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Environmental Protection Technology Series

PREDICTION OF MINERAL QUALITY OF IRRIGATION RETURN FLOW
Volume II. Vernal Field Study

Robert S. Kerr Environmental Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Ada, Oklahoma 74820

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PREDICTION OF MINERAL QUALITY OF IRRIGATION RETURN FLOW

VOLUME II

VERNAL FIELD STUDY

by

Bureau of Reclamation
Engineering and Research Center
Denver, Colorado 80225

EPA-IAG-D4-0371

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DISCLAIMER

FOREWORD

The Environmental Protection Agency was established to coordinate administration of the major Federal programs designed to protect the quality of our environment.

An important part of the Agency's effort involves the search for information about environmental problems, management techniques and new technologies through which optimum use of the Nation's land and water resources can be assured and the threat pollution poses to the welfare of the American people can be minimized.

EPA's Office of Research and Development conducts this search through a nationwide network of research facilities.

As one of these facilities, the Robert S. Kerr Environmental Research Laboratory is responsible for the management of programs to: (a) investigate the nature, transport, fate and management of pollutants in groundwater; (b) develop and demonstrate methods for treating wastewaters with soil and other natural systems; (c) develop and demonstrate pollution control technologies for irrigation return flows; (d) develop and demonstrate pollution control technologies for animal production wastes; (e) develop and demonstrate technologies to prevent, control or abate pollution from the petroleum refining and petrochemical industries; and (f) develop and demonstrate technologies to manage pollution resulting from combinations of industrial wastewaters or industrial/municipal wastewaters.

This report contributes to the knowledge essential if the EPA is to meet the requirements of environmental laws that it establish and enforce pollution control standards which are reasonable, cost effective and provide adequate protection for the American public.

William C. Galegar
Director
Robert S. Kerr Environmental
Research Laboratory

PREFACE

This report is one of a set which documents the development and verification of a digital computer modeling effort to predict the mineral quality changes in return flows occurring as a result of irrigating agricultural lands. The set consists of five separate volumes under one general title as follows:

"Prediction of Mineral Quality of Irrigation Return Flow"

Volume I.	Summary Report and Verification
Volume II.	Vernal Field Study
Volume III.	Simulation Model of Conjunctive Use and Water Quality for a River Basin System
Volume IV.	Data Analysis Utility Programs
Volume V.	Detailed Return Flow Salinity and Nutrient Simulation Model

This set of reports represents the culmination of an effort started in May 1969 by an interagency agreement between the U.S. Bureau of Reclamation and the Federal Water Pollution Control Administration on a joint research proposal on the "Prediction of Mineral Quality of Return Flow Water from Irrigated Land." This research project has had three different project identification numbers during the project period. These numbers (13030 EII, EPA-IAG-048-(D), and EPA-IAG-D4-0371) are given to avoid confusion on the part of individuals who have previously tried to acquire project reports for the earlier project numbers.

ABSTRACT

This volume of the report details the field investigations conducted to develop and validate the "Simulation Model of Conjunctive Use and Water Quality for a River System or Basin" as given in Volume III of this report. The studies were conducted in Ashley Valley, near Vernal, Utah. The investigations included: the quantity and quality of ground water, irrigation water, and return flows; crop inventory and consumptive use; soil chemistry; and hydrological units to define nodes.

This report was submitted in fulfillment of EPA-IAG-D4-0371 by the Bureau of Reclamation Engineering and Research Center, under the sponsorship of the Environmental Protection Agency.

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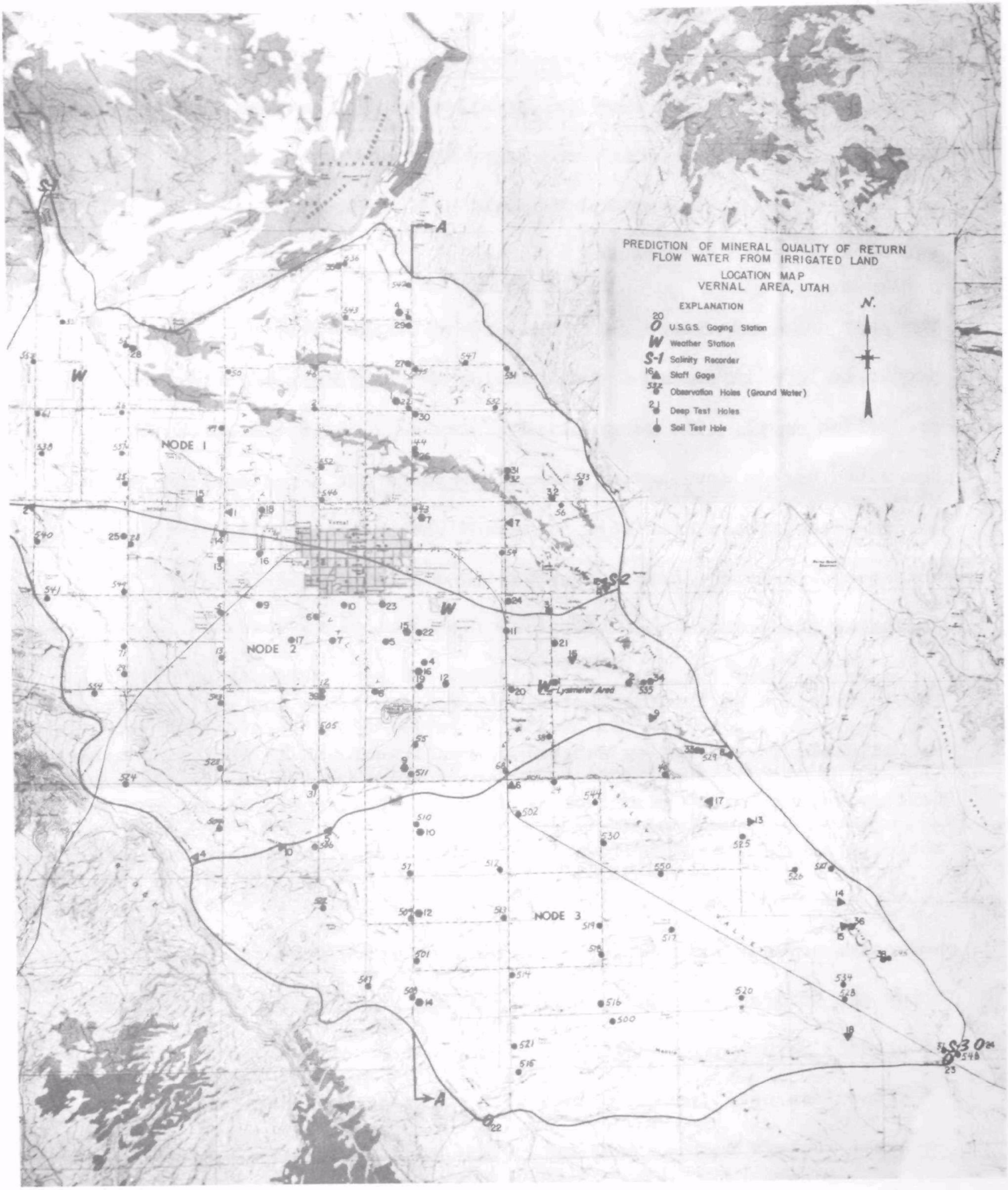
PREDICTION OF MINERAL QUALITY OF RETURN FLOW WATER FROM IRRIGATED LAND
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U.S.G.S. Gaging Station
Weather Station
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INTRODUCTION

Selection of the Vernal area for development of a mathematical model to predict the quality of return flow was based on the availability of past data and the well-defined boundaries where inflow and outflow could be measured accurately.

The past data, of course, were collected for another purpose but proved to be well suited for developing and testing a mathematical prediction model. The description of the data collection process as described herein covers requirements for data for a reclamation project. Nevertheless, these data were necessary to establish water requirements, node boundaries, consumptive use and many other factors used in designing the study.

The information on the test holes, observation holes and soil conditions was valuable in evaluating subsurface conditions and in assigning water quality values to the ground-water storage. Drainage problems were anticipated when the Vernal Unit was being investigated and therefore subsurface conditions were investigated in considerable detail. A large percentage of any salt derived from an irrigation project comes from below the soil surface and not from surface return flows. The ability to predict return flow quality is then a matter of sufficient knowledge of subsurface conditions combined with accurate knowledge of the external factors such as consumptive use and the quality and quantity of the water supply and return flows.

Collection of field data constitutes the bulk of the work done in FY 72 since very little work was done on the mathematical model. A location map of the study area showing node boundaries and data collection points is included. Table 1 contains a description of the data collection points including a numerical identification which corresponds to the numbers shown on the location map.

HISTORIC DATA

Historic data are defined as data collected for development of the Vernal Unit and any other data collected prior to FY 1970 when the Prediction of Mineral Quality investigations were begun.

Land Classification

A detailed land classification survey of the study area was made in 1955 and 1956 as part of the definite plan studies for the Vernal Unit. This survey included all irrigated lands that would receive supplemental water from the Vernal Unit. Because of their rural character, lands in the towns of Maeser and Naples were surveyed and classified in the same manner as other farm lands. Lands in the Vernal townsite and airport were not designated by land class but were merely segregated into either "townsite" or "rights-of-way."

A total of 41,967 acres were classified in the detailed survey. The results are tabulated on page 5.

TABLE 1
WATER QUALITY PREDICTION STUDY
DESCRIPTION OF DATA COLLECTION POINTS
VERNAL AREA

No.	Name	Location	
	CANAL STAFF GAGES		
1	Ashley Central Canal	Node 1-2 boundary	Sec. 22, T4S, R21E
2	Ashley Upper Canal	Node 1-2 boundary	Sec. 19, T4S, R21E
3	Highline Canal	Node 1-2 boundary	Sec. 19, T4S, R21E
4	Highline Canal	Node 2-3 boundary	Sec. 4, T5S, R21E
5	Steinaker Service Canal	Node 2-3 boundary	Sec. 2, T5S, R21E
6	Ashley Central Canal	Node 2-3 boundary	Sec. 6, T5S, R22E
10	Ashley Upper Canal	Node 2-3 boundary	Sec. 3, T5S, R21E
	NATURAL DRAIN STAFF GAGES		
7	North Vernal Drain at Mouth	Node 1	Sec. 19, T4S, R22E
9	Naples Drain	Node 2	Sec. 32, T4S, R22E
12	Spring Creek	Node 3	Sec. 20, T4S, R22E
13	Slaugh Drain	Node 3	Sec. 4, T5S, R22E
14	Slaugh Drain	Node 3	Sec. 10, T5S, R22E
15	Slaugh Drain	Node 3	Sec. 10, T5S, R22E
16	South Vernal Drain at Mouth	Node 2	Sec. 30, T4S, R22E
17	South Naples Drain	Node 3	Sec. 4, T5S, R22E
18	Mantle Gulch at Mouth	Node 3	Sec. 15, T5S, R22E
	STREAMFLOW RECORDERS (USBR)		
8	Ashley Cr. below Naples Drain	Node 2-3 boundary	Sec. 33, T4S, R22E
11	Ashley Creek near Golf Course	Node 1-2 boundary	Sec. 20, T4S, R22E
	(USGS)		
20	Ashley Creek above Dry Fork	Abt. 2 mi. No. of Node 1	Sec. 19, T3S, R21E
21	Dry Fork at Mouth	Abt. 1 mi. No. of Node 1	Sec. 30, T3S, R21E
22	Highline Canal below Mantle Gulch	Node 3 boundary	Sec. 24, T5S, R21E
23	Ashley Creek near Jensen	Node 3 boundary	Sec. 23, T5S, R22E
24	River Irrigation Co. Canal near Jensen	Node 3 boundary	Sec. 13, T5S, R22E
	SALINITY RECORDERS		
S-1	Ashley Creek at Highline Diversion	Node 1 boundary	Sec. 32, T3S, R21E
S-2	Ashley Creek near Golf Course	Node 1-2 boundary	Sec. 20, T4S, R22E
S-3	Ashley Creek near Jensen	Node 3 boundary	Sec. 23, T5S, R22E

Land Classification Summary

Type of land and land class	Acres
Farm land 1/	
Class 1	3,554
Class 2	5,843
Class 3	6,226
Class 6W	8,658
Class 6	15,653
Subtotal	39,934
Rights-of-way	918
Townsite	845
Total	41,697

1/ All farm lands except the class 6 lands are presently irrigated but experience late-season water shortages.

Of the total area classified, 14,781 acres were found irrigable or suitable to receive supplemental water from the Vernal Unit. This acreage includes 14,444 acres of class 1, 2 and 3 land except 238 acres under Steinaker and Pitt ditches which are above Steinaker Feeder Canal, 241 acres required for unit features right-of-way, and 700 acres in Lower Ashley Creek which are irrigated by return flow water. Also in the irrigable area are lands in the Vernal townsite which are utilized for yards and gardens, estimated to be 337 acres.

A productive acreage of 14,041 acres was estimated to be 95 percent of the irrigable acreage to account for farmsteads, farm roads, ditches and other non-productive areas.

Land use studies were not made for the Vernal Unit in 1955. Therefore, the location and types of crops and vegetation cannot be identified from historical data.

Drainage

The floor of Ashley Valley within the study area is covered by alluvial material, including a soil mantle and an underlying layer of cobble. Below the soil and cobble layers is a stratum of shale from the mancos formation which is impermeable and limits downward percolation of ground water.

The soil mantle which varies from 2 to 20 feet in depth is composed of clays, silts, sands and loams. The cobble layer which varies from 4 to 45 feet in thickness consists of water-worn cobble and gravel in a matrix of sand transported principally from the upper Ashley Creek drainage.

About 20 percent of the Vernal Unit lands were found to need drainage. The high water table is caused in part by excessive application of irrigation water, canal seepage, and diversions for stock water during the nonirrigation season.

Also contributing to the high water table are two geologic conditions. First, an overloading of the cobble aquifer due to a decrease in slope and thickness of the aquifer generally from west to east. Second, a cemented barrier has been formed by the precipitation of calcium carbonate in the gravel and boulders along the escarpment adjacent to the entrenched river bottoms. This barrier has the effect of a dike thus restricting the natural outlet for removing surplus ground water from the area.

Seventy-one ground water observation holes with an average depth of about 9 feet were established for the Vernal Unit on a 1-mile grid through most of the area as a basis for determining the depth to, and the fluctuation of, the ground-water surface under pre-project and post-project conditions. The depth to ground water as determined by these wells varied from 0.6 to 10.9 feet.

In addition to the observation wells, 53 deep exploration holes were drilled for the study of subsurface conditions. Data from the deep exploration holes were supplemented by data from 56 seismic exploration holes obtained from private companies.

Depth to water was observed for the period 1956 to 1960 for all observation holes. Observation holes within the drainage deficient area have been observed since 1956.

Figure 1 is a plot of average ground water profiles for summer and winter along transect A-A. Also shown is the approximate cobble layer and shale surface. All depths are referenced to the ground surface.

Figures 2 through 6 are water table hydrographs of the observation holes shown in Figure 1 for the period 1956 through 1968. The hydrographs and average profiles show a consistent increase in ground water storage during the irrigation season and a decrease during the winter period.

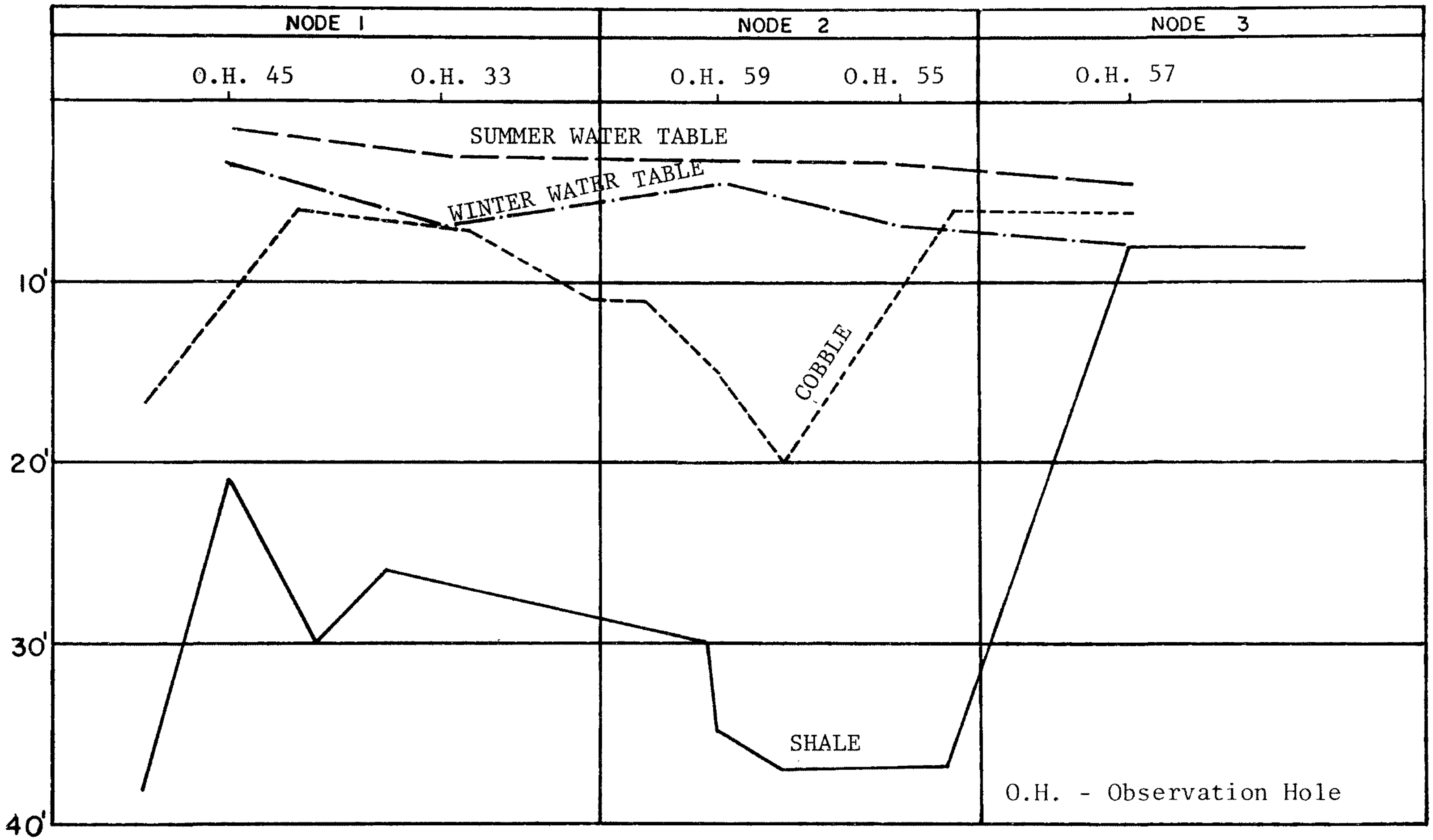


Figure 1. Groundwater profiles, transect A-A, Vernal area, Utah, water quality investigations.

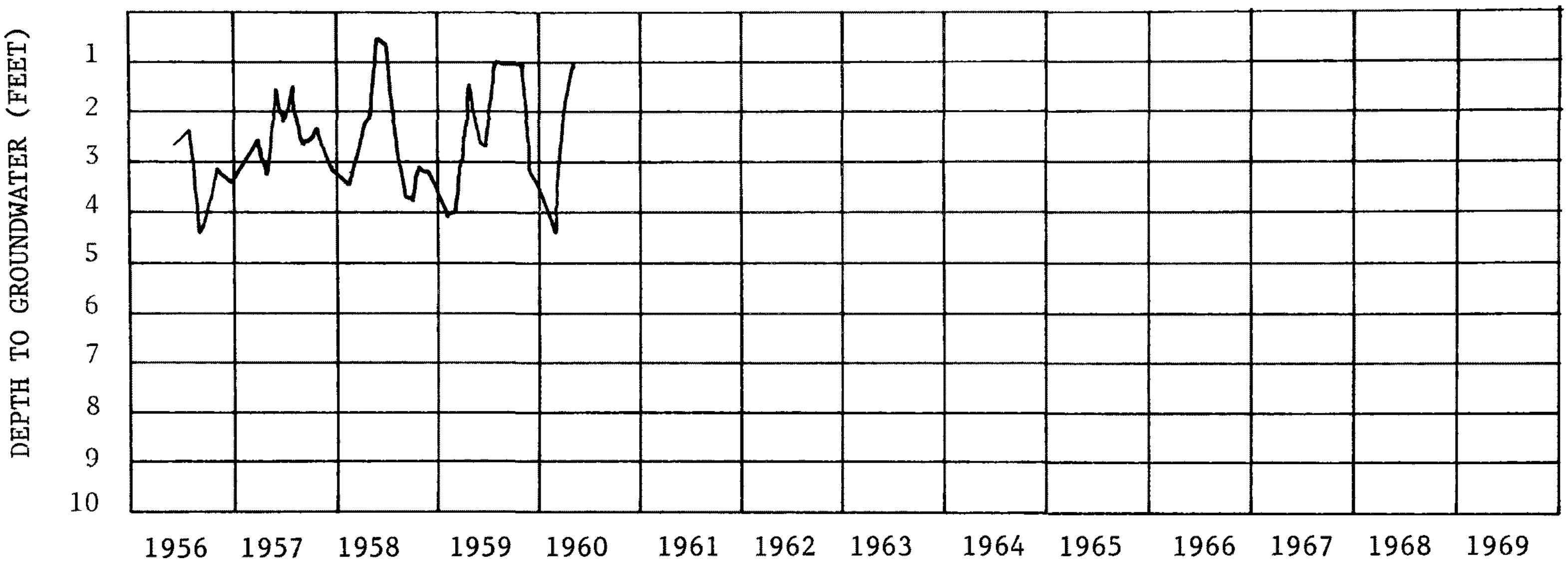


Figure 2. Water table hydrograph, observation hole No. 45, transect A-A, Vernal area, Utah.

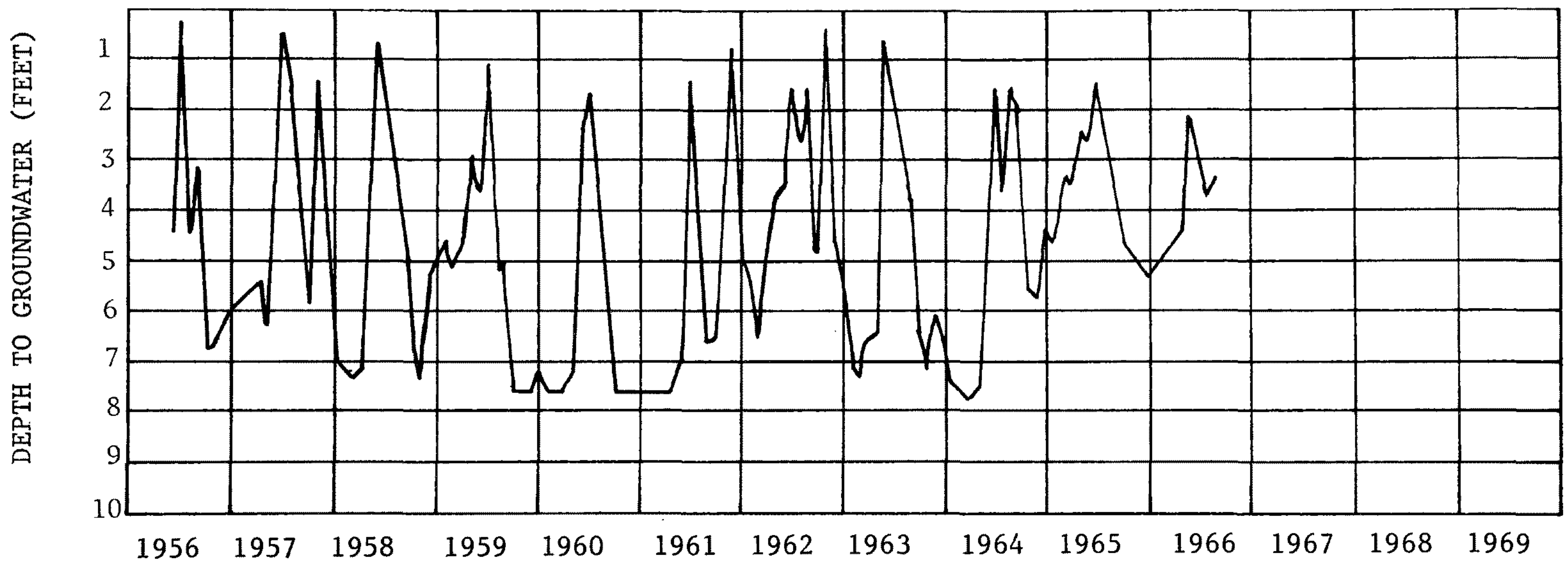


Figure 3. Water table hydrograph, observation hole No. 33, transect A-A, Vernal area, Utah.

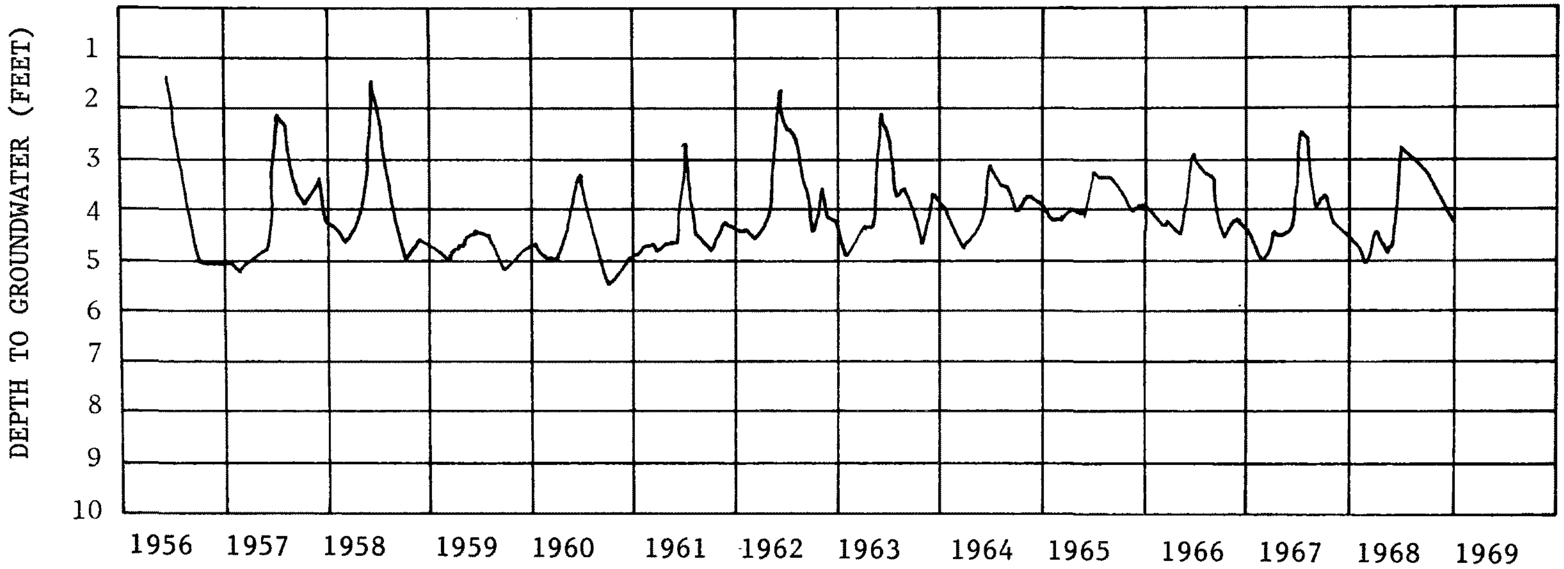


Figure 4. Water table hydrograph, observation hole No. 59, transect A-A, Vernal area, Utah.

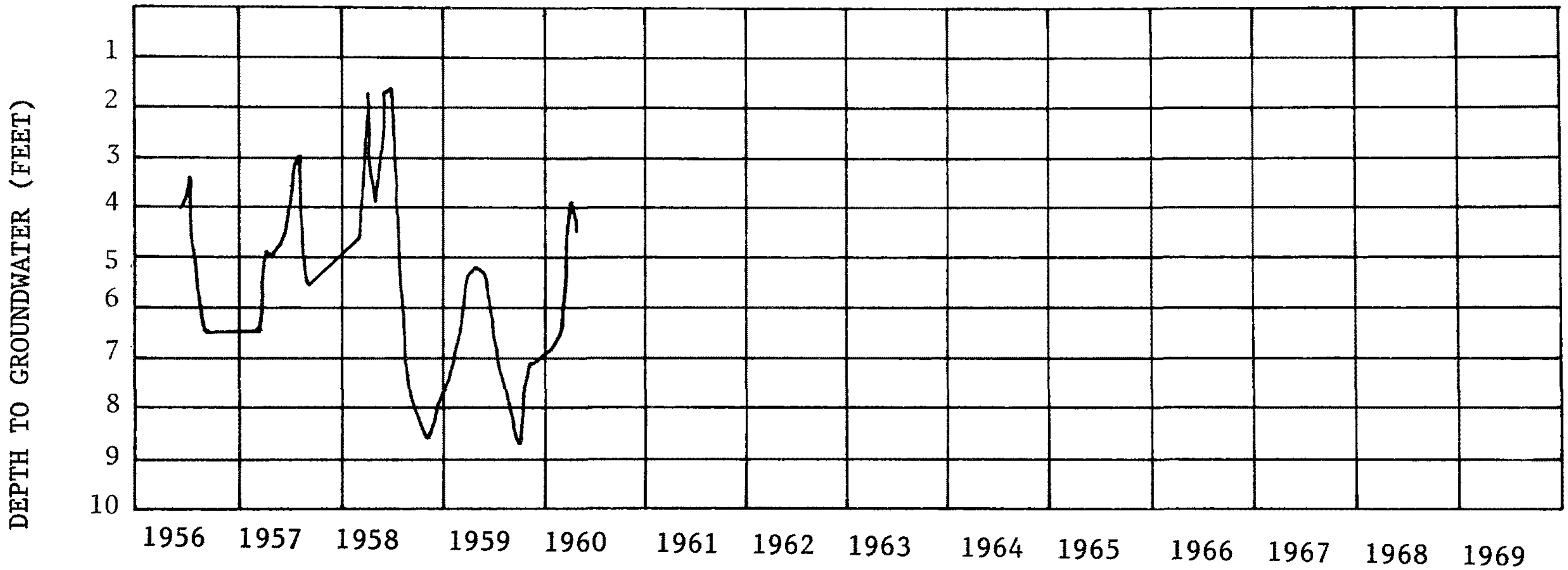


Figure 5. Water table hydrograph, observation hole No. 57, transect A-A, Vernal area, Utah.

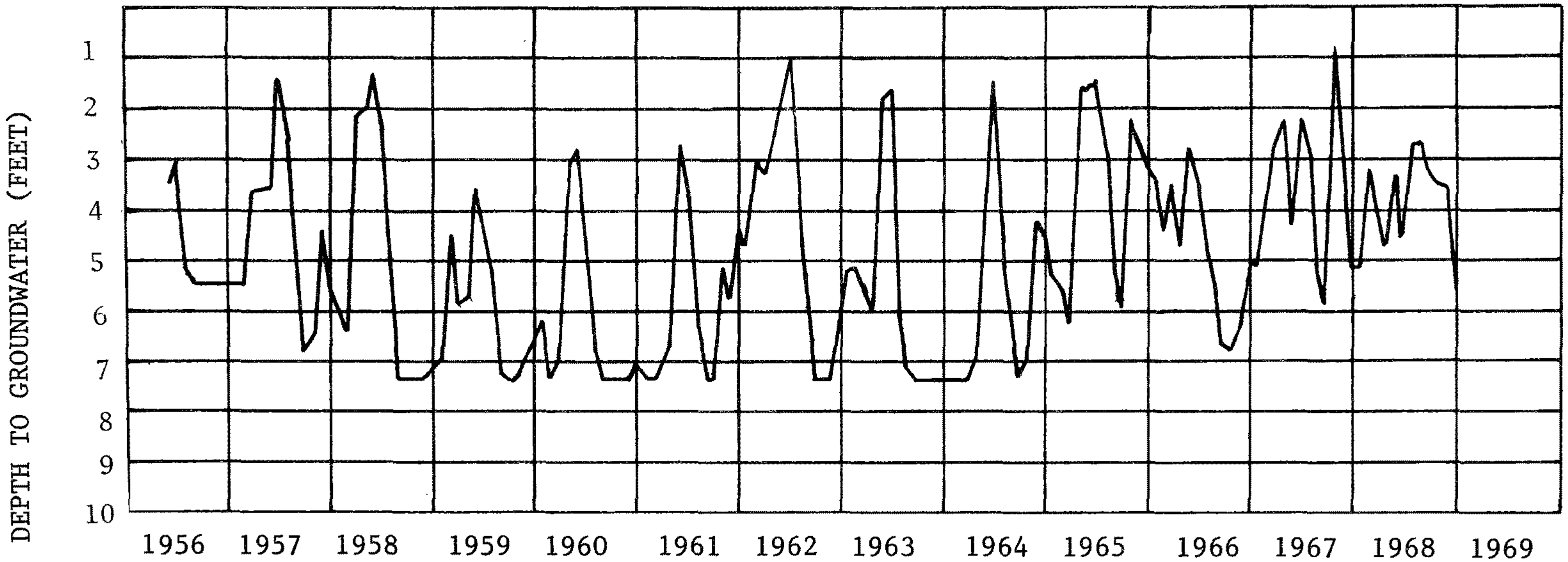


Figure 6. Water table hydrograph, observation hole No. 55, transect A-A, Vernal area, Utah.

Drawing No. 325-418-658 is an isometric drawing of the logs of test holes 1 through 24 which illustrates subsurface conditions in the drainage deficient area.

Final design and construction of the drainage system was deferred until the effects of project operation could be determined. In 1964, 24 deep test holes were drilled as part of the current drainage program.

Water Supply

The sources of irrigation water for the Vernal Unit are Ashley Creek and Brush Creek to the northeast of Ashley Valley from which water is obtained by a transmountain diversion through Oaks Park Canal.

The streamflow available at the head of the unit area was determined from the USGS record at the "Ashley Creek at the Sign of the Maine" gage for the period June 1939 to 1956. For the study period of 1930 to May 1939 flows at the location of the "Sign of the Maine" gage were estimated by correlation with the "Ashley Creek near Vernal" gage which is about 5 miles upstream. The average annual runoff for 1930 to 1956 at the "Sign of the Maine" gage (exclusive of diversions from Oaks Park Reservoir) was 82,400 acre-feet. Existing downstream uses were deducted from the Ashley Creek runoff to determine the flow available for Vernal Unit development.

Quality of Water

Streamflows at the head of the study area were found suitable for irrigation use. Prior to the Vernal Unit the water had been used for irrigation for about 100 years without harmful effects.

DRAWING NO. 325-418-658 IS CONTAINED IN THE POCKET ON THE INSIDE OF THE BACK COVER.

Water below the unit lands in lower Ashley Valley consists primarily of return flow and was found to be generally unsuitable for crop production.

The major natural drains in Ashley Valley and several locations on Ashley Creek have been sampled for water quality, for a minimum of 3 years (1955-1957). Several of the drains were sampled for periods up to 6 years, and Ashley Creek at the head of the study area and "near Jensen" have been sampled continuously since 1955.

Figures 7 and 8 and plots of conductivity versus time for the period 1955-1966 for the natural drains listed below. The numbers in parenthesis refer to corresponding locations on the drains as listed in Table 1, which are currently being sampled.

Drain		Maximum EC	Minimum EC
North Vernal	(7)	2000	475
South Vernal	(16)	1925	1060
Naples	(9)	4175	1560
Slaugh	(13)	4500	1740

Figure 9 is a plot comparing conductivity versus time for three locations on Ashley Creek for the period 1955-1967. These locations are listed below with the number of the corresponding location currently being sampled.

Drain		Maximum EC	Minimum EC
Ashley Creek at Sign of Maine	(S-1)	450	60
Ashley Creek above Naples Drain	(8)	3025	250
Ashley Creek near Jensen	(S-3)	7250	360

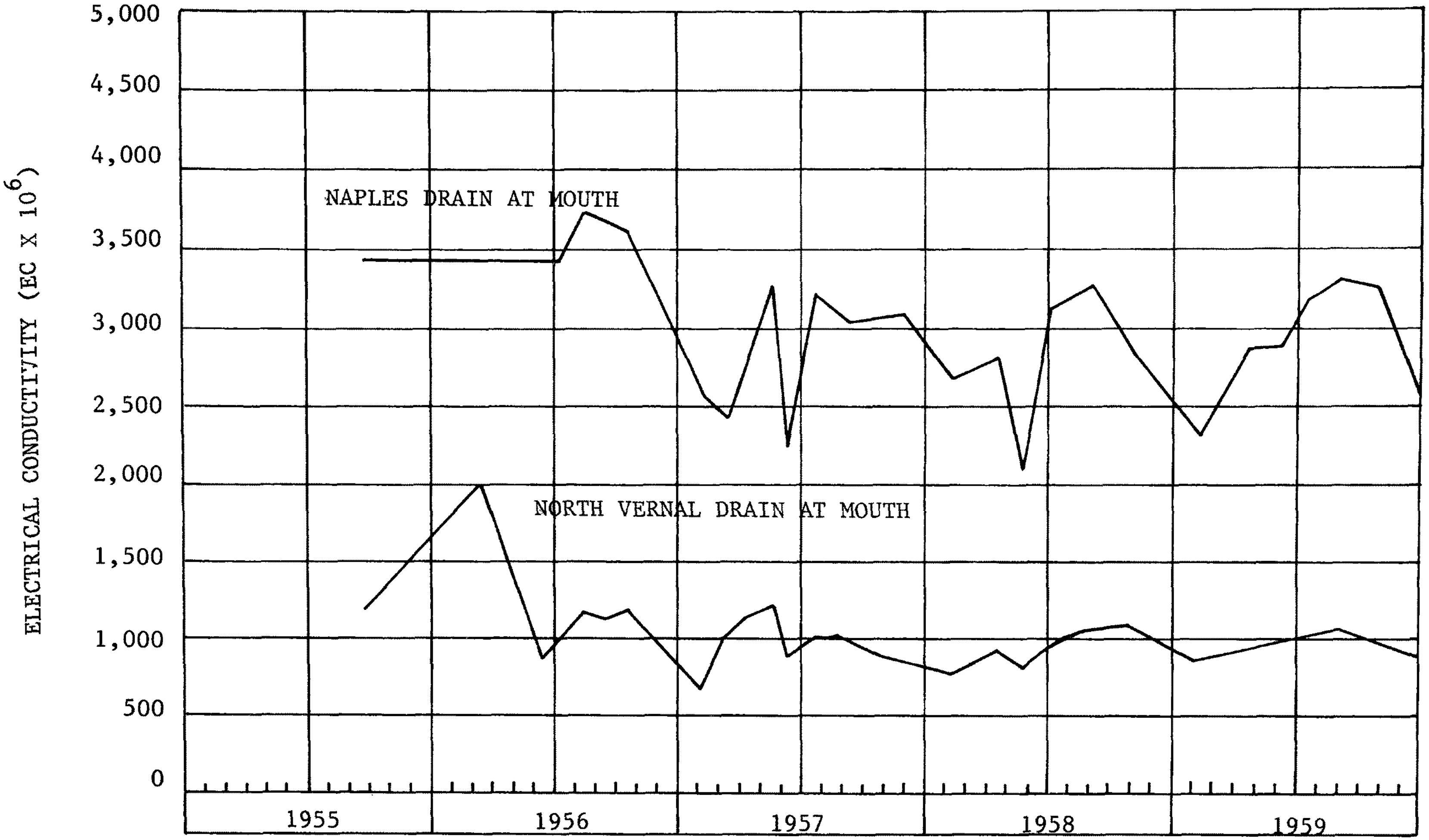


Figure 7a. Electrical conductivity vs time in natural drains, historical data, Vernal area, Utah.

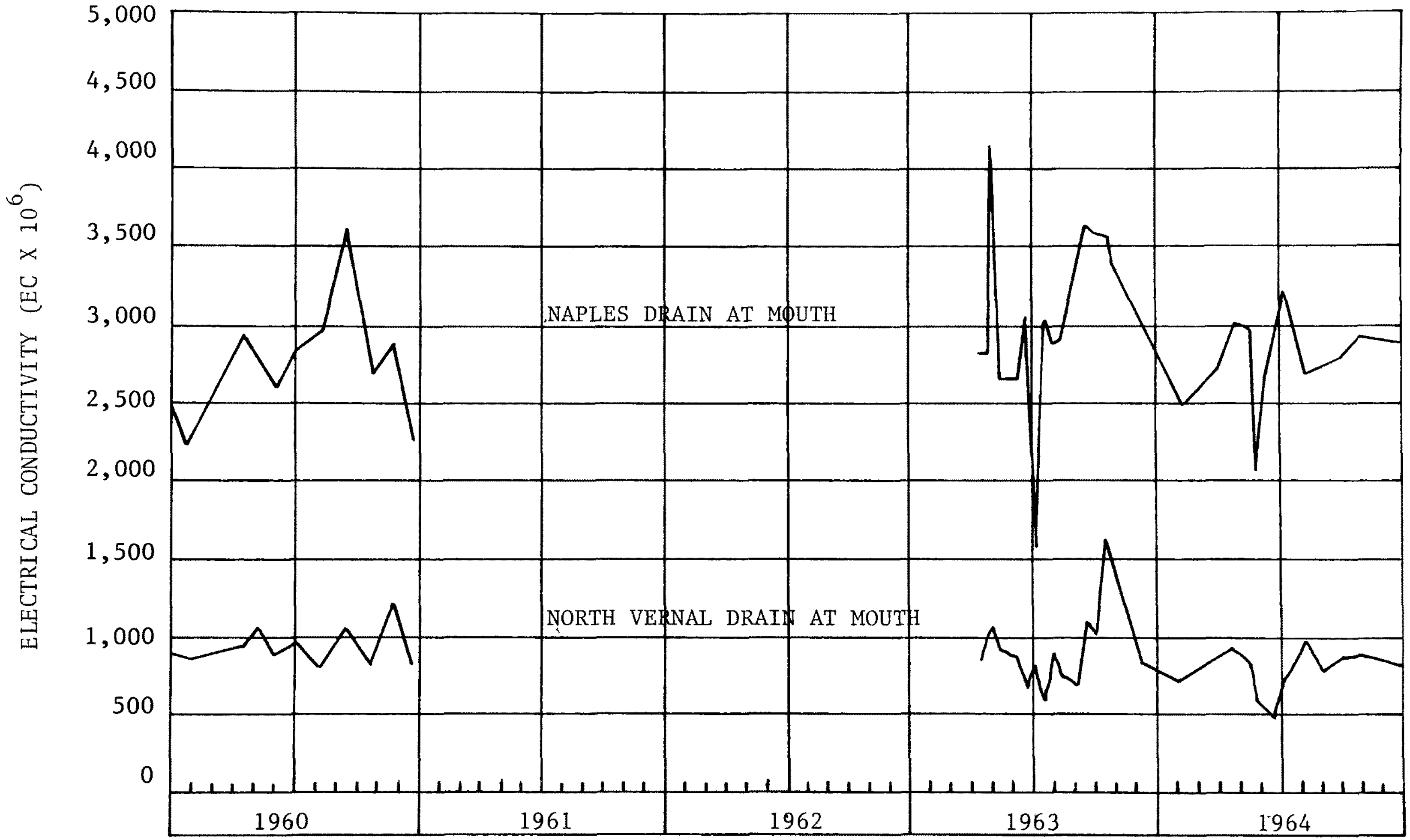


Figure 7b. Electrical conductivity vs time in natural drains, historical data, Vernal area, Utah.

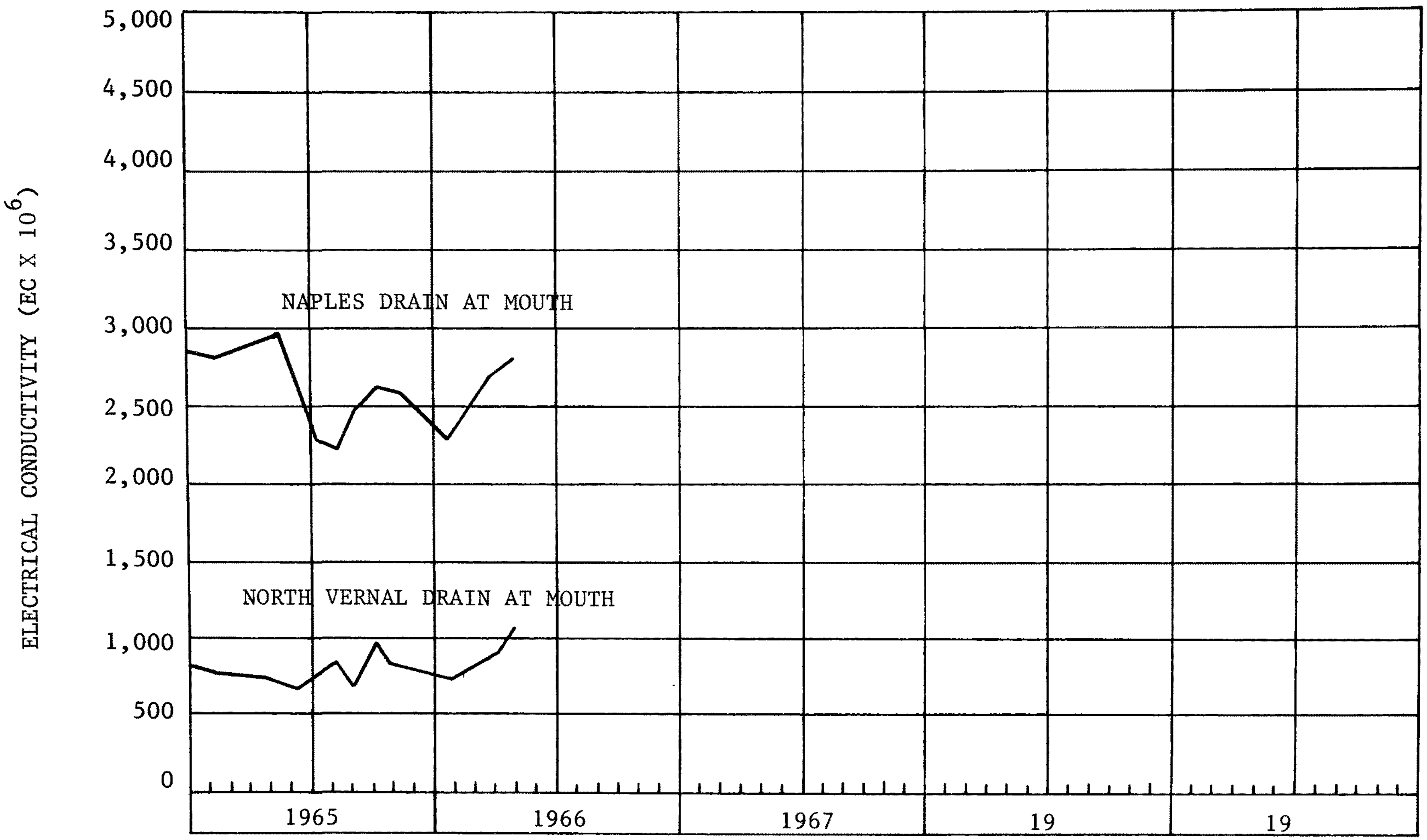


Figure 7c. Electrical conductivity (EC X 10^6) vs time in natural drains, historical data, Vernal area, Utah.

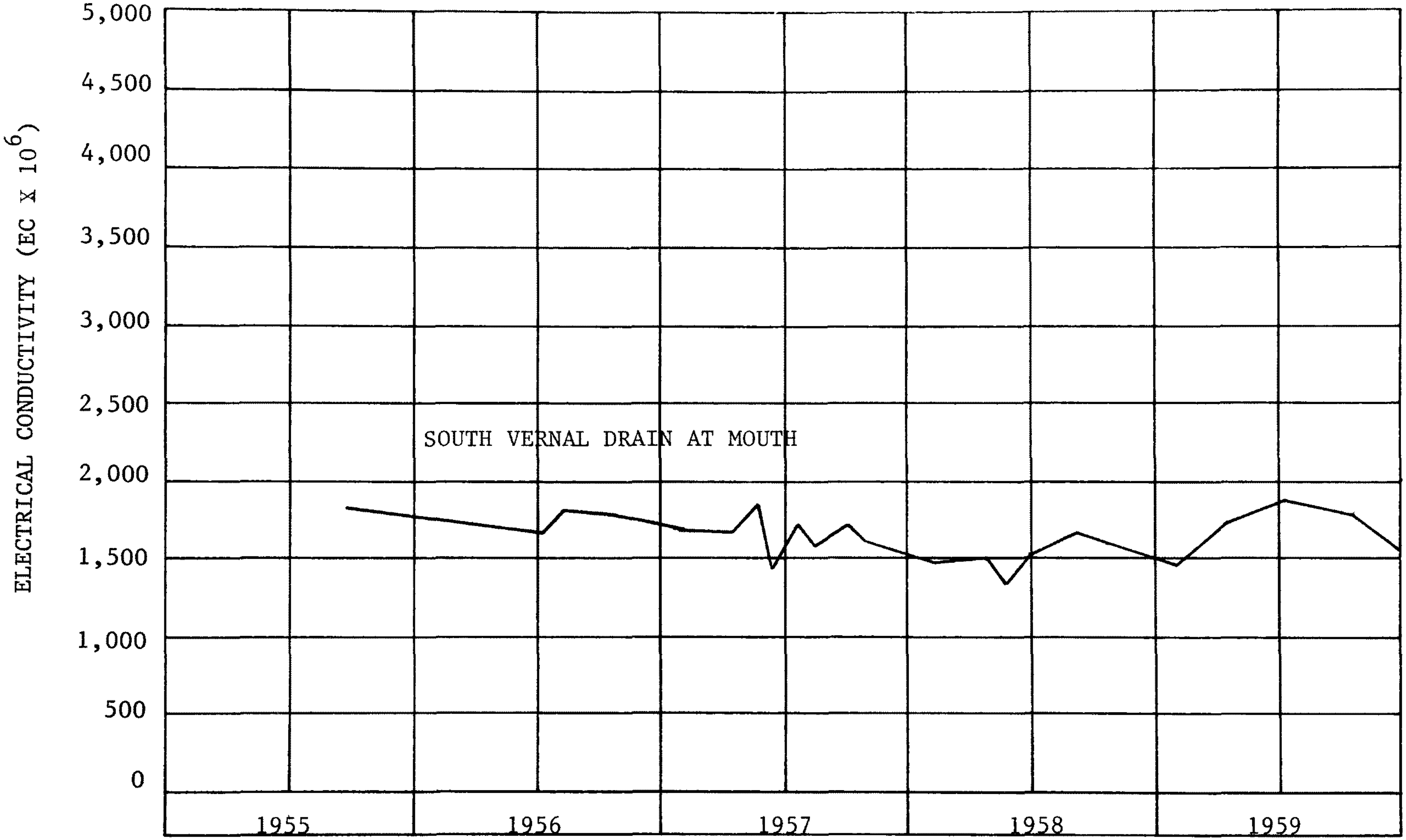


Figure 8a. Electrical conductivity vs time, natural drains, historical data, Vernal area, Utah.

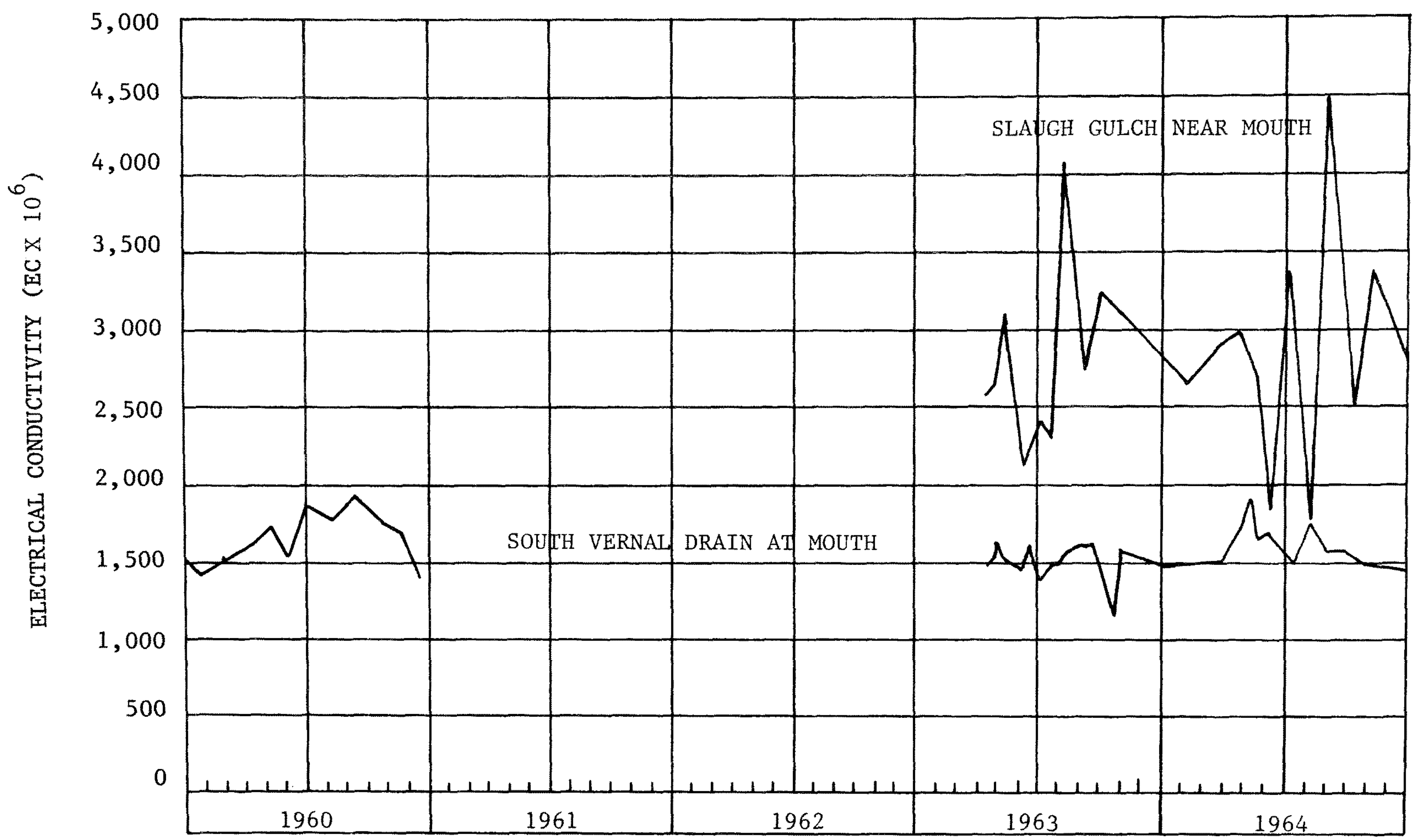


Figure 8b. Electrical conductivity vs time, natural drains, historical data, Vernal area, Utah.

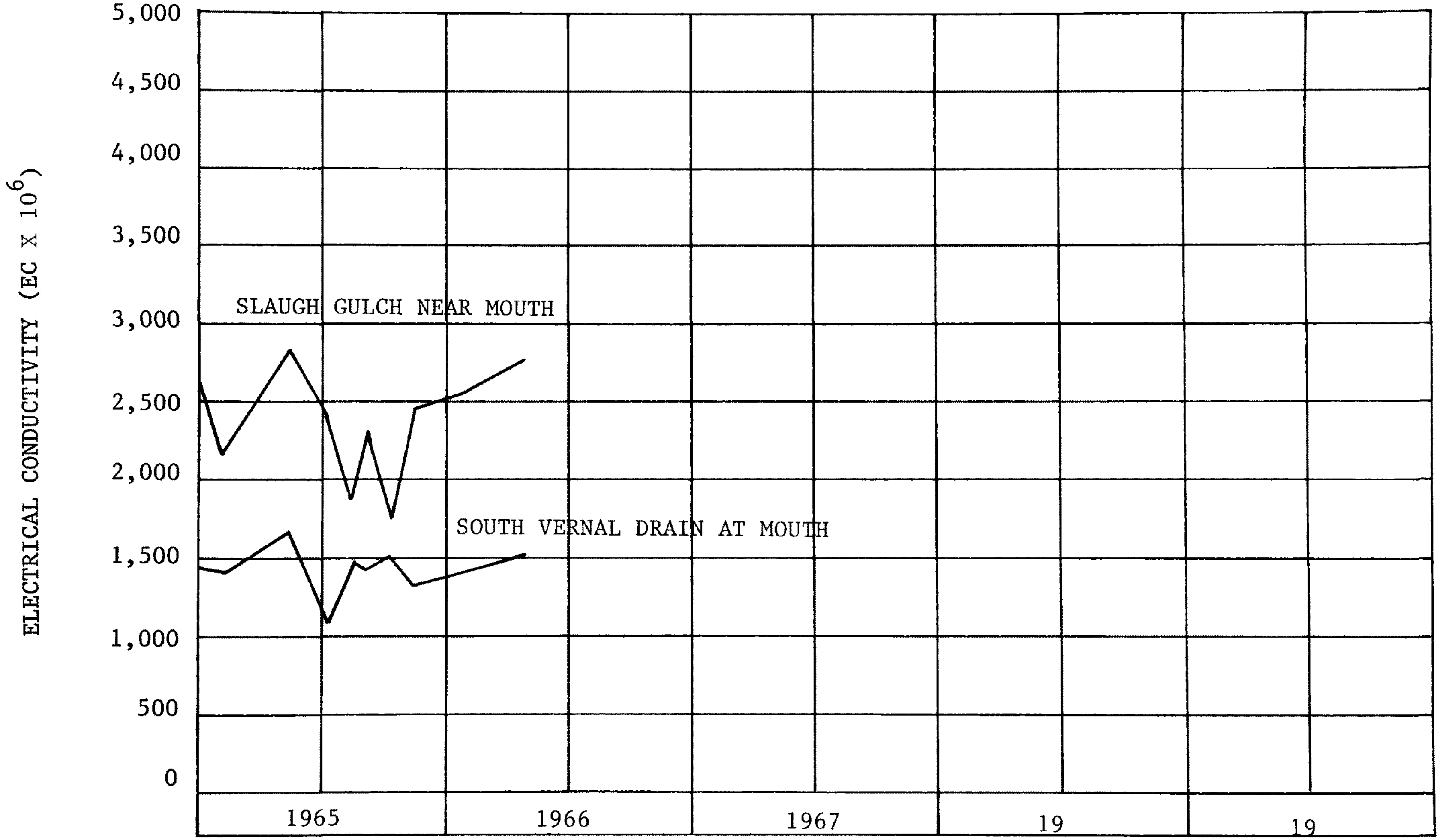


Figure 8c. Electrical conductivity vs time, natural drains, historical data, Vernal area, Utah.

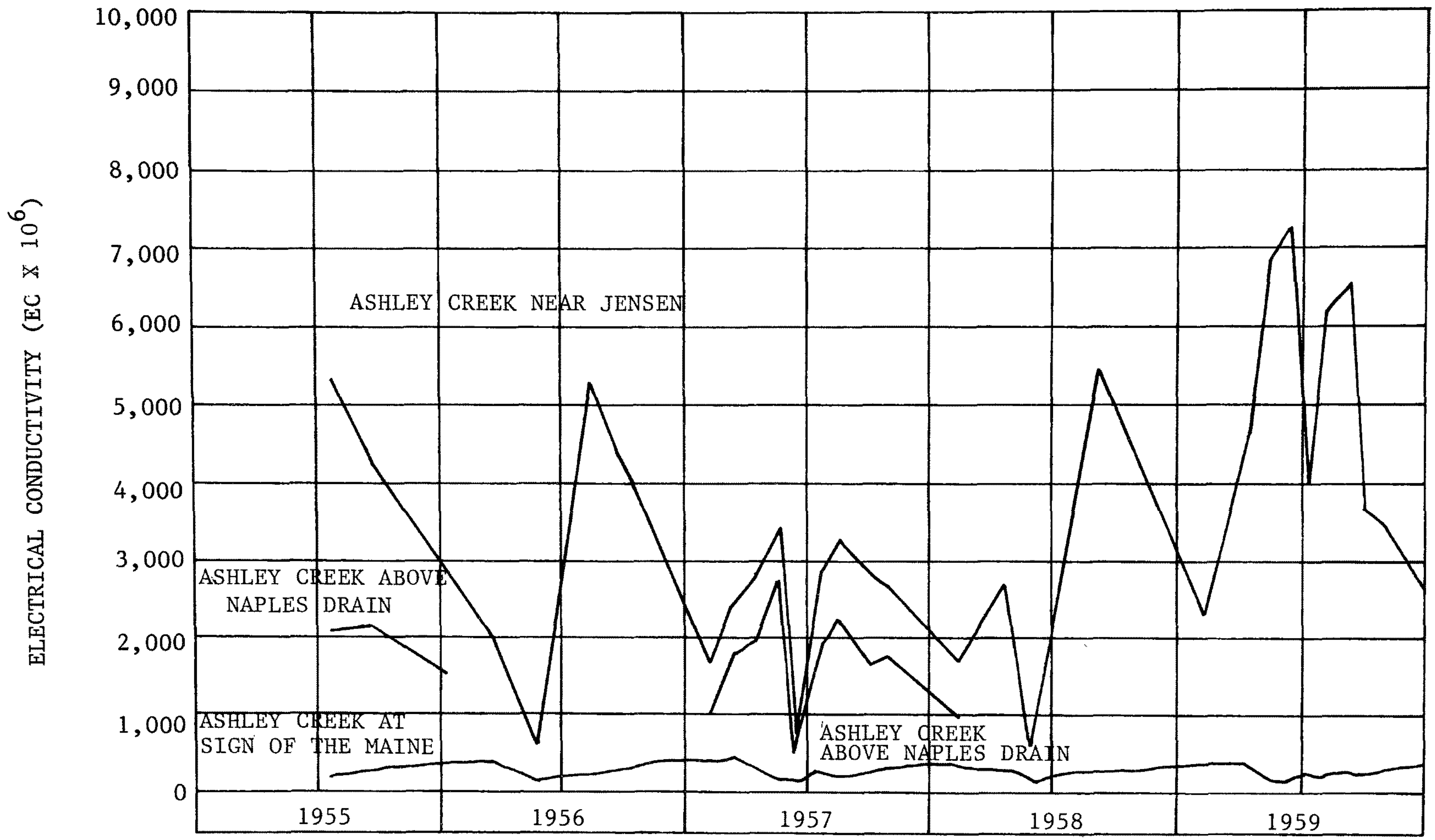


Figure 9a. Electrical conductivity vs time, Ashley Creek, historical data, Vernal area, Utah.

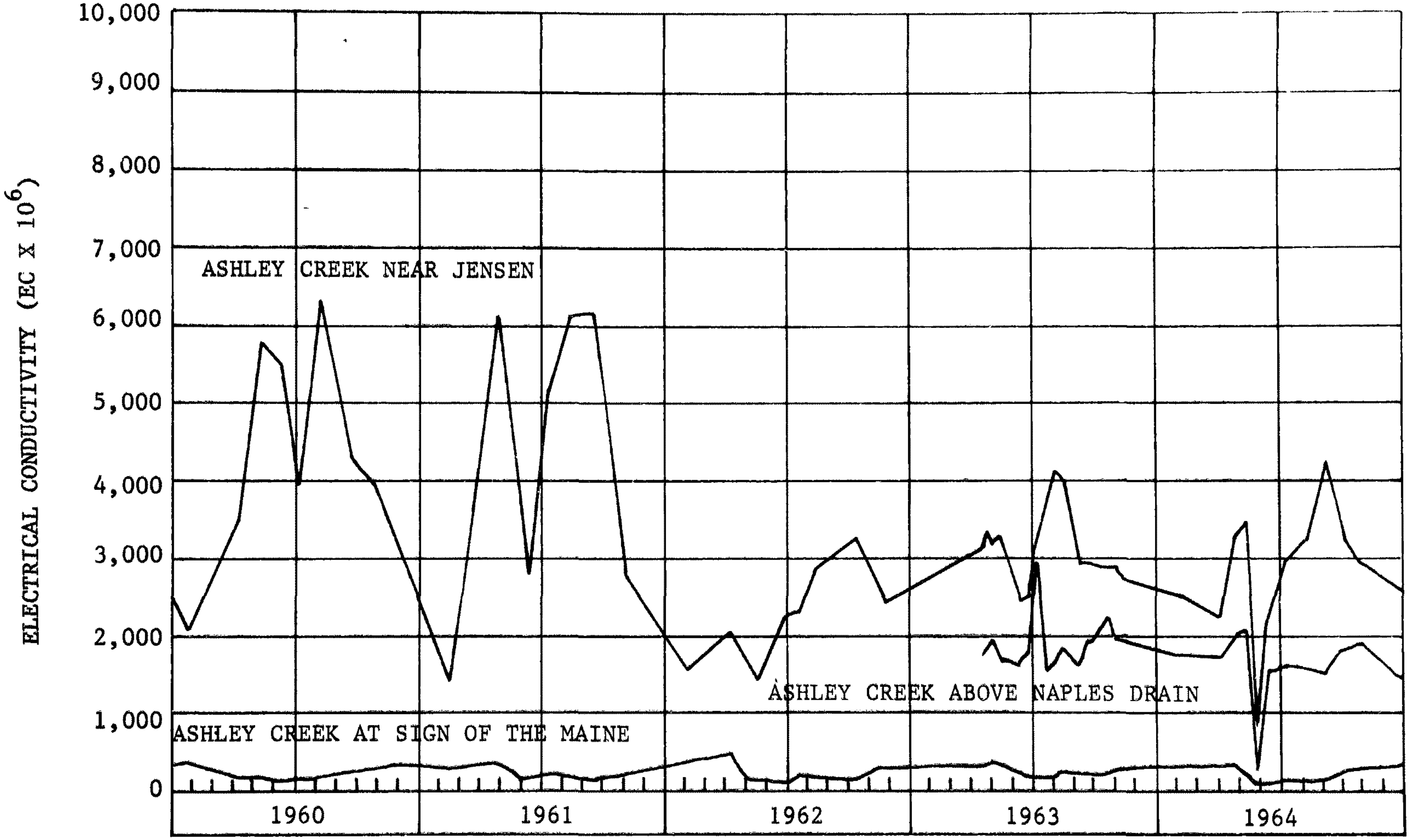


Figure 9b. Electrical conductivity vs time, Ashley Creek, historical data, Vernal area, Utah.

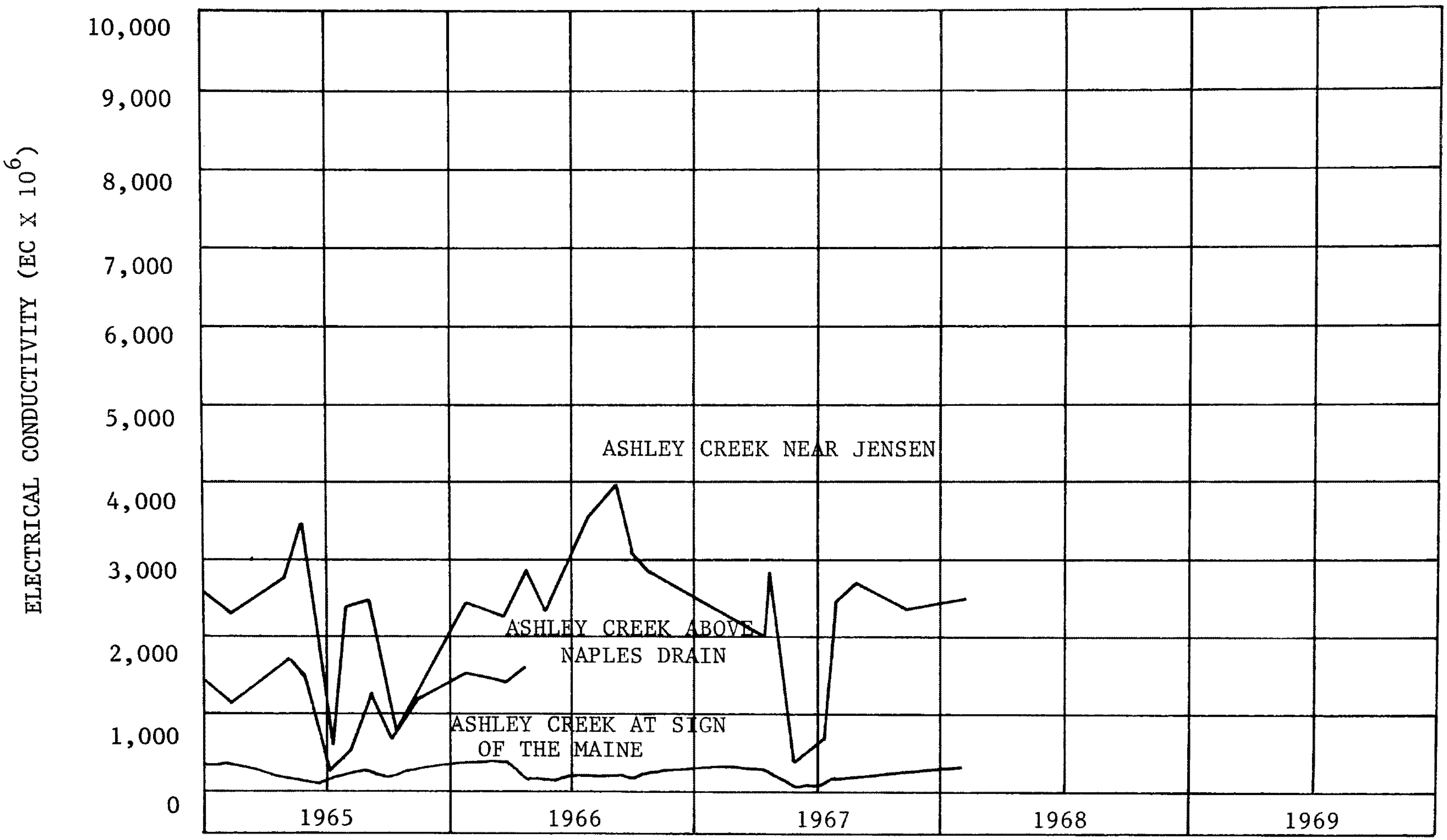


Figure 9c. Electrical conductivity vs time, Ashley Creek, historical data, Vernal area, Utah.

Water Requirements

An average annual irrigation diversion requirement of 3.7 acre-feet per acre was estimated for Vernal Unit lands at the heads of major canals. This estimate was determined by the Blaney-Criddle method which was compared with the results of a 1948-1950 study as summarized in Special Report No. 8, Utah Agricultural Experimental Station, entitled "Consumptive Water Use and Requirements in the Colorado River Area of Utah."

The computations used in determining the diversion requirement and the monthly distribution of the requirement are shown below:

Computation of Annual Diversion Requirement

	Acre-feet per acre Annually
Growing season consumptive use	1.92
Less effective precipitation	.25
Net consumptive use	1.67
Plus farm losses (45 percent of delivery)	1.36
Farm delivery requirement	3.03
Plus canal losses (18 percent of diversion)	.67
Diversion requirement	3.70

Estimated monthly distribution of diversion requirement

	April	May	June	July	Aug.	Sept.	Oct.	Total
Percent	4.8	17.0	20.2	23.0	18.0	12.0	5.0	100.0
Acre-feet per acre	.18	.63	.75	.85	.67	.44	.18	3.70

The over-all annual diversion requirement was estimated to be 51,700 acre-feet. This requirement is based on the productive acreage of 14,041 acres which is distributed as follows:

990 acres under Highline Canal
4124 acres above Steinaker Canal excluding land under Highline Canal
8571 acres below Steinaker Canal
356 acres for the river bottom area. This 356 acres receives about 300 acre-feet in supplemental supply.

Irrigation Methods

Prior to development of the Vernal Unit, irrigated lands in the unit area were served by six major canals and ditches diverting from Ashley Creek. These include the Ashley Upper, Ashley Central, Highline and Rock Point Canals and the Island and Dodds ditches. The Colton ditch is combined in the Ashley Upper Canal and the Hardy ditch in the Ashley Central Canal. There are also some small diversions made by individuals or small groups.

The majority of farms are irrigated by furrow or flooding methods. There is a small amount of sprinkler use. Since the development of the Vernal Unit late irrigation season water is available through storage releases from Steinaker Reservoir in the Steinaker Service Canal.

NEW DATA

The data described in this section of the report have been collected in the Vernal study area since 1969 to aid in the development of the mathematical model for the EPA investigations. Data collected during 1971 and 1972 as used to test the model is summarized in the Appendix. Locations of data collection points are shown on the map of Ashley Valley.

Ground Water

Depth to ground water was observed at 122 holes in the study area. Twenty-nine observation holes and 24 deep test holes were drilled prior to 1969. Fifty-five observation holes and 14 deep test holes were installed in 1969 to complete a grid network and provide additional information for this study. All but one of the deep test holes reached the shale or sandstone surface.

Water depths were measured monthly during the irrigation season and every 2 or 3 months during the non-irrigation season in both the observation and deep test holes. Water quality samples were taken monthly during the irrigation season and every 2 or 3 months during the non-irrigation season in 25 selected deep test holes and observation holes which reach the shale surface. These samples were taken so as to define the changes in water quality with changes in depth. An analysis of these samples indicates an increase of total dissolved solids with an increase in depth toward the shale surface.

Figures 10, 11 and 12 are plots of EC X 10^6 vs. depth for TH-27 in Node 1, TH-19 in Node 2 and OH 509 in Node 3, all located along transect A-A.

Permeability

Pumping tests were conducted in the 24 deep test holes drilled in 1969. Based on the results of these tests, average permeability rates of 6 inches per hour for the fine alluvium and 100 inches per hour for the gravel aquifer were estimated. Complete quality analysis was made on samples taken prior to the pumping tests. The results of these chemical analysis are summarized in Table 2. These 24 holes are located primarily in the drainage deficient area which is in the southern portion of Node 1 and the northern half of Node 2. Additional permeability tests are not needed for the remainder of the study area.

Amount in Storage

Storage coefficients for each nodal area were estimated from pumping tests and soil test data. The coefficients used to determine ground water storage are as follows: 10 percent for Node 1, 10 percent for the north half of Node 2, 5 percent for the south half of Node 2, 5 percent for Node 3, and 10 percent for Node 4. Node 4, which was located along the river bottoms below Node 1, has since been absorbed into Nodes 2 and 3. The storage coefficients for Nodes 1, 2 and 3 are the same with or without Node 4.

To determine the saturated thickness for the historic data, one or more transects were plotted across each node area and the depth to shale and average depth to water estimated for each section. The amount of water

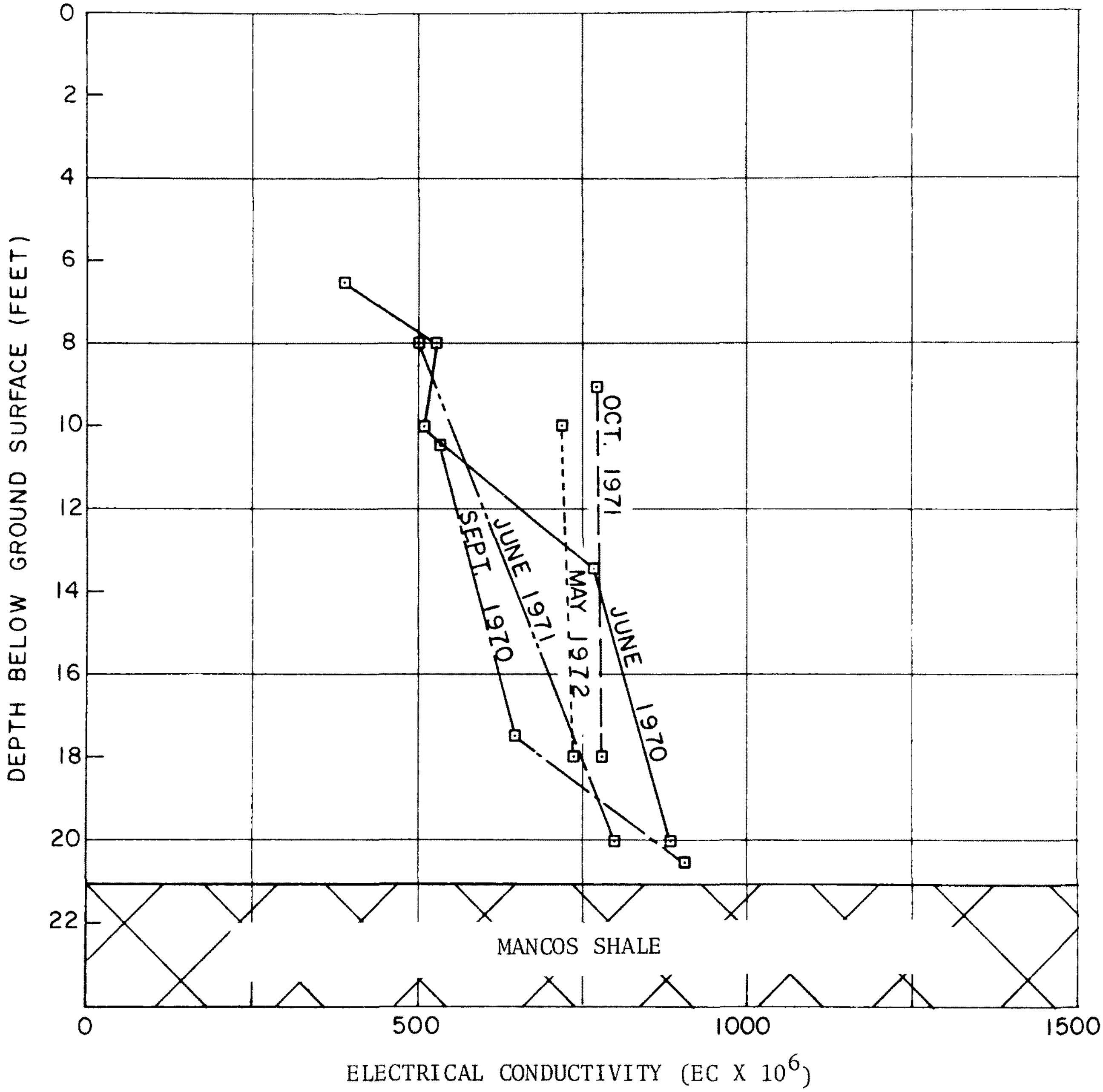


Figure 10. Groundwater Quality, TH-27, Transect A-A, Node 1.

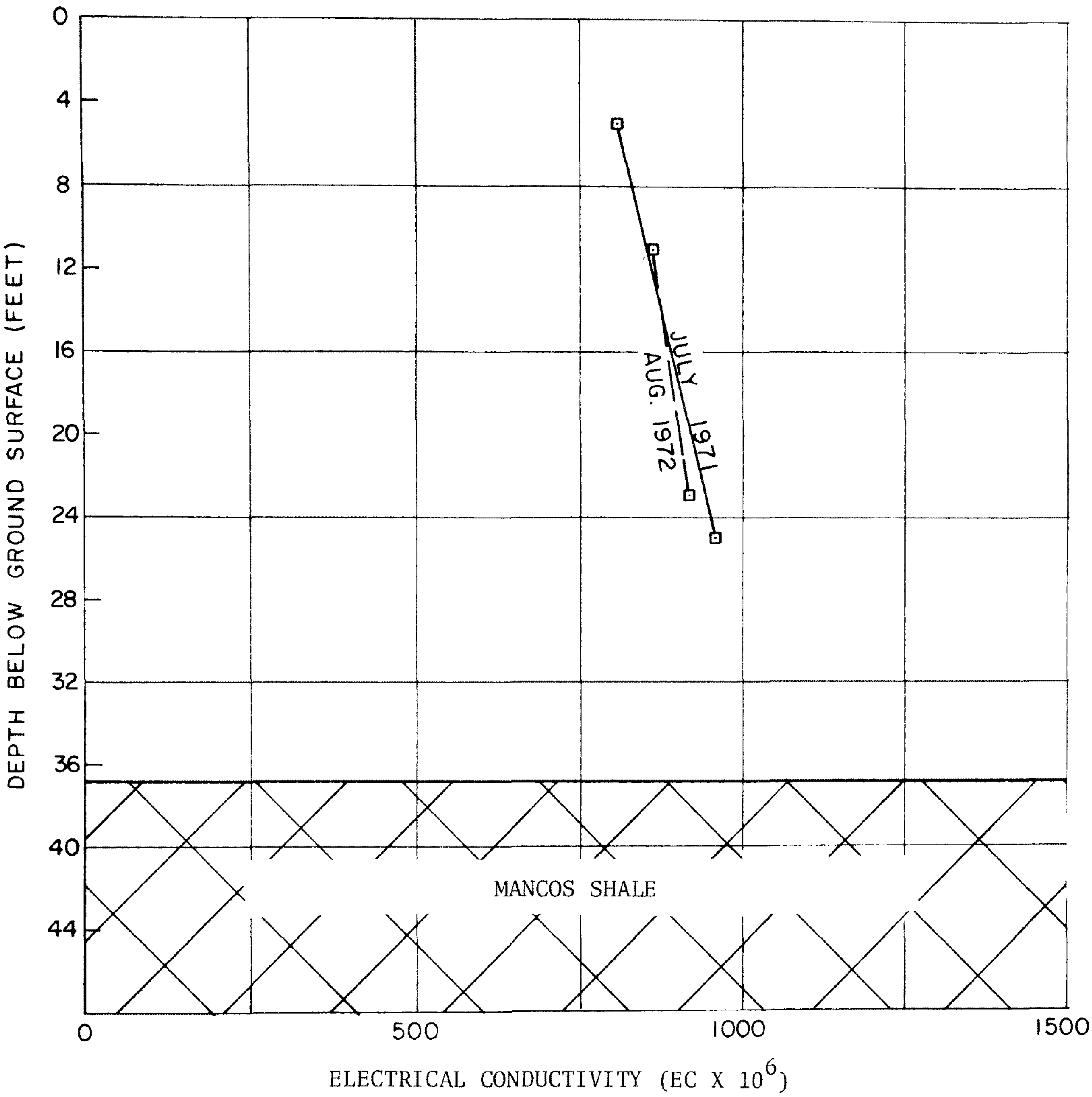


Figure 11. Groundwater Quality, TH-19, Transect A-A, Node 2.

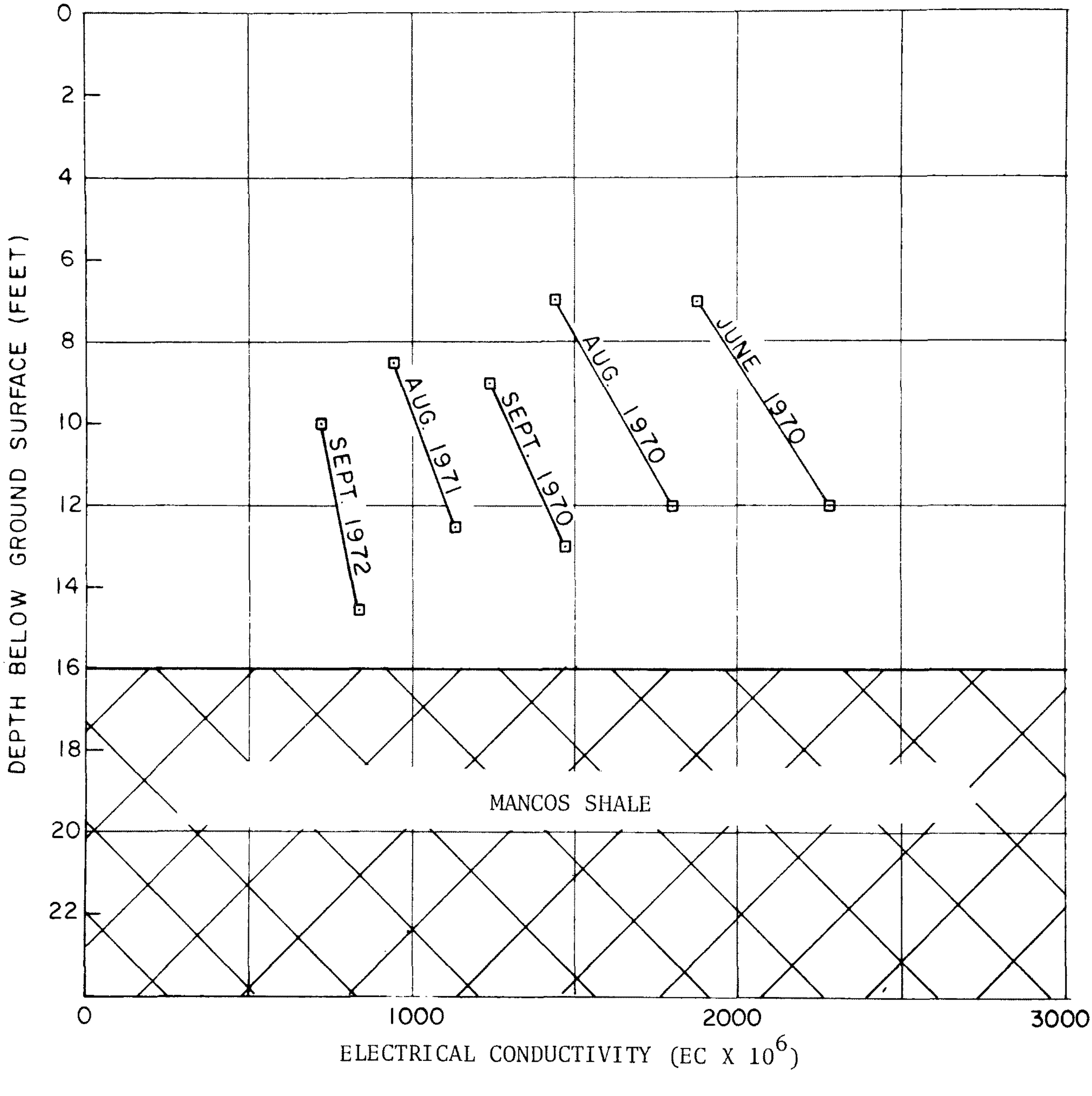


Figure 12. Groundwater Quality, OH-509, Transect A-A, Node 3.

in storage for each node was estimated by multiplying the saturated volume times the storage coefficient.

The maximum ground water in storage as estimated from the historical monthly data (1958-1962) is 31,700 acre-feet for Node 1, 24,400 acre-feet for Node 2, 9,000 acre-feet for Node 3, and 2,500 acre-feet for Node 4. An estimated 900 acre-feet from Node 4 should be included in Node 2 and 1600 acre-feet included in Node 3 for maximum historical ground water storage.

Saturated volumes by node for February 1971 and September 1972 were determined from saturated thickness contour maps of the study area. These maps are based on depth to water measurements and depth to shale information taken from selected observation and test holes. The estimated ground water in storage for these two months is listed below.

Node	Month	Saturated Volume (Acre-feet	Storage Coefficient %	Ground water Storage (Acre-feet)
1	Feb. 1971	243,944	10	24,400
	Sept. 1972	244,782		24,500
2 (North)	Feb. 1971	183,538	10	18,400
	Sept. 1972	176,756		17,700
2 (South)	Feb. 1971	35,900	5	1,800
	Sept. 1972	60,508		3,030
3	Feb. 1971	120,407	5	6,020
	Sept. 1972	94,109		4,700
Totals	Feb. 1971			50,620
	Sept. 1972			49,930

QUALITY OF WATER
DEEP TEST HOLES
TABLE 2

T.H. No.	Field No.	Sampling Date	EC x 10^6 @ 25°C.	pH	Total dis-solved salts p.p.m.	Boron p.p.m.	% Sodium	Sodium Adsorption Ratio	Residual Carbonates me/l	Depth (FT.)	Equivalents per million or milliequivalents per liter							
											Cations				Anions			
											Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
1	3800	10-29-69	3900	7.5	4130	1.5	10	1.2	None	12	25.77	27.83	6.20	.06	None	6.57	1.03	52.26
2	1540	10-31-69	1550	7.6	1370	.05	5.0	.3	None	10	11.22	8.13	1.04	.09	None	5.75	.32	14.41
3	1100	10-29-69	1110	8.1	841	.66	15	.8	None	6.0	2.84	7.84	1.90	.37	None	4.40	.67	7.88
3	1650	10-29-69	1650	7.9	1340	.76	11	.7	None	1510.0	6.08	11.86	2.24	.28	None	7.16	.81	12.49
4	1350	10-30-69	1260	7.7	1030	.38	7.0	.4	None	2020.0	8.04	6.76	1.03	.02	None	5.91	.24	9.70
5	1500	10-30-69	1490	7.6	1300	.38	4.4	.3	None	15.0	10.98	8.13	.88	.04	None	5.50	.30	14.23
6	1670	10-30-69	1690	7.6	1480	.38	4.0	.3	None	15.0	13.72	7.45	.89	.08	None	5.73	.30	16.11
7	1200	10-30-68	1020	7.6	785	.02	5.3	.3	None	8.0	6.96	5.49	.70	.13	None	4.67	.24	8.37
7	1400	10-30-69	1390	7.6	1150	.16	4.4	.3	None	32.0	10.19	6.76	.70	.4	None	5.30	.38	12.10
8	1580	10-30-69	1580	7.8	1340	.29	4.4	.3	None	20.0	11.47	8.53	.93	.09	None	6.66	.67	13.69
9	1750	10-31-69	1720	7.6	1630	.03	2.5	.2	None	17.0	15.63	7.40	.60	.03	None	3.52	.24	19.90
10	960	10-30-69	972	7.7	702	.04	7.1	.4	None	15.0	5.98	5.49	.88	.04	None	6.41	.25	5.72
11	1070	10-29-69	1330	7.6	992	.18	12	.7	None	8.0	5.10	8.53	1.82	.24	None	5.48	.85	9.36
Equivalent Weights											20.0	12.2	23.0	39.1	30.0	61.0	35.5	48.0

QUALITY OF WATER

DEEP TEST HOLES

TABLE 2

T.H. No.	Field No.	Sampling Date	ECx10[6] @ 25°C.	pH	Total dis-solved salts p.p.m.	Boron p.p.m.	% Sodium	Sodium Adsorp-tion Ratio	Residual Carbon-ates me/l	Depth (FT.)	Equivalents per million or milliequivalents per liter							
											Cations				Anions			
											Ca	Mg	Na	K	CO_3	HCO_3	Cl	SO_4
11	1650	10-29-69	1650	7.5	1390	.24	6.8	.5	None	15.0	10.00	10.00	1.48	.16	None	6.99	.49	14.16
12	1300	10-30-69	1300	7.7	1050	.11	6.1	.3	None	12	9.31	6.27	1.03	.14	None	6.44	.26	10.05
12	1450	10-30-69	1420	7.8	1240	None	5.6	.4	None	22	11.07	7.06	1.09	.11	None	6.08	.34	12.91
13	1120	10-31-69	1100	7.6	876	.11	9.6	.5	None	17.0	6.08	6.76	1.36	.03	None	6.79	.34	7.10
14	1000	10-31-69	984	8.0	782	.06	11	.5	None	12.0	4.76	6.13	1.28	.02	None	5.41	.38	6.40
15	970	10-31-69	980	7.7	772	.33	12	.6	None	10.0	4.84	5.86	1.47	.04	None	4.89	.49	6.83
16	1050	10-31-69	1040	7.8	788	.09	10	.6	None	12.0	5.74	5.82	1.32	.02	None	6.80	.41	5.69
17	740	10-30-69	714	8.1	482	None	4.9	.2	None	15.0	4.28	3.40	.40	.04	None	5.54	.14	2.44
17	1030	10-30-69	876	8.0	632	.02	4.6	.2	None	41.0	5.85	4.08	.48	.06	None	5.55	.18	4.74
18	800	10-31-69	679	8.0	489	None	7.9	.3	None	15.0	3.94	3.39	.64	.08	None	5.10	.32	2.63
19	1130	10-30-69	1090	7.9	857	.02	4.7	.2	None	15.0	6.96	5.59	.62	.03	None	4.54	.20	8.46
20	2500	10-29-69	2420	7.3	2250	.51	18	1.6	None	10.0	13.13	13.43	5.84	.11	None	3.57	.93	28.01
21	1500	10-29-69	1540	7.8	1300	.09	4.9	.3	None	15.0	10.49	8.92	1.00	.08	None	6.00	.26	14.23
Equivalent Weights											20.0	12.2	23.0	39.1	30.0	61.0	35.5	48.0

QUALITY OF WATER
DEEP TEST HOLES
TABLE 2
Page 3 of 3

T. H. No.	Field No.	Sampling Date	ECx10^6 @ 25°C.	pH	Total dis-solved salts p.p.m	Boron p.p.m.	% Sodium	Sodium Adsorp-tion Ratio	Residual Carbon-ates me/l	Depth (FT.)	Equivalents per million or milliequivalents per liter							
											Cations				Anions			
											Ca	Mg	Na	K	CO_3	HCO_3	Cl.	SO_4
22	1120	10-30-69	1120	7.8	831	None	6.4	.4	None	15.0	6.66	6.86	.93	.03	None	6.98	.26	7.28
23	900	10-30-69	920	7.8	665	None	6.4	.3	None	18.0	5.91	4.21	.70	.06	None	5.35	.20	5.33
24	1050	10-29-69	1010	7.6	722	None	11	.6	None	12.0	4.90	5.93	1.29	.03	None	5.40	.61	6.14
Equivalent Weights											20.0	12.2	23.0	39.1	30.0	61.0	35.5	48.0

The amount of ground water storage is possibly the most difficult item to evaluate in this type of study. A small variation in the storage coefficient can result in a large change in the estimated amount of ground water. Also, the saturated thickness is difficult to determine even with holes spaced 1 mile apart because of the possible variation in depth between each hole.

Chemical Data on Soils

A complete chemical and mechanical analysis was made on soil samples from 34 test holes, the majority of which were located on two north - south transects about 3 miles apart. A few test holes were dug in the river bottoms and in the northwest corner of the study area.

Table 3 contains a summary of soil test data at nine locations on transect A-A (three test holes in each node). Generally the salinity of the soil increases from north to south with the highest values found in the shallow soils in Node 3. The irrigated lands have a lower salinity regardless of location.

Deep Percolation

No tests have been made to determine the amount of deep percolation and recharge. Based on soil textures in the study area, an estimated 15 to 20 percent of the surface application goes to deep percolation. This estimate is based on the values listed below which were taken from Table 4 of the October 1967 Report, "The Transient Flow Theory and Its Use in Subsurface Drainage of Irrigated Land" by Lee D. Dumm.

TABLE 3
WATER QUALITY PREDICTION STUDY
SUMMARY OF SOIL TEST DATA
TRANSECT A-A

Node No.	Test Hole No.	Depth Inches	Soil PH	T.D.S.	S.A.R.	Texture
1	4	0-12	7.5	3190	2.1	Silty Clay
	1	0-12	8.2	2210	2.1	Sandy Loam
	7	0-14	7.9	1360	0.7	Loam
2	15	0-10	7.7	1620	0.4	Sandy Loam
	16	0-14	7.8	1170	0.4	Sandy Loam
	9	0-6	8.2	15,600	9.3	Sandy Loam
3	10	0-12	8.0	1080	0.7	Loam
	12	0-11	7.7	5280	1.9	Sandy Loam
	14	0-11	8.3	49,100	11.0	Sandy Loam
1	4	12-36	7.6	3050	1.8	Silty Clay
	1	12-36	8.3	554	0.6	Sandy Loam
	7	14-48	8.0	984	0.9	Clay Loam
2	15	10-24	8.0	712	0.4	Sandy Loam
	16	14-42	8.0	602	0.4	Loam
	9	6-12	8.3	15,100	8.5	Loam
3	10	12-28	8,0	598	0.4	Loam
	12	11-25	7.8	3030	1.5	Sn. Cl. Loam
	14	11-22	8.5	28,600	5.9	Sn. Cl. Loam
1	4	36-66	7.7	3460	2.2	Silty Clay
	1	-	-	-	-	-
	7	-	-	-	-	-
2	15	24-50	7.9	518	0.4	Sn. Cl. Loam
	16	42-68	7.9	660	0.8	Clay Loam
	9	12-30	8.0	9700	4.9	Clay Loam
3	10	28-36	7.9	510	0.4	Sandy Clay
	12	25-43	7.9	1270	1.1	Sn. Cl. Loam
	14	22-52	8.2	8280	8.9	Sn. Cl. Loam

Approximate Deep Percolation Loss (Percent of Application)			
Loamy Sand	- 30%	Silt Loam	- 18%
Sandy Loam	- 26%	Sandy Clay Loam	- 14%
Loam	- 22%	Clay Loam	- 10%
		Silty Clay Loam, Sandy Clay, Clay	- 6%

The estimated deep percolation should be adequate for the purposes of this study due to the difficulty of determining other variables which affect ground water storage such as saturated thickness or storage coefficients. For instance, a relatively small change in storage coefficients causes a significant change in the resulting volume of ground water, as previously stated.

Hydrology

Surface Water Measurements

Total inflow and outflow in the study area was measured at five USGS gaging stations. Subsurface flow studies made in Ashley Valley indicate an inflow of from 1.5 to 0.4 cfs and an outflow of from 0.3 to 0.1 cfs which are not significant. Figures 13 and 14 are hydrographs of Ashley Creek which compare inflow and outflow for the study area for 1971 and 1972.

Surface water quality and quantity measurements were made at the node boundaries for the period mid-summer 1970 through September 1972. The data collection points are discussed below and are referenced by number to a location description contained in Table 1.

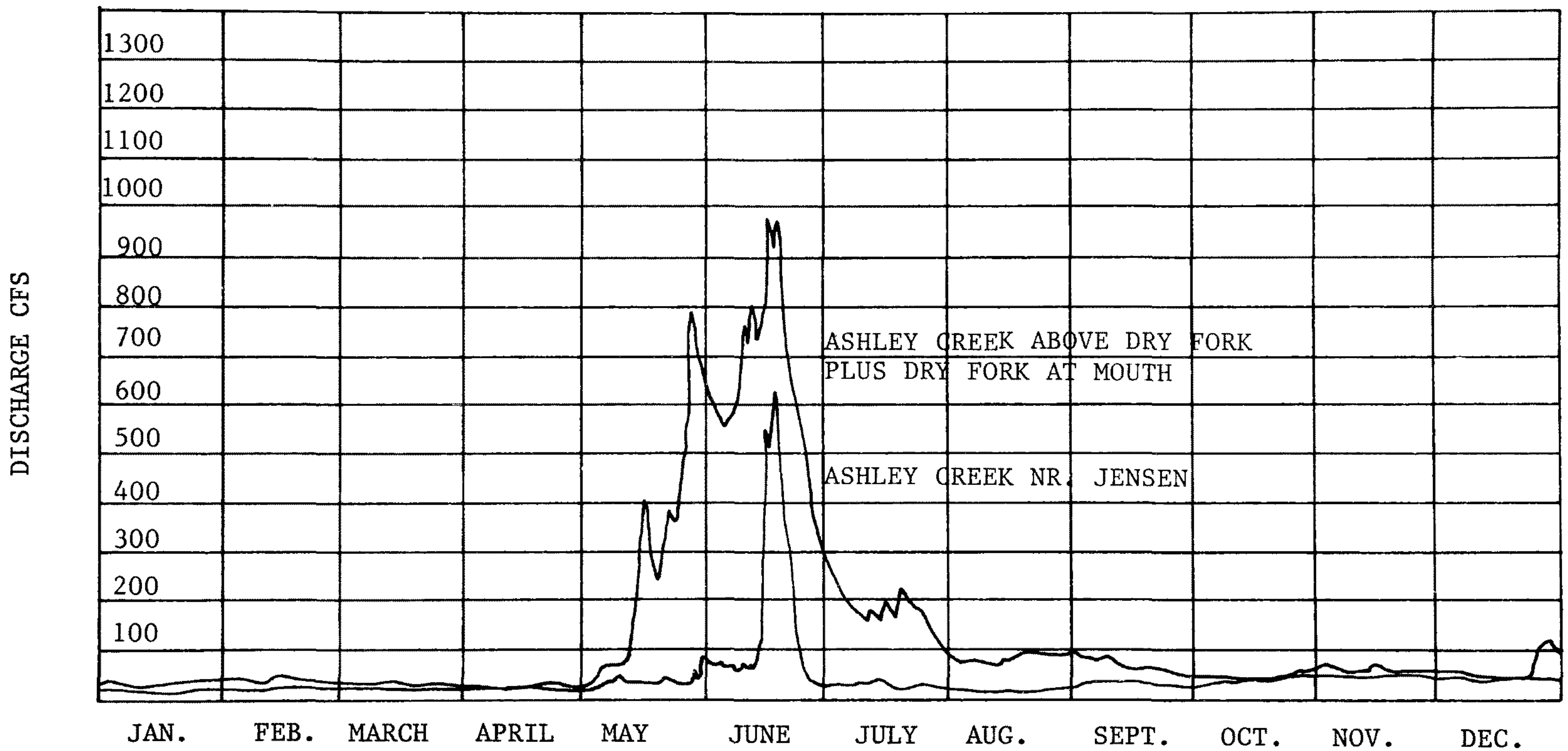


Figure 13. Comparison of streamflows, Ashley Creek, USGS Gages, 1971.

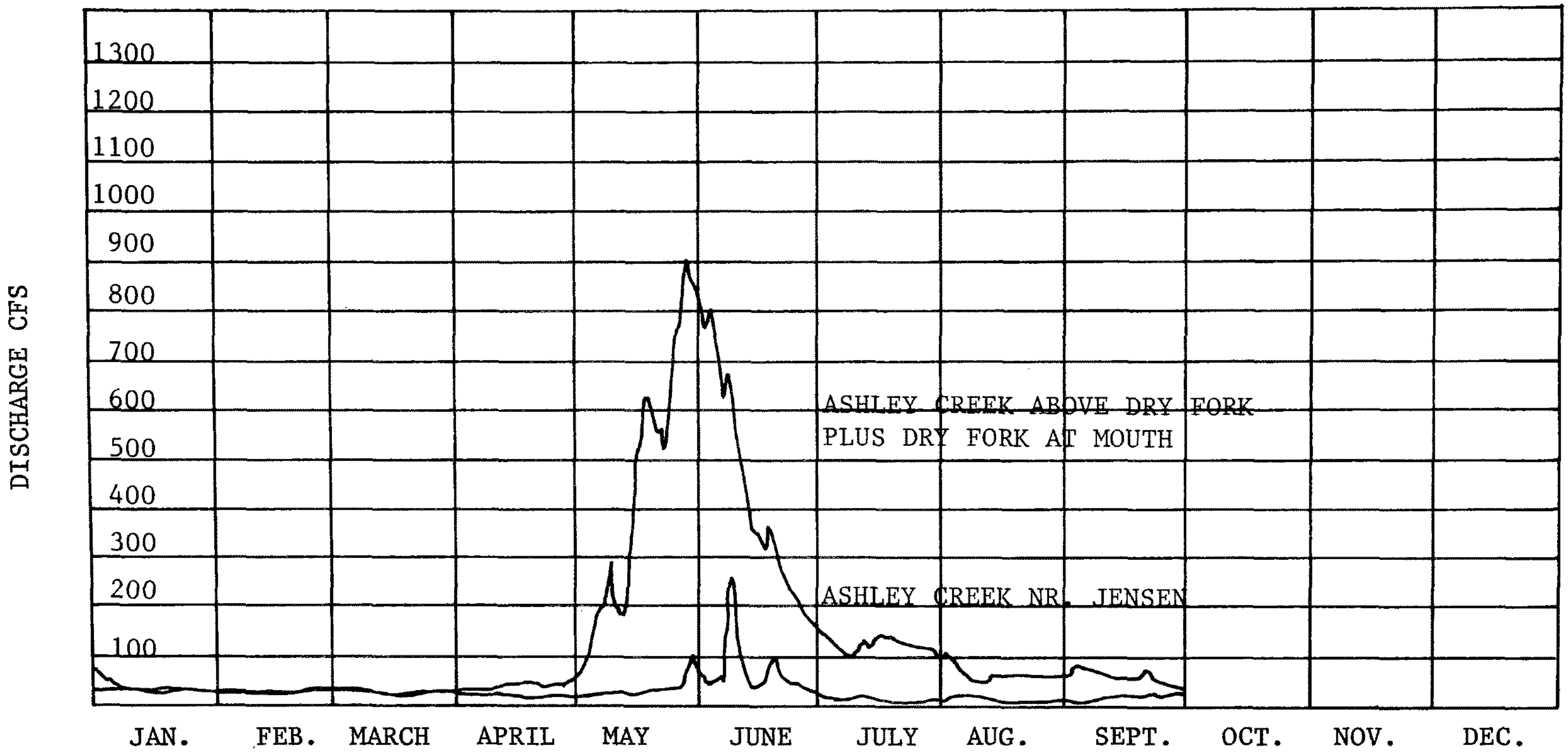


Figure 14. Comparison of streamflows, Ashley Creek, USGS Gages, 1972.

Ashley Creek

The gage "Ashley Creek at Sign of the Maine" was discontinued in September 1965. Since June 1969 the USGS has maintained the gage "Ashley Creek above Dry Fork" (20) and the gage "Dry Fork at Mouth" (21) since July 1954. These gages measure the inflow to the study area.

The outflow from the study area was measured at three USGS gages:

1. "Ashley Creek near Jensen" (23) - operated since October 1946;
2. "River Irrigation Company Canal" (24) - operated since June 1969; and
3. "Highline Canal below Mantle Gulch" (22) - operated since June 1969.

Two continuous recording stream gages were operated at gages 11 and 8 for the period May 1971 through September 1972. These gages were needed to better define flow in Ashley Creek at the boundaries between Nodes 1 and 2 and 2 and 3 respectively. Frequent current meter measurements were made in an attempt to define the stage-discharge relationships at gages 11 and 8.

Continuous conductivity recorders were operated during the irrigation seasons of 1970 through 1972 at three locations on Ashley Creek. The inflow quality was measured at the Highline Canal diversion dam (S-1), quality was recorded at gage 11 (S-2), and the outflow quality was recorded at the "Ashley Creek near Jensen" gage (S-3).

The conductivity recorders would not operate during freezing weather; therefore, portable bridge readings were made during the balance of each year. When possible, bi-weekly portable readings were made at gage 8 during the irrigation seasons.

Maintenance problems with the conductivity recorders caused some inaccuracies in the data. These recorders should be checked frequently to insure that the conductivity cells are free of sediment and mineral deposits and that the recorder E.C. compares favorably with the portable bridge. Two of the recorder installations were modified for 1972 with the expectation that these changes would improve the accuracy of the measurements. The recorder at gage 11 was moved farther down-stream to a point where Ashley Creek and Spring Creek mix more completely than at the previous location. The pipe containing the conductivity cell at "Ashley Creek near Jensen" was extended about 20 feet to a point in the creek where more representative conductivities could be measured. The conductivity data measured at these two locations was more representative of actual conditions due to these modifications.

Quality samples were taken monthly during the irrigation season for lab analysis. A comparison of conductivities on Ashley Creek are shown in Figures 15 and 16 for 1971 and 1972. Figures 17, 18, 19 and 20 are correlations of total dissolved solids with EC X 10^6 for the four locations on Ashley Creek shown in Figures 15 and 16.

Canals

Staff gages were installed in the canals at the node boundaries and an attempt made to rate these sections with current meter measurements. Development of a stage-discharge relationship in most of the canals was not possible due to checks which cause a change in stage for the same flow.

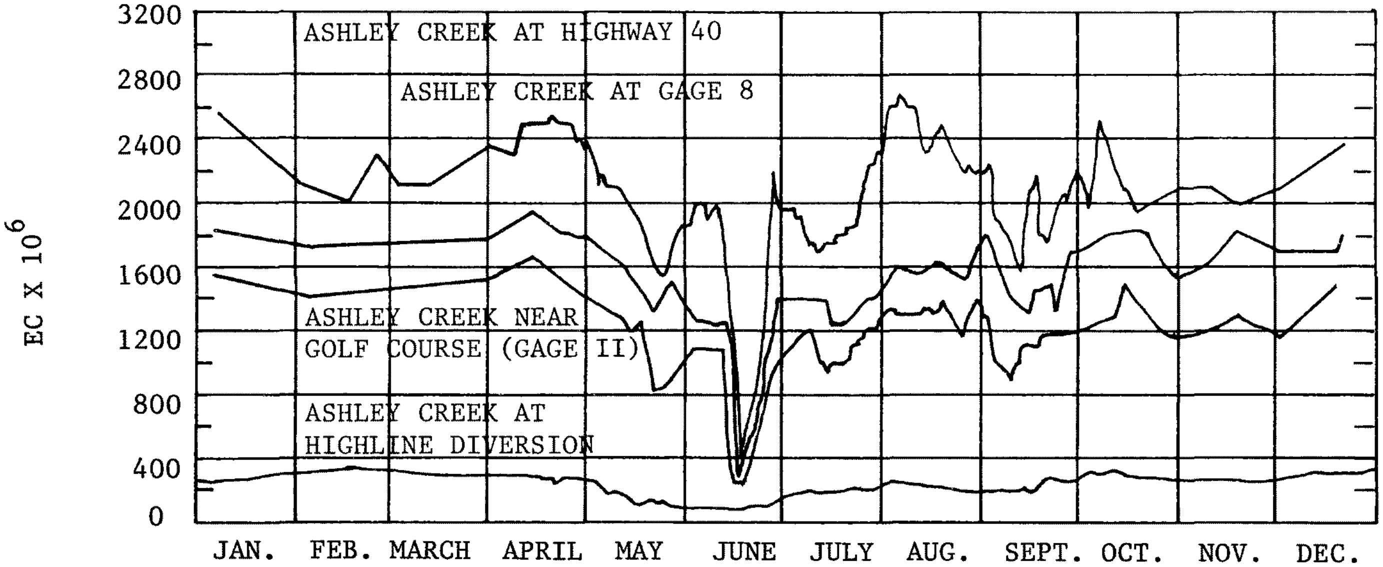


Figure 15. Ashley Creek EC X 10^6 vs time, Vernal EPA study, 1971.

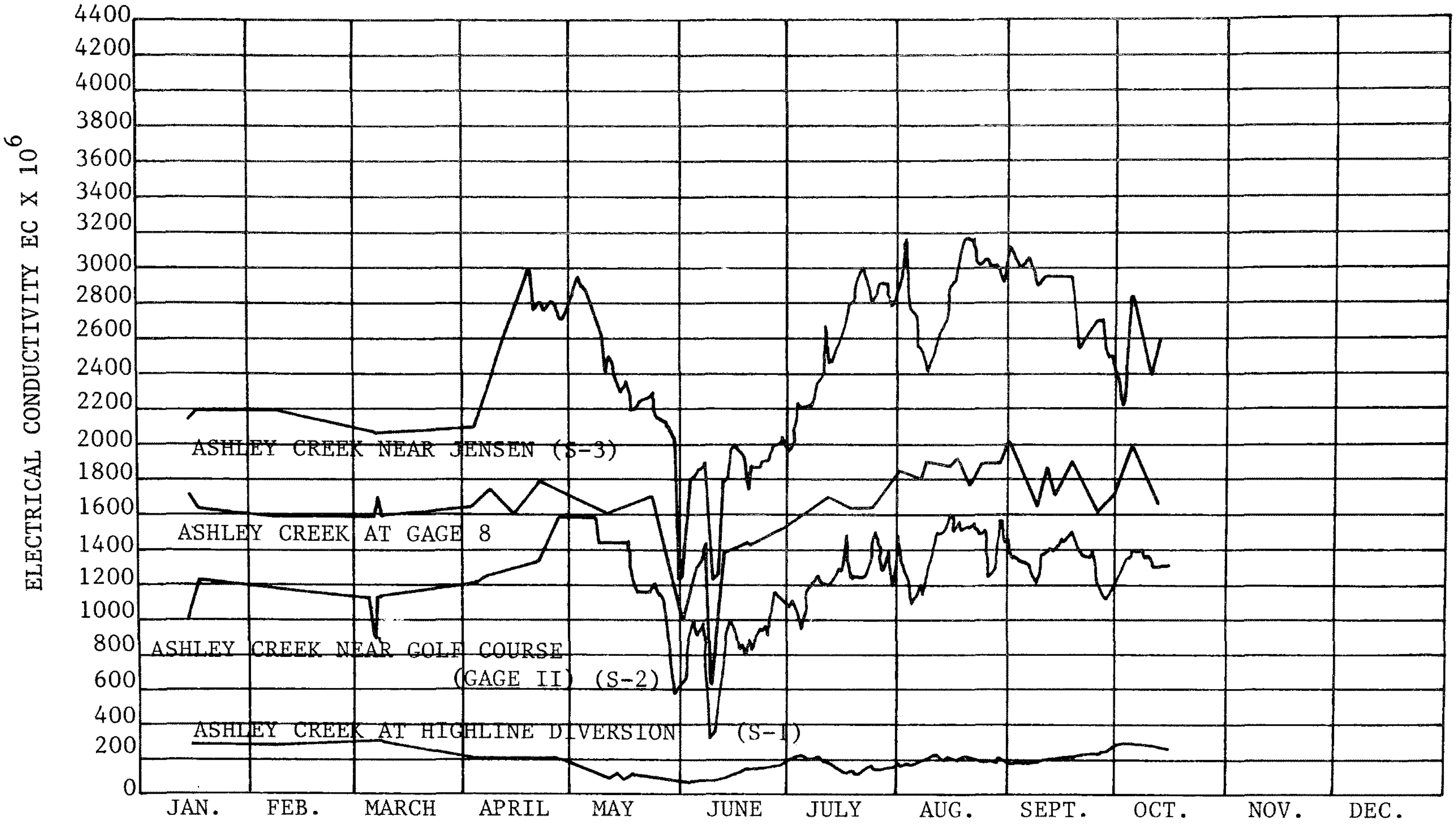


Figure 16. Electrical Conductivity vs time, Ashley Creek, 1972.

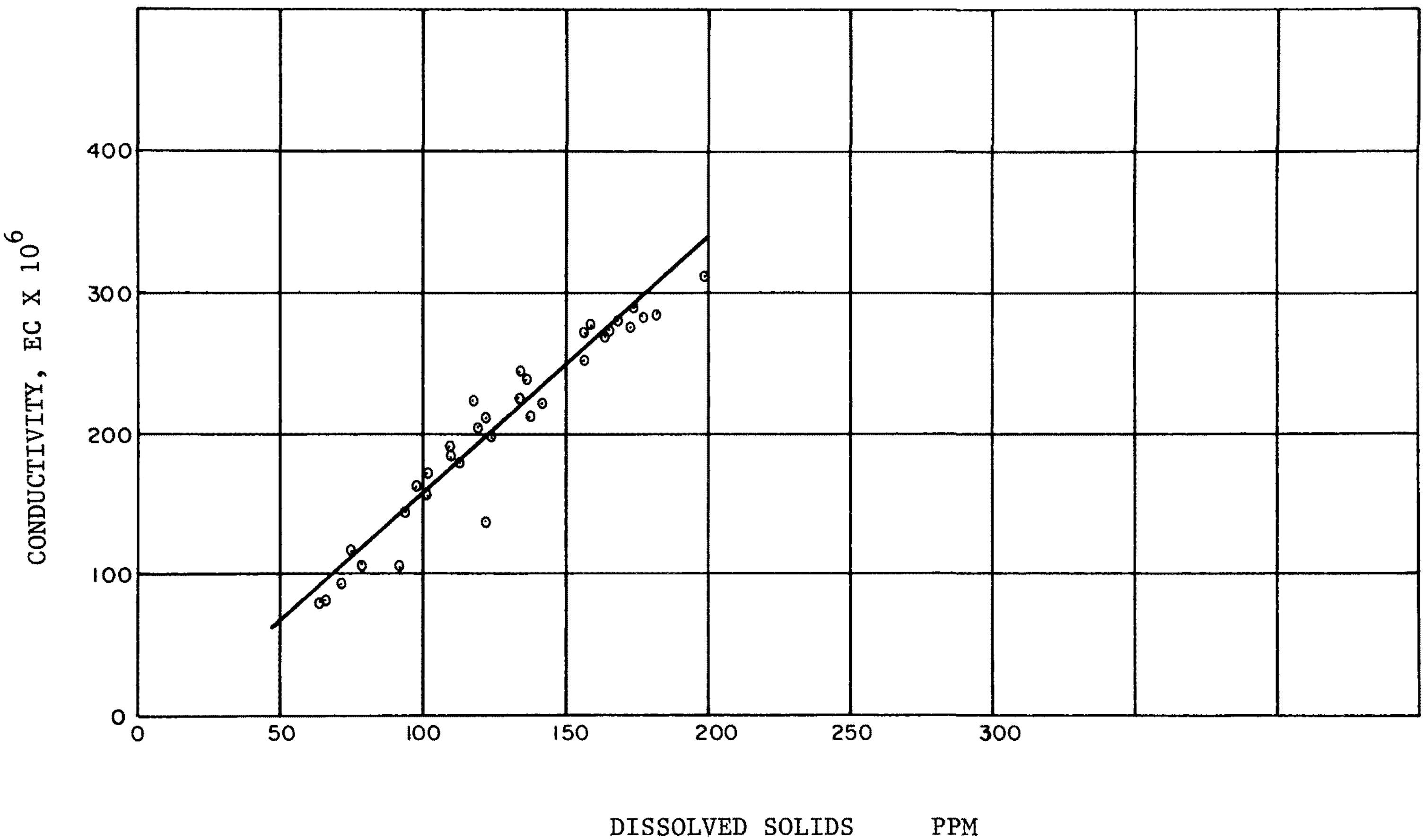


Figure 17. Electrical conductivity vs dissolved solids, Ashley Creek at Highline Canal, salinity recorder S-1, node 1 boundary.

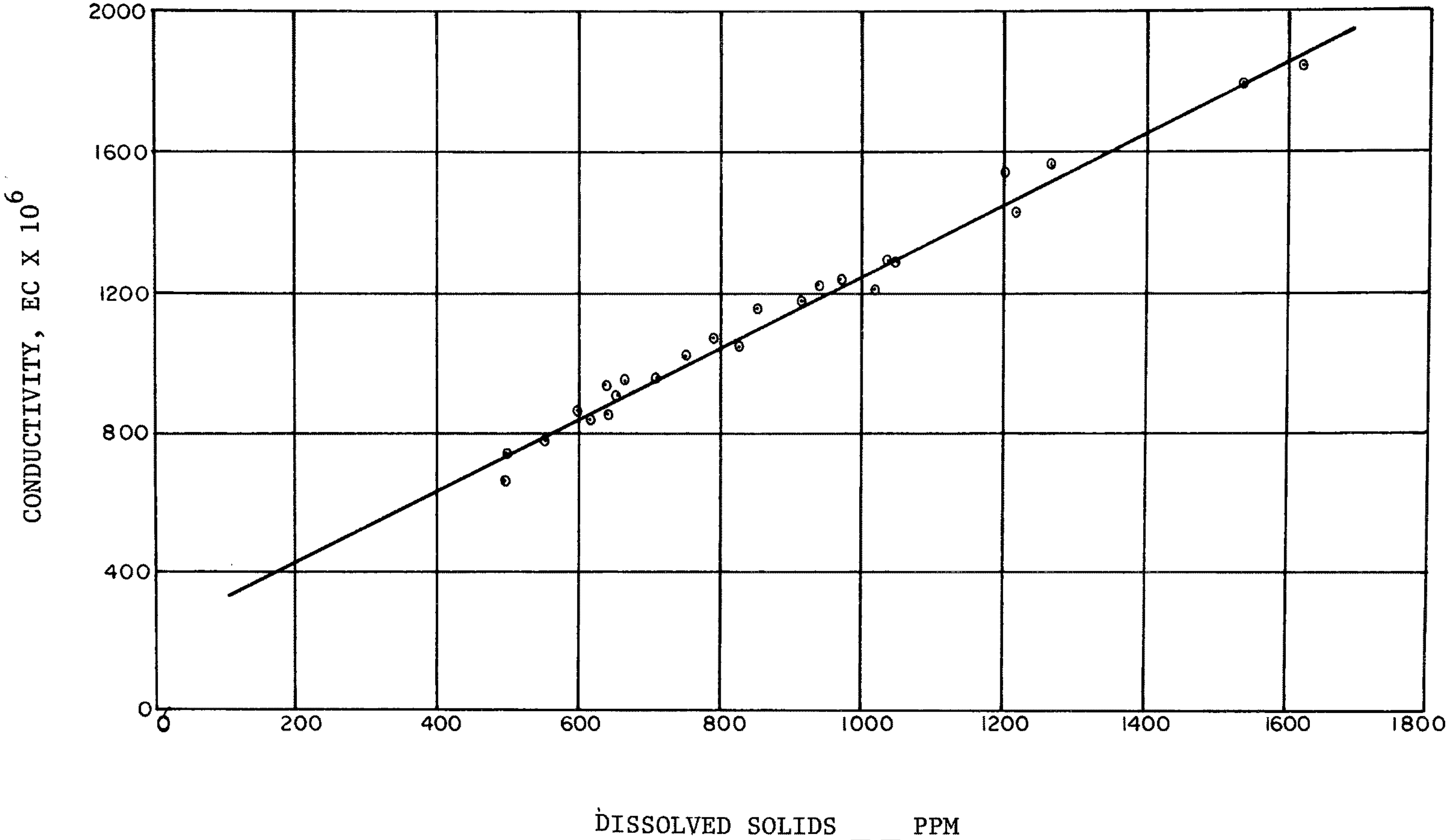


Figure 18. Electrical conductivity vs dissolved solids, Ashley Creek at golf course, gage no. 11, salinity recorder S-2, nodes 1 and 2 boundary.

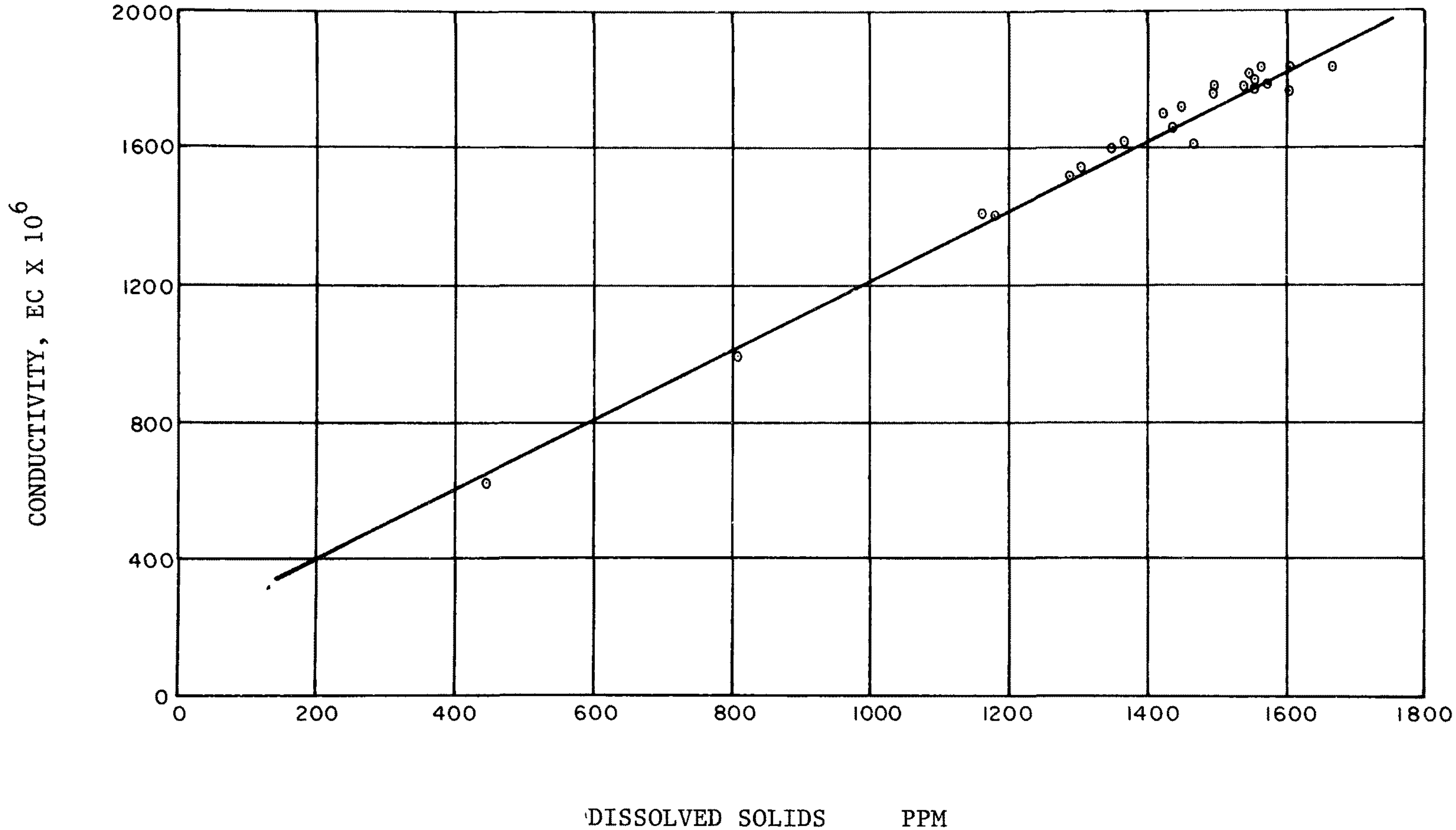


Figure 19. Electrical conductivity vs dissolved solids, Ashley Creek, gage no. 8, nodes 2 and 3 boundary.

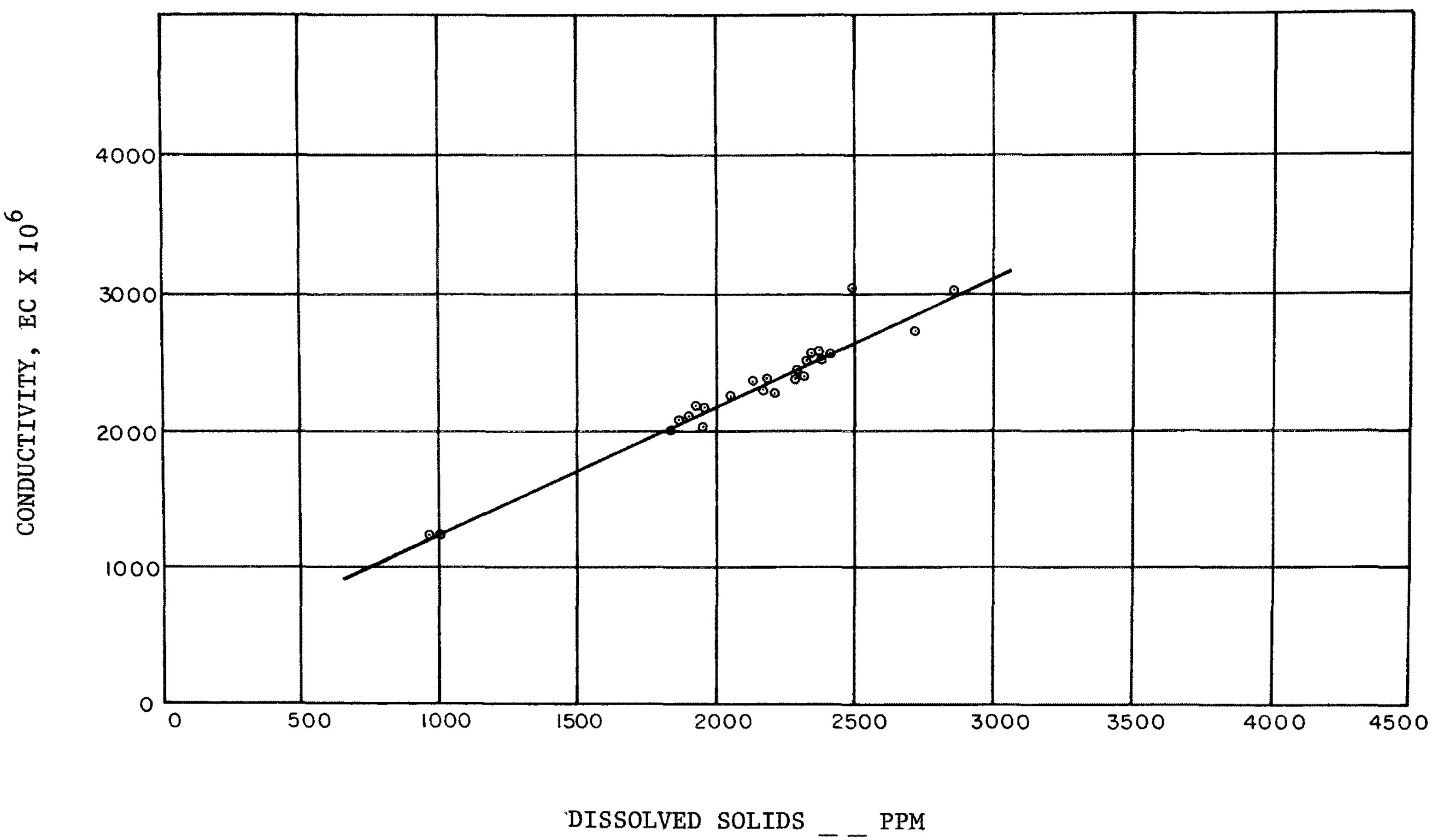


Figure 20. Electrical conductivity vs dissolved solids, Ashley Creek near Jensen, U.S.G.S. gage, Salinity recorder S-3, node 3 boundary.

Due to lack of accurate stage - discharge relationships, flows in the canals at the node boundaries were computed from the watermasters records for the Highline, Upper and Central Canals and from the Uinta Water Conservancy District records for the Steinaker Service Canal. The flow at the canal head, the amount of turnouts before the node boundary, and assumed losses or gains were used in the computations. These computed flows, as summarized in Table 4, compare favorably in most instances with current meter measurements.

A weekly record was kept of the canal gage heights and portable bridge conductivities and monthly samples were taken for lab analysis. The only significant change in total dissolved solids between node boundaries occurs in Central Canal. An increase occurs from gage 1 to gage 6 due primarily to irrigation return flows entering the canal. (Refer to Table 5.)

Drains

Eight major natural drains traverse the study area from west to east and terminate at Ashley Creek along the eastern edge of the study area. The drain channels have cut into the soil mantle and in some areas have penetrated through the cobble layer and into the underlying shale formation.

The table below summarizes locations of the eight drains and the approximate depths of cut through the escarpment adjacent to Ashley Creek:

Drain		Location	Approx. Depth of Cut (feet)
North Vernal	(7)	Node 1	20
South Vernal	(16)	Node 2	80
Naples	(9)	Node 2	80
South Naples	(17)	Node 3	25
Slaugh	(13)	Node 3	25
Slaugh	(14)	Node 3	25
Slaugh	(15)	Node 3	40
Mantle Gulch	(18)	Node 3	15

Drains 7, 16 and 9 cut into the shale formation near the Ashley Creek escarpment. The remainder of the natural drains encounter the shale formation throughout most of the valley.

Staff gages were installed on each of these drains during the summer of 1970 with the exception of South Naples Drain No. 17, which was installed in March 1971.

Staff gages on the drains were read weekly during the irrigation season and monthly during the non-irrigation season until July 1971 when the decision was made to eliminate Node 4. For the period July 1971 through September 1971 staff gage readings were made monthly during the irrigation season. Quality samples were taken on a monthly interval during the irrigation season and every two or three months during the non-irrigation season. Periodic current meter measurements were made in an attempt to rate the gages.

Table 6 contains a monthly summary of estimated average flows and average total dissolved solids in each of the drains for the period September 1970 through September 1972. Figures 21, 24, 27 and 30 are plots of conductivities versus time for drains 7, 16, 9 and 13 for 1971. Figures 22, 25,

Table 4
SUMMARY OF CANAL FLOWS AT NODE BOUNDARIES
(Acre-feet)

VERNAL AREA

Month	Highline			Upper		Central		Steinaker Service		River Irrigation
	Gage 3	Gage 4	USGS	Gage 2	Gage 10	Gage 1	Gage 6	HWY 245	Gage 5	USGS
April (1971)	-	-	1.5	460	307	156	160	440	117	-
April (1972)	-	-	-	1139	776	325	168	964	411	298
May (1971)	1508	645	332	4264	2624	2014	452	984	416	204
May (1972)	2493	1457	519	6687	4284	2859	698	2112	1004	365
June (1971)	4171	2621	696	7609	4504	4268	632	0	0	212
June (1972)	3063	1685	545	6018	3789	2954	488	160	0	167
July (1971)	2490	1392	493	2858	1057	434	352	6224	4564	257
July (1972)	1581	715	86	2027	661	312	439	4665	2400	160
Aug. (1971)	667	288	89	1664	700	142	212	4558	2194	365
Aug. (1972)	418	230	338	1622	851	16	304	3414	1583	297
Sept. (1971)	449	135	128	1674	875	120	214	1269	61	104
Sept. (1972)	788	379	168	1462	913	23	194	1551	516	100
Oct. (1971)	-	-	36	752	482	218	109	-	-	47
Oct. (1972)	-	-	-	900	745	324	218	373	0	-
Totals										
(1971)	9285	5081	1776	19,281	10,549	7352	2131	13,475	7352	1189
(1972)	8343	4466	1656	19,855	12,019	6813	2509	13,239	5914	1387

Table 5
SUMMARY OF AVERAGE T.D.S. (ppm) IN CANALS AT NODE BOUNDARIES

VERNAL AREA

Month	Highline			Upper		Central		Steinaker Service		River Irrigation
	Gage 3	Gage 4	USGS	Gage 2	Gage 10	Gage 1	Gage 6	Hwy 245	Gage 5	USGS
April (1971)	-	-	-	162	160	320	1000	-	225	-
April (1972	-	-	-	150	157	248	712	183	306	1750
May (1971)	85	78	-	85	101	102	638	-	260	-
May (1972)	65	68	92	70	80	82	363	186	200	1675
June (1971)	55	63	-	58	81	80	713	-	-	-
June (1972)	75	80	103	78	100	108	477	181	-	1250
July (1971)	130	112	-	125	127	239	550	-	230	-
July (1972)	128	118	190	133	138	292	482	184	-	1805
Aug. (1971)	155	136	-	138	143	329	588	-	196	-
Aug. (1972)	155	127*	198	138	146	365*	491	184	220	2125
Sept. (1971)	132	-	-	132	137	321	638	-	165	1760
Sept. (1972)	150	151	195	143	150	-	538	176	215	2075
Oct. (1971)	-	-	-	185	177	280	847	-	-	1950
Oct. (1972)	-	-	190	180	172	358	725	180	-	-
AVERAGES										
(1971)	112	97	-	126	132	239	711	-	215	1855*
(1972)	115	109	161	127	135	242	541	182	235	1780

* Based on incomplete data.

TABLE 6

ESTIMATED MONTHLY ACRE-FEET AND AVERAGE TOTAL DISSOLVED SOLIDS FOR DRAINS
VERNAL AREA

Drain		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
North Vernal #7													
AC. FT.	1970								66	84	315	153	124
T.D.S.(ppm)	1970									640	590	610	540
AC. FT.	1971	46	48	35	50	55	88	36	54	53	86	101	51
T.D.S.(ppm)	1971	520	530	530	680	650	440	550	530	610	610	610	510
AC. FT.	1972	42	29	31	30	61	52	22	0	0			
T.D.S.(ppm)	1972	570	590	570	570	590	530						
Naples #9													
AC. FT.	1970								442	456	379	359	282
T.D.S.(ppm)	1970									2390	2610	2690	2690
AC. FT.	1971	267	355	235	224	317	477	512	423	408	283		
T.D.S.(ppm)	1971	2490	2090	2280	2630	2720	2400	2520	2830	2980	3300	3210	3090
AC. FT.	1972				196	281	411	391	325	303			
T.D.S.(ppm)	1972	2960	2840	2700	2570	2470	2470	2640	2700	2520			
Slaugh Drain #13													
AC. FT.	1970									26	222	221	111
T.D.S.(ppm)	1970	2960	2990	3020	3050	2310	1490	1970	3230	3530	3040	2680	2570
AC. FT.	1971	125	98	65	50	97	74	87	80	67	40	38	39
T.D.S(ppm)	1971	2570	2280	2420	2750	4210	3750	2080	2450	2660	3250	2810	2520
AC. FT.	1972	28	20	36	61	74	111	34	36	43			
T.D.S.(ppm)	1972	2490	2500	2530	2660	2730	2440	3450	3090	2720			
Slaugh Drain #14													
AC. FT.	1970									62	269	267	165
T.D.S.(ppm)	1970									3270	3020	3070	3070
AC. FT.	1971	171	136	122	70	14	50	107	122	150	143	179	158
T.D.S.(ppm)	1971	2970	2500	2860	2720	4200	3060	2550	2820	3220	3130	2750	2770
AC. FT.	1972	143	63	48	0	0	80	111	52	74			
T.D.S.(ppm)	1972	2830	2860	2870	2810	2740	2660	4050	4980	5470			

Table 6 Continued

Drain		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Slaugh Drain #15													
AC. FT.	1970									19	228	233	55
T.D.S.(ppm)	1970									5010	3230	2980	3490
AC. FT.	1971	81	84	18	5	29	167	40	48	8	32	54	109
T.D.S.(ppm)	1971	3680	3330	5130	5560	4530	4900	3080	4630	5410	4060	3630	3180
AC. FT.	1972	104	17	22	28	23	19	71	78	101			
T.D.S.(ppm)	1972	3230	4020	4070	2820	3250	4700	3840	3900	4080			
Slaugh Drain #16													
AC. FT.	1970									143	166	187	221
T.D.S.(ppm)	1970										1140	1190	1220
AC. FT.	1971	191	167	216	154	187	134	465	636	335	295	280	
T.D.S.(ppm)	1971	1240	1180	1260	1280	2260	1000	970	1130	1140	1180	1230	1240
AC. FT.	1972			175	193	268	179	198	369	318			
T.D.S.(ppm)	1972	1260	1220	1200	1120	980	1190	1170	1130	1290			
South Naples Drain #17													
AC. FT.	1970												
T.D.S.(ppm)	1970												
AC. FT.	1971		111	65	40	43	68	41	44	44	42		
T.D.S.(ppm)	1971		1580	2000	2550	2420	2150	2230	2340	2820	2960		
AC. FT.	1972				6	65	48	21	0	17			
T.D.S.(ppm)	1972	2760	2700	2640	2420	1770	1840	2380	2300	2210			
Mantle Gulch #18													
AC. FT.	1970									42	141	279	9
T.D.S.(ppm)	1970									2970	2130		
AC. FT.	1971	0	0	5	144	53	208	47	53	11	46	134	138
T.D.S.(ppm)	1971				5220	7700	1690	1040	1940	4230	6240	6620	6990
AC. FT.	1972			42	75	69	39	47	27	31			
T.D.S.(ppm)	1972	6990	7100	7620	8020	4530	2420	1330	1450	1740			

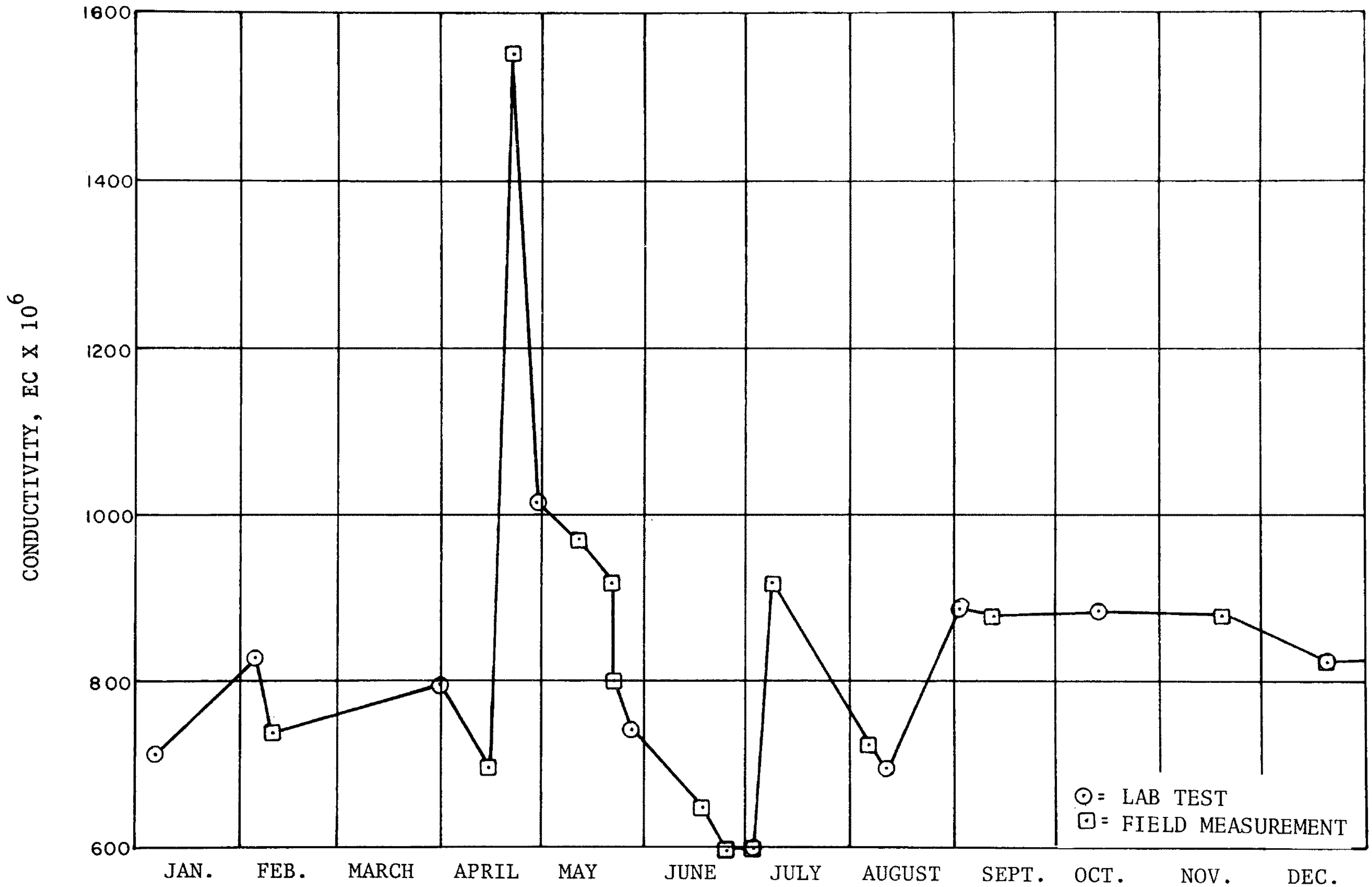


Figure 21. Electrical conductivity vs time, North Vernal drain, gage no. 7, node 1, 1971.

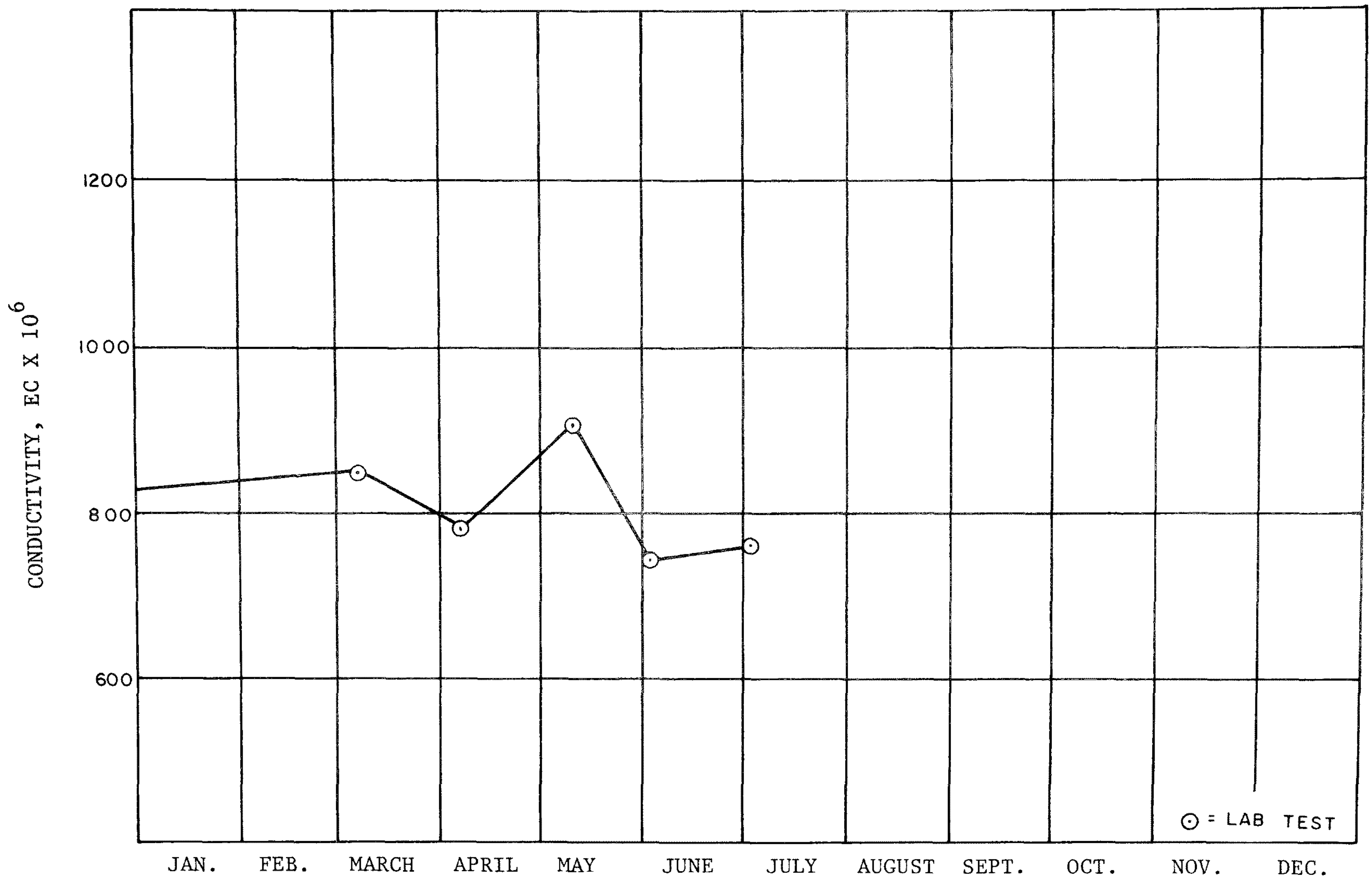


Figure 22. Electrical conductivity vs time, North Vernal drain, gage no. 7, 1972.

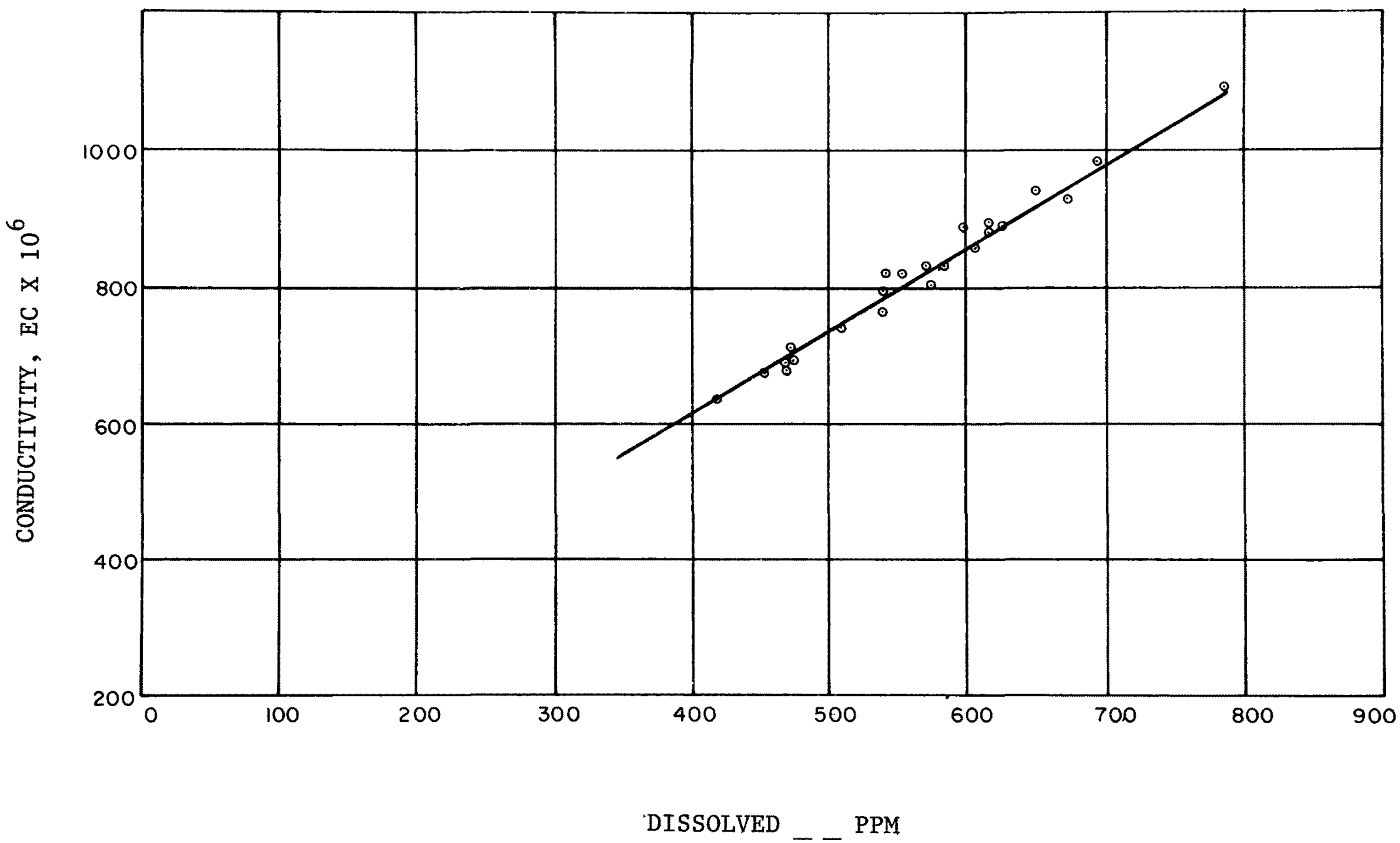


Figure 23. Electrical conductivity vs dissolved solids, North Vernal drain, gage no. 7, node 1.

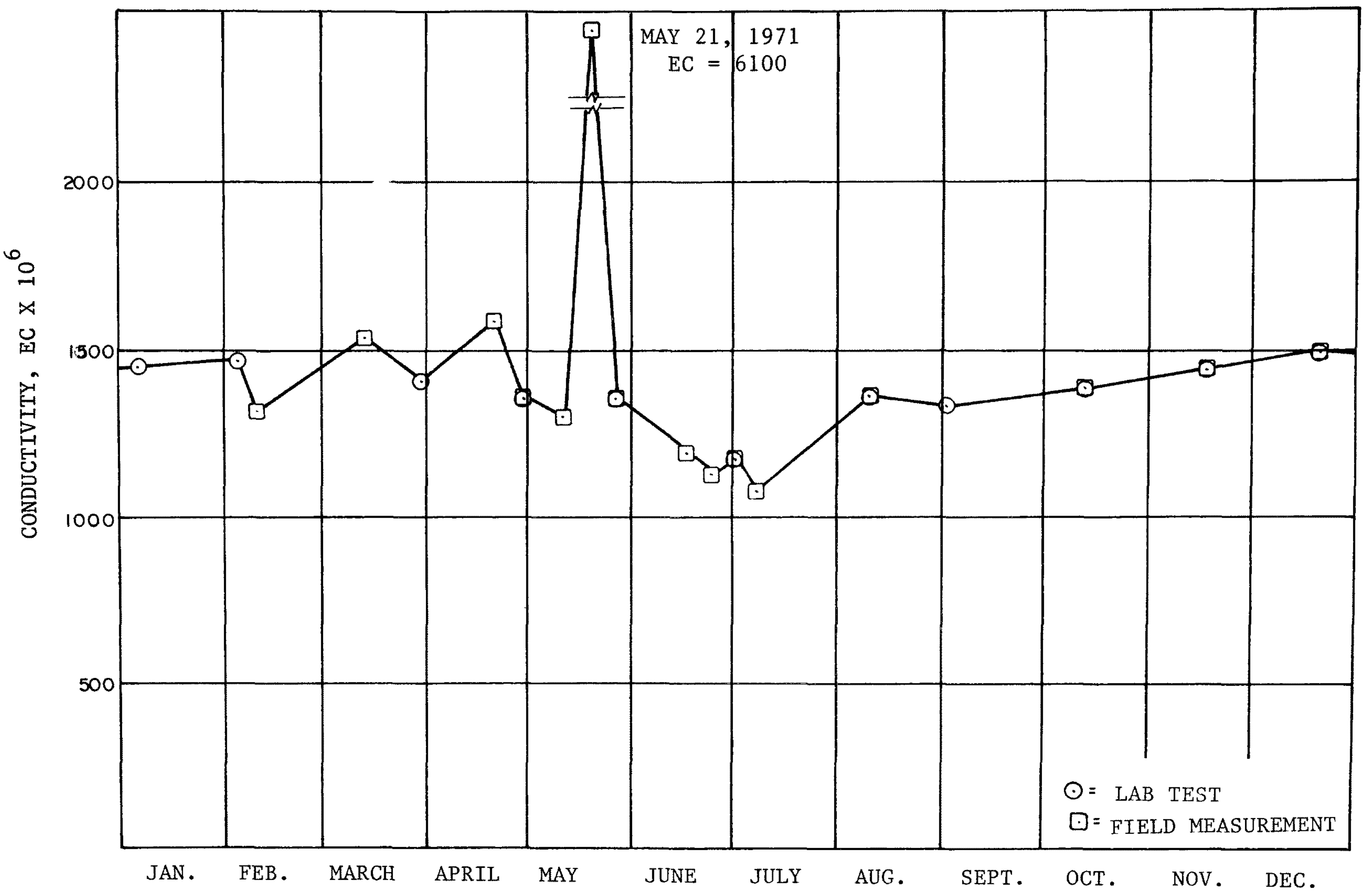


Figure 24. Electrical conductivity vs time, South Vernal drain, gage no. 16, node 2, 1971.

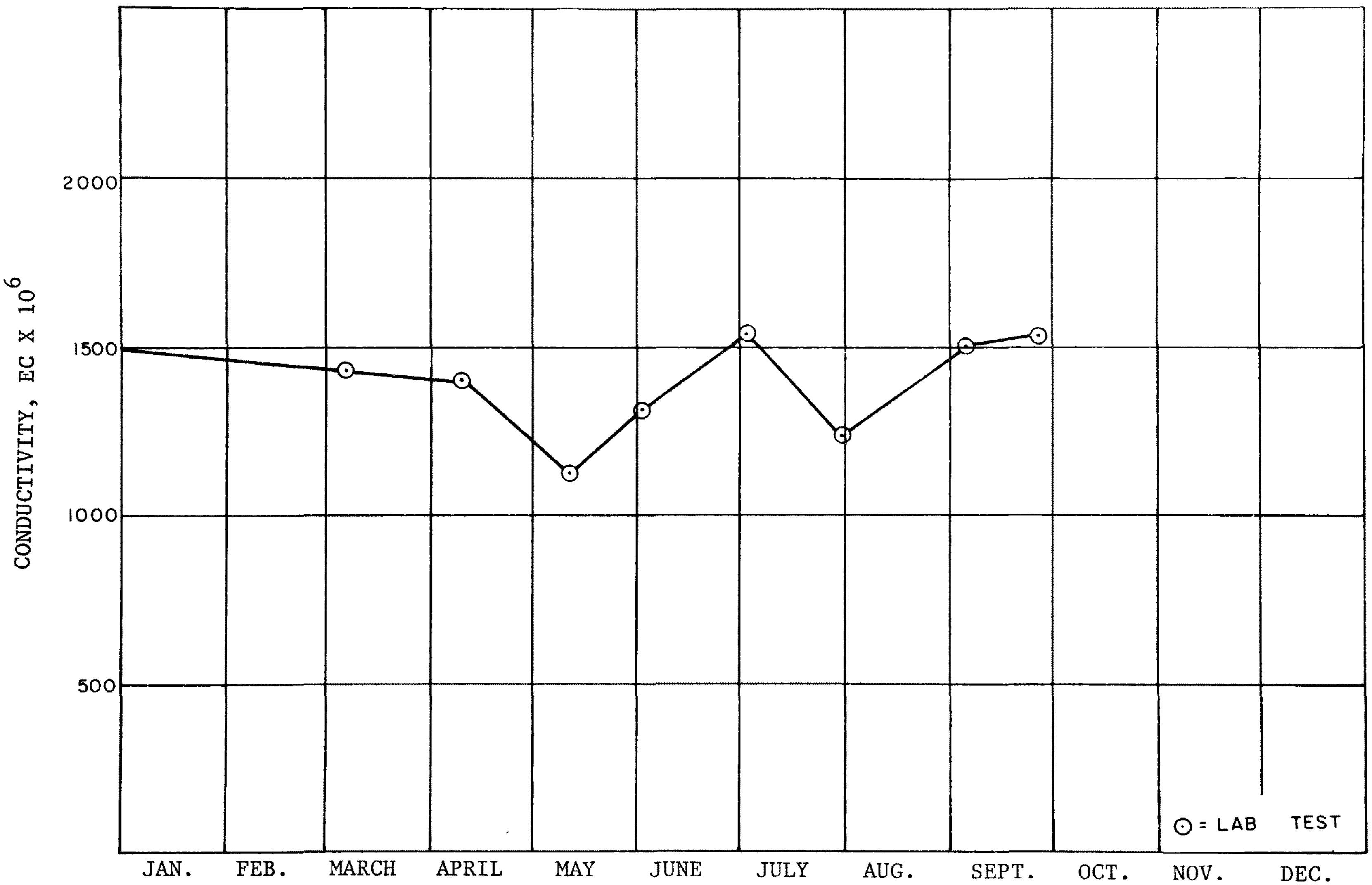


Figure 25. Electrical conductivity vs time, South Vernal drain, gage no. 16, node 2, 1972.

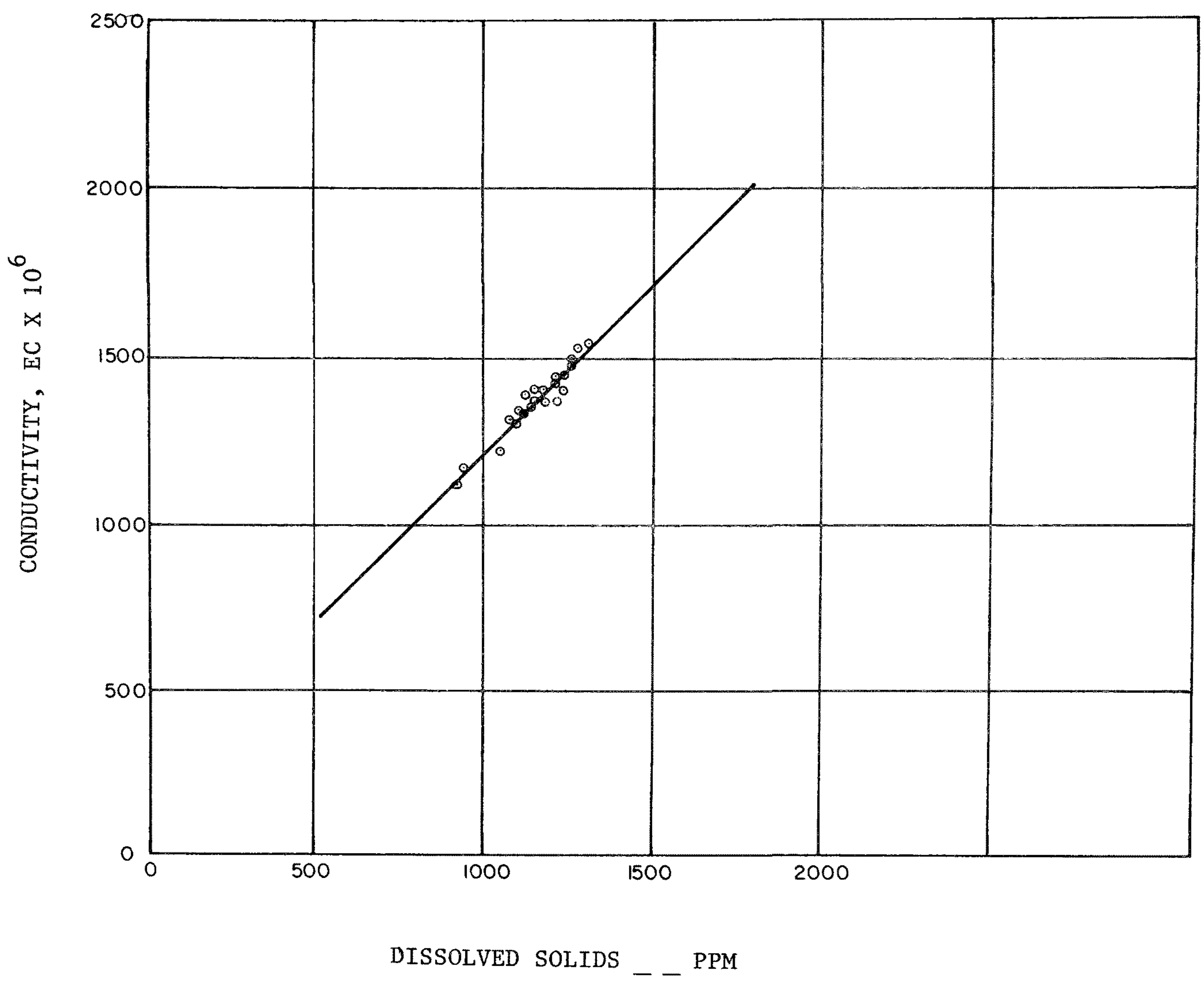


Figure 26. Electrical conductivity vs dissolved solids, South Vernal drain, gage no. 16, node 2.

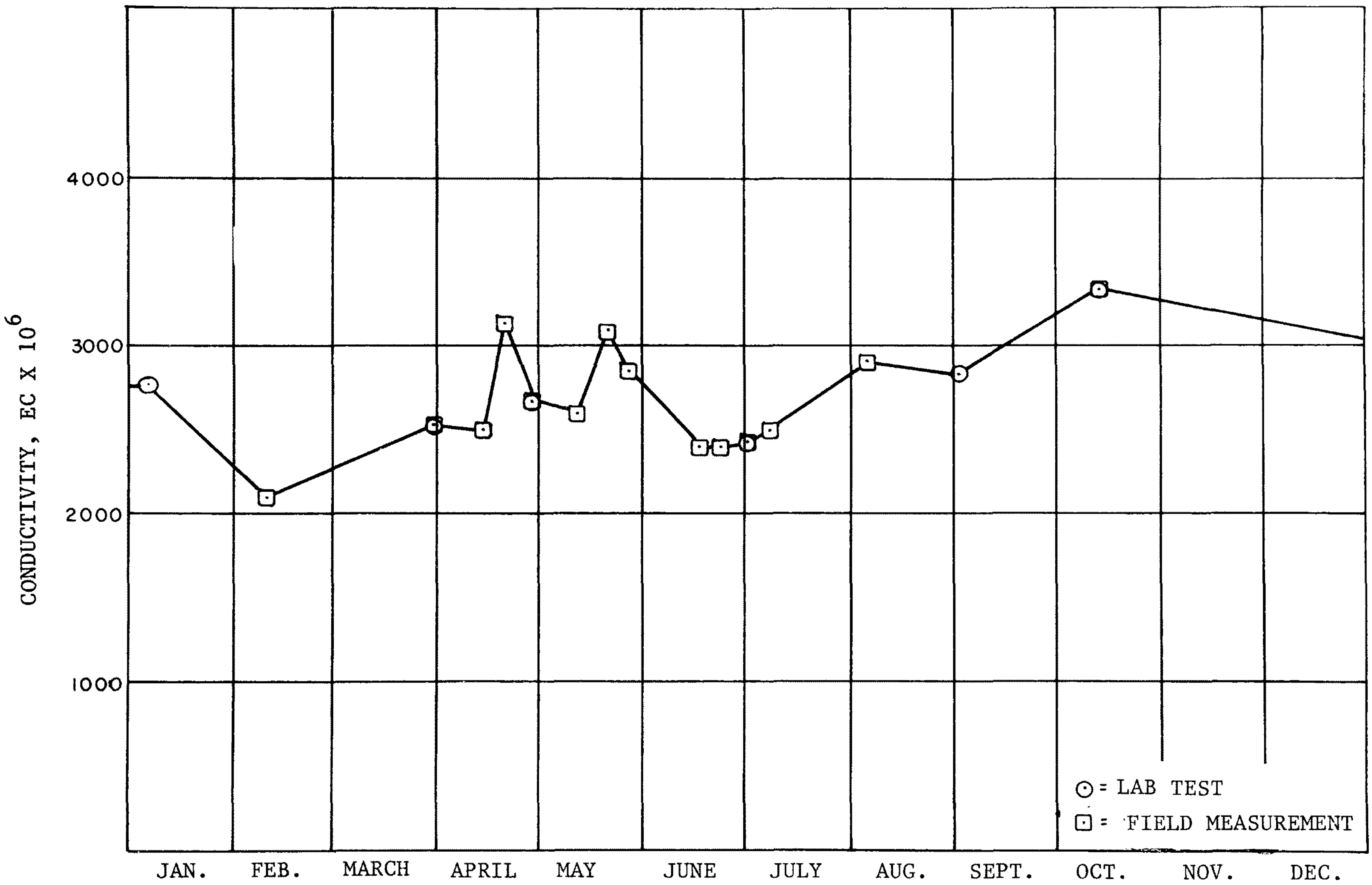


Figure 27. Electrical conductivity vs time, Naples drain, gage no. 9, node 2, 1971.

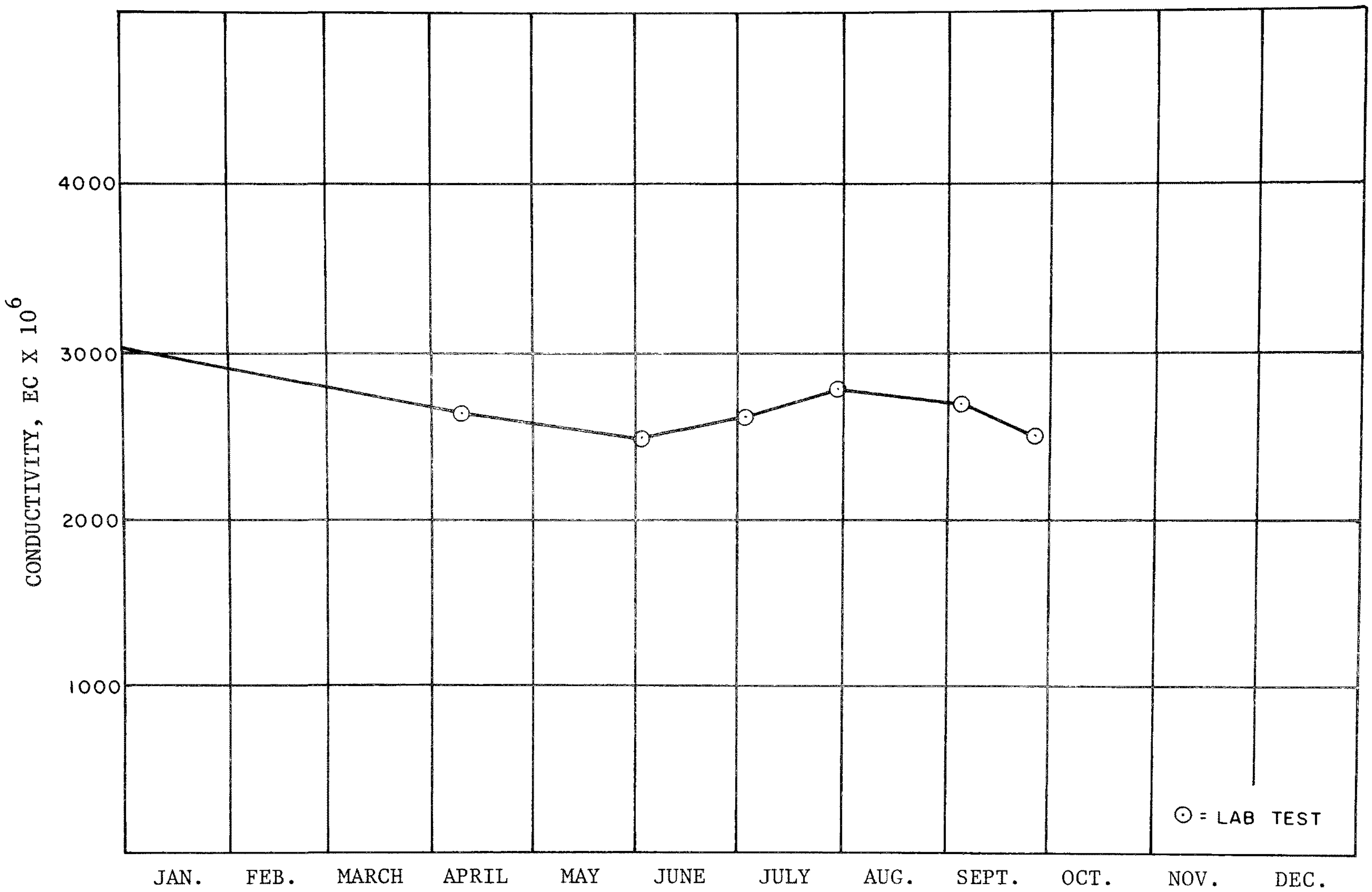


Figure 28. Electrical conductivity vs time, Naples drain, gage no. 9, 1972.

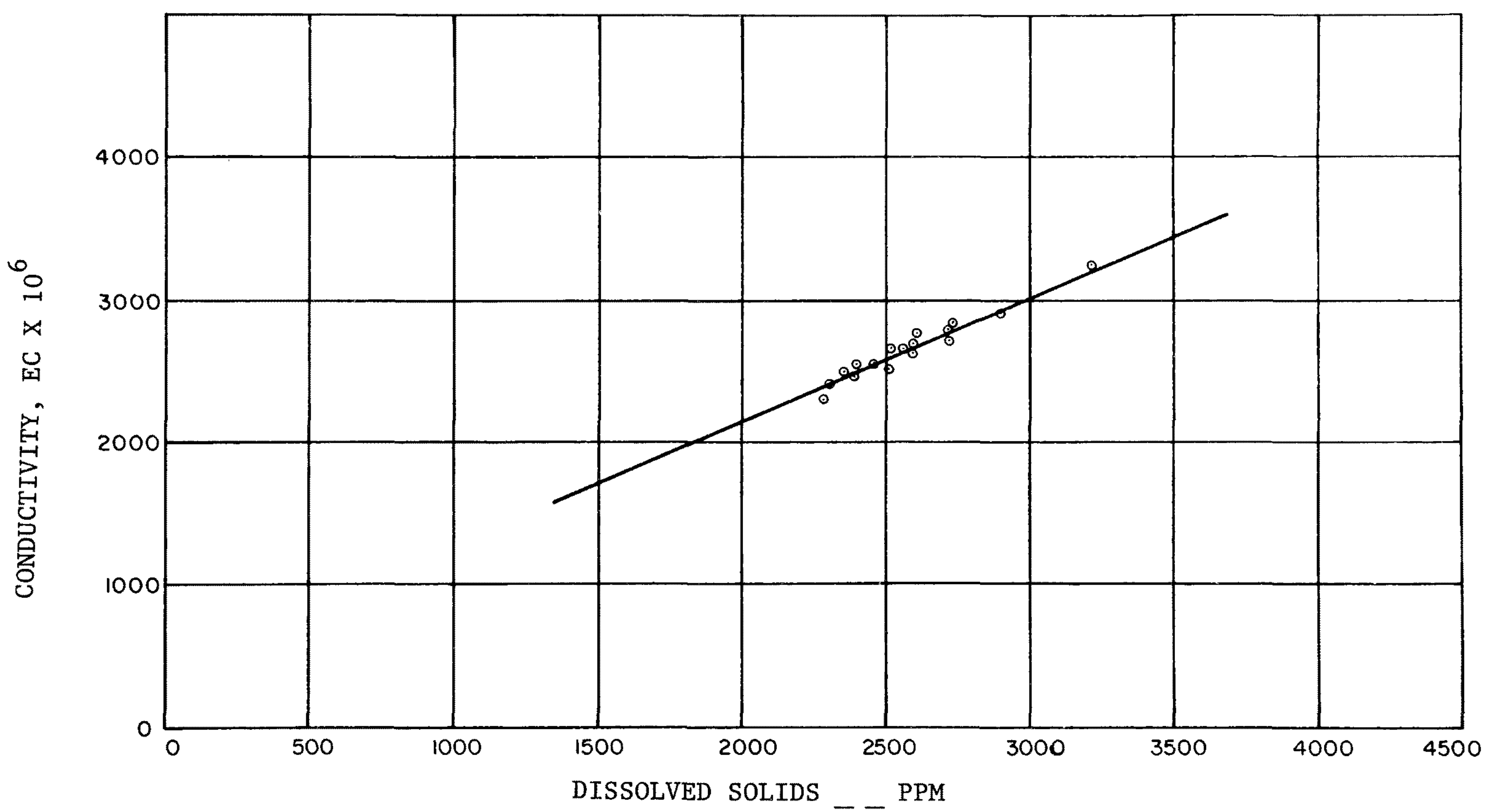


Figure 29. Electrical conductivity vs dissolved solids, Naples drain, gage no. 9, node 2.

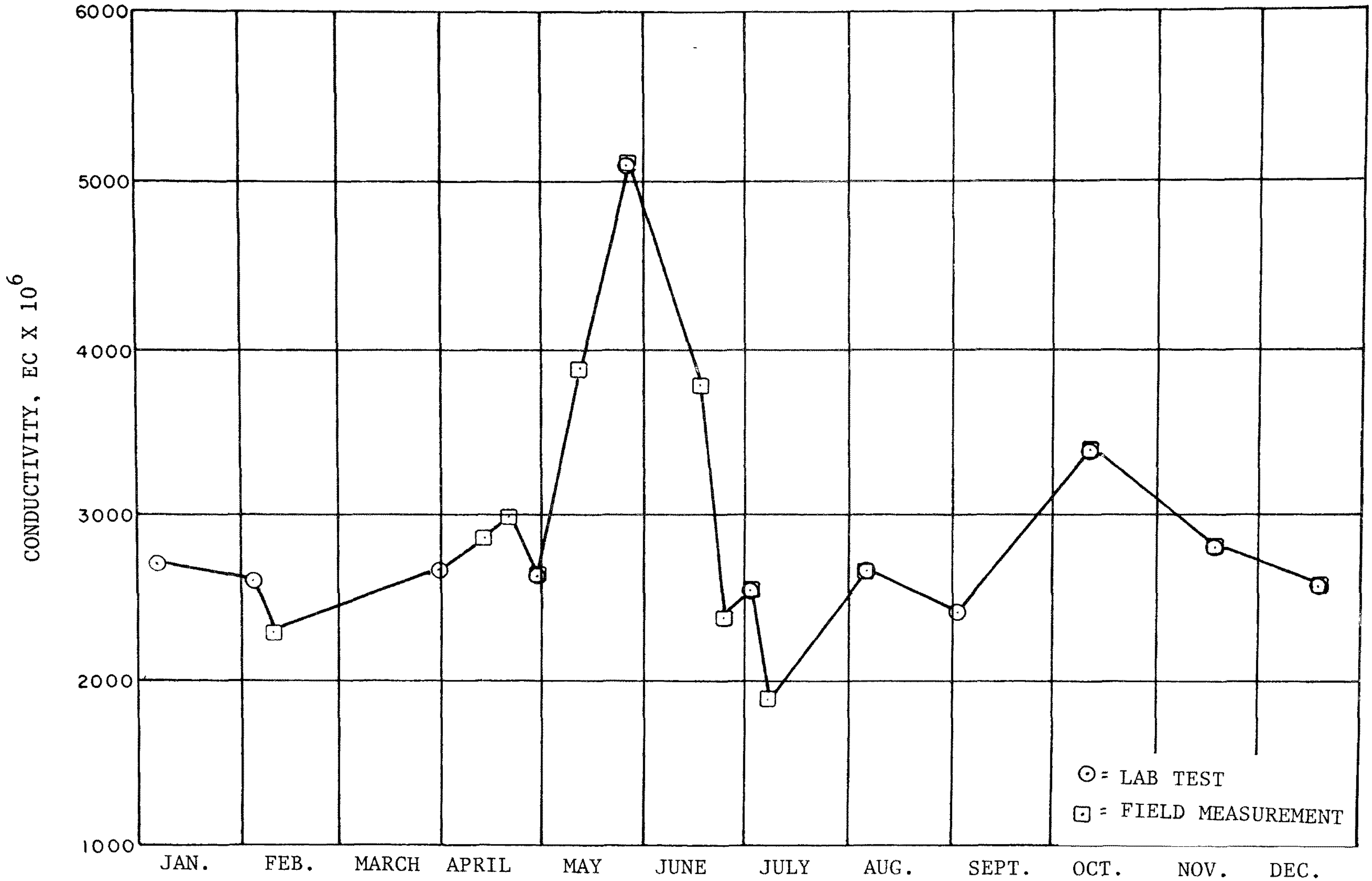


Figure 30. Electrical conductivity vs time, slaugh drain, gage no. 13, node 3, 1971.

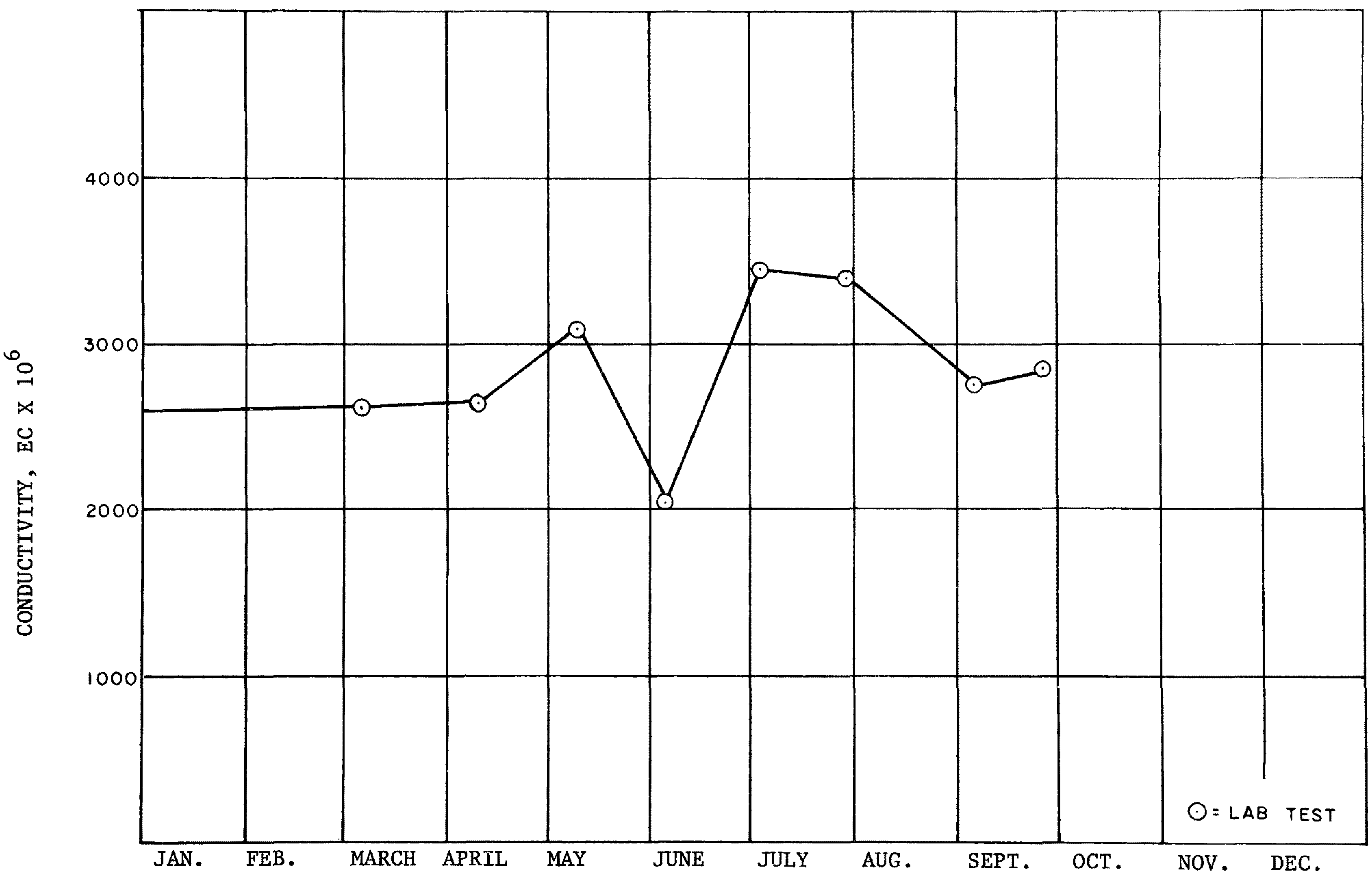


Figure 31. Electrical conductivity vs time, slaugh drain, gage no. 13, node 3, 1972.

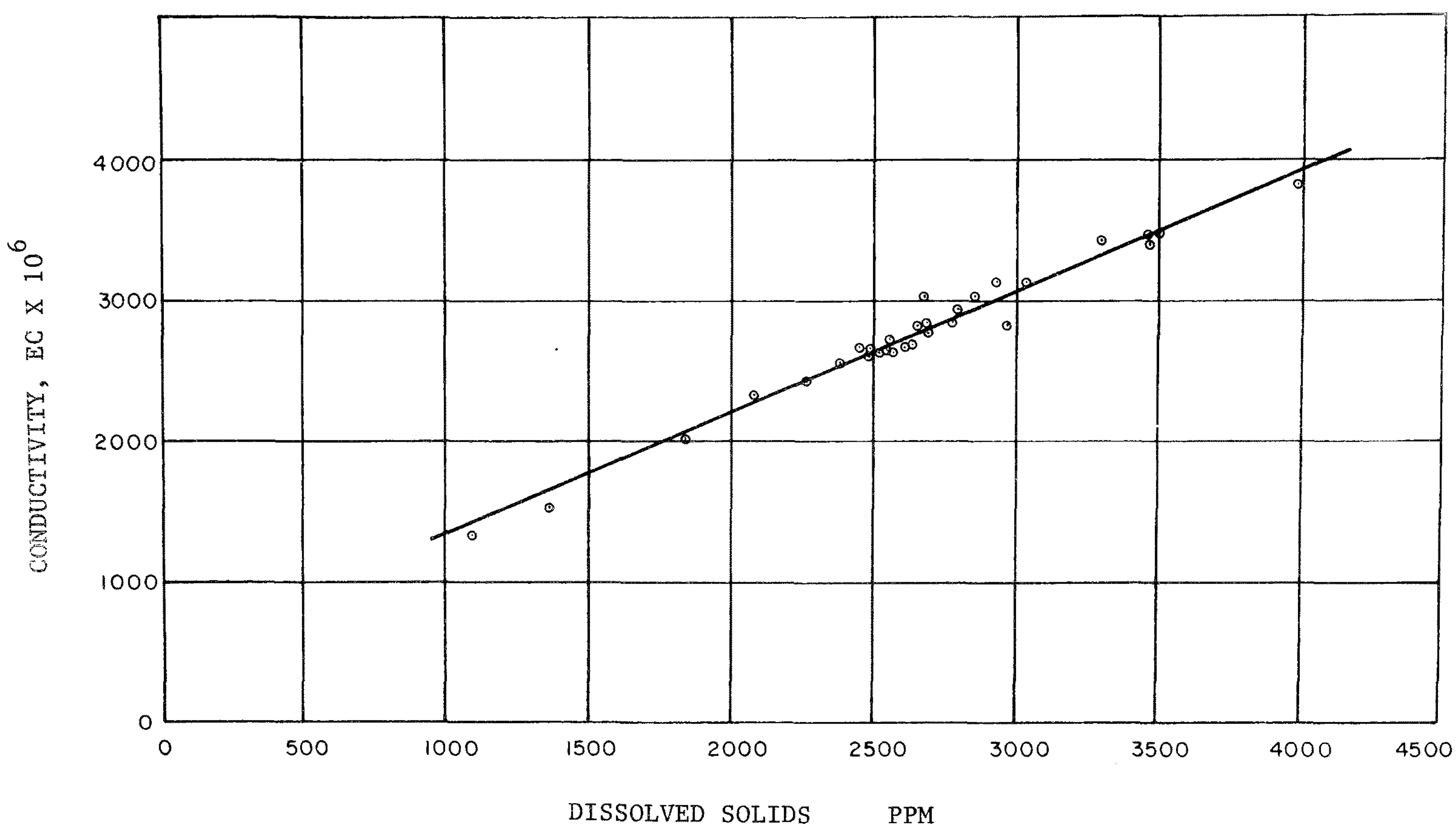


Figure 32. Electrical conductivity vs dissolved solids, slaugh drain, gage no. 13, node 3.

28 and 31 are plots of conductivities versus time for the same drains for 1972. Also included is a correlation of conductivity and total dissolved solids for the same drains.

Lysimeters

Six lysimeters were constructed during F.Y. 1970 for the purpose of measuring consumptive use of the predominant native grasses found in the study area. The lysimeters, which are located about one mile east of the Vernal Airport in Node 2, were built according to the plans shown in Figure 33a, b, and c.

The water in the lysimeters is maintained at the desired depth by two electric probes installed in each lysimeter. These probes are connected through a relay to an automatic control valve in the water supply pipeline. When the water level in the lysimeters drops below the lower electrode, the automatic valve opens and allows water to enter until both electrodes contact the water at which time the valve closes. The amount of water used is continuously metered for each lysimeter.

The six lysimeters were operated for the periods April 8 through October 19, 1971, and May 8 through October 16, 1972. Initially the depths to water in the lysimeters were determined by the average depths to water under similar grasses in Ashley Valley. During the operation several depths to water were decreased in an attempt to improve the growth of the grasses.

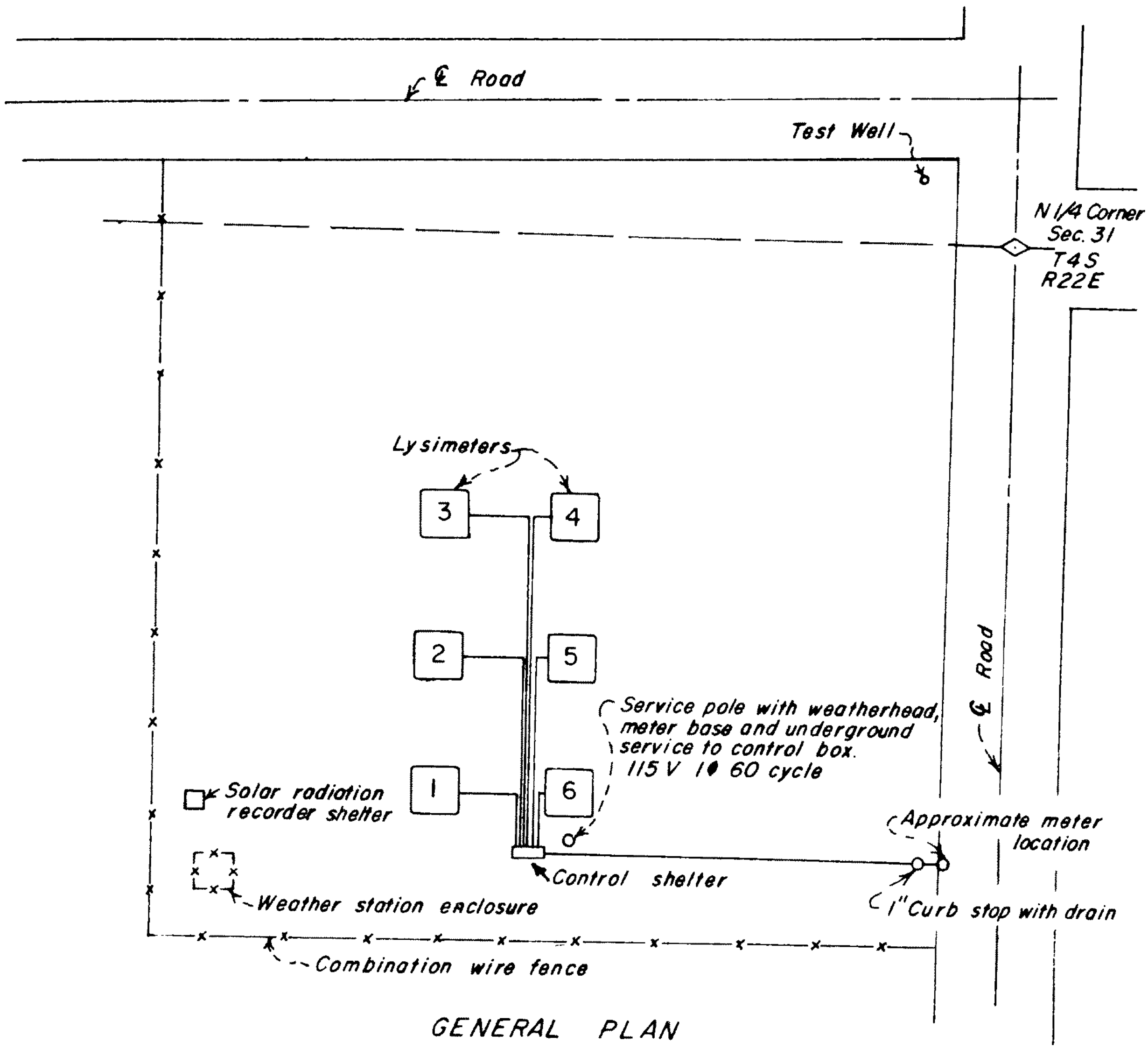
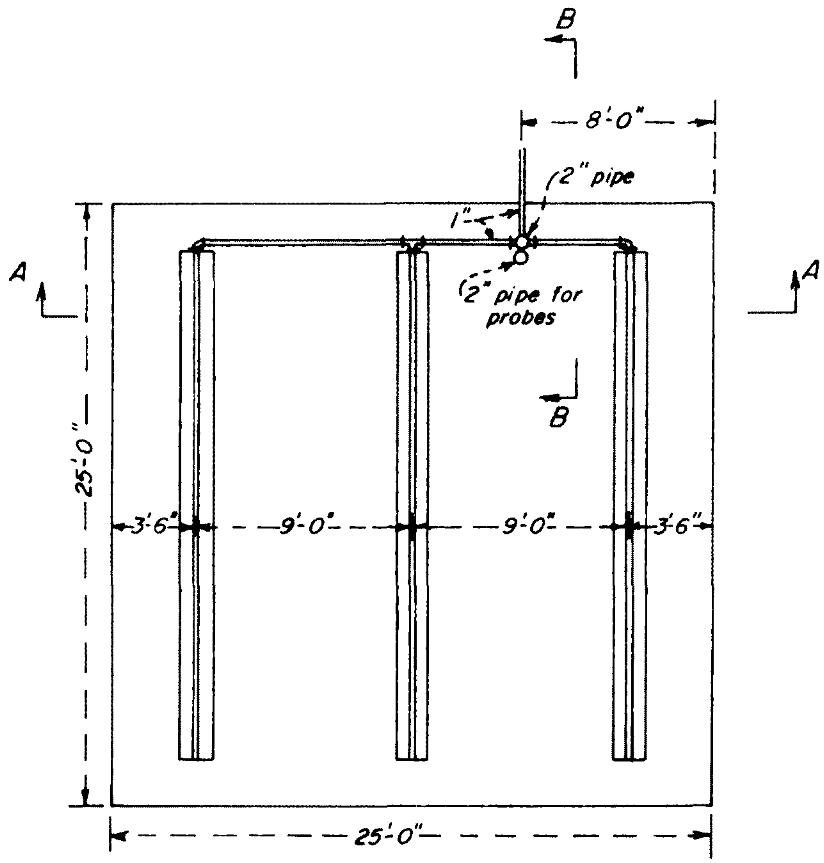
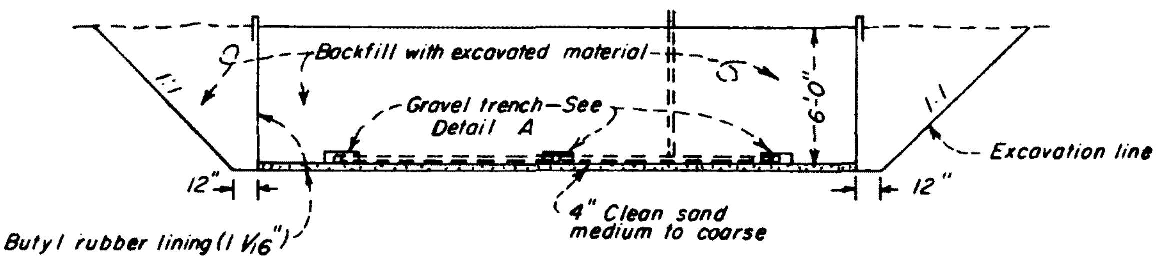


Figure 33a. Lysimeter installations, general plans and details.

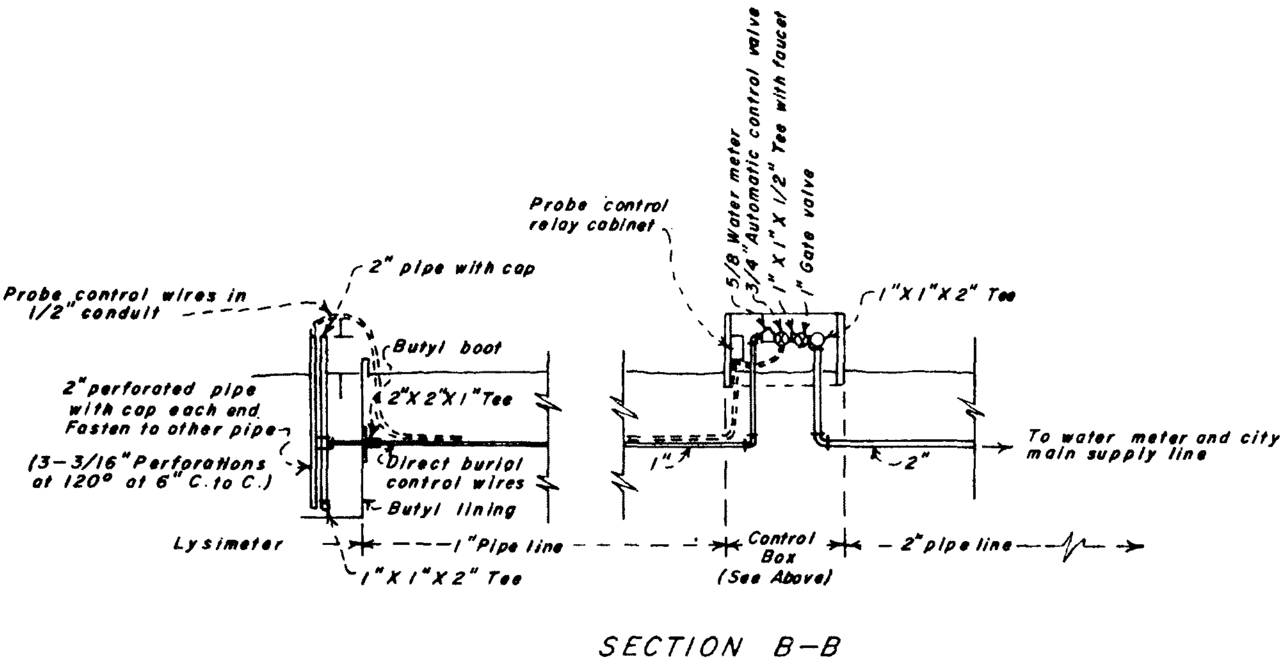


PLAN OF LYSIMETER



SECTION A-A

Figure 33b. Lysimeter installations, general plan and details.



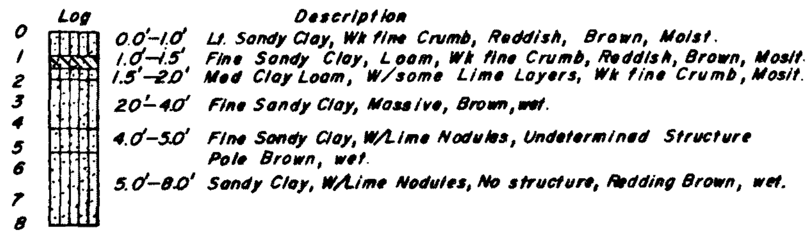


Figure 33c. Lysimeter installations, general plan and details.

Although the lysimeters were filled with Vernal City water (EC X 10^6 of about 100), salinity in the lysimeters increased to a level which was harmful to the two improved pasture plots. The salt and wire grass is more salt tolerant and was apparently not harmed. The vegetation originally planted in the lysimeters and the maximum E.C. and total dissolved solids measured during the 1971 season are summarized below.

Lysimeter No.	Original Vegetation	ECX10^6	Total Dissolved Solids (ppm)
1	Salt Grass	5,500	6,500
2	Improved Pasture (Pm)	13,900	17,900
3	Improved Pasture (Pm)	14,000	18,000
4	Wire Grass	16,500	22,000
5	Wire Grass	9,600	11,500
6	Salt Grass	8,000+	(no samples)

In June 1971 an attempt was made to back flush the improved pasture lysimeters; however, most of the water moved upward around the perimeter of the lysimeter instead of through the soil. The lysimeters were then flushed from the top beginning in August 1971. After each application of water the lysimeters were pumped out sufficiently for the next application. The method of flushing from the top reduced the dissolved solids from an average ppm of 17,900 to 2,910 for lysimeter No. 2 and from 18,000 to 3,070 for lysimeter No. 3. At the beginning of operation in May 1972 the ppm had increased to 6,700 for No. 2 and 5,300 for No. 3.

No attempt was made to flush the lysimeters during the 1972 operation. The types of grasses originally planted in the lysimeters have changed due to natural seeding and the increase in salinity. The predominate types of grasses found in the lysimeters during 1972, and the E.C. and total dissolved solids as measured in September 1972 are listed below:

Lysimeter No.	Predominate 1972 Grasses	$ECX10^6$	Total Dissolved Solids (ppm)
1	Salt and Broom	3,875	4,200
2	Smooth Brame	9,400	10,940
3	Smooth Brame	8,690	10,050
4	Wire and Meadow Fescue	13,700	17,150
5	Wire and Meadow Fescue	12,675	15,600
6	Salt and Broom	13,900	17,100

The total water use for the 159 days of operation in 1971 and 161 days in 1972 is summarized in Table 7. Figures 34 through 45 show total water supplied to each lysimeter for the 1971 and 1972 seasons.

Neutron probe measurements of soil moisture were made monthly by personnel from Utah State University and were supplemented by soil aguer moisture samples.

Table 7
SUMMARY OF TOTAL WATER USE IN LYSIMETERS
VERNAL AREA

LYSIMETER NUMBER	PREDOMINATE GRASS TYPES 1971	PREDOMINATE GRASS TYPES 1972	1971 WATER USE (159 Days) 12 inches 1/ (Inches)	1971 WATER USE (159 Days) 24 inches 1/ (Inches)	1972 WATER USE (161 Days) 12 inches 1/ (Inches)	1972 WATER USE (161 Days) 24 inches 1/ (Inches)
1	Salt and Broom	Salt and Broom	24.09	23.79	21.84	21.48
2	Improved Pasture 2/	Smooth Brame	-	-	20.77	20.45
3	Improved Pasture 2/	Smooth Brame	-	-	17.67	17.36
4	Wire	Wire and Meadow Fescue	26.01 3/	-	33.47	-
5	Wire	Wire and Meadow Fescue	26.12	-	26.74	26.69
6	Salt and Foxtail	Salt and Broom	28.32	28.32	21.45	20.75

1/ Depth below surface of lysimeter.
2/ Damaged by increase in salinity.
3/ Computed for 138 days.

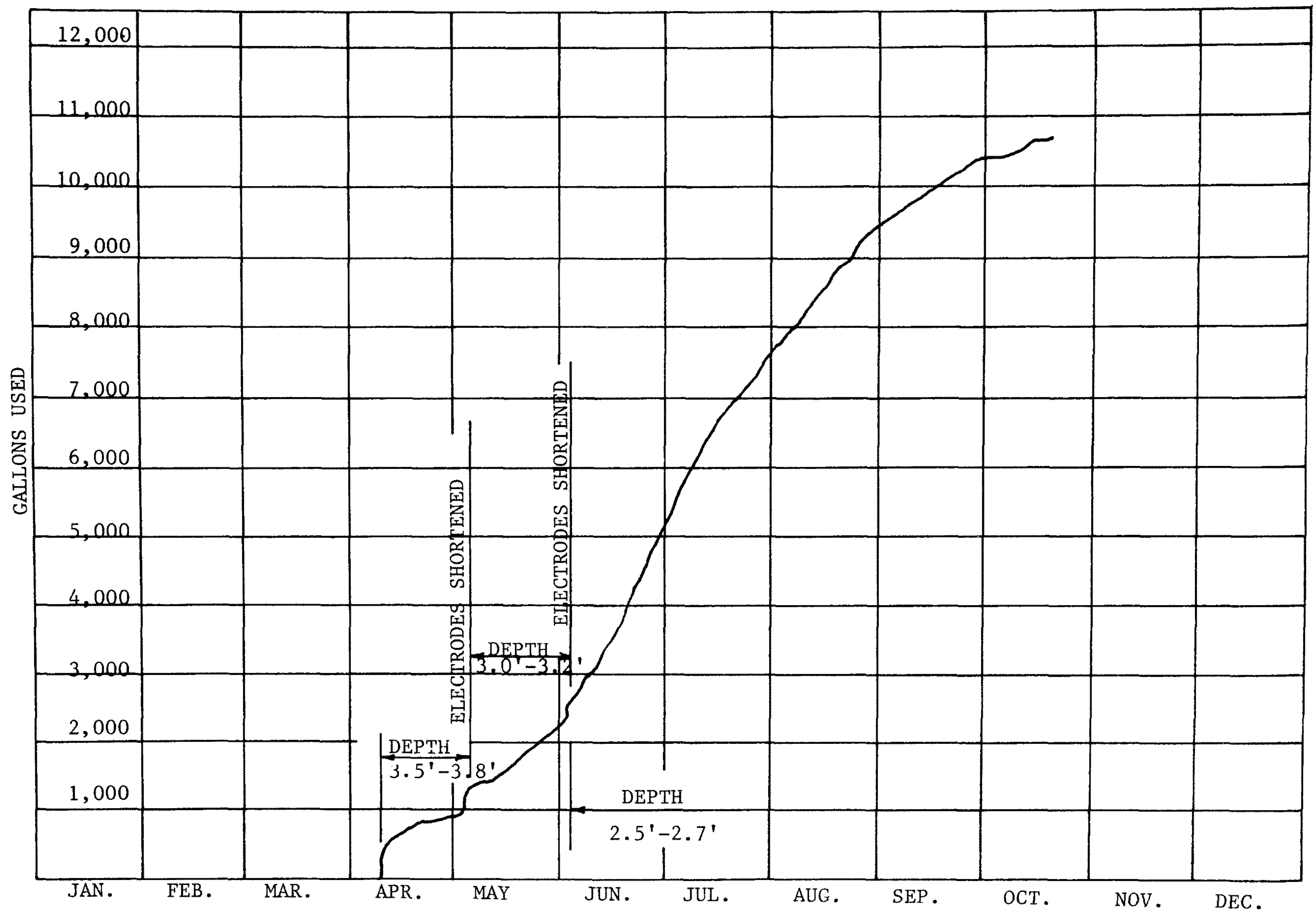


Figure 34. Consumptive water use, lysimeter no. 1, salt and broom grass, 1971.

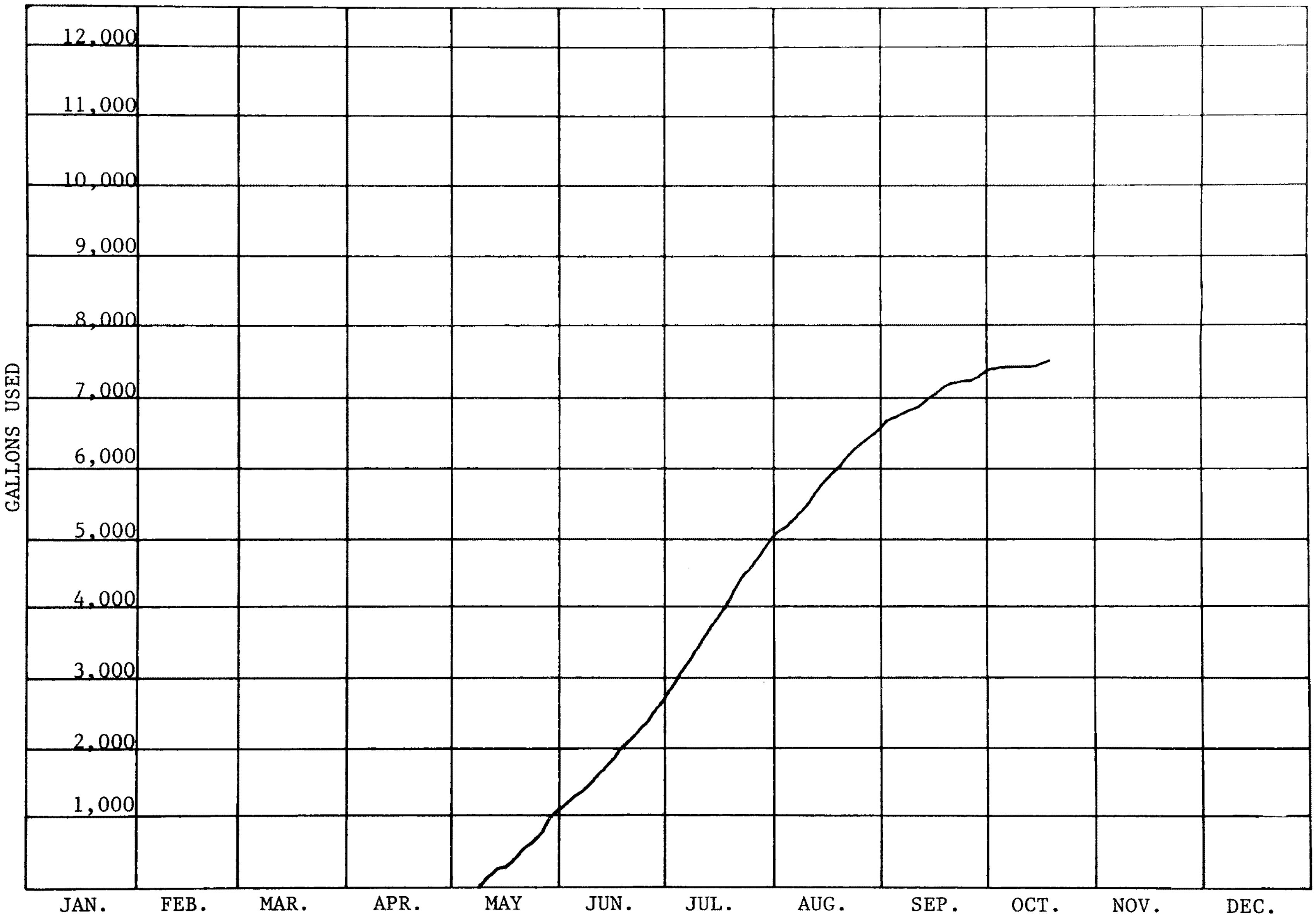


Figure 35. Consumptive water use, lysimeter no. 1, salt and broom grass, depth to water 2.5'-2.7', 1972.

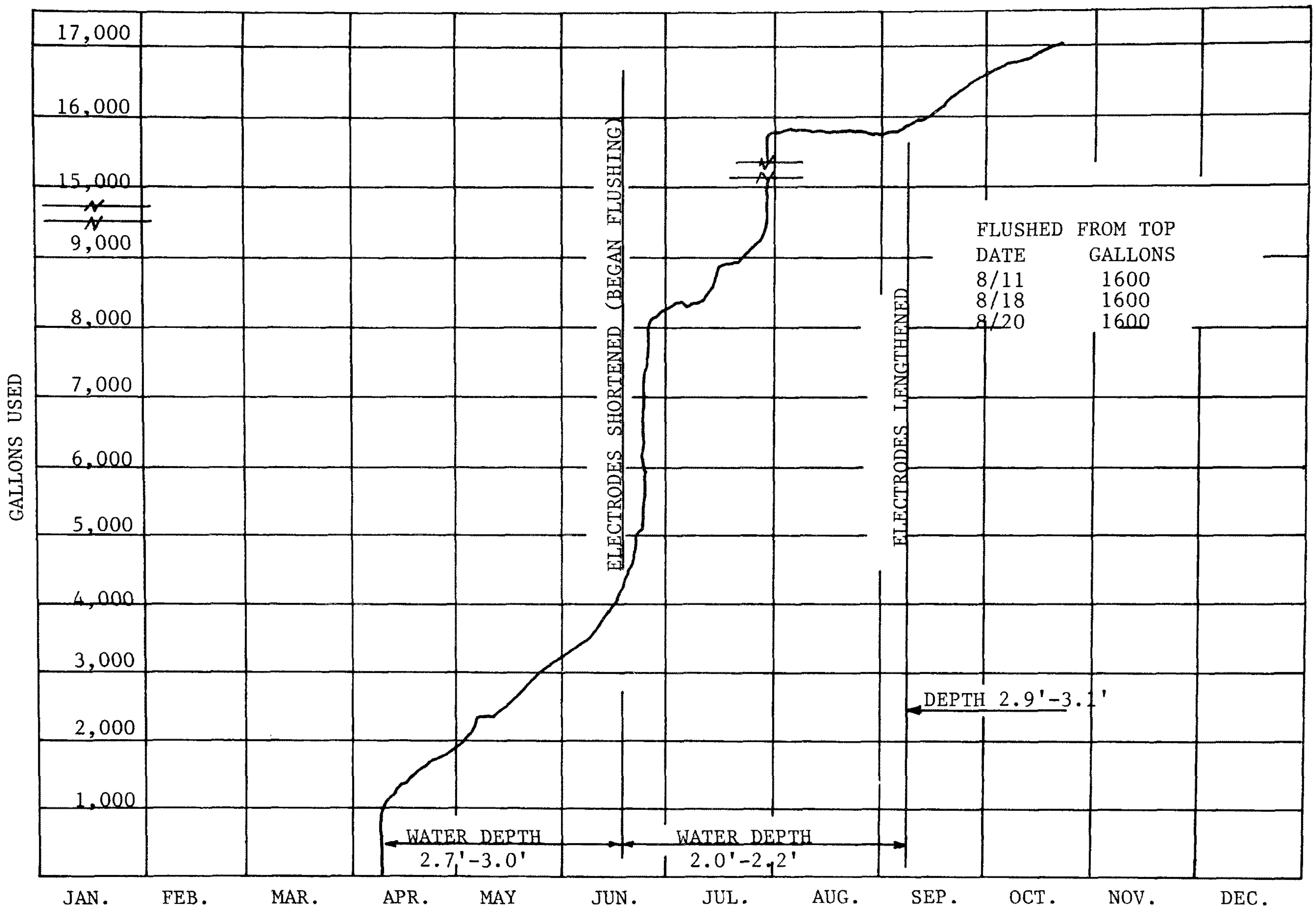


Figure 36. Consumptive water use, lysimeter no. 2, improved pasture, 1971.

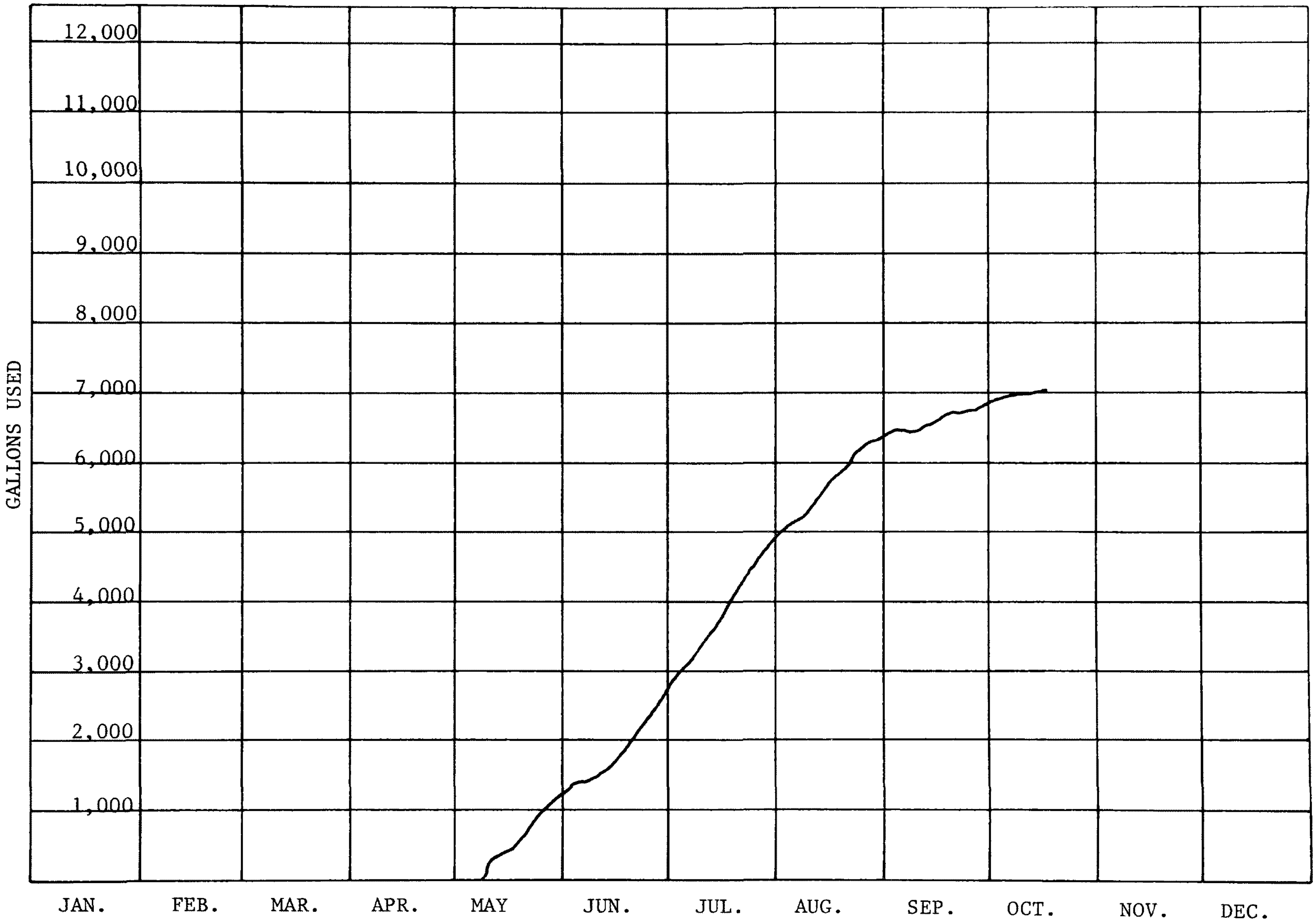


Figure 37. Consumptive water use, lysimeter no. 2, smooth brame, depth to water 2.9'-3.1', 1972.

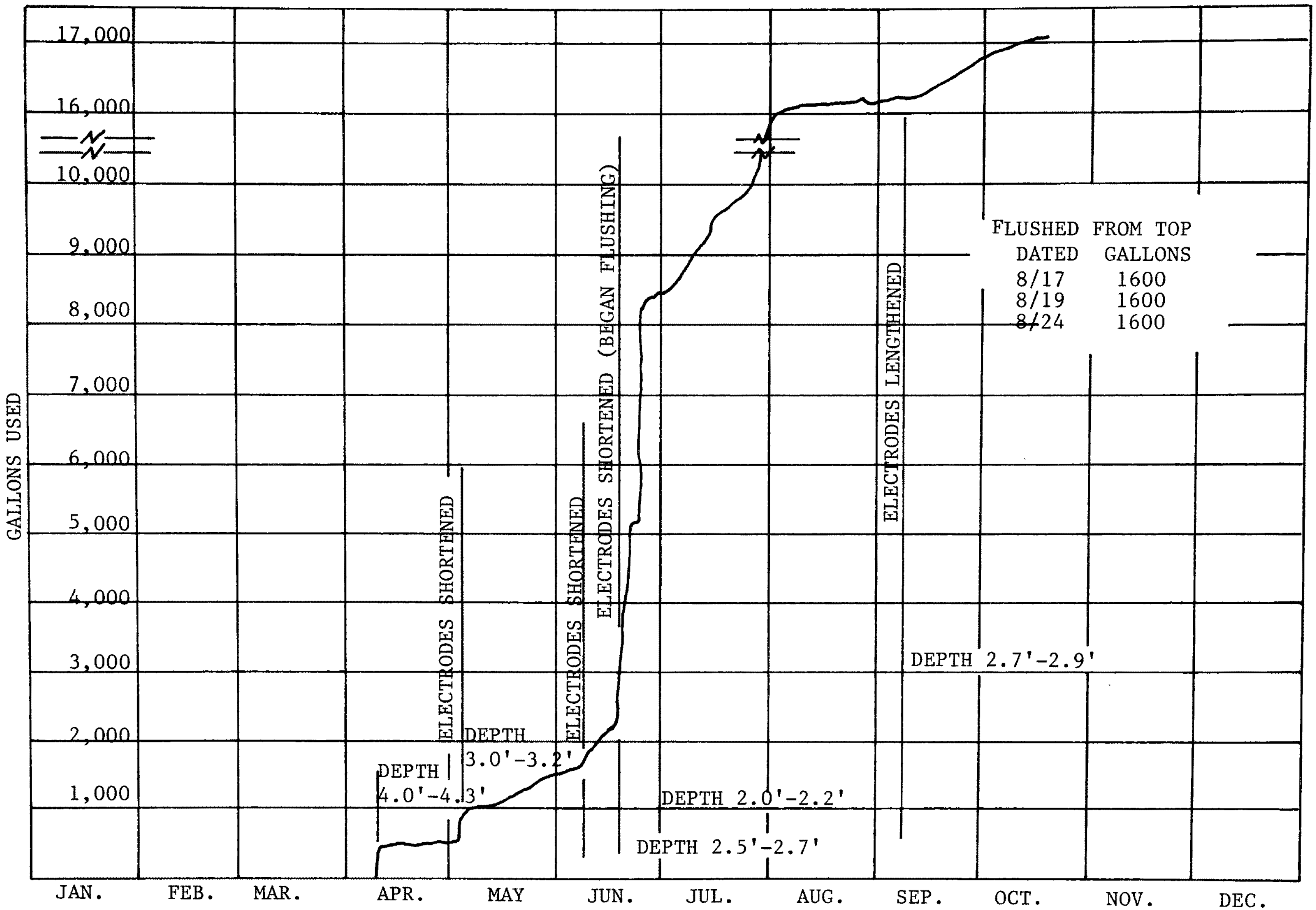


Figure 38. Consumptive water use, lysimeter no. 3, improved pasture, 1971.

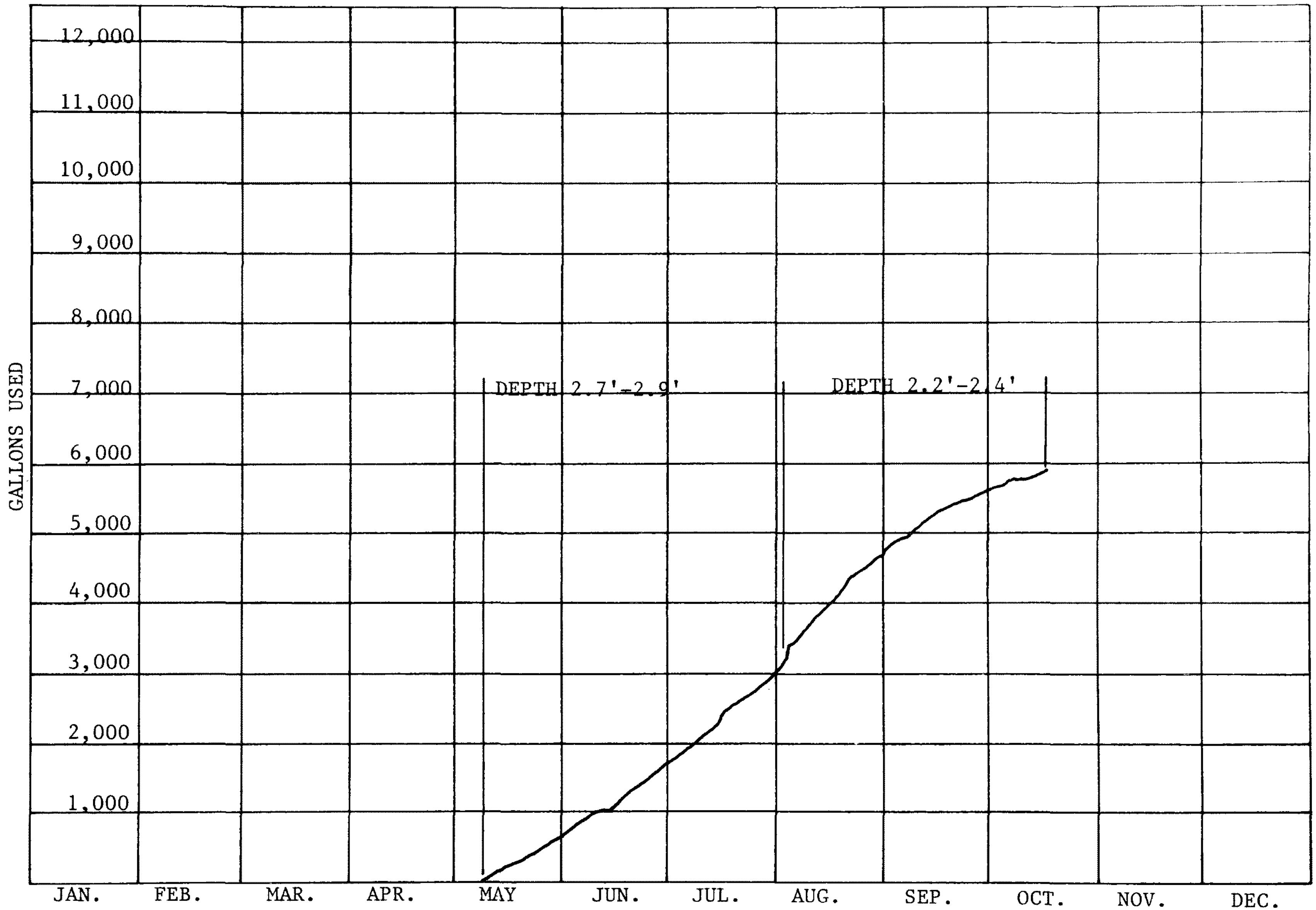


Figure 39. Consumptive water use, lysimeter no. 3, smooth brame, 1972.

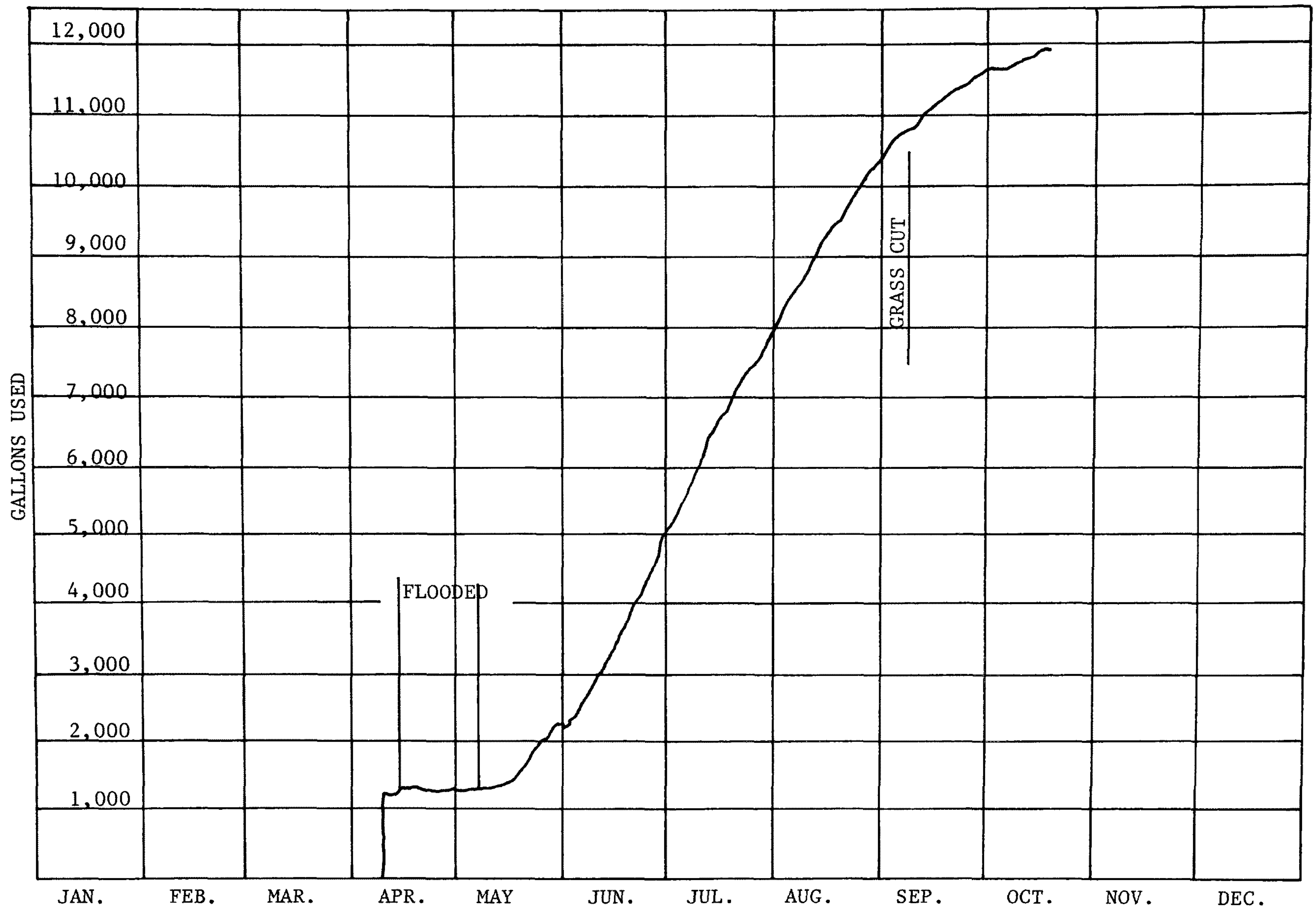


Figure 40. Consumptive water use, lysimeter no. 4, wire grass, water depth 0.5'-0.8', 1971.

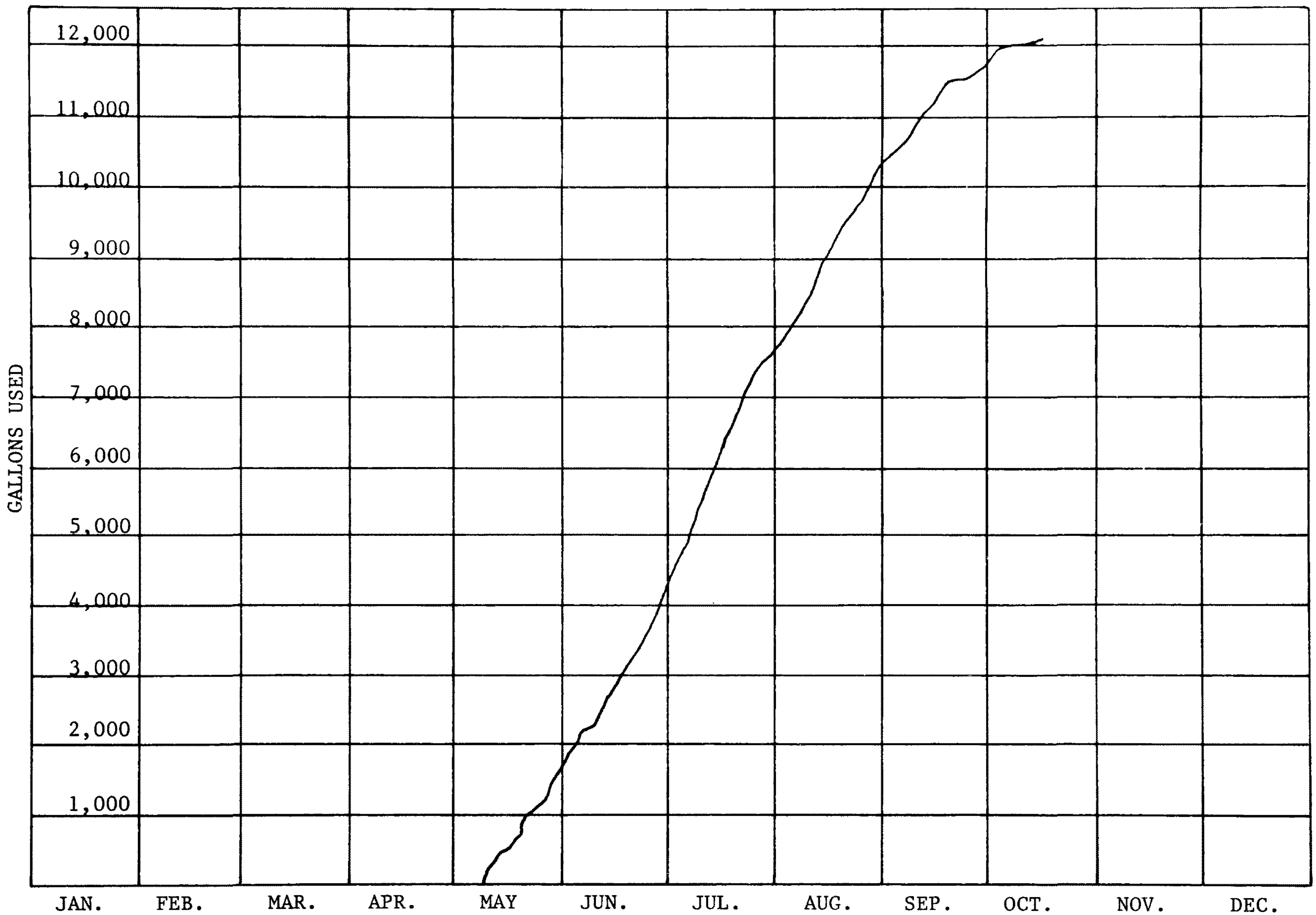


Figure 41. Consumptive water use, lysimeter no. 4, wire grass and meadow fescue, depth to water 0.5'-0.7', 1972.

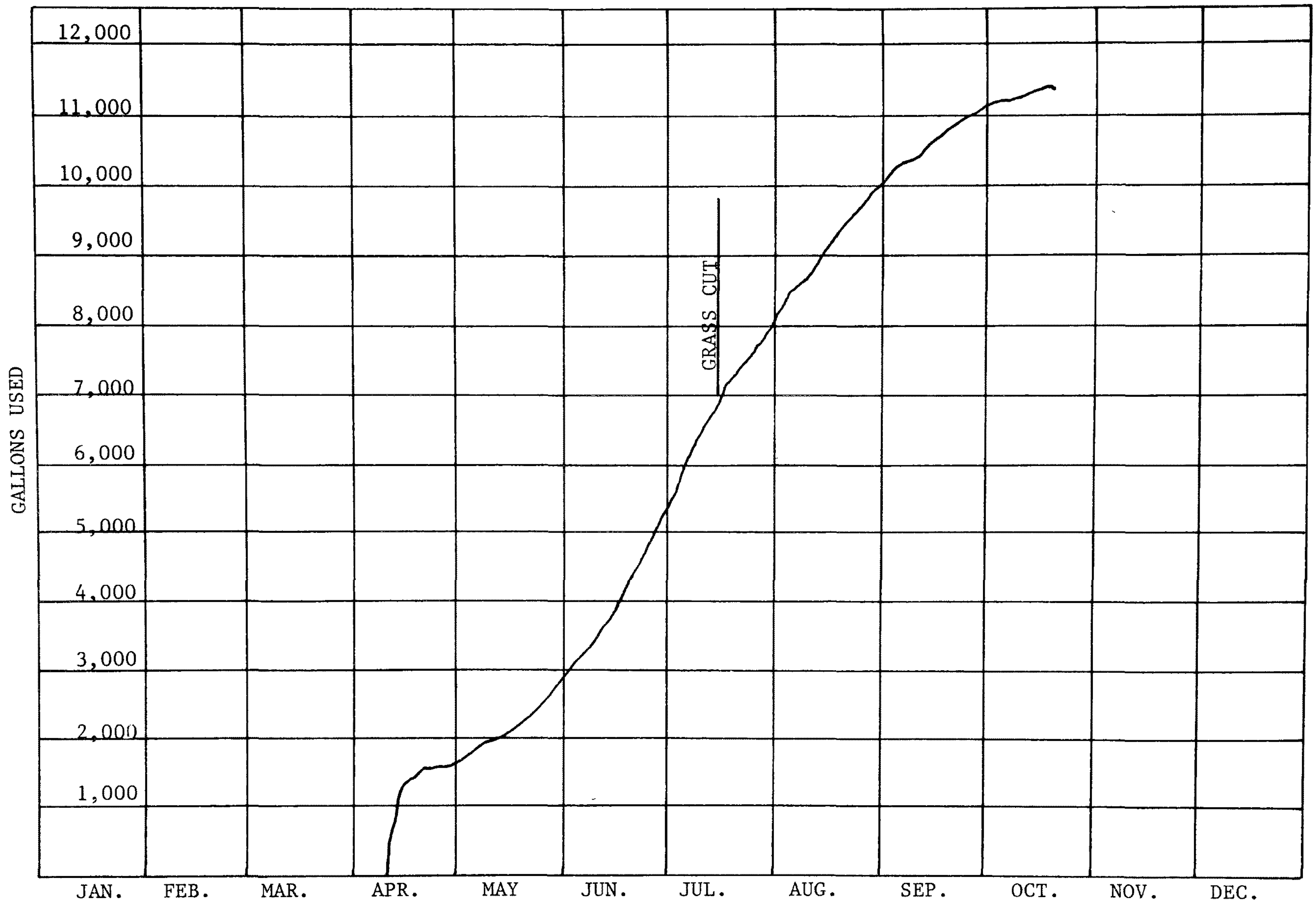


Figure 42. Consumptive water use, lysimeter no. 5, wire grass, water depth 1.9'-2.3', 1971.

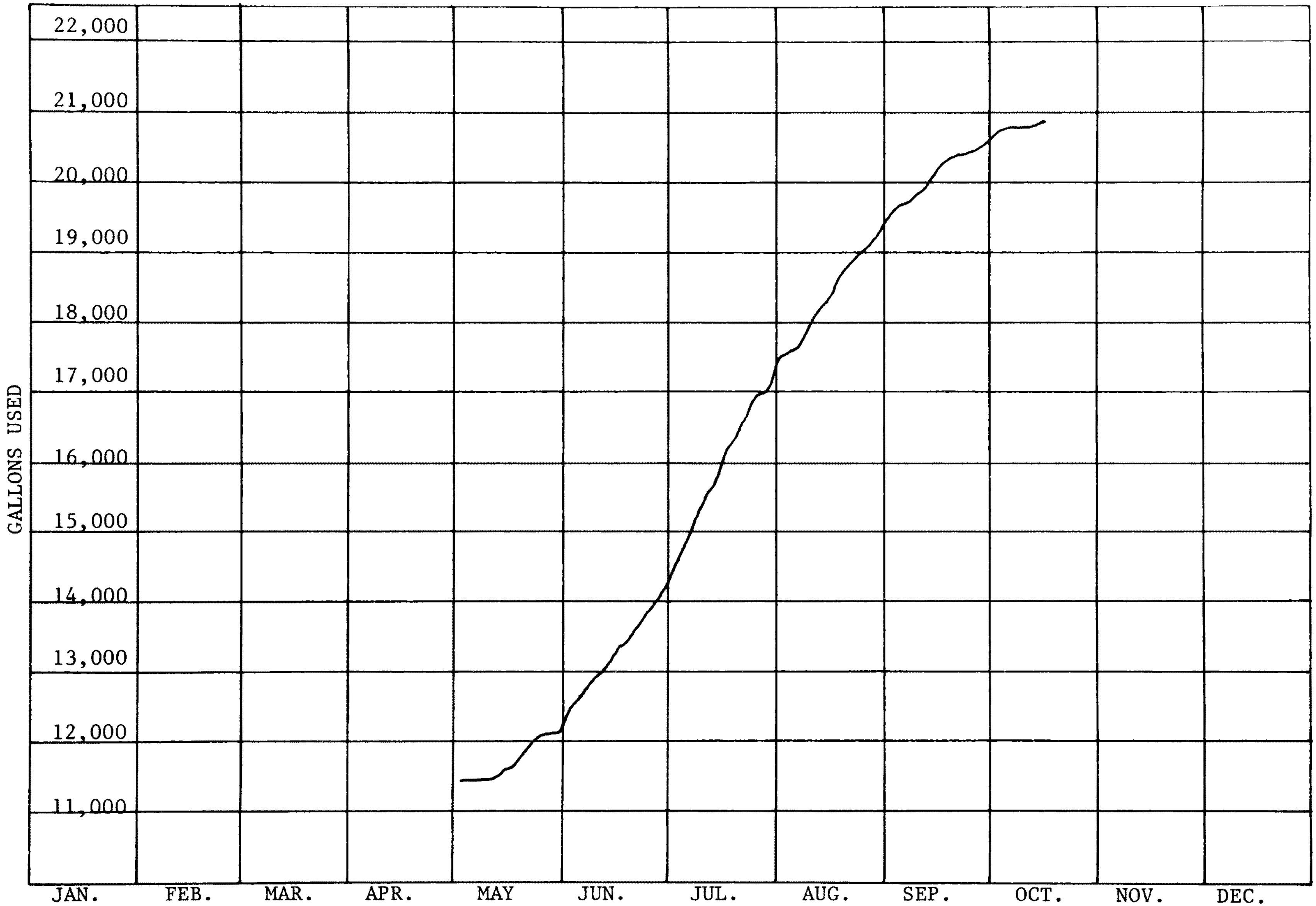


Figure 43. Consumptive water use, lysimeter no. 5, wire grass and meadow fescue, depth to water 1.9'-2.1', 1972.

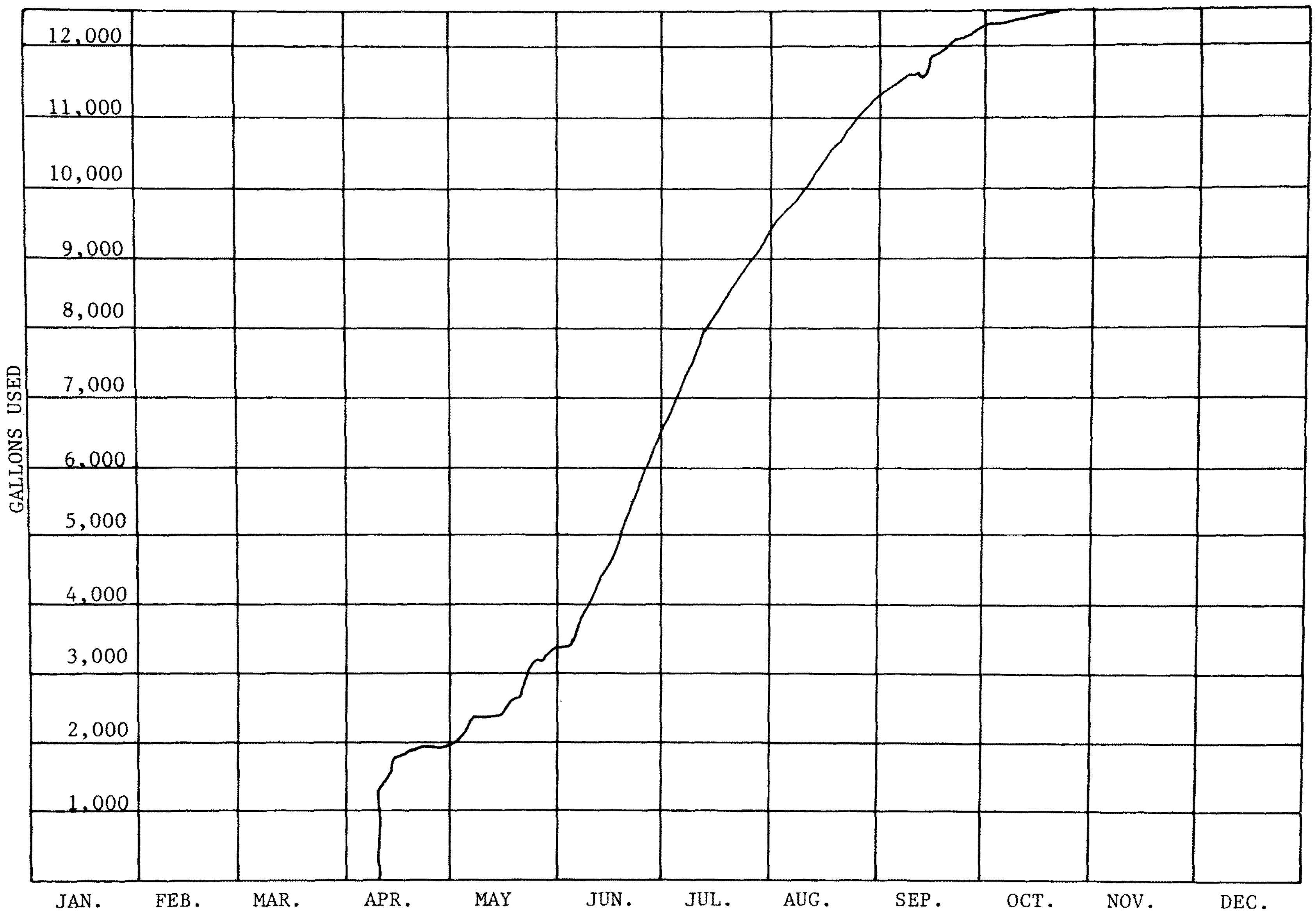


Figure 44. Consumptive water use, lysimeter no. 6, salt grass and foxtail, water depth 2.0'-2.3', 1971.

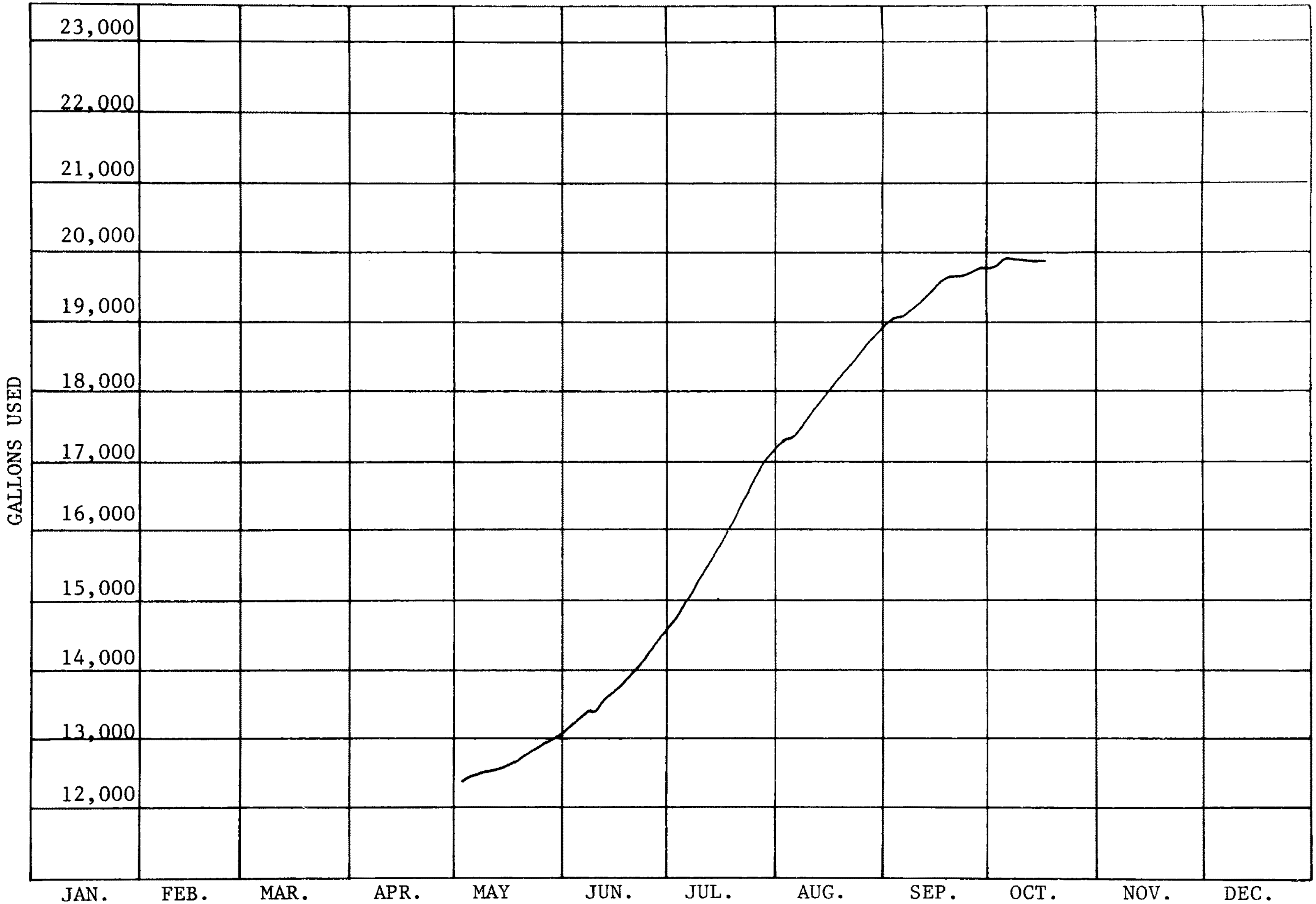


Figure 45. Consumptive water use, lysimeter no. 6, salt and broom grass, depth to water 2.0'-2.2', 1972.

Consumptive Use

Two class "A" weather stations were established in August 1970 and were operated through October 1970 and throughout the irrigation seasons in 1971 and 1972. One weather station was located in the northwest corner of the area in Node 1, and the other near the lysimeters. A continuous record of daily solar radiation was recorded for the period August 1970 through September 1972 at the lysimeter weather station.

The data from these weather stations and solar radiation will be used to determine consumptive use of crops in the study area. The Jensen and Haise method will be used for computing evapotranspiration. The following equations are used in this method:

$$E_t = K_c E_{tp}$$

where E_t = evapotranspiration

K_c = crop coefficient

E_{tp} = potential evapotranspiration

$$E_{tp} = C_t\ (T-T_o)\ R_s$$

Where E_{tp} = potential evapotranspiration in inches

T = mean daily air temperature in °F

C_t = temperature coefficient

T_o = temperature intercept

R_s = solar radiation in inches of evaporation equivalent

Canal Losses

Seepage tests were conducted by the Soil Conservation Service during 1967 and 1968 in the Highline and Central Canals.

The Highline Canal tests were made in two reaches. The reach in which the highest losses was found extended about 7.3 miles north of Highway 40. Based on field measurements the computed losses for this reach range from 34 to 10 percent for flows from 10 to 100 second-feet. The losses measured in a reach south of Highway 40 varied from 3 to 6 percent for flows of 10 to 14 second-feet. Due to the nature of the soils in the lower reach these losses should remain fairly constant.

The Central Canal tests were made in a 1.1 mile reach near Highway 40. The losses in the tested reach varied from 7 to 3 percent for flows from 10 to 7 second-feet.

The canal losses measured by the SCS have been incorporated into the model studies.

During the SCS tests no canal gains were found due to ground-water inflow; however, flows in the Upper and Central Canals do increase due to surface water inflow.

Land Use

In order to assist in the establishment of a water budget in the Ashley Valley area it was determined that a land use survey of the area would be required. The field investigations for this land use survey was accomplished during the 1970 field season. Actual work was started late enough in the growing season to allow for easy identification of vegetative types. The survey included the field investigation of all domestic crops and native vegetation including the identification of phreatophytes. The land use categories were delineated onto aerial photographs in the field. The photographs used had a scale of 1 inch is equal to 660 feet and were a 1963-64 flight. This flight was the most recent that provided adequate coverage of the area.

Control for the area consisted of the location of section corners and establishing the section, township and range lines on the photograph. This was accomplished prior to the field investigation.

The field work was accomplished by the investigator making sufficient traverses and on site observations to identify each area of cultivated crops and native vegetation types and their use and distribution. As each use was identified delineations were made on the aerial photograph. All field boundaries and land use area boundaries were laid out according to the established land use pattern for the area.

A code of designations or categories for land use was developed for this survey using as a base the code established by the soil conservation service in their phreatophyte study of the Sevier River area. A copy of this code is presented in Table 8.

In mapping the native vegetation and particularly the phreatophyte areas it was found that vegetative types often occur in combinations. Where this was found, and no one type predominated, a system of rating by density of growth or cover was established. This indicated the types of vegetation and the cover of each based on a percent of 100 or completed cover. For example, a symbol of .4-P14 & .6-P24, would indicate an area covered with 40 percent greasewood and 60 percent rabbitbrush. This same system was used to indicate the density of ground cover in the case of a single vegetative type. For example, a .2-P4 would show a 20 percent cover of sagebrush with approximately 80 percent bare ground.

In mapping land use in irrigated regions of Utah and other intermountain states it is found that the agricultural economy is established and cropping patterns are generally basic, that is, almost the same acreage of any one crop is grown year after year with some rotation from field to field. This is especially true in an area of cattle related enterprises such as Ashley Valley.

Following the field work the aerial photographs were inked and boundaries defined as permanent records. Each land use or vegetative type was planimetered as they were delineated on the photo. The planimeter units were then converted to acreages using general land office acreages and tabulated by quarter section and section. Table 9 is a summary of the land use by node and by vegetative types.

Table 8

PREDICTION OF MINERAL QUALITY OF RETURN FLOW WATER FROM IRRIGATED LANDS - VERNAL STUDY AREA

LAND USE INVESTIGATIONS: LEGEND

Symbol	Use Description
Ca or Alf	Irrigated Alfalfa--Good, fair, poor
Cg or Sb	Irrigated small grains, wheat, barley, oats
Cc or Co..................	Irrigated field corn
Crp	Irrigated rotation pasture
Pm	Irrigated pasture (meadow), improved grasses and clovers cut for hay (Brome clover, redtop, fescue, blue grass, etc.)
P2	Irrigated pasture (meadows) predominantly native grasses cut for hay (wire grass, sedges, redtop, fescue, etc.)
P25........................	Salt grass pasture, lowlands, seeped or subbed
P20	Wet pasture lands, topographic lows--wire grass, sedges, salt grass, some cattails, etc.
Pd	Dry pasture uplands (idle) poor vegetative cover, salt grass or blue grass, etc. mixed with weeds and forbes
P4	Dry upland areas of sagebrush, sparse understory of native grass may be present
P5	Willows, usually found on wet areas, but may be dry. Where not dense may have understory of native grasses.
P6	Silver buffalo berry, same as P5 usually found on rocky ground, braided throughout field
P14	Greasewood, usually dry surface areas, water table is near the surface
P19	Tamarisk, not usually found in dense cover, scattered along stream channels
P24	Rabbitbrush usually found on higher abandoned lands
P30	Uplands with vegetative cover consisting predominantly of shadscale and other desert shrubs
F10	Broadleaf trees - cottonwood etc., usually found along stream channels
W	Wet areas - cattails, sedges, standing water
Iw	Idle lands - predominantly weeds

Homestead, small orchards and garden spots will be delineated as well as rights-of-way, industrial and residential areas.

Bottomlands with composite vegetative cover will be mapped on a density cover basis.

TABLE 9
WATER QUALITY PREDICTION
LAND USE INVESTIGATIONS SUMMARY
VERNAL UNIT

Land Use Symbol	Acres			
	Node 1	Node 2	Node 3	Total
Ca	2,474	2,751	2,444	7,669
Cg	580	747	584	1,911
Cc	341	416	407	1,164
Crp	1,051	778	591	2,420
Pm	302	155	1	458
P2	2,410	1,854	1,335	5,599
$P2_5$	32	85	349	466
P20	437	291	982	1,710
Pd	518	200	544	1,262
P4	137	749	1,498	2,384
P5	274	232	295	801
P6	368	130	38	536
P14	34	66	1,548	1,648
P19	2			2
P24	2	3	216	221
P30		6	2,064	2,070
F10	850	91	31	972
Iw	106	123	354	583
W		3	3	6
H	1,170	1,619	498	3,287
Totals	11,088	10,299	13,782	35,169

The land use study was also utilized in selection of vegetation or land use types that were included in the lysimeter studies. These studies were to determine the consumptive use of a large part of the irrigated area for which consumptive use data were not available.

APPENDIX

VERNAL PROJECT STUDY-BASIC DATA
STARTING AQUIFER CAPACITIES:

NODE 101 = 24,000 acre-feet
NODE 102 = 20,200 acre-feet
NODE 103 = 6,020 acre-feet

VERNAL PROJECT STUDY-BASIC DATA
CANAL LOSSES:

NODE 101 = 20% of diversion to irrigation
NODE 102 = 15% of diversion to irrigation
NODE 103 = 10% of diversion to irrigation

VERNAL PROJECT STUDY-BASIC DATA
CONSUMPTIVE USE IN ACRE FEET PER MONTH

YEAR	MONTH	NODE 101	NODE 102	NODE 103
1971	APR	0	0	722
1971	MAY	0	0	0
1971	JUN	0	0	0
1971	JUL	2743	2388	3268
1971	AUG	5254	4638	6116
1971	SEP	5499	4874	6491
1971	OCT	4849	4236	5662
1971	NOV	2532	2202	2983
1971	DEC	485	467	581
1972	JAN	168	210	270
1972	FEB	152	155	217
1972	MAR	174	186	279
1972	APR	255	290	406
1972	MAY	372	434	558
1972	JUN	621	577	772
1972	JUL	3578	3186	4245
1972	AUG	4854	4288	5648
1972	SEP	5723	5080	6687
1972	OCT	4659	4074	5440
1972	NOV	3130	2701	3690
1972	DEC	1434	1251	1672

VERNAL PROJECT STUDY-BASIC DATA
INITIAL SOIL COLUMN DATA

NODE NUMBER = 101

	SEG#1	SEG#2	SEG#3	SEG#4	SEG#5	SEG#6	SEG#7	SEG#8
CA-MEQ/L	6.90	6.90	6.90	5.30	5.30	5.30	0.00	0.00
MG-MEQ/L	2.06	2.06	2.06	1.86	1.86	1.86	0.00	0.00
NA-MEQ/L	1.68	1.68	1.68	1.44	1.44	1.44	0.00	0.00
CL-MEQ/L	.65	.65	.65	.34	.34	.34	0.00	0.00
SO4-MEQ/L	3.28	3.28	3.28	4.93	4.93	4.93	0.00	0.00
HCO3-MEQ/L	5.63	5.63	5.63	3.33	3.33	3.33	0.00	0.00
CO3-MEQ/L	1.08	1.08	1.08	0.00	0.00	0.00	0.00	0.00
NO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SOIL/WATER RATIO	.20	.20	.20	.20	.20	.20	0.00	0.00
VOLUME H2O-ML	6.50	6.50	6.50	5.31	5.31	5.31	0.00	0.00
CATION EXCHG-MEQ/100 GR	17.06	17.06	17.06	14.13	14.13	14.13	0.00	0.00
GYPSUM-MEQ/100 GR	.10	.10	.10	.35	.35	.35	0.00	0.00
LIME INDICATOR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BULK DENSITY-GR/CM3	1.30	1.30	1.30	1.30	1.30	1.30	0.00	0.00
LENGTH OF SEGMENT-CM	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00

NODE NUMBER = 102

	SEG#1	SEG#2	SEG#3	SEG#4	SEG#5	SEG#6	SEG#7	SEG#8
CA-MEQ/L	9.88	9.88	9.88	9.88	5.29	5.29	5.29	5.29
MG-MEQ/L	6.82	6.82	6.82	6.82	3.29	3.29	3.29	3.29
NA-MEQ/L	1.36	1.36	1.36	1.36	.99	.99	.99	.99
CL-MEQ/L	.96	.96	.96	.96	.36	.36	.36	.36
SO4-MEQ/L	8.58	8.58	8.58	8.58	5.85	5.85	5.85	5.85
HCO3-MEQ/L	8.52	8.52	8.52	8.52	3.36	3.36	3.36	3.36
CO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SOIL/WATER RATIO	.20	.20	.20	.20	.20	.20	.20	.20
VOLUME H2O-ML	4.05	4.05	4.05	4.05	3.88	3.88	3.88	3.88
CATION EXCHG-MEQ/100 GR	10.94	10.94	10.94	10.94	9.38	9.38	9.38	9.38
GYPSUM-MEQ/100 GR	.25	.25	.25	.25	.48	.48	.48	.48
LIME INDICATOR	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00
BULK DENSITY-GR/CM3	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
LENGTH OF SEGMENT-CM	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00

NODE NUMBER = 103

	SEG#1	SEG#2	SEG#3	SEG#4	SEG#5	SEG#6	SEG#7	SEG#8
CA-MEQ/L	32.40	32.40	32.40	32.40	15.80	15.80	15.80	15.80
MG-MEQ/L	24.70	24.70	24.70	24.70	18.52	18.52	18.52	18.52
NA-MEQ/L	16.70	16.70	16.70	16.70	7.00	7.00	7.00	7.00
CL-MEQ/L	10.75	10.75	10.75	10.75	2.17	2.17	2.17	2.17
SO4-MEQ/L	54.25	54.25	54.25	54.25	35.74	35.74	35.74	35.74
HCO3-MEQ/L	8.80	8.80	8.80	8.80	3.41	3.41	3.41	3.41
CO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SOIL/WATER RATIO	.20	.20	.20	.20	.20	.20	.20	.20
VOLUME H2O-ML	4.33	4.33	4.33	4.33	3.76	3.76	3.76	3.76
CATION EXCHG-MEQ/100 GR	13.94	13.94	13.94	13.94	11.06	11.06	11.06	11.06
GYPSUM-MEQ/100 GR	1.10	1.10	1.10	1.10	.35	.35	.35	.35
LIME INDICATOR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BULK DENSITY-GR/CM3	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
LENGTH OF SEGMENT-CM	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00

VERNAL PROJECT STUDY-BASIC DATA
INITIAL SOIL COLUMN DATA

	SEG#1	SEG#2	SEG#3	SEG#4	SEG#5	SEG#6	SEG#7	SEG#8
NODE NUMBER = 101								
CA-MEQ/L	6.90	6.90	6.90	5.30	5.30	5.30	0.00	0.00
MG-MEQ/L	2.06	2.06	2.06	1.86	1.86	1.86	0.00	0.00
NA-MEQ/L	1.68	1.68	1.68	1.44	1.44	1.44	0.00	0.00
CL-MEQ/L	.65	.65	.65	.34	.34	.34	0.00	0.00
SO4-MEQ/L	3.28	3.28	3.28	4.93	4.93	4.93	0.00	0.00
HCO3-MEQ/L	5.63	5.63	5.63	3.33	3.33	3.33	0.00	0.00
CO3-MEQ/L	1.08	1.08	1.08	0.00	0.00	0.00	0.00	0.00
NO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SOIL/WATER RATIO	.20	.20	.20	.20	.20	.20	0.00	0.00
VOLUME H2O-ML	6.50	6.50	6.50	5.31	5.31	5.31	0.00	0.00
CATION EXCHG-MEQ/100 GR	17.06	17.06	17.06	14.13	14.13	14.13	0.00	0.00
GYPSUM-MEQ/100 GR	.10	.10	.10	.35	.35	.35	0.00	0.00
LIME INDICATOR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BULK DENSITY-GR/CM3	1.30	1.30	1.30	1.30	1.30	1.30	0.00	0.00
LENGTH OF SEGMENT-CM	10.00	10.00	10.00	10.00	10.00	10.00	0.00	0.00
NODE NUMBER = 102								
CA-MEQ/L	9.88	9.88	9.88	9.88	5.29	5.29	5.29	5.29
MG-MEQ/L	6.82	6.82	6.82	6.82	3.29	3.29	3.29	3.29
NA-MEQ/L	1.36	1.36	1.36	1.36	.99	.99	.99	.99
CL-MEQ/L	.96	.96	.96	.96	.36	.36	.36	.36
SO4-MEQ/L	8.58	8.58	8.58	8.58	5.85	5.85	5.85	5.85
HCO3-MEQ/L	8.52	8.52	8.52	8.52	3.36	3.36	3.36	3.36
CO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SOIL/WATER RATIO	.20	.20	.20	.20	.20	.20	.20	.20
VOLUME H2O-ML	4.05	4.05	4.05	4.05	3.88	3.88	3.88	3.88
CATION EXCHG-MEQ/100 GR	10.94	10.94	10.94	10.94	9.38	9.38	9.38	9.38
GYPSUM-MEQ/100 GR	.25	.25	.25	.25	.48	.48	.48	.48
LIME INDICATOR	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00
BULK DENSITY-GR/CM3	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
LENGTH OF SEGMENT-CM	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
NODE NUMBER = 103								
CA-MEQ/L	32.40	32.40	32.40	32.40	15.80	15.80	15.80	15.80
MG-MEQ/L	24.70	24.70	24.70	24.70	18.52	18.52	18.52	18.52
NA-MEQ/L	16.70	16.70	16.70	16.70	7.00	7.00	7.00	7.00
CL-MEQ/L	10.75	10.75	10.75	10.75	2.17	2.17	2.17	2.17
SO4-MEQ/L	54.25	54.25	54.25	54.25	35.74	35.74	35.74	35.74
HCO3-MEQ/L	8.80	8.80	8.80	8.80	3.41	3.41	3.41	3.41
CO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NO3-MEQ/L	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SOIL/WATER RATIO	.20	.20	.20	.20	.20	.20	.20	.20
VOLUME H2O-ML	4.33	4.33	4.33	4.33	3.76	3.76	3.76	3.76
CATION EXCHG-MEQ/100 GR	13.94	13.94	13.94	13.94	11.06	11.06	11.06	11.06
GYPSUM-MEQ/100 GR	1.10	1.10	1.10	1.10	.35	.35	.35	.35
LIME INDICATOR	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
BULK DENSITY-GR/CM3	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
LENGTH OF SEGMENT-CM	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

ASHLEY CREEK AT HEAD OF SYSTEM

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	1379.	1.92	1.00	.15	.03	.77	1.94	.33	0.00
MAY	1971	18160.	1.08	.41	.10	0.00	.37	1.24	0.00	0.00
JUN	1971	37970.	.69	.26	.09	.05	.22	.78	0.00	0.00
JUL	1971	10730.	1.39	.49	.09	.02	.23	1.96	0.00	0.00
AUG	1971	4980.	1.56	.75	.07	.02	.51	1.78	0.00	0.00
SEP	1971	3750.	1.54	.63	.09	.02	.35	1.84	0.00	0.00
OCT	1971	2390.	2.08	.98	.09	.01	.75	2.21	0.00	0.00
NOV	1971	2290.	1.85	.83	.09	.08	.56	2.15	0.00	0.00
DEC	1971	2000.	2.30	1.12	.10	.04	.88	2.43	0.00	0.00
JAN	1972	1810.	2.08	.98	.09	.01	.75	2.21	0.00	0.00
FEB	1972	1620.	2.08	.98	.09	.01	.75	2.21	0.00	0.00
MAR	1972	1650.	2.30	1.12	.10	.04	.88	2.43	0.00	0.00
APR	1972	2180.	1.56	.75	.07	.02	.51	1.78	0.00	0.00
MAY	1972	27120.	.86	.24	.06	.02	.23	.94	0.00	0.00
JUN	1972	25010.	.90	.22	.06	.01	.29	1.01	0.00	0.00
JUL	1972	7460.	1.33	.55	.03	.03	.37	1.56	0.00	0.00
AUG	1972	3760.	1.54	.63	.09	.02	.35	1.84	0.00	0.00
SEP	1972	3350.	1.61	.67	.06	.03	.33	1.98	0.00	0.00
OCT	1972	1690.	2.08	.98	.09	.01	.75	2.21	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

INFLOW FROM STEINECKER RESERVOIR

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	653.	2.09	1.00	.29	.07	1.25	2.09	0.00	0.00
MAY	1971	1324.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
JUN	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JUL	1971	7952.	1.91	.85	.29	.12	.98	1.88	0.00	0.00
AUG	1971	6030.	1.63	.78	.23	.08	.74	1.82	0.00	0.00
SEP	1971	1705.	1.97	.85	.28	.05	.98	1.77	0.00	0.00
OCT	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOV	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEC	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JAN	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	1972	1170.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
MAY	1972	2687.	2.09	1.00	.29	.07	1.25	2.09	0.00	0.00
JUN	1972	260.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
JUL	1972	6770.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
AUG	1972	4662.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
SEP	1972	2065.	1.90	.92	.23	.09	.97	2.05	0.00	0.00
OCT	1972	532.	1.93	.85	.28	.05	.98	1.77	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

HIGHLINE CANAL OUTFLOW GAGE NO. 3

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAY	1971	1508.	1.08	.41	.10	0.00	.37	1.24	0.00	0.00
JUN	1971	4171.	.69	.26	.09	.05	.22	.78	0.00	0.00
JUL	1971	2490.	1.54	.53	.09	.02	.35	1.84	0.00	0.00
AUG	1971	667.	1.59	.95	.10	.03	.65	1.88	0.00	0.00
SEP	1971	449.	1.96	.90	.10	.05	.64	2.25	0.00	0.00
OCT	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOV	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEC	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JAN	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAY	1972	2493.	.90	.32	.06	.01	.29	1.01	0.00	0.00
JUN	1972	3063.	.90	.32	.06	.01	.29	1.01	0.00	0.00
JUL	1972	1581.	1.54	.53	.09	.02	.35	1.84	0.00	0.00
AUG	1972	418.	1.59	.95	.10	.03	.65	1.88	0.00	0.00
SEP	1972	788.	1.71	.84	.10	.01	.55	2.11	0.00	0.00
OCT	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

UPPER CANAL OUTFLOW GAGE NO. 2

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	460.	1.65	.81	.29	.06	.89	1.69	0.00	0.00
MAY	1971	4264.	1.10	.18	.09	.04	.28	1.10	0.00	0.00
JUN	1971	7609.	.71	.17	.02	.01	.22	.73	0.00	0.00
JUL	1971	2858.	1.45	.55	.06	.02	.71	1.68	0.00	0.00
AUG	1971	1664.	1.66	.71	.09	.05	.52	1.98	0.00	0.00
SEP	1971	1674.	1.57	.79	.07	.02	.49	1.94	0.00	0.00
OCT	1971	752.	1.87	.94	.25	.09	1.04	2.10	0.00	0.00
NOV	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEC	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JAN	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	1972	1139.	1.72	.83	.10	.01	.64	2.03	0.00	0.00
MAY	1972	6687.	.92	.17	.08	.01	.21	.98	0.00	0.00
JUN	1972	6018.	1.05	.21	.06	.03	.24	1.08	0.00	0.00
JUL	1972	2027.	1.68	.69	.08	.04	.54	1.96	0.00	0.00
AUG	1972	1622.	1.63	.79	.13	.07	.67	1.75	0.00	0.00
SEP	1972	1462.	1.67	.79	.13	.07	.67	1.75	0.00	0.00
OCT	1972	900.	1.56	1.02	.24	.06	1.19	1.64	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

CENTRAL CANAL OUTFLOW GAGE NO. 1

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	156.	3.06	2.10	.30	.14	1.26	4.12	0.00	0.00
MAY	1971	2014.	1.28	.42	.08	.04	.35	1.45	0.00	0.00
JUN	1971	4268.	1.21	.20	.09	.04	.24	1.23	0.00	0.00
JUL	1971	434.	2.50	1.64	.19	.08	.94	3.14	0.00	0.00
AUG	1971	142.	3.14	2.29	.32	.17	1.30	4.32	0.00	0.00
SEP	1971	120.	3.06	2.10	.30	.14	1.26	4.12	0.00	0.00
OCT	1971	218.	3.06	2.10	.30	.14	1.26	4.12	0.00	0.00
NOV	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEC	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JAN	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	1972	325.	2.50	1.64	.19	.08	.94	3.14	0.00	0.00
MAY	1972	2859.	1.21	.20	.09	.04	.24	1.23	0.00	0.00
JUN	1972	2954.	1.28	.42	.08	.04	.35	1.45	0.00	0.00
JUL	1972	312.	3.05	2.35	.34	.13	1.76	3.51	0.00	0.00
AUG	1972	16.	4.50	4.13	.58	.29	2.29	6.39	0.00	0.00
SEP	1972	23.	3.44	2.36	.35	.17	1.47	4.17	0.00	0.00
OCT	1972	324.	3.44	2.36	.35	.17	1.47	4.17	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

SERVICE CANAL OUTFLOW GAGE NO. 245

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	440.	2.09	1.00	.29	.07	1.25	0.00	0.00	0.00
MAY	1971	984.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
JUN	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JUL	1971	6224.	1.91	.85	.29	.12	.98	1.88	0.00	0.00
AUG	1971	4558.	1.63	.78	.23	.08	.74	1.83	0.00	0.00
SEP	1971	1269.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
OCT	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
NOV	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
DEC	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
JAN	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FEB	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MAR	1972	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
APR	1972	964.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
MAY	1972	2112.	2.09	1.00	.29	.07	1.25	2.09	0.00	0.00
JUN	1972	160.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
JUL	1972	4665.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
AUG	1972	3414.	1.93	.85	.28	.05	.98	1.77	0.00	0.00
SEP	1972	1551.	1.90	.92	.23	.09	.97	2.05	0.00	0.00
OCT	1972	373.	1.93	.85	.28	.05	.98	1.77	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

ASHLEY CREEK OUTFLOW GAGE NO. 11

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	309.	9.20	6.76	3.32	.62	12.80	5.05	0.00	0.00
MAY	1971	1115.	5.88	5.23	1.50	.65	6.54	6.67	0.00	0.00
JUN	1971	6440.	3.98	2.77	1.07	.24	3.66	3.77	0.00	0.00
JUL	1971	735.	6.76	5.28	1.92	.53	6.49	6.42	0.00	0.00
AUG	1971	610.	8.44	5.10	2.56	.40	10.24	5.52	0.00	0.00
SEP	1971	900.	5.99	4.79	2.09	.31	8.62	3.99	0.00	0.00
OCT	1971	1125.	8.44	5.10	2.56	.40	10.24	5.52	0.00	0.00
NOV	1971	930.	7.31	5.43	2.45	.74	8.77	5.76	0.00	0.00
DEC	1971	1090.	8.34	5.68	2.38	.58	9.90	6.04	0.00	0.00
JAN	1972	580.	6.88	5.23	1.50	.65	6.54	6.67	0.00	0.00
FEB	1972	560.	7.48	5.68	2.43	.47	9.36	5.68	0.00	0.00
MAR	1972	880.	4.95	3.36	1.36	.68	3.65	5.80	0.00	0.00
APR	1972	410.	9.16	6.84	3.20	.47	13.13	5.70	0.00	0.00
MAY	1972	970.	7.31	5.43	2.45	.74	8.77	5.76	0.00	0.00
JUN	1972	2740.	4.95	3.96	1.36	.68	3.65	5.80	0.00	0.00
JUL	1972	460.	7.31	5.43	2.45	.74	8.77	5.76	0.00	0.00
AUG	1972	310.	9.16	6.84	3.20	.47	13.13	5.70	0.00	0.00
SEP	1972	420.	6.88	4.88	2.42	.58	8.80	4.96	0.00	0.00
OCT	1972	790.	7.20	5.44	2.56	.74	9.20	5.75	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

RETURN FLOW FROM IRRIGATION

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

INFLOW TO AQUIFER FROM RIVER

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

VERNAL PROJECT STUDY-BASIC DATA

VOLUME IN UNITS OF ACRE FEET AND CONCENTRATIONS IN UNITS OF MEQ/LITER

INFLOW TO RIVER FROM AQUIFER

MONTH	YEAR	VOLUME	CA	MG	NA	CL	SO4	HCO3	CO3	NO3
APR	1971	0.	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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(Please read Instructions on the reverse before completing)

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VOLUMES I, III, IV, V (EPA-600/2-77-179a, 179c thru 179e)

16. ABSTRACT

The development and evaluation of modeling capability to simulate and predict the effects of irrigation on the quality of return flows are documented in the five volumes of this report. The report contains two different modeling packages which represent different levels of detail and sophistication. Volumes I, II, and IV pertain to the model package given in Volme III. Volume V contains the more sophisticated model. User's manuals are included in Volumes III and V.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Mathematical Model, digital simulation, scheduling, Irrigated land, Evapotranspiration, Agriculture, Agronomy, water pollution, water loss	Irrigation Return Flow	02 C/D

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