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**Preliminary Hydrogeological Evaluation of  
Moonlight Springs, Nome, Alaska**

By

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Alaska Division of Geological and Geophysical Surveys  
in cooperation with the City of Nome

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## CONTENTS

	<u>Page</u>
Introduction . . . . .	1
Previous investigations . . . . .	1
Geological setting . . . . .	2
Data collection . . . . .	2
Results . . . . .	3
Hydrology . . . . .	3
Snow surveys . . . . .	3
Water quality and isotopes . . . . .	5
Water budget . . . . .	5
Conclusions . . . . .	6
Acknowledgements . . . . .	7
References cited . . . . .	7

## TABLES

Table 1. Miscellaneous discharge measurements for Anvil Creek . . . . .	4
Table 2. Snow survey measurements, Anvil Mountain area, Nome, Alaska . . . . .	4

## FIGURES

Figure 1. Geologic cross section through Anvil Mountain and Moonlight Springs . . . . .	9
Figure 2. Rating curve for Moonlight Springs overflow discharge . . . . .	10
Figure 3. Total Moonlight Springs discharge and average total water use . . . . .	11
Figure 4. Moonlight Spring overflow discharge and water temperature at the collection gallery . . . . .	12
Figure 5. Total Moonlight Springs discharge and daily average temperature at Nome airport . . . . .	13
Figure 6. Total Moonlight Springs discharge and daily average precipitation at Nome airport . . . . .	14
Figure 7. Nome airport precipitation and water temperature at Moonlight Springs collection gallery. . . . .	15
Figure 8. Moonlight Springs collection gallery daily average water temperature and Nome airport daily average air temperature . . . . .	16
Figure 9. Anvil Creek discharge and daily total precipitation at Nome airport . . . . .	17
Figure 10. Piper diagram of Nome area ground waters . . . . .	18

## SHEETS

Sheet 1. Location of Moonlight Springs and water quality and isotope sample sites	
Sheet 2. Geologic map and hydrologic data collection sites in the Anvil Creek-Moonlight Springs area.	

## APPENDICES

Appendix A Water quality analytical results . . . . .	19
Appendix B Water quality field measurements . . . . .	48
Appendix C Laboratory methodology for tritium and stable isotopes . . . . .	51
Appendix D Water use records and statistics for Nome . . . . .	62

## 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-18) were sampled at locations shown in sheet 1. Appendix C contains sampling and analytical methodologies for isotope analyses.

Tritium, deuterium, and O-18 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.

<u>Location</u>	<u>Discharge (cfs)</u>	<u>Date</u>
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

<u>SITE</u>	<u>SNOW DEPTH (in.)</u>	<u>WATER EQUIVALENT (in.)</u>	<u>DENSITY (%)</u>
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

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-18 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 15-17, 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. 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

The authors acknowledge the City of Nome and the Alaska Department of Environmental Conservation for funding support of this project. Roy Ireland and Stan Carrick of DGGs assisted with field data collection. Tenneco Corporation and Alaska Gold Company provided useful geological information. Special appreciation is extended to Nome area property owners who graciously allowed access to their property for data collection.

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# DESCRIPTION OF MAP UNITS

## UNCONSOLIDATED DEPOSITS

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

## META-IGNEOUS ROCKS

Mod  
Metagrenodioritic sills.

## METASEDIMENTARY ROCKS

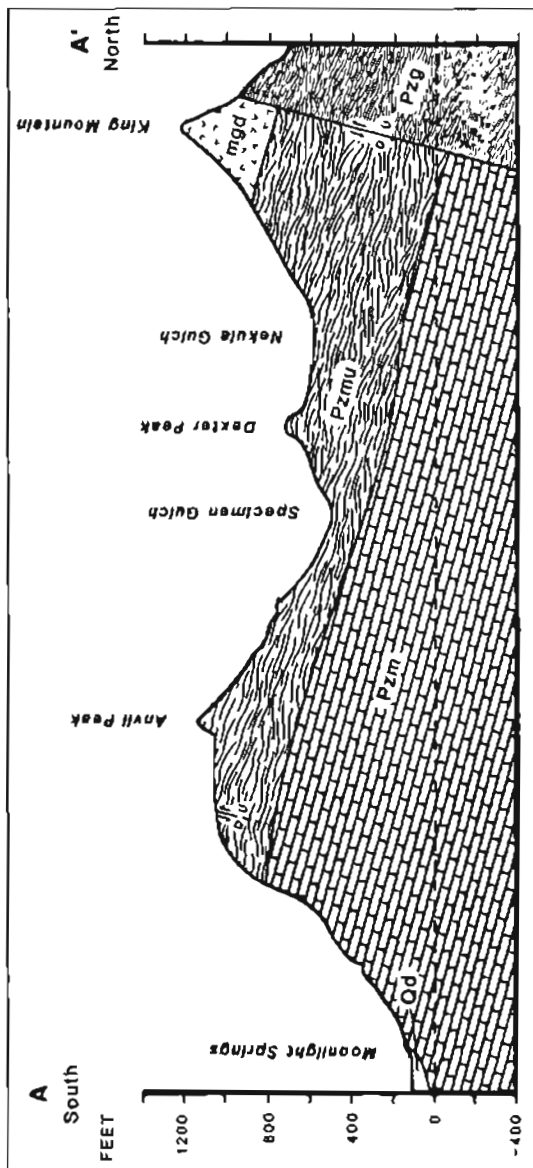
### MARBLE

Pzm  
Pzm—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.

Pzg  
Pzg—principally platy, slabby and massive blue-gray and gray marble, and buff-weathering and gray schistose 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  
Pzg—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. Localized non-graphitic to slightly graphitic quartz-chlorite-muscovite schist, black graphitic quartz schist and black graphitic quartzite.



## MAP SYMBOLS

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

$\frac{U}{D}$  Fault, dashed where approximately located or inferred; dotted where concealed; queried where doubtful.  
U, upthrown side D, downthrown side.

## SCALE



Vertical Exaggeration=5X

FIGURE 1 GEOLOGIC CROSS SECTION THROUGH ANVIL MOUNTAIN AND MOONLIGHT SPRINGS (See sheet 2 for location of the cross section line)

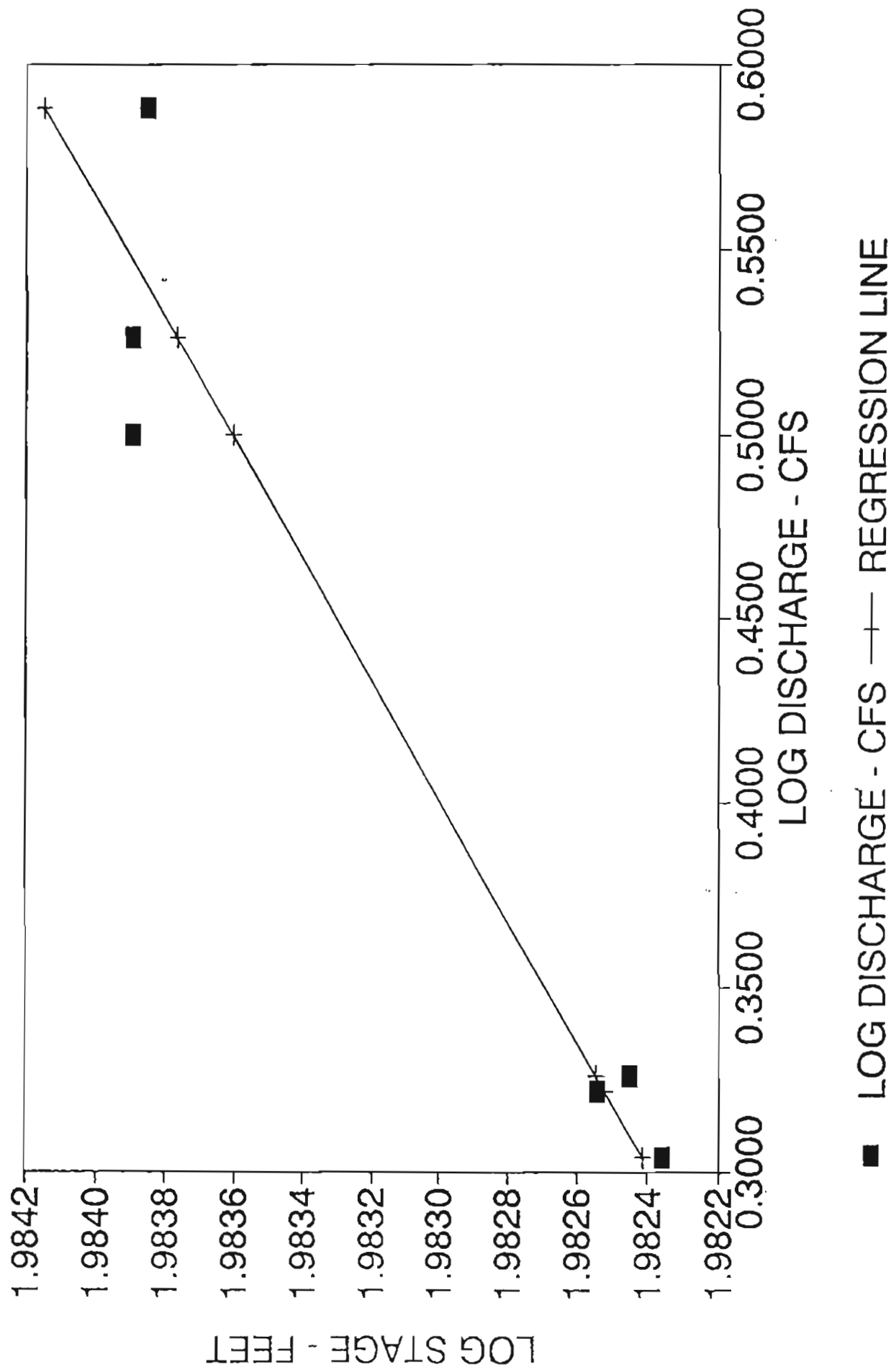


Figure 2. Rating curve for Moonlight Springs overflow discharge.

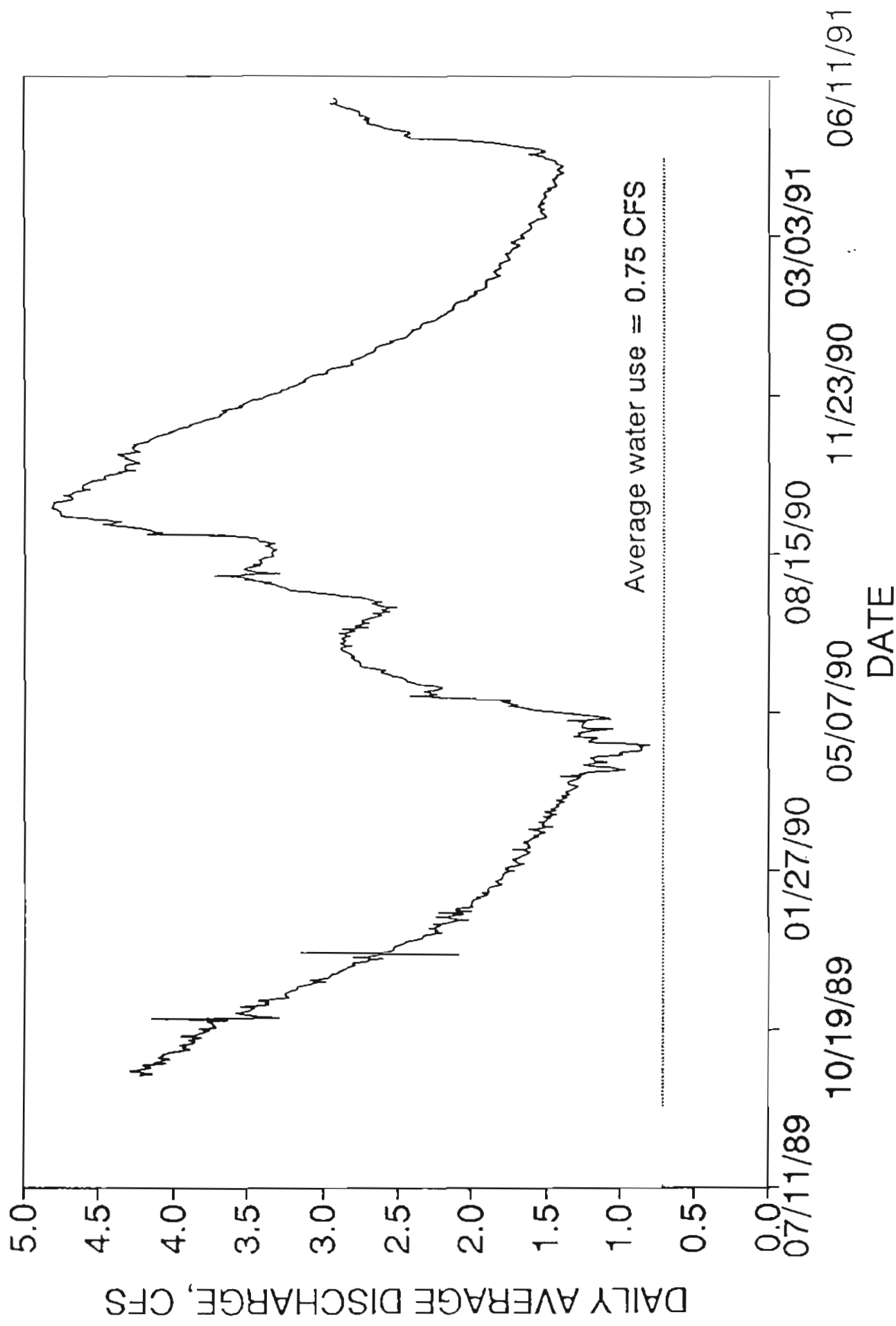


Figure 3. Total Moonlight Springs discharge & average total water use.

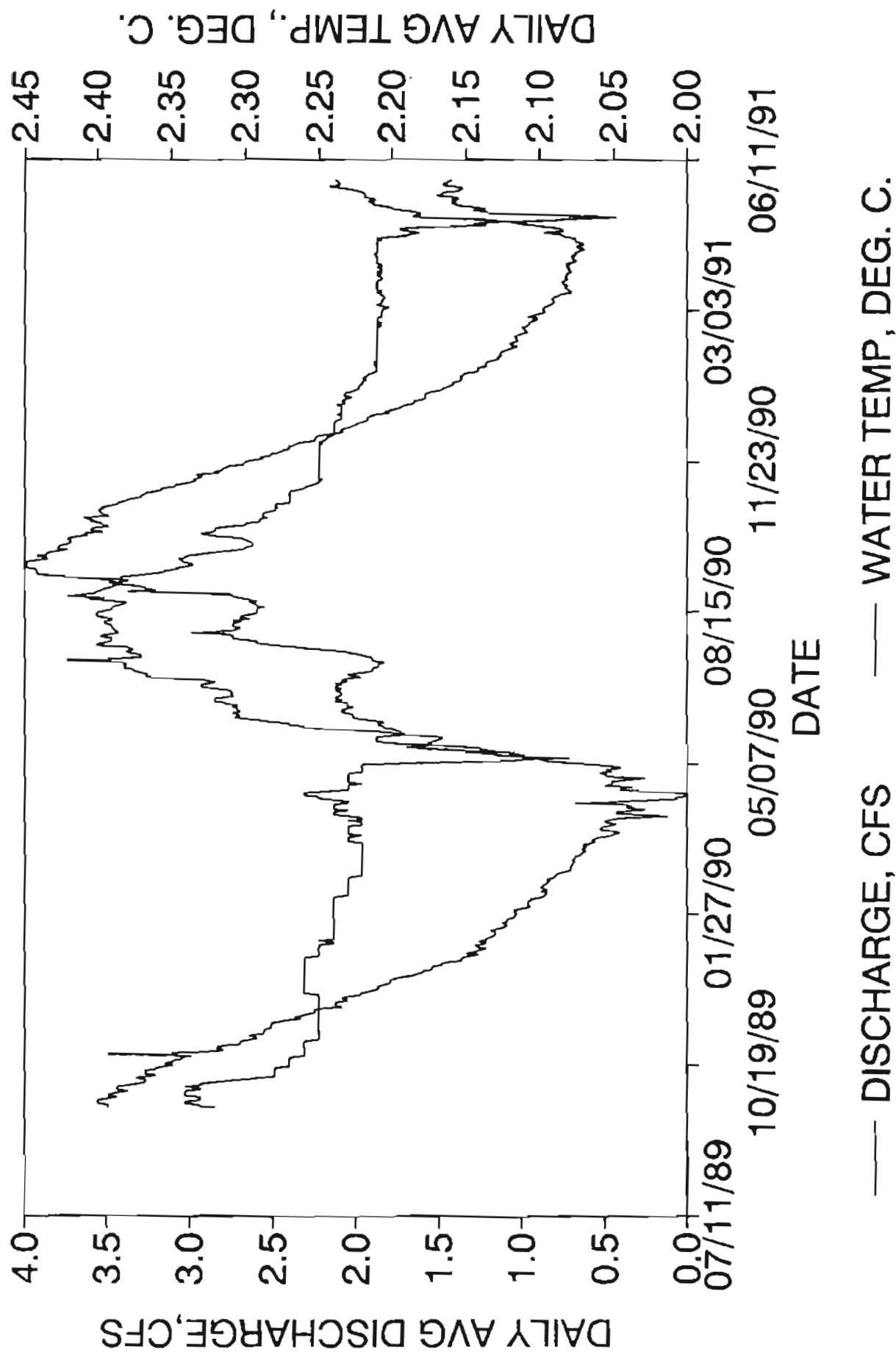


Figure 4. Moonlight Springs overflow discharge & water temperature at the collection gallery.

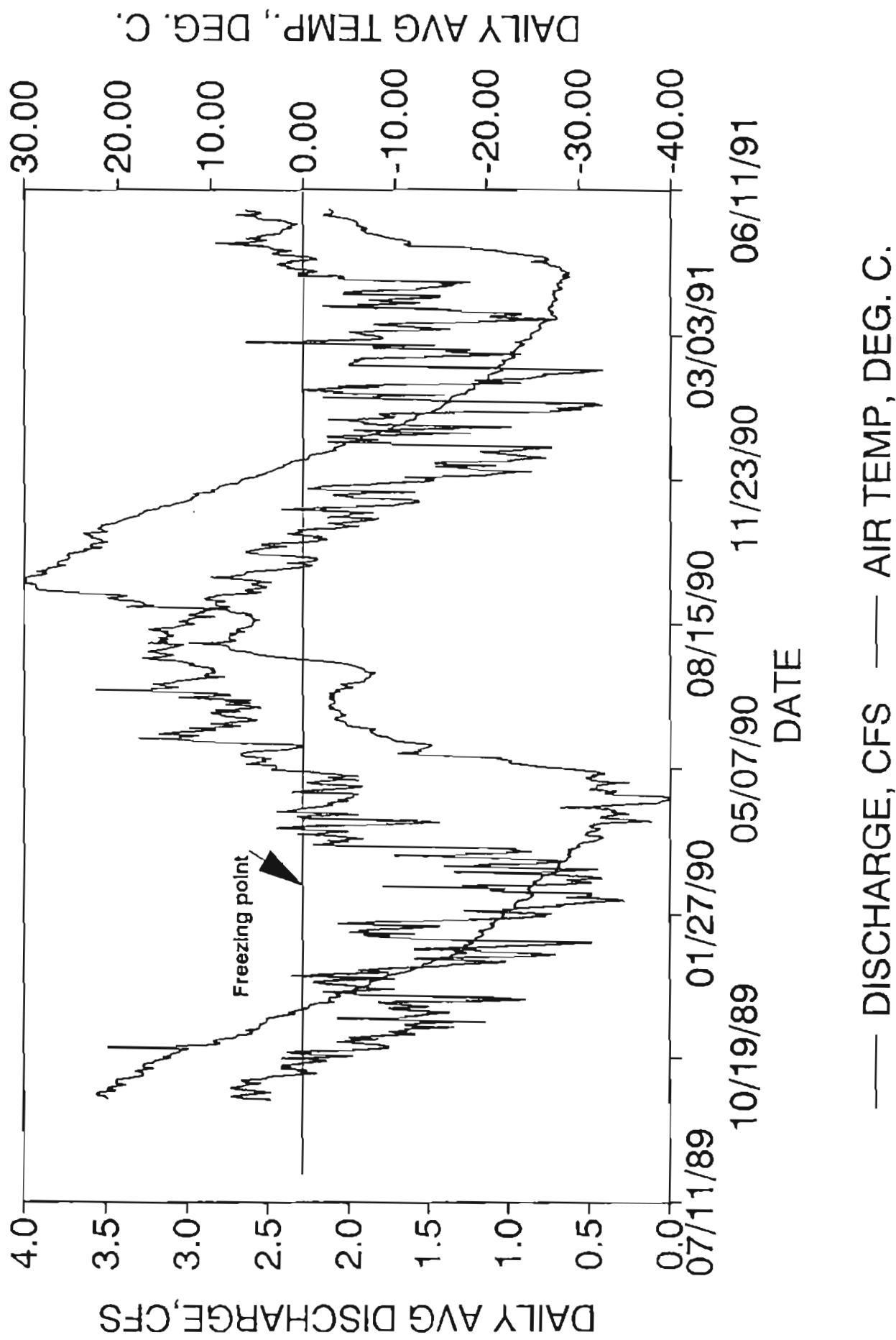


Figure 5. Total Moonlight Springs discharge & daily average air temperature at Nome airport.

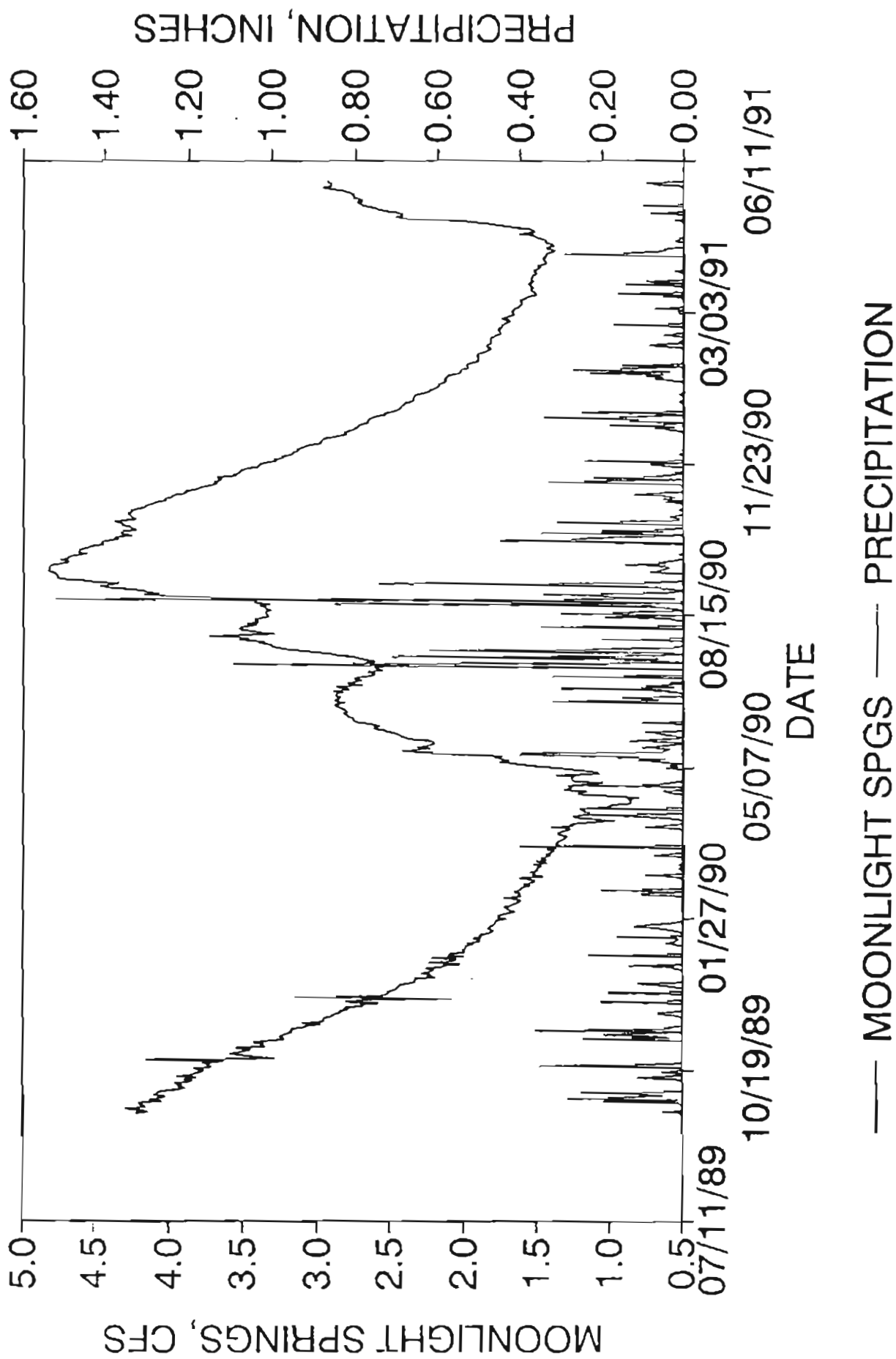


Figure 6. Total Moonlight Springs discharge and daily total precipitation at Nome airport.



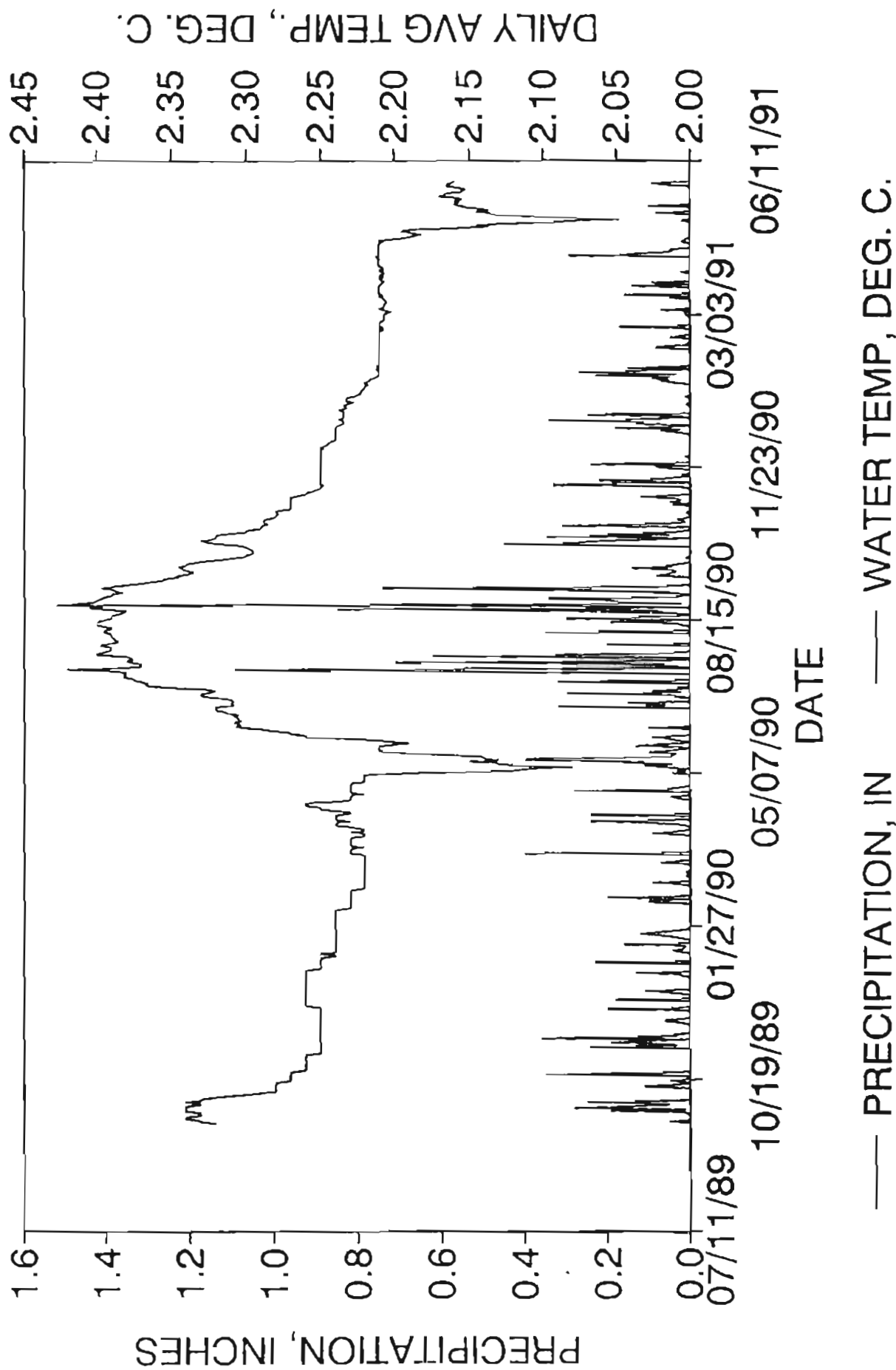


Figure 7. Nome airport precipitation & water temperature at Moonlight Springs collection gallery

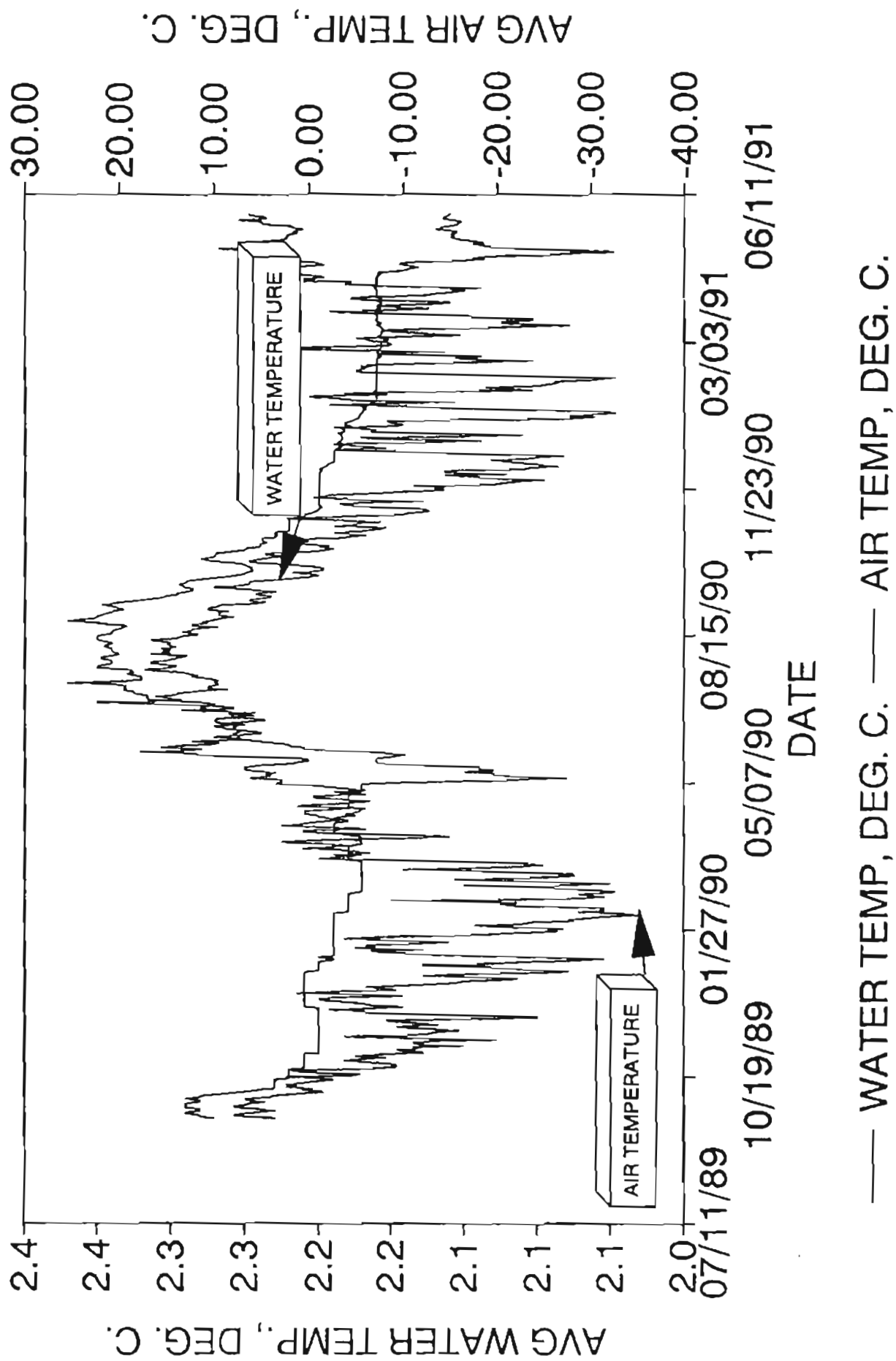


Figure 8. Moonlight Springs collection gallery daily average water temperature & Nome airport daily average air temperature.

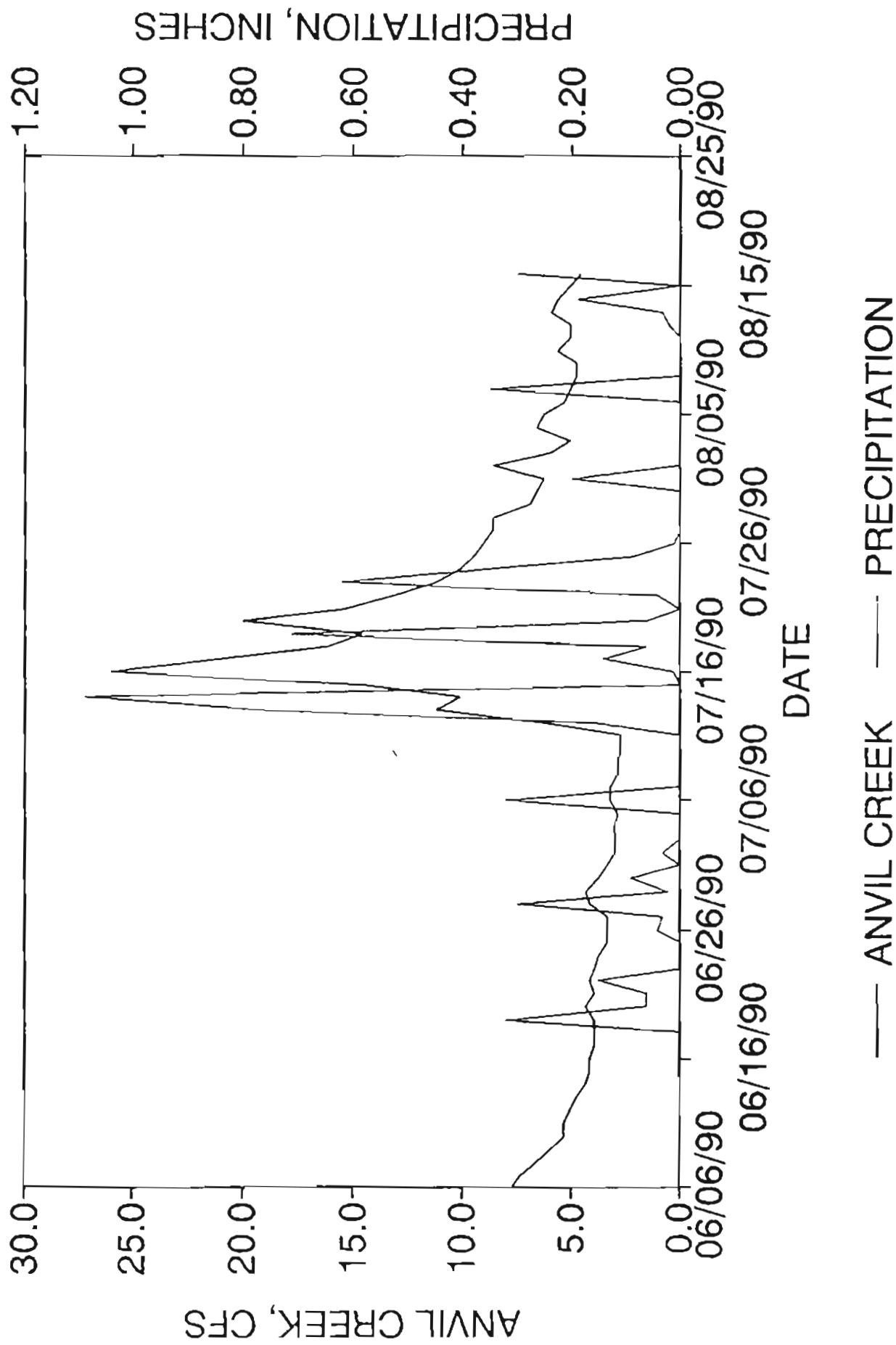
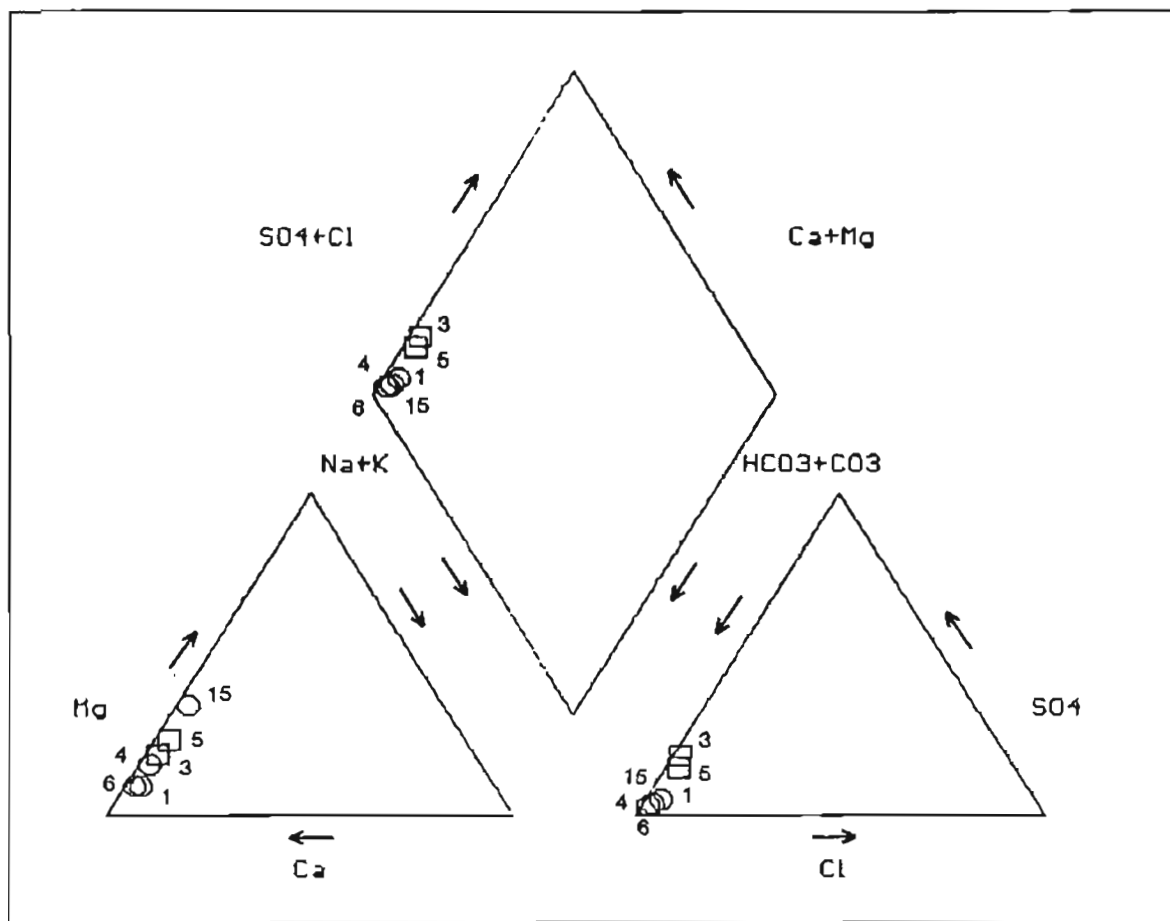


Figure 9. Anvil Creek discharge & daily total precipitation at Nome airport.



### LEGEND

Rock Type	Marble	Schist
Symbol	○	□
Site Name/Number	Moonlight Springs/1	Lindblom spring/3
	Engstrom well/4	Specimen Gulch seep/5
	Barron well/6	
	Anseth well/15	

Figure 10. Piper diagram of Nome area ground waters.

## **APPENDIX A**

### **Water quality analytical results**

# LEGEND TO WATER QUALITY SAMPLING SITES

<u>Map No.</u>	<u>Sample Code</u>	<u>Location</u>
Q-1	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. Engstrom well
Q-5	N-GW-6	Specimen Gulch seep
Q-6	N-GW-7	S. Barron well
Q-7	N-SW-1	Anvil Creek
Q-8	N-SW-2	Anvil Peak (snowmelt)
Q-9	N-SW-3	Little Creek
I-10	N-SW-4	Extra Dry Creek
I-11	N-SW-5	Newton Gulch
I-12	N-GW-8	New Year Gulch
I-13	N-GW-9	Nekula Gulch
I-14	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	SS	Anvil Peak (snow sample)
Q-1	MS	Moonlight Springs
Q-1	OF	Moonlight Springs
Q-1	PH	Moonlight Springs

**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

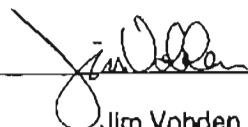
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date: 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

Date 30 NOV 90

**State of Alaska**  
**Division of Geological and Geophysical Surveys**  
**Water Quality Laboratory**

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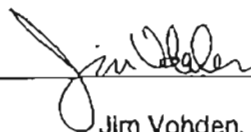
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date: June 11, 1990

Sample	Fluoride	Chloride	Nitrate (as N)	Sulfate
N-GW-1	0.36	3.71	0.60	5.64
N-GW-2	0.30	10.1	<0.02	18.3
N-GW-3	0.55	3.31	<0.02	38.2
N-GW-4	0.55	3.40	<0.02	38.1
N-GW-5	0.37	2.07	0.60	5.18
N-GW-6	0.56	3.11	0.05	19.3
N-GW-7	0.41	2.56	0.22	5.84
N-SW-1	0.29	2.21	0.02	19.3
N-SW-2	0.07	1.64	<0.02	0.41
N-SW-3	0.43	2.57	0.08	14.4
N-GWB-3	<0.01	<0.01	<0.02	<0.01
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	4.4	5.2	1.2	1.7
% Recovery	85	92	86	83

Approved By



Jim Vohden, Chemist

Date 30 NOV 90



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Client: ADGGS - Eagle River

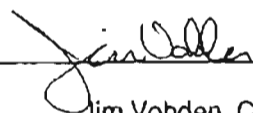
Submitted By: Mary Maurer

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, Chemist

Date 30 NOV 90

**State of Alaska**  
**Division of Geological and Geophysical Surveys**  
**Water Quality Laboratory**

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Client: ADGGS - Eagle River

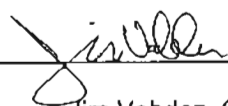
Submitted By: Mary Maurer

Date: June 11, 1990

Sample	Barium	Copper	Chromium	Zinc
N-GW-1	36	<10	<5	<10
N-GW-2	37	<10	<5	<10
N-GW-3	36	<10	<5	<10
N-GW-4	32	<10	<5	<10
N-GW-5	30	<10	<5	<10
N-GW-6	34	<10	<5	<10
N-GW-7	23	<10	<5	14
N-SW-1	31	<10	<5	20
N-SW-2	25	<10	<5	<10
N-SW-3	36	<10	<5	<10
N-GWB-3	<5	<10	<5	<10
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	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



Jim Vohden, Chemist

Date 30 NOV 90

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**Division of Geological and Geophysical Surveys**  
**Water Quality Laboratory**

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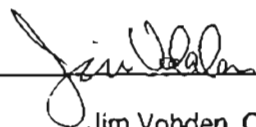
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

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-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

Approved By



Jim Vohden, Chemist

Date 30 NOV 90

**State of Alaska**  
**Division of Geological and Geophysical Surveys**  
**Water Quality Laboratory**

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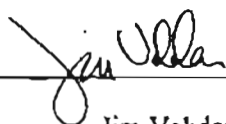
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: September 28, 1990

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 Vohden, Chemist

Date 2 JAN 91

**State of Alaska**  
**Division of Geological and Geophysical Surveys**  
**Water Quality Laboratory**

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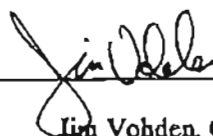
Client: ADGGS - Eagle River

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	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

Approved By \_\_\_\_\_



Jim Vohden, Chemist

Date 2 JAN 91

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**Water Quality Laboratory**  
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Client: ADGGS - Eagle River

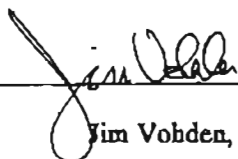
Submitted By: Mary Maurer

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	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, Chemist

Date

25 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: 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

**State of Alaska**  
**Division of Geological and Geophysical Surveys**  
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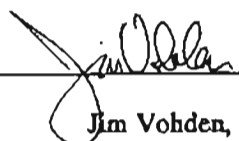
Client: ADGGS - Eagle River

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



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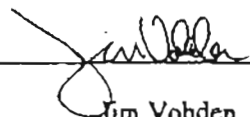
Client: ADGGS - Eagle River

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

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**Division of Geological and Geophysical Surveys**  
**Water Quality Laboratory**  
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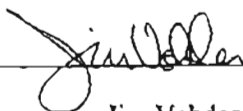
Client: ADGGS - Eagle River

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 <sub>3</sub> *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

**State of Alaska**  
**Division of Geological and Geophysical Surveys**  
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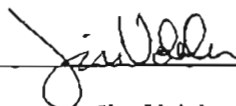
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	Arsenic	Aluminum	Barium	Cadmium	Copper
UT	<DL	<DL	<DL	<DL	<DL
OF	<DL	87	21	<DL	<DL
PH	<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



Jim Vohden, Chemist

Date 24 JUNE 91

**State of Alaska**  
**Division of Geological and Geophysical Surveys**  
**Water Quality Laboratory**  
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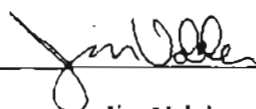
Client: ADGGS - Eagle River

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 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

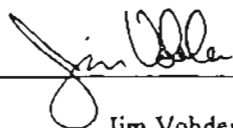
Client: ADGGS - Eagle River

Submitted By: Mary Maurer

Date Submitted: 4 April 1991

Sample	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

OB 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





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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



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: 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  
 18225 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 black ink, 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  
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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Eagle River

April 25, 1991

TRITIUM LABORATORY

Data Release #91-17  
Job # 313

ALASKA DEPARTMENT OF NATURAL RESOURCES  
TRITIUM SAMPLES

Purchase Order D.O. 239014

A handwritten signature in dark ink, 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  
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: 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 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  $\text{H}_2\text{O}$ , or 3.237 pCi/kg  $\text{H}_2\text{O}$ . 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  $\text{H}_2\text{O}$ , 3.193 pCi/kg  $\text{H}_2\text{O}$ . 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	-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



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

## **APPENDIX B**

### **Water quality field measurements**

# Appendix B. Field measurements

MAP NO.	SITE	DATE	TIME	WATER TEMP. (°C)	DISCHARGE (CFS)	CONDUCTIVITY (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 CaCO <sub>3</sub> )	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



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-level gas proportional counting of water sample, required sample volume 15 ml. Processing quantity is fixed at 4 ml. \$140.00

Counting will be performed to  $\pm 3.5\%$ , one sigma, or  $\pm 6$  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  $\pm 3.5\%$ , 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  $\pm 4$  % accuracy in  $^{14}\text{C}$  ( $^{13}\text{C}$  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  $\text{CO}_2$  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  $\text{CO}_2$  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

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. SERVICES RENDERED (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.



### III. TECHNICAL CONDITIONS FOR ACCEPTANCE OF TRITIUM SAMPLES

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.1) 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 treated by 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'.

## 1. LOW LEVEL ANALYSIS

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

### A. Distillation

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 Enrichment

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  $\pm 5$  mg, and adjusted for hydrogen left in the sodium hydroxide.

### C. Preparation of Sampling Gas

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. Low-Level Counting

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 adjusting working voltage using an external radioactive source.

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  $\pm 0.03$  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:

Östlund, 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.

Östlund, H.G., M.O. Rinkel and C. Rooth, 1969. Tritium in the equatorial Atlantic current system, *J. Geophys. 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 time 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 distillation through electrolytic enrichment, vacuum distillation and reduction 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 ANALYSISA. 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. Sample bottles

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, heavy wall 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. Sampling procedure

1. Sample transfer should be done outdoors, unless a specially vented room is available with ban on wristwatches.
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.

## STABLE ISOTOPES

### Introduction

Stable isotope composition is used to study the characteristics and origin of groundwaters. Isotope ratios of hydrogen ( $^2\text{H}/^1\text{H}$ ) and oxygen ( $^{18}\text{O}/^{16}\text{O}$ ) 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 spectrometry at the Stable Isotope Laboratory at Southern Methodist University in Dallas Texas. Water hydrogen samples are analyzed by the uranium method (Bigeleisen and others, 1952). The resolution objective for the  $^2\text{H}/^1\text{H}$  ratio is  $\pm 1$  mill. Water oxygen samples are analyzed by the  $\text{CO}_2\text{-H}_2\text{O}$  equilibration method at  $25^\circ$  Centigrade described by Epstein and Mayeda (1953). The resolution objective for the  $^{18}\text{O}/^{16}\text{O}$  ratio is  $\pm 0.2$  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 O18 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 Reports 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.

# STABLE ISOTOPE LABORATORY

1990-91

## MASS SPECTROMETERS

Finnigan-MAT 251: HD, CO<sub>2</sub>

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

Permanent magnet configuration, triple-collector CO<sub>2</sub>, HD collectors, microvolume inlet system

Finnigan-MAT delta-E: HD, O<sub>2</sub>, N<sub>2</sub>, CO<sub>2</sub>

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

Electromagnet configuration, multiple-sample inlet system, 6 fixed Faraday collectors for CO<sub>2</sub>, N<sub>2</sub>, and O<sub>2</sub>, separate HD collector assembly

## EXTRACTION LINES/ SAMPLE PREPARATION FACILITIES<sup>1</sup>

- 1) Fluorination line (ClF<sub>3</sub> or BrF<sub>5</sub>) silicate and phosphate oxygen
- 2) Carbonate oxygen and carbon line with 25-90 °C water bath reaction temperatures
- 3) Water oxygen (H<sub>2</sub>O/CO<sub>2</sub> 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<sup>2</sup>

### *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

<sup>1</sup> The laboratory performs isotopic analyses on a contract basis. A list of services is available upon request.

<sup>2</sup> As a teaching institution, we train graduate and undergraduate students who work in the laboratory

App D

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# 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	266,119	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	14,896,121	480,520	0.743
Apr	254,594	329,674	158,664	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	13,609,000	759,310	24,494	0.038	14,368,310	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	171,065	7,750	15,206,000	719,221	23,201	0.036	15,925,221	513,717	0.795
Sep	227,060	185,895	147,284	7,500	12,968,000	567,739	18,925	0.029	13,535,739	436,837	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	13,467,162	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	239,156	286,725	139,325	7,604	14,097,150	674,809	22,193	0.034	14,771,959	484,863	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	268,217	143,896	7,000	13,315,000	682,822	23,676	0.037	13,977,822	499,212	0.772
Mar	248,217	261,577	162,256	7,750	15,847,000	678,800	21,929	0.034	16,526,800	533,123	0.825
Apr	234,888	228,025	95,320	7,500	14,833,000	565,733	18,858	0.029	15,398,733	513,291	0.794
May	249,886	261,511	130,599	7,750	13,514,700	649,746	20,960	0.032	14,164,446	458,918	0.707
Jun	240,247	229,903	163,968	7,500	13,893,913	641,618	21,387	0.033	14,535,531	484,518	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	7,750	14,693,000	655,550	21,147	0.033	15,348,550	495,115	0.766
Sep	228,000	301,000	288,000	7,600	15,594,000	824,500	27,483	0.043	16,418,500	529,629	0.819
Oct	253,000	443,900	150,000	7,750	13,709,000	854,650	27,569	0.043	14,563,650	469,795	0.727
Nov	325,000	401,400	158,000	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	159,783	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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