Overview of Environmental and Hydrogeologic Conditions at King Salmon, Alaska

By Christopher F. Waythomas

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CONTENTS

FIGURES

TABLES

CONVERSION FACTORS AND ABBREVIATED WATER-QUALITY UNITS

Multiply	By	To obtain
millimeter (mm)	0.03937	inch
centimeter (cm)	0.3937	inch
meter (m)	3.281	foot
kilometer (km)	0.6214	mile
square kilometer (km^2)	0.3861	square mile
centimeter per second (cm/s)	0.03281	foot per second
liter per second (L/s)	15.85	gallon per minute
liter per day (L/d)	0.2642	gallon per day
cubic meter per second (m^3/s)	35.31	cubic foot per second
degree Celsius (°C)	°F = 1.8 x °C + 32	degree Fahrenheit (°F)

Sea level:

In this report "sea level" refers to the National Geodetic Vertical Datum of 1929--a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

Abbreviated water-quality units in this report:

mg/L, milligram per liter
µg/L, microgram per liter
µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius

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Abstract

The Federal Aviation Administration is conducting preliminary environmental assessments at most of its present or former facilities in Alaska. Information about environmental conditions at King Salmon, Alaska are presented in this report. This report gives an overview of the geology, hydrology, and climate of the King Salmon area and describes general geohydrologic conditions. A thick alluvial aquifer underlies King Salmon and both ground water and surface water are plentiful in the area.

INTRODUCTION

The Federal Aviation Administration (FAA) owns and (or) operates airway support, and navigational facilities throughout Alaska. At many of these sites, fuels and potentially hazardous materials such as solvents, polychlorinated biphenyls, and pesticides may have been used or disposed of. To determine if environmentally hazardous materials have been spilled or disposed of at the sites, the FAA is conducting environmental studies mandated under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund Act") and the Resource Conservation and Recovery Act (RCRA). To complete these environmental studies, the FAA requires information on the hydrology and geology of areas surrounding the sites. This report, the product of compilation, review, and summary of existing hydrologic and geologic data by the U.S. Geological Survey in cooperation with the FAA, describes general ground-water conditions, flood hazards, and other environmental conditions for the FAA facility and nearby areas at King Salmon, Alaska (fig. 1).

A variety of environmental studies related to hydrocarbon contamination of surficial deposits and ground water at the King Salmon Air Force Station have been conducted by private consultants (e.g., Science Applications International, 1993). Although little, if any, of this work is published, many of the reports contain useful information about ground-water conditions and commonly include well logs and water-quality data. Because these reports are difficult to obtain, their utility as a source of information about environmental conditions in the area is somewhat limited.

FAA FACILITIES

The FAA facility at King Salmon is primarily an air navigation station located at the King Salmon Airport. Some of the facilities owned by the FAA include the Outer Marker (OM), the Very High Frequency Omidirectional Range Tactical Air Navigation (VORTAC), the Approach Light System (ALS), an abandoned Remote Center Air/Ground Communications (RCAG) facility, the

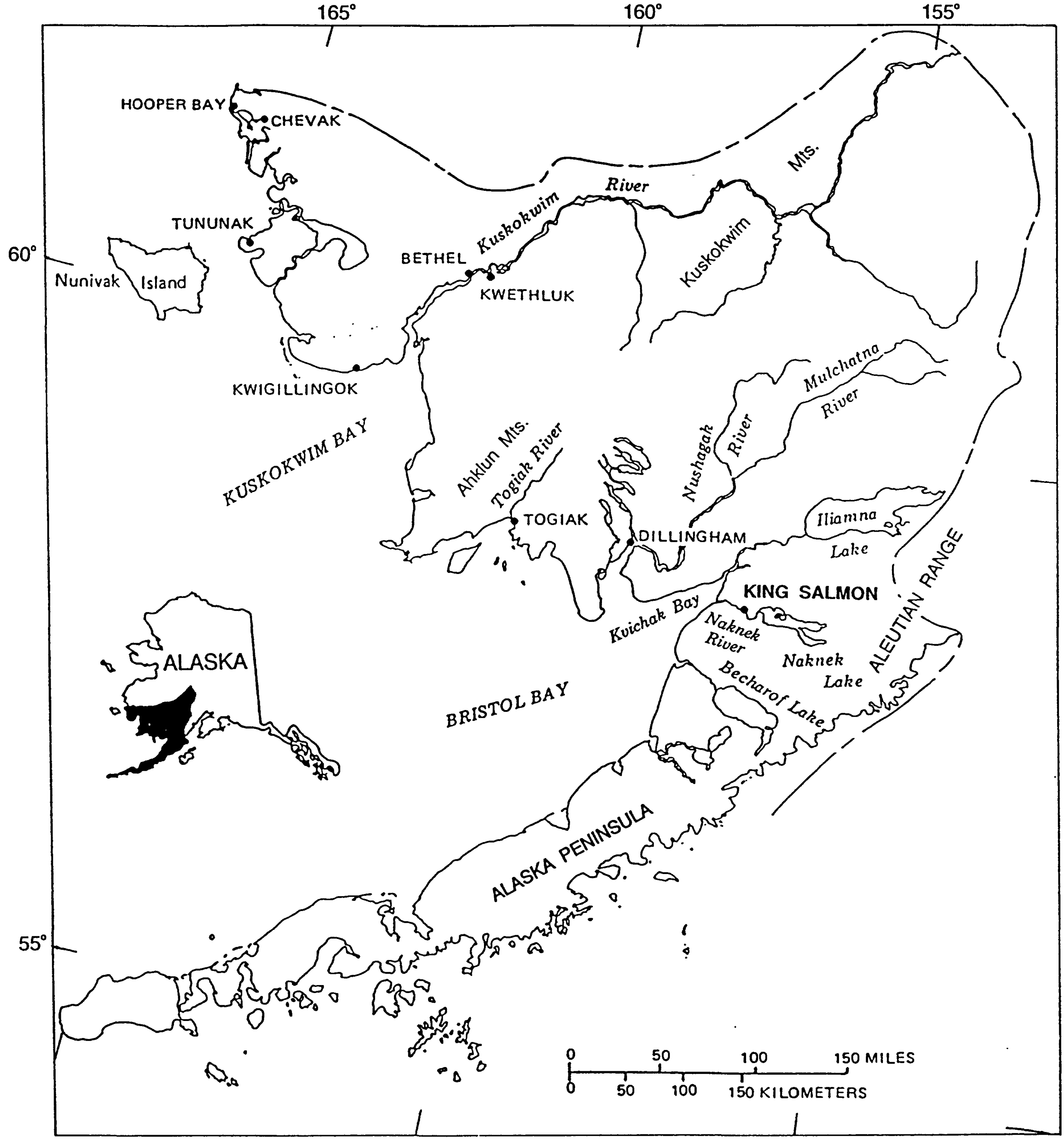

Figure 1. Location of King Salmon.

Glide Slope Indicator/Runway Visual Range facility, the Localizer, the ALS Regulator, and the Quarters Area/Flight Service Station (FSS) (fig. 2). Most of these facilities are located in the vicinity of the King Salmon Airport except the VORTAC and OM facilities, which are located about 8 km northwest of the airport (fig. 2). A detailed description of the FAA facilities at King Salmon is given in a report by Ecology and Environment, Inc. (1992).

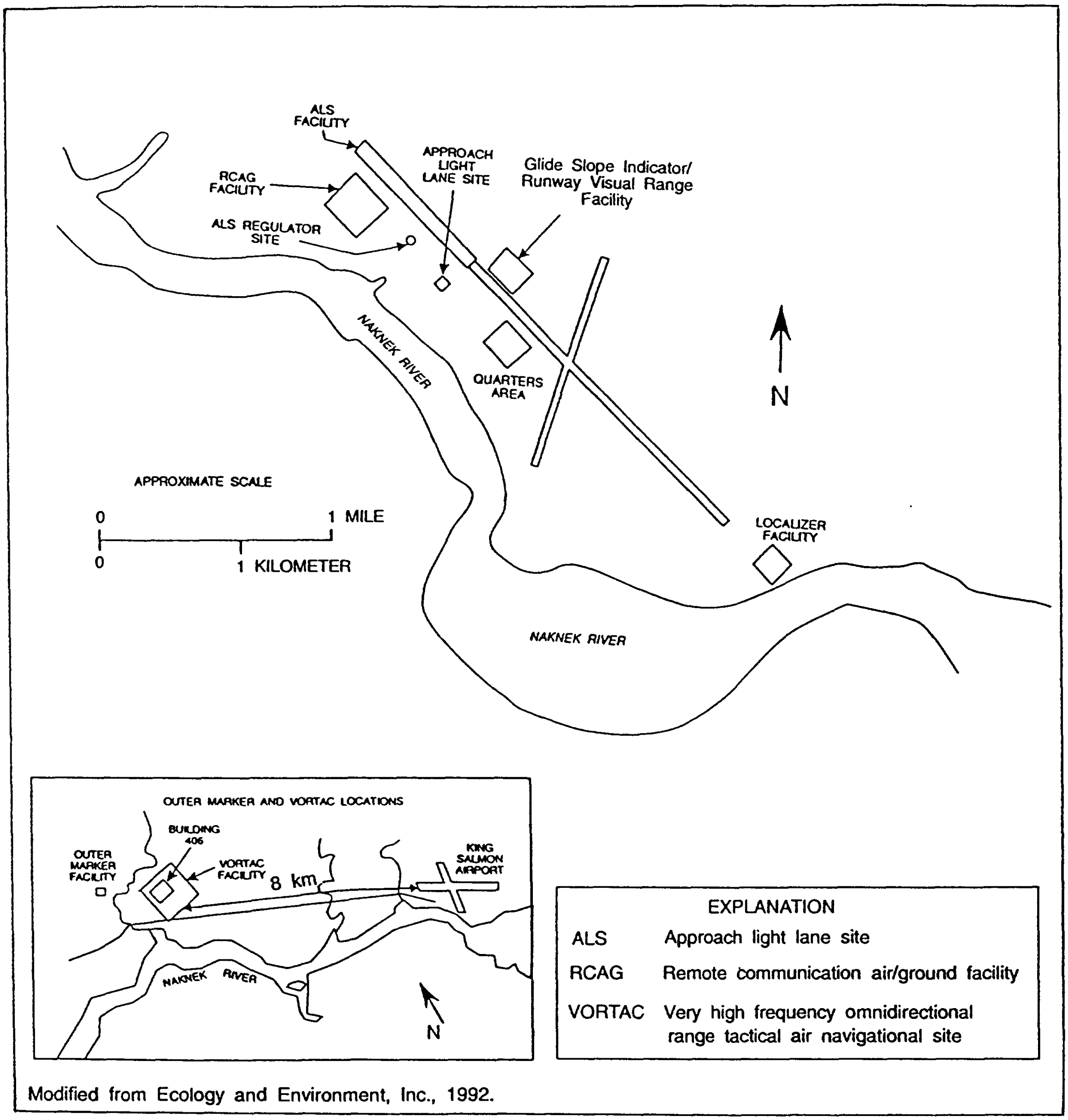

Figure 2. Location of Federal Aviation Administration facilities at King Salmon.

PHYSICAL SETTING

The FAA facilities at King Salmon are located on the northern end of the Alaska Peninsula (latitude 58°41' N., longitude 156°39' W.) about 26 km east of Kvichak Bay and about 14 km west of Naknek Lake (fig. 1). King Salmon is situated in the Nushagak-Bristol Bay lowland, a broad, low-relief piedmont characterized by arcuate belts of morainal topography and numerous small lakes and bogs (Wahrhaftig, 1965). The region is underlain by several tens to perhaps hundreds of meters of unconsolidated glacial, fluvial, and marine sediment, most of which was deposited during Quaternary glaciations of the area (Muller, 1952, 1953; Detterman, 1986).

The Naknek River is the principal drainage in the area (fig. 1). It flows westward from the outlet of Naknek Lake for approximately 35 km and empties into Kvichak Bay (fig. 1). The Naknek River is influenced by tides and the lower part of the river is an estuary that extends at least 10 km upriver. Numerous small creeks enter the Naknek River between Naknek Lake and its mouth.

Shallow permafrost is uncommon in the King Salmon area, but it may be present in low-lying areas with silty substrates and thick tundra vegetation (Muller, 1953; Ferrians, 1965). Deep permafrost has been penetrated by wells in the Bristol Bay region at about 13 m depth, but most of this permafrost is probably relict permafrost that formed during cold periods of the Pleistocene epoch (Muller, 1953).

Socioeconomic Description

Approximately 700 people live in the greater King Salmon area (U.S. Census Bureau, 1991). The community has become an important regional center for government, transportation, and commercial fishing. The King Salmon Air Force Station is located in King Salmon and it shares a large runway with commercial and charter airlines. Several two-lane roads and bridges traverse the area and connect King Salmon with the village of Naknek on the Kvichak Bay coast (fig. 1). The town of King Salmon consists of mostly single-storied structures that serve as private residences, businesses, or support facilities for the Air Force and other Federal and State agencies.

Climate

The King Salmon area has a climate that is transitional between maritime and continental (Hartman and Johnson, 1984). The region is strongly influenced by cyclonic storms that originate in the Aleutians (Selkregg, 1976; Moritz, 1979) and the region experiences cool, cloudy, wet summers, and moderately cold winters (National Oceanic and Atmospheric Administration, 1980). For the period 1955 to 1984, the mean annual temperature at the King Salmon airport was 5 °C and the mean annual precipitation was about 487 mm (table 1). Average annual snowfall is about 1,110 mm.

The modern wind regime at King Salmon is characterized by southeasterly and easterly winter winds (October through March) that are associated with high pressure over northern Alaska and low pressure over the southern Bering Sea or Gulf of Alaska (Keegan, 1958; Moritz, 1979). Summer winds (June through September) are primarily from the south and southeast, and usually result

Table 1. Mean monthly temperature, precipitation, and snowfall for the period 1955-84, King Salmon

[Modified from Leslie (1986); °C, degree Celsius; mm, millimeter]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Temperature (°C)													
Mean maximum	-6.0	-5.1	-1.3	3.9	10.7	15.0	17.1	16.3	12.5	4.3	-1.1	-6.0	5.0
	(Record maximum, 29.4 °C, July 1971)												
Mean minimum	-14.2	-14.1	-10.6	-4.8	1.0	5.2	7.9	7.9	4.1	-3.8	-9.0	-14.4	-3.7
	(Record minimum, -43 °C, January 1975)												
Mean	-9.9	-9.6	-5.8	-0.5	5.7	10.1	12.5	12.1	8.3	0.3	-5.1	-10.2	0.6
Precipitation (mm of moisture)	26.9	21.6	27.9	27.9	31.7	39.9	53.8	74.9	68.6	49.3	33.8	30.5	487
Snowfall (mm)	180.3	167.6	182.9	124.5	22.9	0.0	0.0	0.0	2.5	78.7	144.8	203.2	1,110

from a blocking ridge of high pressure that extends into Alaska from the southeast and cyclonic storm activity over interior Alaska (Reed and Kunkel, 1960; Streten, 1974; Moritz, 1979). Late winter and early spring winds (February through April) are primarily from the north and northeast and also result from high pressure over northern Alaska and low pressure over the Gulf of Alaska (Moritz, 1979).

Vegetation

The lowlands bordering Kvichak Bay are covered by mesic to wet shrub tundra that consists of alder, willow, shrub birch, and sedge tussocks (Viereck and Little, 1972; Selkregg, 1976). Sphagnum bogs and sedge fens also are common in the lowlands. The King Salmon area lies south of the southwestern limit of the boreal forest. However, localized stands of closed-canopy spruce-hardwood forest are present in well-drained sites along the eastern end of Naknek Lake (Viereck and Little, 1972) and on well-drained glacial deposits east of King Salmon (Selkregg, 1976).

BEDROCK GEOLOGY

King Salmon is situated in a lowland that is bounded by the northeastern Aleutian Range on the east, the southern Kuskokwim Mountains on the north, and the Ahklun Mountains on the west (fig. 1). Bedrock crops out mainly in the vicinity of Naknek Lake, where deep glacial erosion has stripped surficial deposits from the underlying bedrock. Scattered outcrops northwest of Naknek Lake and northeast of King Salmon consist of plugs, dikes, and lava flows of basaltic composition and subordinate lava flows and breccia of dacitic to andesitic composition (Church and others, 1989). South of Naknek Lake, a few outcrops consist of lava flows, breccias, and lahars, interbedded with volcaniclastic sandstone, conglomerate, and shale (Church and others, 1989).

Beyond the western perimeter of Naknek Lake, surficial deposits are sufficiently thick to obscure bedrock. At King Salmon, water wells drilled to 65 m depth did not reach bedrock, and bedrock is not exposed in bluffs along the Naknek River at King Salmon (Muller, 1952).

SURFICIAL DEPOSITS

The King Salmon area is underlain by a thick sequence of unconsolidated sediment that was deposited mainly during Quaternary glaciation of the Alaska Peninsula (fig. 3; Muller, 1952; Detterman, 1986; Riehle and Detterman, 1994). Moraines of the last (Brooks Lake glaciation of Muller, 1952; >10,000 yr. B.P.[1], <20,000 yr. B.P.) and penultimate (Mak Hill glaciation of Muller, 1952; >20,000 yr. B.P.) glaciations are preserved in the King Salmon area (fig. 3). During the Mak Hill glaciation, a large lobe of glacier ice extended down the Naknek River valley to within a few kilometers of the present coastline of Kvichak Bay. Till and other glacial sediments were deposited by this advance and are exposed in bluffs along the Naknek River downstream from King Salmon (Muller, 1952).

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[1]Before present

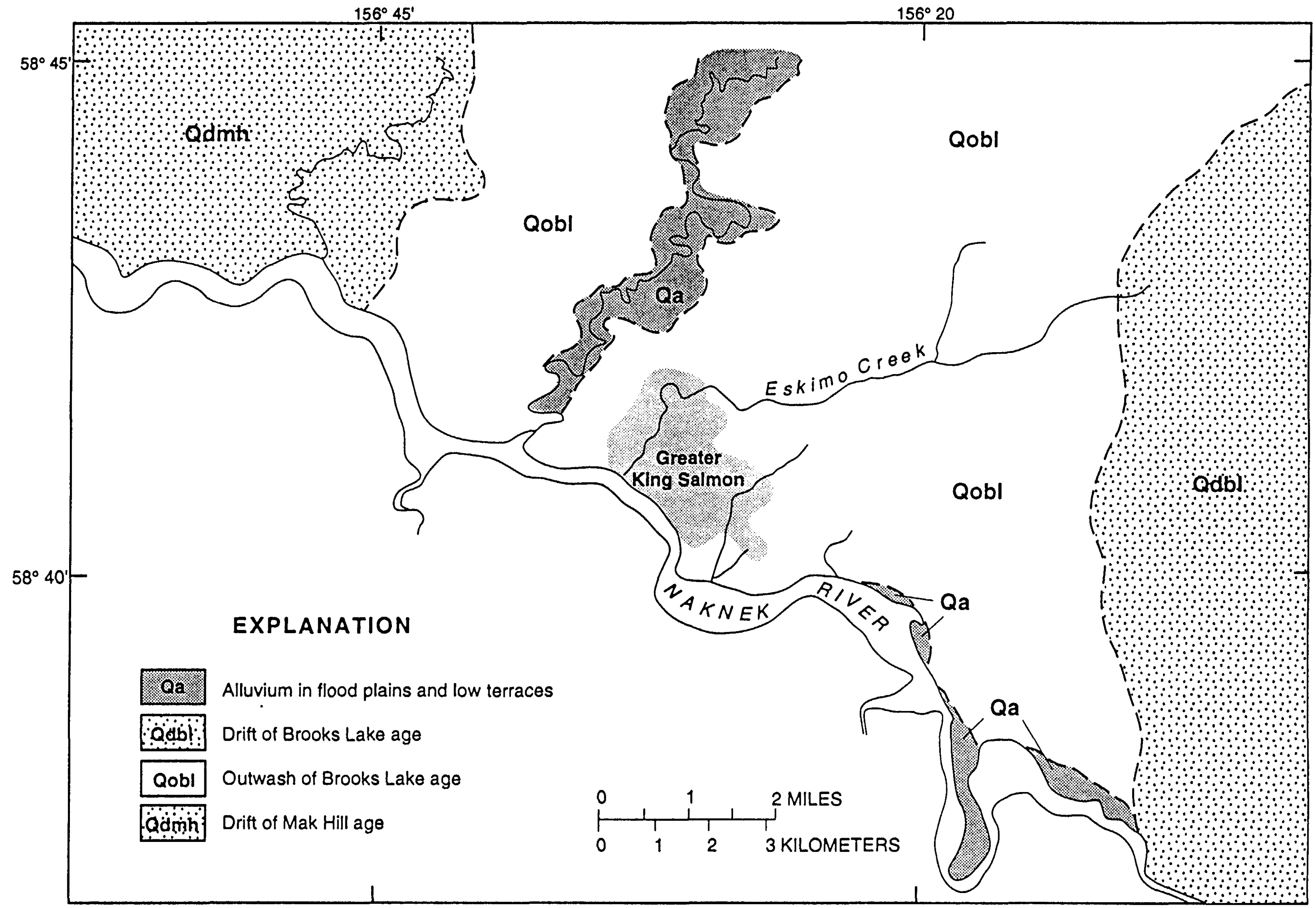

Figure 3. Generalized surficial deposits in the King Salmon area [Names for glacial deposits from Detterman (1986).]

The village of King Salmon is built on outwash deposits of Brooks Lake age (Muller, 1952; Detterman, 1986). The outwash consists of well-sorted sand, silty sand, and minor amounts of gravel that were deposited by glacial meltwater when glaciers on the Alaska Peninsula were at their last glacial maximum position (fig. 3; Muller, 1952; Detterman, 1986). In general, the thickness and particle size of the outwash decreases in the downstream direction and most of the shallow subsurface sediment at King Salmon is sand (Muller, 1952). Drillers' logs described by Muller (1952, p. 59) and Feulner (1963) indicate that deposits of sand, sandy gravel, and gravel are up to 66 m thick in the King Salmon area.

An arcuate belt of hummocky topography with numerous closed depressions and small lakes is a prominent geomorphic feature approximately 6.5 km east of King Salmon. This feature is the Brooks Lake moraine and it records the maximum extent of the glacier that occupied the Naknek River valley during the last (Brooks Lake) glaciation (fig. 3; Muller, 1952).

An older, less prominent moraine is present downstream from King Salmon (fig. 3). This moraine was deposited during the Mak Hill glaciation (Muller, 1952) and records the advance of a glacier down the Naknek River valley to a point about 10 km west of King Salmon. Drift deposited by this advance consists of till and minor amounts of glacial-fluvial sand and gravel. Deposits of Mak Hill age are present in the subsurface beneath King Salmon and are stratigraphically below outwash of Brooks Lake age. The FAA facilities near the King Salmon Airport are situated on outwash gravel deposits of Brooks Lake age (fig. 3; Riehle and Detterman, 1994).

HYDROLOGY

Surface water is a major component of the physical environment of the King Salmon area. The Naknek River is a major tributary to Kvichak Bay and is the outlet stream for Naknek Lake (fig. 1). The region contains numerous fresh-water lakes, streams, and bogs. Moist tundra vegetation is ubiquitous throughout the area indicating abundant water at or near the ground surface. Because the area contains a significant number of surface-water bodies and is underlain by unconsolidated sediment, mainly sand and gravel, ground water also is an important water resource.

Surface Water

Despite an abundance of lakes and streams in the King Salmon area, hydrologic data are limited. The U.S. Geological Survey operated a gaging station on Eskimo Creek at King Salmon (USGS gaging station No. 15297900) (fig. 4) and partial streamflow records were obtained from 1965 to 1967 and from 1969 to 1973. A continuously recording gage was installed in 1973 and water stage was measured from 1973 to 1976 and from 1977 to 1984. During this approximately 10-year period, the average discharge of Eskimo Creek was 0.384 m^3/s (U.S. Geological Survey, 1985). The maximum discharge during this same period was 6.81 m^3/s in June 1967 and the minimum daily discharge was about 0.045 m^3/s from January 13 to 17, 1980. The flood discharge for the 100-year recurrence interval flood at the gage on Eskimo Creek is about 15.8 m^3/s (Jones and Fahl, 1994). Water-quality data for Eskimo Creek were collected in 1971 and 1972 (table 2).

The Naknek River is influenced by tides and brackish water that extend upstream at least to King Salmon. Flow in the Naknek River is related to the discharge of water from Naknek Lake. This large lake probably dampens flood peaks because it occupies a significant portion of the Naknek River drainage basin. Thus, severe flooding at King Salmon from Naknek Lake outflow probably is rare. However, if high outflow from the lake coincides with a high tide or storm surge, areas of backwater and flooding may occur at King Salmon.

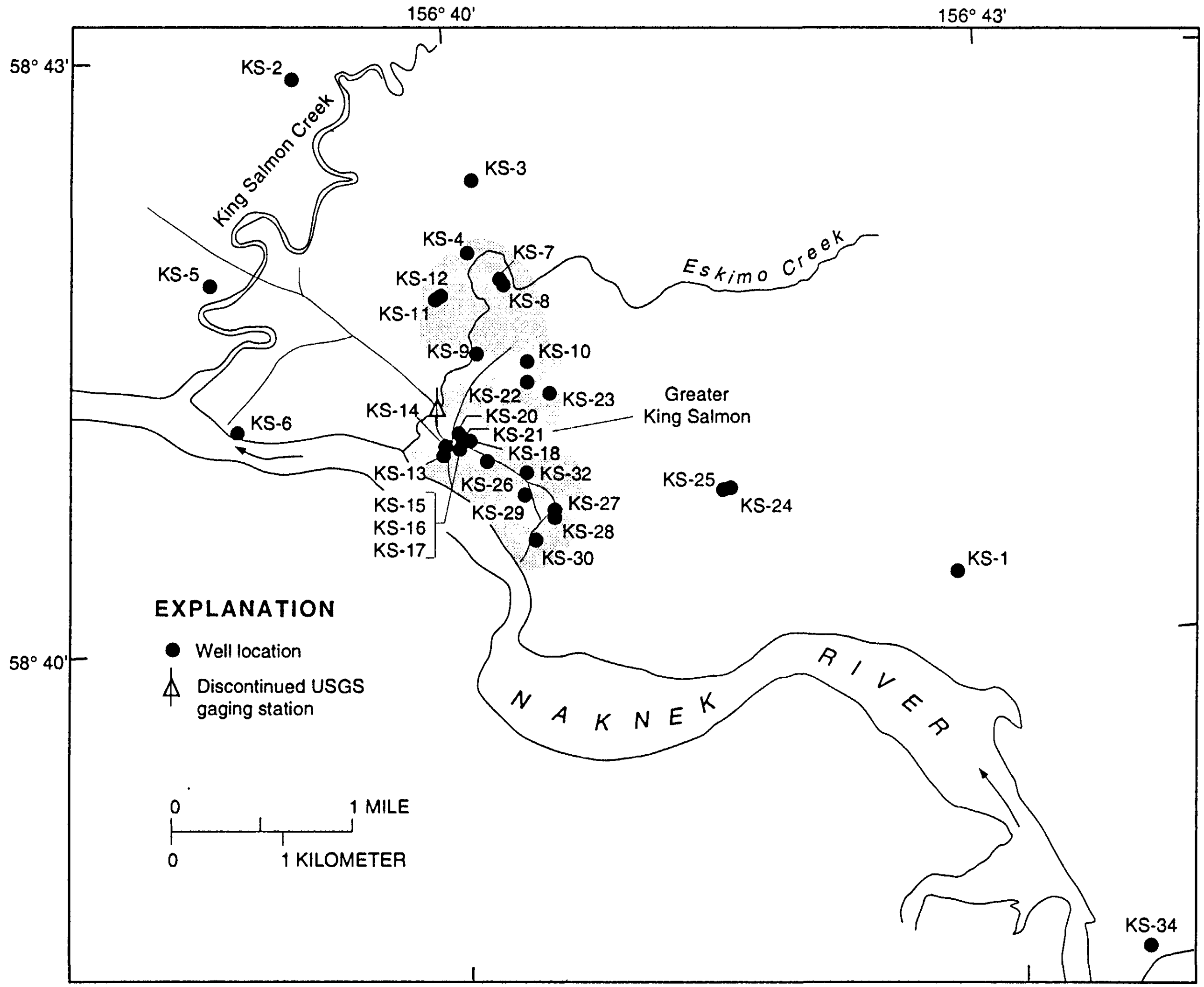

Figure 4. Location of selected wells in the King Salmon area.

Table 2. Selected chemical analyses of water from Eskimo Creek at King Salmon

[Data in milligrams per liter unless otherwise indicated; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; µg/L, micrograms per liter; --, not reported]

Constituent or property	Date water sample collected		
	July 7, 1971	Sept. 17, 1971	Sept. 25, 1972
Specific conductance (µS/cm at 25 °C)	95	78	80
pH (units)	6.9	7.0	6.9
Temperature (°C)	7.5	6.5	6.0
Color (platinum-cobalt units)	5	40	30
Hardness as $CaCO_3$ (Ca, Mg)	34	28	28
Noncarbonate hardness	0	0	0
Calcium (Ca)	8.2	6.6	6.8
Magnesium (Mg)	3.2	2.7	2.7
Sodium (Na)	6.7	5.7	6.3
Potassium (K)	1.1	.7	.6
Bicarbonate (HCO_3)	42	36	39
Carbonate (CO_3)	--	--	0
Sulfate (SO_4)	6.7	3.4	2.2
Chloride (Cl)	4.2	4.2	4.8
Fluoride (Fl)	.1	.1	.1
Silica (SiO_2)	14	14	24
Dissolved solids	66	57	68
Nitrate (NO_3)	.3	.8	.07
Iron, total (Fe) (µg/L)	80	--	
Iron, dissolved (Fe) (µg/L)	--	690	680
Manganese (Mn) (µg/L)	--	--	80

Ground Water

Glacial-fluvial sand and gravel deposits (fig. 5) that underlie King Salmon are the primary aquifer(s) in the area. Although as many as 37 wells were drilled in the King Salmon area (U.S. Geological Survey, unpub. data; fig. 4; table 3), water levels were measured only when the wells were drilled and thus are inappropriate for constructing a map of the ground-water surface. However, the surface elevations of small lakes north of King Salmon decrease toward the Naknek River indicating that the direction of ground-water flow is to the south toward the river. Unpublished data from reports about ground-water conditions at the King Salmon Air Force Station also indicate that ground-water flow is generally toward the Naknek River (Science Applications International, 1993).

Data from wells drilled prior to about 1963 indicate that ground water at that time was about 10 m below the land surface (Feulner, 1963). The deepest well in the area is about 95 m; drillers' logs from this well indicate that water is present between about 20 and 70 m (Feulner, 1963). Well logs for wells drilled more recently do not indicate the depth at which water was reached, but presumably ground water exists between about 10 and 70 m depth. Many well logs indicate that clay is present in the subsurface. This suggests that several aquifers may exist depending on the thickness and extent of the clay beds.

Information about wells in the King Salmon area (some of which are owned by the FAA) is stored in a U.S. Geological Survey database called Ground Water Site Inventory (GWSI). The availability of water-quality data for samples of ground water obtained from wells at King Salmon is shown in table 3. Although these data were not collected systematically, they may indicate some general long-term trends in water quality for the King Salmon area. Water-quality data for two wells (KS-11 and KS-22) are given in table 4. Of the water-quality data for King Salmon in the USGS GWSI database, these two wells have the longest and most comparable records.

The information briefly described above indicates that the general direction of ground-water flow near the FAA facilities is toward the Naknek River. To substantiate this hypothesis would require additional data on the water level in wells from the area and estimates of the hydraulic conductivity of the primary aquifers.

Drinking Water Sources and Water Use

Ground water is the primary source of drinking water in the King Salmon area, including the FAA facilities. Potable ground water appears to be plentiful below about 10 m depth and most domestic wells are at least this deep. Within an 8-km radius of King Salmon, there are more than 100 fresh-water lakes, many of which could be used as a source of drinking water. Although the Naknek River is fed by a fresh-water lake, it is not a suitable source of potable water because tidal effects push brackish water upstream at least as far as King Salmon. The presence of clay-rich beds described in drillers' logs from the King Salmon area indicate that several aquifers may be present in the surficial deposits that underlie the area. Although unsubstantiated, deeper aquifers could be utilized as an alternative source of drinking water. Statewide estimates of average water use (Solley, 1993) indicate that in King Salmon during 1990, about 604,000 L/d were used for commercial purposes and about 132,000 L/d were used domestically.

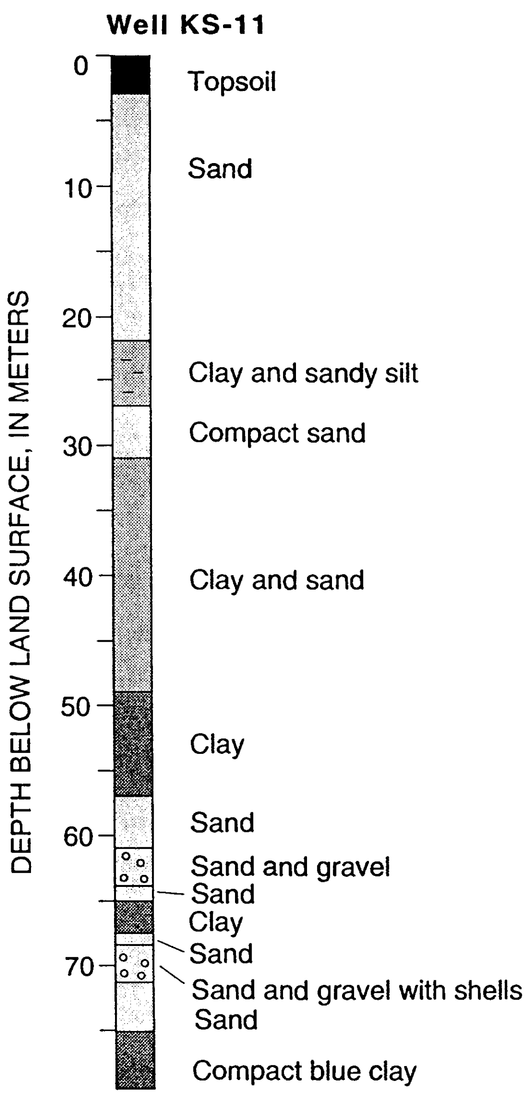

Figure 5. Drillers' logs for wells KS-11 and KS-22. (Locations of wells are shown in figure 4.)

Table 3. Information on selected water wells in the King Salmon area

Well No. (fig. 4)	Local well number	Location		Well depth (meters)	USGS data available	
		Latitude	Longitude		Well log	Water quality
KS-1	SC017044219CBDC1	58°40'19"	156°35'27"	27.6	Yes	No
KS-2	SC01704510DCCC1	58°42'42"	156°39'54"	18.3	Yes	No
KS-3	SC01704514BDDD1	58°42'16"	156°39'54"	33.9	Yes	No
KS-4	SC01704514CDDD1	58°41'50"	156°39'51"	6.0	No	No
KS-5	SC01704522BBBC1	58°41"44"	156°42'16"	24.3	Yes	No
KS-6	SC01704522CCAB1	58°41'08"	156°42'03"	66.0	Yes	Yes
KS-7	SC01704523ABAC1	58°41'43"	156°39'32"	32.4	Yes	No
KS-8	SC01704523ABAC2	58°41'43"	156°39'32"	17.1	Yes	No
KS-9	SC01704523ACCB1	58°41'28"	156°39'33"	42.3	Yes	Yes
KS-10	SC01704523ADCC1	58°41'26"	156°39'17"	51.3	Yes	No
KS-11	SC01704523BACD1	58°41'40"	156°40'05"	68.4	Yes	Yes
KS-12	SC01704523BACD2	58°41'39"	156°40'03"	71.1	Yes	Yes
KS-13	SC01704523CDCA1	58°41'03"	156°40"06"	45.9	No	No
KS-14	SC01704523CDCB1	58°41'01"	156°40'11"	32.4	Yes	Yes
KS-15	SC01704523CDCB2	58°41'01"	156°40'11"	29.1	Yes	No
KS-16	SC01704523CDCB3	58°41'03"	156°40'11"	29.4	No	Yes
KS-17	SC01704523CDCD1	58°40'57"	156°40'10"	18.0	No	No
KS-18	SC01704523CDDC1	58°40'58"	156°39'59"	28.8	No	No
KS-19	SC01704523CDDC2	58°40'59"	156°39'59"	51.6	No	No
KS-20	SC01704523CDDD1	58°40'58"	156°39'51"	28.5	No	Yes
KS-21	SC01704523CDDD2	58°40'56"	156°39'52"	42.3	Yes	No
KS-22	SC01704523DABB1	58°41'21"	156°39'19"	29.1	Yes	Yes
KS-23	SC01704523DADB1	58°41'13"	156°39'09"	33.9	Yes	Yes
KS-24	SC01704525BBDC1	58°40'46"	156°38'42"	68.7	Yes	Yes
KS-25	SC01704525BBDC2	58°40'46"	156°38'41"	18.0	No	No
KS-26	SC01704526ABBB1	58°40'53"	156°39'45"	18.4	Yes	No
KS-27	SC01704526ADAC1	58°40'40"	156°39'11"	34.2	Yes	No
KS-28	SC01704526ADAC2	58°40'40"	156°39'11"	70.8	Yes	Yes
KS-29	SC01704526ADBA1	58°40'42"	156°39'13"	45.6	Yes	No
KS-30	SC01704526ADCB1	58°40'36"	156°39'20"	27.3	Yes	No
KS-31	SC01704526BABB1	58°40'56"	156°40'10"	25.5	No	Yes
KS-32	SC01704526BBAB1	58°40'55"	156°40'10"	17.4	Yes	No
KS-33	SC01704604BBBB1	58°44'22"	156°53'47"	26.1	Yes	No
KS-34	SC01804404CCAC1	58°38'28"	156°33'46"	50.1	Yes	Yes
KS-35	SC01704523ADCC2	58°41'26"	156°39'17"	19.5	No	No
KS-36	SC01704523BBAB1	58°41'46"	156°40'22"	41.1	Yes	Yes
KS-37	SC01704526ADBA2	58°40'42"	156°39'13"	--	Yes	No

Table 4. Selected chemical analyses of water from wells KS-11 and KS-22, King Salmon

[Data in milligrams per liter unless otherwise indicated; μS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius; --, not reported]

Constituent or property	Well KS-11 Date water sample collected			Well KS-22 Date water sample collected		
	Sept. 15, 1955	April 7, 1965	May 5, 1972	Sept. 14, 1955	April 7, 1965	May 5, 1972
Specific conductance (μS/cm at 25 °C)	128	319	298	157	123	119
pH (units)	7.5	8.1	8.3	7.9	7.6	7.4
Hardness as $CaCO_3$ (Ca, Mg)	47	26	16	46	50	52
Noncarbonate hardness	0	0	0	0	1	5
Calcium (Ca)	8.3	5.6	3.8	8.3	8.8	12
Magnesium (Mg)	6.4	2.9	1.6	6.2	6.8	5.4
Sodium (Na)	6.8	70	60	15	5.9	5.4
Potassium (K)	3.5	7.8	5.1	4.5	5.1	2.9
Bicarbonate (HCO_3)	70	210	170	90	60	56
Sulfate (SO_4)	4.5	3.4	2.6	3	13	12
Chloride (Cl)	0	--	10	5	4.6	4.2
Fluoride (Fl)	0	.3	.2	0	.2	.1
Silica (SiO_2)	19	34	33	19	39	39
Dissolved solids, calculated (mg/L)	83	239	200	105	113	109
Dissolved solids, calculated (tons per acre-foot)	.11	.33	.27	.14	.15	.15
Nitrate (NO_3)	.1	.6	.1	.1	.3	.1
Iron (Fe)	.35	20	--	280	150	--

SUMMARY

The FAA facilities at King Salmon, Alaska are situated on outwash sand and gravel near the Naknek River about 26 km east of Kvichak Bay on the northern end of the Alaska Peninsula. The area is characterized by numerous shallow lakes and ponds surrounded by mesic to wet shrub tundra and is beyond the southern limit of the boreal forest in Alaska. Numerous water wells in the King Salmon area indicate that ground water is present at depths of 10 m or less and likely extends to at least 70 m depth. Although not completely substantiated, the direction of ground-water flow in the vicinity of the FAA facilities is toward the Naknek River.

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