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PRELIMINARY WATER RESOURCES ASSESSMENT OF THE PROPOSED HATCHER PASS ALPINE SKI AREA NEAR GOVERNMENT PEAK, SOUTHCENTRAL ALASKA

By
Stan Carrick, Mary Maurer, Danita Maynard, and Jim Munter [1]

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794 University Avenue, Suite 200
Fairbanks, Alaska 99709-3645

[1] ADGGS, P.O. Box 772116, Eagle River, Alaska 99577

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The proposed Hatcher Pass Alpine Ski Area lies entirely within the Little Susitna River drainage basin. Two major tributaries, Fishhook and Government Creeks, and seven secondary tributaries flow through the ski site. In addition, numerous intermittent streams dissect glacial till on the lower slopes below 2700 ft. The U.S. Geological Survey has 40 years of streamflow records for the Little Susitna River at the Fishhook-Willow Road bridge crossing. Alaska Division of Geological and Geophysical Survey (DGGS), Water Resources Section (WRS) hydrologists have also established gaging stations on Government and Fishhook Creeks, and have taken miscellaneous discharge measurements on the 7 secondary tributaries.

The average discharge for the Little Susitna River gaging site for the period of record is 211 cubic feet per second (cfs), with summer flows typically ranging from 300-700 cfs and winter flows from 10-100 cfs. Streamflow in Government Creek ranges from 0.5-3.0 cfs in the winter to 10-20 cfs in the summer. Fishhook Creek, the largest tributary that flows through the proposed ski area, has flows ranging from 2-6 cfs in the winter to 25-100 cfs during the summer and early fall.

There are two main potential impacts to surface water quantity as a result of ski area development: (1) impacts from withdrawals for public water supplies and snowmaking, and (2) impacts related to increased surface water yield from snowmaking and vegetation removal for ski runs. The developer proposes to use up to 1.0 cfs or 680,000 gallons per day (gpd) of water for public, non-snowmaking use and up to 5.6 cfs or nearly 3.5 million gallons per day (mgpd) during snowmaking periods. If this water is derived from the Little Susitna River during winter low flows, downstream users and fisheries could be impacted. In the event that ski area water withdrawals exceed Division of Land & Water Management (DLWM) and Alaska Department of Fish and Game (ADF&G) flow reservations, the developer should consider other forms of water supplies such as ground water, water storage ponds at strategic sites around the ski area, or bringing in water from Borough or City sources.

Applying artificial snow to ski slopes and clearing ski slopes of natural vegetation increases the water yield or runoff to local streams. The amount of increase is dependent on factors such as how much artificial snow was added to the natural snowpack, spring snowmelt conditions, how much vegetation is removed, vegetation removal techniques, and the establishment of new slope vegetation. Field studies have shown up to 78 percent of artificial snow applied to the runs will return to the stream, while water yields from cleared ski slopes increased over 100 percent (Colorado Ski Country USA, 1986). These runoff increases will vary with weather conditions and especially with the surficial geology and soils. The timing of spring runoff can also be affected by snowmaking and slope clearing, by prolonging the runoff period or causing faster surface runoff from non-vegetated runs.

Potential impacts to the area streams and drainages can include slope and channel erosion, local landslides or slumps, erosion to roads or ski area structures, and increased sedimentation. These impacts can be mitigated by implementation of a sound erosion control plan that is based on site-specific soils and hydrology studies. Features of such a plan can include revegetation of disturbed soils, proper sizing of drainage structures, runoff storage ponds, vegetation buffer zones adjacent to streams, and minimizing alterations to a stream's natural channel, among other alternative erosion control measures.

Water quality impacts to area streams are difficult to evaluate without more specific development plans. The Little Susitna River and nine tributaries in the project area have high dissolved oxygen content, slightly basic pH, and low concentrations of dissolved solids. No baseline data exist in the proposed project area for primary contaminants listed in the Alaska Drinking Water Standards. Suspended sediment concentrations in the Little Susitna River during summer months are generally low except during high streamflow events. The most probable water quality impact associated with the construction and operational phase of the proposed project is increased sediment loading in the Little Susitna River.

Ground Water Quality and Quantity

The Hatcher Pass ski resort proposes to extract up to 470 gallons per minute (gpm) of ground water for use as a public water supply. The proposed ski area is in an undeveloped environment with no site specific data on ground-water development potential. Available surficial geologic maps of the ski area show the presence of bedrock units above about 2000 ft elevation, which are expected to yield relatively little (less than 10 gpm) water to wells. At lower elevations, a mixture of till, thin alluvial deposits, and mass wastage deposits occur. The potential for these deposits to supply the anticipated demand is unknown.

A sparsely populated rural area located immediately south of the proposed ski resort area, along Edgerton Parks Road, relies on local ground water resources for domestic, light commercial, and irrigation water supplies. Well logs are available from 39 wells in the area. Most of these wells (85 percent) obtain water from unconsolidated sand-and-gravel aquifers that are at least 100 ft thick in some places. The remainder of the wells obtain water from bedrock, which occurs at depths of 10-91 ft in the Edgerton Parks Road area. The median reported yield of wells tapping sand-and-gravel aquifers is 15 gpm, compared to 3 gpm for wells tapping bedrock aquifers. These data suggest that bedrock is not a likely source of water for the proposed project. The presence of 12 wells with reported yields ranging from 15 to 57 gpm indicates that sufficient quantities of water from properly designed wells or well fields may be available in the area for use at the proposed ski resort. Because unconsolidated deposits are expected to be thinner near the base of Government Peak than near Edgerton Parks Road, commercial quantities (up to 470 gpm) of ground water may not be available on land identified as part of the ski area complex. Site-specific evaluation of ground-water supplies is needed to further assess local development potential.

Since the proposed facility will be located in a recharge area for local aquifers, special consideration for minimizing ground-water contamination is warranted. Major potential sources of contamination are infiltration of sewage; runoff from developed areas; and contamination from storage, use, or accidental release of fuel products, fertilizers, pesticides, road salts, or animal wastes.

INTRODUCTION

An international corporation, Mitsui and Company, is proposing the development of a ski resort on state land in the Talkeetna Mountains near Government Peak, 11 mi northwest of Palmer, Alaska. At the request of the Alaska Division of Land and Water Management (DLWM), hydrologists from the Water Resources Section (WRS) of the Alaska Division of Geological and Geophysical Surveys (DGGS) made a preliminary assessment of the basin hydrology and potential impacts to the water resources of the basin from ski area development, with suggestions for measures to mitigate potential impacts. Staff from DLWM as well as members of the Hatcher Pass Ski Area Planning Team and Citizens Advisory Committee will use this document in their review of the developer's ski area conceptual plan.

This Public Data File Report is preliminary and based on a general knowledge of Mitsui's development plans, a literature review of existing published and unpublished data, and a few days of limited field investigation. Site-specific field studies and conscientious development using sound engineering practices by the developer can mitigate water resources impacts. This report is not intended to present a thorough evaluation of area water resources or a detailed examination of potential impacts or mitigating measures.

EXISTING HYDROLOGY

Surface Water Quantity

With the exception of the Little Susitna River, published information on water resources in and adjacent to the proposed ski area is scarce. The USGS (Lamke, 1988) has 40 years of streamflow record for the Little Susitna River gaging sites at the bridge crossing at mi 8.5 of the Fishhook-Willow Road (fig. 1). The drainage basin encompasses 61.9 sq mi of the southeast Talkeetna Mountains (streams draining the south side of Government Peak flow into the Little Susitna River downstream of the USGS gaging site).

Average discharge for the USGS Little Susitna River site is 211 cubic feet per second (cfs). Summer flows typically range from 300-700 cfs, while winter flows are normally 10-100 cfs. Highest flows during the year usually occur in June when snowmelt peaks or in the late summer/early fall after heavy rains. Annual low flows take place in March and April. Table 1 summarizes USGS streamflow data for the Little Susitna River.

The stream channel of the Little Susitna River upstream of the USGS gaging site consists primarily of large boulders, cobbles, and gravel, and varies between 25 ft and 100 ft wide and 1 ft to 5 ft deep. Most of the channel reach is made up of rapids and small pools; the channel is moderately steep with an average gradient of 78.2 ft/mi.

Flooding occasionally takes place on the Little Susitna River, and the Fishhook-Willow Road has sustained damage in the past. The highest recorded flood in 40 years took place during heavy rains in August 1971, when the discharge was 7840 cfs. Peak flows usually range from 1500 cfs to 3000 cfs and are contained within the channel.

Figure 1

HATCHER PASS ALPINE SKI AREA
HYDROLOGY

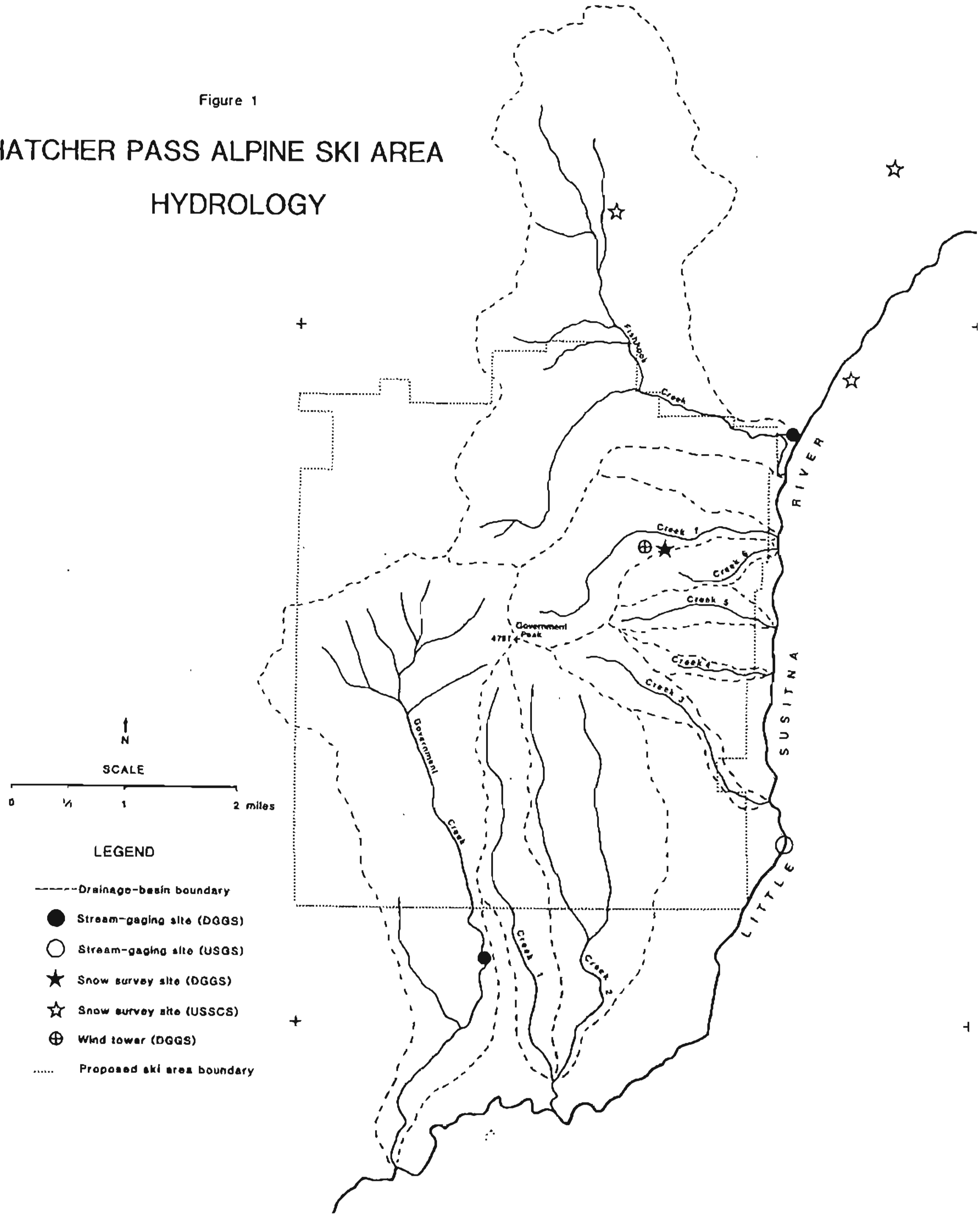

Table 1. Streamflow data for Little Susitna River near Palmer, Alaska, 1949-1987. (Flow figures in cubic feet per second or cfs).

Average Flow: 211
Lowest Annual Flow: 96 (1969)
Highest Annual Flow: 316 (1949)

Monthly Average Flows:	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	29.5	23.5	19.2	22.1	205.0	682.0	551.0	446.0	309.0	138.0	61.5	38.4

Lowest Monthly Flow: 10.0 (April 1955, March 1956)
Highest Monthly Flow: 1215 (June 1977)
Lowest Daily Flow: 8.0 (1956 and 1957)
Highest Daily Flow: 5040 (1971)

Estimated Streamflow Statistics (cfs):

	Mean	Recurrence Interval 10-Yr Flow	Recurrence Interval 50-Yr Flow	Recurrence Interval 100-Yr Flow
1-Day Low Value	16.3	10.9	7.8	6.8
7-Day Low Value	16.5	11.1	8.1	7.1
30-Day Low Value	18.0	12.2	9.0	8.0
7-Day High Value	1158.0	1698.1	2153.0	2332.6
30-Day High Value	783.0	1114.8	1352.8	1439.8

The above data was compiled from USGS computer printouts (Lamke, 1988).

The lowest flow on record occurred both in April 1956 and March 1957, when the discharge measured 8 cfs or just over 5 mgpd. Most years the lowest flows are 14-18 cfs (9-12 mgpd). In early winter, when water demand for snowmaking is normally highest, streamflow ranges from 30-50 cfs (20-50 mgpd).

There are four other streams in the proposed ski area that usually flow year round, and an additional five smaller creeks that have measurable flow during the non-winter months; all of these streams are tributaries of the Little Susitna River. Government and Fishhook Creeks are the most significant tributary streams in the above group of nine. Government Creek drains the south side of Government Peak and has a total basin area of 5.7 sq mi. Fishhook Creek drains Bald Mountain Ridge, as well as the Independence Mine Valley, and has a basin area of 8.5 sq mi.

In August 1988, WRS hydrologists installed a continuous recording stage gage on Government Creek at the Edgerton Park Road crossing (fig. 1). This stream gage will provide technical advisors and planners with streamflow data for that part of Government Peak that flows through the proposed ski site, a drainage basin area of 3.7 sq mi.

During September 1987, WRS hydrologists installed a continuous recording stage gage on Fishhook Creek at the Fishhook-Willow Road crossing (fig. 1). This gaging site will yield streamflow data for the north end of the proposed ski site, as well as for areas affected by development in the Independence Mine/Hatcher Pass Lodge vicinity. Approximately 14 percent, or 1.2 sq mi, of the Fishhook Creek basin receives runoff from the slopes of the proposed ski area. A noteworthy feature of Fishhook Creek is the splitting of the main channel into two smaller distributary channels approximately 100 yds west of the Little Susitna River. One channel flows due east to its confluence with the Little Susitna, while the other channel flows south paralleling the Fishhook-Willow Road for 0.4 mi before it crosses the road and flows into the Little Susitna. Table 2 contains miscellaneous flow data for the Little Susitna River tributaries.

Surface Water Quality

Water quality information has been collected by the U.S. Geological Survey (USGS) at two sites on the Little Susitna River: at the bridge at mi 8.5 Fishhook-Willow Road near Palmer, and the Parks Highway Bridge at Houston. The Palmer site has historical data on cations and anions, hardness, nitrate, specific conductance, pH, and color (Table 3). Suspended sediment data are also available for the Palmer site (Table 4). However, no data have been collected on bacteria, organics, heavy metals, chlorine or turbidity. Limited historical data are available for the Houston site (Table 5). Cation, anion, heavy metal, and nutrient analyses are available, but sediment and microbiological data were collected on one date only. No organic chemistry or turbidity data have been collected at this site.

Based on the available database, both sites on the Little Susitna River have generally good water quality. The mean pH is slightly basic (pH 7.2), and the dissolved oxygen concentration is consistently near saturation. Specific conductance ranges from 42 to 160 µmhos per centimeter and varies inversely with streamflow. The water chemistry is of the calcium-bicarbonate type. Trace metal and nutrient concentrations are low. Concentrations of

Table 2. Miscellaneous streamflow measurements for streams flowing through the proposed ski area.

Stream	Date	Discharge (cfs)
Government Creek	10-06-88	12.5
mi 2.9 Edgerton Parks Rd.	08-25-88	7.2
	08-03-88	10.9
	07-19-88	10.5
Unnamed Creek # 1	08-03-88	1.5
mi 2.1 Edgerton Parks Rd.		
Unnamed Creek # 2	08-03-88	5.0
mi 1.4 Edgerton Parks Rd.		
Unnamed Creek # 3	08-03-88	0.9
mi 8.8 Fishhook-Willow Rd.		
Unnamed Creek # 4	08-03-88	0.4
mi 10.2 Fishook-Willow Rd.		
Unnamed Creek # 5	08-03-88	0.1
mi 10.7 Fishhook-Willow Rd.		
Unnamed Creek # 6	08-03-88	0.8
mi 11.4 Fishhook-Willow Rd.		
Unnamed Creek #7	08-03-88	5.5
mi 11.5 Fishhook-Willow Rd.	04-08-87	0.06 (28.7 gpm)
(drains bowl on N side of Gov't. Peak)	10-07-86	6.0
Fishhook Creek Distributary	10-6-88	3.7
mi 11.9 Fishhook-Willow Rd.	09-23-87	1.5
	04-08-87	0.03 (14.8 gpm)
Fishhook Creek, main branch	10-6-88	25.0
mi 12.3 Fishhook-Willow Rd.	08-03-88	24.8
	06-01-88	53.5
	03-16-88	2.4
	12-15-87	5.3
	09-23-87	24.9
	04-08-87	3.2
	10-07-86	26.7
	06-00-65	380.0*
	06-00-64	500.0*
	08-23-63	960.0*

* Peak flow discharges from USGS (1971); all other figures in Table 2 were measured by DGGS hydrologists.

Table 3. Compilation of records of quantity and quality of surface waters of Little Susitna River near Palmer, lat 61°41'40", long 149°13'40".[1] Chemical analyses in milligrams per liter (mg/L).

Date	Water temperature (°C)	Discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium[2] + (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)
10-19-48	-	125	7.7	-	11	2.4	4.3		42	6.0	4.5
04-18-49	-	26	-	-	-	-	-		48	7.1	19
05-19-49	-	167	6.4	-	-	-	6.0		38	3.1	6.5
10-03-49	-	247	5.2	-	-	-	3.9		34	3.2	4.5
06-15-50	-	456	4.5	0.02	8.9	2.8	0.6		33	3.8	2.4
08-03-50	-	432	4.5	0.04	9.4	-	-		34	1.9	1.4
09-01-50	-	123	4.5	0.05	8.5	1.5	4.8		36	5.6	1.5
03-19-51	-	15	6.8	0.01	12	3.8	12		45	5.1	20
04-18-51	-	25	3.6	0.03	12	2.8	6.3		41	3.5	12
05-24-51	-	206	5.5	0.01	4.7	1.4	9.8		35	4.4	3.2
02-12-52	0.0	14	7.2	0.01	12	3.3	9.1		43	4.4	16
03-12-52	0.5	13	6.7	0.03	13	3.0	11.0		44	5.8	18
04-15-52	1.0	15	6.8	0.01	14	3.0	13.0		46	7.2	21
05-07-52	3.0	29	7.3	0.04	14	3.3	10.0		46	6.3	18
06-11-52	5.0	1230	5.8	0.02	5.9	1.3	3.8		24	4.0	2.8
07-16-52	-	506	4.1	0.02	6.8	1.6	1.1		25	2.8	1.5
08-26-52	6.0	709	6.4	0.10	9.0	1.8	-		34	4.8	0.5
10-27-67	-	66	5.5	0.08	10	2.0	3.9	.5	35	2.0	7.1
02-26-68	-	27	6.5	0.18	12	2.3	9.3	.9	43	.0	17
03-27-68	-	29	6.5	0.13	13	2.9	11	.8	44	1.8	19
03-25-71	-	19	6.3	0.08	14	3.0	12	1.0	44	5.6	-
04-26-71	-	19	5.5	0.05	15	3.1	12	1.0	47	5.6	-
04-25-72	0.5	19	7.7	0	33	4.6	3.7	1.7	103	20	5.2

Date	Fluoride (F)	Nitrate (NO_3)	Dissolved solids (residue on evaporation @ 180° C)	Hardness as $CaCO_3$ Calcium, magnesium	Noncarbonate	Specific conductance (µmhos @ 25° C)	pH	Color	Carbonate, field (mg/L as CO_3)	Carbon dioxide, dissolved (mg/L as CO_2)	Alkalinity, field (mg/L as $CaCO_3$)
10-19-48	0.0	1.4	58	38	3	84	-	-	-	-	-
04-18-49	-	-	-	-	-	143	-	-	-	-	-
05-19-49	-	4.0	-	33	2	95	6.2	-	-	-	-
10-03-49	-	.8	-	30	0	75	7.1	-	-	-	-
06-15-50	0	.8	40	34	7	63.3	7.4	4	-	-	-
08-03-50	-	.5	-	-	-	69.6	7.4	5	-	-	-
09-01-50	-	.4	45	27	0	72.0	-	5	-	-	-
03-19-51	-	0.9	83	46	9	144	7.6	5	-	-	-
04-18-51	-	1.3	62	41	8	119	7.7	5	-	-	-
05-24-51	-	1.3	48	18	0	82.2	7.3	5	-	-	-
02-12-52	0.0	1.0	76	44	9	130	7.3	5	0	3.4	35
03-12-52	0.1	0.8	81	45	9	141	7.1	5	0	5.6	36
04-15-52	0.1	0.8	-	47	9	149	7.2	5	0	4.6	38
05-07-52	0.0	1.5	-	49	11	145	7.3	10	0	3.7	38
06-11-52	0.1	0.5	-	20	0	46	7.0	5	0	3.8	20
07-16-52	0.0	0.6	-	24	3	51	6.5	5	0	13	21
08-26-52	0.1	1.3	-	30	2	66	6.5	5	0	17	28
04-25-72	0.2	0.05	-	102	18	220	8.1	0	0	-	-

[1] U.S. Geological Survey data (USGS, unpublished 1952 WATSTORE data; 1957;1958;1968;1971;1972)
[2] Sodium and potassium values from 1967-1972 are listed separately.

Table 4. Suspended sediment and selected water quality data for the Little Susitna River near Palmer.[1]

Date	Water temperature (°C)	Discharge (cfs)	Suspended sediment (mg/L)	Suspended sediment discharge (t/day)	Specific conductance (µmhos @ 25° C)	Turbidity (JTU)
08-24-59	-	4800. est.	2510	-	-	-
08-26-59	-	1980	122	122	-	-
10-27-67	0	66.1	9	2	-	-
08-27-68	6	191	11	6	-	-
08-28-69	2	25	1	0.07	-	-
12-29-69	1	29.9	1	0.08	-	-
03-26-70	3	20.3	1	0.05	-	-
10-26-70	0	94	3	0.76	97	-
12-28-70	0	43	1	0.12	128	
02-23-71	0	22	2	0.12	146	-
03-25-71	0.5	19	1	0.05	156	-
04-26-71	1.0	19	2	0.10	160	-
05-24-71	2.5	64	3	0.52	105	-
06-25-71	8.5	1560	102	430	42	-
07-26-71	6.0	367	16	16	49	-
10-22-71	0.5	85	0	0	97	-
11-26-71	0.0	51	2	0.28	160	-
01-26-72	0	31	5	0.42	129	-
03-28-72	0	17	0	0	153	-
07-25-72	7.0	347	35	33	74	-
08-28-72	6.0	171	10	4.6	62	-
09-25-72	2.5	187	21	11	71	-
10-26-72	1.0	156	11	4.6	75	2
11-27-72	0.5	71	3	0.58	101	1

[1] U.S. Geological Survey data (USGS, unpublished 1959 WATSTORE data; 1969;1970;1971;1972;1973;1974)

est. = estimated

Table 5. Water quality data for Little Susitna River near Houston (lat 61°37'36", long 149°48'03").[1]

	02-12-72	10-05-78	03-02-83	07-27-83
Streamflow, instantaneous (cfs)	-	150	63	291
Specific conductance (μmhos)	121	110	98	66
pH (units)	7.2	6.8	7.7	7.1
Water temperature (°C)	-	5.0	0.0	13.0
Oxygen, dissolved (mg/L)	-	12.6	12.4	10.1
Coliform, total, (cols. per 100 ML)	-	K2	-	-
Coliform, fecal, (cols. per 100 ML)	-	1	K3	-
Stretococci fecal KF agar (cols. per 100 ML)	-	K2	-	-
Hardness (mg/L as $CaCO_3$)	50	42	-	-
Hardness, non-carbonate (mg/L $CaCO_3$)	21	1	-	-
Calcium dissolved (mg/L as Ca)	16	13	-	-
Magnesium, dissolved (mg/L as Mg)	2.5	2.4	-	-
Sodium, dissolved (mg/L as Na)	3.8	4.0	-	-
Potassium, dissolved (mg/L as K)	.8	.6	-	-
Bicarbonate (mg/L as HCO_3)	58	51	56	-
Carbonate (mg/L as CO_3)	0	0	0	-
Sulfate, dissolved (mg/L as SO_4)	3.1	2.6	-	-
Chloride, dissolved (mg/L as Cl)	6.0	5.5	-	-
Fluoride, dissolved (mg/L as F)	.0	.0	-	-
Silica, dissolved (mg/L as SiO_2)	8.8	7.5	-	-
Solids, residue at 180° C dissolved (mg/L)	-	60	-	-
Solids, sum of constituents, dissolved (mg/L)	71	62	-	-
Nitrogen, NO_2 + NO_3, total (mg/L as N)	-	.22	-	-
Nitrogen, NO_2 + NO_3, dissolved (mg/L as N)	.29	.25	-	-
Nitrogen, ammonia, total (mg/L as N)	-	.00	-	-
Nitrogen, ammonia, dissolved (mg/L as N)	-	.05	-	-
Nitrogen, organic, total (mg/L as N)	-	.23	-	-
Nitrogen, organic, dissolved (mg/L as N)	-	.14	-	-
Nitrogen, ammonia + organic, total (mg/L as N)	-	.23	-	-
Nitrogen, ammonia + organic, dissolved (mg/L as N)	-	.19	-	-
Nitrogen, total (mg/L as N)	-	.45	-	-
Phosphorus, total (mg/L as P)	-	.00	-	-
Phosphorus, dissolved (mg/L as P)	-	.00	-	-
Aluminum, total recoveragle (ug/L as Al)	-	150	-	-
Arsenic, total (ug/L as As)	-	1	-	-
Barium, total recoverable (ug/L as Ba)	-	0	-	-
Cadmium, total recoverable (ug/L as CO)	-	0	-	-
Chromium, total recoverable (ug/L as Cr)	-	0	-	-
Copper, total recoverable as (ug/L as Cu)	-	3	-	-
Iron, total recoverable (ug/L as Fe)	380	390	-	-
Iron, dissolved (ug/L as Fe)	-	90	-	-
Lead, total recoverable (ug/L as Pb)	-	1	-	-
Manganese, total recoverable (ug/L as Mn)	40	10	-	-
Manganese, dissolved (ug/L as Mn)	-	0	-	-
Mercury, total recoverable (ug/L as Mg)	-	.0	-	-
Nickel, total recoverable (ug/L as Ni)	-	1	-	-
Selenium, total (ug/L as Se)	-	0	-	-
Silver, total recoverable (ug/L as Ag)	-	0	-	-
Zinc, total recoverable (ug/L as Zn)	-	0	-	-
Carbon, organic, dissolved (mg/L as C)	-	1.6	-	-
Carbon, organic, suspended total (mg/L as C)	-	.4	-	-
Sediment, suspended (mg/L)	-	2	-	-
Sediment, discharge, suspended (t/day)	-	.81	-	-
Color (Platimum Cobalt Units)	0	-	-	-

[1] U.S. Geological Survey data (USGS 1972;1979;1983)

K = non-ideal colony count

iron and manganese, the most commonly detected trace metals, met state water quality drinking water standards at Houston in 1983 when sampling was last undertaken. Fecal coliform and fecal streptococci bacteria counts are low, based on October 1978 data collected at Houston.

Turbidity and suspended sediment concentrations vary seasonally in the Little Susitna River (Table 4). During the sub-freezing winter months the river flows clear and the suspended sediment concentration approaches 0 milligrams per liter (mg/L) or 0 ppm. After breakup, the river is milky with snow and glacier melt or rainfall runoff, and suspended sediment concentrations rise to a typical range of 10-200 mg/L (10-200 ppm). Summer storms can produce a substantial increase in the suspended sediment concentration, as was the case on August 24, 1959, when a suspended sediment concentration of 2510 mg/L was measured (Table 4).

WRS hydrologists collected minimal baseline water quality data from nine tributary streams that flow through the proposed ski site (Table 6). The data show that pH, dissolved oxygen and specific conductance measurements are similar among streams and indicative of good water quality. Specifically, the mean pH is slightly basic (8.0), the dissolved oxygen concentration exceeds 100 percent saturation in all streams, and the specific conductance ranges from 83 to 132 µmhos per centimeter.

Ground Water Quantity

Hydrogeology

Ground-water data are unavailable for the area within the boundaries of the proposed project. The area is undeveloped, and no water wells are known to exist. Ground-water data are available for the area surrounding Edgerton Parks Road, immediately south of the project area (fig. 2). DGGS examined data on file for Edgerton Parks road and surrounding areas to assess the probable suitability of the ground-water resources for satisfying the water usage needs of the proposed project, estimated at approximately 470 gallons per minute (gpm).

The study area lies south of Government Peak. Major streams in the area include Government Creek, two unnamed streams, and the Little Susitna River, all of which run approximately north-south through the study area. Surficial deposits are glacially-derived and are mapped as till and outwash deposits north of the Little Susitna River and ice-contact deposits south and east of the river (Pewe and Reger, 1983). Drumlins (half-ellipsoid hills commonly composed of till, which may contain bedrock cores), are mapped immediately north of and aligned with the river. Combellick and Reger (1988) describe outwash deposits along the Little Susitna River immediately north of the study area. Most of the unconsolidated deposits are silty sand or sand and gravel. The thickness of the surficial deposits in the study area ranges from a reported minimum of 10 ft (Section 33) to over 100 ft (Section 34). The average thickness is at least 50 ft, and may in fact be significantly thicker. Additionally, examination of limited well log data suggests that the surficial deposits may be more uniformly thick in Section 32 than in the remaining sections.

Examination of driller's logs for water wells in the study area suggests the likelihood of several separate aquifer zones within the unconsolidated

Table 6. Hatcher Pass/Government Peak stream discharge and water quality data, August 3, 1988.[1]

Stream Name	Discharge (cfs)	Water temperature (°C)	pH	Dissolved oxygen (mg/L)	Dissolved oxygen % saturation[2]	Specific conductance (μmhos)
Government Creek, mi. 2.9 Edgerton Parks Road	10.86	7.3	7.9	12.4	100	110
Creek # 1, mi. 2.1 Edgerton Parks Road	1.48	6.7	7.8	11.9	100	90
Creek # 2, mi. 1.4 Edgerton Parks Road	5.00	7.4	7.7	11.7	100	95
Creek # 3, mi. 8.8 Fishhook-Willow Road	0.94	6.7	8.1	12.5	100	132
Creek # 4, mi. 10.2 Fishhook-Willow Road	0.35	6.2	8.0	12.3	100	108
Creek # 5, mi. 10.7 Fishhook-Willow Road	0.06	7.4	8.0	12.0	100	83
Creek # 6, mi. 11.4 Fishhook-Willow Road	0.78	7.0	8.1	12.2	100	88
Creek # 7, mi. 11.5 Fishhook-Willow Road	5.52	7.4	8.3	11.7	100	104
Fishhook Creek, mi. 11.9 & 12.3 Fishhook-Willow Road	28.0[3]	9.4	8.1	11.5	100	83

[1] DGGS Water Resources Section data
[2] all values >100% saturation
[3] approximate

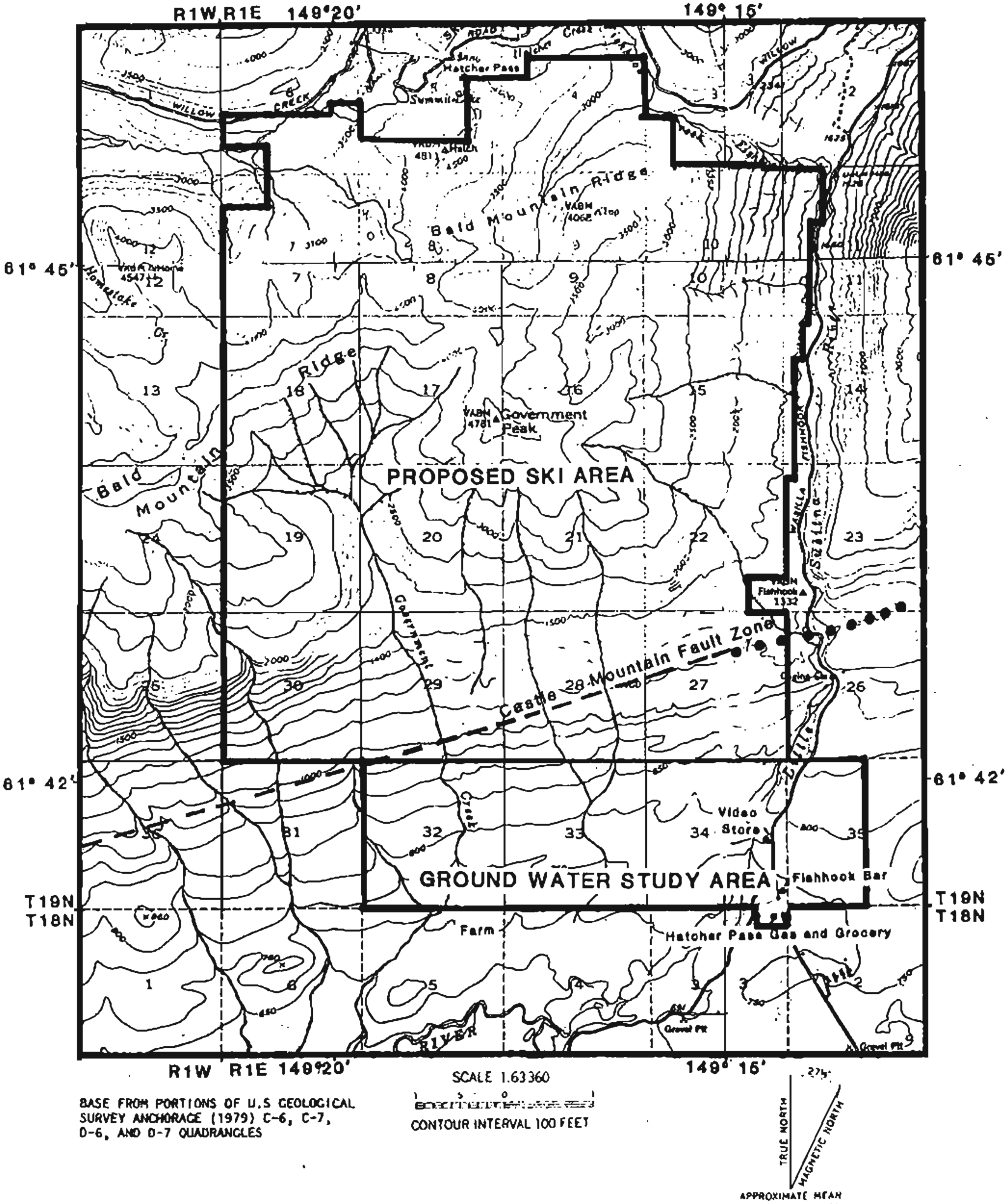

Figure 2. Map showing relationship of proposed ski area to ground-water study area.

deposits, including both unconfined and confined aquifers. Shallow water tables (2-10 ft below land surface) are evident in test pits and drainage ditches, and are suggested by the presence of multiple seeps and small springs in the area. This suggests a surficial, unconfined aquifer tapped by shallow wells encountering no significant fine-grained materials. Wells in much of the area, however, extract water from 30-100 ft below ground and encounter silty or clayey materials which may serve as confining units. Static water levels in these wells are commonly between 15-60 ft below land surface, suggesting the presence of confined aquifers lying below the water table aquifer.

The surficial deposits are underlain by coal-bearing continental clastic sedimentary rocks (hereafter termed "bedrock") of the Tertiary-age Chickaloon Formation. The Chickaloon Formation is described regionally as "moderately to well-indurated feldspathic sandstone, siltstone, claystone, mudstone, and conglomerate with numerous beds of bituminous coal" (Merritt and Belowich, 1984). These rocks are bounded to the north by the Castle Mountain fault, estimated to lie just north of the study area (fig. 2). North of the fault the bedrock consists of highly indurated arkose, conglomerate, graywacke, siltstone, and shales of the Tertiary-age Arkose Ridge Formation, locally cut by hypabyssal rocks (Merritt and Belowich, 1984). Bedrock was encountered during drilling at approximately 40-60 ft below the surface in the central portion of Section 34 and the eastern half of Section 35 (fig. 3). Bedrock was also reportedly encountered in one well in Section 33; however, the lack of other data in the vicinity precludes verification of the accuracy of that information. Bedrock was not encountered by any of 9 wells in Section 32 drilled to depths of 32-82 ft below the surface.

The generalized description of the Chickaloon Formation suggests the possibility of different aquifer zones in bedrock, but defining separate aquifer zones is beyond the scope of this study. For the purposes of this study, the area may be considered to consist of one or more aquifer zones within the unconsolidated, sand-and-gravel aquifer system and a bedrock aquifer system.

Water Use

The area is rural and largely undeveloped with a sparse population. Within the study area, water is used commercially at a small video store/campground at the intersection of Edgerton Parks and Fishhook Roads, and at a small bar/restaurant and a grocery store/laundromat located approximately ½ mi south of the road at the Fishhook intersection. The businesses rely on domestic-type wells for their water supply. Agricultural water usage within the area of interest is limited to a potato farm and commercial greenhouse adjacent to the southern boundary of section 32 (fig. 2). Specific information for the farm, including well logs and irrigation records are not available. The owner withdraws water from 2 wells, each less than 100 ft deep.

Well Log Data

The following summarizes information from well logs contained in the DGGS database for the study area. The wells are, without exception, 6 in. diameter wells designed for domestic or light commercial use, almost always without

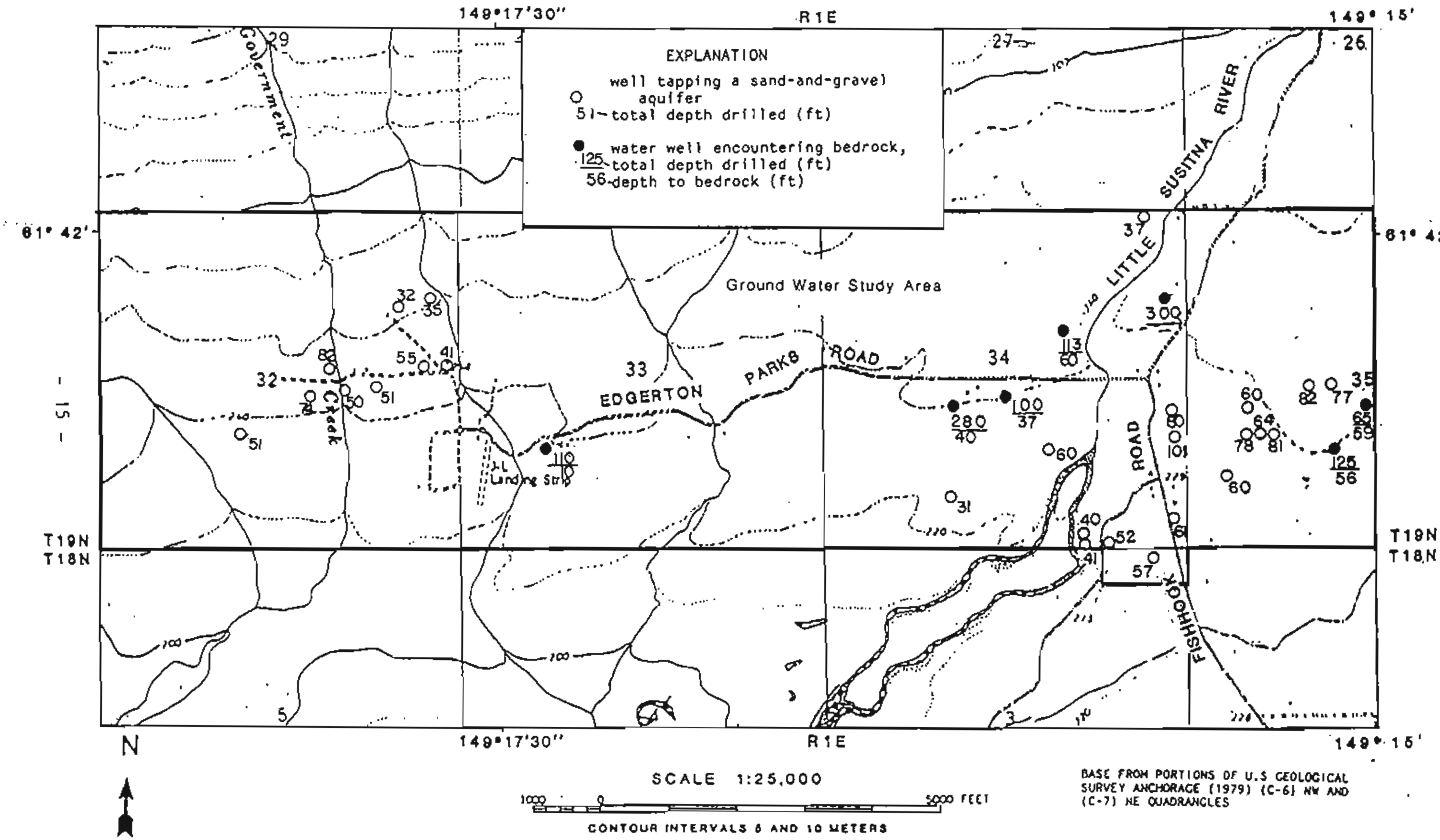

Figure 3. Map showing location, depth, and depth-to-bedrock of water wells in the study area.

screens or perforations (open-ended wells) and without extensive development or pumping tests. The well yields included here are the estimates supplied by the driller at the time the well was drilled, and represent the minimum yields potentially available. The information contained on the logs is summarized in Table 7.

Table 7. Summary of well log data.

Section	Number of well logs	Range of depths (ft)	Range of yields (gpm)	Range of available draw-downs (ft)
32	9	32-82	4-15	10-49
33	1	110	unknown	unknown
34	13	31-300	2-40	15-140
35	9	60-125	2-40	14-98
3	1	57	57	25

Most of these wells (78 percent) are less than 100 ft deep and withdraw water from the unconsolidated gravel or sand-and-gravel deposits. Yields reported for these wells range from 4-40 gpm, with 38 percent reporting 15 gpm or greater. Seven wells are 100 ft or greater in depth. Of these, one (101 ft) is reportedly finished in gravel and yields 40 gpm. Another well does not record the aquifer material or yield, but, based on the well depth and its proximity to exposed Chickaloon Formation rocks, it is assumed to be in bedrock. The remaining 5 encountered sandstone and coal deposits at depths ranging from 10-91 ft, and yield 2-3 gpm.

The reported yields (fig. 4) represent estimates supplied by the driller at the time of drilling. In many instances, the resultant drawdown is not recorded. Where both a yield and drawdown are available, the specific capacity (gallons per minute/foot of drawdown) gives an indication of the well's potential. Calculated specific capacities for the area are given in figure 3. Eleven wells in Sections 32-35 which extract water from the unconsolidated aquifer system had specific capacities from 0.1 to 2.0 gpm/ft at the time of drilling, while 2 wells extracting water from bedrock had specific capacities of 0.02 gpm/ft.

In addition to drillers' estimates of well yield, a pumping test was performed at the Hatcher Pass Gas and Grocery (fig. 2). The well is a typical 6 in. diameter, open-ended well similar to others in the area. The aquifer material is recorded as 57 ft of "sand and gravel all the way." The driller originally estimated the yield at 30 gpm. He later performed the pumping test and revised the yield to a minimum of 57 gpm with a drawdown of 16 ft. At the time of the pumping test, the specific capacity of the well was 3.7 gpm/ft. The driller noted the well yield could have been increased during the test but he did not do so because of the lack of screens in the well.

Examination of land surface elevations, stream locations, and water level data from wells indicates that the proposed ski area on the south side of Government Peak forms a primary recharge area for ground water in the study area. Most ground water in the study area is expected to discharge to the Little Susitna River to the south.

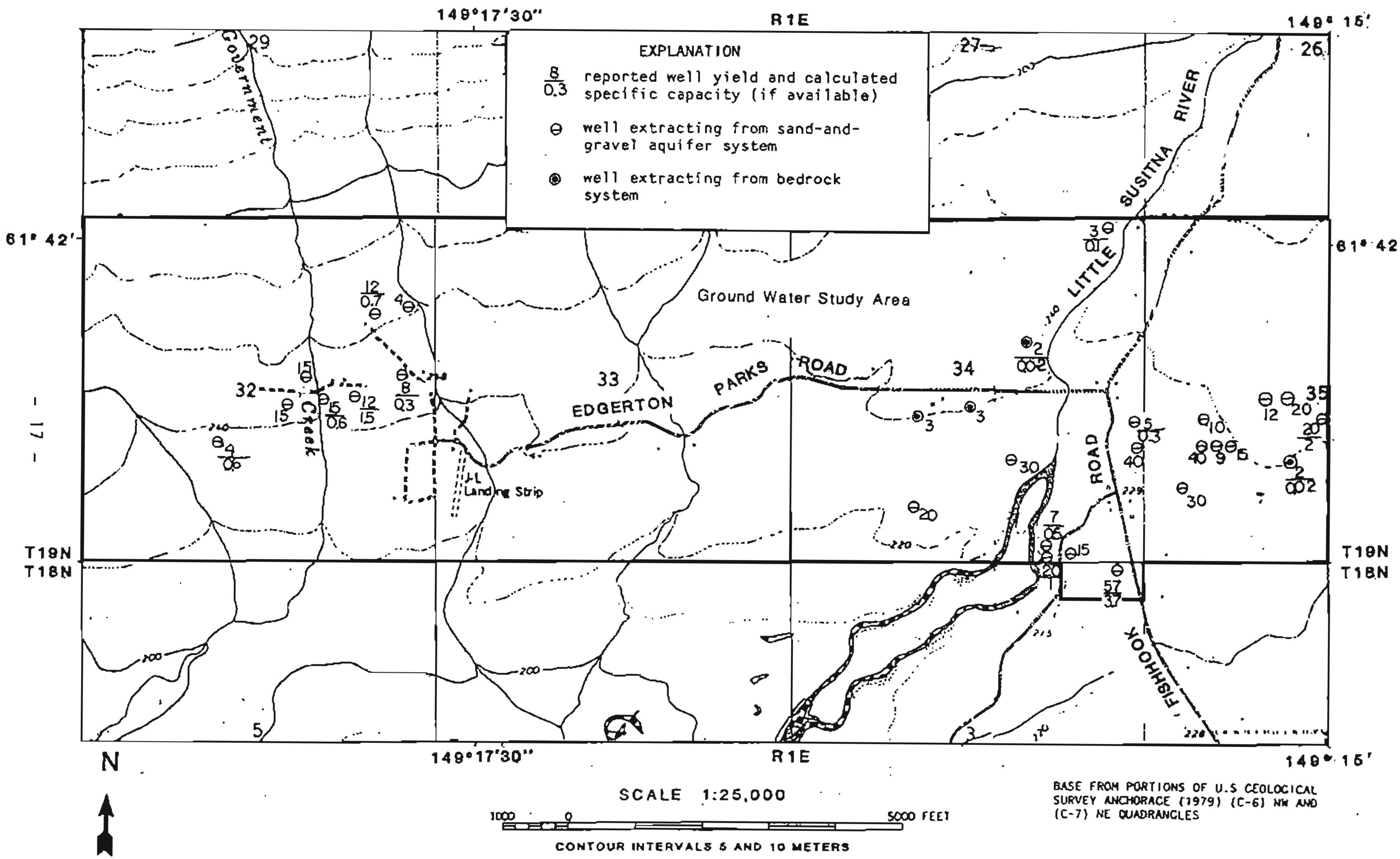

Figure 4. Map showing yields and specific capacities of well in the study area.

Ground-Water Quality

No water quality data are available beyond a single nitrate analysis (0.46 mg/L) for the Fishhook Bar (fig. 2); however, the water supply is free of unusual or undesirable tastes and odors. Residents in the area note a small amount of iron present in their water supplies, as well as insoluble residues characteristic of significant hardness.

WATER RESOURCES IMPACTS AND MITIGATIONS

Surface Water Quantity Impacts and Mitigation

Public Water Supply Withdrawals Impacts

The developer plans on using 136,000 gpd or 0.21 cfs for public water use during phase I, and a total of approximately 680,000 gpd or 1.0 cfs for all phases of development. Public water supplies include most water consumption other that that used for snowmaking, golf course irrigation, etc. A specific source for this water has not been identified, but for this discussion the assumption is made that surface water will be obtained from the Little Susitna River. February, March, and April are the only months when the above withdrawals might have an impact on average Little Susitna flow. During the periods of late winter low flows, public supply use could require up to 13 percent of Little Susitna flow in a worst case scenario of a 100-year, 30-day low flow of 8 cfs. In a normal year, however, approximately 5 percent of river flow would be required for resort public supply use. The impact these withdrawals could have on the Little Susitna River is primarily related to fisheries, a topic addressed by ADF&G.

Mitigating measures for public water supply withdrawals include:

1) On or off-site public water storage for use during abnormally low flows at times of high demand

2) Water conservation programs

3) Ground-water wells

4) Use water from off-site sources, such as public wells, public water utilities, etc.

Snowmaking Withdrawal Impacts

The developer has proposed the use of a snowmaking system in order to have a self-reliant, world-class ski area that is not completely dependent on natural snowfall for adequate cover. Early-season snow depths generally range from 0 - 2 ft at lower elevations, marginal depths for heavy skier traffic.

To date, the developer has identified Little Susitna River streamflow for snowmaking use at a withdrawal rate of nearly 3.5 mgpd or 5.6 cfs (11.0 acre ft/day). It is not known whether this is an average, maximum, or minimum withdrawal rate, nor is the approximate snowmaking area or the means of water distribution to the snowmaking equipment known. In addition, the amount of snow produced by the system is highly dependent on equipment capacity and air temperature (i.e. colder temperatures result in greater snowmaking capacity, all other factors being equal). Consequently, specific evaluation of the snowmaking system is not possible at this time.

Assuming the above 5.6 cfs withdrawal rate is an average for peak snowmaking periods, during a normal early season of October, November, and December, snowmaking demands would equal 4.0, 8.9, and 14.3 percent, respectively, of the monthly Little Susitna average flows. As a worst case, using the lowest flows on record for the early-season period, snowmaking demands would equal 10.7 percent, 22.4 percent, and 31.6 percent for October, November, and December, respectively. Snowmaking withdrawals may or may not have an adverse impact on surface water resources. In October and November it is less likely that snowmaking demands would heavily impact Little Susitna flows, while late winter snowmaking in February or March might require too much water when streamflow is at an annual low.

The developer may have to coordinate water use for snowmaking with DLWM and ADF&G flow reservation needs, as well as with weather and streamflow conditions to ensure adequate water remains in the Little Susitna River.

Mitigating measures for snowmaking impacts include:

1) Use Government Creek for snowmaking in addition to the Little Susitna River

2) Install storage ponds at strategic locations that can be accessed by the snowmaking system - these ponds would contain water diverted to them during periods of pre-season high flows

3) Use ground water to augment snowmaking

4) Time withdrawals to coincide with periods of higher flows

5) Use water from off-site public water sources

Other Water Use Impacts

Water may also be necessary for golf course irrigation or ski slope vegetation planted by the developer. These water demands will normally be made during spring, summer, and fall when streamflow in the Little Susitna and its tributaries is higher. The developer has not provided state officials with water-use figures for other demands, but it is anticipated that withdrawals for the other uses will not significantly impact surface water resources during the non-winter months.

Snowmaking Impacts on Runoff

The addition of artificial snow to ski slopes could significantly increase the runoff to local ski area streams beyond that occurring from natural snowpack runoff. Not only is the quantity of runoff affected by the addition of artificial snow, but the spring snowmelt period normally lasts longer because of increased snow depths. According to one study (Colorado Ski Country USA, 1986), an average of 78 percent of the artificial snow applied to a slope will return to the stream as runoff. The study did not differentiate between water that returned to the stream via surface runoff, with that amount of water returning via the slower ground-water system. To put this another way, approximately 78 percent of the water taken from the stream(s) during snowmaking actually returns to the stream(s) in the spring and summer.

Again, the lack of a detailed snowmaking plan precludes specific potential impact evaluations and mitigating recommendations. The developer will presumably want enough snow for good skiing when the area opens for the season. Depending on ground cover, grooming, and slope packing techniques, the proposed ski area will need up to 2-3 ft of compacted snow for adequate slope cover.

As a possible worst case estimate, if 2 ft of artificial snow (approximately equal to 12 in. of water) is applied to the entire 3645 acre ski area, then a total of 2843 acre feet of water would be available as runoff during spring snowmelt (using the Colorado Ski Country USA 78 percent return figure). A typical snowmelt period is from late April to late June or about 60 days. Therefore, the total water yield from the artificial snow alone would equal an additional 24 cfs for a 60-day period over the entire ski area drained by nine tributary streams. This amount of runoff is less than 12 percent of the average May flow and 3.5 percent of the June flow in the Little Susitna River at the USGS gaging site. Potential impacts to the area tributaries and smaller drainages include: (1) flooding, (2) slope and channel erosion, (3) local landslide or slumps, (4) erosion to roads or ski area structures, and (5) increased sedimentation.

Snowmaking impacts to runoff can be mitigated by a well-engineered erosion control plan that is based on sound site-specific hydrologic studies. Features of such a plan can include proper sizing of drainage structures, runoff storage ponds, and attempting to minimize alterations to a stream's natural channel, among other alternative erosion control measures.

Ski Slope Vegetation Removal Impacts on Runoff

A potentially major impact to surface water in and adjacent to the proposed ski area is the increased runoff generated from slopes cleared of vegetation. Below 2500-2700 ft elevation, ski runs will have to be cleared and groomed for optimum skiing conditions. When vegetation is cleared, less water from snow goes to evaporation and plant growth, and more water returns to the stream as runoff. A Colorado Ski Country USA (1986) report found that cleared runs increased the water yield by up to 112 percent. Most of the vegetation for the Colorado study was forest, where the Government Peak slopes contain mostly tall alder and willow, and lesser cottonwood, birch, and spruce, so the amount of increased runoff may not be the same. In addition, soil conditions below 2700 ft at the proposed ski area are mostly glacial and vegetation removal could affect these soils and their runoff properties more severely. All that can be said now is that any vegetation removal will probably result in increased runoff to the affected streams. The amount of runoff and potential site-specific impacts cannot be determined without a detailed ski area plan.

Careful soil and vegetation studies combined with well-designed ski runs are first steps to mitigating the impacts caused by slope clearing. The developer should attempt to keep as much of the well-rooted vegetation as possible and include immediate revegetation of the disturbed slopes as a part of an erosion control plan. To accommodate the increased runoff that will likely result, the developer can ensure that vegetated buffer zones are left alongside all streams, and that drainages, culverts, etc. are properly sized and routed; runoff storage ponds will also help in minimizing peak runoff events. Monitoring water quantity and quality before, during, and after facility construction is important so that impacts to the local hydrology are defined more completely.

Other Runoff Impacts

Paved parking lots, roof tops, and any other structure that prevents runoff infiltration will increase surface water yield. The developer can include zones within or adjacent to the above facilities where runoff is allowed to enter the ground naturally instead of being channeled directly to surface drainages and streams.

Surface Water Quality Impacts

Potential impacts to the quantity and quality of surface water resulting from the proposed Hatcher Pass alpine ski area are shown on Table 8. The most probable water quality impact associated with both the construction and operational phase of the ski area is increased sediment loading. Combellick and Reger (1988) state that the basal till which comprises most of the lower slopes in the proposed ski area has a high silt content and low permeability, making slopes susceptible to failure. Consequently, the potential for erosion and debris-flows activity and subsequent sediment loading in surface waters is high where: (1) the natural vegetation is removed, (2) surface drainage is modified, or (3) cut-and-fill construction occurs.

Ground Water Quantity Impacts and Mitigations

Extraction of relatively large quantities of ground water may result in undesirable effects upon both surface and ground-water resources. When large production wells or clusters of wells are placed near streams, ground-water extraction may result in the following impacts: (1) reduction of ground-water recharge to gaining reaches of the stream; (2) increased stream recharge to the aquifer in losing reaches; or (3) reversal of the natural hydraulic gradient, resulting in the conversion of gaining reaches to losing reaches. Large production wells or clusters of wells may affect local ground-water resources by: (1) dewatering the production aquifer; (2) reducing the recharge contributed by the production aquifer to other aquifers; or (3) reversing or exaggerating the natural hydraulic gradients.

These potential negative effects could result in a decrease in surface water flow, decreases in available drawdown in nearby wells, or both. The mitigation of these potential impacts is best achieved by appropriate planning measures based on a thorough understanding of the hydrogeology of the area. Wells should be located to avoid unacceptable dewatering effects. This may involve multiple smaller-capacity wells rather than a minimum number of larger-capacity wells. Ground water should be extracted from an area large enough to minimize undesirable impacts at specific locations. Finally, ground-water users whose supplies are unavoidably depleted may be offered the opportunity for incorporation into the ski area's water supply.

Table 8. Potential impacts to surface water quality and quantity resulting from the Hatcher Pass Alpine ski area resort development.

Potential impact	Potential source	Potentially impacted stream	Reference
-change in water temperature	-groundcover & riparian vegetation removal	-small tributary streams, especially on golf course	
	-thermal discharges	-small tributary streams	
-change in depth of water	-increased sediment, erosion &/or deposition	-small tributary streams & Little Susitna River	
	-instream construction activities	- "	
-change in quantity of stream-flow	-increased runoff from impervious surface areas, disturbed slopes, artificial snow areas	-small tributary streams & Little Susitna River	
	-irrigation of golf course	-small tributaries	
	-decreased streamflow fm snowmaking	-Little Susitna River	
-change in velocity of water	-irrigation of golf course	-small tributary streams	
	-increased runoff from impervious surface areas, disturbed slopes, artificial snow areas	-small tributary streams & Little Susitna River	-Colorado Ski Country USA (1986)
-change in turbidity/total suspended sediment	increased sediment load due to:		
	-ski lift & ski run construction & maintenance	-small tributary streams & Little Susitna River	-Colorado Ski Country USA (1986); Molles & Gosz (1980)
	-road construction	- "	
	-building construction	- "	
	-sand and gravel removal from stream	- "	
	-filling in/modifying stream channels & stream banks	- "	
	-pond construction	- "	
	-modifying slope drainage	- "	
	-groundcover and riparian vegetation removal	- "	-Combellick & Reger (1988)
	-golf course construction	- "	
	-airport construction	- "	
	-blasting	- "	
	-stripping of topsoil	- "	
	-in-stream developments: culverts, water intake structures	- "	
-change in dissolved oxygen	-increased nutrient and bacteria load from sewage lagoons	-Little Susitna River	
-change in nitrogen & phosphorus compounds	-increased nutrient load from sewage lagoons	-Little Susitna River	Molles & Gosz (1980)
	-fertilizer on golf course and ski runs	-small tributary streams	
	-increased nutrient load from horse wastes	- "	

Table 8. (continued)

Potential impact	Potential source	Potentially impacted stream	Reference
-change in pH, alkalinity, hardness, cations, anions, salinity	-road salting	-tributaries & Little Susitna River	-Molles & Cosz (1980); Cosz (1977)
	-increased nutrient load from sewage lagoons	- "	
	-on-site solid waste disposal	- "	
-change in heavy metals	-meltwater & storm water runoff, especially from impervious surfaces, parking lots (auto exhaust particulates), and snow dumps	-tributaries & Little Susitna River	-Molles & Cosz (1980); Moore, Gosz, and White (1978)
	-on-site solid waste disposal	-"	
-change in bacteria colonies	-sewage lagoon	-Little Susitna River	-Cosz, Moore, and White (1978)
-change in chlorinated compounds and detergents	-sewage lagoon	-Little Susitna River	
-introduction of biocides	-herbicides and fungicides on golf course	-small tributary streams	
	-other pesticides	- "	
-introduction of synthetic hydrocarbons	-fuel spills and fuel tank leaks	-small tributary streams & Little Susitna River	
	-petroleum products in meltwater and storm water runoff from parking lots, machinery & equipment maintenance areas, airplane fueling areas, ski lift areas	- "	
	-on-site solid waste disposal	- "	

Ground-water Quality Impacts and Mitigations

Potential impacts to ground-water quality attributable to the construction and operation of the ski resort are summarized in Table 9. These include changes in temperature, nutrients, physical characteristics, inorganics, organics, and biological activity. The primary potential sources of the impacts include sewage lagoons, waste disposal sites, fuel storage sites, the golf course, horse barns, and contaminated surface water. These sources are of concern because the natural flow of ground water is to the south towards existing wells.

Potentially, the most problematic source of ground-water contamination, a sewage lagoon or community-scale subsurface disposal field, could be mitigated by construction of a sewage treatment plant with discharge to surface water. Mitigation of other problems would entail (1) common engineering, construction and waste- or product management precautions; (2) monitoring to determine effectiveness of mitigation measures; and (3) avoiding hydrogeologically sensitive areas (shallow water tables or near-surface bedrock) and nearby well fields during placement of potential sources of contamination.

CONCLUSIONS

Based on the limited Mitsui and Company development plans available at this writing, and using existing hydrologic data presented in this report, the following preliminary conclusions are made about water resources and potential impacts to these resources as a result of the Hatcher Pass Ski Area development.

(1) Local streams, in particular the Little Susitna River, should adequately meet the public water-supply needs of the proposed ski area.

(2) Snowmaking water withdrawals may have adverse impacts on Little Susitna River streamflow during the winter low flow months. Alternate means of providing water for snowmaking during these low flow periods should be explored.

(3) It is highly probable that the addition of artificial snow to ski slopes and vegetation removal for skiing and resort facilities will result in increased surface water runoff. Flooding, erosion, and increased sedimentation are the most significant impacts of increased runoff; an approved erosion control plan that is in effect before construction begins could help mitigate these impacts.

(4) A streamflow monitoring program on selected streams should be undertaken. Such a monitoring program will help enable Mitsui and the state to assess potential impacts to streamflow and to develop mitigation measures.

(5) There is no baseline water quality data on turbidity, heavy metals, nitrogen and phosphorus compounds, fecal coliform bacteria counts, biocides, chlorinated compounds, detergents, or synthetic organic hydrocarbons for surface waters in and near the proposed ski area. Baseline suspended sediment data are available for the Little Susitna River drainage.

Table 9. Potential impacts to the water quality of ground water resulting from the Hatcher Pass Alpine Ski Area resort development.

Potential impact	Potential source
-change in water temperature	-sewage lagoon -on-site solid waste disposal
-change in nitrogen/phosphorus compounds	-increased nutrient load from sewage lagoons -fertilizer on golf course -increased nutrient load from horse waste -on-site solid waste disposal
-change in pH, alkalinity, hardness, cations, anions, salinity, total dissolved solids	-road salting and salt storage -on-site solid waste disposal -increased nutrient load from sewage lagoons -irrigation of golf course
-change in heavy metals	-meltwater & storm water runoff especially from impervious surfaces, parking lots and snow dumps -on-site solid waste disposal
-change in biochemical oxygen demand, chemical oxygen demand	-sewage lagoon -on-site solid waste disposal
-change in bacteria colonies	-sewage lagoon
-change in chlorinated compounds and detergents	-sewage lagoon
-introduction of biocides	-pesticides including herbicides and fungicides
-introduction of synthetic hydrocarbons	-fuel spills and fuel tank leaks -on-site solid waste disposal -petroleum products in storm water runoff from parking lots, machinery & equipment maintenance areas, airplane fueling areas, ski lift areas

(6) Pre- and post-project monitoring of water quality constituents at three sites on the Little Susitna River is needed: (a) upstream of project related activities; (b) at the USGS gaging station, mi 8.5 Fishhook-Willow Road; and (c) downstream of the Government Creek mixing zone which would allow potential surface water-quality impacts to be evaluated.

7) The absence of large-capacity wells in the area limits the availability of hydrogeologic data specifically relevant to the proposed project. However, it is evident that ample water is available for typical domestic use and sufficient resources are potentially available to supply the project.

8) The area contains at least two separate aquifer systems; an upper system composed of unconsolidated glacially-derived deposits, and a lower one consisting of consolidated clastic sedimentary rocks.

9) The upper aquifer has significantly higher potential for yielding large quantities of ground water to properly designed wells. The bedrock aquifer may only be sufficiently productive to supply water for domestic or light commercial purposes.

10) Higher well yields may be encountered in unconsolidated deposits near streams in the area, which may contribute to ground-water recharge of shallow sand-and-gravel aquifer systems, especially those near the Little Susitna River where outwash deposits have been mapped.

11) The potential for encountering shallow bedrock, and relatively low well yields, occurs throughout the study area, especially near the Little Susitna River where it crosses Edgerton Parks Road.

12) The maximum thickness of the unconsolidated aquifer system in the area is at least 100 ft. Unconsolidated deposits should be expected to be generally thinner on the north side of the study area, nearer Government Peak.

13) There is no baseline water quality data to assess the effects the proposed ski area project may have on ground-water quality.

14) Pre- and post-project ground-water quality monitoring in and adjacent to the proposed ski area allow the potential effects of development to be assessed.

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