Preliminary Hydtogeological Evaluation of Moonlight Springs, Nome, Alaska

By

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INTRODUCTION

The City of Nome, Alaska, obtains 100% of its water supply from an underground collection gallery at Moonlight Springs. The springs are located at the foot of Anvil Mountain, approximately 3.7 miles inland from Nome and the Bering Sea. Recent gold exploration and mining in the vicinity of the springs has created an increased interest in understanding the origin of the springs and in identifying the recharge area of the springs to protect against possible contamination or diminution of spring flows.

This three-year investigation was initiated in September, 1989, to define the source, the watershed and the recharge area of Moonlight Springs. The paucity of wells in the area required that an indirect approach be used to identify the source and recharge areas of the springs. The approach consisted of:

1.   conducting geologic reconnaissance to determine the structure and composition of rocks forming the Moonlight springs aquifer;

2.   sampling wells, streams and springs in the area to determine water quality variations and to draw inferences about the probable flowpaths of ground-water;

3.   sampling waters for isotopes of hydrogen and oxygen in water molecules to use as tracers to infer origins of the waters.

4.   establishing a water budget for the Anvil Creek-Moonlight Springs area by measuring precipitation, snowpack water equivalent, streamflow and spring discharge;

The indirect approach used in this analysis requires that data, especially water budget data, be collected over a multi-year period to fully understand seasonal and year-to-year variations. This report is a progress report providing data collected through June, 1991, and preliminary interpretations regarding identification of the recharge area of Moonlight Springs.

PREVIOUS INVESTIGATIONS

Active gold mining has occurred in and near Nome since the original gold rush at the turn of the century. Other ore deposits have been mined elsewhere on the Seward Peninsula. As a result, numerous geological reports are available for the Seward Peninsula (Robinson, and others, 1985). 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 (Eggleston, written commun., 1990).

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

Ott Water Engineers (1982) and Alaska Power Authority (1980) collected data to better understand the hydrogeology of the springs. Ott Water Engineers (1982) showed a generalized recharge area for the springs that encompassed Anvil Mountain above an elevation of about 500 ft above sea level.

GEOLOGICAL SETTING

Nome is located on the south coastal plain of the Seward Peninsula adjacent to Norton Sound of the Bering Sea. The coastal plain extends approximately 3.5 mi inland to the base of a series of hills and ridges rising to elevations up to about 1800 ft above sea level (sheet 1). The ridges are oriented predominantly north-south and are separated by south flowing primary drainages. The area surrounding Nome (including the Kigluaik Mountains located about 30 mi north of Nome) was subjected to alpine glaciation during the Pleistocene (Péwé, 1975).

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

Nome lies in the region of discontinuous permafrost. The coastal plain is underlain by continuous or near-continuous permafrost; however, uplands contain mixed frozen and unfrozen areas.

DATA COLLECTION

Water quality samples were collected at 12 sites shown on sheet 1. Methods used to sample, analyze and report water quality are given by Munter and others (1990). Ground-waters and selected surface water samples were analyzed for common dissolved ions, trace metals, radioactivity and total iron. Complete analytical results are provided in Appendix A. Appendix B contains measurements of field parameters made at the time of sample collection.

Isotopes of hydrogen (deuterium and tritium) and of oxygen (O-l 8) were sampled at locations shown in sheet 1. Appendix C contains sampling and analytical methodologies for isotope analyses.

Tritium, deuterium, and O-l 8 analyses are provided in Appendix A.

In order 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 Moonlight Springs 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 and are given in Appendix C. Overflow discharge measurements were determined using the stage of water in the collection gallery and a rating curve developed from gaging the overflow discharge at different flow rates and stage heights. The rating curve is shown in figure 2. 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). A series of discharge measurements were done on June 8 and 9, 1990 at five Anvil Creek locations shown on sheet 2. Rain gages were installed at nine locations in the area, one of which 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).

RESULTS

Hydrology

Figures 3 through 6 show Moonlight Springs discharges for the period of record and average water use, water temperature, air temperature, and precipitation information. Figure 3 shows how the average water use for all Nome area users compares with Moonlight Springs discharge. A seasonal pattern in spring discharge is evident, with low flows occurring in mid-April. In April 1990, the low flow figure very nearly reached the average annual water use. The April 1991 data low flow period was not as low as it was in 1990.

Figure 4 is a plot of Moonlight Springs discharge and water temperature data. This plot shows that water temperature and discharge are closely related. Water temperature drops sharply in early May of each year, at approximately the same time that discharge increases. This is interpreted to be caused by a large influx of cold snowmelt that simultaneously decreases average spring temperature and increases discharge. This relationship reverses in summer, where sudden increases in water temperature are followed closely by increases in discharge. Note how the peak annual water temperature in mid to late August 1990 is followed closely by peak annual discharge.

Figure 5 is a plot of discharge and air temperature. During breakup in early May air temperature and discharge are closely related. Specifically, as the average daily temperature rises above 0 degrees Celsius (the freezing point of water), discharge rises notably as a result of snowmelt.

Figure 6 illustrates the relationship between precipitation and discharge during summer conditions. Two major precipitation events occurred in the summer of 1990. In response, discharge started increasing within one to two days, and peaked 19 days following the precipitation event. Figure 7 shows that the water temperature at Moonlight Springs increased the same day as the precipitation event.

Figure 8 shows a close relationship between air temperature and water temperature at Moonlight Springs. At the onset of breakup in 1990 and 1991, water temperature drops significantly at the same time that the average daily air temperature climbs above freezing. This again is attributed to input of relatively cold snowmelt into the aquifer.

Figure 9 is a plot of Anvil Creek discharge data collected at the gaging site (sheet 2) and precipitation data obtained from the National Weather Service Office (WSO) at the Nome airport. Anvil Creek shows a typical rainfall runoff relationship, with peak discharges following precipitation events in only 2 days, instead of the 19 day lag for Moonlight Springs. The falling limb of the hydrograph is likewise, much steeper.

A series of discharge measurements (table 1) were made at different points on Anvil creek on June 8 and 9, 1990, to identify areas where the stream may be gaining or losing ground-water.

The Anvil Creek basin had not been subjected to any significant rainfall events for at least three days prior to the streamflow measurements. The stream measurements indicate that Anvil Creek gains ground-water above the gage site and loses water below the gage site.

Snow   Surveys

Table 2 shows the results of three snow survey site measurements made on the hillside above Moonlight   Springs.

Table 1. Miscellaneous discharge measurements for Anvil Creek, Nome, Alaska.

Location	Discharge (cfs)	Date
Near Nome/Teller Highway	4.22	June 8, 1990
At recording gage site	6.69	June 8, 1990
Halfway from gage to Glacier Road	5.62	June 8, 1990
Approximately 1/3 mi downstream from Glacier Road	4.89	June 8, 1990
Approximately 1/2 mi above Glacier Road	1.24	June 9, 1990

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

Date of survey: 4-2-91
Samplers: Carrick, Ireland
Weather: clear, winds NE @ 25 mph, temperature 20-30°F

SITE	SNOW DEPTH (in.1	WATER EQUIVALENT (in.)	DENSITY (%)
ss-1	67.0	32.7	49.0
	54.0	23.5	44.0
	37.5	15.3	41 .o
	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>	35.0
Average	46.6	17.1	36.2
single measurement near site SS-3	126.5	43.0	34.0

Note: all sites affected by wind

Each site consists of five separate snow core samples. In addition, a single core measurement was taken approximately 50 ft from site SS-3 where the snow was unusually deep to determine the range of snow thickness and water content in the area. Visual observations made by the sampling team indicate that snowpack thickness at the time of the snow survey was highly variable in the Anvil Mountain area as a result of wind effects.

Water Quality and Isotopes

Results of the common dissolved ion analyses from selected ground-water sites are shown in a Piper diagram (fig. 10). This diagram shows a subtle but consistent difference between water sampled from areas where schist is the predominant rock type versus areas where marble is the predominant rock type. Water from schist areas typically has higher sulfate levels and lower calcium and bicarbonate levels.

Tritium analyses of ground waters and surface waters occur in a relatively narrow range. All values are elevated with respect to pre-1945 values indicating that at least some portions of these waters were recharged subsequent to that date.

A review of the deuterium and oxygen-l 8 data failed to identify trends that might correlate with orographic positions of sample sites or the distances inland from the coast. Seasonal variations in the stable isotope composition of precipitation in the Nome area probably accounts for most or all of the variations observed.

Water Budget

A water budget is an accounting of water movement into or out of an area. In the case of the land area contributing water to Moonlight Springs, a water budget equation can be written in the form:

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

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

The water budget equation must be applied to a specific geographic area, usually a discrete drainage basin, and for a discrete interval of time. In this analysis, the basin supplying Moonlight springs, although not well defined, will be the basin of interest. Water budget calculations will be computed for the one year period May 29,1990, to May 28, 1991.

Rainfall data for the period May 29,1990 to October 1, 1990 totalled 12.14 inches at the Nome Airport. At least 1.14 times as much precipitation falls in the Anvil Mountain area as at the airport, based on limited records from the rain gages. Applying this correction factor, approximately 13.84 inches (1.15 ft) 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 16.4 inches (1.37 ft) on April 2, 1991, The water budget calculation assumes that this is the full amount of water available for snowmelt.

Moonlight Springs discharge for the water budget year was 89,800,000 cubic ft of water. The area (A) of the Moonlight Springs basin will be solved for as the unknown in the equation.

Evapotranspiration in the Nome area is not well defined. Patric and Black (1968) calculated an actual evapotranspiration value of 14.13 inches (1.18 ft) based on the Thornthwaite method.

Surface runoff values for the slopes above Moonlight Springs are expected to be low because of the absence of significant drainages and the ability of the tundra soils to store and transmit moisture to the subsurface during major precipitation or snowmelt events. For the water budget calculations, a value of 1 in. (0.08 ft) is assumed.

The discharge of Moonlight Springs was nearly the same on May 28, 1991, as it was on May 29, 1990, indicating that changes in water storage within the Moonlight Springs basin are probably negligible. A value of 0 was assumed for dS.

Inserting the values described above into the water balance equation and solving for A yields an area A = 2.6 sq mi. This provides an initial estimate of the size of the Moonlight Springs recharge area.

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 comparison purposes. The area of the Moonlight Springs watershed is 0.11 sq mi, which is only 4 percent of the calculated area of the true Moonlight Springs recharge area.
This indicates that Moonlight Springs actually receives water from an area much larger than the watershed depicted on sheet 2.

CONCLUSIONS

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

1.   The marble that outcrops on the Anvil Mountain hillside above Moonlight Springs is the primary aquifer for the springs. Although development of the springs has obscured the natural emanations from the ground, the geology of the site and the geochemistry of the water strongly suggests that water is emitted from the marble aquifer at a shallow depth into the perforated pipes leading to the collection gallery.

2.   The annual discharge of Moonlight Springs occurs as relatively high spring summer and fall flows that show evidence of rapid response times to snowmelt and rainfall events. Wintertime flows exhibit a relatively continuous decline from high fall flows to low flows just prior to spring breakup in early May. These wintertime flows represent a gradual depletion of the Moonlight Springs aquifer. It is unknown whether these flows are from a larger flow system than is inferred to operate during the summer or merely represent depletion of the same flow system.

3.   The travel time of some water from its recharge to its discharge at the springs is short, ranging from a few hours or less to a day or two. This indicates that some recharge to the springs probably occurs within a few hundred feet of the springs and has a relatively short flow path. The fractured nature of the aquifer allows relatively rapid groundwater flow compared to typical unconsolidated aquifers.

4.   Preliminary calculations indicate that the area required to support the annual discharge at Moonlight Springs is approximately 2.6 sq mi, which is slightly larger than the area of Anvil Mountain. Uncertainties in the annual water budget approach are significant and could cause the recharge area calculation to be in error by approximately 50 percent. Even so, the calculations are useful because they indicate that a plausible conceptual model for the Springs' flow system does not require inputs of water from distant areas.

5.   Geochemical data suggest that the water has not flowed through appreciable thicknesses of schist. Regional geologic maps of the area suggest that the likelihood of regional continuity of the marble aquifer to distant recharge areas is low. The geochemical data therefore further support the conceptual model that most recharge occurs locally into the marble aquifer near the Springs.

6.   Ground-water discharge at and near Moonlight Springs occurs in a broad band along the base of the Anvil Mountain slope suggesting that the springs are not part of a single conduit system. Such a conduit system has been postulated because of the presence of a fault in Anvil creek valley. The 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.

7.   Moonlight Springs discharges declined during April of 1990 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 eleven nonconsecutive days during that time. The water supply pipe to the City of Nome ran in a less than pipe-full condition April 15-I 7, 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. The Springs may be inadequate to serve water use demands if demands increase during late winter low-flow conditions or if spring flows are reduced.

ACKNOWLEDGEMENTS

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A
South
FEET

1200

800

400

0

-400

Moonlight Springs

Anvil Peak

Specimen Gulch

Dexter Peak

Nekula Gulch

King Mountain

A'
North

Qd

Pzm

Pzmu

Pzg

mgd

SCALE

0   2000   4000 FEET

Vertical Exaggeration=5X

MAP SYMBOLS

——–?–·– Contact, short dashes where approximately located; short dashes alternating with dots where inferred, extrapolated, or semi-obscured; queried where doubtful.

U / D ——?···· Fault, dashed where approximately located or inferred; dotted where concealed; queried where doubtful.
U, upthrown side D, downthrown side.

DESCRIPTION OF MAP UNITS

UNCONSOLIDATED DEPOSITS

E l Mainly glacial, glaciofluvial, and alluvial deposits of Pleistocene and Recent age but locally includes • luvium and, in a narrow belt along the present coastline, beach deposits of Pleistocene age; small exposures of older, buried beach deposits of Tertiary end Pleistocene (?) age may be spottily exposed in dredged area on coastal plain south of Anvil Mountain.

META-IGNEOUS ROCKS

mgd Metagranodioritic mills.

METASEDIMENTARY ROCKS

MARBLE

Pzmu / Pzm Pzmu--consists mainly of calcareous, quartzo-calcareous, and quartz-chlorite-muscovite schist but includes blue-gray and gray marble, buff-weathering and gray, schistose marble, and black quartzite. Gradational with underlying rock.

Pm--principally platy, slabby and massive blue-gray and gray marble, and buff-weathering and gray ◼ ohimtoma marble; minor units include calcareous chlorite-muscovite schist, and graphitic and non-graphitic chlorite-muscovite schist and quartz-chlorite-muscovite schist. Contact with underlying graphitic, calcareous schist gradational.

GRAPHITIC, CALCAREOUS SCHIST

Pzg Pag--predominantly gray, slightly graphitic, calcareous quartz schist; minor units include blue-gray, gray, and black marble, graphitic chlorite-muscovite schist, quartz-chlorite-muscovite schist, and black quartz schist and black quartzite. Localize(non-graphitic to slightly graphitio quartz-chlorite-muscovite • ohimt, black graphitic quartz schist and black graphitic quartzite.
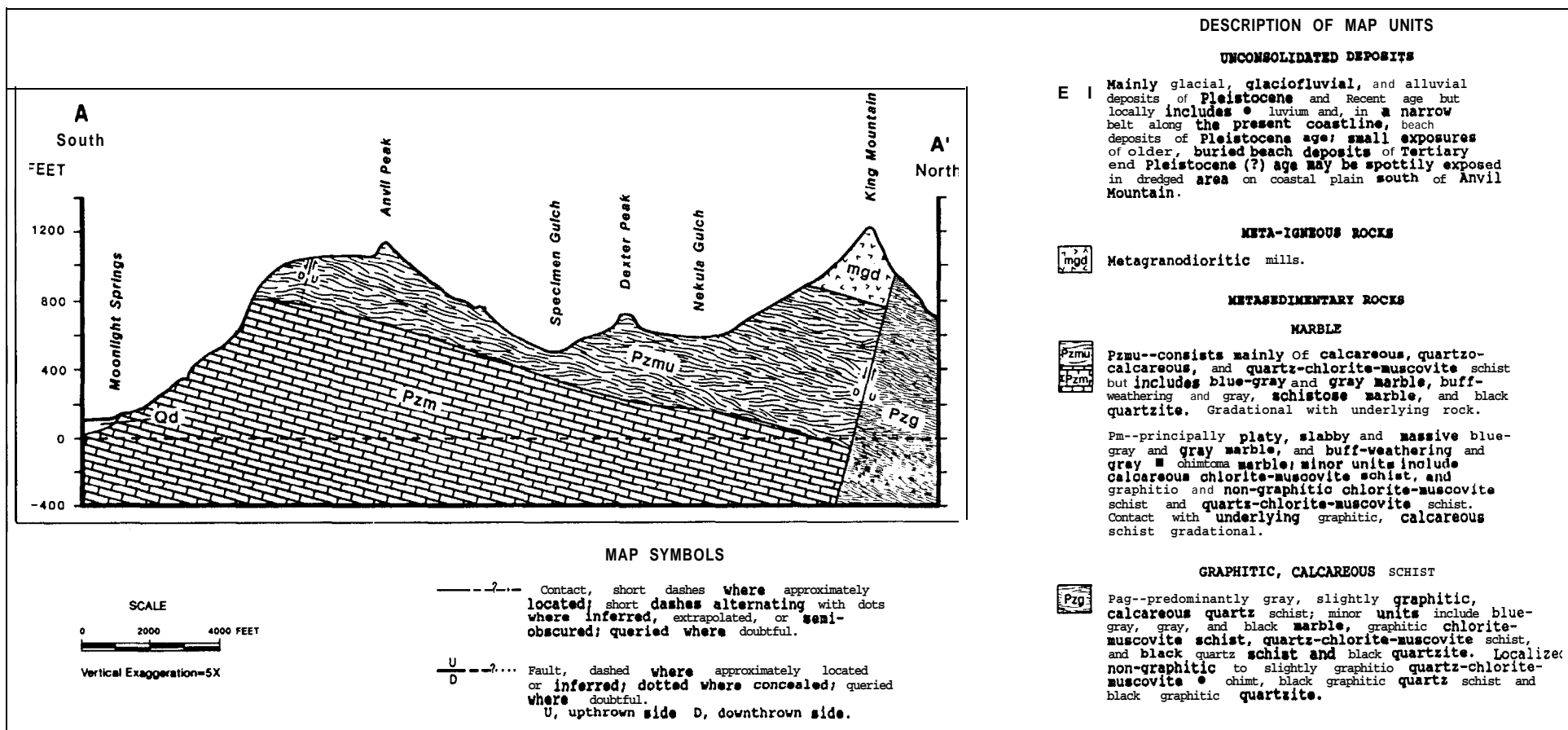
FIGURE 1   GEOLOGIC CROSS SECTION THROUGH ANVIL MOUNTAIN AND MOONLIGHT SPRINGS   (See sheet 2 for location of the cross section line)

Figure 2. Rating curve for Moonlight Springs overflow discharge.

Figure 3. Total Moonlight Springs discharge & average total water use.

Figure 4. Moonlight Springs overflow discharge & water temperature at the collection gallery.

Figure 5. Total Moonlight Springs discharge & daily average air temperature at Nome airport.
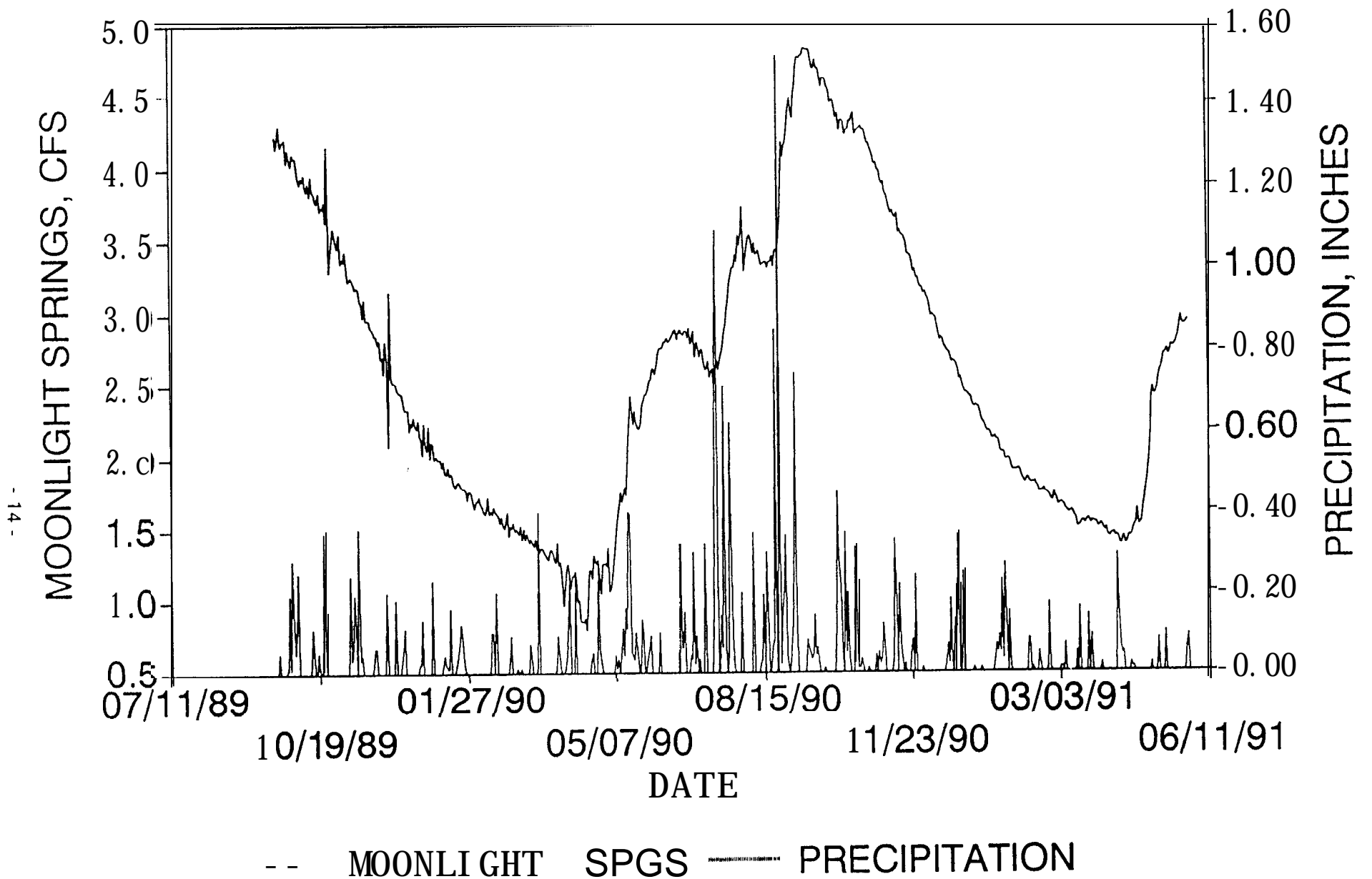
Figure 6. Total Moonlight Springs discharge and daily total precipitation at Nome airport.
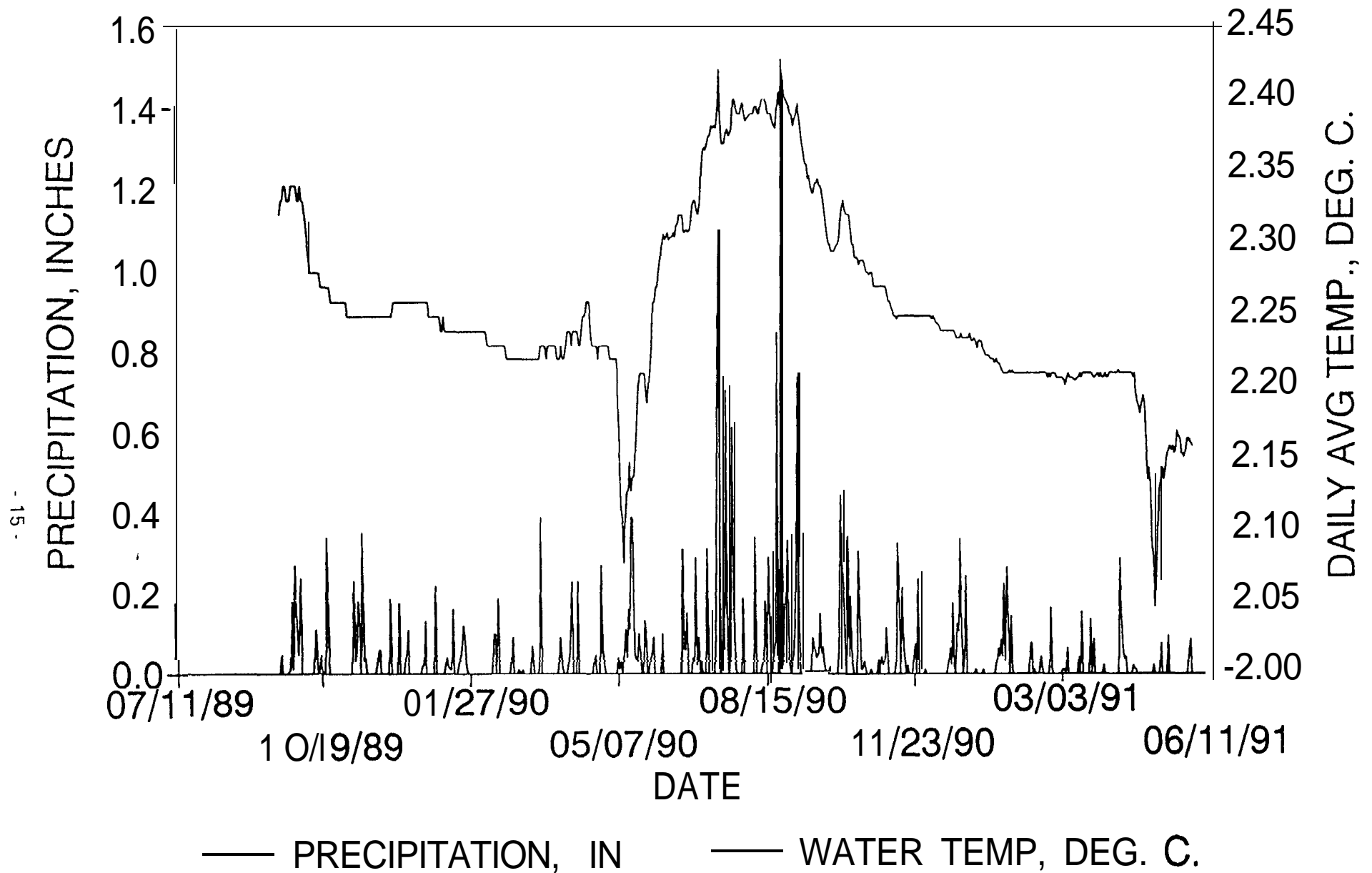
Figure 7. Nome airport precipitation & water temperature at Moonlight Springs collection gallery
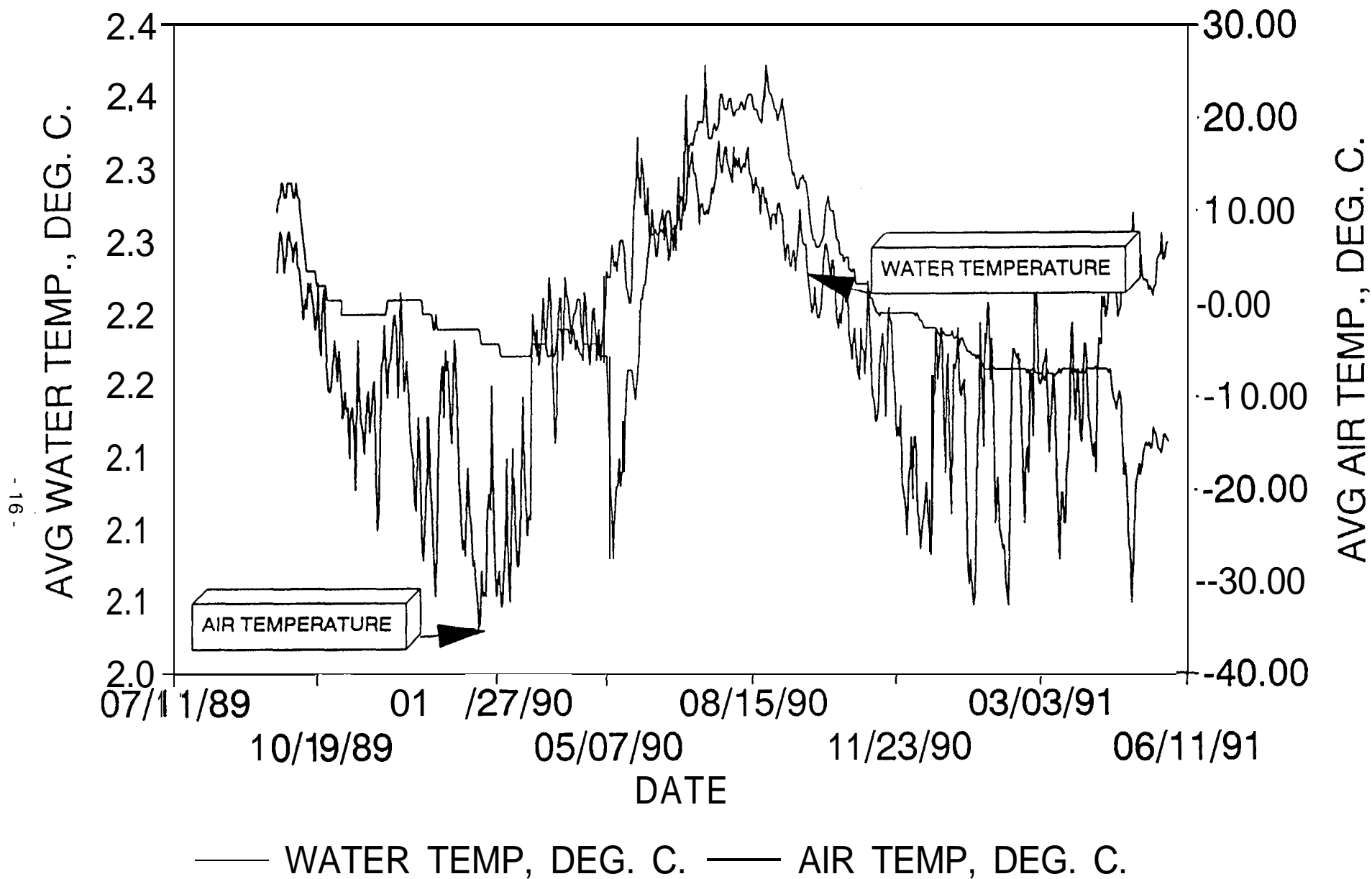
Figure 8. Moonlight Springs collection gallery daily average water temperature & Nome airport daily average air temperature.
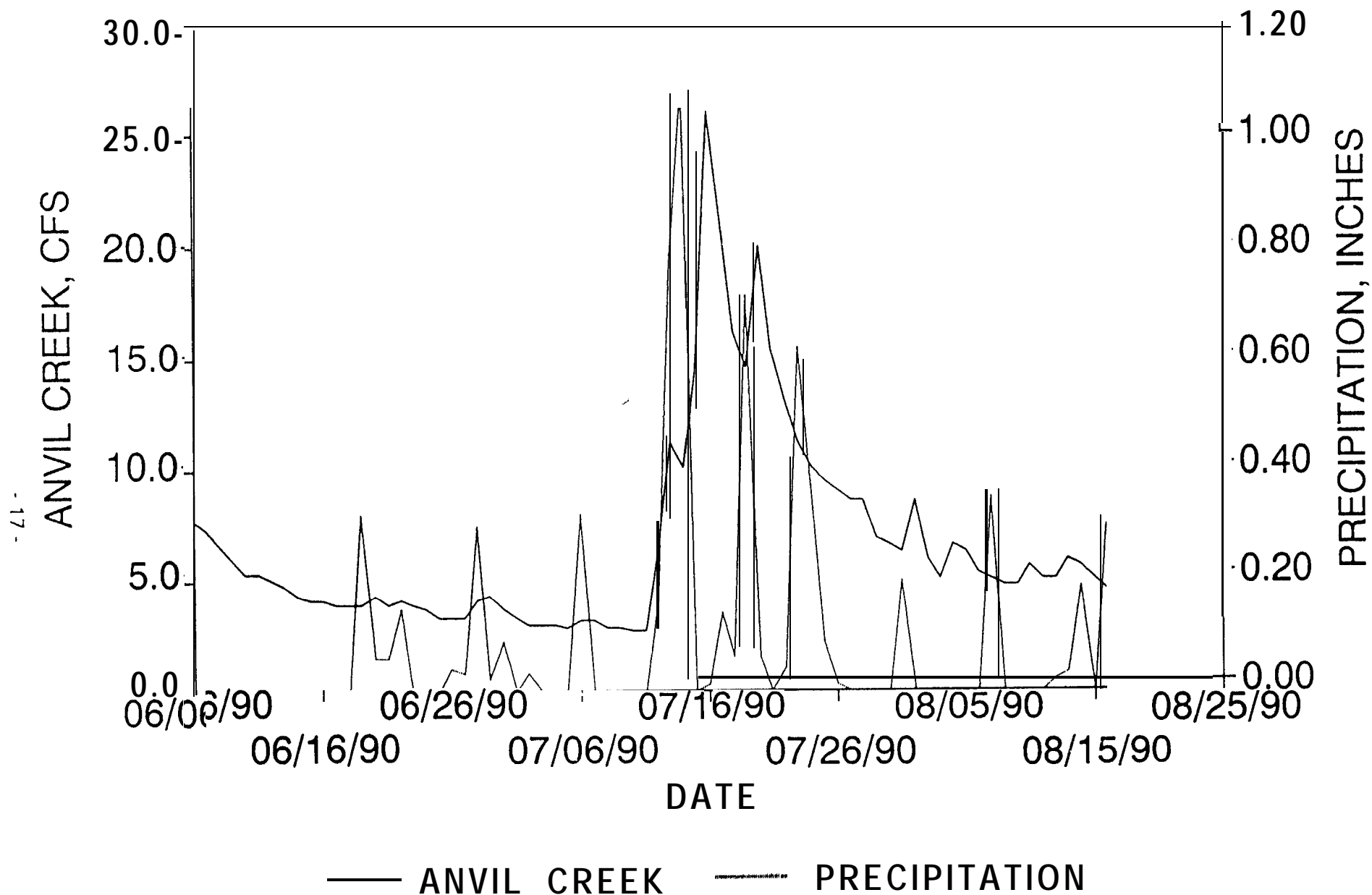
Figure 9. Anvil Creek discharge & daily total precipitation at Nome airport.
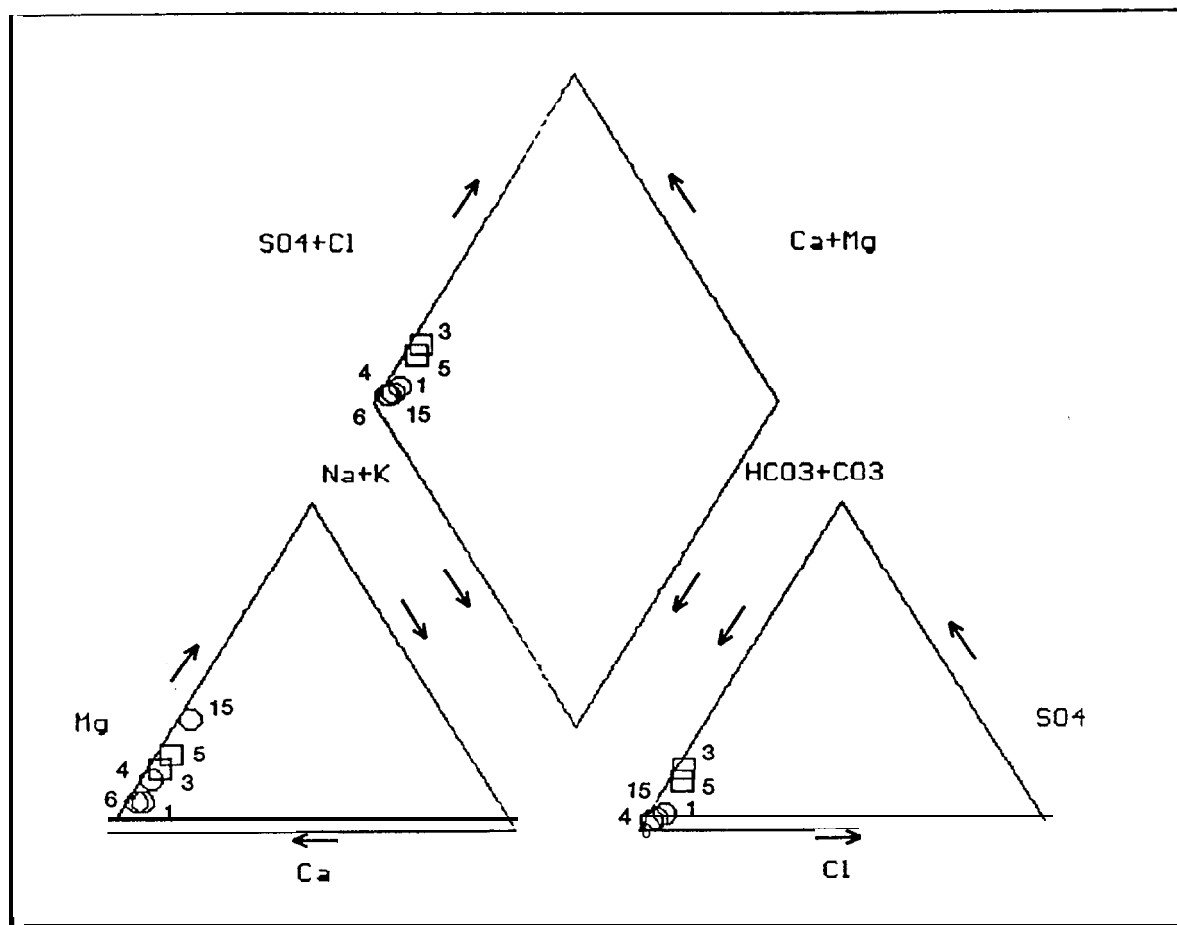
LEGEND

Rock Type	Marble	Schist
Symbol	O	□
Site Name/Number	Moonlight Springs/l	Lindblom spring/3
	Engstrom well/4	Specimen Gulch seep/5
	Barron well/6	
	Anseth well/l 5	

Figure 10. Piper diagram of Nome area ground waters.

APPENDIX A

Water quality analytical results

LEGEND TO WATER QUALITY SAMPLING SITES

Map No.	Sample Code	Location
Q-I	N-GW-1	Moonlight Springs
Q-2	N-GW-2	B. Hill well
Q-3	N-GW-3	Lindblom spring
Q-3	N-GW-4	Lindblom spring
Q-4	N-GW-5	R. Engstom well
Q-5	N-GW-6	Specimen Gulch seep
Q-6	N-GW-7	S. Barron well
Q-7	N-SW-I	Anvil Creek
Q-8	N-SW-2	Anvil Peak (snowmelt)
Q-9	N-SW-3	Little Creek
I-1 0	N-SW-4	Extra Dry Creek
I-1 1	N-SW-5	Newton Gulch
I-I 2	N-GW-8	New Year Gulch
I-1 3	N-GW-9	Nekula Gulch
I-I 4	N-GW-10	East Anvil Mountain
Q-15	AN	L. Anseth well
Q-16	BS	Beltz School well
Q-16	FB	Beltz School well
Q-16	FH	Beltz School well
Q-17	MD	M. Desalernos well
I-18	s s	Anvil Peak (snow sample)
Q-I	MS	Moonlight Springs
Q-I	OF	Moonlight Springs
Q-I	PH	Moonlight Springs

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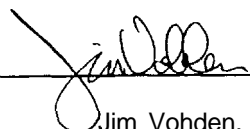
Submitted By: Mary Maurer

Date: June 11, 1990

Sample	Calcium	Magnesium	Sodium	Potassium	
N-GW-1	47.5	3.02	24	0.33	
N-G W-2	32.6	6.09	5.2	0.51	
N-GW-3	72.2	10.9	3.1	037	
N-GW-4	71.1	10.8	3.1	033	
N-GW5	54.3	651	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-l	25.8	5.89	19	033	
N-SW-2	5.89	0.40	09	0.08	
N-S W-3	58.2	5.75	3.0	0.15	
N-GWB3	co.01	co.01	<0.1	< 0.01	

	Calcium	Magnesium	Sodium	Potassium
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 _____   Date 30 NOV 90 _____

Jim Vohden, Chemist

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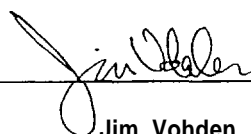
Client: ADGGS · Eagle River

Submitted By: Mary Maurer

Date: June 11.1990

Sample	Fluoride	Chloride	Nitrate (as N)	sulfate	
N-GW-1	036	3.71	0.60	5.64	
N-GW-2	030	10.1	<0.02	183	
N-GW-3	0.55	331	<0.02	38.2	
N-GW-4	0.55	3.40	<0.02	38.1	
N-GWJ	0.37	2.07	0.60	5.18	
N-GW-6	0.56	3.11	0.05	193	
N-GW-7	0.41	2.56	0.22	5.84	
N-SW-l	0.29	2.21	0.02	193	
N-SW-2	0.07	1.64	CO.02	0.41	
N-SW-3	0.43	257	0.08	14.4	
N-GWB-3	co.01	co.01	<0.02	co.01	
Units	mg/l	mg/l	mg/l	mg/l	
EPA Method	300.0	300.0	3U0.0	300.0	
Detection Limit	0.01	0.01	0.02	0.01	
RPD	4.4	5.2	1.2	1.7	
% Recovery	85	92	86	83	

Approved By _____   Date 30 NOV 90 _____

Jim Vohden, Chemist

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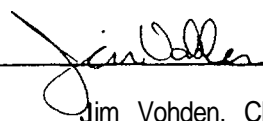
Submitted By: Mary Maurer

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	85	<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-l	<4	c 2	<5	<30	16
N-SW-2	<4	<2	<5	<30	70
N-SW-3	<4	c 2	<5	<30	17
N-GWB-3	<4	<2	<5	<30	C5
Units	μg/l	μg/l	μg/l	μg/l	μg/l
EPA Method	206.3	245.1	AES 0029	AES 0029	AEsoo29
Detection Limit	4	2	5	30	5
RPD	5.7	*	*	*	4.9
% Recovery	91	99	108	101	%

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

Approved By _____   Date 30 NOV 90 _____

Jim Vohden, Chemist

Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date: June 11, 1990

Sample	Barium	Copper	Chromium	Zinc
N-GW-1	36	<10	<5	<10
N-GW-2	37	<10	<5	<10
N-GW3	36	<10	c5	<10
N-GW-4	32	<10	c5	<10
N-GW-5	30	<10	<5	<10
N-GW-6	34	<10	<5	<10
N-GW-7	23	<10	<5	14
N-SW-I	31	<10	<5	20
N-SW-2	25	<10	c5	<10
N-SW-3	36	<10	<5	<10
N-GWB-3	<5	<10	<5	<10
Units	μg/l	μg/l	μg/l	μg/l
EPA Method	AES 0029	AESoo29	AES 0029	AES 0029
Detection Limit	5	10	5	10
RPD	4.8	*	•	3.7
% Recovery	88	106	101	98

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

Approved   By _____   Date 30 NOV 90

Jim Vohden, Chemist
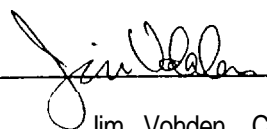
Client: **ADGGS** - Eagle River

Submitted By: Mary Maker

Date: June 11, 1990

Sample	Iron	Iron (total)	Manganese	Manganese (total)	
N-GW-1	52	80	8.0	8.0	
N-GW-2	5150	6650	72	92	
N-GW3	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	μg/l	μg/l	μg/l	μg/l	
EPA Method	AES 0029	AES 0029	AES 0029	AES 0029	
Detection Limit	30	30	5	5	
RPD	3.8	5.8	1.0	53	
% Recovery	100	101	97	97	

Approved By _____ Date 30NOV90

Jim Vohden, Chemist

- 25 -
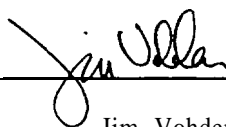
Client: ADGGS • Eagle River

Submitted **By:**   Mary **Maurer**

Date Submitted: September **28, 1990**

Sample	calcium	**Magnesium**	**Sodium**	**Potassium**	
AN	50.6	16.7	26	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	193	3.8	1.26	
M S	46.1	2.80	22	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	20	4.4	
% Recovery	91	9 9	104	103	

Approved By _____   Date ZJAN91 _____

Jim Vohden, Chemist
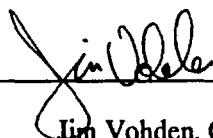
Client: ADGGS • Eagle River

Submitted By   Mary Maurer

Date Submitted: September 28, 1990

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	355	<DL	0.44	
MD	0.58	4.11	0.06	705	
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	12	2.9	9.5	13	
% Recovery	93	93	87	87	

Approved By _____   Date 2JAN91 _____

Jim Vohden, Chemist

Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: September 28, 1990

Sample	Aluminum	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	35	*	*
% Recovery	102	102	98	88	94

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

Approved By _____   Date 2 JAN 91 _____

Jim Vohden, Chemist

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.

Approved By _____   Date 2 JAN 91 _____

Jim Vohden, Chemist

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	AEsoo29	AES 0029	AEsoo29	
Detection Limit	50	50	5	5	
RPD	1.8	1.2	27	1.0	
% Recovery	95	92	101	%	

Approved By _____   Date 2 JAN91 _____

Jim Vohden, Chemist

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	295	23	0.58	
PH	42.1	2.97	21	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	24	03	
% Recovery	96	98	102	109	

Approved By _____   Date 24 JUNE 91 _____

Jim Vohden, Chemist

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
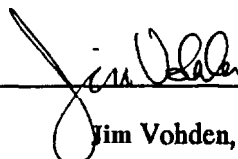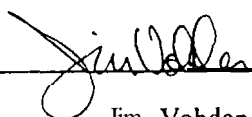
Client: ADGGS • Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Fluoride	Chloride	Nitrate	Sulfate
UT	<DL	<DL	<DL	<DL
OF	036	3.08	0.47	638
PH	0.34	2.95	0.46	638
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 _____   Date 24 JUNE 91 _____

Jim Vohden, Chemist
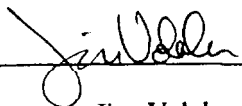
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Arsenic	Aluminum	Barium	cadmium	Copper
U T	<DL	<DL	<DL	<DL	<DL
O F	<DL	87	21	<DL	<DL
P H	<DL	90	21	<DL	<DL
Units	ug/L	ug/L	ug/L	ug/L	ug/L
EPA Method	206.2	AES 0029	AES 0029	213.2	220.2
Detection Limit	1	5	5	1	1
RPD	2.1	2.0	0.7	3.2	7.6
% Recovery	92	90	99	109	91

Approved By _____   Date 24 JUNE 91

Jim Vohden, Ckmist

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

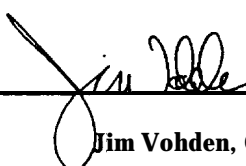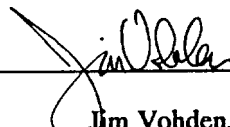Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Chromium	Mercury	Lead	Zinc
U T	<DL	<DL	<DL	<DL
O F	<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	95	5.7
% Recovery	93	92	107	99

Approved By _____   Date 24 JUNE 91 _____
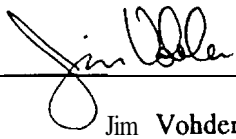
Jim Vohden, Chemist

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 _____   Date 24 JUNE 91 _____

Jim **Vohden,** Chemist

Western Atlas
International

LABORATORY TESTS RESULTS
07/20/90

OB NUMBER: 901868 CUSTOMER: STATE OF ALASKA ATTN: MARY MAURER

AMPLE NUMBER: 1 DATE RECEIVED: 06/22/90 TIME RECEIVED: 14:03 SAMPLE DATE: 06/06/90 SAMPLE TIME: 11:40
ROJECT: MOONLIGHT SPRINGS SAMPLE: N-GW-1D REM:

AMPLE NUMBER: 2 DATE RECEIVED: 06/22/90 TIME RECEIVED: 14:03 SAMPLE DATE: 06/06/90 SAMPLE TIME: 11:34
ROJECT: MOONLIGHT SPRINGS SAMPLE: N-GW-1C REM:

AMPLE NUMBER: 3 DATE RECEIVED: 06/22/90 TIME RECEIVED: 14:03 SAMPLE DATE: 06/08/90 SAMPLE TIME: 10:30
ROJECT: ANVIL CREEK TRIB SAMPLE: N-SW-3D REM:

AMPLE NUMBER: 4 DATE RECEIVED: 06/22/90 TIME RECEIVED: 14:03 SAMPLE DATE: 06/08/90 SAMPLE TIME: 10:30
ROJECT: ANVIL CREEK TRIB SAMPLE: N-SW-3E REM:

AMPLE NUMBER: 5 DATE RECEIVED: 06/22/90 TIME RECEIVED: 14:03 SAMPLE DATE: 06/06/90 SAMPLE TIME: 20:17
ROJECT: NOME • HILL WELL SAMPLE: N-GW-2D REM:

AMPLE NUMBER: 6 DATE RECEIVED: 06/22/90 TIME RECEIVED: 14:03 SAMPLE DATE: 06/06/90 SAMPLE TIME: 20:17
ROJECT: NOME • HILL WELL SAMPLE: N-GW-2C REM:

EST DESCRIPTION	SAMPLE 1	AMPLE 2	SAMPLE 3	AMPLE 4	SAMPLE 5	SAMPLE 6	JNITS 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 8260 1
(307) 235-5741

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:105271	
DETECTION LIMIT:		UNITS:pCi/l		METHOD REFERENCE :EPA 900.0						TECHNICIAN:PL
DUPLICATE	prep	902061-S	0.2	0.3	40					
DUPLICATE	prep	901955-3	4.0	4.7	16.09					
DUPLICATE	prep	901809-8	1.0	1.0	0					
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:PL
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: _____

420 West 1st Street
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/6004-80-032, 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.

Miami
UNIVERSITY OF

July 26, 1990

TRITIUM LABORATORY

Data Release #90-29
Job # 274

ALASKA   DEPARTMENT   OF   NATURAL   RESOURCES
TRITIUM   SAMPLES

Purchase   Order   D.O.   188097

H. Göte   Ostlund
Head, Tritium Laboratory

Distribution:
    Mary A. Maurer
    ALASKA   DEPARTMENT   OF   NATURAL   RESOURCES
    P.O. Box 772116
    Eagle River, Alaska 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-SC 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

UNIVERSITY OF
Miami

November 28, 1990

TRITIUM LABORATORY

Data Release #90-46
Job # 288

ALASKA DEPARTMENT OF NATURAL RESOURCES
TRITIUM SAMPLES

Purchase Order D.O. 237318

H. Göte Ostlund
Head, Tritium Laboratory

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

```
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
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All duplicate runs except #288.05
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UNIVERSITY OF
Miami
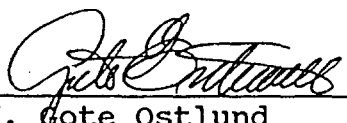
April 25, 1991

TRITIUM LABORATORY ,

Data Release #91-17
Job # 313

ALASKA DEPARTMENT OF NATURAL RESOURCES
TRITIUM SAMPLES

Purchase Order D.O. **239014**

H. Gote Ostlund
Head, Tritium Laboratory

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

```
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
------------
```

GENERAL COMMENTS ON TRITIUM RESULTS

Tritium 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., $\lambda = 5.65\%$ 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., $\lambda = 5.576\%$ 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		18O/16O(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	-23.23 -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

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 I.400	-13.42		-110.8	-108.5
PH-2	4/2/91 1730	-13.75	-13.88	-96.5	

APPENDIX B

Water quality field measurements

Appendix B. Field measurements

MAP NO.	SITE	DATE	TIME	WATER TEMP. (°C)	DISCHARGE (CFS)	CONDUC- TIVITY (μS/CM)	pH (FIELD)
Q-1	Moonlight Springs	06/06/90	0920	2.1	2.0	269	8.4
Q-2	Ben Hill's Well	06/06/90	2016	3.5		241	7.2
Q-7	Anvil Creek	06/06/90	1350	7.8	7.85	198	7.9
Q-8	Anvil Peak	06/07/90	1050	4.1	0.004	47	7.8
Q-3	Lindblom Spring	06/07/90	1426	2.6		418	7.4
Q-4	Ron Engstrom's Well	06/07/90	2000	1.6		248	7.5
Q-9	Little Creek	06/08/90	0935	3.3	0.15	320	7.9
Q-5	Specimen Gulch Seep	06/08/90	1454	1.2	0.003	283	7.0
Q-6	Scott Barron's 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	9.63	233	7.9
Q-15	Leonard Anseth's Well	09/25/90	0946	1.9		361	8.2
Q-17	Matt Desalernos's Well	09/25/90	1350	5.6		651	7.2
Q-1	Moonlight Springs	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 B. Field measurements (continued)

MAP NO.	SITE	DATE	ALKALINITY (MG/L AS CAC03)	DISSOLVED OXYGEN (MG/L)	DISSOLVED OXYGEN SATURATION (PERCENT)	TURBIDITY (NTU)
Q-1	Moonlight Springs	06/06/90	116	13.2	95	0.2
Q-2	Ben Hill's Well	06/06/90	90			
Q-7	Anvil Creek	06/06/90	64	11.7	98	1.1
Q-8	Anvil Peak	06/07/90	15	10.2	79	
Q-3	Lindblom Spring	06/07/90	175			
Q-4	Ron **Engstrom's** Well	06/07/90	163			
Q-9	Little Creek	06/08/90	146	7.7	57	0.4
Q-5	Specimen Gulch Seep	06/08/90	112	3.1	22	
Q-6	Scott **Barron's** Well	06/08/90	204			
I-10	Extra Dry Creek	06/09/90		12.7	98	0.3
Q-16	**Beltz** School Well	09/24/90	274			
Q-7	Anvil Creek	09/25/90		12.9	97	
Q-15	Leonard **Anseth's** Well	09/25/90	200			
Q-17	**Matt Desalernos's** Well	09/25/90	310			
Q-1	Moonlight Springs	09/26/90	132	13.1	94	
Q-1	Moonlight Springs (at pumphouse)	04/02/91	105	7.0	54	

APPENDIX C

Laboratory methodology for tritium and stable isotopes

UNIVERSITY OF

Miami

TRITIUM   LABORATORY

TRITIUM AND C14 MEASUREMENTS

PRICE   SCHEDULE

PROCEDURES   AND   STANDARDS

ADVICE   ON   SAMPLING

1 July 1989

LOW-LEVEL MEASUREMENTS OF TRITIUM AND RADIOCARBON

I.   SCHEDULE OF COSTS (per sample)

A.   **Tritium** measurement
        1. Low-levelgasproportionalcountingofwater sample, requiredsample
           volume 15 **ml.** Processing quantity is fixed at 4 ml. $140.00

        Counting will be performed to ± **3.5%,** one sigma, or ± 6 TU (0.02
           pCi per ml), whichever is larger. For undersized or chemically
           contaminated samples, special arrangements will have to be made.
           For samples suspected to be above 1000 TU (3 **pCi** per ml), we require
           advance notice.

        2. Enrichment and low-level counting of ultra-low activity water
           sample, required sample quantity 1000 ml. Normal starting volume
           is 275 ml. $280.00

           Accuracy and precision will be 0.1 TU (0.0003 **pCi** per ml) or ± 3.5%,
           whichever is larger. For undersized or chemically contaminated
           samples, special arrangements will have to be made. For samples
           suspected to be above 50 TU (0.16 **pCi** per ml), we require advance
           notice.
           NOTE: Stated starting volume is needed for obtaining quoted
           accuracy: a smaller quantity will usually yield less precise
           results. For a first run we will take no more than one third of
           the furnished amount of water.

B.   Sieve extraction (used in atmospheric **tritium** sampling) $50.00

        Extraction of sieve trap or palladium trap, with appropriate
        pushouts and restoring of the trap in condition ready for re-use;
        trap to be of standard configuration.

C.   Precision Radiocarbon measurement $500.00

        Young samples will be determined with ± 4 $^\circ/_{\circ\circ}$ accuracy in ^{14}C (^{13}C
        correction included), by at least 2 periods of counting to a total
        of 2,000 minutes. The sample must consist of 9 lit STP or more of
        CO, in compressed form or dissolved in **NaOH.** We do not offer
        conventional radiocarbon dating service, and cannot handle samples
        involving combustion of **organics** or release of CO, from minerals.

D.   Contract

        Due to the increased amount of administrative and legal input needed
        for a contract, such arrangement may carry a **surcharge,** the size of
        which will depend upon the quantity of administrative work required
        of the University. Any contract **must** include the technical and

                                        1

procedural   specifications set in this Price Schedule unchanged.

E.   Pre-payment must be   sent   with   order.   No samples will be analyzed until
          payment   has   been   received.

II.   <u>SERVICES RENDERED</u> **(Tritium)**

          The University prefers to perform service on Purchase Order basis, for
          which   the   following   services   are   extended:

          Discussion on sample quality, sampling techniques, advice to submitters
          regarding needs and measurement options, and available pertinent
          reprints, etc. are   furnished   free.

          Upon receiving samples for analysis, the Tritium Lab will:

          1. Acknowledge   receipt, if   client   requests.

          2. Check inventory of the bottles received against a packing list, if
          supplied.   Notify   submitter, by   phone   if discrepancy   found.

          3. Prepare and measure each sample to meet specifications.   Unless
              specifically instructed by the client we will start with no more
              than one third of the furnished amount of water. This will allow
              for loss of one **run** and still be enough for duplicate runs, if
              needed.

          4. Report preliminary results as soon as available, upon phone inquiry
              by submitter.

          5. Issue Data Release with final results. For timing see Description
              of Procedures and Standards, Section F, Update.

          6. Issue an invoice

          7. Save remainder of samples for 3 months.

          8. Since this technique is on the very fringe of what is technically
              possible, the University of Miami cannot assume any legal or other
              responsibility for erroneous results. However, if submitter can
              provide a justified reason for suspecting a bad result, we will
              remeasure such a sample at our cost if the sample quantity remaining
              with us allows.

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III. <u>TECHNICAL CONDITIONS FOR ACCEPTANCE OF **TRITIUM** SAMPLES</u>

The machinery of the Tritium Laboratory is designed for operation on only extremely low-level tritium water samples and is, therefore, very vulnerable to samples with unexpectedly high tritium activity.

A. For samples with expected activity above 1000 TU (3 **pCi/ml**) we must be given clear notice. Such "hot" samples would originate from the vicinity of nuclear installations. Direct gas counting (I.A.l) can accept samples up to 10,000 TU (32 **pCi/ml**), but such waters could easily be measured in a commercial-type liquid scintillation system and should not be sent to us.

NOTE: The submitter of a "hot" sample must bear any cost for loss of analytical capability due to the carry-over of tritium from the submitter's samples to other samples in our operation.

B. Samples to be treatedby full electrolytic enrichment **(I.A.2)**, and expected to be above 30 **TU** (0.1 pCi/ml), are treated differently than those close to 0 Tu. In order to preserve optimal accuracy, some preliminary information is desirable on these samples. Submitters of samples are therefore strongly advised to contact the laboratory in order that proper precautions may be taken.

C. Chemically contaminated samples, in general, cannot be handled. Smaller amounts of non-volatile salts like sodium chloride, are allowable, as are low concentrations of hydrogen sulfide. These two classes of contaminants are removed by distillation in oxygen atmosphere and/or by addition of potassium permanganate. Not allowed are, in particular, organic matter like oils, alcohols, phenols, and volatile **inorganics** like arsenic compounds. Such chemicals will cause extensive damage to electrolysis and counting equipment. We reserve the right to refuse processing any samples that we judge to be too contaminated or 'dirty' to run through our system.

D. For his/her own benefit, a potential submitter is advised to contact the laboratory regarding procedures for field sampling and storage of ultra-low-level samples to avoid contamination in the field or during transport. In particular, note that a wristwatch with a luminescent dial is surrounded by a cloud of tritium water vapor! See the section 'Advice on Sampling'.

3

1. <u>LOW LEVEL ANALYSIS</u>

   All numbers of quantities, etc., are typical only and **may** vary from sample
to   sample.

A. <u>Distillation</u>

   300 ml of the water sample are distilled with twin reflux dropcatchers to
dryness or near dryness. During the procedure, the still is vented to the
ambient air through a drying agent to avoid contamination of the sample by
atmospheric water vapor.

B. **Electrolytic** <u>Enrichment</u>

   The object of this procedure is to reduce the volume of the sample from 275
to 3.5 ml while preserving a large fraction of the tritium.

   The normal starting volume is 275 ml of which 75 ml are charged into the
electrolytic enrichment cell. To **that** portion. 1.6 **ml** of concentrated sodium
hydroxide solution (made from dead water and sodium peroxide or oxide) is added,
and the remainder of the sample is transferred to a container on top of the cell.
The sample is electrolyzed for 24 hours at 6 amps, **current-regulated** which
removes 50 ml of water. The solution in the cell is topped up from the container
to the 75 ml mark, and the procedure is continued. When a total of between 20
and 50 **ml** of the sample remains, power is changed to constant voltage of 3.35 V
until the process stops at the *lower* edge of the anode, leaving 3.5 g of enriched
sample. This amount of water typically contains 80% of the original amount of
tritium.   The enriched water sample is vacuum distilled from the sodium
hydroxide, and the yield is weighed to ± 5 **mg,** and adjusted for hydrogen left
in the sodium hydroxide.

C. <u>Preparation of Samnline Gas</u>

   The enriched water sample is injected into a vacuum system.   The water
evaporates, and the vapor is reduced by hot magnesium metal to hydrogen gas which
is absorbed on activated charcoal at liquid nitrogen temperature in a stainless
steel pressure cylinder. Approximately 3 lit **atm** of hydrogen is obtained this
way.

D. <u>Low-Level Counting</u>

   The low-level gas proportional counters have an active volume of 1 lit and
are shielded by 2.5 cm of selected lead, a ring of anti-coincidence Geiger
counters, 10 cm of paraffin wax, boric acid and/or borated polyethylene, and at
least 20 cm of iron, plus the walls and ceiling of the building. The counter
is first filled with 10 psi of propane. Thereafter, the sample hydrogen gas,
under pressure in its cylinder, is added to the counter for a total pressure of
40 psi.   The counter is then sealed off, and the gas amplification is set to
specifications by adjustingworkingvoltage using an external radioactive source.

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After that, counting proceeds until criteria for accuracy or sensitivity'have been met. The pulses are sorted into several channels, of which some are used for continuous control of gas amplification, as shown in the cosmic radiation spectrum, etc. Counting times are 6 to 20 hours. A 1 TU original sample enriched 275/3.5 ml typically shows 1 cpm in the tritium channel above a background of 0.40 cpm, known to ± 0.03 cpm or better. The control of filling and counting procedures and calculation of results, as well as numerous checks on the performance of the machinery, are computerized.

E. Backgrounds and Standard

At least once weekly each counter counts dead hydrogen gas (from petroleum). In addition, water from the deep **Floridan** Aquifer (more than 10,000 years old water) is reduced *to* occasionally check on the tank hydrogen gas. This procedure sets the background count of the counting equipment. Each batch of sodium hydroxide solution is also tested for blank value. A further check on process blanks is that at least once a week a sample of dead water (from the **Floridan** Aquifer) goes through all the same procedures, including enrichment, as the unknown samples. In order to check on the efficiency of the enrichment procedure, at least once a week a sample of **known** activity, prepared from the National Bureau of Standards (NBS) Standard Reference Material (SRM), is processed through the entire system of enrichment, reduction, and counting.

The efficiency of each counter is.determined by counting standard activity hydrogen gas by reduction of standard water in our regular preparation system. This standard water is prepared from NBS SRM **#4926** by dilution by weighing. The dependence of background, efficiency, etc., on pressure, gas composition, gas amplification, etc., is known, and the appropriate corrections are applied via the software of the computing system.

F. Update

Periodically, usually about **every six** weeks, all measurements in all counters for the preceding time period are recomputed, applying statistical tests, and scrutinized for flaws in quality. This includes all measurements of **unknowns,** backgrounds, blanks, enrichment factors, efficiencies, **etc.** Only after this step is the result considered final. The results are then reported in Data Releases, **one** for each project.

G. Further Technical Information

The procedures of tritium analysis are described in the following publications from this Laboratory, reprints furnished on request:

dstlund, H.G. and H.G. Dorsey, 1977. Rapid electrolytic enrichment and hydrogen gas proportional counting of tritium, in *Low-Radioactivity Measurements and Applications,* Proceedings of the International Conference on Low-Radioactivity Measurements and Application, 6-10 October 1975, The High Tatras, Czechoslovakia, Slovenske Pedagogicke Nakladatelstvo, Bratislava.

Östlund, H.G., H.G. Dorsey and C.G. Rooth, 1974. GEOSECS North Atlantic radiocarbon and tritium results, *Earth Planet.* Sci. *Lett., 23, 69-86.'*

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Östlund, H.G., M.O. Rinkel and C. Rooth, 1969. Tritium in the equatorial Atlantic current system, *J. Ceophys. Res., 74*(18), 4535-4543.

Östlund, H.G. and E. Werner, 1962. The electrolytic enrichment of tritium and deuterium for natural tritium measurements, *in Tritium in the Physical and Biological Sciences,* International Atomic Energy Agency, 1962. (Describes an earlier version of the procedure).

2. SAMPLE IDENTIFICATION AND FLOW OF INFORMATION

Water samples for tritium analysis are received and inventoried using the accompanying packing list supplied by the client. A computer worksheet listing sample name, volume, sample collection date, and date of arrival into lab, as well as client information, is generated. At this time, each order is given a unique job number, and each sample decimal numbered within that job. For example, the job-sample number (JB#), 110.01 indicates the first sample in the listing for job 110. The computer input is proofread, and the worksheet is printed. An abbreviated copy of the worksheet listing is given to the administrative personnel to be filed with the client's records. The worksheet is used by the preparation technician to keep track of the progress of the samples. Preliminary results are recorded on this sheet as they become available. through the computer. From the tine the worksheet is printed, the sample is referred to by its JB#.

When processing begins, a label bearing the JB# is attached to the sample and "follows" it through the preparation steps; ie, it is physically transferred to the current container. The same label is used from the beginning distillationthroughelectrolytic enrichment, vacuumdistillationandreduction to hydrogen gas. The label is eventually attached to the face of the pressure gauge of the counter in which the sample is counted.

During each step of the process, a record is kept of the preparation apparatus associated with an individual sample. A yellow preparation card reports the starting date and volume, the order number through, the reduction. system, and the cylinder used to store the gas sample prior to counting.

When the sample is ready for activity measurement, the above information is entered into the computer together with sample pressure and temperature, a unique run number, and the time and date. Upon completion of the counting, temperature and pressure of the sample within the counter are again recorded for comparison and checked for computer input error. All records of the sample preparation information and counting results are stored in computer files.-- A listing of all samples prepared and counted the week before is printed every Monday to study for possible problems with the preparations and/or counting equipment.

Using these procedures, every sample can be traced from the moment it arrives in the lab to the final result.

SAMPLING OF ENVIRONMENTAL WATER
FOR **LOW** LEVEL **TRITIUM ANALYSIS**

A.   **Explanation**

Tritium in environmental samples will be determined with a limit of detection, of 0.1 T-units (TU) (0.0003 **pCi/ml).** Water vapor of the open air varies from 2 to 100 TU. Indoors, the atmospheric humidity may reach 10,000 **TU** from various luminescent dials. Exposure of the water to such air at any temperature might give badly erroneous tritium results.

B.   <u>Sample bottles</u>

For lowest level of tritium samples we recommend using 1 lit. (1 qt.) glass bottles with **"PolySeal",** conical inset, caps. The bottles should be clean and dry, preferably factory fresh. If transfer is to be made indoors, the dry bottles should first be filled with argon gas. See below.

If the very lowest detection level is not needed, heavywall plastic bottles may be acceptable. Must have good caps. Hold a filled bottle upside-down and squeeze hard. No leakage is allowed. Remember that there are large pressure changes in air transport.

C.   <u>**Sampling** procedure</u>
1.   Sample transfer should be done outdoors, unless a specially vented room is available <u>with ban on wristwatches.</u>

2.   THE PERSON PERFORMING THE SAMPLE **TRANSFER** IS NOT ALLOWED TO WEAR A WRISTWATCH, COMPASS OR SIMILAR WITH LUMINESCENT DIALS OR SO CALLED "BETA" LIGHTS.

3.   Fill the bottle close to the neck with sample. Do not rinse. Overflow is not desirable.

4.   Replace and screw cap on tightly.

5.   Record bottle numbers on original field data sheets, and fill in information on bottle label.

6.   If sampling indoors, never let the water be exposed to the air. Pipe the sample water into the middle of an argon-filled bottle (below the argon level). Do not pour the argon out before, by tilting an open **bottle**.

7

STABLE ISOTOPES

Introduction

Stable isotope composition is used to study the characteristics and origin of groundwaters. Isotope ratios of hydrogen ($^2H/^1H$) and oxygen ($^{18}O/^{16}O$) are the most commonly examined. Waters from different geographic origins or of a different hydrological nature have a distinctive isotopic composition. Generally, isotopic composition does not change unless waters originating from different recharge areas mix. These characteristics make stable isotopes well suited to studies concerned with the location of recharge zones, assessments of surface water contribution to groundwaters, and the degree of mixing of different groundwater bodies. (Gat and Gonfiantini, 1981).

Sampling

Samples are collected in a 20-milliliter vial. All air bubbles are removed.

Analysis

Isotope ratios are determined by mass spectometry at the Stable Isotope Laboratory at Sourthern Methodist University in Dallas Texas. Water hydrogen samples are analyzed by the uranium method (Bigeleisen and others, 1952). The resolution objective for the $^2H/^1H$ ratio is $\pm$ 1 mill. Water oxygen samples are analyzed by the CO_2-H_2O equilibration method at 25^0 Centigrade described by Epstein and Mayeda (1953). The resolution objective for the $^{18}O/^{16}O$ ratio is f0.2 mill. A summary of laboratory instrumentation, sample preparation procedures, and laboratory personnel is listed on page 2.

References

Bigeleisen, J., Perlman, M.L., and Prosser, H.C., 1952, Conversion of hydrogenic materials to hydrogen for isotopic analysis: Anal. Chem., v.24, n.8, p. 1356-1357.

Epstein, Samuel, and Mayeda, Toshiko K., 1953, Variation of 018 content of water from natural sources: Geochim. Cosmochim. Acta, v. 4, p.213-224.

Gat, J.R., and Gonfiantini, R., 1981, Stable Isotope Hydrology, Deuterium and Oxygen-18 in the Water Cycle: International Atomic Energy Agency, Technical Repoprts Series No. 210, Vienna, Austria.

Technical Information

Reed, Marshall J., and Mariner, Robert H., Reliability of chemical and isotopic analyses of geothermal water samples: U.S. Dept. of Energy, unpublished draft report, 23 p.

1

STABLE ISOTOPE LABORATORY
1990-91

MASS SPECTROMETERS

Finnigan-MAT 25 1:   HD, CO_2

    Commissioned: 1982; planned modification 1991 (subject to funding)

    Permanent magnet configuration, triple-collector CO_2, HD collectors, microvolume inlet system

Finnigan-MAT delta-E: HD, O_2, N_2, CO_2

    Rebuilt at the Bremen FMAT factory, 1989; recommissioned: 1989

    Electromagnet configuration, multiple-sample inlet system, 6 fixed Faraday collectors for CO_2, N_2, and O_2, separate HD collector assembly

EXTRACTION LINES/ SAMPLE PREPARATION FACILITIES'

1)   Fluorination line (ClF_3 or BrF_5) silicate and phosphate oxygen

2)   Carbonate oxygen and carbon line with 25-90 ° C water bath reaction temperatures

3)   Water oxygen (H_2O/CO_2 equilibration)

4)   Water hydrogen (uranium method)

5)   Radio frequency and resistance furnace line for hydrogen extraction from minerals, fluid inclusions and whole rocks

6)   Gas mixing table for the preparation of isotopic standards

7)   Mineral preparation facilities for magnetic or heavy-liquid mineral separations. Binocular microscopes for micro-sampling

PERSONNEL[2]

Associate Professor
R.T. Gregory, PhD (1981) California Institute of Technology; BA (1974) University of California, San Diego

Research Associates
M.T. Colucci, PhD (1990) S.M.U.; MS (1984) and BS (1982) Rutgers University

K.M. Ferguson, PhD (1990) S.M.U.; MS (1984) Arizona State University; BA (1977) Potsdam State College

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[1] The laboratory performs isotopic analyses on a contract basis. A list of services is available upon request.

[2] As a teaching institution, we train graduate and undergraduate students who work in the laboratory

App D

CD

tatistics for Nome

App D

WATER USE RECORDS & STATISTICS FOR NOME

1989

Month 1989	Anvil Mt. Cor. Fac.	Beltz Hi School	FAA	New Natl Guard Arm	City of Nome	Total use less Nome	Equiv GPD	Equiv. CFS	Total use incl Nome	Equiv GPD	Equiv CFS
Jan	246,355	366,119	138,023	7,750	17,428,500	658,247	21,234	0.033	18,086,747	583,443	0.903
Feb	237,664	311,862	87,329	7,000	15,256,500	643,855	22,995	0.036	15,900,355	567,870	0.879
Mar	258,949	333,764	120,858	7,750	14,174,800	721,321	23,268	0.036	14696,121	480,526	0.743
Apr	254,594	329,674	158,684	7,500	12,590,000	750,432	25,014	0.039	13,340,432	444,681	0.688
May	255,665	346,288	149,607	7,750	13609,000	759,310	24,494	0.038	14368,310	463,494	0.717
Jun	235,135	307,779	117,667	7,500	14,585,000	668,081	22,269	0.034	15,253,081	508,436	0.787
Jul	240,929	305,876	150.585	7,750	15,096,000	705,140	22,746	0.035	15,801,140	509,714	0.789
Aug	249,677	290,729	171,085	7,750	15206,000	719,221	23,201	0.036	15925,221	513,717	0.795
Sep	227,060	185,895	147,284	7,500	12,968,000	567,739	18,925	0.029	13535,739	436,637	0.676
Oct	223,230	235,518	131,297	7,750	12,210,000	597,795	19,284	0.030	12,807,795	413,155	0.639
Nov	219,170	318,122	147,370	7,500	12,775,000	692,162	23,072	0.036	13467,162	448,905	0.695
Dec	221,443	233,068	152,146	7,750	13,267,000	614,407	19,820	0.031	13,881,407	447,787	0.693
1989 AVGS	239,166	288,725	139,325	7,604	14,097,150	674,809	22,193	0.034	14,771,959	484,663	0.750

1990

Month 1990	Anvil Mt. Cor. Fac.	Beltz Hi School	FAA	New Natl Guard Arm	city of Nome	Total use less Nome	Equiv GPD	Equiv. CFS	Total use incl Nome	Equiv GPD	Equiv CFS
Jan	258,710	248,200	131,548	7,750	14,278,000	646,208	20,845	0.032	14,924,208	481,426	0.745
Feb	246,009	266,217	143,696	7:000	13,315,000	662,922	23,878	0.037	13,977,922	499,212	0.772
Mar	248,217	261,577	182,256	7,750	15,847,000	679,800	21,929	0.034	18526,800	533,123	0.825
Apr	234,888	228,025	95,320	7,500	14,833,000	565,733	18,858	0.029	15396,733	613,291	0.794
May	249,886	261,511	130,599	7,750	13,514,700	649,746	20,960	0.032	14,164,446	456,918	0.707
Jun	240,247	229,903	163,988	7,500	13693,913	641,618	21,387	0.033	14535,531	484,618	0.750
Jul	250,172	247,455	154,774	7,750	13,980,000	660,151	21,295	0.033	14,640,151	472,263	0.731
Aug	238,000	270,800	139,000	7,756	14693,000	655,550	21,147	0.033	15,348,550	495,115	0.766
Sep	228,000	301,000	288,000	7,500	15,594,000	824,500	27,483	0.043	16,418,500	529,629	0.819
Oct	253,000	443,900	150,060	7,750	13,709,000	854,650	27,569	0.043	14563,650	469,795	0.727
Nov	325,000	401,400	158,600	7,500	12,991,000	891,900	29,730	0.046	13,882,900	462,763	0.716
Dec	394,000	313,000	200,000	7,750	13,224,000	914,750	29,508	0.046	14,138,750	471,292	0.729
1990 AVGS	263,844	289,416	159,763	7,604	14,156,051	720,627	23,699	0.037	14,876,678	489,112	0.757

| OVERALL AVGS | 251,500 | 289,070 | 149,544 | 7,604 | 14,126,601 | 697,718 | 22,946 | 0.036 | 14,824,319 | 486,988 | 0.753 |

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