PRELIMINARY REPORT ON WATER AVAILABILITY IN THE LOWER SHIP CREEK BASIN, ANCHORAGE, ALASKA - with special reference to the fish hatchery on Fort Richardson and a proposed fish-hatchery site near the Elmendorf Air Force Base powerplant.

U. S. Geological Survey
Water-Resources Investigations 48-75

Prepared in cooperation with the
State of Alaska
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16. Abstracts

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Multiply English units	By	To obtain SI units
cubic feet per second (ft^3/s)	0.02832	cubic metres per second (m^3/s)
feet (ft)	.3048	metres (m)
feet squared per day (ft^2/d)	.0929	metres squared per day (m^2/d)
gallons per minute (gal/min)	.00006309	cubic metres per second (m^3/s)
inches (in)	25.40	millimetres (mm)
miles (mi)	1.609	kilometres (km)
million gallons per day (Mgal/d)	.04381	cubic metres per second (m^3/s)
square miles (mi^2)	2.590	square kilometres (km^2)

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By Geoffrey W. Freethey

ABSTRACT

The availability of surface water and shallow ground water in the lower Ship Creek basin, Anchorage, Alaska, was examined using 28 years of streamflow records and well logs. Streamflow gains and losses were estimated from 23 seepage investigations made since May 1957. A contour map of the top of the principal confining stratum and an isopach map of the saturated material were made in order to locate areas with the greatest potential for unconfined ground-water development.

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At the proposed fish-hatchery site on Elmendorf Air Force Base it probably is not possible to withdraw the required water either from a system of wells in the unconfined ground-water zone or from Ship Creek during periods of low flow. Two areas upstream from the site offer better potential for unconfined ground-water development; however, exploratory test wells and aquifer testing will be required to define areas of greater saturated thickness and effects of withdrawing the water needed.

INTRODUCTION

The purpose of this preliminary study is to examine the surface-water and the unconfined ground-water availability within the Ship Creek drainage basin downstream from a public water-supply diversion dam 10.5 mi (16.9 km) from the creek mouth. Two smaller areas within the basin at stream miles 2.8 (4.5 km) and 7.6 (12.2 km) are given individual attention due to a more immediate water requirement by the Alaska Department of Fish and Game.

This study is limited to potential water supplies from the stream and the unconfined ground-water aquifer. A deeper confined aquifer system is the principal ground-water source utilized by the city and military for water supplies and is discussed in Barnwell and others (1972).

This is the initial phase of a proposed comprehensive hydrologic evaluation of the Ship Creek basin and is being prepared at the request of the Alaska Department of Fish and Game. All streamflow, ground-water, and geologic data are from published and unpublished records of the U.S. Geological Survey.

LOWER SHIP CREEK

Physical Setting

Lower Ship Creek basin (fig. 1) occupies approximately 27 mi^2 (70 km^2) near Anchorage. The area is bounded on the north by the Elmendorf moraine; a hummocky ridge of glacial deposits of mixed grain size. The southern limit of the basin is determined by the existing drainage patterns, most of which are controlled by manmade features.

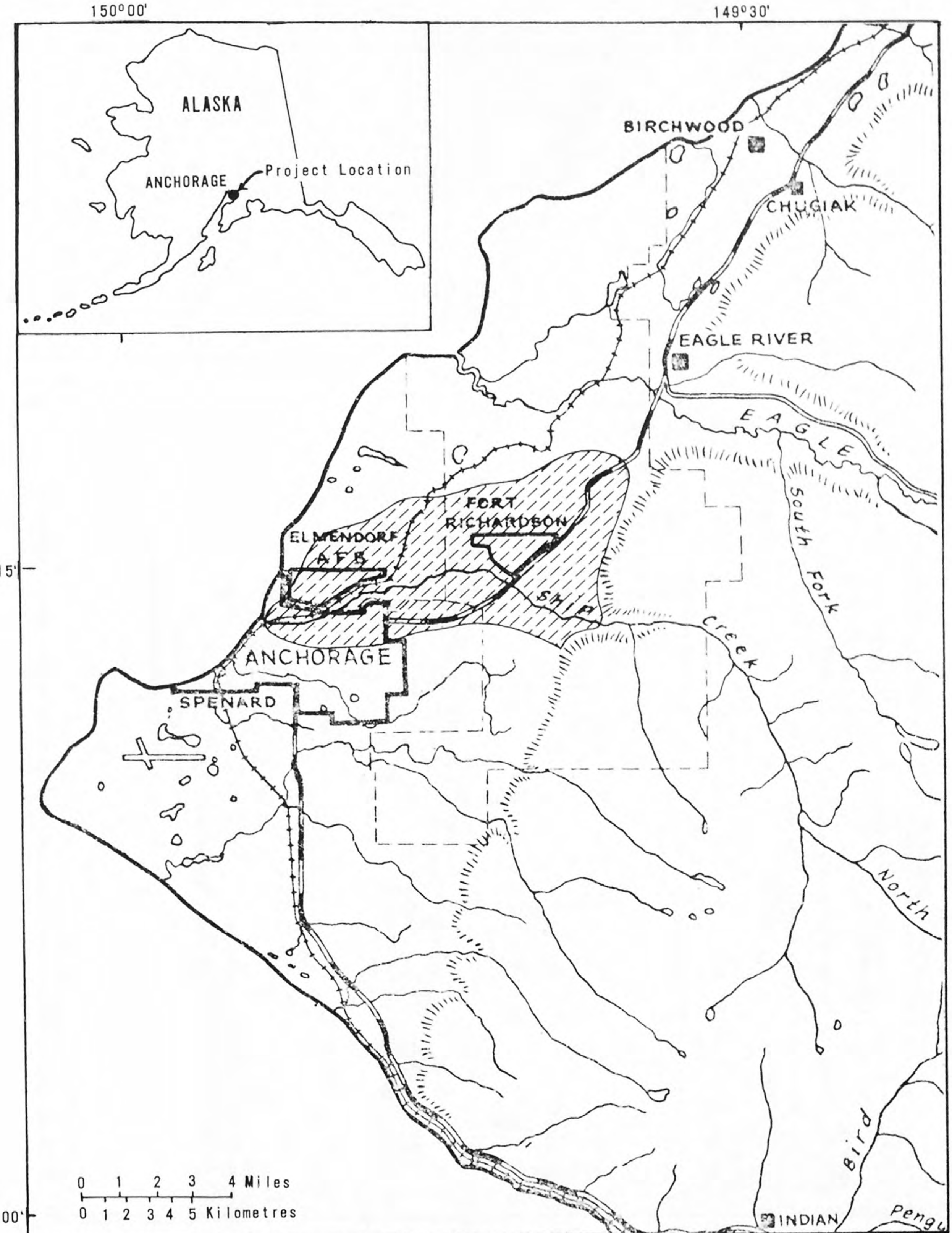
Average annual precipitation ranges from 15 in (380 mm) near the stream mouth to 17.5 in (440 mm) near the mountain front. Temperatures in the Anchorage area range from an average monthly minimum during the coldest month, January, of 3.2°F (-16° Celsius) to an average monthly maximum during the warmest month, July, of 65.3°F (18.5°C) (Climatological Data for Anchorage, Alaska, 1943-1973).

The basin terrain displays a gently sloping glacial outwash plain. The plain grades from an altitude of 500 ft (150 m) at the Chugach Mountain front and Elmendorf moraine to 100 ft (30 m) at the bluffs overlooking Knik Arm. Erosional degradation into this plain by Ship Creek is almost imperceptible in the upper reaches of the stream, whereas downcutting in the lower reaches near the mouth is 90 to 100 ft (27 to 30 m) (fig. 2).

Most of the drainage basin north of the creek and much of the basin south of the creek near the mountain front is within a military reservation. The remaining area south of the creek near Knik Arm is the city of Anchorage as seen in figure 3.

Geology

Lower Ship Creek basin is composed largely of coarse-grained alluvial deposits (fig. 4). The valley bottom consists of very permeable alluvial sand and gravel. The outwash plain is chiefly well sorted gravel to the east grading to sand to the west, also highly permeable. Alluvial fans near the mountain front contain more silt and



Base adapted from U.S. Geological Survey, Anchorage, 1:250,000, 1952.

Figure 1. -- Location of lower Ship Creek study area.

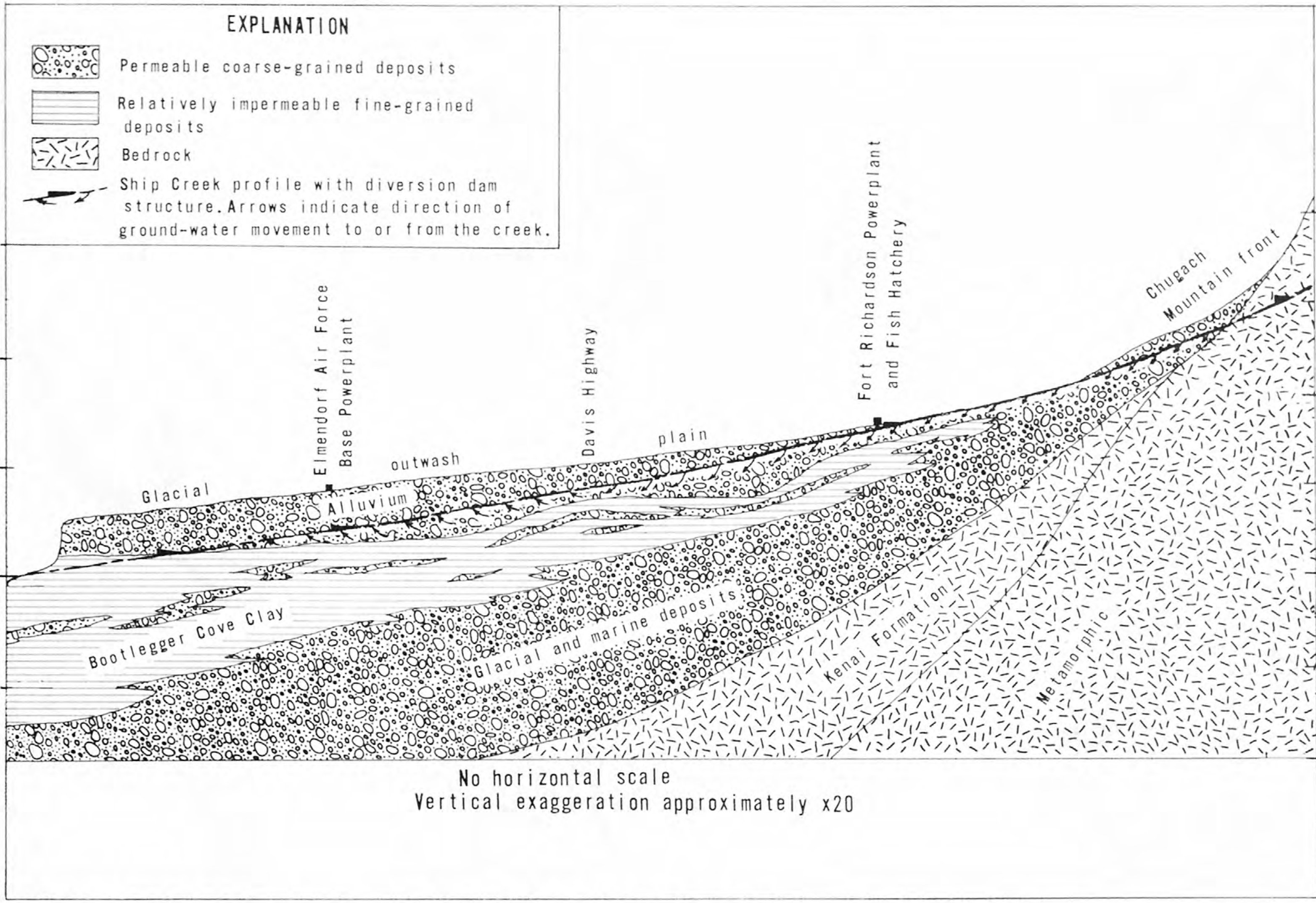
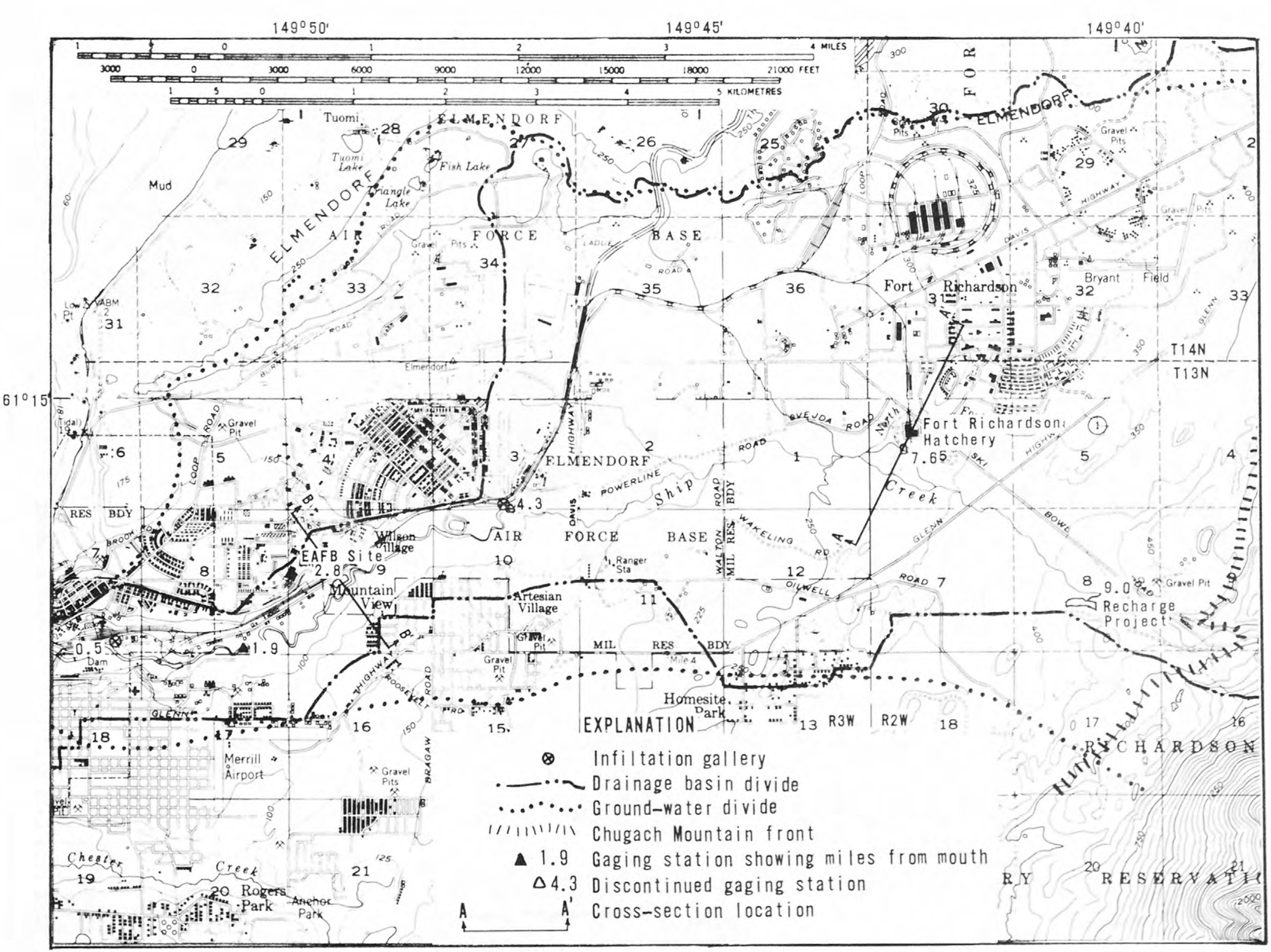
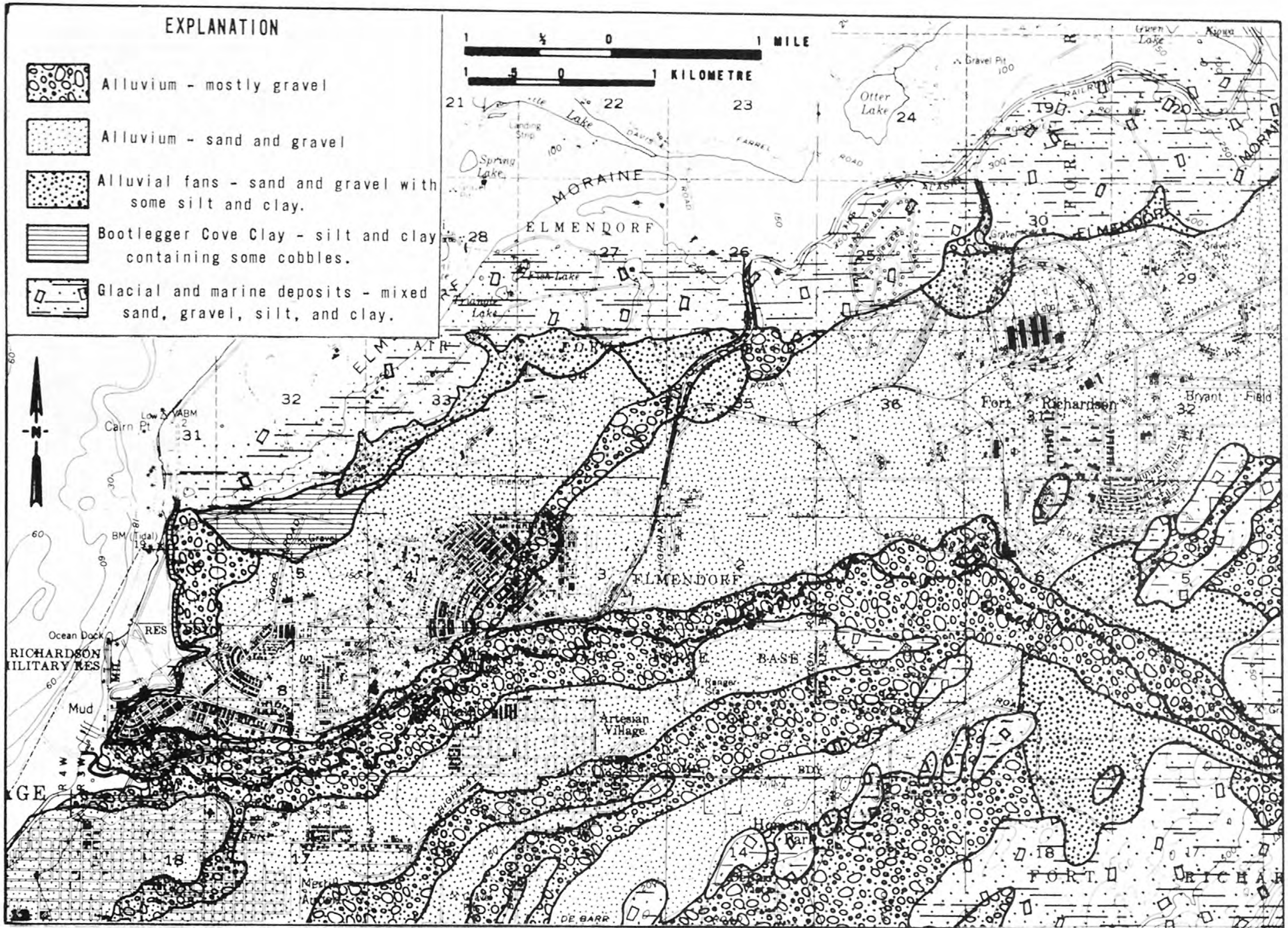


Figure 2. -- Schematic longitudinal profile of Ship Creek.



Base from U.S. Geological Survey, Anchorage, 1:63,360, 1952.

Figure 3. -- Lower Ship Creek basin.



Base from U.S. Geological Survey, Anchorage, 1:63,360, 1952.

Geology generalized from Schmoll and Dobrovolny, 1972.

Figure 4. -- Generalized surficial geology of the lower Ship Creek basin.

clay particles, decreasing permeability, but are typically sand and gravel deposits. These coarse-grained alluvial deposits are underlain by a fine-grained confining stratum which is exposed in the valley walls near the stream mouth (see fig. 2). A more detailed explanation of the origin of these surficial geologic materials is found in Schmoll and Dobrovolny (1972).

Ship Creek Water Use

In 1974, 41 percent of the total amount of water used by the two military bases and the city of Anchorage came from Ship Creek. During the period October 1973 through September 1974 an average of 22.1 ft^3/s or 14.3 Mgal/d (0.63 m^3/s) was diverted for this purpose. The military diversion dam where water is taken from the creek is approximately 10.5 mi (16.9 km) upstream from the mouth (fig. 3). The mean annual flow after the diversion is 141 ft^3/s or 91.1 Mgal/d (3.99 m^3/s) (period of record 1947-74), but decreases to a mean monthly flow of 20.8 ft^3/s or 13.4 Mgal/d (0.59 m^3/s) during February, 15.7 ft^3/s or 10.1 Mgal/d (0.44 m^3/s) during March, and 21.7 ft^3/s or 14.0 Mgal/d (0.61 m^3/s) during April, with short periods of no flow having been recorded.

Since 1973, the Geological Survey has conducted an aquifer-recharging project at stream mile 9.0 (14.5 km). Water was diverted from Ship Creek at an average rate of 6.2 ft^3/s or 4.0 Mgal/d (0.18 m^3/s) over the period from July 25 through September 18, 1973, and from May 20 through November 11, 1974. Since the diversion was in use only during periods of normal or higher than normal stream discharge, no water deficit was noted downstream.

Ship Creek water is used at three additional sites before flowing into Knik Arm: The Fort Richardson powerplant and fish hatchery at stream mile 7.6 (12.2 km), the Elmendorf Air Force Base powerplant at stream mile 2.9 (4.7 km), and the Chugach Electric powerplant at stream mile 0.5 (0.8 km). The water is used for cooling powerplant turbines and is eventually returned to the creek.

Unconfined Ground-Water Occurrence

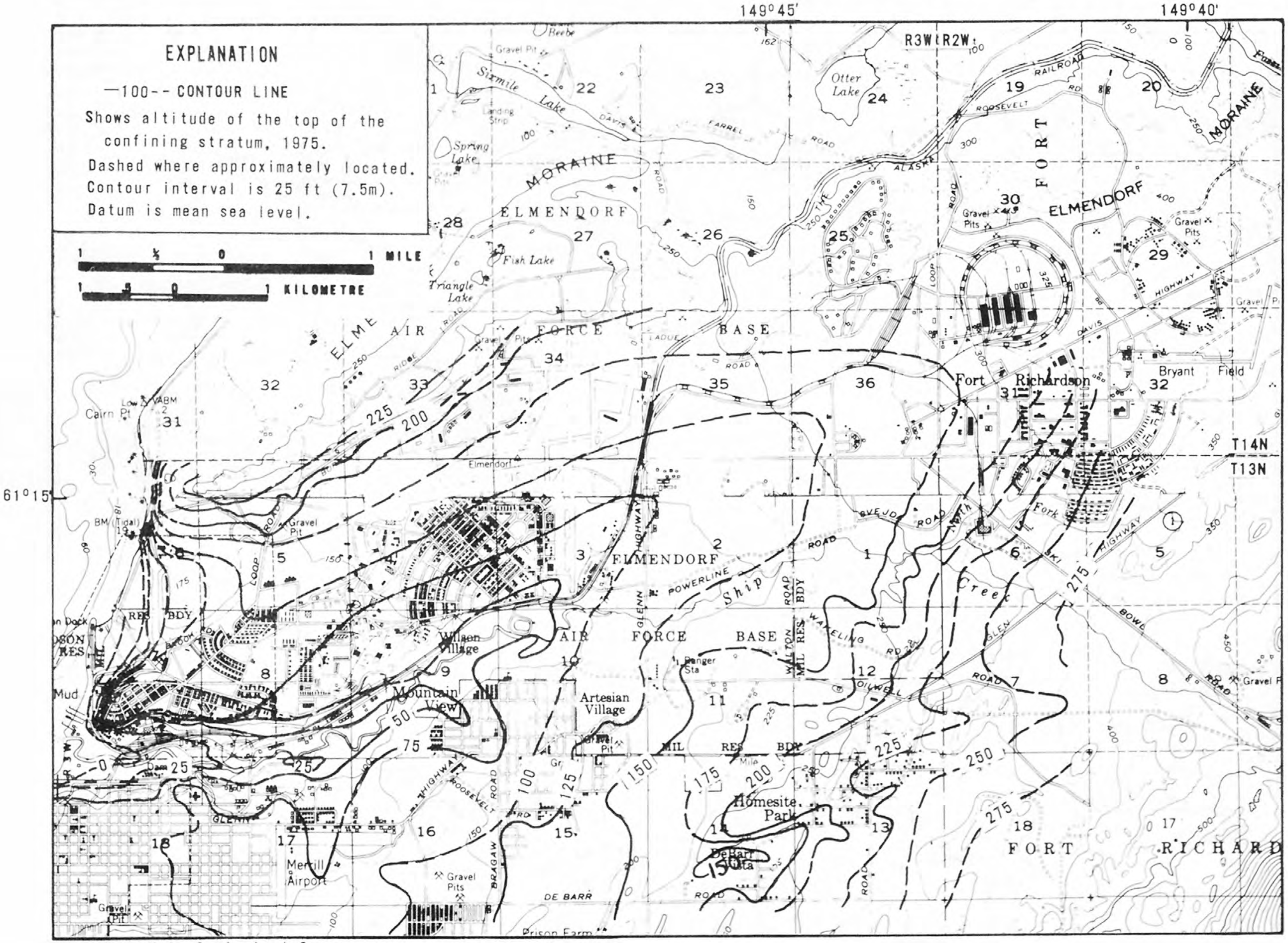
Twenty-three seepage investigations have been made on Ship Creek below the military diversion dam since 1957. A seepage investigation consists of stream discharge measurements made at several measuring sites over a time period in which the stream's stage does not change appreciably. The purpose is to determine the channel gains or losses. The seepage investigations show that Ship Creek is losing water from the diversion dam at stream mile 10.5 (16.9 km) to the discontinued Elmendorf Air Force Base gaging station near the Davis Highway at stream mile 4.3 (6.9 km). From this point to the stream mouth about the same amount of water is regained.

A confining layer of silt and clay, known as the Bootlegger Cove Clay (Miller and Dobrovolny, 1959), underlies the alluvial aquifer under the stream. The stream channel is entrenched into the confining layer in the lower reach of the stream, thus causing unconfined ground water to flow into the creek before reaching the tidal inlet (shown schematically in fig. 2). A contour map showing the approximate altitude of the upper surface of the confining layer is presented in figure 5. The difference between the altitude of this confining layer and the altitude of the water table (fig. 6) defines the thickness of the more permeable saturated material overlying the clay. These differences have been mapped and are shown in figure 7. The saturated thickness is one of the important parameters used for defining the approximate amount of water stored within the unconfined aquifer. Although permeability and the storage coefficient are equally important parameters, a rough estimate of how favorable an area is for unconfined ground-water development can be gained from just saturated thickness. In general, the greater the saturated thickness, the more favorable an area will be.

WATER AVAILABILITY AT THE FORT RICHARDSON HATCHERY SITE

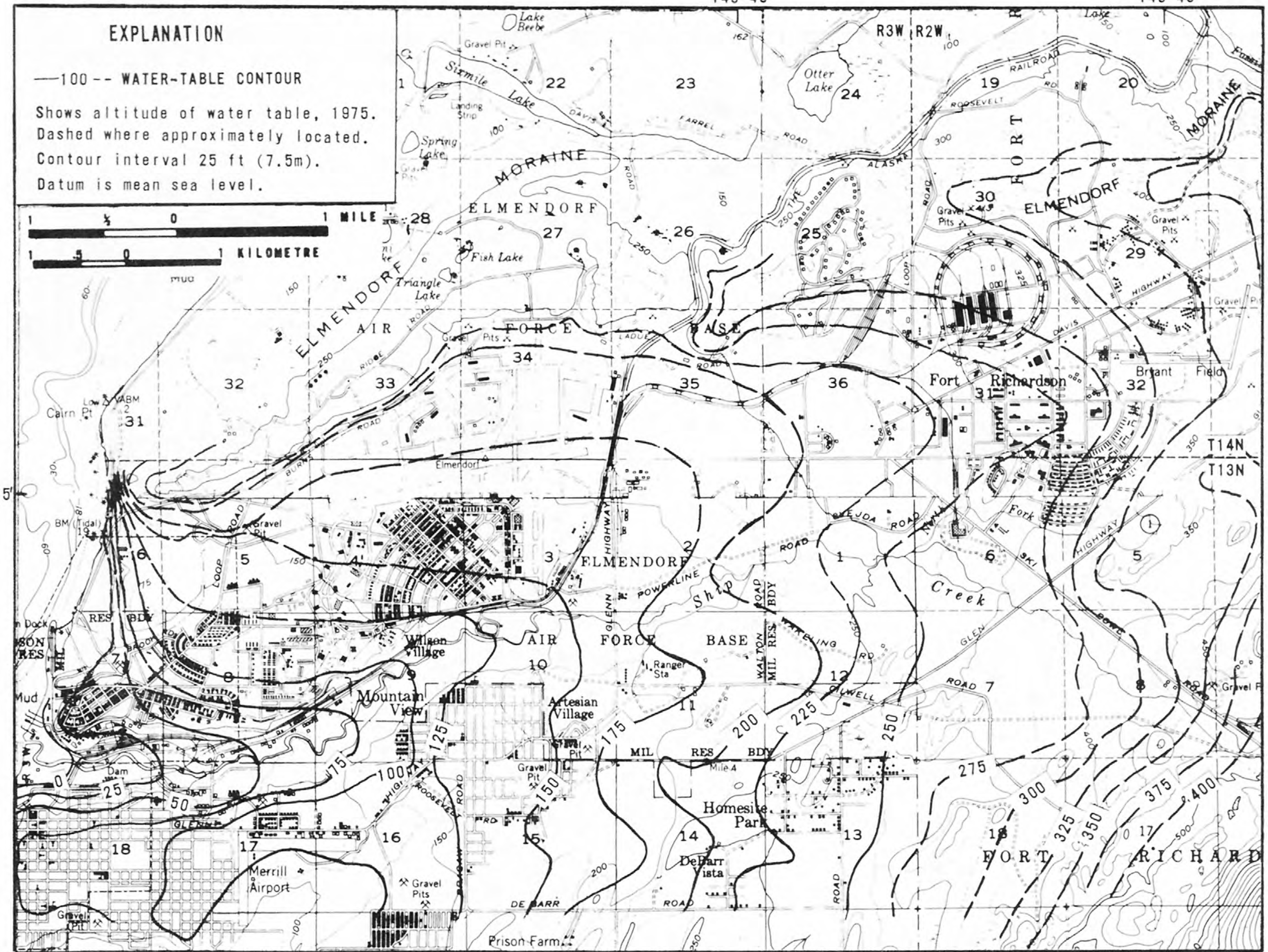
The powerplant at Fort Richardson is located on the north side of Ship Creek at stream mile 7.6 (12.2 km). A cooling pond near the creek is used for circulating and cooling the warm water from the condenser of one turbine unit in the powerplant. The pond is used simultaneously by the Alaska Department of Fish and Game for fish rearing. Cold water for reducing the pond temperature is diverted from Ship Creek during periods of normal or high streamflow. During periods of low or no flow (usually February, March, and April), four wells tapping the unconfined aquifer under Ship Creek supply the necessary cold water. Presently, these 4 wells combined supply about 1,000 gal/min or 2.2 ft^3/s (0.063 m^3/s). The physical layout of the Fort Richardson powerplant and fish hatchery is shown in figure 8.

Based on two seepage investigations where simultaneous stream discharge measurements were made at the gage at stream mile 10.5 (16.9 km) and at the Fort Richardson hatchery site (see fig. 3), an average loss in stream discharge of 8.5 ft^3/s or 5.8 Mgal/d (0.24 m^3/s) occurs between the two measuring points. Consequently, mean annual discharge at the fish-hatchery site will be approximately 8.5 ft^3/s (0.24 m^3/s) less than the mean annual discharge at the diversion dam, or about 132.5 ft^3/s (3.75 m^3/s). Periods of no flow at the fish-hatchery site are, then, most likely to occur when flow past the diversion dam falls below 8.5 ft^3/s (0.24 m^3/s). Generally periods of peak and low flow at the fish-hatchery site are nearly simultaneous with the periods of peak and low flow at the diversion dam. This assumes that lag time between the two sites is negligible.



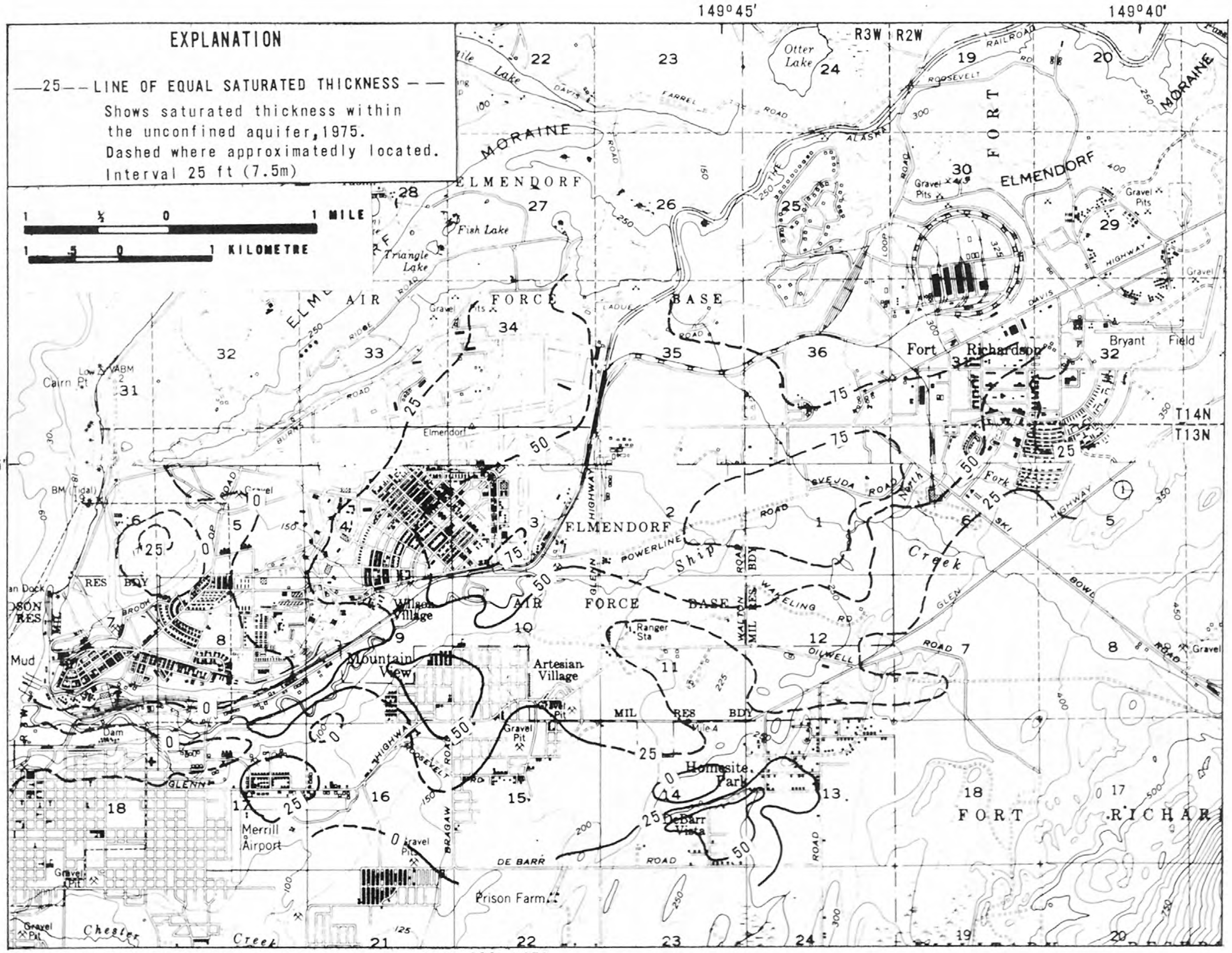
Base from U.S. Geological Survey, Anchorage, 1:63,360, 1952.

Figure 5. -- Configuration of the uppermost confining stratum in the lower Ship Creek basin study area.



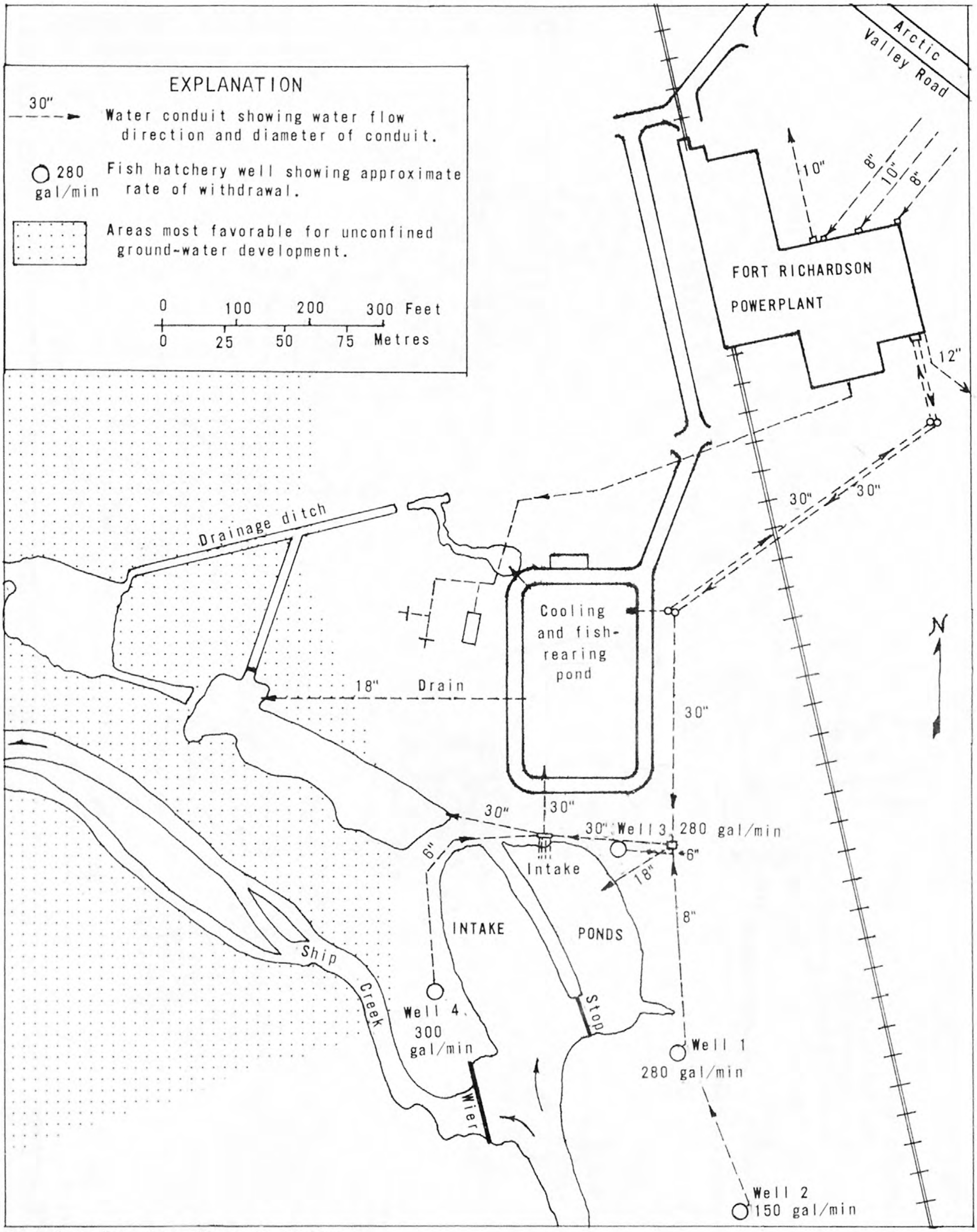
Base from U.S. Geological Survey, Anchorage, 1:63,360, 1952.

Figure 6. -- Configuration of the water table in the lower Ship Creek basin study area.



Base from U.S. Geological Survey, Anchorage, 1:63,360, 1952

Figure 7. -- Saturated material in the unconfined aquifer of the lower Ship Creek basin study area.



Base from U.S. Army Corps of Engineers

Figure 8. -- Powerplant and fish hatchery, Fort Richardson.

Shallow ground water near the Fort Richardson hatchery site may be partially confined, thus providing poor hydraulic connection between Ship Creek and the ground water below. Cross section A-A' (fig. 9) shows saturated thickness to be about 35 ft (11 m) beneath and to the south of the creek, but shows a probable thickening north of the powerplant because of a thinning and eventual pinching out of the confining unit. Downstream from the hatchery a probable increase in saturated thickness to more than 75 ft (23 m) can be seen (fig. 7), whereas upstream saturated thickness decreases to less than 25 ft (8 m). This suggests that to the north and downstream from the present hatchery site are the most favorable areas for unconfined ground-water development.

Upon completion of the present fish-hatchery wells, aquifer tests were made to determine the hydraulic characteristics of the aquifer. An analysis (J. B. Weeks, written commun., 1971) using the Theis image well method indicated that the two intake-thaw ponds act as a source of recharge water to the pumping wells. The transmissivity of the aquifer was calculated to be 5,750 ft^2/d (535 m^2/d), with a storage coefficient of 2 to 4 x 10^{-4}.

Additional cold water is needed at the fish hatchery during periods of low streamflow for reducing the temperature of the heated water from the powerplant. The four existing wells yield an insufficient amount of water to accomplish this task during periods of high power output. The additional water probably is available in the unconfined ground-water zone downstream from the hatchery (fig. 8) where saturated thickness becomes greater. However, aquifer tests of sufficient duration should be run in the existing well field in order to determine the effects of delayed yield from storage and induced surface-water infiltration. Aquifer tests should be made on wells within the downstream area to provide data for establishing a pumping schedule and for determining mutual drawdown interference. These aquifer tests would provide a better understanding of the total unconfined ground-water availability near the losing reaches of Ship Creek.

WATER AVAILABILITY AT THE ELMENDORF AIR FORCE BASE PROPOSED HATCHERY SITE

The powerplant on Elmendorf Air Force Base is above and to the north of the creek on the glacial outwash plain (fig. 2). The cooling pond for the powerplant is below on the creek flood plain, which at this point is contained by steep bluffs approximately 2,000 ft (610 m) apart. The water used by the powerplant for cooling is taken from Ship Creek via a dam and intake structure. The water is piped either directly to the powerplant or into the cooling pond (fig. 10). Warm water is returned to the creek below the dam at an outlet flume. The quantity of water flowing through this flume into the creek varies with the amount of power being produced by the powerplant and the amount of water in the stream available for use. Since the amount of water taken

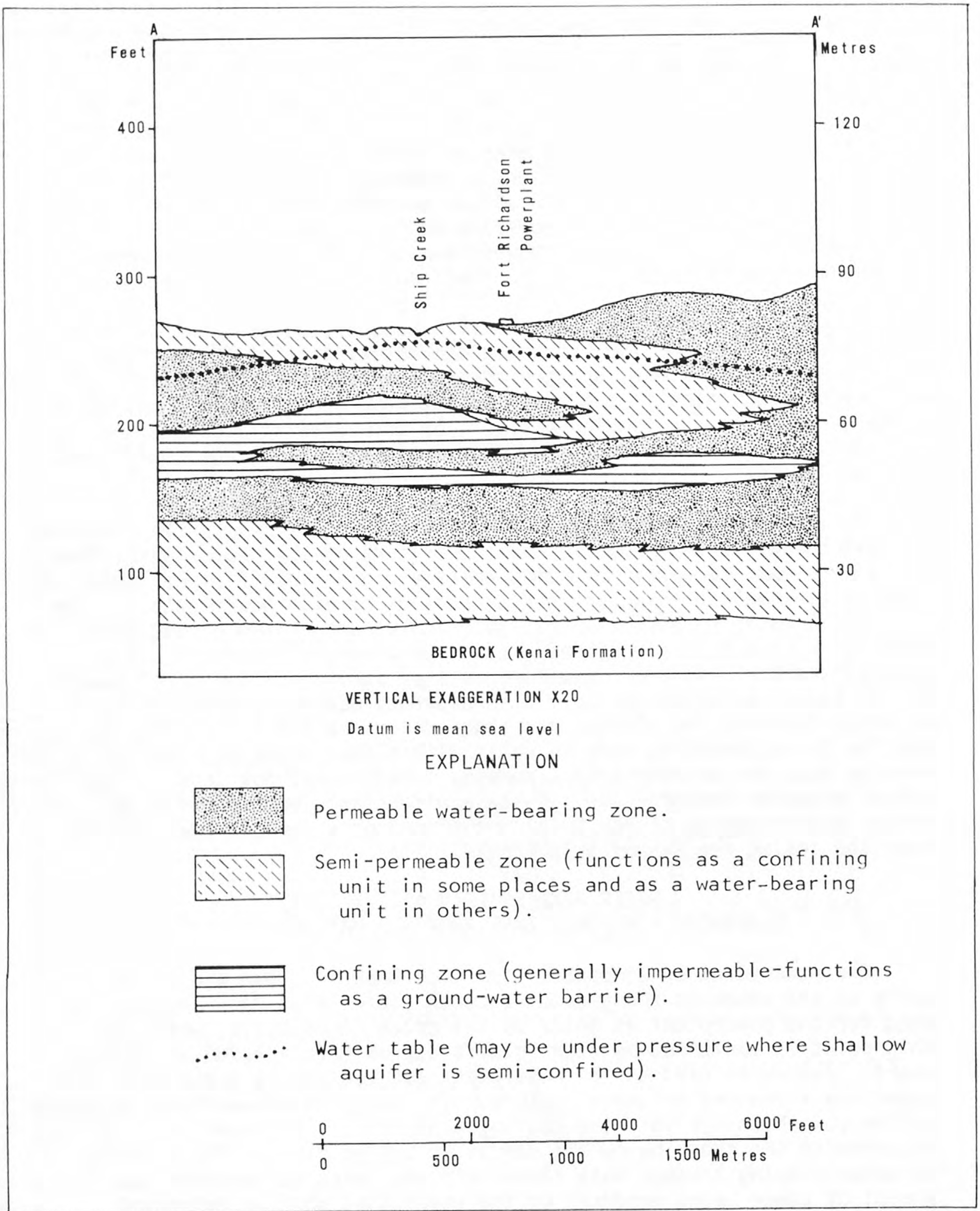
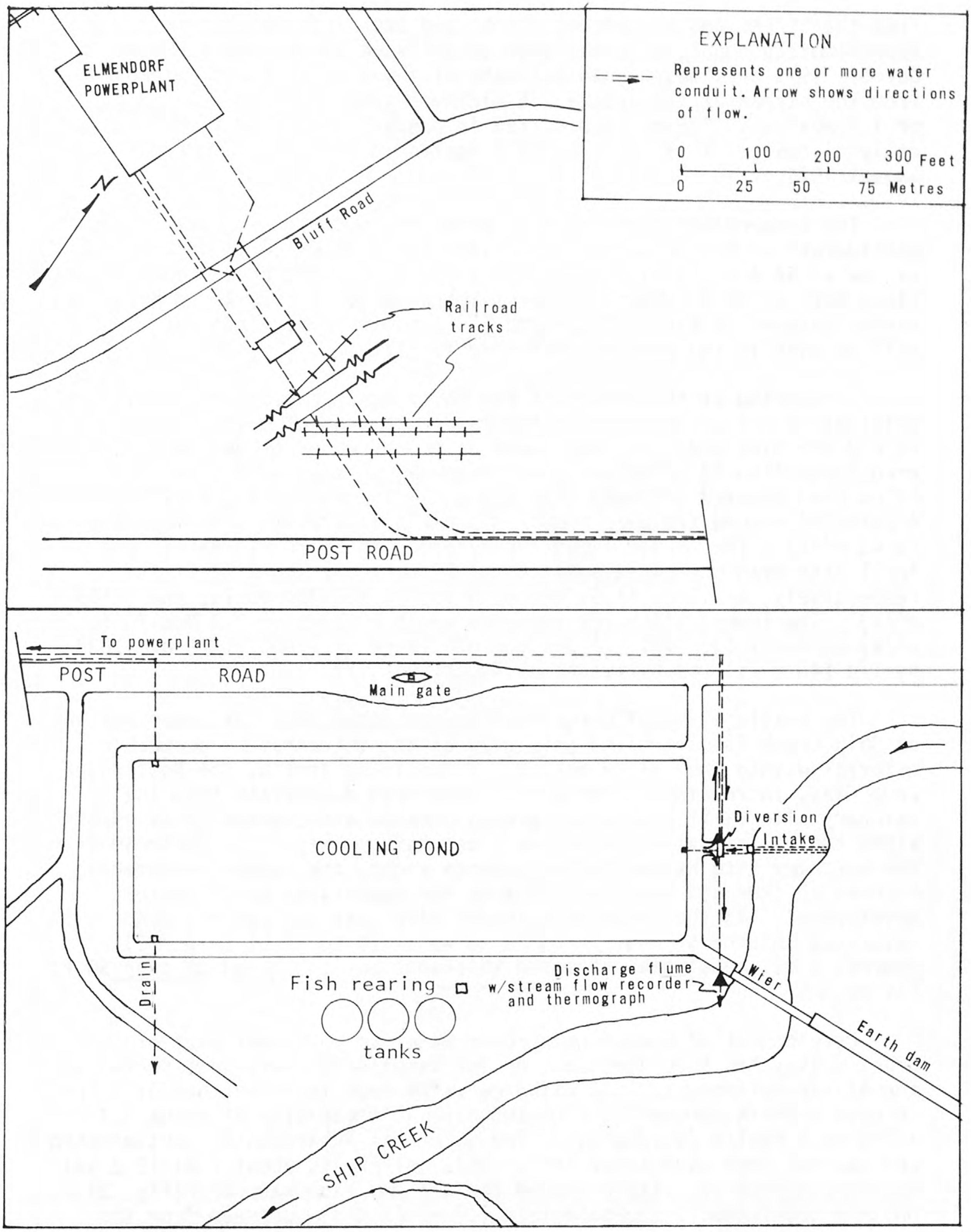


Figure 9. -- Schematic hydrogeologic cross section of the Ship Creek valley near the Fort Richardson powerplant.



Base from U.S. Army Corps of Engineers

Figure 10. -- Powerplant and cooling pond at Elmendorf Air Force Base.

from the stream and the amount discharged back into the stream are approximately equal, a stream gage established on the outlet flume in October 1973 provides a good estimate of the amount of water removed from the stream at the intake. A minimum daily discharge of 2.7 ft^3/s or 1.7 Mgal/d (0.076 m^3/s) occurred in January 1974, and a maximum daily discharge of 19 ft^3/s or 12.3 Mgal/d (0.54 m^3/s) occurred in August 1974.

The temperature of the water being returned to the creek varies considerably. Preliminary records indicate that water temperatures as low as 64.4°F (18°C) and as high as 89.6°F (32°C) have been recorded since October 1974. However, the temperature of this water generally ranges between 75 and 80°F (24 and 27°C). Warm water from the flume will be used in the proposed hatchery facility.

Streamflow at the Elmendorf Air Force Base proposed hatchery is a critical factor in determining the maximum amount of water available at any one time and thus the amount of ground water needed for cooling when streamflow is deficient. A stream-gaging station 0.9 mi (1.4 km) below the proposed hatchery site was established in October 1970. After 4 years of record the mean annual discharge is 122 ft^3/s or 78.8 Mgal/d (3.45 m^3/s). The lowest flows are recorded in February, March, and April with mean monthly discharges of 20.4, 18.5, and 20.1 ft^3/s, respectively, or 13.2, 11.9, and 13.0 Mgal/d (0.578, 0.524, and 0.569 m^3/s). The lowest discharge recorded was 5.8 ft^3/s or 3.8 Mgal/d (0.16 m^3/s) on April 14, 1971. A maximum discharge of 1,600 ft^3/s or 1,034 Mgal/d (45 m^3/s) was estimated on August 9, 1971.

The availability of unconfined ground water near the lower reaches of Ship Creek is controlled primarily by the thickness of permeable material within the valley bottom. A confining strata, the Bootlegger Cove Clay, increasingly limits this thickness downstream from the hatchery site as it approaches ground surface and eventually is exposed along the valley walls and in the creek bottom (fig. 2). Upstream from the hatchery site as the valley becomes wider, the permeable material becomes thicker and more advantageous for unconfined ground-water development. At the proposed hatchery site near the cooling pond saturated thickness ranges from 20 to 40 ft (6 to 12 m) (fig. 11), whereas a mile upstream saturated thickness has increased to over 50 ft (15 m).

Development of unconfined ground water in the lower part of Ship Creek valley has been limited. An infiltration gallery constructed by the Alaska Railroad in 1946 withdrew water from the creek bed alluvium through a 24-in (600-mm) corrugated pipe at a capacity of about 7.7 ft^3/s or 5 Mgal/d (0.22 m^3/s). The water was subsequently contaminated and has not been used since 1952. This gallery is about 2 mi (3.2 km) downstream from the site proposed for the new fish hatchery (fig. 3). Another development, approximately 1.5 mi (2.4 m) upstream from the

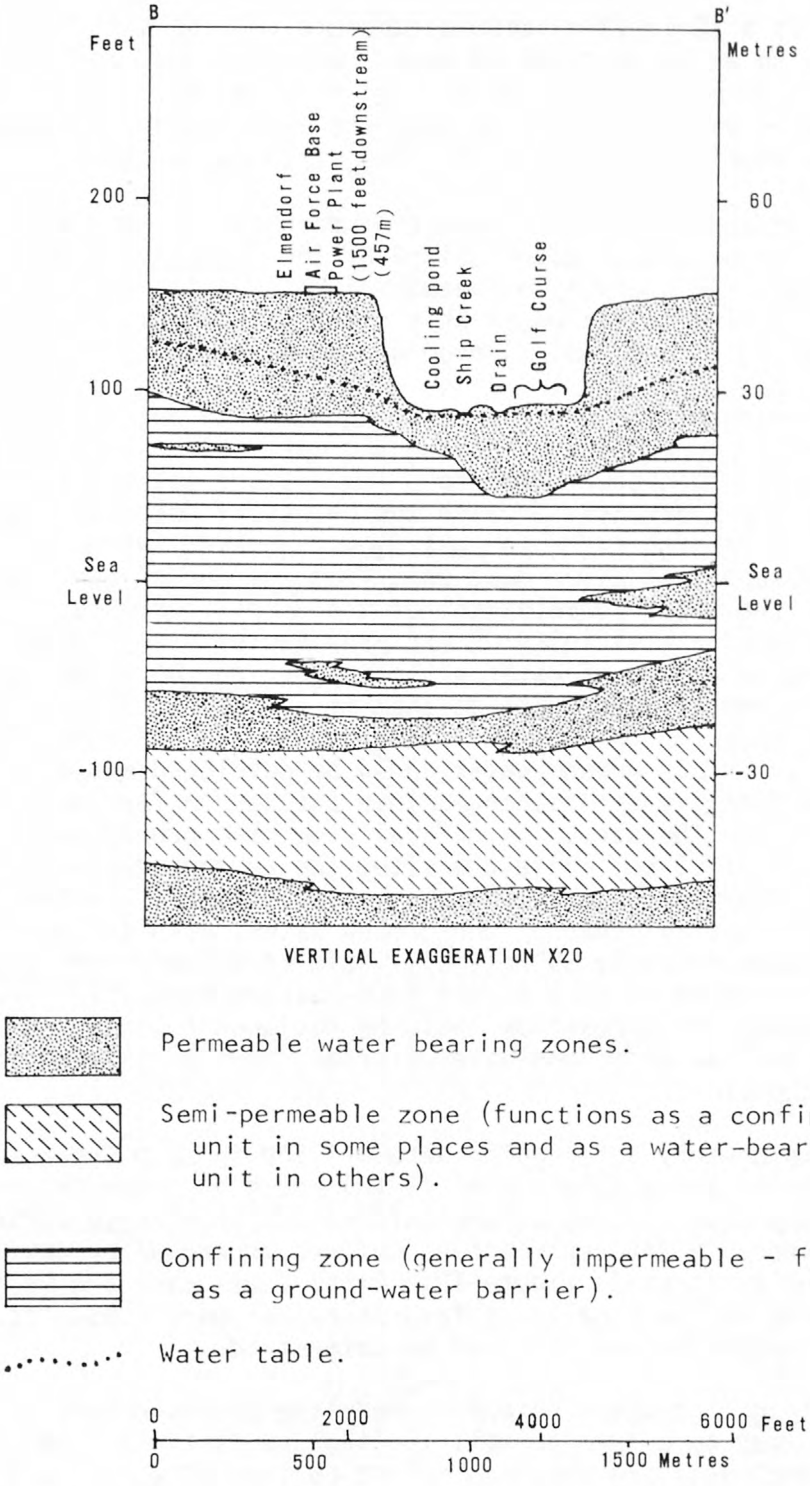


Figure 11. -- Hydrogeologic cross section of the Ship Creek valley near the Elmendorf Air Force Base powerplant.

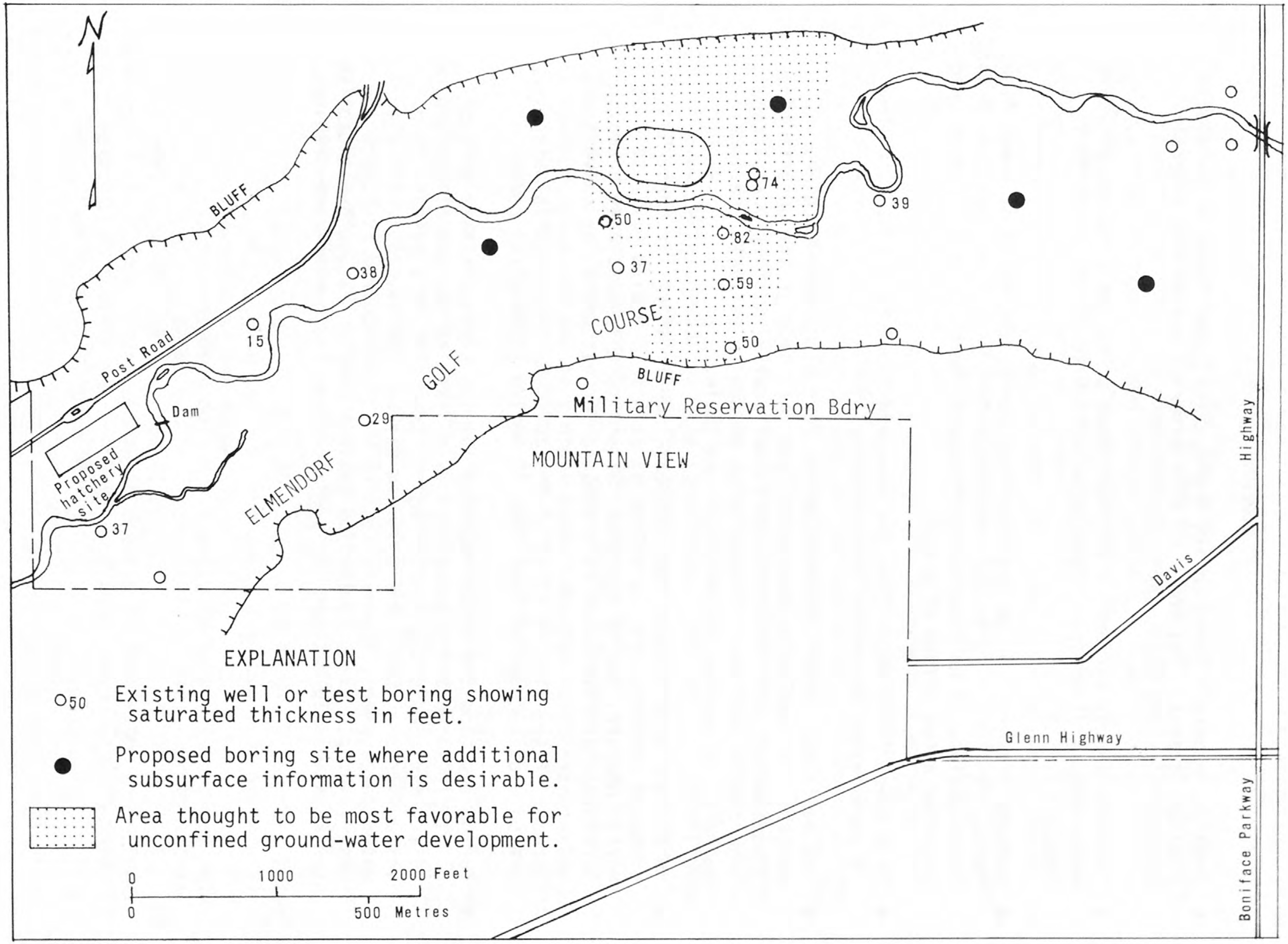
hatchery site, is a 10-ft (3-m) square concrete well on the north bank of the creek. The well, 16 ft (5 m) deep, has a yield of about 3 ft^3/s or 1.9 Mgal/d (0.08 m^3/s) with 4 ft (1.2 m) of drawdown. Water from both these sources is derived partly from the unconfined ground-water zone and partly from Ship Creek by inducing stream water to infiltrate.

Unconfined ground-water flow near the proposed hatchery site can be estimated from the amount of water gained by the creek downstream from the hatchery site. An analysis of seepage investigations has shown that from the hatchery site to the mouth Ship Creek gains from 8 to 12 ft^3/s or 5 to 8 Mgal/d (0.2 to 0.3 m^3/s) from ground-water sources.

Upon completion of the new fish-rearing facility an adequate supply of cold water will be needed for cooling the warm water from the Elmendorf Air Force Base powerplant to a temperature satisfactory for fish rearing. Ship Creek will provide the necessary cold water during periods of normal or higher-than-normal flow. However, when the creek is too low, the supply of water must come from the unconfined ground-water zone near the site. Development of the unconfined ground-water sources in the immediate vicinity of the proposed site will probably not yield the necessary amount of water without lowering the water table and changing the regimen of Ship Creek to that of a losing stream. However, more favorable areas for ground-water development are upstream from the proposed facility. This ground water could be developed and piped directly to the facility or discharged into the stream for low-flow augmentation. Since the stream is naturally gaining ground water for approximately 2 mi (3.2 km) above the site, the augmented flow would not infiltrate the streambed unless drawdown is very severe. Further, by conveyance in the natural channel the ground water, with an ambient temperature of approximately 39°F (4°C), would be allowed some cooling during winter before it is used at the fish-rearing facility. Galleries or wells for augmenting streamflow could be designed to intercept ground-water flow and to draw on ground-water storage, thus minimizing induced recharge from the creek.

Fifteen exploratory auger holes were drilled in Ship Creek valley in 1969. The holes are within a 2-mi (3-km) reach upstream from the proposed hatchery site. Based on the information from these borings, the area most probably favorable for unconfined ground-water development was selected and is shown in figure 12. Other areas east and west of the selected area may be equally as favorable, but more subsurface information is needed before this can be determined.

To evaluate ground-water potential near the proposed hatchery site more accurately and to determine well spacing and distance from the stream, additional data are required. Test borings (fig. 12) will be needed to determine aquifer thickness and depth to water. At least one aquifer test, including a production well and six observation wells, will be needed to verify estimated values of aquifer hydraulic characteristics and to determine accurately hydraulic interconnection between the stream and aquifer.



Base from U.S. Geological Survey

Figure 12. -- Lower Ship Creek valley near proposed fish-hatchery site, Elmendorf Air Force Base.

SUMMARY

- From the mountain front to its mouth, Ship Creek flows on permeable sand and gravel. Thickness of this material varies but generally decreases toward the creek mouth.

- The mean annual streamflow of Ship Creek below the city and military water-supply diversion at stream mile 10.5 is 141 ft^3/s or 91.1 Mgal/d (3.99 m^3/s).

- Average discharge below the diversion during the month of least flow, March, is 15.7 ft^3/s or 10.1 Mgal/d (0.44 m^3/s) at the mountain front. Short periods of no flow during February, March, and April have been reported above stream mile 4.9.

- Ship Creek loses water from the mountain front to the Davis Highway; it gains water below the Davis Highway.

- The additional water required at the Fort Richardson hatchery probably is available downstream from that site in the unconfined ground-water zone; however, additional aquifer testing downstream from the present well field will be needed to estimate the total quantity of shallow ground water available.

- Unconfined ground water passing near the Elmendorf Air Force Base proposed hatchery site is estimated as 5 to 8 Mgal/d (0.22 to 0.35 m^3/s); however, due to the small saturated thickness only a small percentage of this water is available for withdrawal by conventional well-construction methods. Mean monthly stream discharge during periods of low flow is 12 to 13 Mgal/d (0.53 to 0.57 m^3/s) with periodic discharges of less than 10 Mgal/d (0.44 m^3/s) common.

- During low flow the water required for the Elmendorf site will be difficult to obtain without seriously lowering the unconfined ground-water level and changing the regimen from that of a gaining to a losing stream. Locations upstream may be more favorable for ground-water development; however, testing will be required to locate the most favorable areas, determine optimum pumping rates, and establish the relationship between the surface-water and ground-water regimes.

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