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DIVISION OF GEOLOGICAL AND GEOPHYSICAL SURVEYS

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Report of Investigations 92-2
RECHARGE AREA EVALUATION FOR
MOONLIGHT SPRINGS, NOME, ALASKA

By

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Division of Water

In cooperation with the City of Nome



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By
J.A. Munter,¹ M.A. Maurer,¹ M.G. Inghram,¹ and W.A. Petrik¹

INTRODUCTION

The City of Nome, Alaska, obtains 100 percent of its water supply from an underground collection gallery at Moonlight Springs. The springs are located at the foot of Anvil Mountain, approximately 6 km (3.7 mi) inland from Nome and the Bering Sea. Recent gold exploration and mining near the springs have created increased interest in understanding the factors that govern the existence of the springs and in identifying recharge areas to protect from contamination or diminution of spring flows.

This 2-yr investigation was initiated in September 1989 to define the source, watershed, and recharge area of Moonlight Springs. The area's paucity of wells necessitated using an indirect approach to identify the source and recharge areas of the springs. The approach consisted of the following:

1. Reviewing pertinent literature to obtain historic information about the springs;
2. Conducting geologic reconnaissance to determine the structure and composition of rocks forming the Moonlight Springs aquifer;
3. Sampling area wells, streams, and springs to determine water-quality variations and draw inferences about probable flow paths of ground water;
4. Sampling local surface and ground waters for hydrogen and oxygen isotopes to use as tracers to infer water origin;
5. Establishing a water budget for the Moonlight Springs area by measuring precipitation, snowpack water equivalent, streamflow and spring discharge to estimate the size of the Moonlight Springs recharge area; and
6. Delineating primary and secondary recharge area boundaries for the Moonlight Springs recharge area using available hydrogeological data.

ACKNOWLEDGMENTS

We acknowledge the City of Nome and the Alaska Department of Environmental Conservation for partial funding for this project. We thank Ott/HDR Engineering, Inc., especially Scott Wheaton, for providing project notes and work files from previous work in the area. Roy Ireland and Stan Carrick (Division of Water) assisted with field data collection. Tenneco Corporation and Alaska Gold Company provided geological information, and the City of Nome, especially Robert E. Russell, provided information about the Nome water system. Special appreciation is extended to Nome area property owners who graciously allowed access to their property for data collection. Rick Noll (Division of Water) and Scott Wheaton (Ott/HDR Engineering, Inc.) reviewed the report and provided many useful comments.

PREVIOUS INVESTIGATIONS

Gold mining activity has occurred in and near Nome since the original gold rush at the turn of the century, and ore deposits have been mined elsewhere on the Seward Peninsula. As a result, numerous geological reports

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are available for the Seward Peninsula (Robinson and Stevens, 1984). The most detailed published geological map of the Moonlight Springs area was done by Hummel (1962). Additional geological information was provided by a Tenneco geological exploration team (T. Eggleston, written commun., 1990).

Moonlight Springs is mentioned anecdotally as a source of water in early accounts of Nome's development. Waller and Mathur (1960), and Lohr (1957) sampled Moonlight Springs, and six miscellaneous discharge measurements taken at the springs between 1954 and 1976 are stored in the U.S. Geological Survey's database. As-built diagrams of the subsurface collection gallery constructed in 1968 are also available.

Ott Water Engineers, Inc. (1982) and General Electric (1980) collected data to better understand the hydrogeology of the springs and Ott Water Engineers, Inc. (1982) showed a generalized recharge area for the springs that encompassed Anvil Mountain above an elevation of about 150 m (500 ft). Waller and Mathur (1960) noted that the springs emerged from 'flat-bedded limestone.' R&M Consultants, Inc. (1981) discussed the hydrogeology of the springs and mapped a "possible sensitive area" for the catchment area of the springs.

GEOLOGICAL SETTING

Nome is located on the south coastal plain of the Seward Peninsula adjacent to Norton Sound, Bering Sea. The coastal plain extends approximately 5.6 km (3.5 mi) inland to the base of a series of hills and ridges that rise to 550 m (1,800 ft) above sea level (sheet 1). The ridges are oriented predominantly north-south and separated by south-flowing primary drainages. The Nome area [including the Kigluaik Mountains located about 48 km (30 mi) north of Nome] was subjected to alpine glaciation during the Pleistocene Epoch (Péwé, 1975).

Paleozoic to Tertiary metamorphic and igneous rocks in the Nome area are folded into broad anticlines and synclines (sheet 2). Several faults occur in the study area, including a major northeast-trending fault in the Anvil Creek valley. Outcrops are typically found near ridgetops. Lower elevation areas are commonly mantled with colluvium, alluvium, glacial deposits, coastal plain sediments, and placer mine spoils. A geologic cross section through Moonlight Springs and Anvil Mountain is shown in figure 1.

Nome lies in the region of discontinuous permafrost. Except for mined areas and alluvial sands and gravels associated with streams and rivers, the coastal plain is underlain by continuous or near-continuous permafrost. Uplands contain mixed frozen and unfrozen areas. Early 20th century underground miners working in coastal-plain sediments near Nome occasionally encountered "live" water capable of flooding their underground operations. Coastal plain deposits in the near vicinity of Moonlight Springs were extensively mined, but the extent of mining is undefined because the detailed maps are not available to the public.

Moonlight Springs is located at a sharp physiographic boundary between flat coastal-plain topography and the base of the slope leading up to Anvil Mountain. Small water seeps emanate from unconsolidated deposits that mantle the lower slopes of Anvil Mountain. Most water is collected by perforated underground pipes and discharged to the City of Nome and an overflow pipe and drainage ditch at Moonlight Springs. Other ground-water discharges occur at scattered locations along a 500-m-long lateral zone extending west and northwest from Moonlight Springs at elevations of about 130 to 140 m above sea level. Regionally, other springs occur on the southern Seward Peninsula.

DATA COLLECTION

A reconnaissance-level geologic examination of the Moonlight Springs area was conducted to confirm and supplement Hummel's (1962) map. Numerous strikes and dips of rock structure were obtained on Anvil Mountain, records from drill holes in Anvil Creek valley were reviewed, and fault locations were examined. Stereoscopic aerial photographs (scale 1:12,000) were used to interpret geologic features. Shallow holes were excavated at rain-gage sites to examine surficial deposits.

Water samples were collected at 19 sites (sheet 1). Methods used to sample, analyze, and report water quality are given by Munter and others (1990) and Munter and others (1991). Ground-water and selected surface-

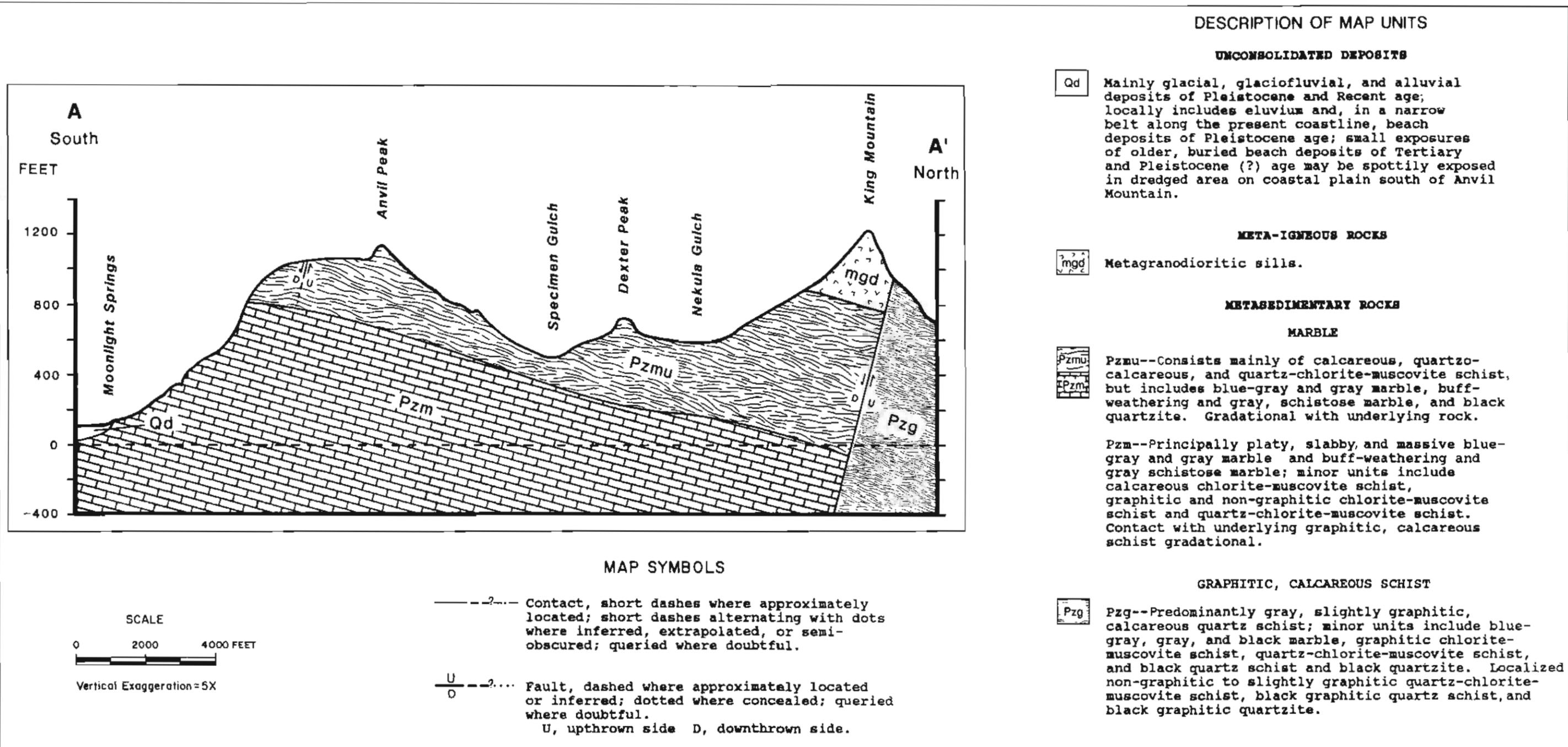


Figure 1. Geologic cross section through Moonlight Springs and Anvil Mountain (see sheet 2 for location of the cross-section line). Map unit descriptions after Hummel, 1962.

water samples from 12 of the 19 sites were analyzed for common dissolved ions, trace metals, radioactivity, and total iron. Appendix A contains measurements of field parameters made at the time of sample collection, and complete analytical results are provided in appendix B.

Stable isotopes of hydrogen (common hydrogen – ^1H ; and deuterium – ^2H) and oxygen (common oxygen – ^{16}O ; heavy oxygen – ^{18}O) were sampled at 18 sites shown on sheet 1 and at precipitation gage 8 (sheet 2). The radioactive isotope of hydrogen, tritium – ^3H , was sampled at 12 sites (Q-1, Q-3 to Q-8, Q-15 to Q-17, and I-18) shown on sheet 1 and at precipitation gage 8 (sheet 2). Tritium analyses and stable hydrogen ($^2\text{H}/^1\text{H}$) and oxygen ($^{18}\text{O}/^{16}\text{O}$) ratio data are provided in appendix B.

Appendix C contains the results of the quality assurance evaluation of data collected during this investigation. Appendix D contains a summary of historic water-quality data from other reports and from the U.S. Geological Survey water-quality database.

To determine Moonlight Springs' overflow discharges and water temperature, a digital stage recorder and thermistor were installed in the Moonlight Springs collection gallery on September 21, 1989. Total discharges were determined by adding total water-use figures to spring-overflow-discharge measurements. Total water-use figures were obtained from the Nome Joint Utilities (app. E). Water-main leaks that may use up to 60,000 gal per day are unaccounted for and not quantifiable (R.E. Russell, 1992, oral commun.). Overflow discharge measurements were determined using the water stage in the collection gallery and a rating curve developed by gaging overflow discharges at different flow rates and stage heights.

From June 6, 1990, through August 16, 1990, a stream-gaging station using a float-driven digital stage recorder was established on Anvil Creek near Moonlight Springs (sheet 2). Discharge measurements were taken on June 8 and 9, 1990, at five Anvil Creek locations (sheet 2). Rain gages were installed at nine locations in the area. One gage was destroyed soon after installation by excavation work (sheet 2).

On April 2, 1991, snow surveys were conducted at three locations shown on sheet 2. Snowpack depth and water equivalent were determined using methods described by Soil Conservation Service (1973). A depth-integrated snow sample was collected at map no. I-18 (see sheet 1) and melted at room temperature for tritium and stable isotopic analyses.

A time-averaged precipitation sample was collected by a precipitation collector installed next to rain gage number 8 (see sheet 2) on May 29, 1991, and retrieved September 25, 1991. The collector was constructed from a 19.5-cm-diam plastic funnel connected to a 4.1 plastic jug by 4.8 mm (inside diam) thick-walled silicone tubing. The jug was partially buried to limit evaporative loss, and the unshielded funnel was mounted approximately 0.5 m above the ground surface. The precipitation sample was submitted for tritium and stable isotopic analyses.

Precipitation and air-temperature data for the Moonlight Springs area was obtained from National Oceanic and Atmospheric Administration (1989-91). These data are gathered at the Nome Airport about 1.6 km (1 mi) northwest of Nome and about 4.8 km (3 mi) south of Moonlight Springs.

RESULTS

GEOLOGY

Fieldwork conducted during this investigation generally confirmed previous geologic mapping. Marble outcrops upslope of Moonlight Springs dip an average of 16° N-NW with a dip range from 6° to 32° in the same general direction. The marble is truncated along the east side of the Anvil Creek valley by a major fault or fault system. The fault is not well exposed; its nature and location are approximately shown on sheet 2. Upland areas covered by tundra vegetation are generally underlain by permafrost, and upland elluvian soils are commonly expressed as solifluction lobes.

HYDROLOGY

Figures 2, 3, and 4 show Moonlight Springs discharges for the period of record and average water use, water temperature, air temperature, and precipitation information. Figure 2 compares Nome area water use with total Moonlight Springs discharge. A seasonal pattern in total spring discharge is evident, with low flows occurring in mid-April. In April 1990, the low flow discharge almost reached average water use for that month. The April 1991 low flow discharge was higher than that of 1990. The brief period of record (approximately 2 yr) precludes correlation of annual low flow discharge rates to specific climatic conditions at Nome. Average water use by the City of Nome increased slightly during the study period (fig. 2).

Figure 3 shows the relationship between precipitation, water temperature, and discharge. Spring flows declined during the winter when precipitation fell as snow. Summer spring discharges typically rise within a few days of large precipitation events, and decline during lengthy periods of scant precipitation. Moonlight Springs discharges peaked 19 days after the two largest precipitation events in 1990.

As shown on figure 3, the temperature of Moonlight Springs water increases within 1 day after large summer precipitation events. This results when relatively warm summer rain water mixes with ground water and moves rapidly to Moonlight Springs.

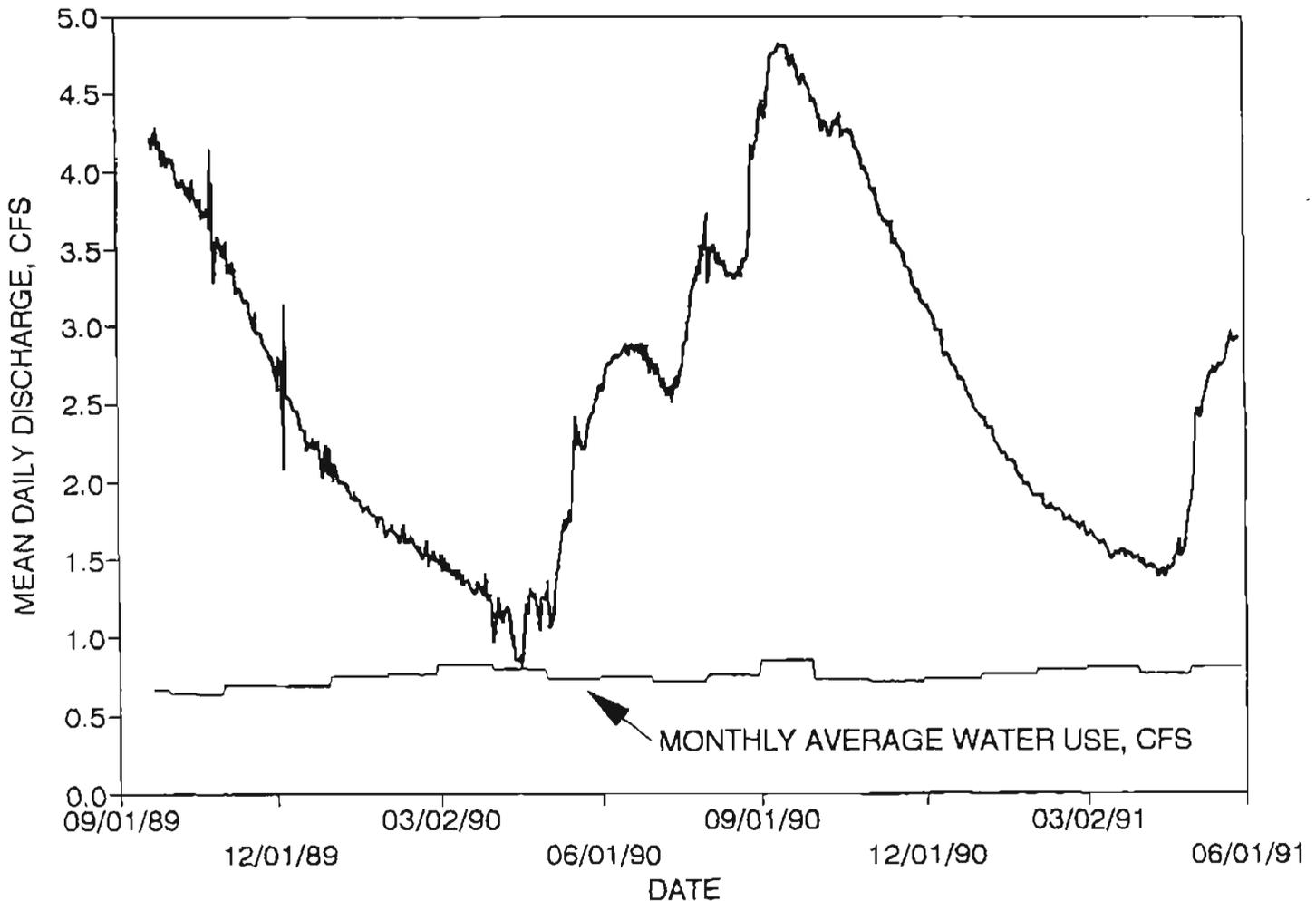


Figure 2. Total Moonlight Springs discharge and average total water use by the City of Nome.

Water temperature and discharge are closely related, as shown in figure 3. Water temperature dropped sharply in early May, at about the same time that discharge increased, probably as the result of a sudden influx of cold snowmelt. The temperature-discharge relationship reversed during summer, when precipitation is warmer than ground water. Peak summer water temperatures coincided with two major precipitation events mentioned previously and with associated increases in discharge. Water temperature increased during the summer and peaked in mid- to late August. Annual peak discharge occurred shortly thereafter.

Figure 4 shows a close relationship between discharge and air temperature, especially during spring snowmelt. Specifically, as the average daily air temperature rose above 0° C in early May, discharge began its sudden seasonal rise due to rapid transmittal of snowmelt water to Moonlight Springs. The close relationship between air temperature and discharge continued until early June, when most snow had melted.

Figure 5 shows a close relationship between air temperature and water temperature at Moonlight Springs. At the onset of breakup in 1990 and 1991, water temperature dropped significantly at the same time that the average daily air temperature climbed above freezing. This is attributed to the addition of relatively cold snowmelt.

Figure 6 is a plot of Anvil Creek discharge data collected at the gaging site (sheet 2) and precipitation data. Anvil Creek shows a typical rainfall runoff relationship with peak discharges following precipitation events by

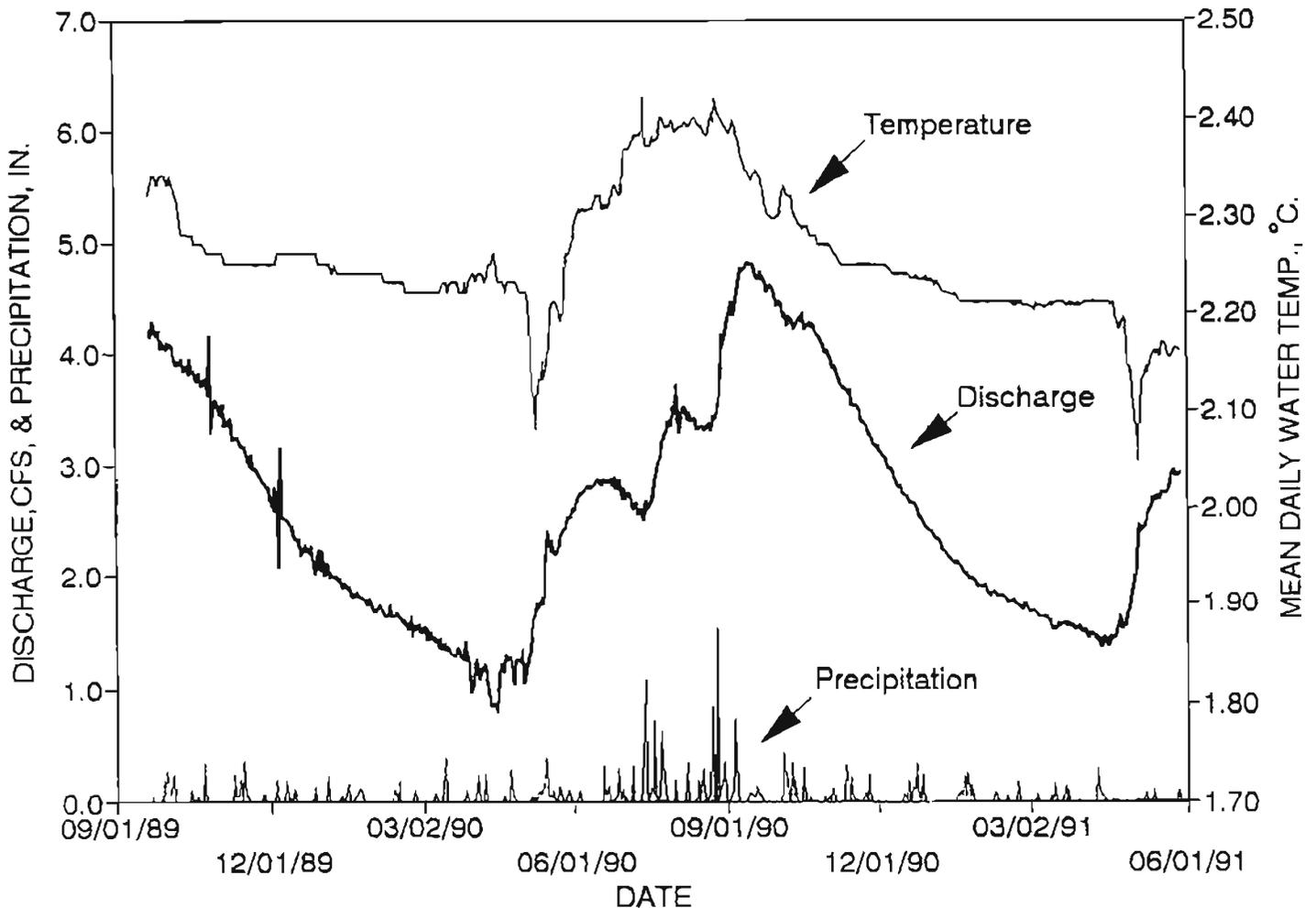


Figure 3. Total Moonlight Springs discharge, water temperature at the collection gallery, and daily precipitation at Nome Airport.

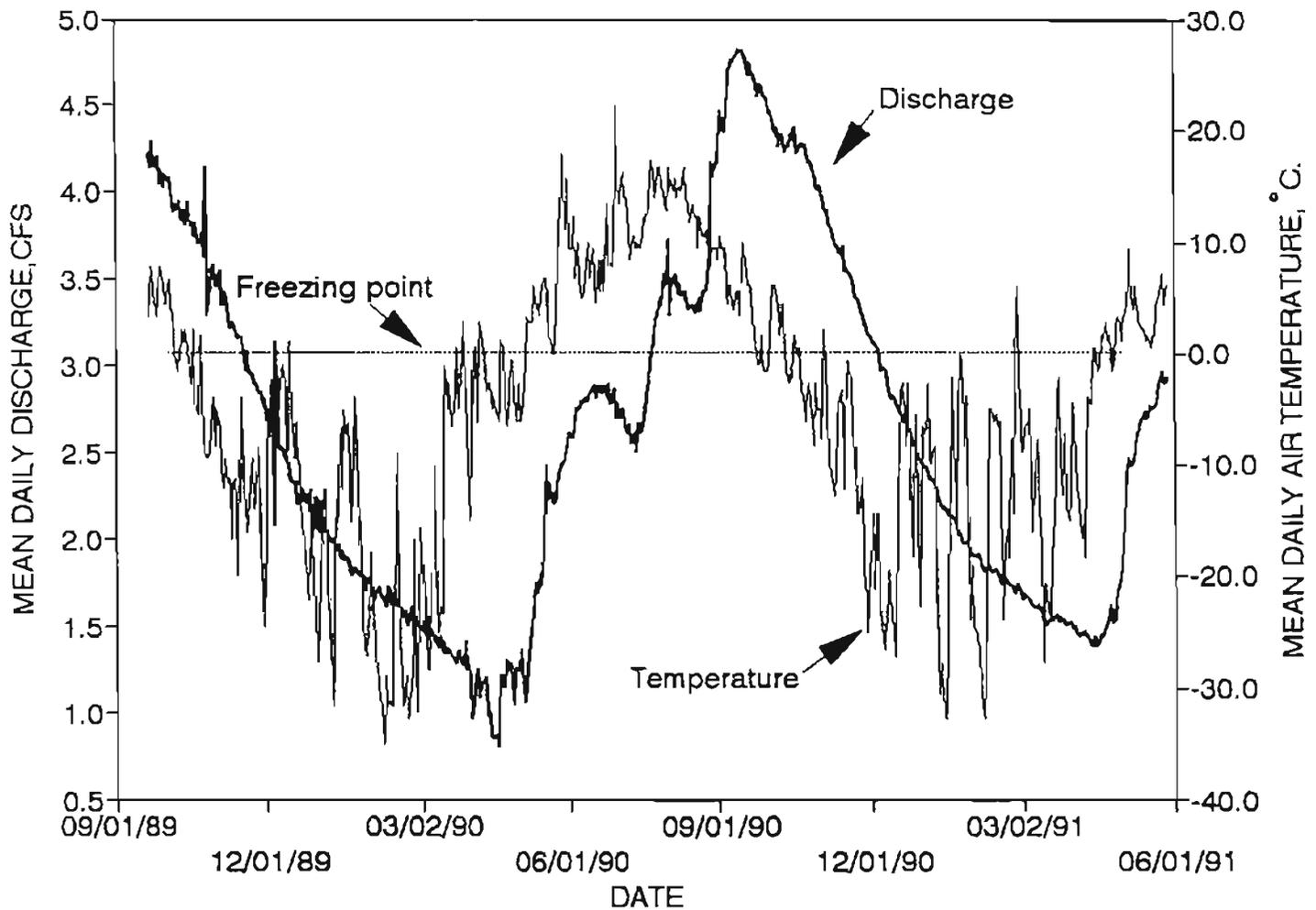


Figure 4. Total Moonlight Springs discharge and mean daily air temperature at Nome Airport.

approximately 2 days instead of the 19-day lag for Moonlight Springs. The falling limb of the hydrograph is likewise much steeper.

Six discharge measurements (table 1) were made at different locations in Anvil Creek on June 8 and 9, 1990, to identify areas where the stream may be gaining or losing ground water. No significant amount of rain fell in the Anvil Creek basin for at least 3 days before the discharge was measured. Stream measurements indicate that Anvil Creek gains ground-water above the gage site and loses water below the gage site. This water loss does not appear to be related to Moonlight Springs discharges because the stream gage is at a slightly lower elevation than Moonlight Springs. It is common for streams such as Anvil Creek to lose water to alluvial gravels where they exit confined valleys and flow onto broad lowland plains.

Table 2 shows precipitation data collected near Moonlight Springs (see sheet 2 for locations) during 1990 and 1991. The data show that average summer precipitation in the Anvil Mountain area is similar to precipitation at the Nome Airport.

SNOW SURVEYS

Table 3 shows results of three snow survey site measurements made on the hillside above Moonlight Springs. Five snowcore samples were collected at each site. In addition, one core measurement was taken

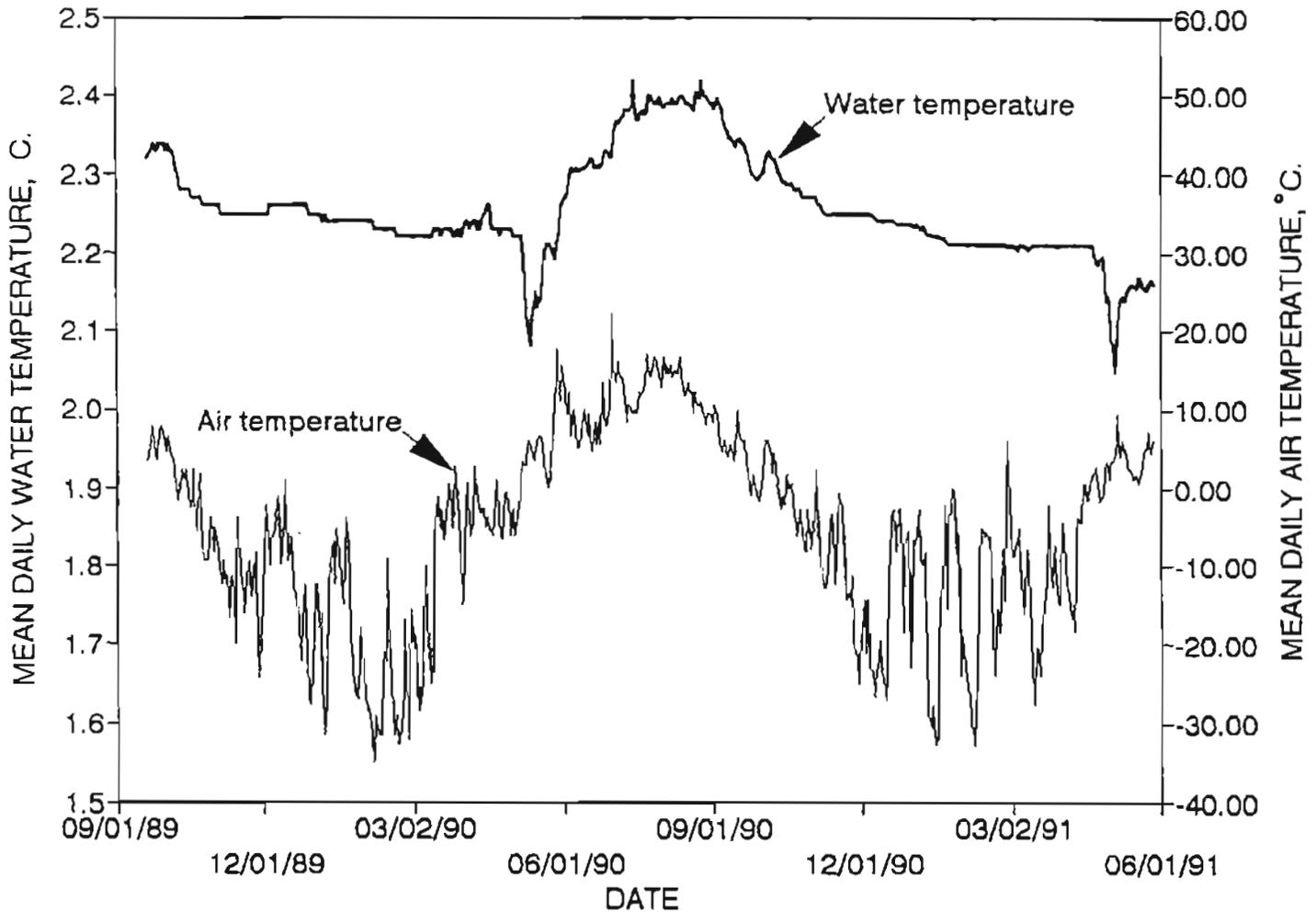


Figure 5. Daily average water temperature for Moonlight Springs collection gallery and daily average air temperature for Nome Airport.

approximately 50 ft from site SS-3, where snow was unusually deep, to determine the ranges of snow thickness and water content in the area. Visual observations made by the snow survey team indicate that wind significantly affected snowpack thickness in the Anvil Mountain area.

WATER QUALITY AND ISOTOPES

WATER ANALYSIS RESULTS AND DISCUSSION

All water sample collected during this investigation are classified as fresh. The specific conductance of water is an indication of its degree of mineralization. The specific conductance of Moonlight Springs and nearby surface and ground waters ranges from 47 to 651 $\mu\text{S}/\text{cm}$, which is considered acceptable for domestic and other water uses. Three ground-water sites, the spring near Lindblom Creek, Beltz School well, and M. Desalernos well, have a conductivity value $>400 \mu\text{S}/\text{cm}$. Schist is predominant near the spring near Lindblom Creek, and the two wells are in unconsolidated coastal plain deposits that appear to have been placer mined.

Iron and manganese are the only inorganic constituents in the sampled water with concentrations that exceed Alaska Drinking Water Standards [Alaska Department of Environmental Conservation (ADEC), 1991]. The highest dissolved iron concentration is 5.1 mg/l in water from a well adjacent to the Snake River at the Teller Highway. The highest dissolved manganese concentration is 1.4 mg/l from a seep in Specimen Gulch.

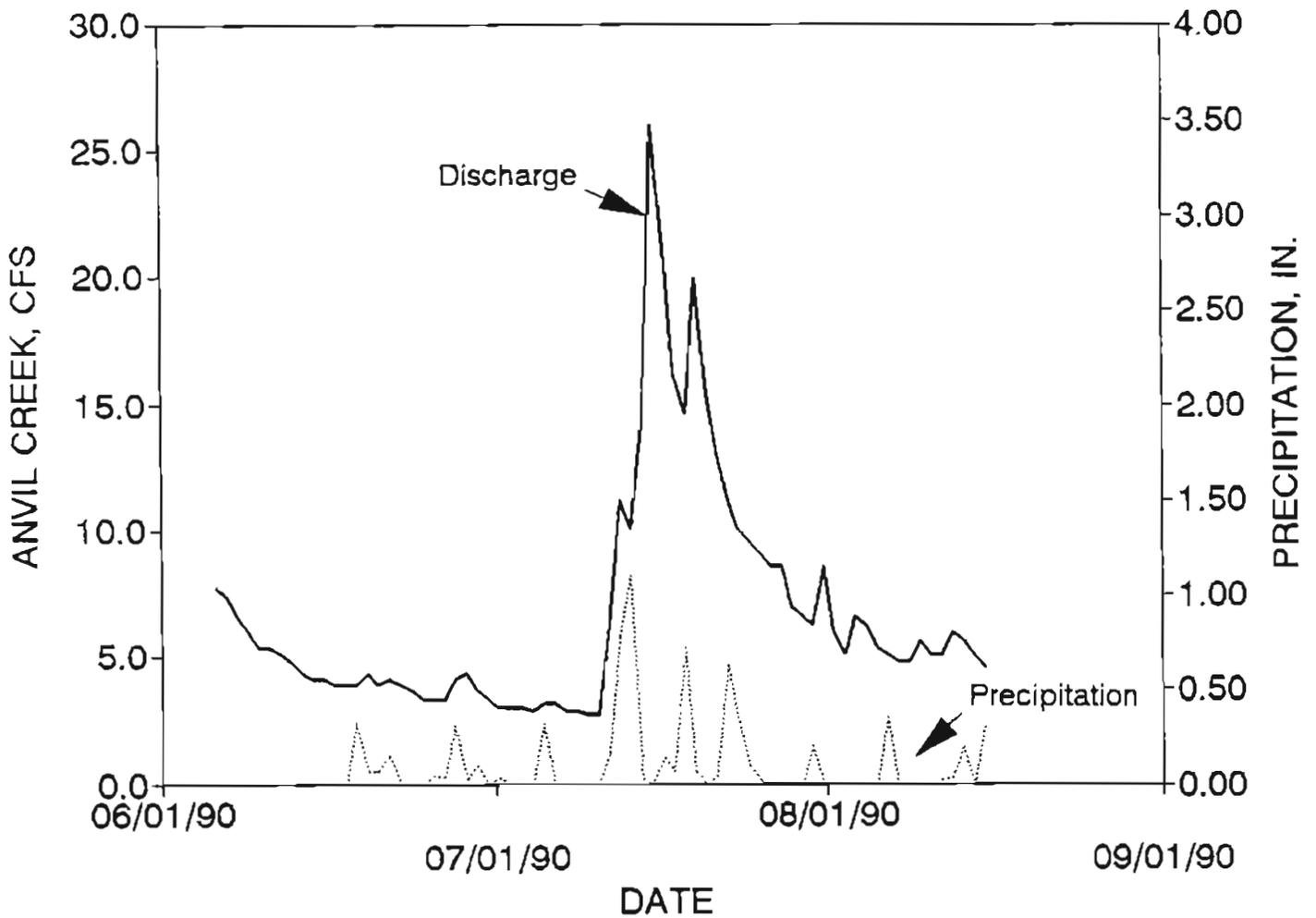


Figure 6. Anvil Creek discharge and daily precipitation at Nome Airport (see sheet 2 for gage location).

Table 1. Miscellaneous discharge measurements for Anvil Creek, Nome, Alaska (see sheet 2 for site locations)

Site number	Location	Discharge (cfs ^a)	Date
1	Near Nome/Teller Highway	4.2	June 8, 1990
2	At recording gage site	6.7	June 8, 1990
3	Halfway from gage to Glacier Road	5.6	June 8, 1990
4	Approximately 1/3 mi downstream from Glacier Road	4.9	June 8, 1990
5	Approximately 1/2 mi above Glacier Road	1.2	June 9, 1990

^a1 cfs = 28.317 l/s

Table 2. Precipitation data collected near Moonlight Springs during 1990 and 1991 (see sheet 2 for site locations)

Gage location	Precip. (cm) 6/9/90-9/25/90	Precip. (cm) 5/29/91-9/25/91
1	36.20 ^a	20.16
2	36.83 ^a	18.18
3	38.10 ^a	19.53
4	Destroyed	
5	31.12	20.40
6	37.16 ^a	22.47
7	30.48	19.61
8	35.89	0.00
9	34.77 ^a	18.18
Averages	35.07	19.79
Nome WSO	30.45	20.73
Factor	1.15	0.95
Avg. factor	1.05	

^aGage full at end of sampling period, value represents minimum precipitation.

Table 3. Snow survey measurements, Anvil Mountain area, Nome, Alaska (see sheet 2 for site locations)

Date: April 2 1991
 Samplers: Carrick, Ireland
 Weather: Clear, winds NE @ 25 mph, temperature 20-30°F
 Site conditions: All sites affected by wind

Site	Snow depth (in.)	Water equivalent (in.)	Density (%)
SS-1	67.0	32.7	49.0
	54.0	23.5	44.0
	37.5	15.3	41.0
	25.0	9.5	38.0
	<u>17.0</u>	<u>6.5</u>	<u>38.0</u>
Average	40.1	17.5	42.0
SS-2	25.0	11.3	45.0
	29.0	11.7	40.0
	48.0	19.3	40.0
	46.5	19.5	42.0
	<u>29.5</u>	<u>11.0</u>	<u>37.0</u>
Average	35.6	14.6	40.8
SS-3	50.5	19.1	38.0
	73.5	28.5	39.0
	41.5	15.0	36.0
	26.5	8.7	33.0
	<u>41.0</u>	<u>14.3</u>	<u>35.0</u>
Average	46.6	17.1	36.2
Single measurement near site SS-3	126.5	43.0	34.0

Gross alpha and gross beta radioactivity of Moonlight Springs and nearby waters is very low, (<0.3 to 3.7 pCi/l). The Alaska Drinking Water Standard is 15 pCi/l for gross alpha radioactivity and 50 pCi/l for gross beta radioactivity (ADEC, 1991).

The accuracy of dissolved ion values, based on the calculated cation-anion balance, shows that all 17 samples have an acceptable sample error of <4 percent. All surface and ground waters examined are classified as calcium-bicarbonate waters. Results of the common dissolved ion analyses from selected ground-water sites are shown in figure 7. Note the subtle but consistent difference between water from areas where schist is the predominant rock type and water from areas where marble is the predominant rock type. Water from schist areas typically has higher sulfate levels and lower calcium and bicarbonate levels.

Tritium values for ground and surface waters occur in a relatively narrow range (app. A). Thirteen samples from Moonlight Springs and nearby ground waters had a mean of 26 tritium units (TU). Rainfall had a tritium value of 12 TU. A water sample derived mainly from a nearby melting snowfield (sample code N-SW-2, map number Q-8) and a snow core sample (sample code SS, map number I-18) had tritium values of 7.3 TU and 5 TU, respectively. These data are compared to historical data described below.

Stable isotope values do not correlate with the orographic position of sample sites or the distances inland from the coast. Two sites sampled in June and September 1990, Moonlight Springs and S. Barron well, showed slightly lower $^2\text{H}/^1\text{H}$ values in June. Rainfall and snow have the lowest $^2\text{H}/^1\text{H}$ values, and rainfall also has a lower $^{18}\text{O}/^{16}\text{O}$ value than snow. Seasonal variation in the stable isotope composition of precipitation apparently accounts for at least some variation in stable isotope composition among sites.

HISTORICAL DATA VALIDITY

Dissolved-constituents

Sample error, based on the cation-anion balance, was calculated on 19 historical analyses (app. D) to determine data accuracy. Sample error is less than 10 percent for historical analyses, except for a sample labelled 'Spring, 150 ft S 45° E of overflow.' Therefore, 18 samples are considered accurate and useable for data comparison.

Tritium

Eight previously collected tritium values (appx. D) were verified on unpublished laboratory reports provided by Ott/HDR Engineering, formerly Ott Water Engineers Inc., to determine data validity. Transformed tritium values were 1.4 to 2.2 TU lower than those reported by Ott (1982). Because these small differences do not affect overall data validity, the data are deemed useable for comparison.

HISTORICAL DATA COMPARISONS

Specific conductance measured at Moonlight Springs during this investigation is similar to historical specific conductance values. At the 95-percent confidence level, there is no statistical difference between the mean specific conductance for this investigation (mean=258 $\mu\text{S}/\text{cm}$, range= 248-269 $\mu\text{S}/\text{cm}$, n=3 samples) and historical investigations (mean=233 $\mu\text{S}/\text{cm}$, range= 200-271 $\mu\text{S}/\text{cm}$, n=13 samples). The consistency in specific conductance values indicates an insignificant change in the dissolved mineral composition of Moonlight Springs water during the past 37 yr.

Moonlight Springs tritium values determined in this investigation ranged from 23 to 26 TU, compared to 47 to 64 TU for Moonlight Springs and nearby springs in Ott (1982). These data indicate tritium content in Moonlight Springs water has decreased by 50 percent in 10 yr. The lack of a 1982 tritium value for rainfall precludes a definitive interpretation of the data. Since Moonlight Springs receives at least part of its recharge from local rainfall, the drop in tritium is probably related to the worldwide trend of decreasing tritium in rainfall due to less atmospheric nuclear-weapons testing (Hem, 1985).

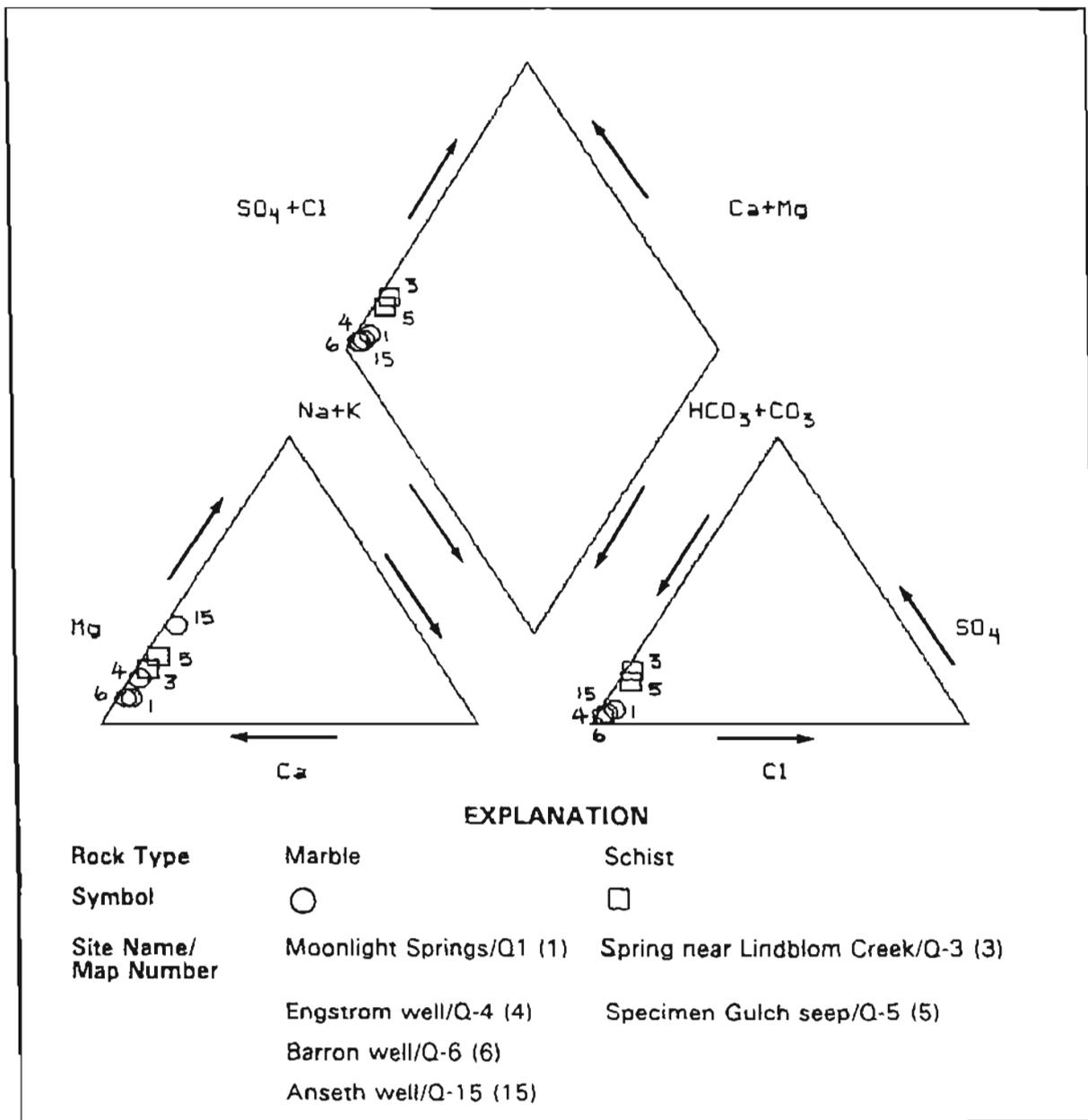


Figure 7. Trilinear diagram of Nome area ground waters (after Piper, 1944).

WATER BUDGET

A water budget is an accounting of water movement into and out of an area. For the land area that contributes water to Moonlight Springs, a water budget equation for a discrete time interval, such as a year, is written as follows:

$$R + S = Q/A + ET + RO \pm dS$$

Where R = rainfall (m);
 S = snowmelt (m);
 Q = total Moonlight Springs discharge (m³);
 A = Area of basin (m²);
 ET = evapotranspiration (m);
 RO = surface runoff (m); and
 dS = changes in water in storage (m).

The water budget equation must be applied to a specific geographic area, usually a discrete drainage basin. In this analysis, the basin that supplies Moonlight Springs, although not well defined, is the basin of interest. This analysis assumes that any ground water flowing beneath or around Moonlight Springs into or through the coastal plain is not part of the basin that supplies Moonlight Springs. The water budget equation can be solved for the basin area:

$$A = Q / (R + S - ET - RO \pm dS)$$

Terms on the right side of the equation can be measured or estimated for the period May 29, 1990, to May 28, 1991, and an estimate for the size of the Moonlight Springs recharge area is therefore calculable.

Rainfall for the period May 29 to October 1, 1990 was 30.8 cm (12.1 in.) at the Nome Airport. During this period, at least 115 percent as much precipitation fell in the Anvil Mountain area as at the airport (table 3). Applying this correction factor, approximately 35.4 cm (13.9 in.) of rainfall is available for the water budget calculation.

The average water equivalent at three snow survey sites on the hillside above Moonlight Springs was 41.7 cm (16.4 in.) on April 2, 1991, which we assume represents total water available from snowmelt on the southwest flanks of Anvil Mountain. This amount is significantly higher than the recorded precipitation [17.5 cm (7.3 in.)] at Nome between October 1, 1990, and April 2, 1991. Prevailing wind direction causes considerable snow drifting on the southwest slopes of Anvil Mountain, which results in higher average precipitation than measured at the Nome Airport.

Moonlight Springs' discharge for the water budget year was 2,540,000 m³ (671 million gal) of water. This includes water used by the City of Nome and overflow discharges.

Although evapotranspiration in the Nome area has not been studied in detail, Patric and Black (1968) calculated (using the Thornthwaite method) an evapotranspiration value of 35.9 cm (14.1 in.) for Nome.

Surface runoff values for the Moonlight Springs recharge area are difficult to estimate. Much of the upland area of Anvil Mountain consists of tundra or frost-rived rock surfaces. Field observations suggest that surface runoff does not occur on rock surfaces due to the high permeability of surficial materials. Near-water quality sample site Q-8, for example, surface runoff from upslope melting snowfields disappeared into the ground downslope from the sample site but upslope from a vegetation-bare rock slope. In addition, ditches dug during early mining activities ring Anvil Mountain and tend to intercept runoff and promote infiltration and recharge because of their slight hydraulic gradients and capacity to store water until it infiltrates. An initial estimate of the size of the recharge area can be made assuming that all recharge to Moonlight Springs occurs in areas where surface runoff is negligible. Correspondingly, surface runoff is assigned a value of zero in the water balance equation. The estimated size of the recharge area calculated using this assumption is smaller than the true recharge area if areas of nonzero runoff exist in the recharge area.

The discharge of Moonlight Springs was nearly the same on May 28, 1991, as it was on May 29, 1990, which indicates that changes in water storage within the Moonlight Springs basin are probably negligible. A value of zero was assumed for dS.

Using these values (converted to consistent units) in the water balance equation yields a recharge area (A) of 6.2 km² (2.4 mi²). Because this estimate is inherently uncertain due to simplifying assumptions used to make the calculations, it provides only a general indication of the size of the Moonlight Springs recharge area.

INTERPRETATIONS

MOONLIGHT SPRINGS GROUND-WATER FLOW SYSTEM

The marble unit that crops out on the Anvil Mountain hillside above Moonlight Springs is interpreted to be the primary aquifer for Moonlight Springs. Where exposed, the marble exhibits sufficient jointing and fracturing for adequate permeability for the transmission of water to Moonlight Springs. Although development of Moonlight Springs has destroyed most natural ground discharges, the geology of the site and the geochemistry of the water strongly suggest that water is emitted from the marble aquifer at a depth of a few meters and flows through unfrozen gravels into perforated pipes leading to the collection gallery. The geology of the site may have been better exposed prior to construction of the collection gallery, leading to Waller and Mathur's (1962) comment that the source of Moonlight Springs water was "flat-bedded limestone."

Geochemical data suggest that the water has not flowed through appreciable thicknesses of schist, and regional geologic maps suggest that the marble aquifer is probably not continuous to distant recharge areas. The geochemical data therefore further support the conceptual model that most recharge occurs locally in the marble aquifer near Moonlight Springs.

Ground-water discharge at and near Moonlight Springs occurs at various locations along a 500-m-long ground-water discharge zone at the base of the Anvil Mountain slope, elevation about 130 to 140 m. This suggests that Moonlight Springs is not part of a single conduit-type system that has been postulated near the major fault in Anvil Creek valley. Water emanating in the Moonlight Springs area is probably doing so because it is blocked from flow towards Anvil Creek by the lower permeability schist on the west side of the fault.

The location of Moonlight Springs at the distinctive boundary between the coastal plain deposits and the lower slopes of Anvil Mountain is probably controlled by local topography and geology. The springs exist because the site's land surface is lower than the potentiometric surface of the Moonlight Springs aquifer, which results in an upward hydraulic head gradient and discharge of ground water. High hydraulic heads in the aquifer may be partially sustained by lower permeability permafrost zones or surficial deposits near the springs that tend to block ground-water discharges.

Sheet 2 shows the Moonlight Springs watershed boundary drawn on the basis of topographic contours. Watershed boundaries are normally drawn for surface water drainage systems, but an examination of the Moonlight Springs watershed is useful for illustrative and comparative purposes. The area of the Moonlight Springs watershed is 0.28 km² (0.11 mi²), which is only 4.6 percent of the calculated area of the Moonlight Springs recharge area. This indicates that Moonlight Springs actually receives water from an area much larger than the watershed depicted on sheet 2.

Delineation of the Moonlight Springs recharge area is complicated by the absence of direct information about the configuration of the water table or potentiometric surface of the Moonlight Springs aquifer beneath Anvil Mountain. Nevertheless, examination of surficial geological features allows separation of areas based on their relative likelihood of being in the recharge area. Sheet 2 shows the approximate boundaries for primary recharge areas, secondary areas, and low or non-recharge areas.

PRIMARY RECHARGE AREA BOUNDARY

The primary recharge area (sheet 2) was approximated using the following criteria:

1. The area is directly upslope or updip from Moonlight Springs;

2. Marble is the predominant rock type;
3. Dips of rocks are favorable for directing flow towards Moonlight Springs; and
4. Surface runoff is low to nonexistent because of abundant outcrops or frost-rived rocky slopes.

Most water that infiltrates the primary recharge area probably emerges at Moonlight Springs. The primary recharge area encompasses 4.6 km² (1.8 mi²). A local ground-water flow system is inferred to exist within the primary recharge area to provide relatively short (<3 km) flow paths for ground water.

SECONDARY RECHARGE AREA BOUNDARY

The secondary recharge area boundary encompasses an area that contributes less water to Moonlight Springs or is less likely to discharge to the springs at all. This area has a greater potential for surface runoff because of the presence of permafrost soils or less permeable rocks, or both. Because the area is farther from the springs, water entering the secondary recharge area has a greater likelihood of discharging somewhere other than Moonlight Springs. These alternate discharge areas could be small hillside seeps or springs, base flow discharges to Anvil Creek or Nome River or its tributaries, or discharges to Norton Sound through or beneath coastal-plain sediments. Although the western edge of the secondary recharge area does not exactly follow the mapped location of the fault in Anvil Creek valley (the fault location is somewhat uncertain), the western edge of the secondary recharge area is considered to be at the marble/schist contact at the fault. The primary and secondary recharge areas together encompass 18.7 km² (7.2 mi²).

LOW OR NON-RECHARGE AREAS

Areas outside the secondary recharge area boundary shown on sheet 2 have low to zero potential for contributing to Moonlight Springs. Areas at elevations lower than the springs do not contribute to spring discharges because water cannot flow upgradient, and distant areas of the Seward Peninsula are unlikely to contribute to spring flows. Data indicate that we cannot exclude highland areas between the Snake and Nome Rivers from contributing to Moonlight Springs discharges. The persistence of the springs through the winter and their location springs relatively near the coast suggest that some regional flow component may be present.

The recharge areas shown on sheet 2 pertain to ground-water flow systems that currently exist. Should large-scale mining activity near the mapped boundaries result in major changes to local ground-water flow systems, the location of recharge areas would also change. For example, a large open-pit type mine at the major fault in Anvil Creek valley could dewater part of Moonlight Springs aquifer and intercept flow that currently discharges at the springs.

CONCLUSIONS

The indirect methods used in this study provide evidence to support several conclusions about the aquifer that supplies water to Moonlight Springs:

1. The annual discharge of Moonlight Springs occurs as relatively high spring, summer, and fall flows with rapid response times to snowmelt and rainfall events. Winter flows exhibit a relatively continuous decline from high fall flows to low flows just prior to spring breakup in late April to early May. These winter flows represent a gradual depletion of the Moonlight Springs aquifer. It is unknown if these flows are from a regional flow system or if they represent depletion of the same local flow system providing most of the summer flow.
2. The travel time of some water from its recharge to its discharge at the springs is short, from a few hours or less to a day or two. This indicates that some recharge probably occurs within several hundred meters of the springs and has a relatively short flow path. The aquifer's fractured nature allows relatively rapid

ground-water flow compared to typical unconsolidated aquifers. Most water probably follows a longer flow path, as shown by peak discharges that follow precipitation events by 19 days.

3. A general indication of the size of the Moonlight Springs recharge area can be obtained by calculating a water budget. These calculations indicate that about 6.2 km² (2.4 mi²) are necessary to support the annual discharge of Moonlight Springs. This area is slightly larger than Anvil Mountain. Although the annual water budget approach contains inherent uncertainties that could cause significant errors in the recharge area calculations, the calculations are useful because they indicate that a plausible conceptual model for Moonlight Springs flow system does not require input of water from distant areas.
4. Approximate locations of primary and secondary recharge areas are based on their relative likelihood for contributing water to Moonlight Springs. The locations of recharge boundaries are considered to be most probable, based on existing information. Although the recharge area boundaries are indirectly inferred, they could be used to guide water management or land-use decisions that might affect spring flows.
5. In April 1990, Moonlight Springs discharges declined to flow rates that were approximately equal to the rate of water use by the City of Nome. The overflow pipe went dry during parts of at least 11 nonconsecutive days during that time. The water-supply pipe to the City of Nome ran in a less than pipe-full condition April 15 to 17, 1990. Spring discharges did not drop to such low levels during 1991. Continuous flow data are not available for previous years to determine the typical range of low flow conditions during the spring. Moonlight Springs may be inadequate to meet water-use demands if demands increase during late winter low-flow conditions or if spring flows are reduced. Water demands on Moonlight Springs could increase through ordinary growth in water use or through water line leaks.
6. Protection of Moonlight Springs flows should consider disturbance of both recharge areas and permafrost areas near the springs. Maintenance of the permafrost regime could be important in maintaining aquifer pressure that creates flowing conditions into the collection gallery.

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Appendix A. Water-quality field measurements made by Alaska Division of Water, 1990-1991.

MAP NO.	SITE	DATE	TIME	WATER TEMP. (°C)	DISCHARGE (CFS)	SPECIFIC CONDUCTANCE (μS/CM)	pH
Q-1	Moonlight Springs, at overflow channel	06/06/90	0920	2.1	2.0	269	8.4
Q-2	B. Hill well	06/06/90	2016	3.5		241	7.2
Q-7	Anvil Creek	06/06/90	1350	7.8	7.9	198	8.9
Q-8	Anvil Peak	06/07/90	1050	4.1	0.004 (est.)	47	7.8
Q-3	Spring near Lindblom Creek	06/07/90	1426	2.6		418	7.4
Q-4	R. Engstrom well	06/07/90	2000	1.6		248	7.5
Q-9	Little Creek	06/08/90	0935	3.3	0.2	320	7.9
Q-5	Specimen Gulch seep	06/08/90	1454		0.003	283	7.0
Q-6	S. Barron well	06/08/90	1920	3.3		273	8.2
I-10	Extra Dry Creek	06/09/90	1130	3.6		110	8.1
Q-16	Beltz School Well	09/24/90	1538	3.1		508	7.6
Q-7	Anvil Creek	09/25/90	1420	2.8	9.6	233	7.9
Q-15	L. Anseth well	09/25/90	0946	1.9		361	8.2
Q-17	M. Desaternos well	09/25/90	1350	5.6		651	7.2
Q-1	Moonlight Springs, at overflow channel	09/26/90	1030	2.2		257	7.3
Q-1	Moonlight Springs (at pumphouse)	04/02/91	1730	4.5		248	7.4

APPENDIX A
WATER-QUALITY FIELD MEASUREMENTS

MAP NO.	SITE	DATE	TIME	ALKALINITY (MG/L as CaCO ₃)	DISSOLVED OXYGEN (MG/L)	DISSOLVED OXYGEN SATURATION %	TURBIDITY (NTU)
Q-1	Moonlight Springs, at overflow channel	06/06/90	0920	116	13.2	95	0.2
Q-2	B. Hill well	06/06/90	2016	90			
Q-7	Anvil Creek	06/06/90	1350	84	11.7	98	1.1
Q-8	Anvil Peak	06/07/90	1050	15	10.2	79	
Q-3	Spring near Lindbiom Creek	06/07/90	1426	175	1.9	14	
Q-4	R. Engstrom well	06/07/90	2000	163			
Q-9	Little Creek	06/08/90	0935	146	7.7	57	0.4
Q-5	Soecimen Gulch seep	06/08/90	1454	112	3.1	22	
Q-6	S. Barron well	06/08/90	1920	204			
I-10	Extra Dry Creek	06/09/90	1130		12.7	98	0.3
Q-16	Beltz School well	09/24/90	1538	274			
Q-7	Anvil Creek	09/25/90	1420		12.9	97	
Q-15	L. Anseth well	09/25/90	0946	200			
Q-17	M. Desalernos well	09/25/90	1350	310			
Q-1	Moonlight Springs, at overflow channel	09/26/90	1030	132	13.1	94	
Q-1	Moonlight Springs, at pumphouse	04/02/91	1730	105	7.0	54	

**APPENDIX B
WATER-QUALITY ANALYTICAL RESULTS**

Samples were analyzed by one of the following laboratories:

State of Alaska Division of Water
(formerly Division of Geological & Geophysical Surveys),
Water Quality Laboratory, Fairbanks, Alaska

Core Laboratories, Casper, Wyoming

University of Miami, Tritium Laboratory, Miami, Florida

Southern Methodist University Stable Isotope Laboratory, Dallas, Texas

Appendix B
Key to water-quality sampling sites shown on sheet 1

Map no.	Sample code	Site	Sampling date	Analytical report
Q-1	N-GW-1	Moonlight Springs	06/06/90	p. 26-30; 41; 44; 52
Q-1	MS	Moonlight Springs	09/26/90	p. 31-35; 46; 53
Q-1	OF; PH	Moonlight Springs	04/02/91	p. 36-40; 48; 54
Q-2	N-GW-2	B. Hill well	06/06/90	p. 26-30; 41; 44; 52
Q-3	N-GW-3; N-GW-4	Spring near Lindblom Creek	06/07/90	p. 26-30; 44; 52
Q-3	LS	Spring near Lindblom Creek	09/25/90	p. 53
Q-4	N-GW-5	R. Engstom well	06/07/90	p. 26-30; 44; 52
Q-5	N-GW-6	Specimen Gulch seep	06/08/90	p. 26-30; 44; 52
Q-6	N-GW-7	S. Barron well	06/08/90	p. 26-30; 44; 52
Q-6	BW	S. Barron well	09/24/90	p. 53
Q-7	N-SW-1	Anvil Creek	06/06/90	p. 26-30; 52
Q-7	AC; AB	Anvil Creek	09/24/90	p. 53
Q-8	N-SW-2	Anvil Peak	06/07/90	p. 26-30; 44; 52
Q-9	N-SW-3	Little Creek ¹	06/08/90	p. 26-30; 41; 44; 52
I-10	N-SW-4	Extra Dry Creek	06/09/90	p. 52
I-11	N-SW-5	Newton Gulch	06/09/90	p. 52
I-12	N-GW-8	New Year Gulch	06/09/90	p. 52
I-13	N-GW-9	Nekula Gulch	06/09/90	p. 52
I-14	N-GW-10	East Anvil Mountain	06/09/90	p. 52
Q-15	AN	L. Anseth well	09/25/90	p. 31-35; 46; 53
Q-16	BS; FH	Beltz School well	09/24/90	p. 31-35; 46; 53
Q-17	MD	M. Desalernos well	09/25/90	p. 31-35; 46; 53
I-18	SS	Anvil Peak (snow sample)	04/02/91	p. 48; 54
8 ²	Precipitation gage, Nome	Near Moonlight Springs	09/26/91	p. 50; 54

¹Misidentified as Anvil Creek tributary on p. 41 and p. 44 of this report.

²See sheet 2.

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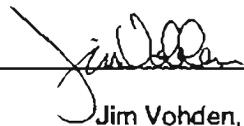
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date: June 11, 1990

Sample	Calcium	Magnesium	Sodium	Potassium
N-GW-1	47.5	3.02	2.4	0.33
N-GW-2	32.6	6.09	5.2	0.51
N-GW-3	72.2	10.9	3.1	0.37
N-GW-4	71.1	10.8	3.1	0.33
N-GW-5	54.3	6.51	1.8	0.38
N-GW-6	39.9	7.80	1.9	0.53
N-GW-7	72.0	4.70	1.9	0.32
N-SW-1	25.8	5.89	1.9	0.33
N-SW-2	5.89	0.40	0.9	0.08
N-SW-3	58.2	5.75	3.0	0.15
N-GWB-3	<0.01	<0.01	<0.1	<0.01
Units	mg/l	mg/l	mg/l	mg/l
EPA Method	AES 0029	AES 0029	273.1	258.1
Detection Limit	0.01	0.01	0.1	0.01
RPD	5.8	1.0	0.1	0.5
% Recovery	99	100	100	104

Approved By _____



Jim Vohden, Chemist

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Submitted By: Mary Maurer

Date: June 11, 1990

Sample	Arsenic	Mercury	Cadmium	Lead	Aluminum
N-GW-1	<4	<2	<5	<30	7
N-GW-2	10	<2	<5	<30	180
N-GW-3	8.5	<2	<5	<30	14
N-GW-4	9.0	<2	<5	<30	12
N-GW-5	<4	<2	<5	<30	10
N-GW-6	<4	<2	<5	<30	14
N-GW-7	<4	<2	<5	<30	9
N-SW-1	<4	<2	<5	<30	16
N-SW-2	<4	<2	<5	<30	70
N-SW-3	<4	<2	<5	<30	17
N-GWB-3	<4	<2	<5	<30	<5
Units	µg/l	µg/l	µg/l	µg/l	µg/l
EPA Method	206.3	245.1	AES 0029	AES 0029	AES 0029
Detection Limit	4	2	5	30	5
RPD	5.7	•	•	•	4.9
% Recovery	91	99	108	101	96

* Relative Percent Difference (RPD) cannot be calculated when values are less than the detection limit.

Approved By Jim Vohden Date 30 NOV 90
 Jim Vohden, Chemist

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Sample	Iron	Iron (total)	Manganese	Manganese (total)
N-GW-1	52	80	8.0	8.0
N-GW-2	5150	6650	72	92
N-GW-3	470	510	26	30
N-GW-4	460	460	24	26
N-GW-5	79	130	6.0	6.0
N-GW-6	210	650	1450	1580
N-GW-7	52	110	9.0	11
N-SW-1	52	52	<5	<5
N-SW-2	52	52	<5	6.0
N-SW-3	52	79	6.0	7.0
N-GWB-3	<30	<30	<5	<5
Units	$\mu\text{g/l}$	$\mu\text{g/l}$	$\mu\text{g/l}$	$\mu\text{g/l}$
EPA Method	AES 0029	AES 0029	AES 0029	AES 0029
Detection Limit	30	30	5	5
RPD	3.8	5.8	1.0	5.3
% Recovery	100	101	97	97

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Sample	Calcium	Magnesium	Sodium	Potassium
AN	50.6	16.7	2.6	0.70
BS	87.0	12.7	5.8	0.95
FB	<DL	<DL	<DL	<DL
FH	86.4	12.7	5.7	0.96
MD	110	19.3	3.8	1.26
MS	46.1	2.80	2.2	0.29
Units	mg/l	mg/l	mg/l	mg/l
EPA Method	AES 0029	AES 0029	273.1	258.1
Detection Limit	0.01	0.01	0.1	0.01
RPD	1.7	1.1	2.0	4.4
% Recovery	91	99	104	103

Approved By Jim Vobden Date 2 JAN 91
 Jim Vobden, Chemist

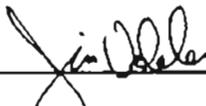
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Sample	Fluoride	Chloride	Nitrate (as N)	Sulfate
AN	0.41	3.15	0.10	8.12
BS	0.52	3.61	<DL	0.41
FB	<DL	<DL	<DL	<DL
FH	0.52	3.55	<DL	0.44
MD	0.58	4.11	0.06	70.5
MS	0.28	3.04	0.11	5.88
Units	mg/l	mg/l	mg/l	mg/l
EPA Method	300.0	300.0	300.0	300.0
Detection Limit	0.01	0.01	0.02	0.01
RPD	1.2	2.9	9.5	1.3
% Recovery	93	93	87	87

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Sample	Aluminium	Arsenic	Barium	Cadmium	Chromium
AN	65	<DL	26	<DL	<DL
BS	100	<DL	51	<DL	<DL
FB	<DL	<DL	<DL	<DL	<DL
FH	99	<DL	51	<DL	<DL
MD	121	7	47	<DL	<DL
MS	60	<DL	20	<DL	<DL
Units	ug/l	ug/l	ug/l	ug/l	ug/l
EPA Method	AES 0029	206.3	AES 0029	AES 0029	AES 0029
Detection Limit	5	4	5	5	5
RPD	2.2	4.0	3.5	•	•
% Recovery	102	102	98	88	94

* Relative Percent Difference (RPD) cannot be calculated when values are less than the detection limit.

Approved By Jim Vohden Date 25 AN 91
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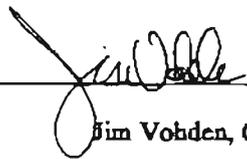
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: September 28, 1990

Sample	Copper	Lead	Mercury	Zinc
AN	<DL	<DL	<DL	<DL
BS	239	<DL	<DL	10
FB	<DL	<DL	<DL	<DL
FH	241	<DL	<DL	10
MD	<DL	<DL	<DL	10
MS	<DL	<DL	<DL	<DL
Units	ug/l	ug/l	ug/l	ug/l
EPA Method	AES 0029	AES 0029	245.1	AES 0029
Detection Limit	10	50	2	10
RPD	1.1	•	•	0.9
% Recovery	107	104	106	106

* Relative Percent Difference (RPD) cannot be calculated when values are less than the detection limit.

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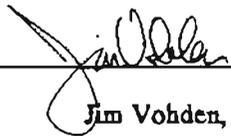
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: September 28, 1990

Sample	Iron	Iron (total)	Manganese	Manganese (total)
AN	<DL	68	<DL	<DL
BS	50	222	807	827
FB	<DL	<DL	<DL	<DL
FH	<DL	210	802	807
MD	128	480	12	13
MS	50	82	<DL	5
Units	ug/l	ug/l	ug/l	ug/l
EPA Method	AES 0029	AES 0029	AES 0029	AES 0029
Detection Limit	50	50	5	5
RPD	1.8	1.2	2.7	1.0
% Recovery	95	92	101	96

Approved By _____



Jim Vohden, Chemist

Date 2 JAN 91

State of Alaska
Division of Geological and Geophysical Surveys
Water Quality Laboratory
 209 O'Neill University of Alaska Fairbanks Fairbanks, Alaska 99775 (907)474-7713

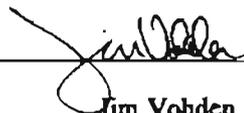
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Calcium	Magnesium	Sodium	Potassium
UT	<DL	<DL	<DL	<DL
OF	41.6	2.95	2.3	0.58
PH	42.1	2.97	2.1	0.56
Units	mg/L	mg/L	mg/L	mg/L
EPA Method	AES 0029	AES 0029	273.1	258.1
Detection Limit	0.01	0.01	0.1	0.01
RPD	0.9	0.4	2.4	0.3
% Recovery	96	98	102	109

Approved By _____



Jim Vohden, Chemist

Date 24 JUNE 91

State of Alaska
Division of Geological and Geophysical Surveys
Water Quality Laboratory
 209 O'Neill University of Alaska Fairbanks Fairbanks, Alaska 99775 (907)474-7713

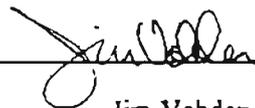
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Fluoride	Chloride	Nitrate	Sulfate
UT	<DL	<DL	<DL	<DL
OF	0.36	3.08	0.47	6.38
PH	0.34	2.95	0.46	6.38
Units	mg/L	mg/L	mg NO ₃ *N/L	mg/L
EPA Method	300.0	300.0	300.0	300.0
Detection Limit	0.01	0.01	0.02	0.01
RPD	0.1	0.1	0.1	0.2
% Recovery	96	102	90	91

Approved By



Jim Vohden, Chemist

Date 24 JUNE 91

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Division of Geological and Geophysical Surveys
Water Quality Laboratory
 209 O'Neill University of Alaska Fairbanks Fairbanks, Alaska 99775 (907)474-7713

Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Chromium	Mercury	Lead	Zinc
UT	<DL	<DL	<DL	<DL
OF	<DL	<DL	<DL	4.6
PH	<DL	<DL	<DL	4.9
Units	ug/L	ug/L	ug/L	ug/L
EPA Method	218.2	245.1	239.2	289.2
Detection Limit	1	2	1	1
RPD	2.2	2.0	9.5	5.7
% Recovery	93	92	107	99

Approved By _____

Jim Vobden

Jim Vobden, Chemist

Date 24 JUNE 91

State of Alaska
Division of Geological and Geophysical Surveys
Water Quality Laboratory
 209 O'Neill University of Alaska Fairbanks Fairbanks, Alaska 99775 (907)474-7713

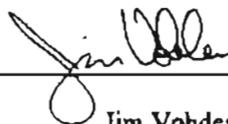
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Iron	Iron (total)	Manganese	Manganese (total)
UT	<DL	<DL	<DL	<DL
OF	<DL	<DL	<DL	<DL
PH	<DL	<DL	<DL	<DL
Units	ug/L	ug/L	ug/L	ug/L
EPA Method	AES 0029	AES 0029	AES 0029	AES 0029
Detection Limit	30	30	5	5
RPD	2.0	2.0	1.7	1.9
% Recovery	104	107	98	95

Approved By _____



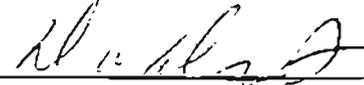
Jim Vohden, Chemist

Date 24 JUNE 91

LABORATORY TESTS RESULTS
07/20/90

JOB NUMBER: 901868		CUSTOMER: STATE OF ALASKA		ATTN: MARY MAURER	
SAMPLE NUMBER: 1	DATE RECEIVED: 06/22/90	TIME RECEIVED: 14:03	SAMPLE DATE: 06/06/90	SAMPLE TIME: 11:40	
PROJECT: MOONLIGHT SPRINGS		SAMPLE: N-GW-1D		REM:	
SAMPLE NUMBER: 2	DATE RECEIVED: 06/22/90	TIME RECEIVED: 14:03	SAMPLE DATE: 06/06/90	SAMPLE TIME: 11:34	
PROJECT: MOONLIGHT SPRINGS		SAMPLE: N-GW-1C		REM:	
SAMPLE NUMBER: 3	DATE RECEIVED: 06/22/90	TIME RECEIVED: 14:03	SAMPLE DATE: 06/08/90	SAMPLE TIME: 10:30	
PROJECT: ANVIL CREEK TRIB		SAMPLE: N-SW-3D		REM:	
SAMPLE NUMBER: 4	DATE RECEIVED: 06/22/90	TIME RECEIVED: 14:03	SAMPLE DATE: 06/08/90	SAMPLE TIME: 10:30	
PROJECT: ANVIL CREEK TRIB		SAMPLE: N-SW-3E		REM:	
SAMPLE NUMBER: 5	DATE RECEIVED: 06/22/90	TIME RECEIVED: 14:03	SAMPLE DATE: 06/06/90	SAMPLE TIME: 20:17	
PROJECT: NOME - HILL WELL		SAMPLE: N-GW-2D		REM:	
SAMPLE NUMBER: 6	DATE RECEIVED: 06/22/90	TIME RECEIVED: 14:03	SAMPLE DATE: 06/06/90	SAMPLE TIME: 20:17	
PROJECT: NOME - HILL WELL		SAMPLE: N-GW-2C		REM:	

TEST DESCRIPTION	SAMPLE 1	SAMPLE 2	SAMPLE 3	SAMPLE 4	SAMPLE 5	SAMPLE 6	UNITS OF MEASURE
Gross Alpha, total	2.4		0.0		3.7		pCi/l
Gross Alpha, total, error, +/-	2.5		1.9		2.9		pCi/l
Gross Alpha, total, LLD	0.5		0.5		0.6		pCi/l
Gross Beta, total		0.9		0.4		2.9	pCi/l
Gross Beta, total, error, +/-		1.3		1.4		1.5	pCi/l
Gross Beta, total, LLD		0.3		0.3		0.3	pCi/l

APPROVED BY: 

420 West 1st Street
Casper, WY 82601
(307) 235-5741

The data and results in this report are based on the information provided by the customer. The accuracy of the data and results is dependent on the quality of the sample and the methods used. The results are expressed in the best judgment of the laboratory. The results are not to be used for legal purposes. The results are not to be used for any other purpose without the written consent of the laboratory.



QUALITY ASSURANCE REPORT
07/20/90

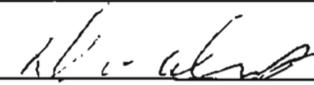
JOB NUMBER: 901868

CUSTOMER: STATE OF ALASKA

ATTN: MARY MAURER

ANALYSIS				DUPLICATES		REFERENCE STANDARDS		MATRIX SPIKES			
ANALYSIS TYPE	ANALYSIS SUB-TYPE	ANALYSIS I.D.	ANALYZED VALUE (A)	DUPLICATE VALUE (B)	RPD or (A-B)	TRUE VALUE	PERCENT RECOVERY	ORIGINAL VALUE	SPIKE ADDED	PERCENT RECOVERY	
PARAMETER: Gross Alpha, total			DATE/TIME ANALYZED: 07/20/90 12:47			QC BATCH NUMBER: 105270					
DETECTION LIMIT:			UNITS: pCi/l			METHOD REFERENCE : EPA 900.0			TECHNICIAN: PLJ		
DUPLICATE	prep	902061-5	0.2	0.3	40						
DUPLICATE	prep	901955-3	4.0	4.7	16.09						
DUPLICATE	prep	901809-8	1.0	1.0	0						

ANALYSIS				DUPLICATES		REFERENCE STANDARDS		MATRIX SPIKES			
ANALYSIS TYPE	ANALYSIS SUB-TYPE	ANALYSIS I.D.	ANALYZED VALUE (A)	DUPLICATE VALUE (B)	RPD or (A-B)	TRUE VALUE	PERCENT RECOVERY	ORIGINAL VALUE	SPIKE ADDED	PERCENT RECOVERY	
PARAMETER: Gross Beta, total			DATE/TIME ANALYZED: 07/20/90 12:57			QC BATCH NUMBER: 105274					
DETECTION LIMIT:			UNITS: pCi/l			METHOD REFERENCE : EPA 900.0			TECHNICIAN: PLJ		
DUPLICATE	prep	902061-5	3.7	3.2	14.49						
DUPLICATE	prep	901955-3	12.0	10.3	15.25						
DUPLICATE	prep	901809-8	0.6	0.7	15.38						

APPROVED BY: 

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Casper, WY 82601
(307) 235-5741

PAGE:1

NC = Not Calculable due to values lower than the detection limit

Quality Control Acceptance Criteria:

- Blanks.....: Analyzed Value less than or equal to the Detection Limit
- Reference Standards: 100 +/- 10 Percent Recovery
- Duplicates.....: 20% Relative Percent Difference, or +/- the Detection Limit
- Spikes.....: 100 +/- 25 Percent Recovery

- (1) EPA 600/4-79-020, Methods for Chemical Analysis of Water and Wastes, March 1983
- (2) EPA SW-846, Test Methods for Evaluating Solid Waste, Third Edition, November 1986
- (3) Standards Methods for the Examination of Water and Wastewater, 16th, 1985
- (4) EPA/600/4-80-032, Prescribed Procedures for Measurement of Radioactivity in Drinking Water, August 1980
- (5) Federal Register, Friday, October 26, 1984 (40 CFR Part 136)
- (6) EPA 600/8-78-017, Microbiological Methods for Monitoring the Environment, December 1978

NOTE - Data reported in QA report may differ from values on data page due to dilution of sample into analytical ranges.



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JUL 30 1990

Div. of Geological Survey
Eagle River

July 26, 1990

TRITIUM LABORATORY

Data Release #90-29
Job # 274

ALASKA DEPARTMENT OF NATURAL RESOURCES
TRITIUM SAMPLES

Purchase Order D.O. 188097

A handwritten signature in cursive script, appearing to read "H. Gote Ostlund".

H. Gote Ostlund
Head, Tritium Laboratory

Distribution:

Mary A. Maurer
ALASKA DEPARTMENT OF NATURAL RESOURCES
P.O. Box 772116
Eagle River, Alaska 99577-2116

Rosenstiel School of Marine and Atmospheric Science
Tritium Laboratory
4600 Rickenbacker Causeway
Miami, Florida 33149-1098
(305) 361-4100

Client: ALASKA DEPT. NATURAL RESOURCES
 Recvd : 90/06/20
 Job# : 274
 Final : 90/07/24

Purchase Order: D.O.18897
 Contact: Mary Maurer (907)696-0070
 1822S Fish Hatchery Road
 Eagle River, AK 99577-2116

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
N-GW-1E Moonlight Spr.	274.01	900606	1000	256	25.8	0.9
N-GW-3C Lindbloom Crk. Spr.	274.02	900607	1000	275	30.1	1.1
N-GWB-3C Lindbloom Crk. Spr.	274.03	900607	1000	274	36.8	1.3
N-GW-4C Nome Spring	274.04	900607	1000	275	30.8	1.0
N-GW-5C Engstrom'S Well	274.05	900607	1000	275	15.2	0.6
N-GW-6C Specimen Gulch	274.06	900608	1000	275	15.7	0.5
N-GW-7C Barron S. Well	274.07	900608	1000	272	14.8	0.5
N-SW-2C Anvil Peak	274.08	900607	1000	273	7.29	0.24
N-SW-3C Anvil Creek Trib.	274.09	900608	1000	259	14.8	0.5



November 28, 1990

TRITIUM LABORATORY

Data Release #90-46
Job # 288

ALASKA DEPARTMENT OF NATURAL RESOURCES
TRITIUM SAMPLES

Purchase Order D.O. 237318

A handwritten signature in cursive script, appearing to read "H. Gote Ostlund", written over a horizontal line.

H. Gote Ostlund
Head, Tritium Laboratory

Distribution:

Mary A. Maurer
ALASKA DEPARTMENT OF NATURAL RESOURCES
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Eagle River, Alaska 99577-2116

Rosenstiel School of Marine and Atmospheric Science
Tritium Laboratory
4600 Rickenbacker Causeway
Miami, Florida 33149-1098
(305) 361-4100

Client: STATE of ALASKA DEPT. NATURAL RESOURCES Purchase Order: 237318
 Recvd : 90/10/11 Contact: Mary Maurer 907/696-0070
 Job# : 288 PO Box 772116 EAGLE RIVER, ALASKA 99577-2116
 Final : 90/11/27

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
ALASKA-BS-2	288.01	900924	1000	DIR	35	5
ALASKA-FB-2	288.02	900924	1000	DIR	7	4
ALASKA-FH-2	288.03	900924	1000	DIR	31	5
ALASKA-AN-2	288.04	900925	1000	DIR	30	5
ALASKA-MD-2	288.05	900925	1000	DIR	23	5
ALASKA-MS-2	288.06	900925	1000	DIR	23	5

 All duplicate runs except #288.05



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Eagle River

April 25, 1991

TRITIUM LABORATORY

Data Release #91-17
Job # 313

ALASKA DEPARTMENT OF NATURAL RESOURCES
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H. Gote Ostlund
Head, Tritium Laboratory

Distribution:

Mary A. Maurer
ALASKA DEPARTMENT OF NATURAL RESOURCES
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Eagle River, Alaska 99577-2116

Rosenstiel School of Marine and Atmospheric Science
Tritium Laboratory
4600 Rickenbacker Causeway
Miami, Florida 33149-1098
(305) 361-4100

Client: STATE OF ALASKA DEPT. NAT. RES.

Purchase Order: 239014

Recvd : 91/04/18

Contact: Mary A. Maurer 907/696-0070

Job# : 313

Div. G.G.S. P.O. Box 772116

Final : 91/04/24

Eagle River, AK 99577-2116

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
ALASKA-OF-1 MOONLIGHT SPRGS	313.01	910402	800	DIR	35	5
ALASKA-PH-1 MOONLIGHT SPRGS	313.02	910402	800	DIR	26	5
ALASKA-SS-1 SNOW	313.03	910402	300	DIR	5	5



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ALASKA DNR/DIV OF WATER
EAGLE RIVER ALASKA

November 27, 1991

TRITIUM LABORATORY

Data Release #91-63
Job # 360

ALASKA DEPARTMENT OF NATURAL RESOURCES
TRITIUM SAMPLES

Purchase Order ER 92-06

A handwritten signature in cursive script, appearing to read "Gote Ostlund".

H. Gote Ostlund
Head, Tritium Laboratory

Distribution:

Mary A. Maurer
ALASKA DEPARTMENT OF NATURAL RESOURCES
P.O. Box 772116
Eagle River, Alaska 99577-2116

Rosenstiel School of Marine and Atmospheric Science
Tritium Laboratory
4600 Rickenbacker Causeway
Miami, Florida 33149-1098
(305) 361-4100
Fax (305) 361-4112

Client: STATE OF ALASKA
Recvd : 91/11/12
Job# : 360
Final : 91/11/26

Purchase Order: ER 92-06
Contact: Mary Maurer, 907/696-0070, -0078(F)
Alaska D.N.R.; P.O. Box 772116
Eagle River, Alaska 99566-2116

Cust LABEL INFO	JOB.SX	REFDATE	QUANT	ELYS	TU	eTU
AK-Precipitation, Nome	360.01	910926	1000	DIR	12	5

GENERAL COMMENTS ON TRITIUM RESULTSTritium Scales

The tritium concentrations are expressed in TU, where 1 TU indicates a T/H ratio of 10^{-18} . The values refer to the old, internationally-adopted scale of U.S. National Bureau of Standards (NBS), which is based on their tritium water standard #4926 as measured on 1961/09/03, and age-corrected with the old half-life of 12.26 years, i.e., $\lambda = 5.65\% \text{ year}^{-1}$. In this scale, 1 TU is 7.186 dpm/kg H_2O , or 3.237 pCi/kg H_2O . TU values are calculated for date of sample collection, REFDATE in the table, as provided by the submitter. If no such date is available, date of arrival of sample at our laboratory is used. The stated errors, eTU, are one standard deviation (1 sigma) including all conceivable contributions.

In the table, QUANT is quantity of sample received, and ELYS is the amount of water taken for electrolytic enrichment. DIR means direct run (no enrichment).

It has been found lately that a better value for the half-life is 12.43 years, i.e., $\lambda = 5.576\% \text{ year}^{-1}$. This will cause a change in the TU scale, which is still based on the same NBS standard (#4926) as of the same date, 1961/09/03 (Mann *et al.*, 1982). In the new scale, 1 TU(N) is 7.088 dpm/kg H_2O , 3.193 pCi/kg H_2O . As of mid-1989, the numerical TU values were 3.8% higher in the new scale than in the old, and the difference is slowly increasing with time.

Very low tritium values

In some cases, negative TU values are listed. Such numbers can occur because the net tritium count rate is, in principle, the difference between the count rate of the sample and that of a tritium-free sample (background count or blank sample). Given a set of "unknown" samples with no tritium, the distribution of net results should become symmetrical around 0 TU. The negative values are reported as such for the benefit of allowing the user unbiased statistical treatment of sets of the data. For other applications, 0 TU should be used.

Mann, W.B., M.P. Unterweger, and B.M. Coursey, Comments on the NBS tritiated-water standards and their use, *Int. J. Appl. Radiat. Isot.*, 33, 383-386, 1982.

State of Alaska; Mary Maurer
 16 samples received 7/90
 Analyses by: SMU/ISEM Stable Isotope Laboratory

Sample	Date/Time	18O/16O(SMOW)	D/H(SMOW)
N-GW-9	6/9/90 1100	-13.15 -13.34	-96.0
N-GW-2A	6/9/90 2016	-13.76	-101.6
N-SW-1B	6/6/90 1436	-14.38	-105.9
N-SW-2A	6/7/90 1057	-16.46	-116.8
N-SW-3A	1027	-15.44 -15.45	-111.9 -114.3
N-GWB-3A	6/7/90 1544	-20.05	-156.2
N-GW-3A	6/7/90 1457	-13.29	-95.7
N-SW-4	6/9/90 1130	-14.16	-106.0
N-GW-4A	6/7/90 1620	-12.50	-95.9
N-SW-5	6/9/90 1210	-14.91 -14.92	-109.9 -107.9
N-GW-5A	6/7/90 1944	-14.47	-107.6
N-GW-6A	6/8/90 1456	-14.61	-109.3
N-GW-1F	6/6/90 1150	-14.07	-105.3
N-GW-7A	6/8/90 1917	-15.01	-106.2
N-GW-8	6/9/90 0945	-13.20 -13.30	-97.6 -98.8
N-GW-10	6/9/90 1016	-12.82	-96.3

State of Alaska; Mary Maurer
 10 samples received 10/90
 Analyses by: SMU/ISEM Stable Isotope Laboratory

Sample	Date/Time	$^{18}\text{O}/^{16}\text{O}$ (SMOW)		D/H(SMOW)	
AB-1	9/24/90 1345	-11.38	-13.31	-90.4	-92.4
AC-1	9/24/90 1346	-13.27	-13.23 -13.27	-95.7	-100.0
BS-1	9/24/90 1607	-14.33	-14.29	-105.5	-102.9
BW-1	9/24/90 1910	-14.90	-14.79 -14.81	-107.0	-103.9
FB-1	9/24/90 1655	-2.60	-2.63	-18.8	-18.6
FH-1	9/24/90 1746	-11.82	-14.19 -14.15	-104.7	-103.6
AN-1	9/25/90 1004	-13.84	-13.65	-103.2	-101.2
LS-1	9/25/90 1150	-13.43	-13.32	-99.1	-96.8
MD-1	9/25/90 1407	-13.46	-13.33	-102.7	-101.4
MS-1	9/26/90 1038	-13.83	-13.99	-100.5	-100.9

Author's note: The first column under $^{18}\text{O}/^{16}\text{O}$ and D/H, respectively, represents the original analyses of samples, which were somehow fractionated during analysis, making results erroneous (per Michael Colucci, written commun., 12-18-90). The second column under $^{18}\text{O}/^{16}\text{O}$ and D/H, respectively, represents the reanalysis of samples. These values are used in our discussion in the text.

State of Alaska; Mary Maurer
 4 samples received 5/91
 Analyses by: SMU/ISEM Stable Isotope Laboratory

Sample	Date/Time	18O/16O(SMOW)	D/H(SMOW)
SS-2	4/2/91 1400	-13.35	-107.9
OF-2		-13.21	-102.8
SS-3	4/2/91 1400	-13.42	-110.8 -108.5
PH-2	4/2/91 1730	-13.75 -13.88	-96.5

State of Alaska; Mary Maurer
 3 samples received 11/11/91
 Analyses by: SMU/ISEM Stable Isotope Laboratory

Sample	Date/Time	18O/16O(SMOW)	D/H(SMOW)
Precip. Gauge	9/26/91	-15.09	-112.1
Nome	1115		
Same		-15.13	-113.9
Same		-14.60 -14.68	-112.7 -112.9

APPENDIX C
LABORATORY QUALITY ASSURANCE EVALUATION REPORT

Appendix C

Laboratory quality assurance evaluation on water samples collected for the recharge area evaluation project, Moonlight Springs area, Nome, Alaska

This quality assurance (QA) evaluation covers water samples collected from Moonlight Springs and nearby surface and ground waters between June 1990 and September 1991 and associated field and laboratory check samples.

Seventeen common dissolved ion and trace-metal samples were analyzed by the Alaska Division of Water Laboratory, formerly Alaska Division of Geological and Geophysical Surveys Water Quality Laboratory, Fairbanks, Alaska. Six gross alpha and gross beta radioactivity samples were analyzed by Core Laboratories, Casper, Wyoming. Seventeen tritium samples were analyzed by the Tritium Laboratory at University of Miami, Miami, Florida. Thirty-one isotope ($^2\text{H}/^1\text{H}$ and $^{18}\text{O}/^{16}\text{O}$) samples were analyzed by the Stable Isotope Laboratory at Southern Methodist University, Dallas, Texas. Each analytical laboratory is discussed separately. Sample handling, holding times, analytical methods, and data-quality objectives are listed in the quality-assurance project plan (Munter and others, 1990).

Alaska Division of Water Laboratory

Sample handling: All samples were received intact by the laboratory according to chain-of-custody records.

Field quality control checks: Two equipment blank samples, GWB-3 and FB, and one trip blank sample, UT, were collected. The equipment blank and trip blank samples are free of contamination.

Three blind field duplicate samples were collected. Sample GW-4 was collected at Lindblom spring, sample FH was collected at Beltz School well, and sample PH was collected at Moonlight Springs.

Laboratory quality control checks: All method-required quality control (QC) checks, including reagent blanks, laboratory duplicate samples, matrix spike samples, matrix spike duplicate samples, and standard reference samples, were performed by the laboratory.

Timeliness: All samples were analyzed within holding time limits.

Initial and continuing calibration: Instrument calibrations were within acceptable limits.

Blanks: Field and laboratory blanks associated with the samples are free of contamination.

Detection limits: Acceptable.

Matrix spikes (accuracy): Constituent-specific data quality (DQ) objectives for accuracy were not available from published literature at the time the quality assurance plan was written (Munter and others, 1990). Consequently, no constituent-specific comparison with the DQ objective can be made. For evaluation purposes, the accuracy objective for all constituents is 80 to 120 percent recovery. The accuracy actually obtained is 83 to 109 percent recovery.

Field duplicates (overall precision): Overall precision, which is a measure of both field and lab precision, is calculable for samples GW-3 and its field duplicate GW-4, BS and its field duplicate FH, and OF and its field duplicate PH. The relative percent difference (RPD) is less than 10 percent for all constituents for the BS/FH and the OF/PH comparison and less than 20 percent for the GW-3/GW-4 comparison.

Laboratory duplicates (lab precision): Three constituents do not meet DQ objectives for lab precision:

<u>Constituent</u>	<u>Date Collected</u>	<u>Precision</u>	<u>DQ objective</u>
Fl	June 1990	4.4 %	3.14 %
SO ₄	June 1990	1.7 %	1.2 %
SO ₄	Sept. 1990	1.3 %	1.2 %
Zn	April 1991	5.7 %	4 %

Fluoride and zinc concentrations are either at or below the lower end of the optimal concentration range for the analytical method used.

Lab precision, which is also expressed as relative percent difference (RPD), cannot be calculated when values are less than the detection limit. Lab precision is calculated for constituents below detection limits in the April 1991 sample set because samples from other sources, which had detectable concentrations, were analyzed during the same determination. The resultant RPD values are a measure of the analytical precision of the instrument at that time.

Conclusion: Accuracy for all analyzed constituents is within 80 to 120 percent recovery. Overall precision is within 20 percent for all constituents. Lab precision meets or closely approaches DQ objectives. Therefore, all data are deemed acceptable for use.

Core Laboratories

Sample handling: All samples were received intact by the laboratory according to chain-of-custody records.

Field quality control checks: The collection of equipment blank samples, a trip blank sample, and a field duplicate sample were inadvertently omitted from the field sampling program.

Laboratory quality control checks: All method-required QC checks, as specified in EPA Method 900.0, were performed by the laboratory.

Timeliness: All samples were analyzed 6 wk after collection, within the 6-mo holding time limit.

Detection limits: Acceptable.

Matrix spikes (accuracy): The QC acceptance criteria listed on the lab's quality assurance report is 100 ± 25 percent recovery (see Munter and others, 1991, page 37).

Laboratory duplicates (lab precision): Relative percent difference for the samples is not shown on the lab's quality assurance report because they were not selected out of a larger batch of potential duplicate samples. Five of the six samples that were analyzed as duplicates have a PRD of less than 20 percent. Analysis I.D. 902061-5 has a RPD of 40 percent, but the actual values (0.2 pCi/l and 0.3 pCi/l) are below the lower limit of detection (LLD) of 0.5 pCi/l for the analytical method.

Conclusion: These data are deemed acceptable for use.

University of Miami Tritium Laboratory

Sample handling: All samples were received intact by the laboratory according to chain-of-custody records.

Field quality control checks: Two equipment blank samples, N-GWB-3C and FB-2, consisting of deionized water, were collected. These samples are not valid as blanks because the field quality control check procedure was incorrectly designed. The appropriate field check sample is a trip "blank" with a quantified tritium value that is

prepared in the laboratory prior to the sampling trip and accompanies the tritium samples from collection to analysis.

Three blind field duplicate samples were collected. Sample N-GW-4C was collected at a spring near Lindblom Creek, sample FH-2 was collected at Beltz School well, and sample PH-1 was collected at Moonlight Springs.

Laboratory quality control checks: All method-required QC checks were performed by the laboratory as specified in the laboratory's Procedures and Standards document (Munter and others, 1991, p. 57).

Timeliness: All samples were analyzed within 9 weeks, an acceptable turnaround time.

Detection limits: 0.1 Tritium Units (TU), which is equal to 0.0003 pCi/ml, is acceptable.

Matrix spikes (accuracy): Accuracy data, listed as stated error (eTU), is one standard deviation, including all conceivable contributions. All samples had a stated error of ≤ 5 eTU. A lower stated error, 0.24 - 1.1 eTU, is listed for the June 1990 sample set because low-level counting and enrichment was mistakenly performed.

Field duplicates (overall precision): The precision objective for field duplicates is ≤ 5 TU. The differences between sample N-GW-3C and its field duplicate N-GW-4C, BS-2 and its field duplicate FH-2, and OF-1 and its field duplicate PH-1 are 1 TU, 4 TU, and 11 TU, respectively.

Laboratory duplicates (lab precision): Lab precision data are listed as stated error (eTU), and represent one standard deviation, including all conceivable contributions. Samples have a stated error of ≤ 5 eTU. A lower stated error, 0.24 - 1.1 eTU, is listed for the June 1990 sample set because low-level counting and enrichment were mistakenly performed.

Conclusion: Fifteen of 17 samples are acceptable for use because sample error is less than the DQ objective of ± 6 TU. The numerical values for samples OF-1 and its field duplicate, PH-1, are unuseable because sample error exceeds 5 TU.

Southern Methodist University Stable Isotope Laboratory

Sample handling: All samples were received intact by laboratory according to chain-of-custody records.

Field quality control checks: Two equipment blank samples, GWB-3A and FB-1, consisting of deionized water, were collected. These samples are not valid as blanks because the field quality control check program was incorrectly designed. The appropriate field check sample is a trip "blank," with quantified $^2\text{H}/^1\text{H}$ and $^{18}\text{O}/^{16}\text{O}$ ratios, that is prepared in the laboratory prior to the sampling trip and accompanies the stable isotope samples from collection to analysis.

A set of six field duplicate samples were collected: N-GW-4A (collected at a spring near Lindblom Creek), AB-1 (collected at Anvil Creek), FH-1 (collected at Beltz School), PH-2 (collected at Moonlight Springs), SS-3 a melted snow sample (collected on Anvil Mountain), and uncoded rain samples (labeled "precip. gauge") collected from a precipitation collector at Moonlight Springs.

Laboratory quality control checks: All method-required QC checks were performed by the laboratory, as specified in 'Technical Information' (Munter and others, 1991, p. 60).

Timeliness: All samples were analyzed within 12 wk from the time they were collected, which is acceptable.

Matrix spikes (accuracy): No accuracy data were included in the analytical report.

Field duplicates (overall precision): Isotopic ratios are considered reliable if field duplicate samples differ by less than 2‰ for hydrogen and by less than 0.2‰ for oxygen. Three of the six duplicate sample sets exceed the DQ objective for hydrogen and oxygen.

<u>Sample</u>	<u>Field Duplicate Sample</u>	<u>Difference</u>	<u>DQ Objective</u>
Hydrogen Isotopes			
AC-1	AB-1	+7.6‰	± 2‰
OF-2	PH-2	+6.3‰	± 2‰
SS-2	SS-3	+2.9‰	± 2‰
Oxygen Isotopes			
N-GW-3A	N-GW-4A	+0.79‰	± 0.2‰
OF-2	PH-2	-0.60‰	± 0.2‰
Precip. gauge	Same	0.41-0.53‰	± 0.2‰

The second run of ratios for September 1990 samples (app. B, p. 53) was used in this analysis because several samples in the first run were apparently fractionated, and results are considered erroneous (M. Colucci, Stable Isotope Lab-SMU, written commun., December 1990).

Laboratory duplicates (lab precision): All samples meet the DQ objectives of ± 2‰ for hydrogen, except samples N-SW-3A (-2.4‰) and SS-3 (+2.9‰). All samples meet the DQ objective of ± 0.2‰ for oxygen.

Conclusion: The isotopic ratios for samples AC-1, AB-1, OF-2, PH-2, SS-2, and SS-3 are considered unusable because the hydrogen DQ objective for overall precision is not met. The isotopic ratios for sample N-GW-3A, N-GW-4A, OF-2, PH-2, and the precipitation gage samples are unusable because the oxygen DQ objectives for overall precision are not met. A total of 11 isotope samples do not meet DQ objectives. All other data are acceptable for use.

Overall Comments

Completeness: The stated objective for completeness, the percentage of usable data, is 100 percent. Excluding field blanks, 71 samples were collected during this investigation. Of this the usable data total 58 samples. The completeness is 82 percent, which is acceptable.

References

- Munter, J.A., Maurer, M.A., and Moorman, M., 1990, Evaluation of the hydrology and geology of the Moonlight Springs area, Nome, Alaska: Quality Assurance Project Plan: Alaska Division of Geological and Geophysical Surveys Public-data File 90-8, 23 p.
- Munter, J.A., Maurer, M.A., Inghram, M.G., and Petrik, W.A., 1991, Preliminary hydrogeological evaluation of Moonlight Springs, Nome, Alaska: Alaska Division of Geological and Geophysical Surveys Public-data File 91-28, 63 p.

**APPENDIX D
HISTORICAL WATER-QUALITY DATA FOR MOONLIGHT SPRINGS
AND VICINITY, 1954-83**

Locations of data:¹

USGS:

U.S. Geological Survey
Water Resources Division
4230 University Drive, Suite 201
Anchorage, Alaska

CH2M Hill:

Data was obtained from report entitled: Water and Sewer Master Plan.
Prepared for City of Nome by CH2M Hill, August 1976.

Ott Water Engineers:

Data was obtained from an unpublished report submitted to City of Nome by Ott
Water Engineers in 1982.

Alaska Gold Co.:

Data was obtained from Alaska Dept. of Environmental Conservation files, Nome, Alaska.

ADEC:

Data was obtained from Alaska Dept. of Environmental Conservation files, Nome, Alaska.

¹Copies of data are available at Alaska Division of Water, 18225 Fish Hatchery Road, P.O. Box 772116, Eagle River, Alaska 99577.

APPENDIX D. Historical data, Moonlight Springs and vicinity, 1954-83.

SITE	DATA COLLECTOR ¹	DATE	WATER Temperature (°C)	DISCHARGE (CFS)	SPECIFIC Conductance (μS/CM)	pH	HARDNESS (MG/L as CaCO ₃)
Moonlight Springs	USGS	06/25/54	3.0		235	6.8	110
Moonlight Springs	USGS	09/12/60		0.84	238	7.5	130
Moonlight Springs	USGS	03/18/63	3.5		246	8.2	120
Moonlight Springs	USGS	04/18/64			240	7.8	120
Moonlight Springs	USGS	06/10/67			207	7.8	100
Moonlight Springs	USGS	07/12/67	1.5	6.7	271	7.6	
Moonlight Springs	USGS	04/23/68	2.0	0.38	234	7.3	120
Moonlight Springs	USGS	06/05/68	5.0	2.5	207	7.5	100
Moonlight Springs	USGS	07/10/68	5.0	2.5	233	7.8	110
Moonlight Springs	USGS	03/10/69	2.0	0.25	251	7.9	130
Moonlight Springs	USGS	06/22/76			256		130
Moonlight Springs	CH2M Hill	02/04/76			215		122
Moonlight Springs, collection gallery overflow	Ott Water Engineers	10/11/82	2.0	2.5	200	7.7	127
Spring, 100' S 45° E of overflow	Ott Water Engineers	10/11/82	1.0		260	7.2	230
Spring, 150' N 42° W of overflow	Ott Water Engineers	10/11/82	1.0		200	7.7	136
Spring, 550' NW of overflow	Ott Water Engineers	10/11/82	1.0		280	7.7	201
Spring, 1100' NW of overflow	Ott Water Engineers	10/12/82			370	7.5	231
Anvil Creek, near Moonlight Springs	Ott Water Engineers	10/12/82		23.2	210	7.9	138
Spring, 130' N 5° W of overflow	Ott Water Engineers	10/12/82	2.0		220	7.7	137
Spring, in dredge pond, 2000' SW of overflow	Ott Water Engineers	10/12/82			390	7.7	185
Alaska Gold Company camp well	Ott Water Engineers	10/12/82			350	7.7	229
Alaska Gold Company camp well	Alaska Gold Co.	04/12/77			344	7.5	175

SITE	DATA COLLECTOR ¹	DATE	CALCIUM (MG/L)	MAGNESIUM (MG/L)	SODIUM (MG/L)	POTASSIUM (MG/L)	BICARBONATE (MG/L)
Moonlight Springs	USGS	06/25/54	40	3.1	2.3	0.6	129
Moonlight Springs	USGS	09/12/60	36	8.6	2.1	0.4	142
Moonlight Springs	USGS	03/18/63	43	2.4	2.4	0.3	140
Moonlight Springs	USGS	04/18/64	46	1.9	2.4	0.1	140
Moonlight Springs	USGS	06/10/67	38	2.4	2.1	0.5	130
Moonlight Springs	USGS	04/23/68	43	2.7	1.6	0.8	142
Moonlight Springs	USGS	06/05/68	38	2.3	1.7	0.3	124
Moonlight Springs	USGS	07/10/68	41	2.9	2.2	0.1	140
Moonlight Springs	USGS	03/10/69	46	2.6	2.7	1.5	153
Moonlight Springs	USGS	06/22/76	48	3.4	2.0	0.3	152
Moonlight Springs	CH2M Hill	06/26/74		3.6			
Moonlight Springs	CH2M Hill	02/04/76			2.4		
Moonlight Springs, collection gallery overflow	Ott Water Engineers	10/11/82	46	2.9	2.3	0.3	146
Spring, 100' S 45° E of overflow	Ott Water Engineers	10/11/82	87	3.1	2.4	1.2	215
Spring, 150' N 42° W of overflow	Ott Water Engineers	10/11/82	49	3.3	2.9	0.35	146
Spring, 550' NW of overflow	Ott Water Engineers	10/11/82	65	9.4	2.7	0.5	207
Spring, 1100' NW of overflow	Ott Water Engineers	10/12/82	78	8.8	3.8	2.1	278
Anvil Creek, near Moonlight Springs	Ott Water Engineers	10/12/82	40	9.3	2.2	0.4	122
Spring, 130' N 5° W of overflow	Ott Water Engineers	10/12/82	50	2.9	2.3	0.5	171
Spring, in dredge pond, 2000' SW of overflow	Ott Water Engineers	10/12/82	66	4.9	5.0	0.85	220
Alaska Gold Company camp well	Ott Water Engineers	10/12/82	82	5.8	2.8	0.75	290
Alaska Gold Company camp well	Alaska Gold Co.	04/12/77	48	7.2			183
Well, Flat Creek Subdivision, Lot 4, Parcel B-2	ADEC	10/13/83			3.8		

APPENDIX D (con). Historical data, Moonlight Springs and vicinity, 1954-83.

SITE	DATA COLLECTOR ¹	DATE	SULFATE (MG/L)	CHLORIDE (MG/L)	NITRATE (MG/L as N)	SILICA (MG/L)	FLUORIDE (MG/L)
Moonlight Springs	USGS	06/25/54	9.0	3.5	0.09	5.1	
Moonlight Springs	USGS	09/12/60	8.0	5.0	0.02	5.1	
Moonlight Springs	USGS	03/18/63	6.0	4.5	0.07	4.8	0.2
Moonlight Springs	USGS	04/18/64	7.0	4.5	0.07	4.6	0.1
Moonlight Springs	USGS	06/10/67	3.0	3.2	0.05	5.0	
Moonlight Springs	USGS	04/23/68	5.0	3.9	0.09	4.7	0.1
Moonlight Springs	USGS	06/05/68	4.2	2.6	0.02	4.2	
Moonlight Springs	USGS	07/10/68	5.9	3.0		4.8	0.1
Moonlight Springs	USGS	03/10/69	6.6	3.2		4.3	0.1
Moonlight Springs	USGS	06/22/76	8.6	4.0		4.5	<0.1
Moonlight Springs	CH2M Hill	06/26/74	9.4	3.3			
Moonlight Springs	CH2M Hill	02/04/76	7.3	4.9	0.16		0.2
Moonlight Springs, collection gallery overflow	Ott Water Engineers	10/11/82	3.3	4.0			
Spring, 100' S 45° E of overflow	Ott Water Engineers	10/11/82	4.0	4.0			
Spring, 150' N 42° W of overflow	Ott Water Engineers	10/11/82	3.3	4.0			
Spring, 550' NW of overflow	Ott Water Engineers	10/11/82	9.0	4.0			
Spring, 1100' NW of overflow	Ott Water Engineers	10/12/82	16	8.0			
Anvil Creek, near Moonlight Springs	Ott Water Engineers	10/12/82	19	4.0			
Spring, 130' N 5° W of overflow	Ott Water Engineers	10/12/82	3.9	4.0			
Spring, in dredge pond, 2000' SW of overflow	Ott Water Engineers	10/12/82	3.5	9.0			
Alaska Gold Company camp well	Ott Water Engineers	10/12/82	8.1	5.0			
Alaska Gold Company camp well	Alaska Gold Co.	04/12/77		14			0.3

SITE	DATA COLLECTOR ¹	DATE	TOTAL DISSOLVED SOLIDS (MG/L)	CARBON DIOXIDE (MG/L)	COLOR (PCU)	GROSS ALPHA (PCI/L)	TRITIUM (TU)
Moonlight Springs	USGS	06/25/54	127	32			
Moonlight Springs	USGS	09/12/60	135	7.1			
Moonlight Springs	USGS	03/18/63	133	1.4			
Moonlight Springs	USGS	04/18/64	136	3.6			
Moonlight Springs	USGS	06/10/67	119	3.3	2		
Moonlight Springs	USGS	04/23/68	132	11	5		
Moonlight Springs	USGS	06/05/68	114	6.2	5		
Moonlight Springs	USGS	07/10/68	129	3.5	5		
Moonlight Springs	USGS	03/10/69	142	3.1	5		
Moonlight Springs	USGS	06/22/76	146		5		
Moonlight Springs	CH2M Hill	06/26/74	140		1		
Moonlight Springs	CH2M Hill	02/04/76			1		
Moonlight Springs, collection gallery overflow	Ott Water Engineers	10/11/82	135				63.9 ± 2.2
Spring, 100' S 45° E of overflow	Ott Water Engineers	10/11/82	215				57.4 ± 1.9
Spring, 150' N 42° W of overflow	Ott Water Engineers	10/11/82	137				66.7 ± 2.2
Spring, 550' NW of overflow	Ott Water Engineers	10/11/82	195				47.7 ± 1.9
Spring, 1100' NW of overflow	Ott Water Engineers	10/12/82	256				
Anvil Creek, near Moonlight Springs	Ott Water Engineers	10/12/82	137				43.1 ± 1.9
Spring, 130' N 5° W of overflow	Ott Water Engineers	10/12/82	150				56.4 ± 1.9
Spring, in dredge pond, 2000' SW of overflow	Ott Water Engineers	10/12/82	200				67.6 ± 2.2
Alaska Gold Company camp well	Ott Water Engineers	10/12/82	260				
Alaska Gold Company camp well	Alaska Gold Co.	04/12/77	202		5		
Well, Flat Creek Subdivision, Lot 4, Parcel B-2	ADEC	10/13/83				2	

APPENDIX D (con). Historical data, Moonlight Springs and vicinity, 1954-83.

SITE	DATA COLLECTOR ¹	DATE	IRON TOTAL, (µG/L)	IRON DISSOLVED (µG/L)	LEAD (µG/L)	MANGANESE, TOTAL (µG/L)	MANGANESE, DISSOLVED (µG/L)
Moonlight Springs	USGS	09/12/60	20				
Moonlight Springs	USGS	03/18/63	20			20	
Moonlight Springs	USGS	04/18/64	30				
Moonlight Springs	USGS	04/23/68	290				
Moonlight Springs	USGS	06/05/68	80				
Moonlight Springs	USGS	07/10/68	10				
Moonlight Springs	USGS	03/10/69	20				
Moonlight Springs	USGS	06/22/76		<10	<100		<10
Moonlight Springs	CH2M Hill	06/26/74	10		2		
Moonlight Springs	CH2M Hill	02/04/76	<50		<50	<50	
Well, Flat Creek Subdivision, Lot 4, Parcel B-2	ADEC	10/13/83	6400		<5	220	

SITE	DATA COLLECTOR ¹	DATE	ARSENIC (µG/L)	BARIUM (µG/L)	CADMIUM (µG/L)	CHROMIUM (µG/L)	COPPER (µG/L)
Moonlight Springs	USGS	06/22/76	1	<100	<10	<10	2
Moonlight Springs	CH2M Hill	06/26/74	4				5
Moonlight Springs	CH2M Hill	02/04/76	10	50	<5	<20	
Well, Flat Creek Subdivision, Lot 4, Parcel B-2	ADEC	10/13/83	130	<200	<2	<5	

SITE	DATA COLLECTOR ¹	DATE	MERCURY (µG/L)	SELENIUM (µG/L)	SILVER (µG/L)	ZINC (µG/L)
Moonlight Springs	USGS	06/22/76		<1	<1	<10
Moonlight Springs	CH2M Hill	02/04/76	<1	<10	<20	
Well, Flat Creek Subdivision, Lot 4, Parcel B-2	ADEC	10/13/83	<1	<2	<2	

APPENDIX E
WATER-USE RECORDS AND STATISTICS FOR NOME, ALASKA
(Quantities in gallons unless otherwise noted)

WATER-USE RECORDS AND STATISTICS FOR NOME, ALASKA

(Quantities in gallons unless otherwise noted)

FULL YEAR PERIOD OF RECORD

Month	Armed Mt.	Beltz Mt.	FAA	New Hall	City of	Total use	Equip.	Equip.	Total use	Equip.	Equip.
	Cor. Fac.	School		Guard Arm	Nome	less Nome	GPD	CFS	incl Nome	GPD	CFS
OVERALL	283,694	300,918	187,813	7,804	14,215,068	769,827	24,982	0.039	14,974,863	492,088	0.761
AVGS											

1989

Month	Armed Mt.	Beltz Mt.	FAA	New Hall	City of	Total use	Equip.	Equip.	Total use	Equip.	Equip.
	Cor. Fac.	School		Guard Arm	Nome	less Nome	GPD	CFS	incl Nome	GPD	CFS
Jan '89	248,358	289,118	138,023	7,750	17,429,500	858,287	21,234	0.033	18,088,747	583,443	0.903
Feb	237,894	311,882	87,329	7,000	16,258,500	843,868	22,888	0.038	15,900,368	587,870	0.879
Mar	256,840	303,784	120,868	7,750	14,174,800	721,321	23,288	0.038	14,896,121	480,820	0.743
Apr	254,894	328,874	158,894	7,500	12,680,000	750,432	25,014	0.039	13,340,432	444,891	0.688
May	254,895	348,288	148,807	7,750	13,808,000	759,310	24,484	0.036	14,388,310	483,484	0.717
Jun	238,135	307,779	117,887	7,500	14,688,000	888,081	22,289	0.034	15,253,081	508,438	0.787
Jul	240,829	305,878	150,688	7,750	18,098,000	705,140	22,746	0.035	15,801,140	509,714	0.780
Aug	249,877	290,729	171,085	7,750	15,208,000	718,221	23,201	0.038	15,928,221	513,717	0.786
Sep	227,080	188,895	147,284	7,500	12,908,000	667,739	18,928	0.029	13,576,739	438,837	0.678
Oct	223,230	238,818	131,287	7,750	12,210,000	597,785	18,284	0.030	12,807,785	413,185	0.639
Nov	218,170	314,122	147,370	7,500	12,778,000	682,182	23,072	0.038	13,467,182	448,805	0.688
Dec	221,443	233,888	152,148	7,750	13,287,000	814,407	18,820	0.031	13,881,407	447,787	0.683
AVGS	239,164	284,785	138,325	7,804	14,087,180	874,808	22,183	0.034	14,771,959	484,883	0.760

1990

Month	Armed Mt.	Beltz Mt.	FAA	New Hall	City of	Total use	Equip.	Equip.	Total use	Equip.	Equip.
	Cor. Fac.	School		Guard Arm	Nome	less Nome	GPD	CFS	incl Nome	GPD	CFS
Jan '90	284,710	248,200	131,648	7,750	14,278,000	849,208	20,848	0.032	14,924,208	481,428	0.745
Feb	248,009	288,217	143,898	7,000	13,315,000	882,822	23,678	0.037	13,977,822	499,212	0.772
Mar	248,217	281,577	182,288	7,750	16,847,000	878,800	21,888	0.034	18,128,800	533,128	0.828
Apr	234,888	228,088	85,320	7,800	14,833,000	588,733	18,888	0.029	15,388,733	513,281	0.784
May	249,888	281,811	130,888	7,750	13,514,700	848,748	20,988	0.032	14,184,448	458,818	0.707
Jun	244,267	228,803	183,888	7,500	13,883,813	841,818	21,387	0.033	14,535,831	484,818	0.760
Jul	280,172	247,488	154,774	7,750	13,980,000	880,151	21,288	0.033	14,860,151	472,283	0.731
Aug	238,000	278,800	138,000	7,750	14,883,000	858,860	21,147	0.033	15,348,860	488,115	0.768
Sep	228,000	301,000	284,000	7,500	15,884,000	824,500	27,483	0.043	16,418,500	528,828	0.818
Oct	253,000	443,800	160,000	7,750	13,708,000	854,850	27,588	0.043	14,563,850	488,785	0.727
Nov	328,000	401,400	158,000	7,500	12,881,000	881,800	28,730	0.048	13,882,800	482,783	0.718
Dec	384,000	313,000	200,000	7,750	13,224,000	914,760	28,508	0.048	14,138,760	471,282	0.729
AVGS	263,844	289,418	158,783	7,804	14,158,051	720,827	23,689	0.037	14,878,878	480,112	0.757

1991

Month	Armed Mt.	Beltz Mt.	FAA	New Hall	City of	Total use	Equip.	Equip.	Total use	Equip.	Equip.
	Cor. Fac.	School		Guard Arm	Nome	less Nome	GPD	CFS	incl Nome	GPD	CFS
Jan '91	344,000	319,000	201,000	7,750	14,617,000	871,750	28,121	0.044	15,388,750	498,411	0.788
Feb	271,000	257,700	215,000	7,000	13,889,000	750,700	28,811	0.041	14,319,700	511,418	0.791
Mar	287,000	283,400	173,000	7,750	18,422,000	751,180	24,231	0.037	18,173,180	521,716	0.807
Apr	259,000	279,200	272,000	7,500	14,170,000	817,700	27,257	0.042	14,987,700	498,800	0.773
May	278,000	338,200	232,000	7,750	15,482,000	848,850	27,418	0.042	16,311,850	528,182	0.814
Jun	328,000	281,800	261,000	7,500	15,315,000	848,300	28,210	0.044	16,181,300	538,710	0.833
Jul	283,000	444,800	327,000	7,750	17,088,800	1,042,250	33,821	0.052	18,141,850	583,221	0.905
Aug	284,000	463,000	471,000	7,750	14,335,000	1,178,750	37,887	0.068	15,513,750	588,347	0.774
Sep	284,000	323,100	471,000	7,500	12,878,000	1,085,800	31,820	0.057	13,770,800	444,213	0.687
Oct	288,000	338,200	384,000	7,750	13,250,000	978,860	31,579	0.048	14,228,860	458,888	0.710
Nov	288,000	437,800	83,000	7,500	12,848,000	804,400	28,813	0.041	13,748,400	458,313	0.709
Dec	278,000	212,300	128,000	7,750	13,844,000	824,050	20,131	0.031	14,588,050	485,802	0.751
AVGS	284,083	324,808	263,750	7,804	14,381,887	884,048	28,083	0.045	15,278,013	502,227	0.777