materials and the angular fragments are rounded to form gravel. Typically, in the subsurface these stream-laid deposits form long narrow beds of permeable sand and gravel, which yield water to wells.



Base from U.S. Geological Survey Anchorage, Alaska 1:24 000, 1962 R3W R2W

EXPLANATION

GEOLOGIC UNITS
see table 1 for hydrogeologic characteristics

- Alluvium
- Slope deposits
- Lake and pond deposits
- Bedrock
- Water-laid, glacially derived deposits
- Morainal deposits
- Morainal deposits modified by marine inundation

Contact (often very gradual change in the field)

A — A' Lines of section (Fig. 6)

Geology from 'Generalized geologic map of Anchorage and vicinity, Alaska' by Schmoll and Dobrovolny, 1972 (Map I 787 A)

Figure 5.-- Generalized surficial geology of the Hillside area.

Table 1.-- Generalized hydrogeologic characteristics of surficial deposits.
(See figure 5 for map of surficial deposits).

Geologic unit	Geologic material	Topographic expression	Distribution	Surficial drainage, infiltration and permeability	Water content	Water-yielding capability	Hydrologic characteristics related to liquid waste disposal
Alluvium	Primarily water-washed sand and gravel, commonly well bedded and sorted but may be silty or clayey. Deposited by ancient and modern streams. Includes glacial alluvium such as kames and kame terraces.	Modern and abandoned stream channels, with little relief. Alluvial fans and kame terraces above 1,100 feet altitude with steeper smooth slopes.	Widespread throughout the area; extensive deposits in Little Campbell Creek valley below 900 feet altitude and in Rabbit Creek and upper Little Rabbit Creek valleys.	Low runoff, rapid infiltration and relatively high permeability except where silt is abundant. Rapid movement of water into and through this unit recharges shallow and perhaps deep aquifers.	Commonly saturated 10 to 20 feet below the surface, particularly along stream channels. Discontinuous perched water bodies may exist at shallower depths.	Fair to good. Shallow wells may yield 10-50 gal/min where saturated thickness of unit exceeds 10 feet.	Generally has adequate percolation capacity. However, percolation rate in some permeable deposits may be too rapid to allow adequate attenuation of contaminants in distances less than 300 feet.
Slope deposits	Intermixed deposits of fresh and weathered bedrock fragments and reworked glacial drift which contains clean and well-sorted or dirty sand and gravel.	Rather smooth slopes of talus fans and cones near bedrock exposures. Somewhat gentler slopes toward downhill boundary. Steep valley slopes along major streams.	Common on steep hillsides above 1,000 feet altitude and along steeper valley walls. Thin deposits downslope from bedrock outcrops common.	Where loosely compacted, little runoff, rapid infiltration and high permeability; allowing rapid vertical flow through materials. At high altitudes, important to recharge of lower-altitude aquifers.	Typically unsaturated except for short periods after heavy rains.	Poor. Usually will not yield a significant supply of water due to sporadic saturation and thinness of unit.	Percolation rates are rapid and contaminants may not be adequately attenuated before liquid reaches fractured bedrock or shallow water in underlying material.
Lake and pond deposits	Thin to thick deposits of silt and clay with some interbedded fine sand and locally thin gravel beds. Formed where mountain streams were dammed by glacial ice or lateral moraines.	Smooth gentle slopes of former lake bottom surfaces. Locally dissected by modern streams.	Primarily deposited where land surface exceeds 800 feet altitude and flanking stream valleys or at the heads of minor drainages.	Generally high runoff. Little infiltration and very slow movement of water in material due to low permeabilities. Springs may occur along uphill contact with alluvium and slope deposits.	May be saturated at or near the surface but probably unsaturated at greater depths.	Poor. However, excavations usually fill with water due to a slow constant seepage of water near the surface.	Percolation rates very low. Where unit is not penetrated, liquid wastes will eventually pond at the surface.
Water-laid glacially derived deposits	Primarily interbedded fine sand and clay with some gravel and cobbles. Commonly gradational to other deposits.	Broad, smooth to slighty hummocky plain with nearly constant slope; little relief and poorly developed drainage.	Restricted to western part of map area below 800 feet altitude. Widespread in Little Campbell Creek basin.	Commonly runoff is moderate, infiltration low to moderate, and permeability varies from very low, to moderate; locally, higher water absorption and conduction rates exist in sandy material.	Mostly unsaturated, except generally saturated along drainages.	Generally poor. Unit is either too thin or is not saturated.	Generally fair. Percolation characteristics not adequate where high silt or clay content is present.
Morainal deposits	Well-mixed deposits of fragmented rock that contain lenses of poorly sorted sand and gravel; directly deposited by ice.	Elongated slopes or crested hills or ridges with generally smooth topography; some local rounded mounds.	Mostly within lateral moraine belt that descends in altitude from 900 - 1,300 feet in the north to 700 - 1,000 feet in the south, parallel to the mountain front. Remnants of older moraines scattered at higher altitudes.	Infiltration rates and permeability are commonly moderate; however locally steep landslopes cause most water to run off. Where compacted or contains much clay, water does not infiltrate and ponds in depressions.	Commonly saturated at considerable depth in deposits thicker than 50 feet. Perched water may exist at shallow depth during wet seasons.	Good to poor. Ordinarily does not yield significant quantities of water to wells or excavation. However, saturated sand and gravel lenses, where present, commonly yield 5 to 20 gal/min.	Percolation rates adequate except where hardpan perches percolating liquids at shallow depths.
Morainal deposits modified by marine inundation	Mixture of silt, sand, gravel, cobbles and boulders of glacial origin and reworked by marine waters. Commonly contains or is overlain by beds of silt, sand and gravel.	Parallel, narrow-crested, northwest-trending ridges with low relief.	Generally below 700 feet altitude and restricted to southwest part of map area.	Generally, low runoff, moderate infiltration rates, and moderate permeability exist near the surface, except locally where high silt content or greater compaction has reduced infiltration of water.	Mostly unsaturated except where silt beds at shallow depths have caused bogs to develop in depressions.	Generally poor. Unit is either too thin or is not saturated.	Percolation rates fair except poor in localities of high sediment compaction and/or high silt content.
Bedrock	Weakly metamorphosed siltstone, graywacke, arkose, conglomeratic sandstone and cherty greenstone, associated with argillite. Near Rabbit Creek, limestone, marble, greenstone and cherty argillite (Clark, 1973).	Steep-sided ridges and knobs.	Exposed only on steepest slopes and some ridge crests above 1,000 feet altitude. In places thinly mantled by colluvium or morainal deposits.	Runoff high if bedrock is exposed. Infiltration and permeability usually very low except where rock is greatly decomposed or extensively fractured. Limited quantities of ground water are commonly found at bedrock-sediment interface.	Fresh, unfractured or non-weathered bedrock does not contain significant quantities of water due to low porosity and permeability.	Generally poor. Yields of 1-5 gal/min obtained from sporadic fractures or from the weathered bedrock, if present. Rare fracture zones may yield 10 gal/min or more.	Characteristics poor for disposal of liquid wastes. Contaminants may readily travel for great distances through bedrock fractures to reach wells which may intersect these fractures downgradient.

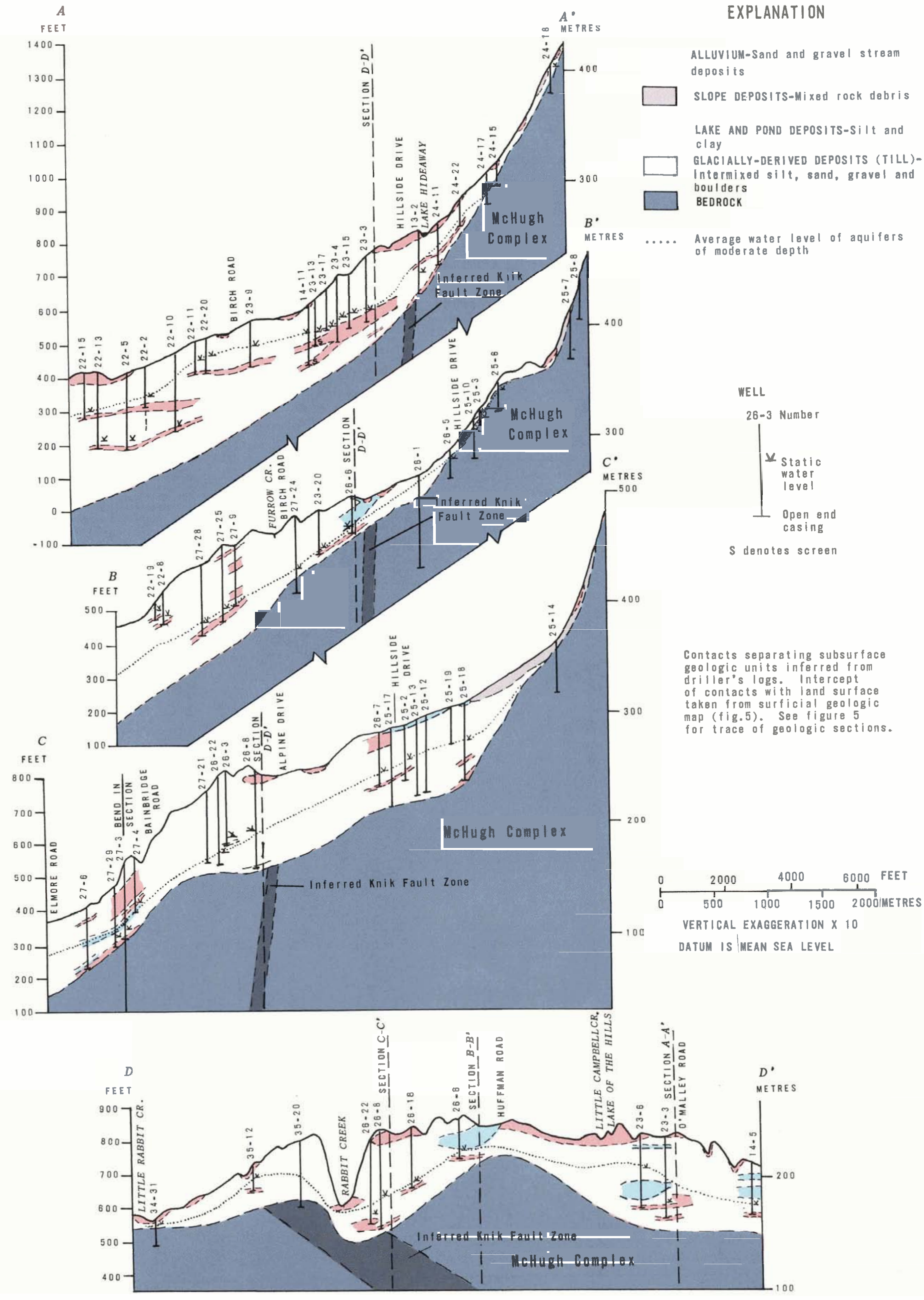


Figure 6.-- Generalized geologic sections.

WATER AVAILABILITY

- THERE IS WIDESPREAD CONCERN THAT ADEQUATE WATER SUPPLIES MAY NOT BE AVAILABLE IN THE HILLSIDE AREA. FOR PURPOSES OF THIS REPORT, THE AREA HAS BEEN DIVIDED INTO TWO GROUND-WATER AVAILABILITY ZONES.

- THE UNCONSOLIDATED SAND AND GRAVEL AQUIFERS UNDERLYING THE AREA WEST OF HILLSIDE DRIVE PROBABLY CAN SUPPLY THE WATER NEEDS OF A RESIDENTIAL COMMUNITY OF 20,000 TO 40,000 PEOPLE, ASSUMING A PER CAPITA USE RATE OF 100 GALLONS (378 LITRES) PER DAY.

- IN CONTRAST, BEDROCK AQUIFERS WHICH UNDERLIE THE UPPER HILLSIDE AREA, GENERALLY EAST OF HILLSIDE DRIVE, ARE MUCH LESS PRODUCTIVE. TYPICAL YIELDS ARE LESS THAN 3 GAL/MIN (0.2 L/S), AND IN SOME LOCATIONS A RESIDENTIAL WATER SUPPLY MAY NOT BE AVAILABLE.

- RABBIT AND LITTLE RABBIT CREEKS ARE NOT PRACTICAL SOURCES FOR PUBLIC WATER SUPPLY BECAUSE OF THEIR LOW DISCHARGE IN WINTER MONTHS AND PROBABLE LACK OF SURFACE-STORAGE SITES.

Sources of Ground Water

Ground water in the Hillside area is obtained from many individual residential wells and from several public-supply wells. Wells generally produce water from either permeable unconsolidated sedimentary lenses of sand and gravel or fractured and weathered bedrock. The occurrence and abundance of ground water in the Hillside area is highly variable because favorable geologic conditions are irregularly distributed. Dry holes drilled 200-400 ft (61-122 m) into sediments or bedrock have been reported. In general, however, adequate water-yielding sediments are found at depths of less than 300 ft (91 m) in the area west of Hillside Drive and in places where the land-surface altitude is less than about 800 ft (244 m). At higher altitudes, wells commonly withdraw marginal supplies of water almost exclusively from bedrock at depths ranging from 50 to 400 ft (15 to 122 m).

Unconsolidated Sediments

The primary subsurface water-producing zones, termed aquifers, are lenses of sand and gravel within and between less permeable till layers. These aquifers are generally 1 to 5 ft (0.3 to 1.5 m) thick and are rarely more than 10 ft (3 m) thick. Such deposits are often called stringers because they are thin and lack continuity as a result of deposition in small, braided, glacial stream channels. Their lateral extent is commonly only several hundred feet. As a result, correlation of individual aquifers from drillers' logs of wells (appendix A-1, A-2), even on adjacent lots, is often impossible. Aquifers are not abundant and make up only a small percentage of the total sediment thickness.

In most of the Hillside area, till does not yield appreciable water to wells due to its generally low permeability. However, a few wells are finished in loosely compacted, sandy or gravelly till and will produce 5 gal/min (0.3 l/s) or more, an adequate supply of water for single-family use.

Compact and commonly "dry" layers within till that are very resistant to drilling are locally called hardpan. These strata are the chief confining layers in the artesian ground-water system underlying the Hillside area. Generally ground water more than 50 ft (15 m) below the land surface is confined by hardpan. Consequently, water in most aquifers is under pressure and water levels in the wells tapping these aquifers will rise above the top of the water-bearing strata. However, in a few localities, ground water occurs above shallow "tight" till and water table (unconfined) conditions exist.

An indication of the thickness of glacial deposits and the distribution with depth of known aquifers are shown on four hydrogeologic sections (fig. 6) and on the sediment-thickness map (fig. 7). Sections A-A′, B-B′, and C-C′ are perpendicular to the mountain front, whereas section D-D′ parallels the mountain front at an approximate surface altitude of 700 ft (213 m). In many places, the lower limits of aquifers shown on the sections were not defined because most wells were drilled just deep enough to obtain a supply and do not fully penetrate the permeable zone. Water-bearing lenses that are very thin or produce silty water are not shown. Future drilling may discover significant aquifers between or below the aquifers shown.

In section A-A′, parallel to O'Malley Road, unconsolidated sediments rapidly thicken to more than 200 ft (61 m) west of Lake Hideaway and to about 400 ft (122 m) in the western part of the map area. Seismic and drilling records indicate that at least 700 ft (213 m) of unconsolidated sediments overlie bedrock along the shore of Turnagain Arm, about 3 mi (4.8 km) farther west. The thickness of unconsolidated sediments along section B-B′, approximately parallel to Huffman Road, follows the same general trend as section A-A′ and increases rapidly near Birch Road.

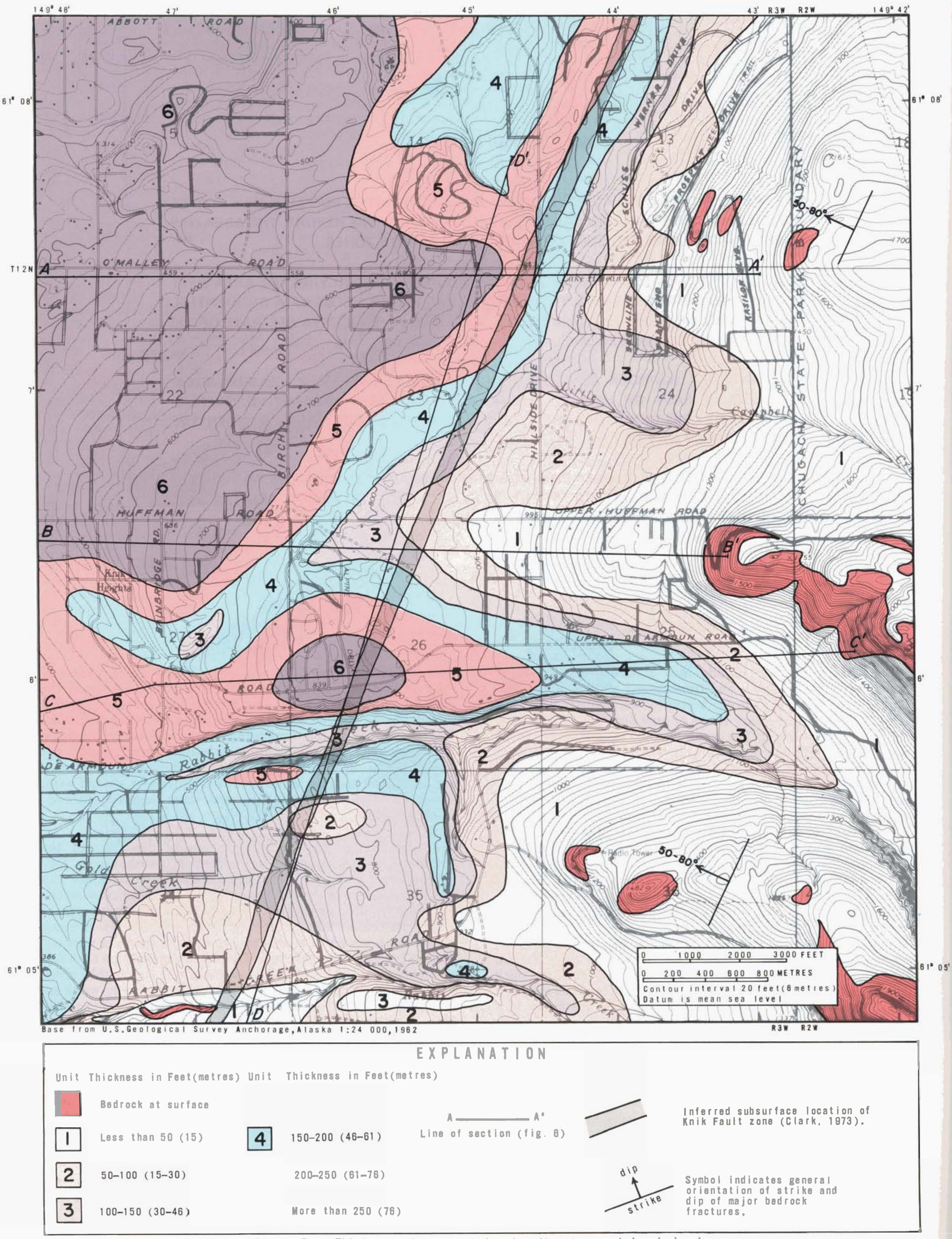


Figure 7.-- Thickness of unconsolidated sediments overlying bedrock.

However, the thickness of saturated sediments is about 100 ft (30 m) less along this section than in the O'Malley Road section. Sections C-C' and D-D' indicate that a buried bedrock ridge extends westward from the Chugach Mountain front to the vicinity of Bainbridge Road (figs. 6 and 7). Sediments overlying the ridge are thin. These two sections also indicate a thinning of water-saturated sediments in the Rabbit and Little Rabbit Creek basins in the southern Hillside area. Here, several perched water zones have been found above the main ground-water body, but their yields were inadequate for well development.

The probable range of drilling depth required to reach aquifers in the map area can be estimated from figure 8. This map shows depths to the shallowest water-yielding stratum that generally will produce an adequate water supply for domestic use (approximately 5 gal/min, or 0.3 l/s).

Aquifers commonly are more than 200 ft (61 m) below land surface along the north side of Rabbit Creek. These aquifers probably were deposited in the pre-Wisconsin stream channel of Rabbit Creek and are oriented in an east-west direction. Water levels in wells tapping these strata are relatively deep, and pumping lifts are nearly 200 ft (61 m).

Water levels in wells finished in confined aquifers indicate a gradual loss of hydraulic head toward Turnagain Arm (see fig. 6, sec. A-A', B-B', and C-C'). Most strata are hydraulically connected and any well pumped at a high rate will cause water-level decline in nearby wells. In several areas where shallow unconfined ground water is perched above the deeper confined water, the hydraulic connection between water table and deeper aquifers probably is severely restricted.

Figure 9 is a generalized map of the depth below land surface to which water rises in wells tapping aquifers generally lying 100-250 ft (31-76 m) deep. The height of the water column in a proposed well can be estimated by subtracting the most probable depth to the water level (interpolated at the well site using figure 9) from the anticipated depth to the aquifer (fig. 8). The minimum height of pump lift at a well site can also be determined directly from figure 9.

Pumping data from well-construction records are shown in appendix A-3. The data consists of the pumping rate, water-level drawdown, and duration of pumping during well development at various sites. Generally, yields from open-end, 6-in (25 mm) diameter wells are less than 10 gal/min (0.6 l/s) in the Hillside area. However, yields of nearly 300 gal/min (19 l/s) have been obtained from a few large-diameter wells that are finished with screens. Some domestic-supply wells that are 300 ft (91 m) or more deep produce as little as 1 gal/min (0.06 l/s).

The probable maximum yield of wells listed in appendix A-1, or other Hillside wells similarly constructed, may be estimated by multiplying the ratio of the recorded yield for a given well to the corresponding drawdown by the total permissible drawdown in that well. For example, if a well was pumped at 10 gal/min (0.6 l/s) and drawdown at that pumping rate stabilized at 20 ft (6 m) below the non-pumping water level and if the maximum allowable drawdown is 80 ft (24 m), then it is probable that 40 gal/min (2.5 l/s) can be pumped for at least short periods of time.

Bedrock

Two bedrock units having very low permeability underlie the unconsolidated sediments of the Hillside area (Clark, 1973). An inferred northeastward-trending fault, named the Knik fault, separates the McHugh Complex that consists of metamorphosed coarse clastic and submarine volcanic rocks of Jurassic and (or) Cretaceous age on the east from older, more highly metamorphosed rocks of Permian to Jurassic age on the west.

The yield of bedrock wells is commonly low and often insufficient for a residential supply. Ground water generally is obtained from weathered or fractured zones where they are present in the metamorphosed bedrock. However, many water-bearing fractures do not supply enough water, and some wells have to tap multiple fractures at various depths. Table 2 indicates that about 70 percent of bedrock wells checked in the Hillside area east of Hillside Drive produce less than 5 gal/min (0.3 l/s). About 40 percent of the wells produce less than 3 gal/min (0.2 l/s).

Table 2.-- Yields from bedrock wells.

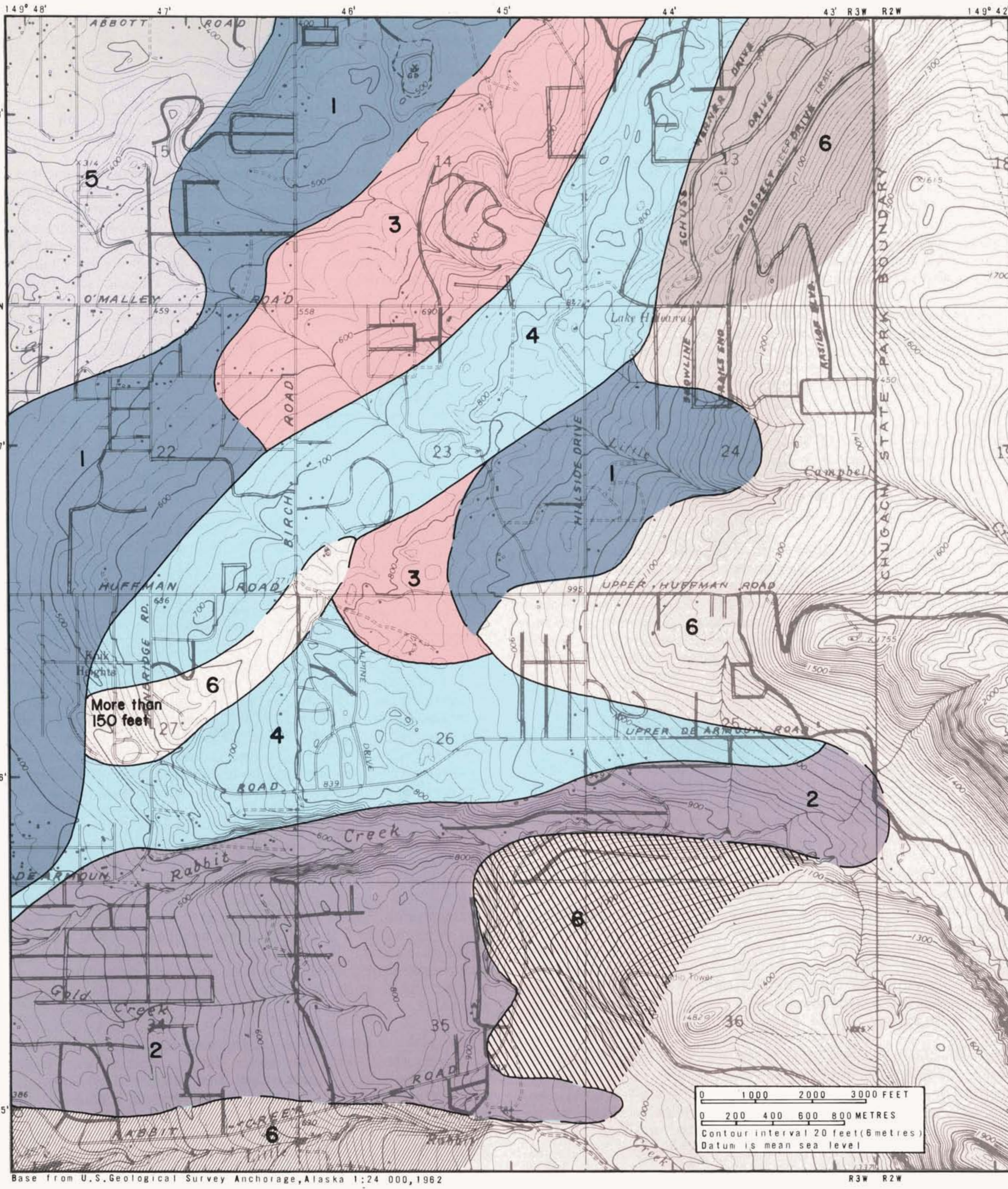
Yield, in gpm	Number of wells	Percent of total
1 or less	11	28
Between 1 and 5	16	41
5 or more	12	31
Total	39	100

Knowledge of the location and the general orientation of fractures in bedrock can help in the selection of well sites in the eastern Hillside area. In this area the trend of fractures is northeast-southwest (Clark, 1973). The dip, or inclination, of the fracture planes is mostly 50 to 70 degrees from the horizontal plane and inclined to the northwest. Consequently, the probability of success for a new well will be highest if it is located either to the northeast or southwest of a nearby bedrock well successfully completed in fractured bedrock.

A zone of weathered bedrock is generally present at the contact between bedrock and overlying sediments, except in the easternmost (high altitude) area. It commonly is thinner than 5 ft (1.5 m) but may be as thick as 25 ft (7.6 m). Wells generally produce more than 3 gal/min (0.2 l/s) from weathered bedrock that is more than 5 ft (1.5 m) thick, but they produce less from thinner zones. The extent, thickness, and hydrologic characteristics of the weathered zone are poorly defined at present because most wells have been completed in the overlying sediments.

In many places where the weathered bedrock zone does not yield sufficient water, wells are drilled deeper. Most of these wells intersect fractures at depths of less than 250 ft (76 m) below the bedrock surface. These fractures generally yield 1 to 5 gal/min (0.06 to 0.3 l/s), and the yield decreases with depth. However, one well (well 21, sec. 25) was drilled nearly 400 ft (122 m) into bedrock before adequate water from fractures was obtained.

In summary, because bedrock yields are low, every effort should be made to locate and complete wells at sites where the unconsolidated sediments are thickest. The probability of finding aquifers increases as the thickness of sediment overlying bedrock increases. Figure 7 shows the generalized thickness of the unconsolidated sediments overlying bedrock. Bedrock is at or near the surface and the sedimentary layer is thin in much of the eastern half of the study area (map units 1-3). In the northwest quarter of the study area (unit 7), the depth to bedrock increases to more than 250 ft (76 m).



EXPLANATION

PREDOMINANTLY UNCONSOLIDATED AQUIFERS

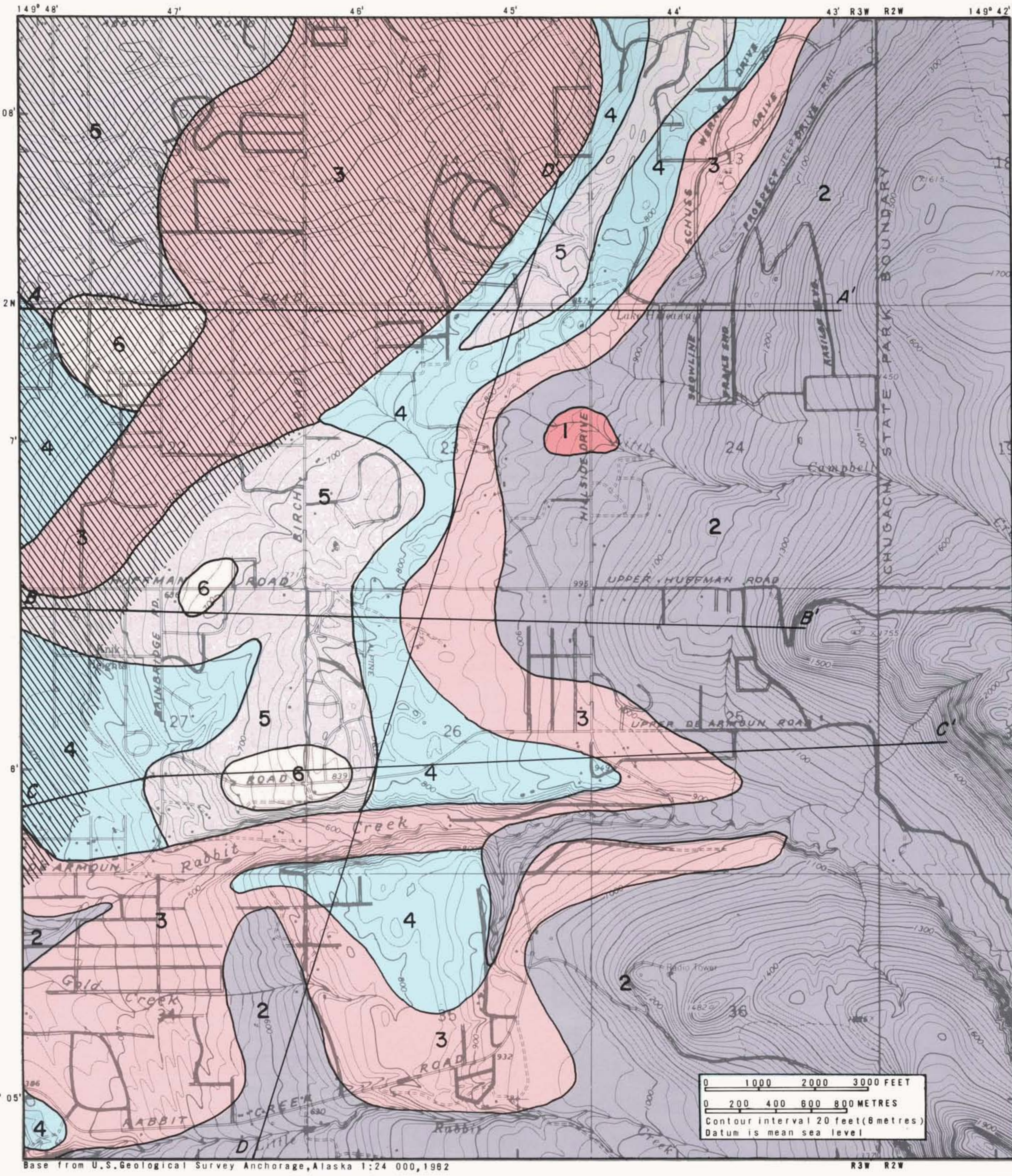
Unit	Depth below land surface in feet (metres)
1	Less than 100(30)
2	50–150(15–46)
3	100–150(30–46)
4	150–250(46–76)
5	150–300(46–91)

PREDOMINANTLY BEDROCK AQUIFERS

Unit	Depth below land in feet (metres)
6	50–400(15–122) highly variable
(hatched)	Generally 50–150(15–46)
	More than 100(30)
(blank)	Generally 100–200(30–61)

All contacts between adjacent units are gradational. Contacts are dashed where poorly defined.

Figure 8.-- Generalized depth to shallowest domestic-supply aquifers.



EXPLANATION

Depth to static water level in feet (metres) below land surface

1	Wells will flow at or above land surface
2	Less than 50 (15)
3	50-100 (15-30)
4	100-150 (30-46)
5	150-200 (46-61)
6	More than 200 (61)

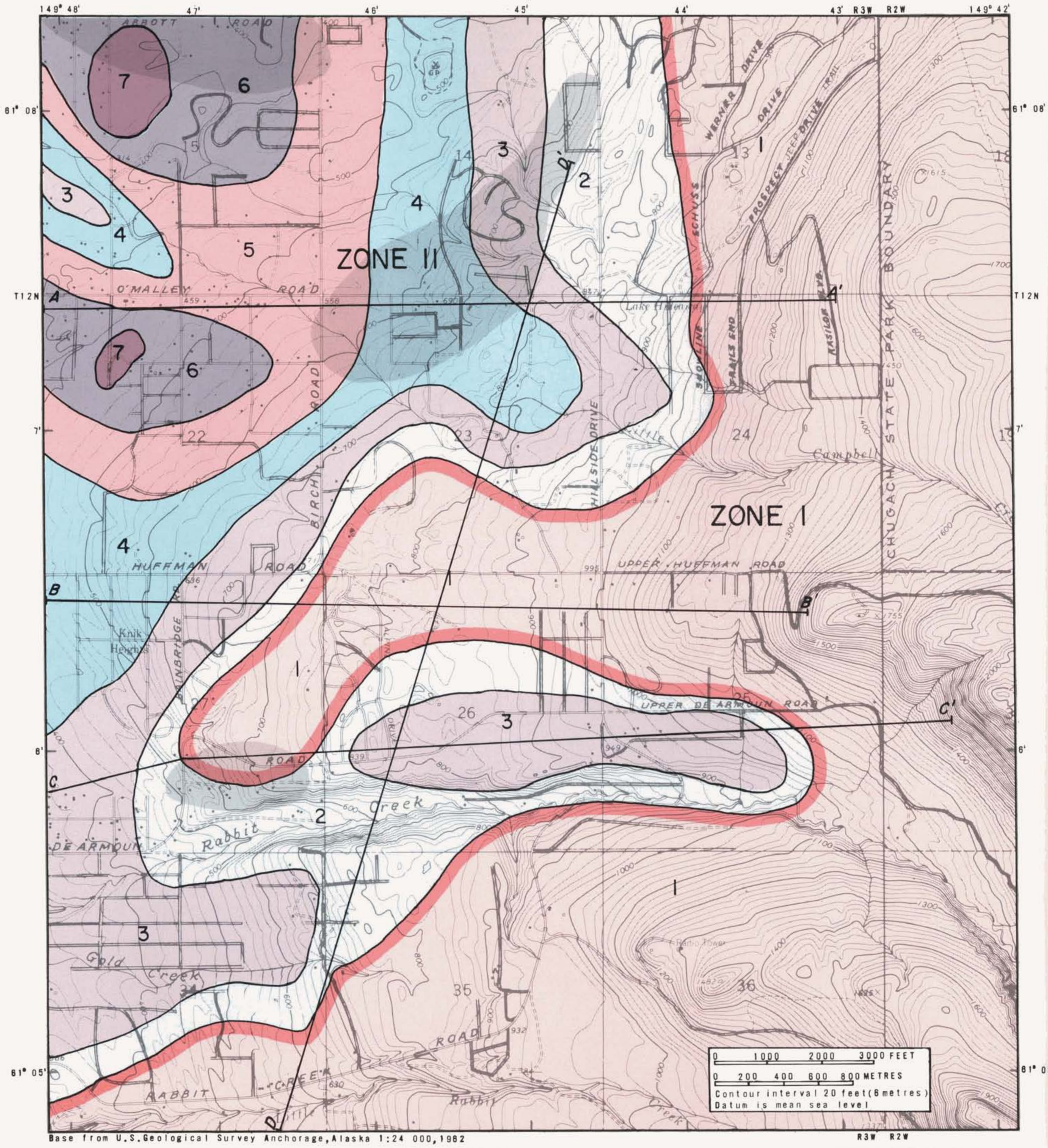
A ——— A'

Line of section (fig. 6)

Static water levels are highly variable. Water levels in wells less than 100 ft. (30m) deep are 30 to 80 ft. (9 to 24m) below land surface.

Note: This map does not indicate depths of wells or depths to aquifers, but shows the approximate distance below land surface to which water will rise in wells tapping aquifers 50 to 200 ft. deep (15 to 61m).

Figure 9.-- Depth to static water level in wells of moderate depth.



EXPLANATION

THICKNESS OF SATURATED SEDIMENTS

Unit	Thickness in feet (metres)	Unit	Thickness in feet (metres)
1	0-50 (0-15)	5	200-250 (61-76)
2	50-150 (15-46)	6	250-300 (76-91)
3	100-150 (30-46)	7	More than 300 (91)
4	150-200 (46-61)		Line of section (fig. 6) A⊢—⊣A'

Shaded areas indicate that moderate yields of 40 to 300 gal/min (2.5 to 19 l/s) are possible.

YIELD OF WELLS

Zone I — Poor aquifers found generally in both sediments and bedrock. Yields commonly less than 3 gal/min (0.3 l/s).

Zone II — Sand and gravel lenses in saturated material, are mostly fair to good aquifers. Low yields common, ranging from 5 to 40 gal/min (0.3 to 2.5 l/s).

Estimated center of transition belt separating Zone I and Zone II aquifers.

Figure 10.-- Thickness of saturated sediments and generalized yield of wells.

Outlook for Ground Water

For planning purposes, zones of ground-water availability are delineated in figure 10. In zone I saturated sediments overlying bedrock are less than 50 ft (15 m) thick, aquifers are scarce, and well yields rarely exceed 10 gal/min (0.5 l/s). Most wells draw water from the underlying bedrock where yields generally are less than 5 gal/min (0.3 l/s). The present average daily pumpage from zone I is estimated at 0.1 Mgal/d (0.004 m^3/s).

In zone II where more than 50 ft (15 m) of saturated sediments overlies bedrock most wells tap unconsolidated sedimentary aquifers. Although shown as a line in figure 10, the boundary separating zone I from zone II is gradational. Aquifers in zone II generally yield 5 to 40 gal/min (0.3 to 2.5 l/s) to domestic wells finished with open-end casings. In the three dotted areas shown in figure 10, well-yield data indicate a high probability that yields of 70 to 300 gal/min (4.4 to 19 l/s) may be obtained. Present production from unconsolidated sedimentary aquifers in zone II is estimated at 0.3 Mgal/d (0.01 m^3/s).

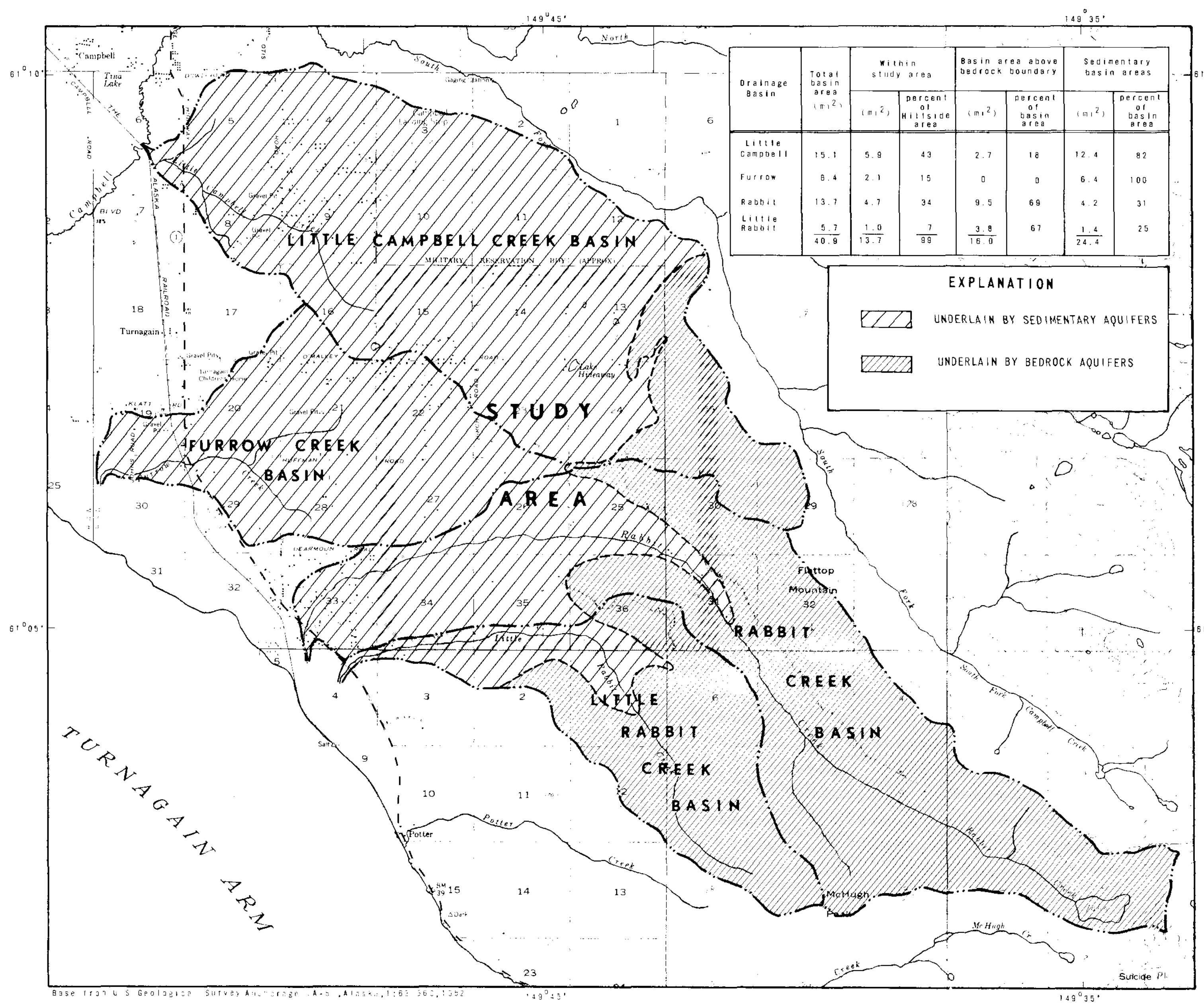
Total ground-water pumpage in the study area is about 0.4 Mgal/d (0.014 m^3/s) from both zones. Pumpage was estimated by assuming that the 4,000 residents in the area use 100 gallons (378 l) of water per day per person.

The Natural Water Budget

An approximation of the water budget in four Hillside basins (fig. 11) can be used to obtain perspective on long-term availability of ground water. Assuming that a nearly constant volume of water enters the area annually through precipitation, streamflow, and ground-water inflow (fig. 12) and that ground-water storage remains constant year after year, the same quantity of water must leave the area on an annual basis as enters it. Under this long-term, steady condition ground-water recharge equals ground-water discharge, and the flow of water through the subsurface sediments maintains relatively constant ground-water levels. An equation representing the natural water budget in the area shown as underlain by sedimentary aquifers in figure 11 is:

Precipitation + stream inflow + ground-water inflow = stream outflow + evaporation + transpiration + ground-water outflow ± change in storage.

The average daily flow of ground water (fig. 11) is estimated to be 10 to 16 Mgal/d (0.4 to 0.7 m^3/s). Although the subsurface materials transmit at least 10 Mgal/d (0.4 m^3/s) and contain a vast amount of water in storage, only a small percentage is recoverable through wells. Permeable deposits, or aquifers, occupy a very small part of the total volume of saturated materials and, therefore, wells can withdraw water only in a severely limited spatial arrangement. Water flows at exceedingly low rates from till deposits to aquifers because most tills have very low permeabilities. Consequently, recharge to some aquifers may be insufficient to maintain withdrawal rates from domestic wells for prolonged periods.



Drainage Basin	Total basin area (mi^2)	Within study area (mi^2)	Within study area percent of Hillside area	Basin area above bedrock boundary (mi^2)	Basin area above bedrock boundary percent of basin area	Sedimentary basin areas (mi^2)	Sedimentary basin areas percent of basin area
Little Campbell	15.1	5.9	43	2.7	18	12.4	82
Furrow	6.4	2.1	15	0	0	6.4	100
Rabbit	13.7	4.7	34	9.5	69	4.2	31
Little Rabbit	5.7	1.0	7	3.8	67	1.4	25
	40.9	13.7	99	16.0		24.4	

Figure 11.-- Drainage basins in the Hillside area.

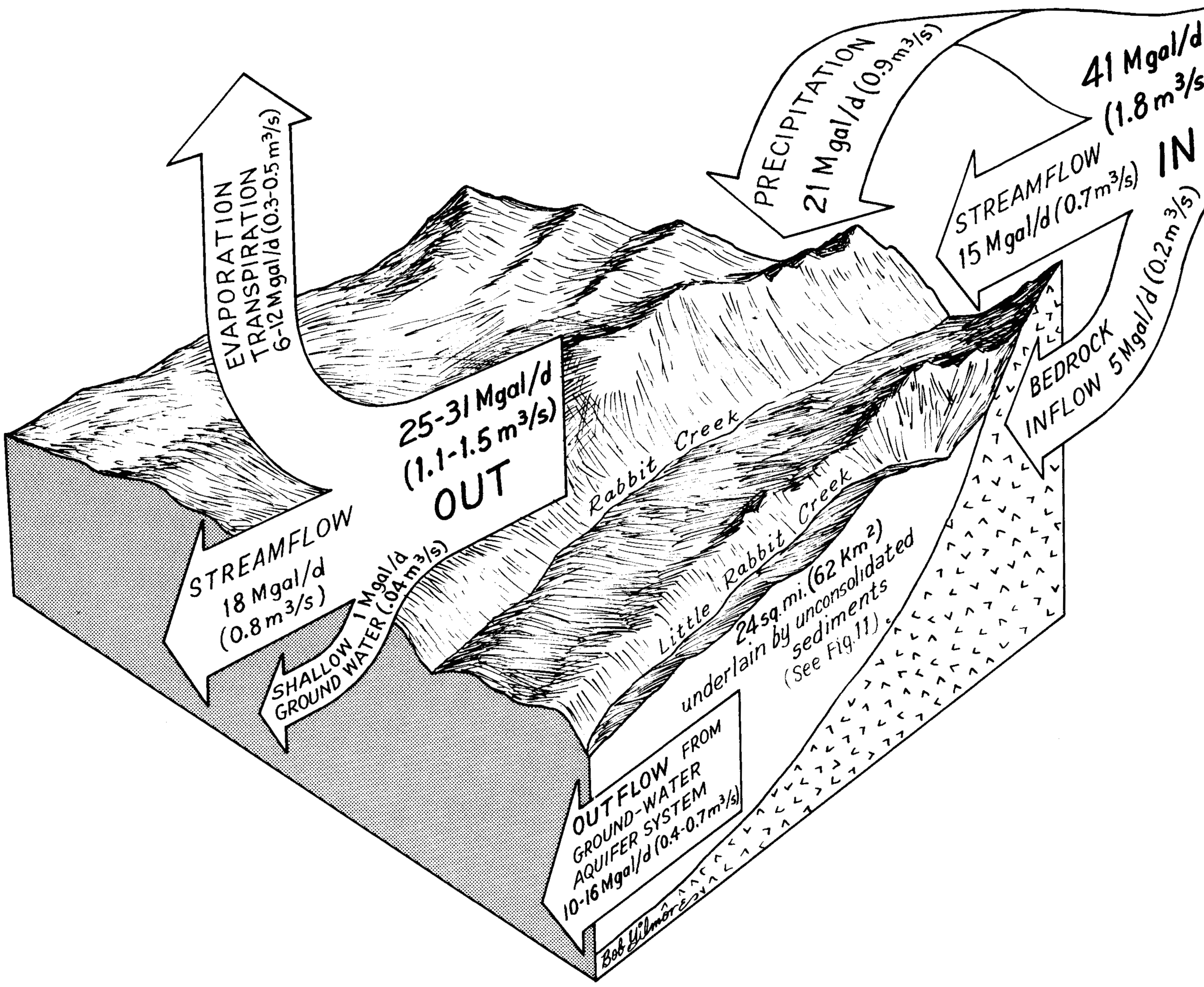


Figure 12.-- Water budget of the area underlain by sedimentary aquifers.

Estimation of Ground-Water Yield

Assuming the rate of recharge remains constant, as shown in figure 12, an estimated sustained yield of 2 to 4 Mgal/d (0.08 to 0.17 m^3/s) can be developed in zone II (fig. 10), enough to supply 20,000 to 40,000 residents. Pumpage at these rates may best be achieved through numerous, evenly distributed, low-yield wells so that water levels will not be excessively drawn down in any locality. Present data suggest that sustained yields of more than 0.1 Mgal/d (70 gal/min or 4.4 l/s) may be possible in three areas shown in figure 10, or in about 10 percent of the total study area. Interference with existing individual residential wells can be minimized if sufficient spacing is used when locating public-supply wells.

At this time, the potential areal yield from zone I cannot be determined. However, the probability of successfully completing a public-supply well is poor. In much of this area the clustering of domestic wells within small tract developments may not be desirable because the total quantity of recoverable water in bedrock fractures can be so small that closely-spaced wells may deplete the local supply.

In areas where yields of bedrock wells are less than about 2 gal/min (0.1 l/s) some wells have been drilled 100 to 200 ft (30 to 61 m) deeper than the producing zone, resulting in additional water storage within the well bore. This water is recovered by setting the pump intake near the bottom of the well. As an alternative, surface tanks with water-holding capacities of several hundred gallons can be used to compensate for marginal well yields.

Sources of Surface Water

Streams

The study area includes three major drainage basins, Little Campbell, Rabbit and Little Rabbit Creeks, and the headwaters of a fourth basin, Furrow Creek (fig. 11). Stream discharge from the major basins is small, but all streams flow year-round. A stream channel has not developed in upper Furrow Creek basin and recent runoff is not evident.

The drainage in Little Campbell Creek basin is poorly developed west of Hillside Drive. A main channel heads in mountainous terrain at about 1,300 ft (396 m) altitude. At lower altitudes Little Campbell Creek flows in a narrow meandering channel through several swampy areas that lie between stream reaches with steeper gradients and straighter channels. Small intermittent tributaries flow from springs or drain wet land and join the main channel below Hillside Drive. Although no residents are known to use creek water for household use, some water is reportedly diverted for livestock. Streamflow less than 1 Mgal/d (0.04 m^3/s) during most of the year and often severe winter icing almost completely stops flow. The creek derives much of its flow from ground-water seepage.

Rabbit and Little Rabbit Creeks in the southern Hillside area exhibit flow characteristics similar to Campbell and Ship Creeks near Anchorage. They head at higher altitudes in the bedrock terrain of the Chugach Mountains and, like Ship Creek (Barnwell and others, 1972), have no significant tributaries downstream from the mountain front. Rabbit Creek flows from a 150-acre (0.6-km^2) lake that occupies a remnant glacial cirque about 5 mi (8 km) southeast of the report area (fig. 11).

The mean annual flow of Rabbit Creek near its mouth is estimated from water-budget studies and miscellaneous discharge measurements to be about 11 Mgal/d (0.5 m^3/s). Two sets of streamflow measurements made in April 1972 and 1973 during low flow indicate no appreciable loss or gain of water below an altitude of 900 ft (272 m). This suggests that ground-water seepage is not a significant increment of streamflow under low flow conditions. A flow of 3 Mgal/d (0.1 m^3/s) was measured in April 1972 at the Old Seward Highway before spring runoff. Simultaneous measurements made at three points along Rabbit Creek in September 1971 indicate a gain of about 1 Mgal/d from Hillside Drive to the Old Seward Highway.

Water-budget studies and miscellaneous measurements indicate that the mean annual flow of Little Rabbit Creek near its mouth is approximately 4 Mgal/d (0.2 m^3/s). Field measurements made at low flow during April 1972 and 1973 and at medium flow in September 1971 indicate a small downstream gain. A low flow of 0.75 Mgal/d (0.03 m^3/s) was measured in early April 1972 at the Old Seward Highway.

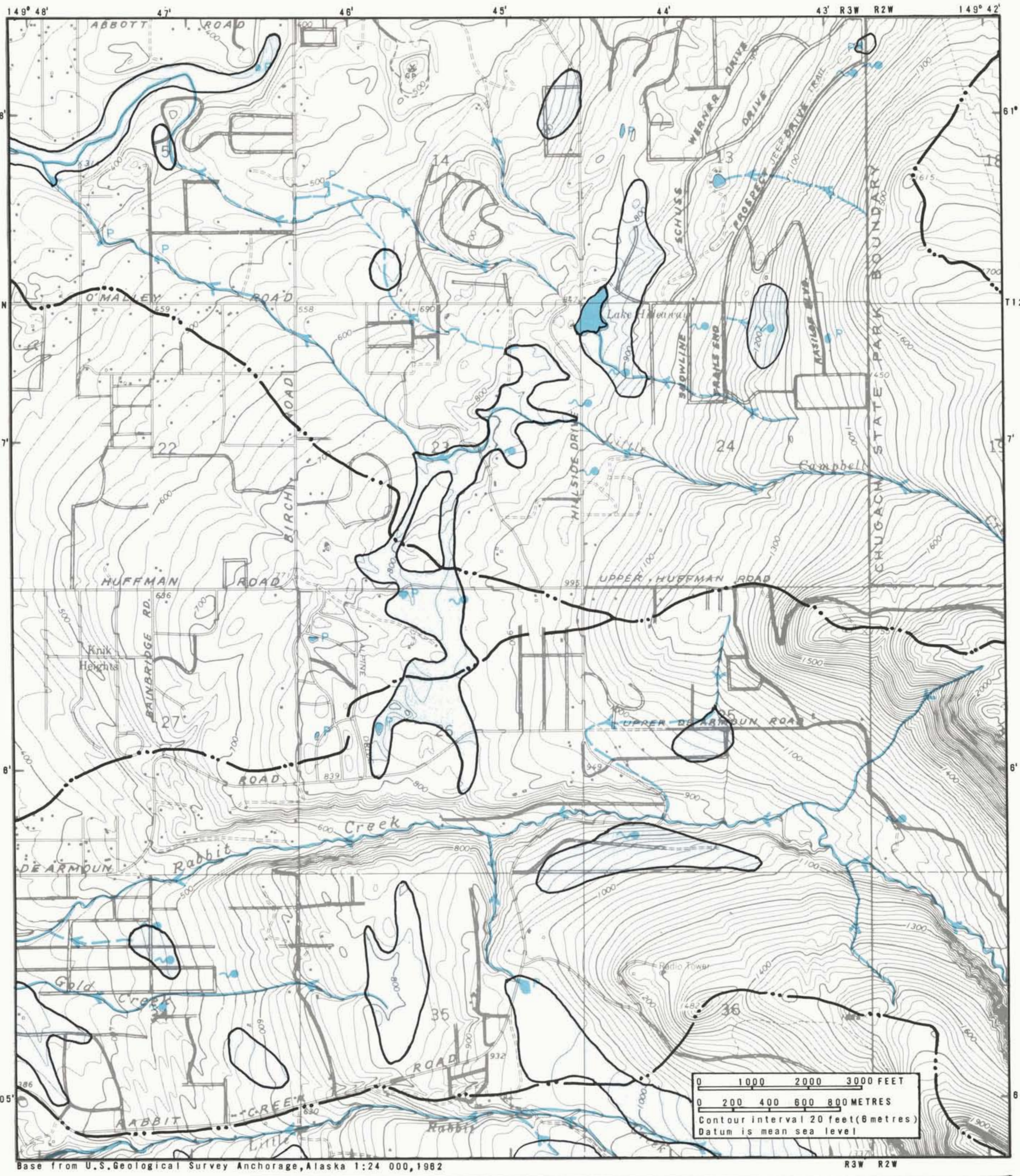
Water from both Rabbit and Little Rabbit Creeks has been used for household purposes by residents living near these streams. In recent years, however, drilled wells have become the predominant water source because ground water is a more convenient supply and is not as susceptible to contamination.

Based on discharge data, Rabbit Creek may have some potential as a water-supply source. Because of the low winter flow of Rabbit Creek, storage in a sizable surface reservoir would be required in order to provide a significant firm yield. Although dam sites have not been studied, the lake at the head of Rabbit Creek may be suitable as a storage reservoir.

Springs

Small localized springs are common in the Hillside area (fig. 13). Most of these springs flow at less than 1 gal/min (0.06 l/s) and do not have sufficient flow to be considered sources of domestic water. In a few places, abnormally large springs have been developed for single-family use by digging shallow sumps which serve as storage reservoirs. The flow of some of these developed springs is reported to have declined or stopped during prolonged cold periods. In general, springs are undependable water sources in the area, and many may become contaminated from animal or human wastes.

Figure 13.-- Water from springs along a power line. Ground water surfaces upslope (left side) and seeps into a deep bulldozer rut. Although a shallow sump may be capable of supplying enough water for a household, the source may freeze or become contaminated.



EXPLANATION

Surface-water Features

Lake or pond (p). Ponds may be dry at times

Stream with perennial flow

Drainage channel with intermittent flow. Usually some flow during spring runoff or during heavy rains but may not flow even once a year.

Spring or localized ground-water seep

Land Features

Waterlogged land and land known to be underlain by shallow ground water within 25 ft. (7.5m) of surface. Boundaries are gradational and are only approximately located. Other high water table areas than those shown may exist along some drainages and in depressions.

Drainage divide between basins

Figure 14.-- Land drainage.

LAND DRAINAGE PROBLEMS

- **LOCALIZED RUNOFF PROBLEMS OCCUR ANNUALLY DURING SPRING THAW, AND IN OTHER LOCALITIES DRAINAGE PROBLEMS MAY DEVELOP DURING HEAVY OR EXTENDED RAINSTORMS.**
- **MOST OF THE HILLSIDE AREA IS WELL ABOVE THE ALTITUDE OF THE MAJOR FLOOD PLAINS, BUT SMALLER DRAINAGE CHANNELS AND ROADSIDE DITCHES MAY NOT ACCOMMODATE HEAVY RUNOFF AND COULD OVERFLOW ROADWAYS AND YARDS.**
- **CONSTRUCTION OF ROADS AND HOMES ON POORLY DRAINED LAND IS CAUSING DRAINAGE PROBLEMS. WHERE SWAMPS AND LESS OBVIOUS WATERLOGGED CONDITIONS EXIST, SEEPAGE PROBLEMS AND STRUCTURAL DAMAGE CAUSED BY FROST HEAVING COMMONLY PLAGUE DEVELOPMENT. ROADS CONSTRUCTED ACROSS THESE AREAS OFTEN BECOME IMPASSABLE DURING THE SPRING THAW AND MAY BE COVERED BY SIZEABLE ICINGS DURING THE WINTER.**

Provision for drainage and storm runoff is becoming increasingly necessary as residential development and other construction projects proceed. In the past, homesteaders avoided localities with a high potential for drainage problems by building homes and roads on the ridges and knobs. Now, with the increasing demand for new homesites, development is beginning to infringe on waterlogged land, areas of ground-water seepage or flowing springs, and flood plains.

In this section of the report, two major drainage considerations, waterlogged lands and channeling of surface runoff, are discussed in relation to potential water problems faced by planners and large-tract developers. These potential problems are the result of pronounced variations in topography and surficial geology. Consequently, detailed hydrological studies may be needed to adequately define the extent and magnitude of surficial drainage characteristics at specific sites.

Waterlogged Areas

The principal waterlogged areas of the Hillside area are shown in figure 14. In these places the ground is generally saturated at or close to the surface. Other areas of waterlogged surficial material not defined on this map undoubtedly occur. Frequently, it is possible to predetermine the location of these areas and the probable potential for drainage problems by noting the type of surficial material (see fig. 5 and table 1) and the slope of the land. Generally, shallow subsurface drainage will be good where permeable deposits occur on sloping land. Conversely, poor drainage can be expected in fine-grained deposits and on gently sloping land where a thin layer of permeable material is immediately underlain by tight material.

Some low-lying areas contain ponded surface water during years of normal precipitation but become dry during drought periods. Field inspection, preferably during spring runoff, is invaluable in evaluating potential surficial drainage problems. Test borings to a depth of at least 15 ft (4.5 m) or to the water table may be needed to adequately delineate the depth to ground water.

Perched ground water occurs in some muskeg-filled depressions and may have no connection with the deeper lying water table. Peaty material on the surface often appears dry, but it acts as a sponge and normally is saturated 1 or 2 ft (0.3 or 0.6 m) beneath the surface. Material below the peat, however, may not be saturated. If wet muskeg is removed and adequate surface drainage provided, these lands may be made suitable for development.

Continuously flowing springs and areas of ground-water seepage occur throughout the area (fig. 14), particularly where moderate to steep landslopes flatten abruptly. Also seepages commonly develop along the uphill banks of roads cut into major slopes. Although not mapped, intermittent seeps are likely to form during wet periods where permeable surficial material (such as alluvium, see fig. 5) lies in contact with and upslope from clay deposits or impermeable fine-grained till. The flow of ground water from these drainage features generally is very low; however, roads built immediately downslope usually require frequent maintenance (fig. 15).

During winter months, the discharge from springs often freezes and forms sizeable icings. Roads that are constructed in seepage areas may become hazardous to traffic during the winter (fig. 16). Although the source of icings cannot be eliminated, the effect of icings can often be substantially reduced by consideration of local conditions in road design.

Surface Runoff

Mean annual streamflow through the Hillside area approximates 18 Mgal/d (0.8 m^3/s). However, about 15 Mgal/d (0.7 m^3/s) of this flow originates in the mountains east of the study area (fig. 12). Two major streams, Rabbit and Little Rabbit Creeks, conduct most of the mountain runoff through the area and into Turnagain Arm. These streams flow in straight valleys that slope steeply westward (fig. 14); their channels meander through narrow flood plains in the valley bottoms. Little Campbell Creek flows on glacial sediments in a poorly developed channel. Much of the basin lacks an effective network of natural drainage channels, probably because most rainfall infiltrates the glacial sediments of the relatively young hummocky terrain. Many depressions contain swamps or bogs; however, water is commonly ponded during spring breakup or prolonged heavy rainfall in other depressions as well.

High flows in the few tributary channels in the study area are rare and may not occur even during the annual peak runoff. However, the main streams of Rabbit, Little Rabbit, and Little Campbell Creeks are subject to flooding during infrequent intense rainstorms and heavy snowmelt runoff over frozen ground.

In June 1964, severe flooding along Rabbit Creek caused damage to homes and to the Old Seward Highway. The magnitude of the peak flow is unknown. The accumulation of debris played a major role in the flooding by plugging culverts and impounding water that then overflowed streambanks (U.S. Army Corps of Engineers, 1973). The 1964 flood was reported to be caused by a breakout of water backed up by a snowslide in the drainage basin east of the study area.

The peak flow of a 100-year flood on Rabbit Creek has been estimated by the Corps of Engineers at 550 ft^3/s (15.6 m^3/s or 355 Mgal/d). A flood of this magnitude, called the Intermediate Regional Flood (IRF), has a 1 percent chance of occurring during any given year.

Figure 15.-- Ground-water seepage crossing road in upper O'Malley area.

This road was built along a terrace and formed a barrier causing shallow ground water to surface. Water has ponded on the uphill side and flowed over the road. Icing problems at this site are probable during the winter months.

Figure 16.-- Summer drainage and winter icing at Patrick Road and upper DeArmoun Road.

Year-round ground-water seepage from a nearby slope has caused a buildup of ice in the roadside ditch during winter months. This icing in December 1971 created impassable road conditions for several weeks. Excess water flowed over the icing, infiltrated the snow cover, and then seeped over the frozen ground into nearby yards.

Figure 17.-- 1964 flood on Rabbit Creek.
The stream overflowed its banks and caused uprooting of trees along the flood plain. In this vicinity a wooden bridge was washed away. More severe floods than this are expected to occur.
Photograph courtesy of Ruth Brewster

Flood conditions have not occurred in recent years, and some residents have built on or very near the flood plain. The valley bottom of Rabbit Creek that would be inundated by the IRF has been mapped as a belt along the main channel mostly less than 50 ft (15 m) wide (U.S. Army Corps of Engineers, 1973). The flood plain for the IRF could be wider than that mapped because of the likelihood of some backing-up of water by debris lodging in the channel (fig. 17). The magnitude of backwater effects cannot be determined beforehand.

At times during the winter, stream channels in the Anchorage area become extensively iced. In recent years, unseasonal winter rainstorms have not produced enough water to cause floodflow over the ice. Heavy rainfall and runoff could cause ice jams in channels and result in stream levels rising several feet higher than the peak water level of the same magnitude flood under ice-free conditions. Flooding could be increased further by rapid melting of a deep snow cover or by runoff resulting from an intense rainfall over bare frozen ground.

Flood-plain maps are not available for Little Campbell and Little Rabbit Creeks. The potential for flood damage probably is not as great on these streams as on Rabbit Creek because their drainage areas lying in mountainous terrain are much smaller. However, serious flooding could develop as a result of abnormally heavy rainfall, particularly if stream channels were heavily iced at the time.

The flood potential of smaller Hillside drainages and roadside ditches is now small but undoubtedly will increase with development of the area. Overland runoff into these channels will increase as the natural vegetation and topsoil is stripped and replaced by impervious surfaces. Peak flows can also be expected to increase if additional ditching and straightening of existing channels occurs. Commonly, as runoff becomes more rapid, the frequency of high flows increases. Storm discharges in channels will become flashy, banks will erode more rapidly, and streams will carry greater silt loads, causing the natural quality of these drainages to deteriorate.

Severe erosion of streambanks and roads during future floods on Rabbit and on Little Rabbit Creeks may result in additional risks to homes and private utilities (figs. 18 and 19). Many of these potential erosion problems could be minimized if erosion-control measures such as the use of vegetation, installation of storm-drainage systems, use of bank stabilization techniques, and provision for green belts along the major floodways were implemented. In addition, the construction of debris-collection basins along the major streams may prevent culverts and bridges from becoming plugged and reduce backwater flooding during heavy rains.

Figure 18.-- Streambed and bank erosion during 1964 flood.
A relatively steep channel in alluvial material allows Rabbit Creek to erode its banks rapidly during floods. Undermining of large trees by the shifting streamflow increases the potential for clogging of the channel.
Photograph courtesy of Ruth Brewster

Figure 19.-- Washout of Old Seward Highway roadbed by 1964 flood on Rabbit Creek.
Photograph courtesy of Ruth Brewster

A small earth dam in the Hillside area failed in the spring of 1972. The earth dam was constructed in 1964 across the mouth of a swampy depression about three-fourths of a mile above Birch Road (NW¼ sec. 23; fig. 3). Little Campbell Creek was partly diverted into the area, creating a 6-acre (0.02-km^2) lake. When the dam failed, a flood of water discharged into the main channel of Little Campbell Creek (figs. 20 and 21). Driveways and culverts across the creek were washed out, and one child was drowned.

Figure 20.-- 'Lake of the Hills' earth dam after failure in 1972.

The sudden discharge of water flooded into nearby Little Campbell Creek and disrupted the natural channel. Photograph taken June,1973.

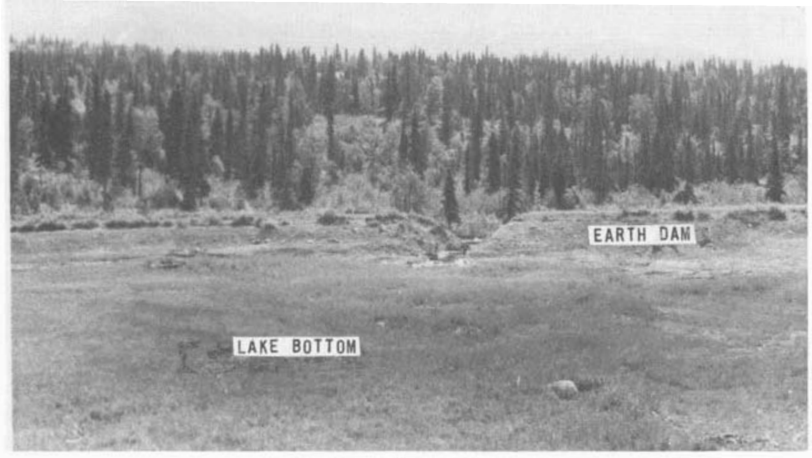


Figure 21.-- Remnant 'Lake of the Hills' after 1972 breakout.

Children fishing in Little Campbell Creek, which now flows across the dried lake bottom, indicate the size of the earth dam and impounded lake. Photograph taken June 1973; view to the south.

MAN'S IMPACT ON THE QUALITY OF WATER

- THE NATURAL QUALITY OF GROUND WATER AND WATER IN STREAMS AND LAKES IS GENERALLY GOOD. HOWEVER, INCREASED LAND DEVELOPMENT MAY CAUSE DEGRADATION OF WATER QUALITY IF POTENTIALLY HARMFUL PRACTICES ARE NOT RECOGNIZED BY PLANNERS AND AVOIDED BY DEVELOPERS.

- THE MOST PERTINENT PROBLEM IS POLLUTION OF THE WATER RESOURCES BY DISCHARGE FROM SEPTIC-TANK SYSTEMS. IN PLACES POLLUTION HAS IMPAIRED WATER QUALITY CHEMICALLY OR BACTERIOLOGICALLY AND CONSEQUENTLY HAS RESULTED IN A HAZARD TO PUBLIC HEALTH; THIS CONDITION IS CALLED CONTAMINATION. ALTHOUGH THE PRESENT POPULATION DENSITY IS LOW, SOME STREAM WATER IS ALREADY UNSAFE TO DRINK. FAILURE OF PRIVATE SEPTIC SYSTEMS HAS CAUSED POLLUTED WATER TO SEEP TO THE SURFACE AT SOME SITES, AND THIS CAN CONTAMINATE NEARBY DOMESTIC WELLS.

- IF THE PRESENT TREND OF SUBDIVISION DEVELOPMENT CONTINUES, THE DENSITY OF RESIDENTIAL SEPTIC SYSTEMS COULD INCREASE THREE- OR FOUR-FOLD BEFORE PUBLIC SEWERS BECOME AN ECONOMIC POSSIBILITY. UTILIZATION OF HYDROLOGIC DATA WOULD RESULT IN LESSENING THE CHANCES OF POLLUTION FROM SEPTIC-TANK SYSTEMS.

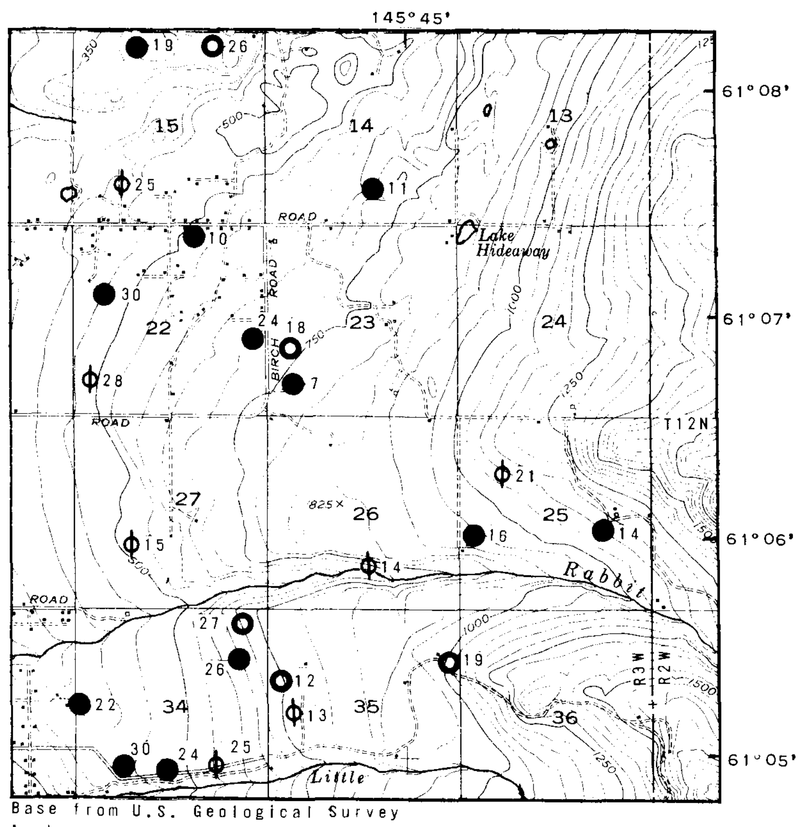
The Natural Quality of Hillside Area Water

Ground Water

Ground water at present is generally of good potable quality, although in places water from wells may require treatment to remove iron or to reduce hardness. Appendix A-4 shows the concentrations of the common water-quality constituents in samples obtained from 12 Hillside wells. These wells and additional wells where some chemical information was obtained are shown in figure 22.

Most ground water in the area is of the calcium bicarbonate type and is moderately hard. A comparison of data in appendix A-4 shows that the concentrations of all constituents, except iron, are within the maximum recommended limits for drinking water set by the Environmental Protection Agency (1972) and the U.S. Public Health Service (1962).

The concentration of iron in water from more than one-third of the wells sampled was in excess of 0.3 mg/l (milligram per litre), and several wells had concentrations of five times this amount. If these samples are typical of ground water in the Hillside area, high dissolved-iron concentrations may be widespread. Ground-water quality problems occur more frequently in the Rabbit and Little Rabbit Creek drainage basins where wells tap bedrock or sedimentary aquifers immediately above bedrock. High iron concentrations are more likely to be found in ground water obtained at depths of more than 200 ft (61 m) below land surface in both unconsolidated sediments and in fractured bedrock. Unless special water conditioners are used to remove most of the iron, homeowners may experience objectionable iron staining of clothing and appliances.



Base from U.S. Geological Survey
Anchorage (A-8), Alaska 1:63 360, 1952

EXPLANATION

● (19) Selected chemical analysis of well water given in table 4.

O (26) Partial field chemical analysis.

Φ (25) Well water quality problems reported.

Number refers to well number within each section.

0 — 1 Mile

0 — 1 Kilometre

CONTOUR INTERVAL 50 FEET
DOTTED LINES REPRESENT 25-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

Figure 22.-- Sampling sites for ground-water quality analyses.

Ground water in the Hillside area commonly is also high in carbonate hardness (the hardness as $CaCO_3$ exceeds 100 mg/l). All but one of the chemical analyses in appendix A-4 show a hardness that approaches or exceeds this amount. Again, the data show that deep wells, especially those tapping bedrock, tend to produce harder water. Residents may find that a water conditioner is worthwhile in reducing soap consumption and in preventing formation of carbonate scale in water pipes. However, for health reasons some people should not drink the high sodium content water produced by some conditioners.

The temperature of Hillside ground water averages about 37°F (3°C). It is similar to the temperature of ground water throughout the Anchorage area and, although low, presents no problems for residential use.

Surface Water

The natural quality of surface water in lakes and streams is good. The water is soft to moderately hard and meets public health drinking water standards for chemical constituents. However, high bacteria counts indicate that most surface water probably is unsafe to drink without treatment. Generalizations made concerning the concentration of chemical constituents and bacteria in this report are based on a small number of samples (fig. 23; appendix A-5). Stream samples taken in April 1972 and 1973 represent low-flow conditions because no snowmelt runoff had occurred prior to sampling. All other samples were collected when streamflow was more than base flow but less than high flow.

An appreciable increase in the concentrations of various chemical constituents in Lake Hideaway, such as dissolved solids, is suggested by two water analyses taken 6 years apart. However, these two samples may not be representative, and additional samples would need to be obtained to verify the apparent change. Septic-tank effluent may eventually contribute undesirable materials to a lake even if seepage pits are constructed in earth materials that are highly suitable for effective drainage (Rickert and Spieker, 1971). The water table in the vicinity of Lake Hideaway is near the surface, and the lake is fed by ground-water seepage. Consequently, it is probable that effluent from seepage pits constructed in the surficial glacial alluvium (fig. 5) upgradient from the lake may mix with the shallow ground water and enter the lake.

State and Federal agencies have set maximum concentration levels for several types of bacteria for the various uses of water. The sanitary quality of drinking water is commonly determined by relating the concentration of total coliform and (or) fecal coliform bacteria groups to established standards. The concentration of bacteria from either group can be used to estimate the probability of the presence of disease-causing bacteria, or pathogens. Pathogens originate in the feces of warm-blooded animals, including man, and may survive in streams for miles beyond their point of injection.

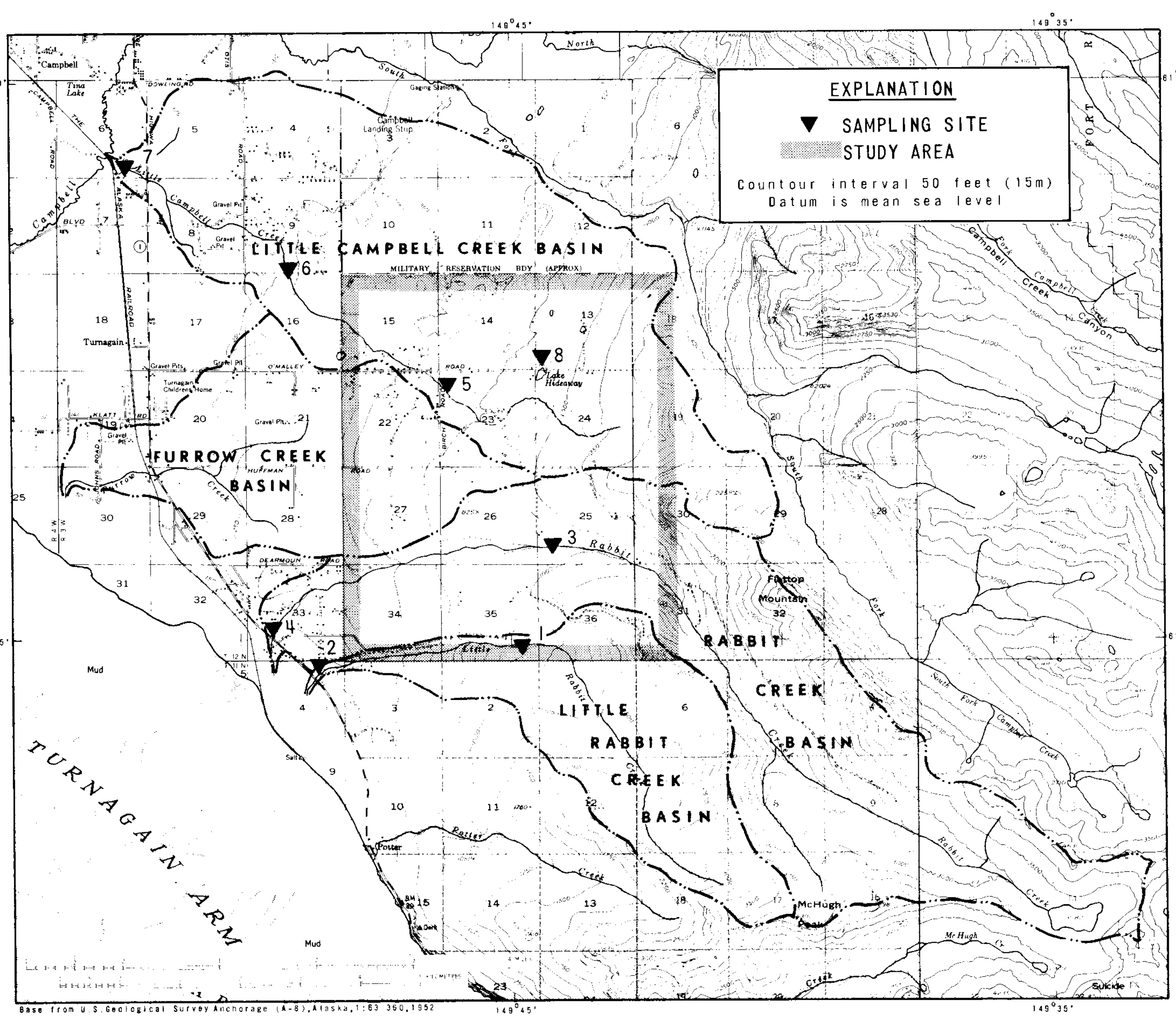


Figure 23.-- Sampling sites for surface-water quality analyses.

Analyses for total coliform bacteria counts in samples taken during low-flow conditions in April 1973 showed that these microorganisms were present at all seven stream sites (appendix A-5). These total coliform counts do not necessarily imply fecal pollution because the observed coliform organisms could have originated from nonfecal sources, such as soil.

However, at a few sites, the high counts of total coliform organisms strongly suggest that the water may have been fecally polluted. Total coliform concentrations of more than 2,400 MPN (most probable number of organisms in 100 millilitres of water) were found in stream water collected near the mouths of Little Rabbit and Little Campbell Creeks (fig. 23, sites 2 and 3) in 1973. More specific data are needed on these creeks. According to State water-quality standards[1], water is unsuitable for irrigation, livestock, and human contact when the MPN count of more than 20 percent of the samples exceeds 2,400 total coliform organisms.

At all other sites, except site 6, the MPN count of total coliform organisms was less than 50, the maximum allowable concentration for class A water. Class A water requires only simple disinfection treatment, such as boiling, to meet State standards.

Total coliform concentrations of less than 50 MPN are thought to be within the range of background contamination from wildlife and other sources, and, therefore, pathogens from human wastes probably are absent (Kyle Cherry, Alaska Dept. of Public Health, oral commun., 1973). The low total coliform concentrations observed at upstream sampling sites suggest that the high concentrations at downstream sites may reflect fecal pollution.

No conclusions can be drawn at this time about the presence of pathogenic organisms in Hillside streams. MPN determinations made during low flow in April are valuable in detecting inflow of polluted water, but these results probably are not representative of conditions during high runoff periodsor during warm months. A series of samples taken during critical flow conditions over a period of several years would determine: (1) the presence of fecal coliforms and their concentrations, (2) the effect of heavy storm runoff on fecal coliform concentration, and (3) the long-term trends of fecal coliform concentrations in streams where pollution is identified.

Other important water-quality parameters are temperature and sediment transport. The available stream data define a temperature range from 32°F (0°C) in the winter to 43°-46°F (6°-8°C) during summer months. Definitive data are not available on the sediment concentration in Hillside area streams. However, visual inspection of these streams under natural conditions suggest an insignificant suspended-sediment load except during periods of high flow.

Susceptibility of Water Resources to Pollution from Onsite Sewage Disposal

The Hillside area is developing rapidly from a rural homestead area to a suburban community. However, waste-disposal practices have not changed, and in 1972 about 1,000 families were using individual onsite septic-tank systems within the study area. The density averages about one system per 9 acres (0.04 km^2); however, density varies with development and in section 15 there is one waste-disposal system per 4 acres (0.02 km^2) of land.

As septic system density in the study area increases, effluent will increase the rate of recharge to the areal ground-water body. A future population of 10,000 people in the study area may require as many as 3,000 systems, or one system per 3 acres (0.012 km^2). The total daily discharge of these systems probably would increase from the current estimated 0.4 million gal (1,500 m^3) to about 1.2 million gal (4,500 m^3). This increase represents an average distribution of about 130 gal (492 l) of septic wastes per day on each acre of the study area. If the water supply continues to be obtained from local wells, the supply will be in part recycled by the residents. Analysis of the water budget (fig. 12) indicates that ground-water recharge from precipitation is between 300 and 700 gal (1,140 and 2,650 l) per day per acre. If it is assumed that all effluent percolates to the ground-water body, a density of one system per 3 acres (0.012 km^2) will increase local recharge by 19 to 43 percent. If development density reaches one system per acre, local recharge will be increased 56 to 130 percent and total septic system discharge may be as much as 3.6 Mgal/d (0.16m^3/s) in the study area. Present land-use trends indicate that these systems will not be evenly distributed. Consequently, pollution problems may result where high septic-tank density coincides with areas where the susceptibility of the physical environment to pollution is high (fig. 24).

Figure 24.-- Ground water flowing through partly buried septic tank.

In this steep-sloped locality shallow ground water creates adverse conditions for the use of septic-tank systems.

Photograph courtesy of Greater Anchorage Area Borough

[1] State of Alaska, Title 18, Environmental Conservation, chap. 70, Water Quality Standards.

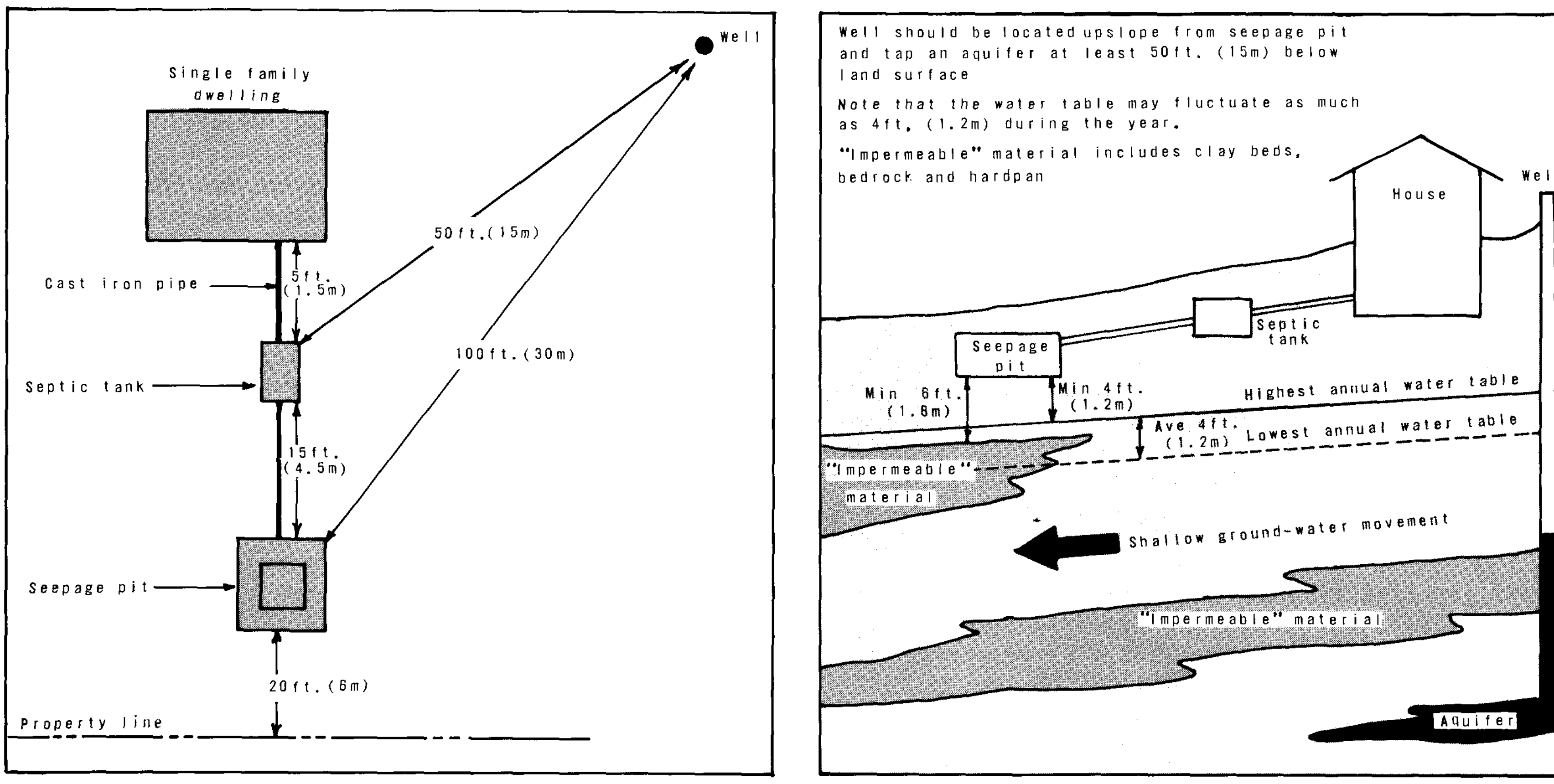


Figure 25.-- Minimum requirements for sewer and water systems for single family residences in the Greater Anchorage Area Borough.[1]

Environmental Considerations of Septic-tank Systems

In recognition of the potential for ground-water pollution from sewage-disposal systems, the Borough and State governments have established the regulations[1] shown in figure 25. A further stipulation requires that before subdivision approval, earth materials must be tested in place at the site to define the absorptive capacity at proposed seepage-pit sites.

The following discussion is based on the legal requirements cited above and on documented studies made outside Alaska. The authors emphasize that the statements made in the following paragraphs represent the best available estimates of knowledgeable hydrologists and sanitarians. These generalities are offered as guidelines for areawide planners. A detailed field investigation of most Hillside sites would be required to assure that disposal of wastes at that location will not, in fact, cause pollution.

In the Hillside area, waste-disposal regulations require that sewage be piped into a septic tank before passing into a porous-walled seepage pit. In the septic tank the solids and liquids are detained so that biological processes can decompose the mixture. A residual liquid then overflows into the seepage pit where it infiltrates through the walls into the surrounding earth materials and moves downward under the force of gravity and laterally by capillary forces.

Septic-tank effluent has a high pollution potential because many chemicals and most detergents and viruses are not decomposed or removed in the septic tank. After the effluent flows from the seepage pit into earth materials, the chemical and biological contaminants are depleted or changed through chemical and physical interactions with the subsurface environment. Reduction in concentration of contaminants in the effluent is principally caused by physical sorption and by chemical dilution. Under certain conditions, decontamination of the waste water may not be complete before the effluent reaches shallow aquifers or water wells (Schneider, 1970).

[1] Greater Anchorage Area Borough Code of Ordinance 28-68, Article 6, Sewage Disposal Practices; State of Alaska, Title 18, Environmental Conservation, chap. 72, Wastewater Disposal.

Additional treatment of effluent from septic tanks depends on the reactivity of subsurface materials at ambient temperatures and the rate of movement in these materials. The principal geohydrologic characteristicsthat determine the effect of infiltrating pollutants on ground water in the Hillside area are:

1. Depth to the water table.
2. Thickness of unconsolidated sediments overlying bedrock.
3. Distance to surface-water bodies.
4. Permeability and sorptive capacity of surficial earth materials.
5. Slope of the land surface in disposal area.
6. Frozen ground or depth of seasonal frost.

In figure 26 these characteristics are considered as independent variables that either aid or impede the cleansing and purifying of the effluent as it moves through the soil. The significance of each is briefly discussed in the following paragraphs.

The depth to the water table and the thickness of unsaturated sediments overlying bedrock or a relatively impermeable stratum are critical factors that largely determine how rapidly the percolating effluent will reach the ground-water body. Attenuation of contaminants increases with the time of travel through sedimentary materials. In the unsaturated zone biologic processes and adsorption tend to accelerate attenuation. In this zone much of the effluent will be absorbed by earth materials and widely dispersed by capillary forces to satisfy moisture deficiencies in the sediments. Whereas most of the effluent eventually reaches the water table in flat terrain, a significant quantity may move laterally to the surface downslope from seepage pits in foothill environments. Here, shallow clay and dense till lenses may cause the effluent to be perched above the water table. Ultimately, transpiration by plants and surface evaporation in the summer may be an effective mechanism for dissipating much of the effluent in these localities.

In subsurface environments of glacial sedimentary origin, granular earth materials are capable of removing many potential pollutants, including bacteria, within 10 to 20 ft (3 to 6 m) of travel. However, chloride, nitrate, and other chemicals have been found to move with water percolating through unconsolidated sediments to greater depths (Crosby and others, 1968; McGaughey and Krone, 1967). Fecal bacteria, viruses, and some chemicals may travel much farther in coarse sand and gravel strata under aerobic conditions than in fine-grained sediments which are more anaerobic. In coarse-grained materials, nutrients and bacteria have been found at depths of 40 ft (12m) (Franks, 1972; Bouma and others, 1972).

State and Borough regulations require a minimum of only 4 ft (1.2 m) of material between the bottom of a seepage pit and the water table, and 6 ft (2 m) between pit bottom and bedrock (see fig. 25). But, data from a number of studies suggest that the minimum safe distance needed to reduce coliform bacteria in waste water to acceptable concentrations is more likely two or three times these distances. If fecal coliform organisms and viruses reach the ground-water body, they may move with the normal ground-water flow for hundreds of feet and enter pumped wells.

Commonly, septic-tank systems with seepage pits in the Hillside area discharge waste water into the earth about 10 ft (3 m) below the land surface to avoid seasonally frozen ground. Where the water table and bedrock are more than about 25 ft (7.5 m) below the surface, protection of ground water from serious pollution appears reasonably assured, except where highly permeable gravel is the only percolation medium. There is a high probability of ground-water contamination where either the water table or bedrock lies between 15 and 25 ft (4.5 and 7.5 m) below the surface. If septic-tank systems are installed where either the water table or bedrock surface is less than 15 ft (4.5 m) below the surface, ground-water contamination is a strong possibility.

Where a seepage pit is constructed in saturated material, the effluent may overflow the pit and eventually rise to the surface (fig. 27). This occurs where the capacity of the material to transmit water is too small to allow the dispersion of septic-tank discharge. Contaminants in the effluent also mix with and pollute the shallow ground water surrounding the seepage pit.

Contaminated effluent probably will find its way into bedrock fractures if seepage pits are constructed in sediments that are only 15 ft (4.5 m) thick or less. Where fractures in the bedrock contain ground water, pollution may spread rapidly and wells tapping fractures more than 1 mile (1.6 km) away may pump contaminated water in a relatively short time after the effluent reaches bedrock.

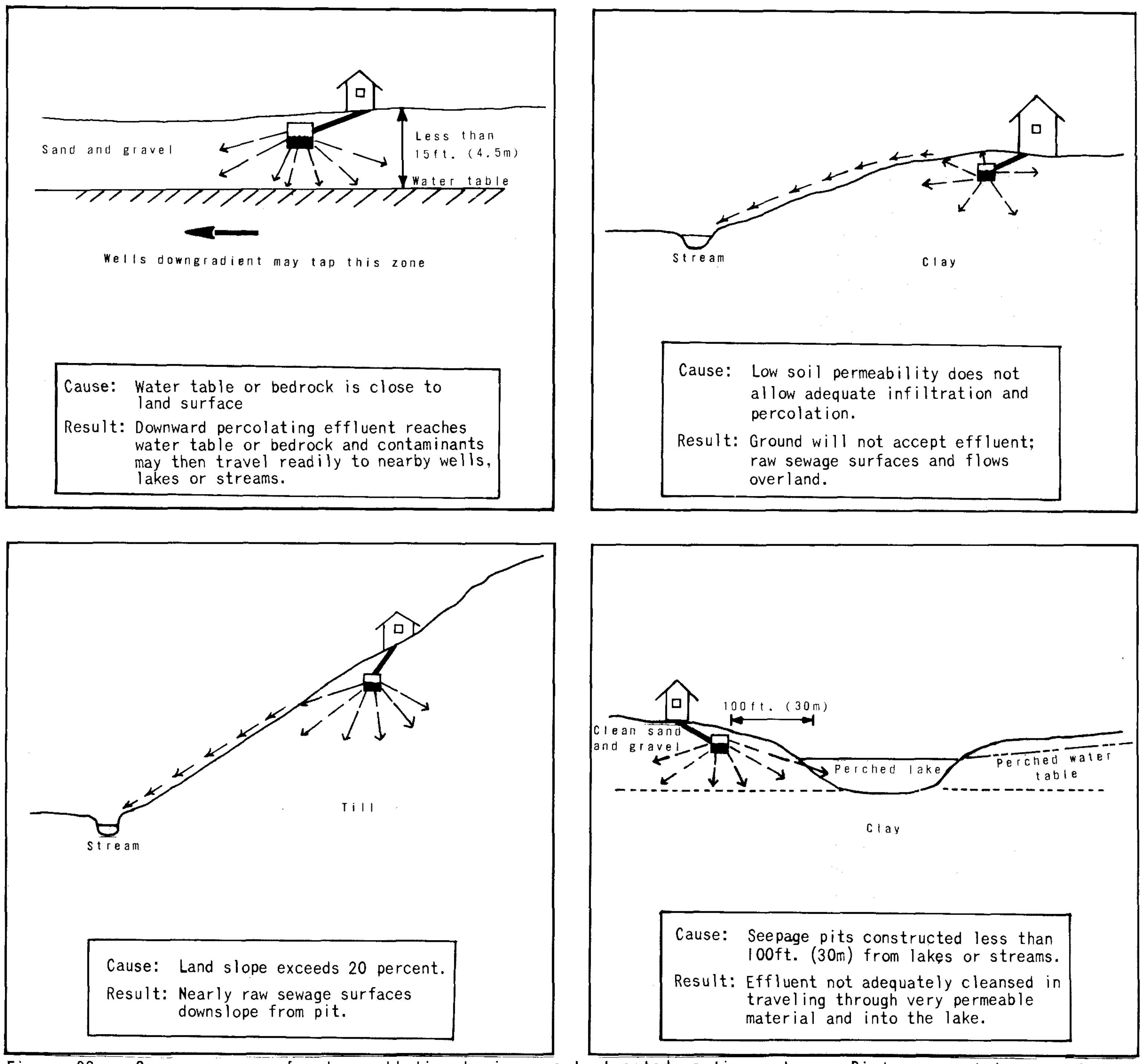


Figure 26.-- Common causes of water pollution by improperly located septic systems. Distances and degrees of slope are not drawn to scale (generalized). The values cited are not necessarily applicable to any specific site.

Figure 27.-- Cesspool cribbing floating in shallow ground water.

Pollution of ground water is imminent where household wastes are injected directly into saturated soils. In this type of installation, raw sewage would probably back up and overflow at the surface due to the inability of the effluent to disperse effectively. During winter months the water table may drop enough to allow freezing around a shallow disposal pit and result in a sewage back-up.

Photograph courtesy of Greater Anchorage Area Borough

Pollutants may reach and move into bedrock where waste water is discharged into sediments that range from 15 to 25 ft (4.5 to 7.5 m) thick. In these situations the probability of ground-water pollution is largely dependent upon the permeability and sorptive capacity of the sediments, and ranges from low to moderate.

The element of probability due to the depth to the water table in relation to the bedrock may be explained by comparing two sites where the thickness of unsaturated sediments is identical. Disposal of polluted waste water at the site where the water table lies above the bedrock surface poses less risk than at the site where the water table is below the bedrock surface. At the former site pollutants will be diluted and generally move slowly downgradient near the surface of the ground-water body while further attenuation occurs. In contrast, at the latter site pollutants may move rapidly downward in bedrock fractures to well intakes as less dilution and travel time results in less attenuation.

The distance to surface-water bodies is a factor because of the possibility of lateral migration of waste water either in local perched zones above the water table or in the saturated zone. Greater Anchorage Area Borough regulatory ordinances specify that the minimum distance between a water well, lake, or stream and a seepage pit will be 100 ft (30 m). However, the potential for pollution is high at greater distances where saturated well-sorted gravel occurs at shallow depth. Franks (1972) reported that biological pollutants traveled as far as 232 ft (71 m) in such strata.

Permeability and sorptive capacity, which are determined by the size and shape of sediment particles, are also critical characteristics of the shallow subsurface environment. Permeability and sorption generally are inversely related. Fine-grained materials have a much greater sorptive capacity than coarse-grained materials; however, the smaller the grain size the less the permeability of a material. Clays have the highest sorptive capacity because the vast surface area their particles provides for adsorption, but they also have extremely low permeability. Clean, well-sorted gravels have the highest permeability, but they lack the sorption and filtering capacities needed to adequately cleanse septic-tank effluent.

The optimum earth material in which to place a seepage pit is a moderately permeable material which permits percolation and drainage and also provides maximum sorption as well. Uncemented clayey or silty sand and gravel, typically found in glacially derived deposits, provides adequate treatment of septic-tank effluent if the sediments are unsaturated and aerobic conditions prevail. Thus, maximum attenuation of pollutants occurs as the effluent moves slowly away from the pit walls. Metamorphic bedrock, which is relatively impermeable and lacks sorptive capacity except where weathered, provides inadequate treatment of septic-tank effluent. If the metamorphic rocks are not fractured, very little drainage takes place; if fractured, effluent is transmitted rapidly to the zone of saturation.

Where the slope of the land surface exceeds 20 percent (5:1 slope), the successful operation of septic-tank systems is unlikely. Effluent probably will flow to the surface downhill from seepage pits regardless of the permeability of the earth material and depth of the seepage pit bottom (Franks, 1972). As the slope of the land increases, the distance that the effluent travels through the earth materials before reaching the surface decreases. Thus, the volume of material that is effective in the adsorption and filtering processes also decreases, and seepage at the surface may contain a high concentration of contaminants.

In the design and location of road cuts on slopes, the possibility of intersecting strata containing dispersed effluent should be considered. Seepage pits located a short distance upslope from existing road cuts may constitute a serious pollution hazard because many Hillside road cuts intercept ground water or intermittent springs that flow during periods of rapid snowmelt or heavy rain.

Seasonally frozen ground, or the formation of seasonal frost, may strongly influence the movement of liquid waste. In the Hillside area frost commonly penetrates to depths of 8 to 10 ft (2.5 to 3 m), and effluent may freeze and retard normal dispersion. Upward moisture movement in the vapor phase toward surficially frozen soil due to vapor pressure differences has been reported by several investigators (Ferguson, Brown, and Dickey, 1964, and Harlan, 1972). Taylor and Cary (1965) indicate that the force acting to move liquid water in soil resulting from temperature gradients may be many times greater than that of gravity. Under these conditions effluent may become frozen in the soil near the surface during late winter and early spring months. When this upward displaced effluent is freed by spring thaw, there is an increased possibility of polluted water migrating laterally and joining any nearby surface seeps.

Table 3.-- Numerical rating for determination of pollution susceptibility of water resources.

Geohydrologic characteristic	Map symbol	Rating points	Field condition
Depth to ground water	W	20	All land that is swampy or waterlogged, or where the water table is less than 15 ft (4.5 m) in depth.
		11	All land where ground water occurs at depths of 15-25 ft (4.5-7.5 m).
Distance to surface-water bodies	D	20	All land within 100 ft (30 m) of lakes, ponds, and streams.
		7	All land within 100-200 ft (30-61 m) of lakes, ponds, and streams.
		1	All land within 200-300 ft (61-91 m) of lakes, ponds, and streams.
		0	All land more than 300 ft (91 m) from lakes, ponds, and streams.
Permeability and sorptive capacity of surficial material	P	20	Bedrock, generally impermeable. Very low sorptive capacity.
		12	Lake and pond deposits; mostly silts and clays of low permeability. High sorptive capacity.
(See table 1, p.5)		4	Alluvium and slope deposits; normally highly permeable material such as sand and gravel, and fragments of bedrock. Low to moderate sorptive capacity.
		2	Glacially derived deposits; low to moderate permeability. Moderate to high sorptive capacity.
Slope of land surface	S	20	Prevailing slope greater that 25 percent.
		10	Pervailing slope 15-25 percent.
		2	Prevailing slope 5-15 percent.
		0	Prevailing slope 0-5 percent.
Thickness of sedimentary deposits overlying bedrock	T	20	Less than 15 ft (4.5 m).
		15	15-25 ft (4.5-7.5 m).
		1	25-50 ft (7.5-15 m).
		0	More than 50 ft (15 m).

TO OBTAIN POLLUTION SUSCEPTIBILITY RATING: For each applicable geohydrologic characteristic, determine the field condition which is most appropriate and record the rating points for each. Then total the rating points of all pertinent field conditions and select the map unit in figure 28 which represents this total.

An Evaluation of the Hillside Area Environment

A numerical rating system can be used to evaluate the relative susceptibility of the hydrologic environment to pollution, as has been demonstrated by LeGrand (1964). Once the principal geohydrologic characteristics that determine pollution susceptibility have been identified and mapped for a given area, a rating table can be devised that integrates these factors into a total response to liquid waste disposal. Thus, a pollution susceptibility map may be prepared which approximates the land's capacity to absorb septic-tank discharge without endangering the water resources.

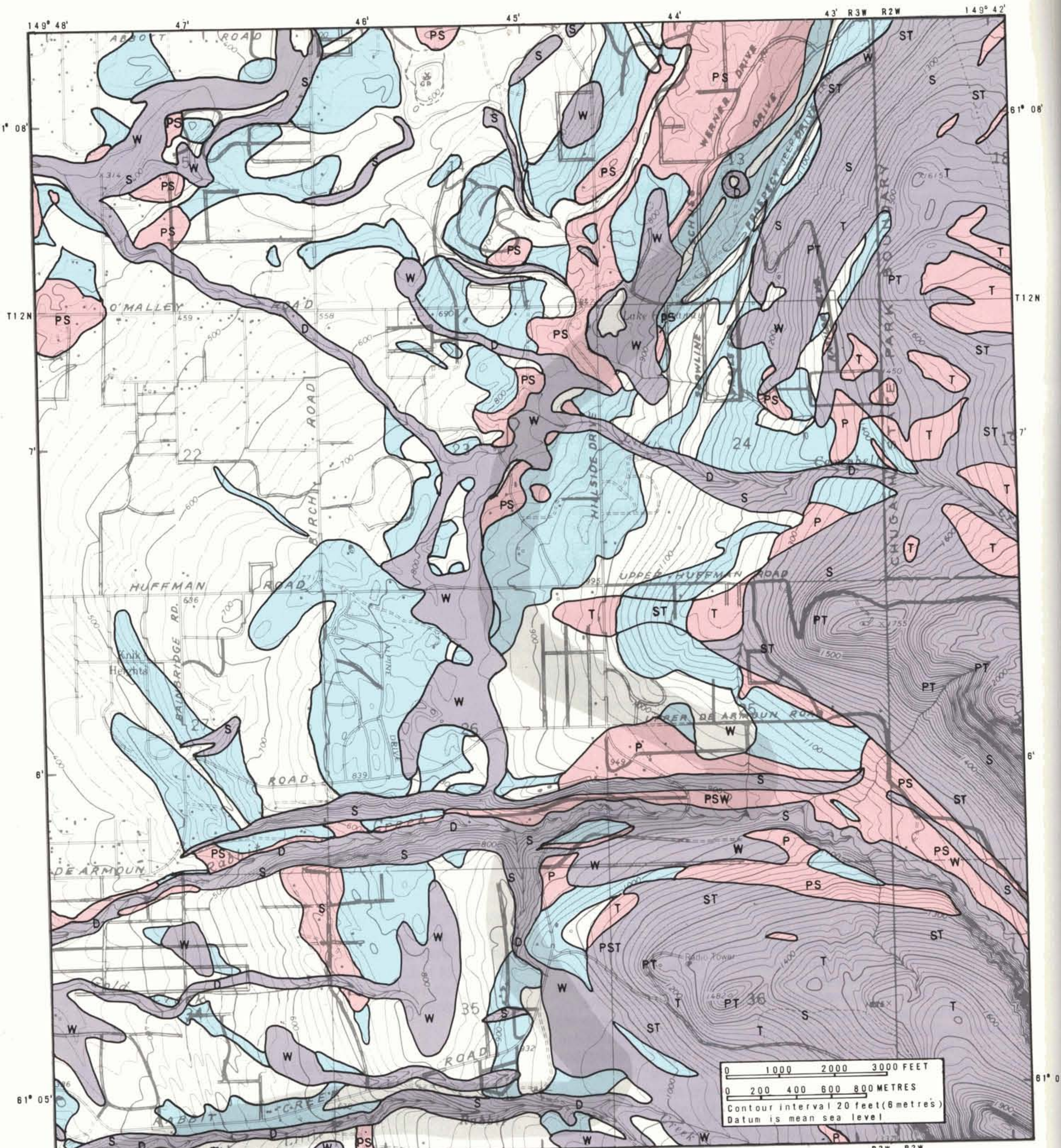
A pollution-susceptibility map for the Hillside area, figure 28, is based on a numerical rating table (table 3) and two basic-data maps which delineate the principal geohydrologic characteristics (figs. 29 and 30).

Table 3 numerically rates the importance of each field condition for its potential of increasing the possibility of water-resource pollution from septic tanks. A rating of 20 points indicates a geohydrologic condition with the greatest potential to cause pollution, and a point rating of 0 indicates a condition with the least potential to cause pollution. The interrelation of rating points between these extremes is not linear; that is, a rating of 4 does not mean a given condition has the potential to cause an area to be twice as susceptible to pollution as a rating of 2.

Figure 29 shows lakes and streams, areas of waterlogged land, seepages, and areas where ground water is near the surface. These features were defined in the section on land drainage problems (see fig. 14). Relative permeability of surficial earth materials is also shown in figure 29 and was derived from the surficial-geologic map and accompanying table (fig. 5 ; table 1).

Figure 30 is a land-slope map (Schmoll and Dobrovolny, 1972) that also includes a generalized representation of the thickness of unconsolidated sediments overlying bedrock. Because local detail of land slope cannot be shown, specific sites may be locally different than shown on this map. Similarly, the thickness of sediments may be more irregular than shown in figure 30, and test borings to 25 ft (7.5 m) in depth may be necessary to determine the thickness of unconsolidated sediments in many localities east of Hillside Drive.

The pollution-susceptibility map was constructed by superimposing the two basic-data maps. Numerical ratings were then obtained (table 3) and added to arrive at a total value for each differing segment of Hillside land. Finally, each locality was classified as belonging to one of four susceptibility units (see explanation, fig. 28) depending upon the magnitude of the sum of the rating points.



Base from U.S.Geological Survey Anchorage,Alaska 1:24 000,1982

EXPLANATION

Relative susceptibility of streams, lakes and shallow ground water to pollution from septic-tank systems.

	Rating points from table 3.
HIGH	20 or more
MODERATE	14-19
LOW	6-13
VERY LOW	0-5

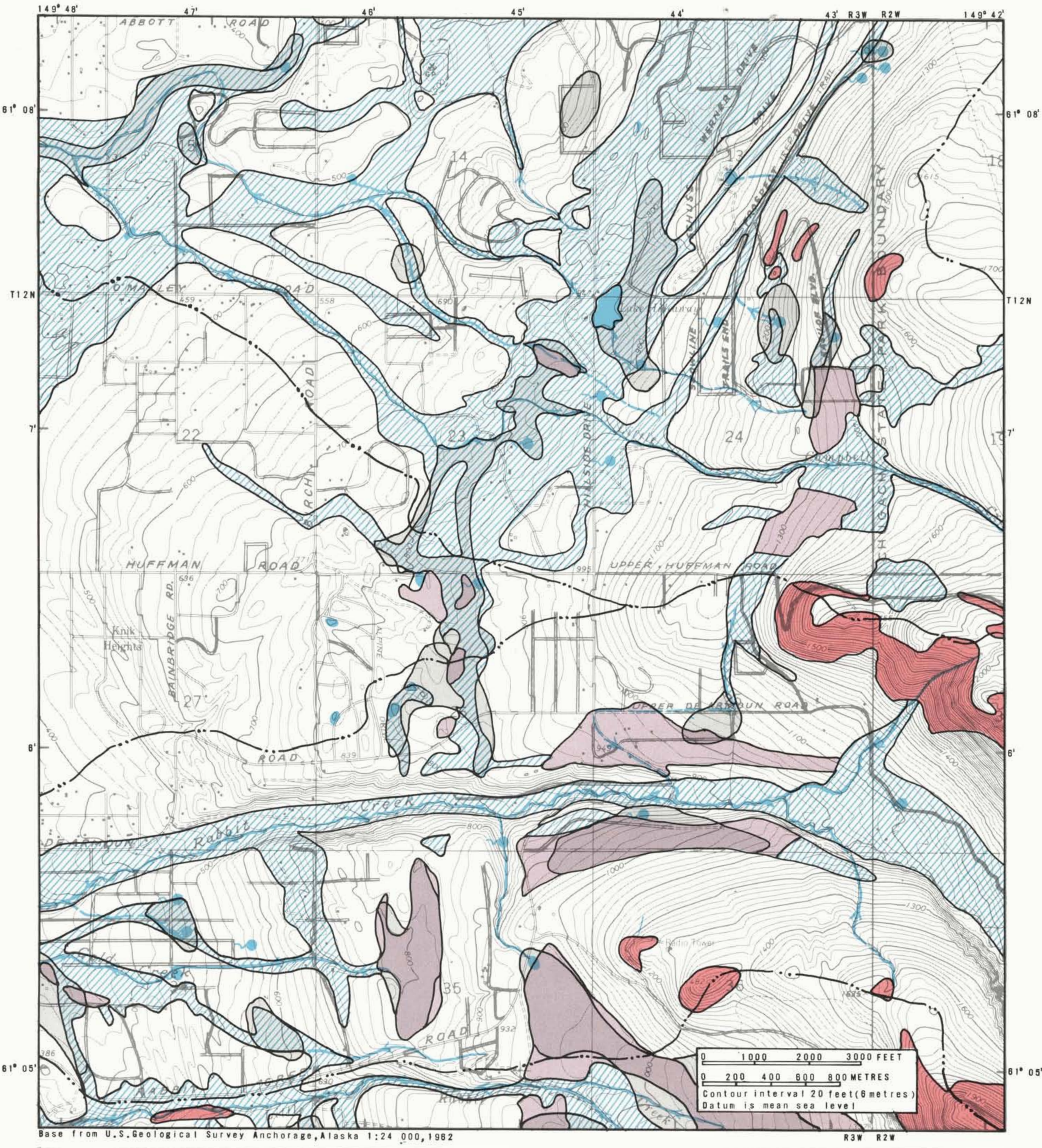
Letter symbols indicate prime reasons for moderate or high susceptibility. See table 3 for definitions.

Interpretative Guides

This divide approximately represents the transition area where to the east pollution of supply aquifers may result from indiscriminate disposal of liquid wastes. To the west aquifers are less likely to be polluted by overlying septic systems.

Note: This map was constructed to serve as a guide for planners and developers. Conditions at specific sites may differ from those shown. Onsite field tests are recommended for design purposes.

Figure 28.-- Relative susceptibility of water resources to pollution by liquid waste disposal.



Base from U.S.Geological Survey Anchorage, Alaska 1:24 000, 1962

EXPLANATION

Surface-water features and near-surface ground water

- Lake or pond
- Spring
- Waterlogged land or ground water within 15ft. (4.5m) of the surface
- Stream
- Intermittent drainage
- Drainage basin divide

Relative permeability of surficial soils (see table 1)

- HIGH - alluvium and slope deposits (sand and gravel)
- MODERATE - glacially-derived deposits (till)
- LOW - lake and pond deposits (silt and clay)
- VERY LOW - bedrock (siltstone and greenstone)

Figure 29.-- Distribution of surface water, near-surface ground water, and relative permeability of surficial soils.

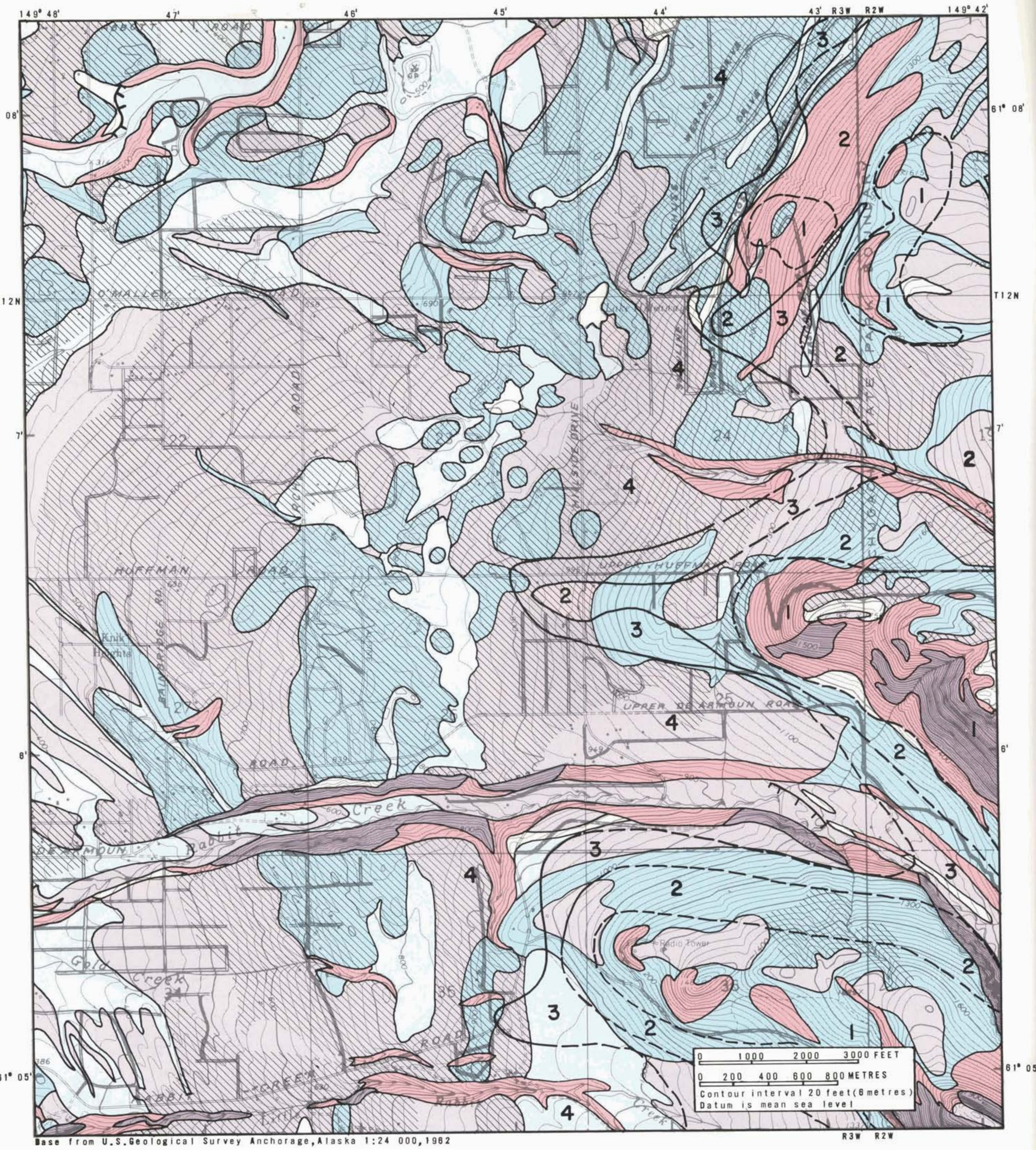


Figure 30.-- Generalized landslope and sediment thickness near mountain front. (Landslope map by Schmoll and Dobrovolny, 1972).

EXPLANATION FOR FIGURE 30

LANDSLOPE

Slope Unit	Description of Units
Less than 5 percent (3°)	Nearly flat to very gentle slopes - Generally on alluvial surfaces and in broad areas formerly occupied by lakes and ponds. Locally hummocks have steeper slopes with relief up to 20 feet (6m). Some of the nearly flat areas are boggy or poorly drained and will present problems to developers, while others are good construction sites.
5-15 percent (3°-$8\frac{1}{2}^{\circ}$)	Gentle to moderately gentle slopes - Fairly smooth extensive slopes on some alluvial fans and terraces, and in some stream valley bottoms. Hummocky topography having relief of generally less than 20 feet (6m) occurs on some glacial deposits. Land surface slope is satisfactory for most types of land development. Scattered wet localities result from poor drainage.
15-25 percent ($8\frac{1}{2}^{\circ}$-14°)	Moderate slopes - Smooth slopes on the steepest parts of the morainal ridge traversing the hillside, glacial knob and kettle terrain, and the slide-deposit slopes of the lower parts of the Chugach Mountains. Extensive areas of hummocky ground may have more than 50 feet (15m) of relief locally. Such areas commonly have internal drainage systems and ponding occurs in enclosed depressions. Construction on moderate slopes may require considerable engineering to accomodate local gradients and drainage.
25-45 percent (14°-24°)	Steep slopes - Steep valley sides of stream channels and valleys, and mountain escarpments shallowly underlain by steeply sloped bedrock. Slope stability and surface runoff problems may occur unless surface and ground water are carefully considered before development.
45-100 percent (24°-45°)	Very steep slopes - Long narrow escarpments along high valley walls where underlying deposits are generally concealed by colluvium. On the steepest mountain slopes in the Upper Hillside bedrock is commonly exposed. The potential for landslides and severe ground erosion from disruption of natural water drainage make most types of development risky.
	Areas of hummocky topography - Slopes range from nearly flat on tops of hills and bottoms of depressions to steep on hill sides. Areas are shown in slope unit that is prevalent.
	Escarpments generally less than 20 feet (6m) high; steep to very steep slopes. Line marks top of escarpment; ticks are on lower side.

SEDIMENT THICKNESS

Thickness Unit	Vertical thickness, in feet (metres) of unconsolidated sediments overlying bedrock
1	Less than 10 (3). Bedrock is exposed at land surface in places (see fig. 7)
2	10 to 25 (3-7.5)
3	25 to 50 (715-15)
4	More than 50 (15)
	Estimated divide between thickness units. Dashed where uncertain.

The pollution-susceptibility map indicates only the areal distribution of susceptibility units and as such provides information for general planning purposes. If one of the geohydrologic characteristics in a given locality was most undesirable (20 points), then that locality was classified as a high risk area regardless of the rating of other characteristics. For example, susceptibility was classified as high in localities where sediment thickness is less than 10 ft (3 m), even though depth to water is great, the land slope is slight, and the sediment permeability is moderate. Although figure 28 can be used to indicate the relative pollution susceptibility between differing localities, it may not represent local conditions at specific sites.

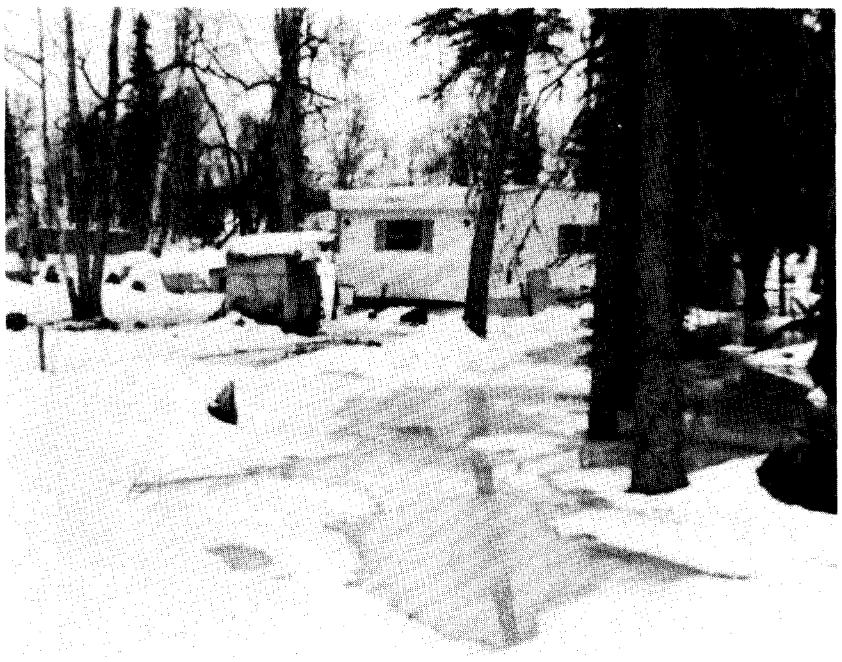


Figure 31.-- Ponded sewage from overflowing seepage pit. Overflows of septic effluent may contaminate nearby wells, lakes, and streams.

Photograph courtesy of The Greater Anchorage Area Borough

The most immediate pollution problem is the possibility of waste-water seepage directly into nearby wells. Seepage pits can become plugged and eventually overflow (fig. 31) because of low permeability of the surrounding earth materials or because of biologic failure. Soil stratification and steep slopes can cause seepage-pit effluent to move horizontally in the subsurface to wells or to rise to the surface and flow overland to well sites, lakes, and streams. In these instances, contaminants may enter a well if the casing is not watertight or if surface drainage easily moves down the outside of the casing to the aquifer. The mounding of earth and the emplacement of a concrete pad around the casing above the general ground level will cause drainage away from the well and help prevent surface-water leakage to the aquifer. In other areas where ground water occurs near the surface, overflowing effluent may flow overland from malfunctioning seepage pits and infiltrate to the water table and move downgradient to surround wells or to discharge into lakes and streams.

Ground water in the Hillside area probably has not been polluted by the current density of domestic sewage systems. However, the probability of future aquifer pollution because of a much greater density of onsite waste-disposal systems is relatively high in the upper Hillside area, or generally east of the dashed band in figure 28. This band follows closely the map contact between units 2 and 3 in figure 9, or where the depth to water below the land surface is less than 50 ft (15 m) to the east of this contact. West of this band the probability is generally much lower that aquifers will be polluted by septic-tank discharge.

CONCLUSIONS

Potable water supplies, surficial drainage, and onsite waste disposal may be limiting factors in single-family housing in some Hillside areas. Dense development may result in the local depletion of aquifers or increased surface drainage problems, or lead to ground- and surface-water pollution unless community water and sewage facilities are substituted for individual systems in the susceptible areas. The major water-resource considerations facing planners and developers are briefly summarized below.

Ground-water sources generally are available, but yields to many wells are less than 5 gal/min (0.3 l/s). Where wells produce from bedrock aquifers in the eastern Hillside area, yields commonly are less than 3 gal/min (0.2 l/s) and rarely more than 10 gal/min (0.6 l/s). Development of public-supply wells that yield more than 0.1 Mgal/d (70 gal/min or 4.4 l/s) is possible only in a few localities (fig. 10). A total sustained yield of at least 2 Mgal/d (0.08 m^3/s), and possibly as much as 4 Mgal/d (0.17 m^3/s) can be obtained from small-yield domestic wells tapping sedimentary aquifers underlying the study area. A small number of public-supply wells properly spaced in the best producing aquifers might provide a significant part of the total areal production. Surface-water reservoirs or diversions from the streams crossing the area do not appear to be practical sources of water.

Surface-water runoff and waste-water disposal is perhaps more of a problem than providing an adequate supply of potable water. In numerous locations, steep slopes, swamps and shallow ground water, and low permeability of surficial earth materials could make the use of septic-tank systems hazardous to public health, and also cause critical drainage conditions. Septic-tank effluent must percolate into and be cleansed by surficial sediments; otherwise, streams, lakes, aquifers, and even the land surface can become contaminated. At this time, the total load of pollutants that the sediments can absorb is not determinable, but onsite waste disposal has the potential to cause pollution in much of the Hillside area (fig. 28). Particularly where the land is not conducive to cleansing liquid-waste discharge within critical distances, the density of development will determine the degree of change in water quality locally and downslope from development.

Preservation of natural stream channels and the use of runoff design criteria in the construction of roads, ditches, and small drainage channels during development will reduce problems associated with surface-water drainage and winter icings. Fortunately, the two major streams, Rabbit and Little Rabbit Creeks, flow through incised valley channels and pose a flood threat to only those residents who live within the narrow flood plain. However, a number of closed depressions are subject to ponding of water during unusually heavy runoff periods.

Use of water-resources data by community planners, developers, and property owners could assist them in assessing potential water supply, drainage, and pollution problems, particularly in areas such as the Hillside where public water and sewers are not now planned.

SELECTED REFERENCES

Barnwell, W.W., George, R.S., Dearborn, L.L., Weeks, J.B., and Zenone, Chester, 1972, Water for Anchorage--An atlas of the water resources of the Anchorage area, Alaska: U.S. Geol. Survey open-file report (pub. by city of Anchorage and Greater Anchorage Area Borough), 77 p.

Bender, W.H., 1961, Soils suitable for septic-tank filter fields--A soil map can help you: U.S. Dept. Agriculture, Soil Conservation Service, Agriculture Inf. Bull. 243, 12 p.

Bouma, J., Ziebell, W.A., Walker, W.G., Olcott, P.G., McCoy, E:, and Hole, F.D., 1972, Soil absorption of septic tank effluent--A field study of some major soils in Wisconsin: Wisconsin Univ. Extension, Geol. and Nat. History Survey, Soil Survey Div., Inf. Circ. 20, 235 p.

Clark, S.H.B., 1973 The McHugh Complex of south-central Alaska: U.S. Geol. Survey Bull. 1372-D, p. D1-D10.

Clark, S.H.B., and Bartsch, S.B., 1971, Reconnaissance geologic map and geochemical analyses of stream-sediment and rock samples of the Anchorage B-7 quadrangle, Alaska: U.S. Geol. Survey open-file report, 70 p.

Cederstrom, D.J., Trainer, F.W., and Waller, R.M., 1964, Geology and ground-water resources of the Anchorage area, Alaska: U.S. Geol. Survey Water-Supply Paper 1773, 108 p.

Crosby, J.W., III, Johnstone, D.L., Drake, C.H., and Fenton, R.L., 1968, Migration of pollutants in a glacial outwash environment: Water Resources Research, v. 4, no. 5, p. 1095-1113.

Environmental Protection Agency, 1972, Water quality criteria 1972--A report of the Comm. on Water Quality Criteria, Environmental Studies Board, Natl. Acad. of Sci., Natl. Acad. of Eng.: Washington, U.S. Govt. Printing Office, 594 p. [1973]

Federal Water Pollution Control Administration, 1968, Water quality criteria--A report of the Natl. Tech. Advisory Comm: Washington, U.S. Govt. Printing Office, 234 p.

Ferguson, Hayden, Brown, P.L., and Dickey, D.D., 1964, Water movement and loss under frozen soil conditions: Soil Sci. Soc. America Proc., v. 28, p. 700-703.

Franks, A.L., 1972, Geology for individual sewage disposal systems: California Geology, v. 25, no. 9, p. 195-203.

Greater Anchorage Area Borough, Comprehensive Planning and Technical Services Division, 1972, People in Anchorage: Greater Anchorage Area Borough, 109 p.

Greater Anchorage Area Borough, Planning Department, 1972, Population Projections - 1970-1980: Greater Anchorage Area Borough, 15 p.

Guy, H.P., 1970, Sediment problems in urban areas: U.S. Geol. Survey Circ. 601-E, p. E1-E8.

Harlan, R.L., 1972, Ground conditioning and the groundwater response to surface freezing, in Proc. of Banff Symposia on the Role of Snow and Ice Hydrology, Banff, Canada, 1972: Internat. Assoc. of Sci. Hydrology Pub. 107, v. 1, p. 326-341.

Hines, W.G., 1973, Evaluating pollution potential of land-based waste disposal, Santa Clara County, California: U.S. Geol. Survey Water-Resources Inv. 31-73, 17 p. (pamphlet to accompany map).

Karlstrom, T.N.V., 1964, Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geol. Survey Prof. Paper 443, 69 p.

LeGrand, H.E., 1964, System for evaluation of contamination potential of some waste disposal sites: Am. Water Works Assoc. Jour., v. 56, no. 8, p. 959-974.

Leopold, L.B., Clarke, F.E., Hanshaw, B.B., and Balsley, J.R., 1971, A procedure for evaluating environmental impact: U.S. Geol. Survey Cir. 645, 13 p.

McGaughey, P.H., and Krone, R.B., 1967, Soil mantle as a wastewater treatment system: California Univ. Sanitary Eng. Research Lab., SERL Rept. 67-11, 201 p.

McHarg, I.L., 1969, Design with nature: Garden City, N.Y., Natural History Press (for Am. Mus. Nat. History), 198 p.

Peck, E.L., 1974, Effect of snow cover on upward movement of soil moisture: Am. Soc. Civil Eng. Proc., Jour. Irrigation and Drainage Div., v. 100, p. 405-412.

Rickert, D.A., Schneider, W.J., and Spieker, A.M., 1973, A procedure for assessing water resources for urban planning: Am. Water Resources Assoc., Water Resources Bull., v. 9, no. 4, 25 p.

Schmoll, H.R., and Dobrovolny, Ernest, 1972, Generalized geologic map of Anchorage and vicinity, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-787-A.

——— 1972, Slope map of Anchorage and vicinity, Alaska: U.S. Geol. Survey Misc. Geol. Inv. Map I-787-B.

Schneider, W.J., 1970, Hydrologic implications of solid-waste disposal: U.S. Geol. Survey Circ. 601-F, p. F1-F10 [1972, 1973].

Schneider, W.J., Rickert, D.A., and Spieker, A.M., 1973, Role of water in urban planning and management: U.S. Geol. Survey Circ. 601-H, p. H1-H10.

Sommers, D.A., and Marcher, M.V., 1965, Water resources appraisal of the Anchorage area, Alaska - Water conservation through conjunctive use: U.S. Geol. Survey open-file report, 34 p.

Spieker, A.M., 1970, Water in urban planning, Salt Creek basin, Illinois--Water management as related to alternative land-use practices: U.S. Geol. Survey Water-Supply Paper 2002, 147 p.

State of Alaska, 1963, Greater Anchorage water pollution survey, 1961 (July 17 through November 30), Alaska: Dept. of Health and Welfare, Hydrol. Data report 20, 12 p.

Taylor, S.A., and Cary, J.W., 1965, Soil-water movement in vapour and liquid phases, in Eckardt, F.E., ed., Methodology of plant eco-physiology: Paris, France, Proc. of the Montpellier Symposium UNESCO, p. 159-165.

Trainer, F.W., and Waller, R.M., 1965, Subsurface stratigraphy of glacial drift at Anchorage, Alaska: U.S. Geol. Survey Prof. Paper 525-D, p. D167-D174.

U.S. Army Corps of Engineers, 1973, Flood-plain information, Rabbit Creek, Anchorage, Alaska: U.S. Army Corps of Eng., Alaska Dist., 27 p., 29 pl.

U.S. Public Health Service, 1962, Public Health Service drinking water standards: U.S. Public Health Service Pub. 956, 61 p.

Water Well Journal, 1970, The authoritative primer; Ground water pollution: Water Well Jour., v. 24, no. 7, 93 p.

Zenone, Chester, 1973, Geology of water resources of the Girdwood-Alyeska area, Alaska: U.S. Geol. Survey open-file report (pub. by Greater Anchorage Area Borough), 24 p.

Zenone, Chester, Schmoll, H.R., and Dobrovolny, Ernest, 1974, Geology and ground water for land-use planning in the Eagle River-Chugiak area Alaska: U.S. Geol. Survey open-file report 74-57 (pub. by Greater Anchorage Area Borough), 25 p.

APPENDIX A-1 Drillers' logs of selected wells in the Hillside Area, Anchorage, Alaska

Well no: SB012 003 13 DDAD; map no. 1
Owner: Carl Luchsinger
Driller: C. P. Foss

	Thickness (feet)	Depth (feet)
Clay, sand, and gravel, brown, medium hard	40	40
Bedrock, grey, soft	10	50
Bedrock, grey, hard	75	125

open-end finish

Well no: SB 012 003 13 DDDC; map no. 2
Owner: Allen Woodward
Driller: Swafford Drilling Co.

	Thickness (feet)	Depth (feet)
No record	96	96
Clay and gravel, hard, greenish	9	105
Sand and gravel, greenish	30	135
Sand, silty, medium, brown	57	192
Sand and gravel, hard, brown	4	196
Sand and gravel, clean; water	2	198

Open-end finish

Well no: SB 012 003 13 BBBC; map no. 8
Owner: James Tanaka
Driller: Dotten Drilling Co.

	Thickness (feet)	Depth (feet)
Till, gravelly, tan	45	45
Gravel, dry	2	47
Gravel and boulders, very hard	44	91
Till, gravelly, tan	25	116
Till; wet	6	122
Gravel and till	1	123
Silt, tan	1	124
Sand and gravel; varying amounts of water	19	143

open-end finish

Well no: SB 012 003 13 ABDD; map no. 20
Owner: Carl Luchsinger
Driller: Foss Drilling

	Thickness (feet)	Depth (feet)
Clay, sand, gravel, brown, hard	23	23
Bedrock, grey, medium hard	37	60
Bedrock, light grey, hard	20	80
Bedrock, red, medium hard	20	100

open-end finish

Well no: SB 012 003 13 DCBB; map no. 21
Owner: Charles Houtchens
Driller: Foss Drilling

	Thickness (feet)	Depth (feet)
Sand and gravel, brown, medium hard	20	20
Sand and gravel, brown, hard	20	40
Bedrock, grey, soft	10	50
Bedrock, grey, medium hard	10	60
Bedrock, green, medium hard; water	10	70
Bedrock, brown streaks, medium hard	15	85
Bedrock, grey, medium hard	29	114
Bedrock, grey, hard	16	130
Bedrock, brown streaks, medium hard; water	20	150
Bedrock, green, medium hard	8	158

open-end finish

Well no: SB 012 003 14 DADB; map no. 5
Owner: Ronald Siefker
Driller: Clemenson Drilling Co.

	Thickness (feet)	Depth (feet)
Clay	17	17
Hardpan	13	30
Clay	21	51
Till	9	60
Hardpan	4	64
Clay	28	92
Hardpan	2	94
Clay	11	105
Till, hard to medium	41	146
Sand and gravel; water	4	150

Open-end finish

Well no: SB 012 003 14 DCBC; map no. 11
Owner: Vali Vue Subdivision
Driller: Clemenson Drilling Co.

	Thickness (feet)	Depth (feet)
Gravel	20	20
Gravel, clayey	23	43
Clay, brown, very little gravel; water seepage	3	46
Clay, sandy, gravelly	38	84
Clay, gravelly; water seepage	23	107
Silt, grey; water, 2 gpm	7	114
Silt, grey; water-bearing sand and gravel at 115'; 22 gpm, static level 85'	2	116
Sand, silty, brown, very little gravel	6	122
Gravel and sand, a little silt at 128', clayey at bottom; water-bearing, screened 120'-130' and tested at 50 gpm, static level 60'	8.5	130.5
Clay, grey, very little gravel; no water	12.5	143
Clay, gravelly, grey; water seepage	7	150
Clay, gravelly, to clayey gravel; no water	21.5	171.5
Sand and gravel, some clay; bailed 7.5 gpm	3.5	174
Gravel, sandy, and gravelly sand; water-bearing	5	179
Pumped 168 gpm, 25 hours with 107' drawdown		

Screen 174'-179', 200-slot

Well no: SB 012 003 15 DDAA; map no. 1
Owner: LeRoy Allinger
Driller: Swafford Drilling Co.

	Thickness (feet)	Depth (feet)
Clay, sand and gravel, brown, soft	30	30
Gravel and clay, blue-grey	50	80
Sand and gravel; a little water	9	89
Clay, sand and gravel, soft	10	99
Hardpan	5	104
Clay and gravel, soft	10	114
Sand, fine; a little water	1	115
Sand and gravel; water	2	117

Open-end finish

Well no: SB 012 003 15 ADCD; map no. 5
Owner: Sterling
Driller: Swafford Drilling Co.

	Thickness (feet)	Depth (feet)
Clay and gravel, moderately hard	35	35
Rocks and gravel, hard	5	40
Clay and gravel, brown to blue, soft	40	80
Sand and gravel; water	5	85

Open-end finish

Well no: SB 012 003 15 BBCD; map no. 6
Owner: C. S. Sullivan
Driller: A & L Drilling Co.

	Thickness (feet)	Depth (feet)
Overburden	12	12
Boulders and gravel	16	28
Clay and gravel	17	45
Clay and boulders	4	49
Clay and gravel	26	75
Mud; saturated	4	79
Clay and gravel	11	90
Mud and gravel	8	98
Clay and gravel	32	130
Mud and gravel	8	138
Clay and gravel	16	154
Gravel and fine sand; water-bearing	1	155
Clay and gravel	7	162
Silt and fine sand	3	165
Clay and sand	6	171
Sand, hard packed	5	176
Clay and fine gravel	11	187
Sand, fine, and gravel	2	189
Hardpan; water-bearing	3	192

Open-end finish

Well no: SB 012 003 15 CCAB; map no. 25
Owner: James M. Ryan
Driller: John Cox and Dotten Drilling Co.

	Thickness (feet)	Depth (feet)
Clay, brown, and rock and sand	15	15
Clay, yellow, and sand	32	47
Hardpan, gravelly	3	50
Clay, yellow and sand	23	73
Hardpan, sandy, gravelly, extremely hard	5	78
Gravel, sand, yellow clay	7	85
Hardpan, sandy	8	93
Gravel and yellow clay, soft	32	125
Sand, gravel and clay in alternating layers, becoming grey	15	140
Hardpan, sandy, gravelly; static water level in January 1955 was 131 ft, 5 gpm with 15' drawdown	11	151
Clay, grey, and sand, silt and 1/4" gravel, layered; static water level in March 1955 was 101 ft	30	181
Sand and gravel, grey, till streaks; wet, water-bearing at bottom of strata	14	195

Open-end finish

Well no: SB 012 003 15 ABAB; map no. 26
Owner: Harold Henrickson
Driller: Penn Jersey Drilling Co.

	Thickness (Feet)	Depth (feet)
Gravel	73	73
Clay and gravel	9	82
Gravel, large	6	88
Gravel, clean, hard	14	102
Rock	2	104
Gravel, clean, hard	5	109
Clay and gravel	35	144
Sand; a little water	3	147
Clay	21	168
Hardpan	6	174
Clay and gravel, brown	35	209
Gravel, some clay	5	214
Sand, fine	3	217
Sand; a little water	3	220
Sand, fine	2	222
Sand; a little water	8	230
Sand; water	2	232

Open-end finish

Well no: SB 012 003 22 CDCB; map no. 8
Owner: Bruce Bowden
Driller: Clemenson Drilling Co.

Fill	4	4
Topsoil	1	5
Sand and gravel, brown, with large rocks	10	15
Hardpan, brown, with rocks	74	89
Sand and gravel; water	1	90

Open-end finish

Well no: SB 012 003 22 ABBA; map no. 10
Owner: John Hershe
Driller: John Cox

Clay, yellow, with sand and fine gravel	42	42
Clay, grey, and sand	10	52
Hardpan, sandy	5	57
Gravel, fine, hard	11	68
Rock	.5	68.5
Hardpan, sandy, grey	1.5	70
Silt and sand, soft	8	78
Silt and sand, hard	3	81
Rocks, small, silty	4	85
Hardpan, gravelly; a little water	3	88
Hardpan, sandy, silty	12	100
Silt and sand	3	103
Hardpan, sandy	4	107
Hardpan, fine to medium gravel	13	120
Sand, fine, hard	3	123
Sand	1	124
Hardpan, gravelly, sandy, light grey	20	144
Sand	9	153
Quicksand; hit water at 159'	10	163
Sand, yellow; water	11	174
Clay, yellow, with fine gravel and sand, soft and hard layers	24	198
Hardpan, gravelly, sandy, grey	20	218
Clay, yellow	2	220
Sand, fine; silty, water	14	234
Hardpan, fine gravel, tan, grey	at	234

Open-end finish

Well no: SB 012 003 22 DCDA; map no. 17
Owner: Dale Wells
Driller: Clemenson Drilling Co.

Sand and gravel	5	5
Till, brown	65	70
Till, blue	27	97
Till, with boulders	18	115
Till, blue	71	186
Gravel, sandy	7	193
Clay	16	209
Clay, sandy	6	215
Sand, silty	13	228
Hardpan, with sand and gravel	2	230
Sand and gravel; water	2	232

Open-end finish

Well no: SB 012 003 22 ACCD; map no. 21
Owner: William C. Chamberlin
Driller: M - W Drilling, Inc.

Cobbles	2	2
Sand	5	7
Gravel, silty	8	15
Sand, silty	6	21
Gravel, silty	5	26
Sand, silty, fine	9	35
Hardpan, silty	40	75
Gravel, sandy	7	82
Hardpan, silty, with gravel seams	13	95
Gravel, sandy; water-bearing	3	98
Hardpan, silty	12	110

Well no: SB 012 003 22 BCAC; map no. 30
Owner: Taku Developers
Driller: Sommerville Well Drilling

	Thickness (feet)	Depth (feet)
Topsoil	8	8
Clay, sandy	6	14
Hardpan, yellow clay, gravel	16	30
Clay and sand, grey	38	68
Sand, hard	10	78
Sand and clay	20	98
Gravel, clay and sand	7	105
Clay, blue	7	112
Clay and gravel	15	127
Sand; a little water	12	139
Hardpan, tan	21	160
Rock and sand	15	175
Hardpan, tan	25	200
Sand, brown	18	218
Hardpan	2	220
Gravel; a little water	1	221
Clay, sandy	5	226
Sand, gravel; a little water	7	233
Hardpan	1	234
Gravel, fine; a little water	1	235
Hardpan	3	238
Sand, and gravel; a little water	1	239
Hardpan	6	245
Gravel and sand; a little water	1	246
Hardpan	5	251
Sand and gravel; a little water	6	257
Sand and gravel; water	1	258

Open-end finish

Well no: SB 012 003 23 DACD; map no. 5
Owner: G. W. Parik
Driller: Swafford Drilling Co.

Clay	24	24
Clay, gravelly, blue	26	50
Till	23	73
Sand; a little water	1	74
Till	4	78
Sand; a little water	1	79
Till	14	93
Bedrock	12	105

Perforated finish

Well no: SB 012 003 23 ABCC; map no. 12
Owner: Robert Woosley
Driller: Clemenson Drilling Co.

Sand and gravel	19	19
Hardpan (till)	61	80
Clay, blue	13	93
Silt, sandy	4	97
Till	18	115
Clay, blue	9	124
Sand; silty water	2	126
Till	1	127
Clay	37	164
Till	23	187
Sand and gravel; silty water	11	198
Sand and gravel; water, clean	2	200

Open-end finish

Well no: SB 012 003 23 BBDD; map no. 13
Owner: Anchorage Borough School District
Driller: Swafford Drilling Co.

Clay and gravel	23	23
Gravel	59	82
Clay and gravel	5	87
Clay	36	123
Sand and clay	2	125
Sand; water	2	127
Sand and gravel; water	15	142

Screen finish

Well no: SB 012 003 23 CCDD; map no. 20
Owner: George Wooliver
Driller: Swafford Drilling Co.

Clay and gravel, brown, soft	73	73
Clay and gravel, blue-grey, medium hard	27	100
Clay and gravel, brown, medium hard	15	115
Clay and gravel, blue-grey, hard	9	124
Sand; water; bottomed in gravel	2	126

Open-end finish

APPENDIX A-1 -- Continued

Well no: SB 012 003 23 CBDB; map no. 25
Owner: Charles D. Evans
Driller: Clemenson Drilling Co.

	Thickness (feet)	Depth (feet)
Clay, sandy	7	7
Sand, gravel, with clay	12	19
Clay, sandy, brown, soft	20	39
Sand, silty, brown	13	52
Sand, silty brown, soft	82	134
Till, hard	7	141
Sand and gravel, silty; dry	14	155
Clay, gravelly, blue, medium hard	18	173
Sand, silty; water	2	175
Clay, sandy, blue	6	181
Till, gravelly, very hard	1	182
Sand and gravel; water	4	186

Open-end finish

Well no: SB 012 003 24 BBDD; map no. 10
Owner: John Morholt
Driller: Dotten Drilling Co.

	Thickness (feet)	Depth (feet)
Till, gravelly, tan; rock at 43 feet; weak water towards bottom	100	100
Silt, sandy, tan; dry	8	108
Till, gravelly, tan; a little water	9	117
Sand and gravel, medium to coarse tan; water		at 117

Open-end finish

Well no: SB 012 003 24 BBDD; map no. 12
Owner: Al Patten
Driller: Dotten Drilling Co.

	Thickness (feet)	Depth (feet)
Till, light brown	35	35
Mud, brown, runny	11	46
Till, gravelly, tan	9	55
Till, tan, very hard	16	71
Till, dark brown	8	79
Weathered rock (bedrock); water	27	106

Open-end finish

Well no: SB 012 003 24 ACBA; map no. 16
Owner: William Reavis
Driller: Foss Drilling

	Thickness (feet)	Depth (feet)
Clay, sand, and gravel, grey, medium hard	28	28
Clay, sand, and gravel, grey, hard	17	45
Clay, sand, and gravel, grey, medium hard	27	72
Bedrock	13	85

Slot-type perforated finish

Well no: SB 012 003 24 AABB; map no: 18
Owner: Keith Giddings
Driller: Swafford Drilling Co.

	Thickness (feet)	Depth (feet)
Clay, sand, and gravel, brown, medium hard	40	40
Bedrock, fractured, brown, soft; some water	6	46
Bedrock, green, medium hard; some water	19	65
Bedrock, red, medium hard	35	100

Open-end finish

Well no: SB 012 003 24 CDBD; map no. 20
Owner: Bob Prescott
Driller: Sommerville Well Drilling

	Thickness (feet)	Depth (feet)
Sand and gravel	23	23
Clay, yellow	23	46
Sand	4	50
Rock, streaks of yellow clay (bedrock?)	20	70
Rock, light grey; a little water at 75' (bedrock)	5	75
Rock, light grey (bedrock)	100	175

Well no: SB 012 003 25 CBBD; map no. 2
Owner: Eugene Januiewiz
Driller: Swafford Drilling Co.

	Thickness (feet)	Depth (feet)
Clay and gravel, brown, medium hard and hard	65	65
Clay and gravel, blue, hard	22	87
Clay and gravel, brown, medium hard	10	97
Clay and gravel, blue, medium hard; water seepage	33	130
Sand and gravel; water (3-1/2 gpm)	2	132
Clay and gravel, brown, some silty sand, medium hard	25	157
Sand, fine; water	2	159

Open-end finish

Well no: SB 012 003 25 CCAA; map no. 5
Owner: B. Yost
Driller: Swafford Drilling Co.

	Thickness (feet)	(Depth (feet)
Sand and gravel, brown	8	8
Clay and gravel, blue	15	23
Sand and gravel, hard; water	2	25

Open-end finish

Well no: SB 012 003 25 ABDD; map no. 8
Owner: H. Roy Fisk
Driller: A & L Drilling Co.

	Thickness (feet)	Depth (feet)
Topsoil, frozen	1	1
Bedrock, decomposed	15	16
Bedrock; no water	78	94
Bedrock, fractured; water (2 gpm)	1	95
Bedrock; no water	13	108
Bedrock, fractured; water (2-1/2 gpm)	4	112
Bedrock, hard	13	125

Open-end finish below 42 feet

Well no: SB 012 003 25 BDBD; map no. 23
Owner: John T. Jensen
Driller: Sommerville Well Drilling

	Thickness (feet)	Depth (feet)
Clay, grey, and rock	42	42
Rock, grey; water from crack at 60'	18	60
Rock, grey	38	98
Rock, red; water from crack at 170'	80	178
Rock, green and red	7	185

Open-end finish

Well no: SB 012 003 25 BBBD; map no. 24
Owner: James Fuerstenberg
Driller: Clemenson Drilling Co.

	Thickness (feet)	Depth (feet)
Sand, gravel and boulders	20	20
Bedrock	75	95

Open-end finish

Well no: SB 012 003 26 CBCB; map no. 3
Owner: L. B. Martin
Driller: Swafford Drilling Co.

	Thickness (feet)	Depth (feet)
Clay, sand and gravel, brown	60	60
Clay and gravel, blue, hard	20	80
Clay, sand and gravel, brown	20	100
Clay and gravel, brown and blue alternating	118	218
Sand and gravel; water	2	220

Open-end finish

Well no: SB 012 003 26 AAAA; map no. 5
Owner: Stanford Spendlove
Driller: Hyland Drilling Co.

	Thickness (feet)	Depth (feet)
Till, yellow	10	10
Till, gravelly, yellow; dry	14	24
Cemented stone (bedrock?), grey; water	55	79

Open-end finish

Well no: SB 012 003 26 DADA; map no. 7
Owner: Frank Morgan
Driller: John Cox

	Thickness (feet)	Depth (feet)
Clay, yellow	10	10
Sand, gravel	40	50
Hardpan	15	65
Gravel, fine, and yellow clay	23	88
Clay, yellow, and fine gravel (streaks of stones)	18	106
Clay, yellow, soft,and fine gravel	9	115
Clay, grey, and coarse rock	36	151
Sand, silt; water	4	155
Hardpan	1	156

Open-end finish

Well no: SB 012 003 26 DDDC; map no. 15
Owner: Don Grey, Jr.
Driller: C. P. Foss

	Thickness (feet)	Depth (feet)
Clay and gravel, brown, soft	22	22
Clay and gravel, grey, medium hard; water hit at 40 feet	25	47
Bedrock	41	88

Open-end finish; perforated 39'-40'

Well no: SB 012 003 26 BCBA; map no. 18
Owner: Dick Rains
Driller: Clemenson Drilling Co.

Clay and sand, with gravel	8	8
Sand	12	20
Gravel	4	24
Sand, silty	21	45
Sand, silty, and gravel	5	50
Till, brown	40	90
Sand, silty, and gravel	5	95
Sand, silty	25	120
Till, brown	60	180
Sand and gravel; water	3	183

Open-end finish

Well no: SB 012 003 27 CADA; map no. 3
Owner: Marvin Miller
Driller: Swafford Drilling Co.

Gravel, brown, hard	70	70
Gravel and rock, hard	50	120
Gravel, grey, hard	9	129
Gravel and rock, brown, medium hard	43	172
Clay, brown, soft	17	189
Clay and gravel, brown, hard	22	211
Sand and gravel; water	2	213
Clay and gravel; water	17	230

Open-end finish

Well no: SB 012 003 27 CCDA; map no. 5
Owner: G. Heaverly
Driller: Clemenson Drilling Co.

Till	11	11
Gravel with boulders, silty, brown; water seepage	43	54
Till, blue, (hardpan)	9	63
Sand, silt, and gravel (till), soft	7	70
Till, sandy, silty, gravelly, with boulders, brown	44	114
Silt, sand and gravel; dry	10	124
Sand and silt; water (dirty)	4	128
Till, sandy, blue	14	142
Till, sandy, brown	3	145
Gravel, sandy, grey, hard	12	157
Gravel, sandy, blue, hard, with large rocks	7	164
Gravel, sandy, blue, hard, very dense	6	170
Sand, brown, and gravel; water		170

Open-end finish

Well no: SB 012 003 27 ABCA; map no. 25
Owner: Edward McCain
Driller: Arctic Drilling

Clay and gravel	25	25
Gravel, sandy	10	35
Till, brown; boulder from 105 to 110'	120	155
Hardpan	60	215
Sand, silty; water	6	221
Gravel; water	1	222

Open-end finish

Well no: SB 012 003 27 BDCB; map no. 27
Owner: Arthur Parker
Driller: Clemenson Drilling Co.

Till, gravelly	24	24
Clay, brown	81	105
Till, gravelly, hard	22	127
Till, gravelly, sandy, soft	47	174
Till, hard	6	180
Bedrock	85	265

Open-end finish

Well no: SB 012 003 34 CCDB; map no. 1
Owner: Curtis Young
Driller: Robert Cross

Record missing (dug well)	38	38
Sand, brown	2	40
Hardpan	5	45
Gravel and sand; water	5	50
Clay and gravel	9	59
Hardpan	47.5	108.5
Bedrock	143.5	275

Open-end finish

Well no: SB 012 003 34 BBBB; map no. 2
Owner: Earl Morell
Driller: Swafford Drilling Co.

Clay and gravel, brown and blue alternating; a little water at 53 feet	165	165
Sand and gravel; water	4	169

Open-end finish

Well no: SB 012 003 34 BAAA; map no. 4
Owner: G. Buchanan
Driller: Clemenson Drilling Co.

Gravel and boulders	20	20
Till	10	30
Till, blue, medium hard	32	62
Till, brown, medium hard	38	100
Sand and gravel; water	1	101

Open-end finish

Well no: SB 012 003 34 AADC; map no. 27
Owner: Robert Arwezon
Driller: Hyland Drilling Co.

Till, grey	8	8
Boulders	4	12
Till, grey, stone, gravel	2	14
Till, yellow, rock, clay, sand, and gravel	9	23
Till, grey	5	28
Clay, sand, and gravel	33	61
Shale	3	64
Till, grey, stone and clay	24	88
Till, yellow, sand, silt and clay	21	109
Till, grey, sand; water	1	110

5 feet of 30-slot screen finish

Well no: SB 012 003 34 DDCA; map no. 31
Owner: Ralph D. Riggs
Driller: Swafford Drilling Co.

Clay and gravel, brown, hard	20	20
Rock, blue-grey, soft	14	34
Rock, blue-grey, medium hard	41	75

Well no: SB 012 003 35 CCDA; map no. 1
Owner: John Wills
Driller: Lloyd Wilson

Rock and clay, compacted	15	15
Rocks, large	30	45
Hardpan and rock	15	60
Hardpan	15	75
Clay and rock, reddish; sticky	19	94
Gravel strips, wet	6	100
Gravel and sand, medium hard	19	119

Open-end finish

Well no: SB 012 003 35 BCCA; map no. 10
Owner: Grant Means
Driller: John Cox

Clay, yellow, and sand and stones	13	13
Hardpan, grey	13	26
Rocks	10	36
Sand, fine gravel, and clay; a little water at 40 feet	25	61
Hardpan	18	79
Clay, yellow, softer; a little water in sand streak at 80 feet	7	86
Hardpan	2	88
Sand, fine, very hard	5	93
Clay, yellow, soft	12	105
Hardpan	0.5	105.5
Sand; water	0.5	106

Open-end finish

Well no: SB 012 003 35 ACCA; map no. 15
Owner: Clark Degarmo
Driller: Cox

Till, yellow to grey, stones	11	11
Gravel, grey clay, sand	15	26
Till, yellow, gravel	19	45
Hardpan	24	69
Till, yellow, sand and gravel	30	99
Till, grey	23	122
Till, yellow, gravel	6	128
Hardpan, yellow, small stones	7	135
Sand, compact		135

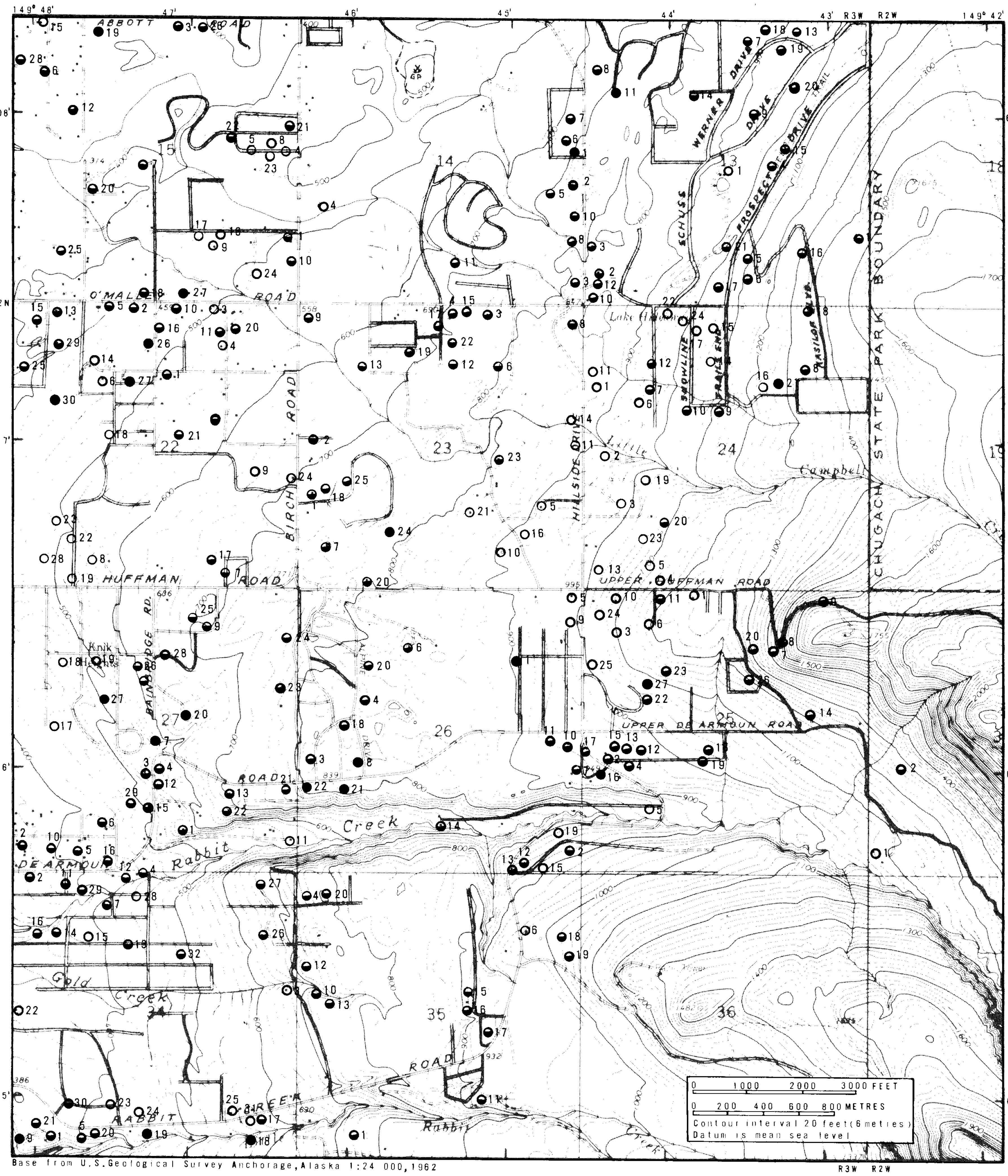
Open-end finish

Well no: SB 012 003 35 AADD; map no. 18
Owner: Ray Jones
Driller: Swafford Drilling Co.

Till, grey, brown	18	18
Rock, grey	5	23
Rock, lime	16	39
Rock, grey	15	54
Rock, lime	6	60
Conglomerate, grey	4	64

Open-hole finish

APPENDIX A-2 Locations of selected ground-water wells.



Base from U.S. Geological Survey Anchorage, Alaska 1:24 000, 1962

EXPLANATION

Well symbol

○ less than 100 feet deep

◒ 100-250 feet deep

● greater than 250 feet deep

The number beside the well symbol is a sequential number arbitrarily assigned within a square mile section. A data-listing by this num-system is given in appendix A-3.

APPENDIX A-3 Reported data on water wells.

Explanation

Section and map number: Section refers to land line township-range square-mile grid. Map number refers to the sequential listing of wells within square-mile sections (see fig. A-2 for map locations).

Owner: Person responsible for the well at time of original inventory, usually the person who had the well drilled.

Well depth: Maximum depth drilled during construction of the well.

Altitude: Approximate height above sea level of the land surface at the well site.

Aquifer zone and material: Depth to top and bottom of water-bearing strata below land surface and the predominant geologic composition of the aquifer.

Static water level: Depth to water in well below land surface on a specified date after completion of the well.

Pumping data: Yield is gallons of water per minute produced during a test of the well and aquifer performance. B indicates that yield was dertermined by the bailing method. Drawdown is total distance of water level decline from static level at the end of the pumping test. Duration refers to length of pumping test.

Remarks: L indicates that a driller's log is available. LP indicates that the driller's log is given in table A-1. C denotes that chemical analyses of well water are given in table A-4. Chemical data given under remarks were determined in the field and are only approximations.

Note: Nearly all wells are completed with open-ended 6-inch casings. Casings of wells producing water from bedrock were usually driven several feet into bedrock with open-hole exposures at greater depth.

Section and Map No.		Owner	Depth drilled	Altitude	Aquifer		Static Water Level		Pumping Data			Remarks
					Zone	Material	feet below surface	date measured	yield (gpm)	drawdown (feet)	duration (hours)	
					Township 12N., Range 3W.							
13	1	Luchsinger, Carl	125	1480	49-50?	bedrock	40	5/72	3/4	--	--	LP, bedrock at 40 feet
	2	Woodward, Allen	198	845	196-198	sand, gravel	130	3/65	8	--	--	L
	3	Neilson	192	810	-	-	131	/58	8	--	--	Hit bedrock?
	4	Reed, Robert	170	1040	30-57	till	40^{+}	4/71	40	small	--	L, bedrock at 59 feet
					59-170	bedrock						
	5	Hammond	223	1090	$>70^{+}$	bedrock	--	--	1	--	--	Bedrock at 25 feet
	6	Warren, Al	120	1130	$>70^{+}$	bedrock	--	--	--	--	--	
	7	Gillotte, Daltrice	114	910	-	-	--	--	7B	--	1	
	8	Tanaka, Jim	143	640	139-143	sand, gravel	104	11/65	11	--	5	LP
	9	Brothertow	200	930	90-100	bedrock	60	7/69	1	140	--	Bedrock at 60 feet
	10	Larson, Robert	200^{+}	845	-	-	104	12/71	--	--	--	
	11	Rigler, Jerry	270	740	260-270	bedrock?	--	--	--	--	--	L, bedrock apparently at 227 feet
	12	Prickett, Harvey	128	850	120-128	sand, gravel	100	9/71	15	--	--	L
	13	Clark, Collin	100	930	70^{+}	-	--	--	4	--	--	Bedrock at 70 feet
	14	Hawley, Charles	215	830	173^{+}	sediments	147	11/69	2B	--	--	L, bedrock at 173 feet
	15	Faltin, Howard	150	1040	-	bedrock?	18	/65	5	82	--	Bedrock at 47 feet
	16	Armstrong, John	100	1300	32-100	bedrock	12	5/71	7	66	--	L, bedrock at 8 feet
	17	Nelson, David C.	175	1030	at 70	-	50	/67	1	--	--	Bedrock at 70 feet
	18	Lohrey, John	105	880	-	-	93	5/70	5	--	--	Bedrock at 95 feet
	19	Ellington, Clayton	110	930	-	-	86	/70	--	--	--	Bedrock at 86 feet
	20	Luchsinger, Carl	100	980	-	bedrock	18	4/72	2-1/2	75	--	LP, bedrock at 23 feet
	21	Houtchens, Charles	158	1000	60-70	bedrock	43	4/72	$>1/2^{+}$	--	--	LP, bedrock at 40 feet
					130-150							
14	1	Heikes, Melvin	181	710	at 181	gravel	165	10/57	4	10	5	L
	2	Bumgarner, William	225	760	220-225	gravelly sand	156	10/57	10	24	--	L
	4	Craig	90	476	89-90	gravel	--	--	--	--	--	L
	5	Siefker, Ronald	150	710	146-150	sand, gravel	125	10/64	9	12	16	LP
	6	Lustig, George	126	670	75-85	-	70	5/65	7	--	--	
	7	Lally, R.	152	660	-	-	34	/68	10	--	--	
	8	Tremblay, R.	225	780	at 225	sand, gravel	185	8/69	10	--	--	L
	9	Moe, J.	240	810	at 240	sand, gravel	178	9/69	10	--	--	L
	10	Mensing, Bob	200	775	182-200	sand.	155	7/69	20	4	--	L
	11	Vali Vue Subdivision	179	620	174-179	gravel	43	4/72	168	107	24	LP, C

APPENDIX A-3--Continued

Section	Map No.	Owner	Depth drilled	Altitude	Aquifer: Zone	Aquifer: Material	Static Water Level: feet below surface	Static Water Level: date measured	Pumping Data: yield (gpm)	Pumping Data: drawdown (feet)	Pumping Data: duration (hours)	Remarks
		Township 12N., Range 3W.										
15	1	Allinger, Leroy	117	510	114-117	sand, gravel	77	9/62	8	8	5	L
	3	Strultz, R.	103	390	94-103	gravel	43	6/58	$>2^{+}$	--		L
	4	Whittier, Gordon	62	480	60-62	sand, gravel	55	8/63	11	1	1	L
	5	Sterling	85	460	80-85	sand, gravel	64	8/63	10	12	2	LP
	6	Sullivan, C.	192	346	189-192	till?	150	/64	4	40	3	LP
	7	Lenhart, Victor	255	460	-	-	241	--	1	--	--	
	8	Barker, Thor	22	470	21-22	sand, gravel	12	10/59	8	7	2	L
	9	Cardwell, William	74	470	72-74	sand, gravel	30	8/62	12	30	3	L
	10	Coleman, H.	122	524	120-122	sand, gravel	72	8/62	4	45	17	L
	12	Engersall	227	370	226-227	sand, gravel	47	8/65	15B	173	--	L
	15	Unknown	82	324	75-81	gravel, cobbles	63	10/65	15	total	2	L
	16	Dehart, William	62	465	61-62	sand	30	6/56	5	22	2	L
	17	Loudermilk, Lindon	65	460	60-65	sand	30	3/56	8	20	3	L
	18	Enke, Alma	186	445	at 186	sand	170	12/55	8	--	--	L
	19	Jesse Lee Home	280	390	263-280	-	187	7/65	222	13	6	C, screened 263'-280'
	20	Kahn, Harold	199	375	197-199	sand, gravel	170	11/66	10B	--	--	L
	21	Parrish, Robert	115^{+}	470	-	-	--	--	--	--	--	L
	22	Brauch, Fred	106	460	103-106	gravelly sand	50	5/68	5	51	27	L
	23	Diamond, Tim	55	470	52-55	sand, gravel	33	10/65	15B	--	1	L
	24	Brady and Everett	79	510	75-79	sand, gravel	55	8/66	10	1	3	L
	25	Ryan, James	195	385	at 195	sand, gravel	162	12/67	(4)	--	(3)	L, (pumping data for 181-foot water zone) water contains some iron
	26	Henrickson, Harold	232	395	222-232	sand	200	7/60	17	10	--	LP; 0.1 mg/l iron; sp. c. 220; hard. 120 field
	27	Roland, Robert	284	470	281-284	sandy gravel	275	11/71	--	--	--	L
	28	Kranich, Bill	*225	330	-	-	175	/71	9	20	--	*was 140 feet. Had to deepen
22	1	Springer, J.	137	512	119-137	sand, gravel	86	11/58	--	--	--	L
	2	Landes, Wesley	193	442	186-191	gravel	56	4/59	--	81	--	L
	3	Groh, O.	67	500	65-67	sand, gravel	36	2/63	5	29	13	L
	4	Clauson, J.	58	528	57-58	sand, gravel	48	6/61	6	9	1/2	L
	5	Clare, John	230	418	220-230	sand, gravel	203	6/64	8	24	3	L
	6	Straus, R.	84	460	at 81	sand, gravel	62	1/58	--	--	--	L
	7	Dafoe, Harold	214	690	190-214	sand, gravel	198	6/71	10	4	--	L
	8	Bowden, Bruce	90	562	89-90	sand, gravel	74	8/63	16	8	5	LP
	9	Smith, Bert	41	650	at 41	till	20	--	5	10	--	L
	10	Hershe, John	234	480	220-234	sand	214	4/55	--	--	--	LP, C
	11	McCoy, Charles	100	520	95-100	sand	55	3/55	15	--	1	L
	12	Cummings, Jim	107	580	90-100	sand	69	8/54	--	--	--	L
	13	Arcand, George	229	423	224-227	sand	204	11/54	8	3	--	L, screened 224'-227'
	14	Bumgarner, James	143	444	-	till?	37	7/54	--	--	--	L
	15	Roguska, Gene	136	425	132-136	sand	120	5/55	--	--	--	L
	16	Marcy	127	478	126-127	sand, gravel	-	--	10	--	43	L
	17	Wells, Dale	232	680	230-232	sand, gravel	213	7/65	15	3	3	LP
	18	Riem	66	500	50-66	sand	15	7/68	10	0	--	L
	19	Parks	48	530	44-48	sand, gravel	29	12/65	5B	19	1	L
	20	Klementson, Klement	110	530	106-110	sand, gravel	55	--	15	45	--	L
	21	Chamberlin, William	110	560	95-97	sandy gravel	75	9/72	4-1/2	22	1	LP
	22	Hunsberger, Glenn	64	520	59-64	sand, gravel	35	5/66	5	10	2	L
	23	Scott	62	485	59-62	sand, gravel	51	10/65	10B	6	1	L
	24	Reed, J.	42	700	at 42	gravel	15	3/59	10	20	2-1/2	L, C
	25	Mattingley, C.	155	390	at 155	gravel	-	--	--	--	--	L
	26	Smith, Francis Jr.	289	470	-	-	268	12/69	--	--	--	
	27	Froelicher, Franz	280	490	-	-	210	1/71	15	--	--	L, screen installed at 255 feet
	28	Kay, Gale	65	480	-	-	50	8/69	small	--	--	Reported heavy mineral content in water
	29	Lipscomb, Wayland	243	410	-	-	193	11/64	--	--	--	L
	30	Taku Developers	257	430	257-258	sand, gravel	219	6/72	20	30	1	LP, C
23	1	Crow, Richard	211	710	at 211	gravel	200	9/60	10	--	--	L
	2	Ostrandes, Norman	222	675	207-222	sand, gravel	143	5/60	10	47	--	L
	3	Dault, Harvey	194	770	at 194	gravel	154	7/59	40	10	--	L
	4	Graham F.	200	720	151-200	gravel	127	4/58	100	24	--	L, recovered to static in 2 minutes
	5	Parik, G.	105	910	73-74	sand	29	7/58	1	35	240	LP, bedrock at 93 feet
	6	Weeks, Ralph	214	800	211-214	sand	100	3/70	12B	--	--	L
	7	Gillette, Don	324	744	-	bedrock	184	/54	--	--	--	L, C, bedrock at 233 feet
	8	Moerlein, George	114	850	-	-	98	8/52	--	--	--	L, drilled about 30 feet deeper in 1968
	9	Forsythe, Grant	138	580	136-138	gravel	78	6/55	--	--	--	L
	10	Wright, Gerald	49	906	47-49	gravel	22	1/56	10	2	7	L
	11	Fuller, Keith	98	888	61-73	till	+5	11/64	10	43	4	LP, bedrock was encountered
	12	Woosley, Bob	200	740	187-200	sand, gravel	100	8/64	10	80	14	LP
	13	O'Malley Elem. School	142	646	127-142	sand, gravel	97	9/66	150	1-1/2	18	L, screened
	14	Brewster, Herbert	60	865	-	-	flowing	/65	--	--	--	20 lbs. artesian pressure reported
	15	Temple, Brad	170^{+}	725	-	-	124	4/69	--	--	--	
	16	Ward, Frederick	54	900	52-54	sand, gravel	29	7/69	10	--	11	L
	17	Autten	126	680	124-126	gravel	118	9/66	8	2	21	L
	18	Kurtz, Irvin	230	715	-	-	-	--	3	--	--	Field quality: Fe 0.1 mg/l; sp. cond. 265; hard.138
	19	Block, Ed	196	685	-	-	90?	/62	10	--	--	
	20	Wooliver, George	126	800	124-126	sand, gravel	116	7/65	7	8	--	LP
	21	Copelin, Charles	92	845	-	-	$>25^{+}$	2/60	--	--	--	Adequate supply
	22	Woosley, Bob	197	730	194-197	sand, gravel	150	8/70	15B	3	--	L
	23	Mobley, John	225	825	185-214	bedrock	30	/66	4-1/2	180	--	L, bedrock at 185 feet(?)
	24	Engle, Stan	322	780	120-178	till	148	9/70	1	--	--	L, bedrock at 178 feet
	25	Evans, Charles	186	730	182-186	sand, gravel	161	4/69	5	20	13	LP
24	1	Woodbury, George	98	860	-	bedrock	10	9/67	10	--	--	L, bedrock at 86 feet
	2	Wood, Vernon	50	930	-	-	-	--	--	--	--	
	3	Cummings, Robert	55	980	-	-	-	--	12	--	--	
	4	Thomas, Leonard	98	1160	-	-	-	--	40?	--	--	Well yield not documented
	5	Scott, L.	50	1110	-	-	20	7/67	--	--	--	Screened
	6	David, Clinton	56	955	-	-	-	--	--	--	--	
	7	Stetson, Gilbert	113	965	at 113	sand, gravel	48	6/66	6	--	5	L
	8	Muth, John	175	1340	-	bedrock?	70	/69	--	--	--	Well drilled into bedrock
	9	Swank, Russ	126	1120	at 36	-	-	--	--	--	--	Perforated at 36 feet
	10	Morholt, John	117	1040	at 117	sand, gravel	46	7/65	5	--	1-1/2	LP
	11	Richter, Donald	135	870	-	-	65^{+}	/63	12	--	--	Screened, well was 99 feet deep prior to 1965

APPENDIX A-3--Continued

Section and Map No.	Owner	Depth drilled	Altitude	Aquifer: Zone	Aquifer: Material	Static Water Level: feet below surface	Static Water Level: data measured	Pumping Data: yield (gpm)	Pumping Data: drawdown (feet)	Pumping Data: duration (hours)	Remarks
	Township 12N., Range 3W.										
12	Patten, Al	106	970	79-106	bedrock	45	8/65	6	50	--	LP, bedrock at 79 feet
13	Frost, Stan	63	1010	-	-	51	10/65	--	--	--	Reported to hit bedrock 65 feet
14	Glenn, Leland	65	1080	at 24	-	-	--	3	--	--	Water is silty at times
15	Boedecker, Wayne	75	1060	24-38	bedrock	15	7/69	3	55	--	L, bedrock at 24 feet
16	Reavis, William	85	1250	43-48	till	40	8/71	1/2	40	--	LP, bedrock at 72 feet
17	Luchsinger, Carl	85	1020	50-85	bedrock	39	1/69	1-3	--	--	L, bedrock at 50 feet
18	Giddings, Keith	100	1360	40-65	bedrock	19	8/69	7	70	1	LP, bedrock at 40 feet
19	Herbst, Marvin	35	1020	-	-	-	--	--	--	--	Dug well, ample supply
20	Prescott, Bob	175	1090	70-75	bedrock	70	8/71	2	105	--	L, bedrock at 70 feet
21	Jokil, Zig	250	1280	-	bedrock	60	/68	7	--	--	Bedrock at about 8 feet
22	Arnett, Russell	85	940	80-?	gravel	-	--	--	--	--	Adequate yield reported
23	Meredith, Jerry	63	1060	-	-	-	--	adequate	--	--	Well drilled into bedrock
24	Matthews, Eugene	85	990	50-70	bedrock	40	8/71	3	40	--	L, bedrock at 50 feet
25 1	Evans, Glynn	80	1240	-	bedrock?	24	/66	7	--	--	L, bedrock at 23 feet
2	Januiewiz, Eugene	159	954	157-159	sand	100	8/62	10	35	2	LP
3	Yost, Robert	50	1100	at 35	till	30	8/55	1	--	--	L, bedrock at 38 feet(?)
4	Cox, John Jr.	108	964	at 108	gravel	77	7/54	--	--	--	L
5	Yost, B.	25	856	23-25	sand, gravel	--	-	7	--	1	LP
6	Mayfield, Earnest	92	1190	-	bedrock	30	7/60	--	--	--	L, bedrock at 18 feet
7	Moore, Pat	140	1400	at 56	bedrock	--	-	1-2	--	5	L, bedrock at surface
8	Moore, Pat	125	1500	at 94,110	bedrock	49	2/68	4	29	--	LP, bedrock at surface
9	Garland, Gerry	125	1600	-	bedrock	--	-	--	--	--	Bedrock close to surface
10	Holland, Russel	120	1080	-	bedrock	41	2/68	ample	--	--	Bedrock at 30 feet
11	Ward, Harry	125	1200	-	bedrock	15	8/67	--	--	--	Bedrock at 30 feet
12	Swanson, Frank	220	980	-	-	--	-	--	--	--	
13	Markson, Louis	220	970	-	-	--	-	12	10	72	Reported 0.2 mg/1 iron
14	Spendlove, Rod	155	1200	144-155	bedrock?	--	-	--	--	--	C, bedrock at 144 feet(?)
15	Birtciel, J. (tennant)	80	960	-	-	--	-	--	--	--	
16	Mohammad	107	930	-	-	--	-	--	--	--	C
17	Kilmer, J.	220	940	-	-	--	-	--	--	--	
18	Shumaker, Joe	224	1030	221-224	gravel	110	/70	6	--	--	L
19	Buden, Vern	109	1000	106-109	gravel	65	7/70	5	--	--	L
20	Breedlove, William	120	1300	-	-	110	-	--	--	--	
21	Sears, David	475	1070	at 400	bedrock	42	7/71	ample	--	--	Bedrock at 87 feet
22	Connor, Pat	170	1040	-	-	--	-	$>2^+$	--	--	
23	Jensen, John	185	1120	at 60, 170	bedrock	18	6/70	6	158	--	LP, bedrock at 42 feet
24	Fuerstenberg, James	95	1070	at 95	bedrock	15	7/65	1/2	--	--	LP, bedrock at 20 feet
25	Champion, C.	45	1010	none	-	--	-	no water	--	--	Bedrock reported at 45 feet
26	Robinson, Monroe	173	1200	-	bedrock	$>50^+$	5/72	14	small	--	Bedrock about 15 feet below surface
26 1	Arturo	275	910	at 275	bedrock	--	-	5	--	--	Bedrock at 79 feet
2	Pinnick, V.	230	880	at 230	bedrock	60	/70	small	--	--	Bedrock at 68 feet
3	Martin, L.	220	824	218-220	sand, gravel	200	8/63	--	18	--	LP
4	Thiel, Ronald	238	830	-	-	--	-	--	--	--	
5	Spendlove, Stanford	79	980	-	bedrock	26	1/56	12	48	--	LP, bedrock at 24 feet(?)
6	Knapp, John	111	850	106-111	sand, gravel	97	12/55	12	3	2	L
7	Morgan, Frank	156	930	151-155	silty sand	112	3/55	10	33	--	LP
8	Breedon, Don	292	820	at 292	gravel	187	3/54	5B	--	--	L
9	Miller, Harold	72	980	-	bedrock	15	/60	3	--	--	Bedrock at 15 feet
10	Bennett, Rex	280	940	-	-	--	-	--	--	--	
11	DePalatis, Sam	260	945	-	-	--	-	--	--	--	
12	Cox, C.	100	870	-	-	dry?	-	--	--	--	
13	Huckabee, Bill	100	870	-	-	--	-	ample	--	--	
14	Godfrey, Keith	112	680	at 112	-	--	-	small	--	--	Water reported to be hard and irony
15	Grey, Don Jr.	88	890	at 40	till?	30	6/70	1/2	--	--	LP, bedrock at 47 feet
18	Rains, Dick	183	800	180-183	sand, gravel	163	6/68	10	10	1	LP
19	Bedford, Wallace	110	840	-	-	$>50^+$	/69	$>5^+$	--	--	
20	Steward, Harley	230	840	-	-	--	-	small	--	--	
21	Geuss, Arthur	262	820	-	-	--	-	--	--	--	
22	Hanson, H.	258	805	240-258	till, gravel	223	6/60	5	33	--	
27 1	Nogaard, Quentin	215	590	200-215	sandy till	197	10/62	--	--	--	L
2	Lyons, M.	115	370	114-115	sand, gravel	75	2/59	8	38	8	L
3	Miller, Marvin	230	560	211-230	sand, gravel	206	5/63	11	2	1	LP, originally 213 feet deep. Had to drill deeper after 1964 Earthquake
4	Kirsch, Andrew	148	570	140-148	sand, gravel	140	6/63	8	5	2	L
5	Heaverly, G.	170	414	at 170	sand, gravel	105	8/63	9	43	3	LP
6	Jensen, Richard	182	422	181-182	sand, gravel	100	7/61	10	68	4	L
7	McCabe, J.	272	580	173-272	bedrock	100	3/54	1	--	--	L, bedrock at 173 feet
9	Moralli, Pete	187	700	184-187	sand, gravel	180	5/65	7	7	1	L
10	Pool, Bob	144	394	138-144	sand, gravel	114	7/65	15	30	1	L
11	Cannon, Charlie	20	560	-	-	--	-	--	--	--	
12	Currin, W.	232	560	-	-	--	-	12	--	--	Screened
13	Hokama, Fred	217	700	-	-	--	-	$>50^+$	--	--	Screened
14	Emmel, James	178	600	-	-	143	10/71	--	--	--	Screened
15	Minnis, Willson	106	500	at 106?	sand, gravel	--	-	--	--	--	Reported iron and lime in water
16	McDowel	115	430	112-115	-	100	/58	--	--	--	
17	Gillie	60	445	at 60	-	--	-	--	--	--	
18	Menzel	78	480	-	-	--	-	--	--	--	
19	Sanden	77	500	-	-	--	-	--	--	--	
20	Harms, Rex	300	660	-	bedrock	127	/57	--	--	--	Bedrock at 83 feet
21	Swenson, Niel	218	770	-	-	--	-	--	--	--	
22	Hines, Louis	295	680	-	-	--	-	--	--	--	
23	Johnson, Ronald	183	770	-	-	--	-	--	--	--	
24	Rooth, Gunnar	200	760	160-200	bedrock	160	/71	8B	--	--	Bedrock at about 160 feet
25	McCain, Edward	222	700	215-222	sand, gravel	192	10/71	10	20	--	LP
26	Jutsum, John	199	600	196-199	-	--	-	--	--	--	
27	Parker, Arthur	266	500	225-265	bedrock	47	6/70	$>3^+$	--	--	LP, bedrock at 180 feet
28	Peterson	209	640	207-209	sand, gravel	174	5/72	12	16	1-1/2	LP
29	Putman	175	480	168-175	gravel	150	9/72	8	20	1	L

APPENDIX A-3--Continued

Section	Map No.	Owner	Depth drilled	Altitude	Aquifer: Zone	Aquifer: Material	Static Water Level: feet below surface	Static Water Level: date measured	Pumping Data: yield (gpm)	Pumping Data: drawdown (feet)	Pumping Data: duration (hours)	Remarks
34	1	Young, Curtis	275	382	-	-	100	/63	3	175	--	LP, to 123 feet
	2	Morell, Earl	169	356	165-169	sand, gravel	124?	9/63	6	43	6	LP
	3	Goodland, R.	54	665	at 54	sand, gravel	22	-	--	--	--	L
	4	Buchanan, Garner	101	440	100-101	sand, gravel	50	6/63	6	40	5	LP
	5	Hamilton, James	172	380	at 115	top of bedrock	60	7/68	1/2	--	--	L, bedrock at 115 feet
	7	Kucera, Thomas	108	410	-	-	50	8/69	--	--	--	
	9	Jackson, George	285	320	-	bedrock	--	-	--	--	--	L, bedrock at 171 feet
	11	Chisum, Paul	135	390	-	-	--	-	--	--	--	
	12	Lenz, R.	126	420	-	-	65	/63	--	--	--	Casing perforated at 106?
	13	Best, Gordon	100	420	99-100	gravel	55	6/67	10	33	--	L
34	14	Nix, Kenneth	122	360	-	--	62	11/67	7	--	--	
	15	Caress, James Jr.	112	380	111-112	sand, gravel	70	5/67	8	32	--	L
	16	Venne, Wesley	126	340	-	--	38	/65	10	73	--	
	17	Bird, James	122	580	-	--	30	6/65	8	--	--	
	18	Miller, Leo	400	570	18-400	bedrock	10	1/72	2	--	--	L, bedrock at 18 feet
	19	Young, William	275	450	-	bedrock?	50	-	3	--	--	Bedrock at about 40 feet
	20	Young, Don	220	400	-	--	--	-	--	--	--	
	21	Brown, Gene	154	380	at 154	sand	126	2/67	4	--	--	L
	22	Elmore, William	50	340	47-50	--	--	-	--	--	--	C
	23	McInnes	42	420	-	--	--	-	--	--	--	
	24	Bouschor, Sid	80	460	-	--	--	-	--	--	--	C
	25	Mallory	65	540	-	--	--	-	--	--	--	Bedrock well? Water hard with iron
	26	Anderson, Lester	107	640	-	--	--	-	10	--	--	C
	27	Arewzon, Robert	116	680	111-116	sand	80	8/56	10	21	--	LP, screened, field quality: Fe 0.3 mg/l; Sp. cond. 160
	28	Kenneth, Don	77	440	74-77	gravelly sand	--	-	7B	--	2	L
	29	AhYou, Allen, Sr.	142	390	140-142	sand, gravel	60	7/68	--	--	--	L
	30	Player, Gary	140	390	at 125	bedrock	80	4/71	less than 1	total	--	C, weathered bedrock at 125 feet
	31	Riggs, Ralph	75	570	-	bedrock	12	9/67	1^+	58	--	LP, bedrock at 20 feet
	32	Nance, Martin	163	490	at 163	--	90^+	11/71	2	--	--	Perforated at 70 feet, little water gained
35	1	Wills, John G.	119	750	100-119	sand, gravel	50	8/70	45	5	--	L, well finished in large gravel
	4	Arians, Arthur	178	760	165-178	sand, gravel	78	3/68	3	--	--	L
	6	Stork, R.	75	980	72-75	bedrock	37	5/58	3	--	--	L, bedrock at 51 feet?
	10	Means, Grant	106	740	105-106	sand	64	4/55	10	10	2	LP
	11	Michael, W.	154	930	-	gravel	50	/56	ample	--	--	Screened, did not hit bedrock
	12	Wagner, D.	75	730	69-75	silty gravel	39	8/56	7	--	--	L, screened, field quality: Fe 0.3 mg/l; Sp. cond. 220
	13	Hanson, James	180	740	-	--	--	-	--	--	--	Reported hard water
	15	DeGarmo, Clark	135	920	at 135	compact sand	95	/58	2	--	--	LP, may have hit bedrock at bottom
	16	Jackson, Brady	168	920	162-168	gravel	92	5/59	--	--	--	L
	17	Dennison, K	250	930	-	bedrock	--	-	--	--	--	Bedrock at 38 feet
	18	Jones, Ray	105	1025	-	bedrock	80	/65	3	--	--	LP, bedrock at 18 feet
	19	Budd, Jerry	112	960	-	--	--	-	ample	--	--	Screened(?) field quality: no iron; Sp. cond. 305
	20	Lemp, Paul	200	800	-	bedrock?	112	5/68	1	--	--	Bedrock at 185 feet
		Township 12N., Range 2W.										
30	1	Collier, Monty	58	1080	at 58	--	--	-	adequate	--	--	Reported hit bedrock at 58 feet
	2	Lust, Dean	150	1280	at 120	--	--	-	3^+	--	--	Bedrock at 12 feet

APPENDIX A-4 Chemical analyses of water from wells
(Location of wells shown inappendix A-2)

Parameter	Well designation: Section - number within section												Recomended limits EPA (1972)	Significance to domestic and public water supply users
	14-11	15-19	22-10	22-24	22-30	23-7	25-14	25-16	34-22	34-24	34-26	34-30		
Sample date	4/72	8/66	12/52	/50	6/72	7/55	2/68	2/68	2/68	2/68	2/68	12/71		
Dept to aquifer (ft)	174	263	234	42	257	233*	150*	107	47	80	87	125*		*Bedrock aquifer tapped
Silica (mg/l)	12	12	20	17	8.2	16	9.8	11	16	21	12	11		Excessive amounts may inhibit deterioration of zeolite water softeners
Iron (mg/l)	0.22	0.48	1.5	.08	.15	3.1	.10	.06	.05	.35	.14	--	0.3 maximum	Excessive amounts cause staining, unpleasant taste, objectionable odor
Calcium (mg/l)	35	36	26	9	33	41	42	37	46	28	28	22		Primary causes of hardness
Magnesium (mg/l)	7.2	6.8	8.2	3.2	7.4	10	5.1	12	5.3	6.1	6.1	9.6		
Sodium (mg/l)	2.9	2.8	3.2	--	3.0	18	2.5	3.5	3.7	3.7	3.0	16		In combination with chloride, cause salty taste. In most waters the concentrations of these ions are too low to affect use.
Potassium (mg/l)	0.6	1.0	1.4	--	0.9	1.2	0.4	1.3	0.7	0.4	0.7	1.0		
Bicarbonate (mg/l)	138	150	113	56	129	149	135	180	137	113	112	146		Primary component of alkalinity
Sulfate (mg/l)	9.8	0	6.0	--	8.2	40	12	3.8	18	14	7.5	6.5	250 maximum	Excessive amounts cause bitter taste; may have laxative effects
Chloride (mg/l)	0.6	1.4	5.0	3.5	9.0	2.0	1.8	1.8	5.7	3.9	3.2	1.5	250 maximum	Large quantites cause corrosion; with sodium may give salty taste
Fluoride (mg/l)	0.1	0.1	--	--	0	0	0	0	0	0	0	0.3	2.4 maximum at 50°F	Maximum recommended consumption varies with temperature; very high fluoride contents cause scaling on teeth
Nitrate (mg/l)	1.5	0	1.4	--	1.4	0	7.8	0.4	9.0	0.9	0.9	0.2	10 maximum	Very high contents may indicate pollution from wastes. Excessive amounts may cause nitrate poisoning
Dissolved Solids (mg/l)	138	135	127	--	128	214	148	160	171	134	117	140		Excessive amounts may make water unsuitable for drinking and other purposes
Total Hardness (mg/l)	121	118	106	36	118	147	141	142	162	113	98	94	no limits specifed	Hardness of more than 150 mg/l causes excessive soap consumption and may lead to formation of scale in pipes
Specific Conductance (micromhos at 25°C)	236	242	191	112	217	337	254	279	280	210	191	241		A measure of the capacity of water to conduct eletricity; directly related to dissolved solids content
pH	7.8	7.9	7.2	6.7	8.1	8.5	7.9	7.9	7.9	7.3	7.9	8.2	5.0-9.0	Corrosiveness of water increases with decreasing pH; waters with high pH may cause incrustation.

APPENDIX A-5.-- Chemical analyses of surface water. (Sampling sites are shown in figure 23)

General properties							Concentration of major constituents Milligrams per litre (mg/l)												Concentration of heavy metals Micrograms per litre (μg/l)							Bacteriologic determination
Site No. (see fig.23)	Date sampled	Stream discharge (ft3/s)	Temperature (°C)	Color (platinum-cobalt units)	pH (units)	Specific conductance (micromhos at 25°)	Dissolved solids	Total hardness (as $CaCO_3$)	Calcium Ca	Magnesium Mg	Sodium Na	Potassium K	Bicarbonate HCO_3	Chloride Cl	Sulfate SO_4	Nitrate NO_3	Fluoride F	Silica SiO_2	Cadmium Cd	Copper Cu	Iron Fe	Lead Pb	Manganese Mn	Strontium Sr	Zinc Zn	Total coliform group MPN***
Little Rabbit Creek at Mountain Air Drive																										
1	04-06-72	e 1.0	.0	0	7.7	149		70	22	3.8	2.6	.3	69	.5		1.6	.1	9.7			110d		10d			
	04-10-73	e 1.5	.0	8	7.5	154	94	77	23	4.8	2.4	.5	66	1.3	17	2.9	.2	9.4			50d		20d			23
Little Rabbit Creek at Old Seward Highway																										
2	07-28-61		14.0	10	7.6	115	75	55	20	1.2	1.7	.4	56	1.0	12	.9	.1	9.7			30u		30u			
	10-31-66		1.0		7.5	124	77	60	17	4.3	1.2	.1	53	.0	17	1.2	.1	8.9			1510u					0
	05-15-67	2.1	5.0	10	7.1	95	65	45	14	2.5	1.7	.5	40	.0	12	4.6	.5	8.3	14*	17*	790u	0*	150*	50*	150*	
	04-06-72	1.2	.0	0	7.8	162	99	79	25	4.1	2.7	.3	78	.8	16	1.8	.1	10			50d		10d			
	04-10-73		.0	6	7.6	161	101	78	25	3.8	2.8	.6	75	2.8	17	2.3	.1	9.6	0	6	30d	2	20d		10	> 2400
Rabbit Creek 300 feet below Hillside Drive																										
3	11-02-66		1.0	5	7.6	74	42	31	8.8	2.2	.5	.0	26	1.4	7.2	.8	.2	7.5			40u					5
	05-26-67								11	2.5	2.2	.3							10	72	10	0	5	60	29	
	09-10-71	23.6	4.5	5	7.6	74	49	35	11	1.8	1.4	.2	32	.2	9.0	1.5	.1	7.5			0d		0d		290	
	04-06-72	4.5	.0	0	7.1	90	55	40	12	2.3	1.6	.1	37	.2	10	1.7	.0	8.6			30d		10d			
	04-10-73	e 4.0	.5	1	7.6	92	57	42	13	2.3	1.6	.2	38	.7	10	1.6	.1	8.3		14	90d		10d			5
Rabbit Creek at Old Seward Highway																										
4	07-28-61			10	7.6	72	47	32	11	1.2	1.1	.2	31	1.0	8.0	.7	.0	8.4			50u		0u			
	10-31-66		2.0		7.4	83	45	33	10	1.9	.8	.0	30	.7	7.2	.9	.1	8.7			180u		0u			60
	05-26-67								15	3.0	2.5	.3							16	56	40	0	15	50	100	
	09-10-71	24.8	6.0	0	7.6	83	53	38	12	2.0	1.6	.3	37	.5	9.2	1.3	.1	7.7			10d		10d			
	04-06-72	4.8	.0	0	7.0	100	60	44	13	2.5	2.3	.1	41	.7	12	1.3	.1	8.5			50t		0t			
	04-10-73	e 5.0	.5	7	7.4	103	68	48	15	2.5	2.1	.4	47	3.0	11	1.9	.1	8.3	0	4	30d	3	10d		10	49
Little Campbell Creek at Birch Road																										
5	05-26-67								12	2.6	2.5	.4							18	17	20	0	5	48	100	
	04-10-73		.0	10	7.5	192	124	90	27	5.4	8.6	.7	99	6.9	11	4.4	.1	11	0	6	110d	2	10d		0	49
Little Campbell Creek at Abbott Road																										
6	05-26-67								14	3.2	2.8	.7							26	50	70	0	80	43	100	
	04-10-73		.0	30	7.4	186	112	83	25	4.9	4.8	1.1	90	9.4	8.8	3.1	.1	9.7	0	9	250d	5	30d		10	350
Little Campbell Creek at Nathan Drive near mouth**																										
7	02-04-60		.0		7.6	182		102					100								240u					
	05-03-60	20	5.0		7.4	108		78					57								280u					
	07-28-61			30	7.3	152	95	83	23	4.5	2.4	.7	84	1.0	10	.9	.1	12			70u		0u			
	11-02-66				7.0	175	106	95	26	5.1	2.1	.3	94	2.5	7.7	2.1	.1	13			600u					
	04-10-71	e 6.0	.0	70	7.0	119	77	58	15	4.9	3.7	1.8	49	5.7	12	2.0	.2	6.8	0	20	690d	9	120d		30	> 2400
Lake Hideway																										
8	05-15-67		9.0	10	7.6	118	63	52	15	3.6	2.0	.7	60	1.4	9.0	.5	.1	1.1			90u					
	04-11-73		2.5	10	6.9	164	92	82	24	5.4	2.6	.9	84	2.4	9.0	3.2	.1	2.6	1		110d	3	40d		20	8

e estimated

* value from samples of May 26, 1967

** outside of Hillside Area

*** most probable number of organisms counts determined by Department of Health and Social Services, State of Alaska

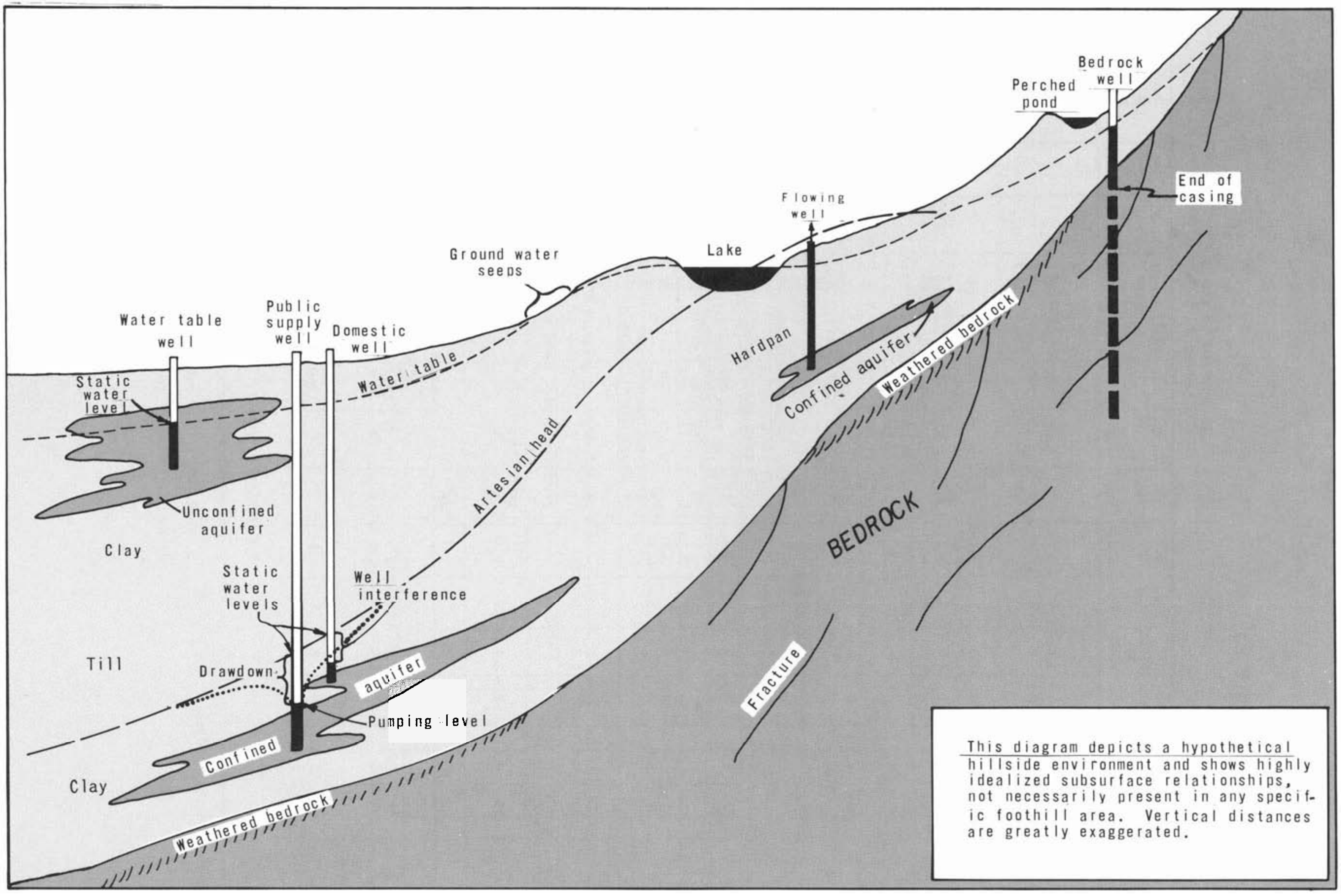
For iron and manganese

d concentration in solution when sampled

t total amount in suspended sediment and solution at collection

u undifferentiated; treatment of sample after collection unknown

APPENDIX A-6



Definition of hydrologic terms as applied to a glaciated foothill environment.

Artesian head - The height above a standard datum (usually mean sea level) that water will rise in a well tapping a confined ground-water body.

Attenuation - A steady reduction with time in the strength or concentration of chemical constituents or biologic organisms to natural levels found in an environment.

Coliform - A grouping of certain bacterial organisms which live in feces or other environments such as soil, water, and vegetation. Coliform bacteria have long been used as indicators of sanitary quality of water because they are normally abundant in water polluted by sewage.

Confined aquifer - A water-yielding stratum that is under hydraulic pressure significantly greater than atmospheric. Water in wells tapping confined aquifers stands above the top of the producing zone.

Drawdown - The amount of lowering of the natural (or static) water level in a well caused by pumping the well.

Fecal coliform - A specific group of coliform bacteria that characteristically inhabits the intestines of warmblooded animals and, therefore, are considered indicators of recent fecal pollution if found in water supplies.

Flood plain - The low-lying land bordering a stream channel which may be submerged by flood waters.

Hardpan - Locally, a term used to denote unusually compact and very resistant layers of sediments; generally found within till deposits, and usually composed of tough clay with rocks ranging in size from gravel to boulders.

Icing - A localized buildup of ice caused by the continual addition of water which freezes rather than drains from the locality.

Infiltration - The process by which water leaves the land's surface and enters the soil; thus, vertical penetration of the crust or organic mat is accomplished.

Perched ground water - Unconfined ground water which is separated from an underlying body of ground water by an unsaturated zone and is supported by a relatively impermeable stratum.

Percolation - The downward (usually vertical) movement of water through unsaturated subsoil due to the force of gravity.

Permeability - A measure of the relative ease with which a porous medium can transmit a liquid, given a potential gradient. Soils with a high permeability are capable of conducting water at a rapid rate.

Pumping level - The level of water in a well during pumping, commonly referenced to land surface.

Seep - A wet area on the land surface caused by a general dispersion of ground water which has surfaced.

Sorptive capacity - The ability of earth materials to attract and hold chemical constituents by either molecular adhesion or chemical ion exchange. Sorption generally increases as permeability decreases or as the inter-granular surface area per unit volume increases.

Spring - A flow of water from the ground at a point or in a small area defined by abrupt topographic features, such as the head of a ravine. Springs are differentiated from seeps by their much smaller discharge area.

Static water level - The naturally occurring level, commonly referenced to land surface, of water in a well open to an aquifer. Synonymous with the nonpumping level in a well, but a static water level may be significantly lowered by nearby or regional pumping.

Till - Fragmental unconsolidated material deposited by or from glacial ice with little or no modification by water during deposition.

Unconfined aquifer - A water-yielding stratum in which ground water is not subjected to pressures greater than atmospheric. The water surface of an unconfined aquifer constitutes the water table.

Well interference - The lowering of the water level in a well caused by pumping (withdrawal of water) in another nearly well. A pumping well produces a cone of drawdown surrounding itself; any well inside the horizontal boundaries of the cone will experience well interference.

Well log - A descriptive account of the earth materials and drilling conditions observed during drilling a well.