DEVELOPMENT OF EVAPOTRANSPIRATION CROP COEFFICIENTS, CLIMATOLOGICAL DATA, AND EVAPOTRANSPIRATION MODELS FOR THE UPPER GREEN RIVER IN WYOMING

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November 1983
WWRC-83-01

Annual Progress Report

Submitted to

Wyoming Water Development Commission
Cheyenne, Wyoming

by

Agricultural Engineering Department
University of Wyoming
Laramie, Wyoming

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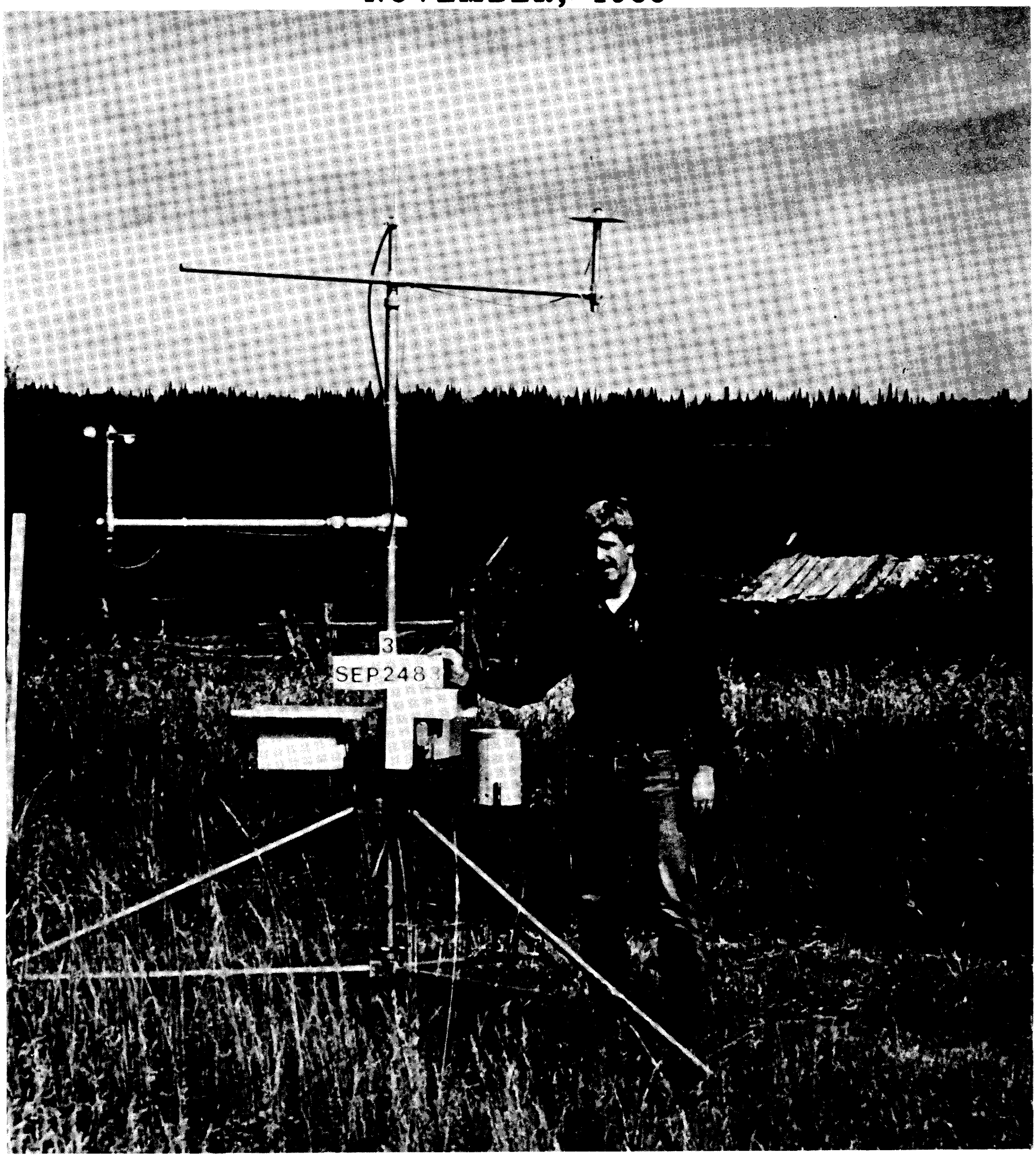
PROGRESS REPORT
NOVEMBER, 1983



Annual Progress Report

to

THE WYOMING WATER DEVELOPMENT COMMISSION

by

THE AGRICULTURAL ENGINEERING DEPARTMENT

of the

University of Wyoming

DEVELOPMENT OF EVAPOTRANSPIRATION CROP COEFFICIENTS, CLIMATOLOGICAL DATA, AND EVAPOTRANSPIRATION MODELS FOR THE UPPER GREEN RIVER

September 28, 1983

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INTRODUCTION

In the summer of 1982 negotiations began between the Agricultural Engineering Department, College of Engineering of the University of Wyoming, and the Wyoming Water Development Commission which led to a research project with the basic objective of developing an accurate method of calculating agricultural water consumption in the Green River Basin. A proposal was submitted by the Department on July 6, 1982. The proposal was accepted through a memorandum of agreement dated August 9, 1982. The project has been reviewed and accepted by the Commission for a second year's operation. The project is jointly funded by the Wyoming Water Development Commission and the University of Wyoming Water Research Center.

The research project has the following objectives. This report will address these objectives.

1. To develop grass and alfalfa reference crop coefficients at Farson and Fontenelle, Wyoming.
2. To develop grass and alfalfa reference crop coefficients and crop coefficients for mountain meadow grasses at Daniel, Wyoming.
3. To collect solar radiation, wind, humidity, temperature, and precipitation from a network of seven sites in the Upper Green River Basin.
4. To develop methods for transferring crop coefficients from location to location.
5. To use existing ET models to estimate consumptive use of agriculture, reservoir, and phreatophyte use within the Upper Green River Basin.
6. To develop a basin wide model for consumptive use.

7. To obtain existing ET data applicable to the Upper Green River Basin.

Lysimeters were fabricated and partially installed in the fall of 1982. Automated weather stations were purchased and their operation de-bugged during the fall and winter of 1982-1983.

The installation of all lysimeters and weather stations was completed during the spring of 1983 and routine operations were established. Weather stations were located at or near Rock Springs, Farson, Daniel, Merna, Big Piney, Seedskadee, and Mountain View. Two lysimeters were installed at both Farson and Seedskadee. Ten lysimeters were installed on or very near the Horse Creek watershed. The weather stations and lysimeters are all located on land owned by cooperators. Figure 1 is a map of the Green River Basin in Wyoming and shows the locations of weather stations and lysimeters. (All figures and tables appear at the end of this report.)

This progress report will have sections dealing with the operation of weather stations and lysimeters. In addition, initial investigations dealing with statistical and physical methods of extending results to the whole Green River Basin from research sites will be discussed. Samples of data acquired will be shown and an example of methods of extending data will be shown.

WEATHER STATION LOCATION AND OPERATION

Introduction

Seven weather stations utilizing CR-21* microloggers manufactured by Campbell Scientific of Logan, Utah for continuous recording of weather data, have been installed in the Green River Basin. The stations measure temperature, relative humidity, solar radiation, wind run and precipitation. The CR-21 microloggers have microprocessors programmed to record the aforementioned weather parameters at specified time intervals. See Figure 1 for locations of the weather stations.

Operation

The weather stations were installed during April and May 1983, as weather permitted; operation began immediately. The weather stations were reprogrammed for reduced data accumulation for winter months about October 1st. During winter months stations only need to be serviced at six week intervals. The following parameters are being measured at the specified time interval during summer months:

1) total 24 hour precipitation
2) total 24 hour solar radiation
3) maximum and minimum temperature and time of each over a 24 hour period
4) maximum and minimum relative humidity and time of each over a 24 hour period
5) average daily temperature

*The mention of brand names does not imply endorsement.

6) average daily relative humidity

7) total wind run each 4 hour period

8) relative humidity sampled at 4 hour intervals

9) temperature sampled at 4 hour intervals.

The number and frequency of weather parameter readings being recorded allows for a maximum interval of 15 days between visits.

The data stored on the micrologger are "dumped" onto a portable cassette tape recorder. The tape is then transported to Laramie and connected to the University computer system where the recorded data are transferred and stored.

Weather stations are usually visited on a weekly basis during the crop growing season. Lysimeter operation ceased October 8th and 9th and the weather stations were reprogrammed to sample fewer parameters. This enables a maximum of 43 days of data to be stored between visits.

The climatic parameters measured between mid-October and mid-April are:

1) total 24 hour solar radiation

2) total 24 hour wind run

3) relative humidity sampled at 24 hour intervals

4) temperature sampled at 24 hour intervals

5) maximum and minimum daily temperature.

Tables 1A and 1B show samples of data output from the weather stations at Upper and Lower Horse Creek. Similar data is available for all stations for the entire summer and fall of 1983.

Additional Weather Data

Current and historic climatic data for twelve additional sites in the Green River Basin is available from the National Weather Service. The locations of the National Weather Service stations are shown in Figure 1.

Approximately thirty years of historical data - precipitation, maximum, minimum, and mean temperature - has been obtained to observe historical weather patterns in the Basin (see Spatial Extrapolation of Meteorological Data section). Historical weather patterns should indicate historical ET patterns.

LYSIMETER INSTALLATION AND OPERATION

Lysimeter Construction

The lysimeters used on the Green River Basin project to measure evapotranspiration were made from one-eighth inch thick steel plate and resemble a rectangular box with the top open. The lysimeters are 60 in. deep and 39.4 in. on a side. All corners are welded and sealed to prevent water from leaking in or out and the entire steel lysimeter is coated with paint. Figure 2A shows dimensions and construction details. All welded seams were caulked to prevent leaks.

An aluminum access tube, 1.5 in. diameter by 60 in. long with a rubber stopper in each end was installed to provide access for the measurement of soil moisture. A 4 in. diameter by 60 in. long perforated PVC pipe with a removable lid was fabricated for use as an access to measure water table depths and to pump water out of the lysimeters when needed. This pipe was wrapped in fine mesh screen to prevent soil from entering the perforations. A small, 3/4 in. diameter by 60 in. long perforated PVC pipe was installed to be used outside the lysimeter to monitor outside water tables to the depth of the lysimeters.

Lysimeter Installation

After fabrication, and as weather permitted, the 14 lysimeters were transported to the selected field locations in the Green River Basin. The holes to be dug were marked using a template which was slightly larger than the bottom of the lysimeter and then the sod was cut and removed with a shovel. To insure minimal disruption of soil stratification, each layer of soil was carefully removed and placed in a separate pile. When the hole was approximately 58 in. deep, the lysimeter was placed in the hole and leveled. The 4 in. perforated PVC pipe was placed vertically in one corner and the aluminum access pipe was positioned vertically in the center of the lysimeter. The soil was then replaced inside the lysimeter in the reverse order of removal and the sod replaced on top. At six locations, the sod was not replaced because these lysimeters were planted with alfalfa or alta fescue grass. To complete the lysimeter installation, the small perforated PVC pipe was placed vertically in a pilot hole located outside, but near the lysimeter. Figure 2B shows a typical completed lysimeter installation, ready for operation.

Lysimeter Operation

Once the lysimeters are installed, it is relatively simple to determine the evapotranspiration (ET) from each site. Knowing the quantity of precipitation which falls on each lysimeter (P), the amount of water added or removed (W_A - W_R), and the change in soil moisture (ΔS_M), one can apply a simple water balance to determine ET.

$$ET = P + (W_A - W_R) + \Delta S_M$$

During the summer of 1983, all the lysimeters were monitored once every week. The amount of precipitation at each lysimeter site was measured using a tipping bucket rain gauge that is wired into a CR-21 micrologger or by a simple, non-recording plastic rain gauge. A quantity of water, slightly in excess of the anticipated weekly ET, was added to the vegetated surface of the lysimeter in a fashion to simulate flood irrigation. This amount of water becomes W_A in the water balance. Figure 3 shows the addition of water to a lysimeter. The only remaining term is the change in soil moisture, ΔS_M, which is determined by measuring the weekly fluctuation in water table depth within the lysimeter along with the change in the soil moisture above the water table. A neutron soil probe is used to measure the soil moisture above the water table. Figure 4 shows the use of a neutron soil probe. Occasionally, after heavy rainfall, it is necessary to remove water from a lysimeter. This is done using a hand operated diaphragm pump as shown in Figure 5. To lower the water table in a lysimeter, water must also be pumped out. The amount of water removed is measured and becomes W_R in the water balance.

A computer at the University of Wyoming is utilized to compile all the field data and to print out values of ET for each lysimeter. Tables 2a through 2e show a typical computer print out of pertinent information relating to four lysimeter units. The computer is also used to plot cumulative ET graphs as shown in Figure 7. All values shown are provisional and may be revised upon additional analysis and review. None of the results should be considered as being final. The data is shown to illustrate the information being generated by this project.

The crops inside the lysimeters were cut at the same time the surrounding fields were harvested. The cuttings were dried and weighed and will be used to estimate crop yields. Figure 6 shows a crop of fescue grass being cut on a lysimeter.

SPATIAL EXTRAPOLATION OF METEOROLOGICAL DATA

Meteorological data are an essential component of all models to estimate the consumptive use of water by agriculture, reservoirs and phreatophytes in the Upper Green River Basin (UGRB). Since it is impossible to collect this data at all locations within the basin for which consumptive use estimates are needed, the data available will be extrapolated to intermediate locations of interest. This will be done through a 2-stage modeling process.

In the first stage, a model will be used to exploit the relationships between meteorological variables and physiographic information. Regression analysis will be used to detect relationships between the available meteorological data and selected physiographic features (i.e. elevation, slope, etc.). Simple statistical models will be formed to describe these relationships and to predict values of relevant meteorological variables at intermediate locations.

The second stage will refine the stage one predicted values. For those sites with data, predicted values will be compared with measured values, and a local correction factor (observed value - predicted value) calculated. The correction factor values will then be spatially extrapolated over the UGRB, and provide estimated model corrections for intermediate locations. The purpose of the spatial extrapolation procedure is to describe the weather patterns endemic to the area which could not be accounted for in the prediction model. The final estimates to be used in the consumptive use models, will be of the form

$$Y = \text{(1st stage model prediction)} + \text{(estimated model correction)}.$$

One spatial extrapolation technique (second stage of the modeling process) is illustrated in Figure 8a through 8d. Figure 8a gives the location of 10 stations within the basin for which average daily temperature values are available for June, 1983. Figure 8b gives the average daily temperatures reported at each station. Figure 8c is the map of the triangulation used to extrapolate these values. Figure 8d is the contour map of average daily temperatures for June, 1983 produced by the extrapolation program. Several numerical and statistical extrapoliation techniques will be compared in stage two of the modelling process, and the most useful one selected.

The final products of this spatial extrapolation of meteorological data will be a set of meteorological maps for the basin for each month of the year. These maps will in turn be used in the consumptive use models to produce a 30-year average consumptive use estimate for the UGRB, as well as a frequency distribution for consumptive use estimates for the basin. The frequency distribution will facilitate water use planning under unusual climatic conditions, such as in 1983, as well as under "average" conditions.

Transfer of Crop Coefficients

The determination of crop coefficient values requires direct measurement of consumptive use by the crops of interest. At present, this information is available only through lysimeter operation. Since this information has not been previously collected in the UGRB, the lysimeters installed for this project will be operated for three consecutive years to insure sufficient data for reliable crop coefficient estimation.

Once the crop coefficients have been determined at each lysimeter site for the crops of interest (mountain meadows and alfalfa), the 2-stage modeling process outlined above (see also spatial extrapolation of meteorological data) will be used to transfer these coefficients to other locations in the basin.

Basin-Wide Estimation of Consumptive Use

The spatial extrapolation of meteorological data and crop coefficients will provide the necessary input for consumptive use models at locations on a regular grid across the basin. The appropriate model (i.e. for agriculture, phreatophytes, and reservoirs) will then be applied at each grid point to get local estimates of consumptive use. A basin-wide estimate of consumptive use will be constructed from a weighted sum of these local estimates.

This procedure will be repeated using various meteorological patterns observed in the UGRB to produce a frequency distribution for basin-wide consumptive use. A graphical illustration of a consumptive use frequency distribution is given in Figure 9. Figure 9 is a histogram of the frequency distribution of estimated total ET at Big Piney as calculated from the meteorological data for 1942 through 1978.

PLANS FOR FUTURE WORK

Lysimeters and Weather Stations

Operation of the lysimeters and weather stations has been on a routine basis during the summer of 1983. The collection of data will continue in the summer of 1984 with minor modifications resulting from experience gained in the summer of 1983.

Numerical Modeling

Existing models useful for predicting agricultural water consumption in the Green River area will be put in a useful form for computer analyses. In addition, new models will be developed where necessary. Aggressive activity on the models is necessary because of the immense amount of data being collected.

UPPER GREEN RIVER BASIN

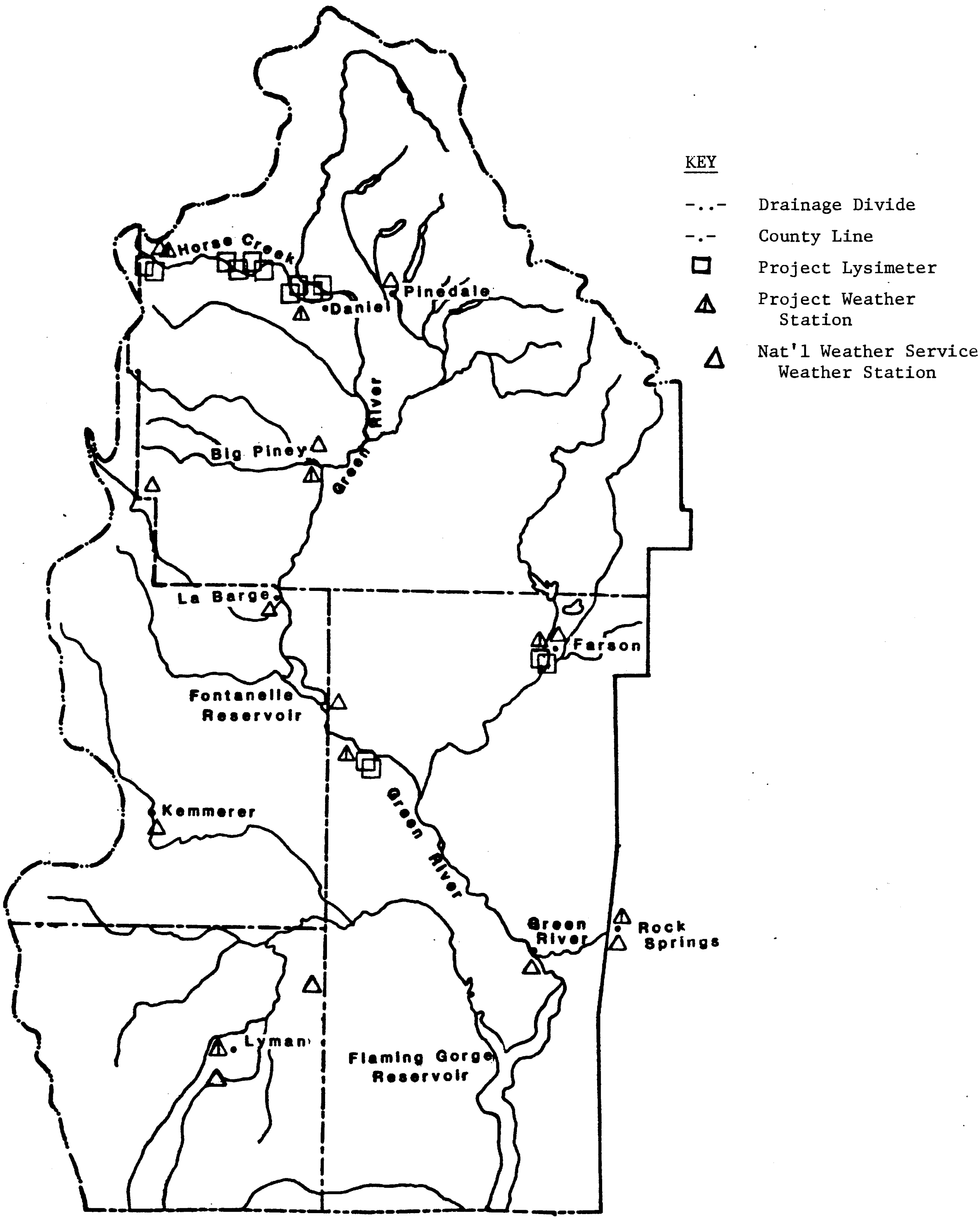

Figure 1.

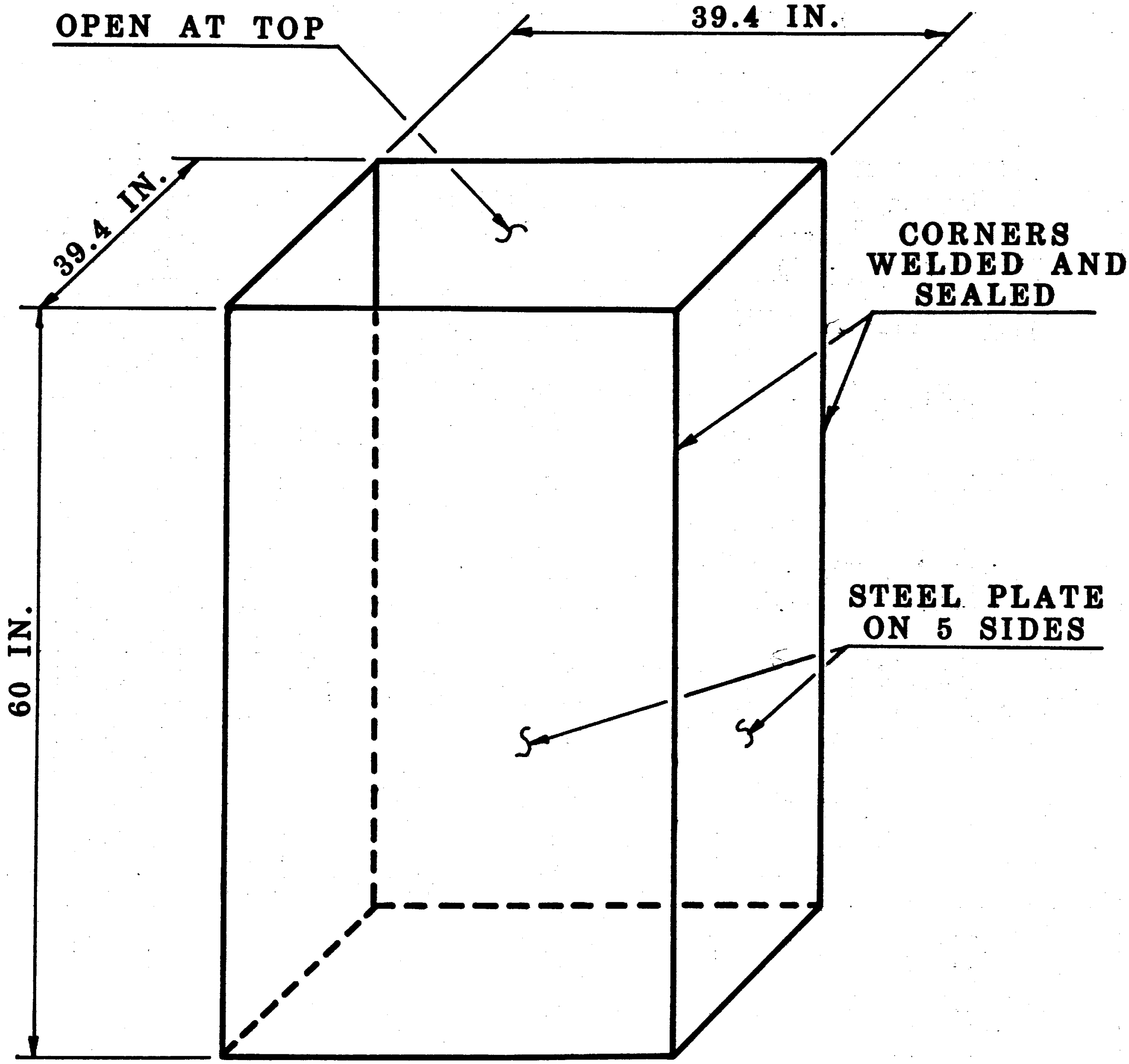

FIGURE 2A

LYSIMETER PLAN

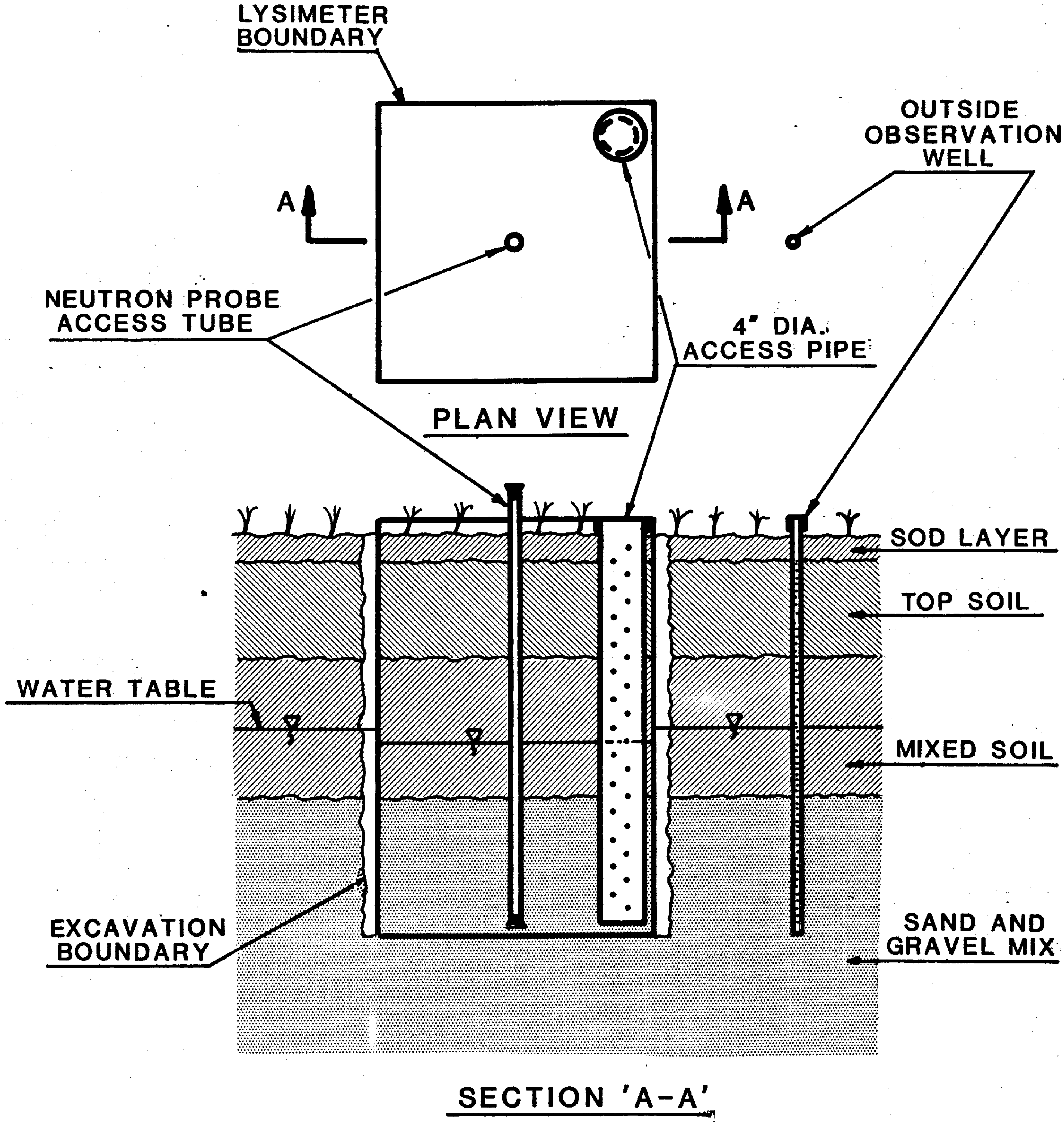

FIGURE 2B

LYSIMETER INSTALLED

Figure 3 - Adding Water to a Lysimeter

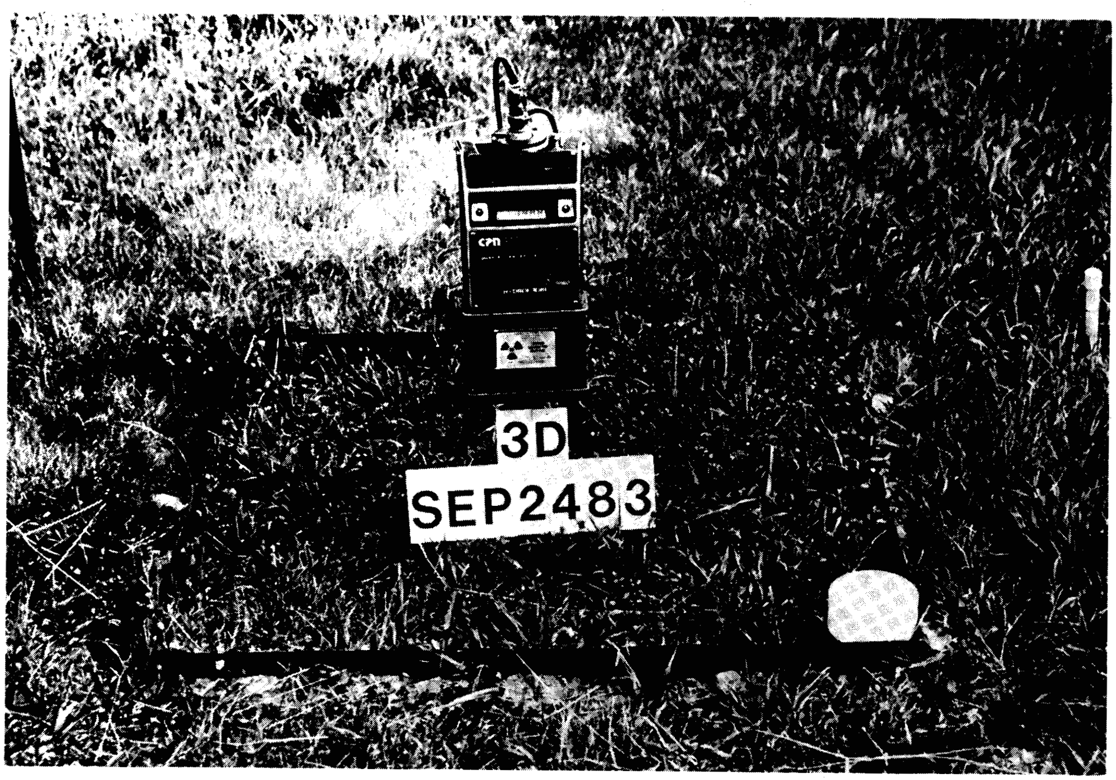

Figure 4 - Using a Neutron Soil Probe to Measure Soil Moisture

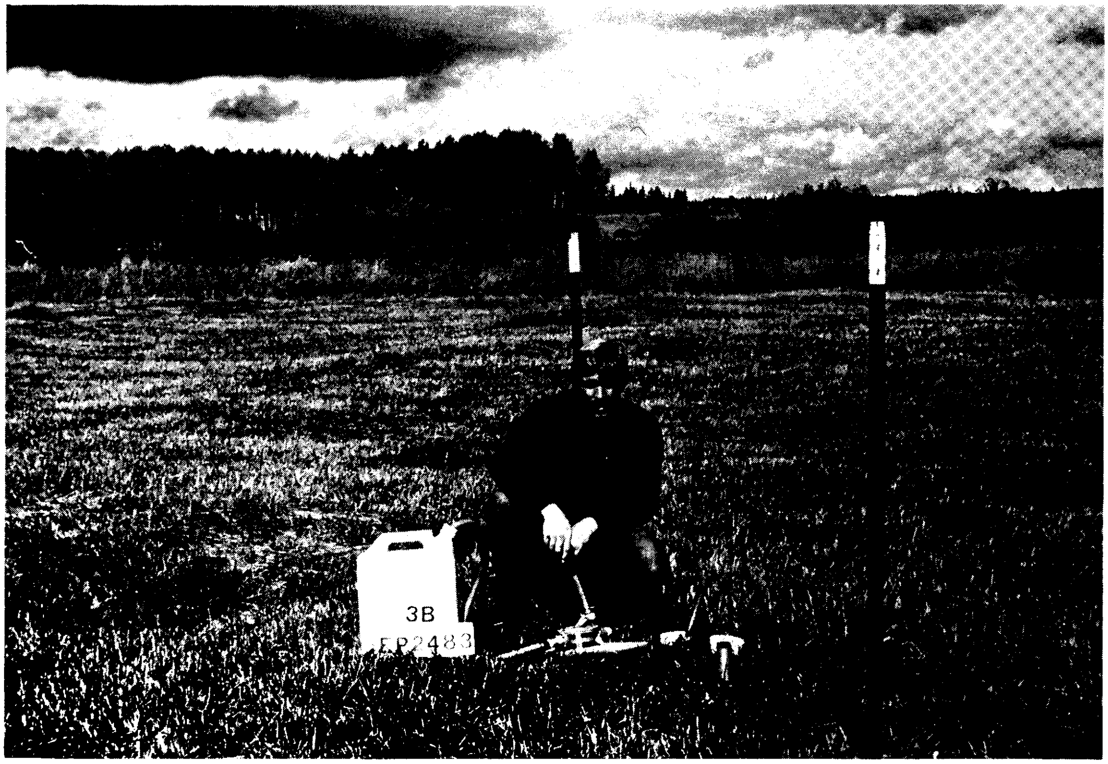

Figure 5 - Pumping Water Out of a Lysimeter

Figure 6 - Harvesting a Crop on a Lysimeter

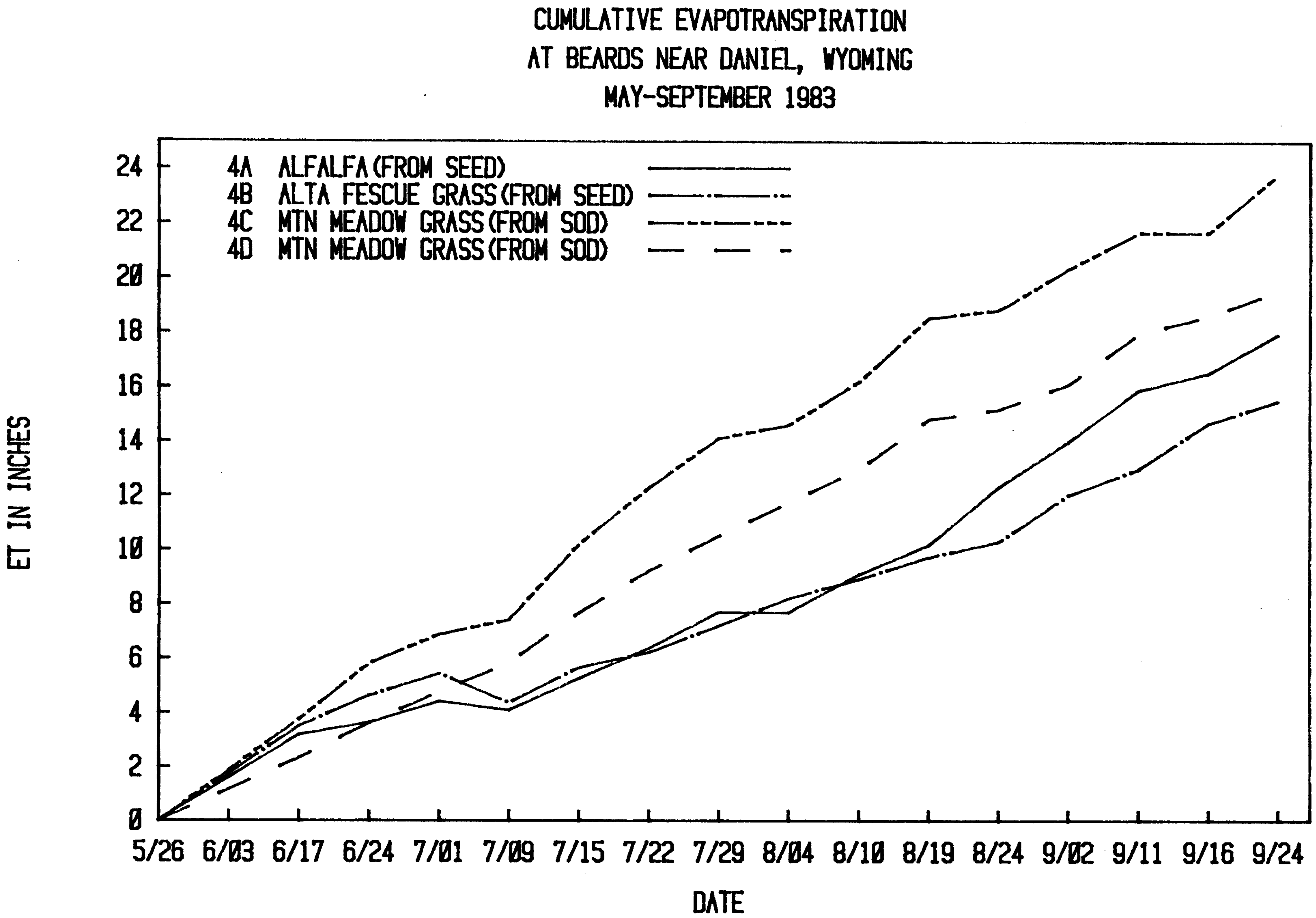
CUMULATIVE EVAPOTRANSPIRATION
AT BEARDS NEAR DANIEL, WYOMING
MAY-SEPTEMBER 1983
4A ALFALFA (FROM SEED)
4B ALTA FESCUE GRASS (FROM SEED)
4C MTN MEADOW GRASS (FROM SOD)
4D MTN MEADOW GRASS (FROM SOD)
ET IN INCHES
0
2
4
6
8
10
12
14
16
18
20
22
24
5/26
6/03
6/17
6/24
7/01
7/09
7/15
7/22
7/29
8/04
8/10
8/19
8/24
9/02
9/11
9/16
9/24
DATE

Figure 7.

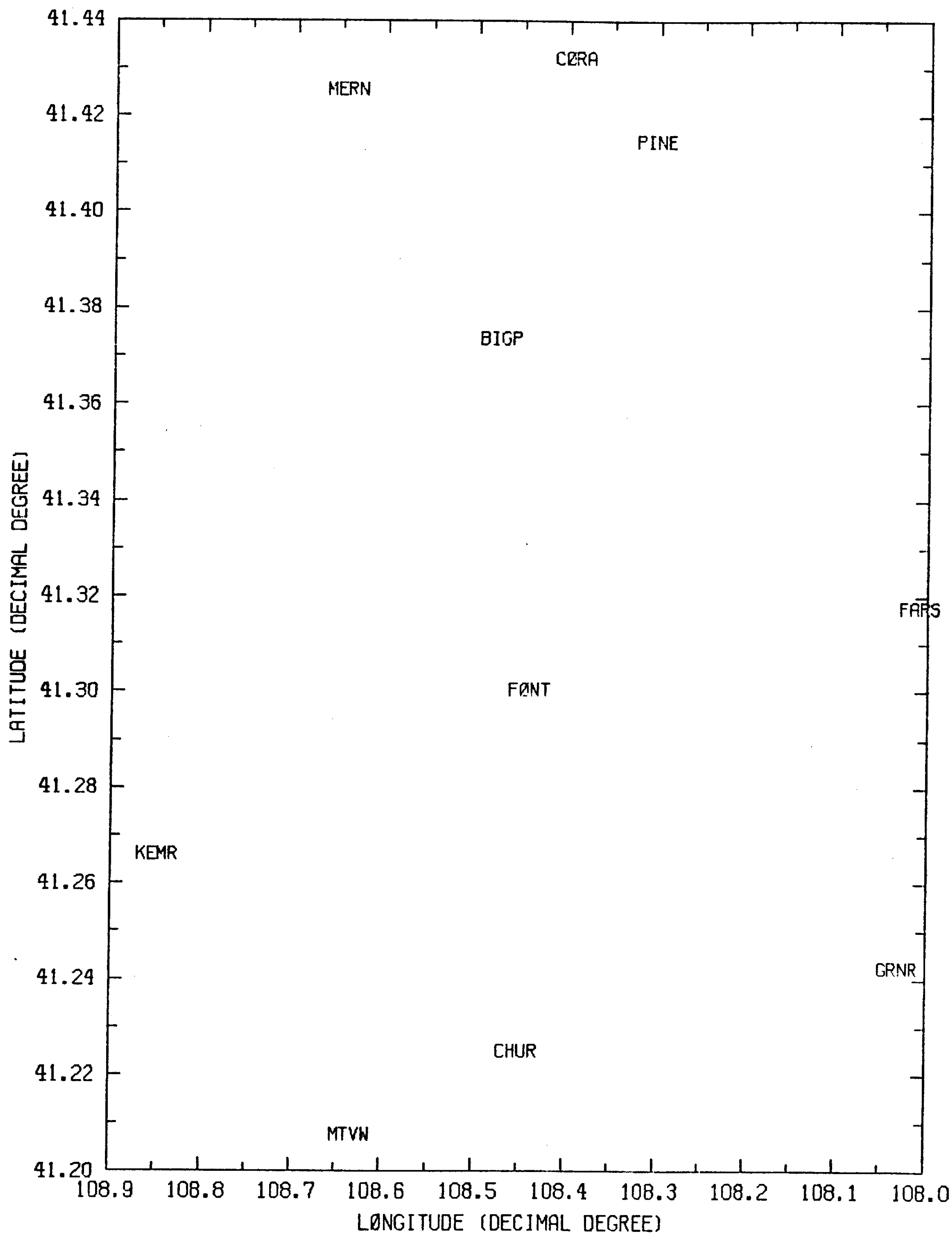

Figure 8a. Reference map of NOAA weather stations in Upper Green River Basin.

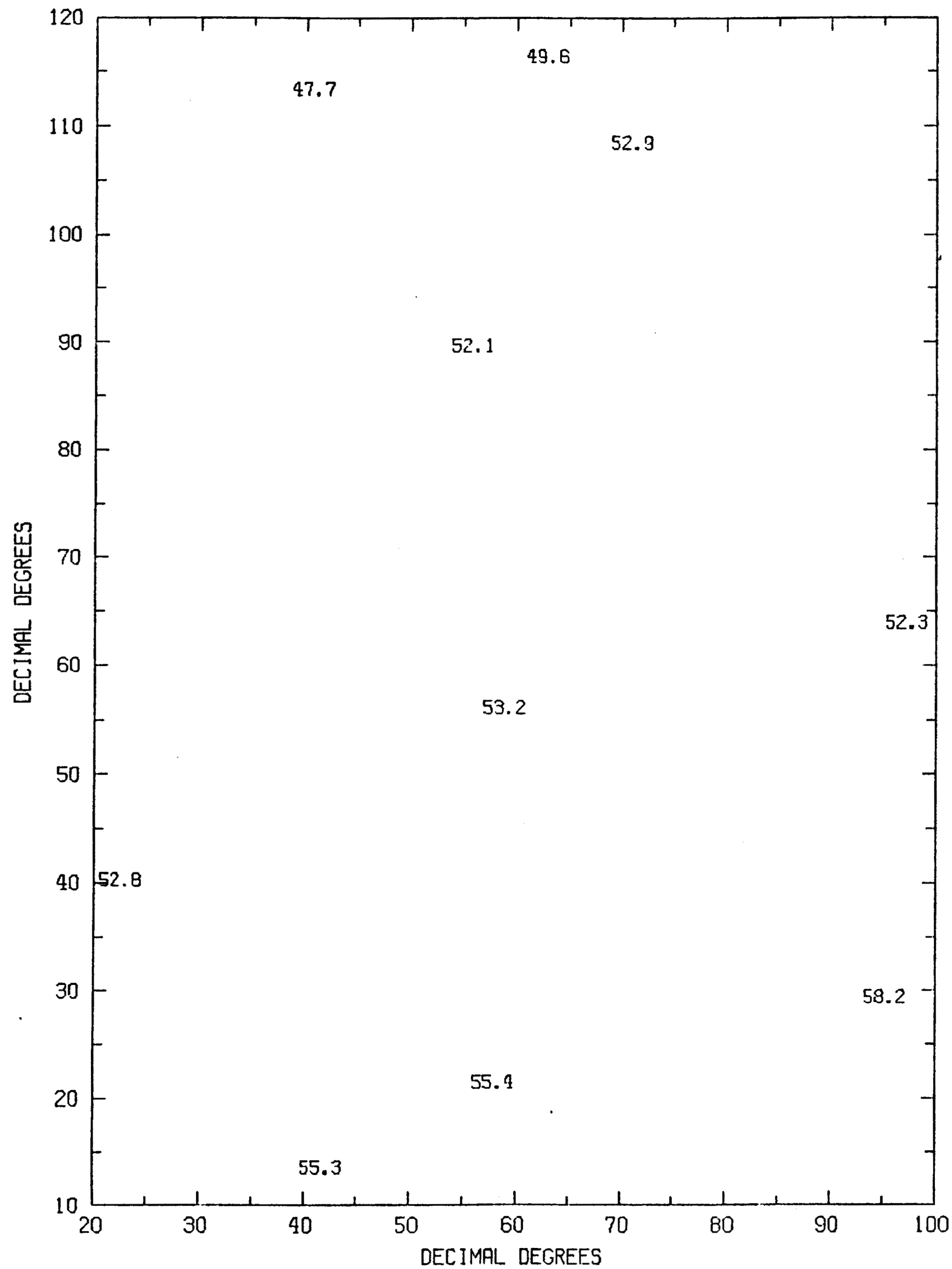

Figure 8b. Average daily temperature for June, 1983.

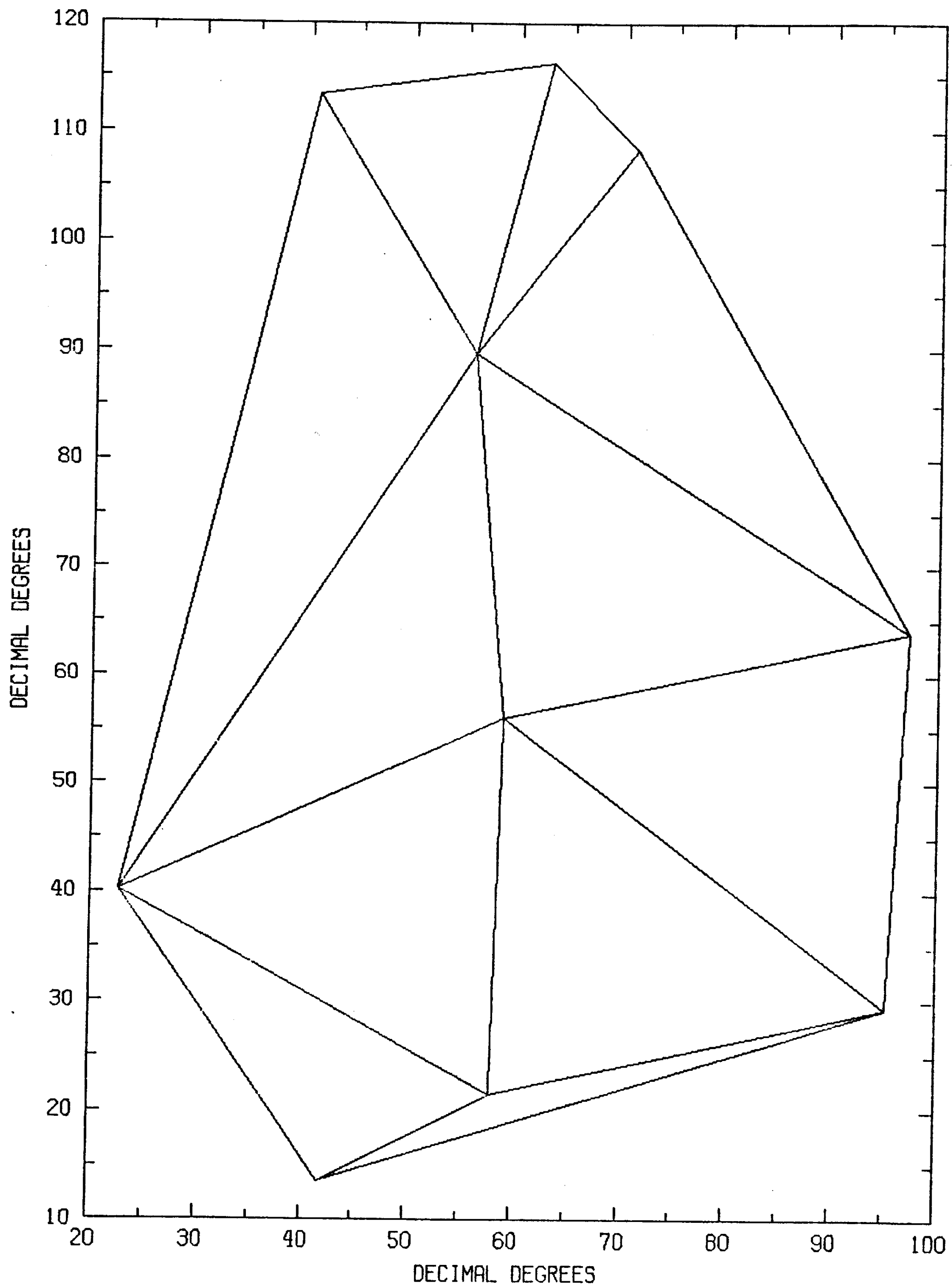

Figure 8c. Map of the triangulation used by the contouring routine.

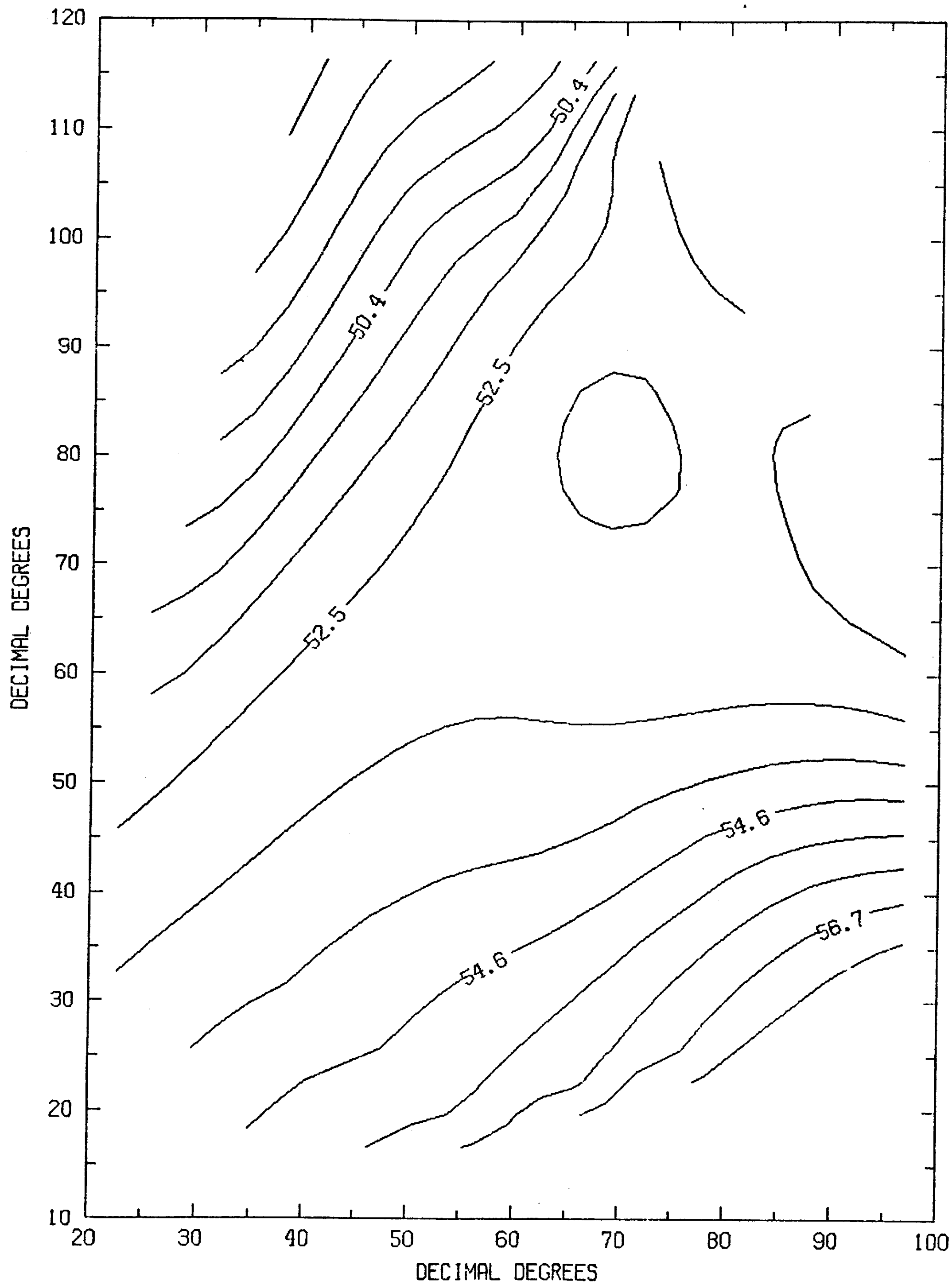

Figure 8d. Contour map of average daily temperatures for June, 1983.

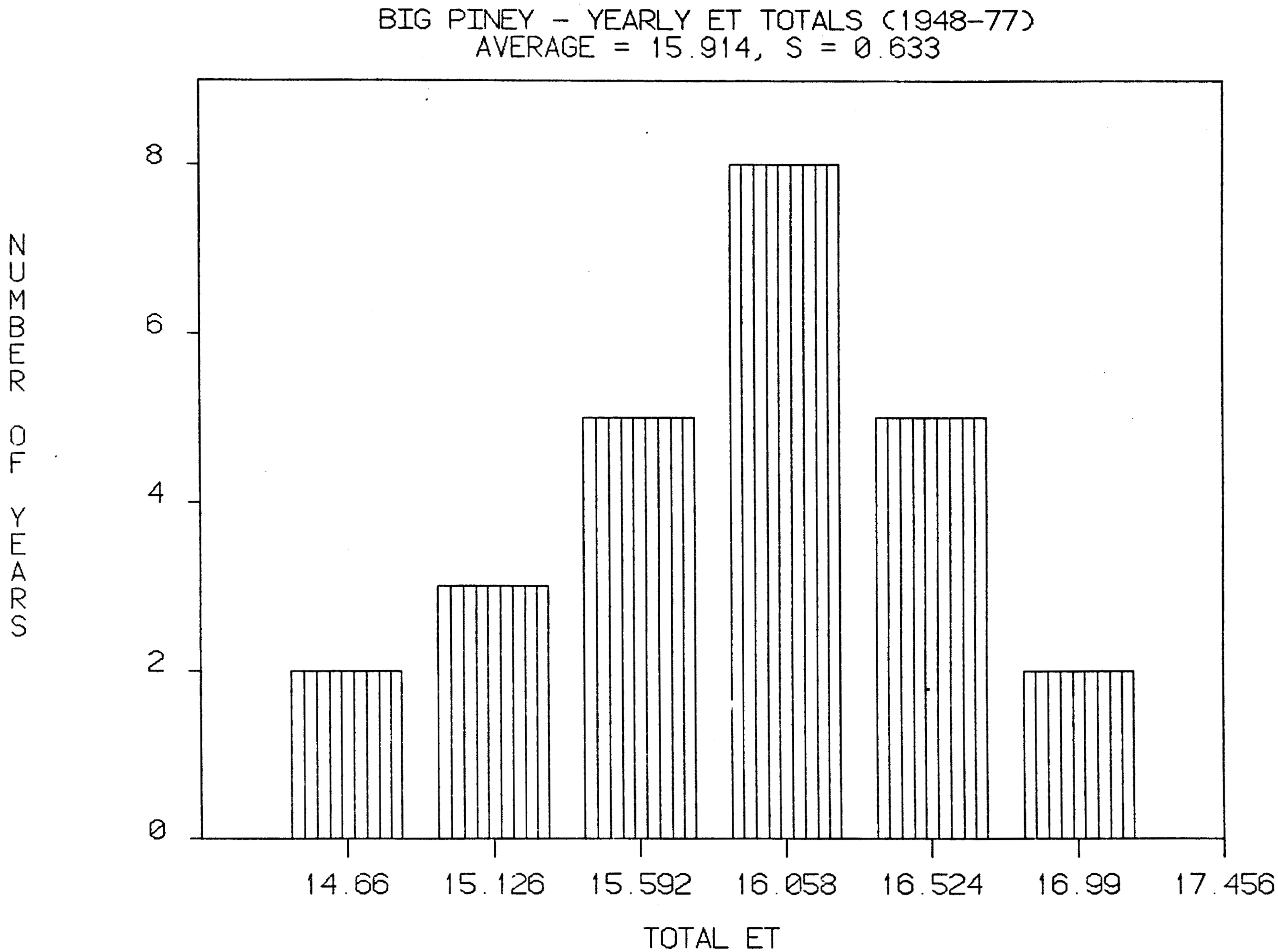
BIG PINEY - YEARLY ET TOTALS (1948-77)
AVERAGE = 15.914, S = 0.633
NUMBER OF YEARS
8
6
4
2
0
14.66
15.126
15.592
16.058
16.524
16.99
17.456
TOTAL ET

Figure 9.

3 -UPPER HORSE CREEK

DATE YR/MO/DY			RAIN TOTAL (IN)	RADTN TOTAL (LY)	TEMP MAX (F)	TEMP MIN (F)	TEMP AVG (F)	AVG RH (%)	AVG WIND (MPH)
83	8	1	.04	392	73.0	47.	58.2	86	3.5
83	8	2	.00	493	76.8	42.	59.1	76	3.2
83	8	3	.00	487	79.7	43.	60.1	75	3.2
83	8	4	.00	453	80.3	46.	61.3	75	3.2
83	8	5	.00	654	81.7	45.	63.0	66	4.0
83	8	6	.00	652	87.4	45.	65.0	61	3.3
83	8	7	.00	620	88.7	47.	66.4	61	3.5
83	8	8	.12	448	85.9	48.	62.9	73	3.6
83	8	9	.04	454	83.0	51.	62.9	82	4.1
83	8	10	.08	536	83.3	49.	63.6	76	3.6
83	8	11	.08	377	75.5	47.	59.1	88	3.1
83	8	12	.00	619	72.6	43.	57.1	69	4.2
83	8	13	.00	502	77.2	40.	56.9	74	4.2
83	8	14	.00	536	76.6	41.	57.9	69	4.2
83	8	15	.08	253	75.9	46.	58.1	81	3.6
83	8	16	.28	200	68.6	46.	55.4	98	2.9
83	8	17	.31	219	66.5	49.	56.1	98	2.9
83	8	18	.47	137	61.3	51.	55.1	100	2.6
83	8	19	.51	160	62.6	51.	55.0	100	3.2
83	8	20	.04	433	70.6	42.	56.0	87	3.5
83	8	21	.24	333	64.8	39.	50.7	93	4.3
83	8	22	.04	500	71.3	37.	52.8	80	3.3
83	8	23	.04	447	69.2	38.	51.9	75	3.7
83	8	24	.00	583	72.9	36.	53.3	65	4.2
83	8	25	.00	587	74.0	37.	54.6	68	3.5
83	8	26	.00	590	74.9	37.	54.6	59	3.9
83	8	27	.00	569	78.5	36.	55.2	55	3.7
83	8	28	.00	471	74.9	35.	53.5	59	4.3
83	8	29	.00	478	76.2	37.	52.9	75	3.6
83	8	30	.00	466	74.4	40.	54.7	73	3.4
83	8	31	.00	449	77.3	39.	55.7	70	3.1

Table 1A. Climatic Data for July 1983 from Upper Horse Creek.

STATION NUMBER 4 -LOWER HORSE CREEK

DATE YR/MO/DY			RAIN TOTAL (IN)	RADTN TOTAL (LY)	TEMP MAX (F)	TEMP MIN (F)	TEMP AVG (F)	AVG RH (%)	AVG WIND (MPH)
83	8	1	.00	426	76.7	51.	61.9	79	4.1
83	8	2	.04	465	79.9	44.	61.0	73	2.9
83	8	3	.00	564	82.3	43.	62.1	68	3.2
83	8	4	.00	459	83.1	44.	62.7	71	3.2
83	8	5	.00	641	84.3	45.	66.1	62	4.1
83	8	6	.00	646	90.7	46.	67.4	58	2.8
83	8	7	.00	629	91.2	45.	68.6	55	3.0
83	8	8	.00	523	91.7	44.	66.6	65	3.3
83	8	9	.00	461	89.3	51.	66.5	68	4.6
83	8	10	.08	554	91.4	48.	66.3	67	3.7
83	8	11	.39	443	79.4	50.	62.0	80	4.6
83	8	12	.00	618	74.8	45.	59.8	65	4.7
83	8	13	.00	436	78.2	41.	59.9	68	3.2
83	8	14	.00	541	79.3	39.	60.3	62	3.7
83	8	15	.12	320	81.9	47.	61.8	67	3.4
83	8	16	.43	324	73.9	51.	58.9	92	3.0
83	8	17	.28	302	70.3	51.	58.8	92	3.4
83	8	18	.28	152	66.1	52.	57.0	98	2.9
83	8	19	.08	195	67.9	52.	57.5	96	3.0
83	8	20	.04	392	72.1	47.	58.2	86	3.1
83	8	21	.16	345	69.7	39.	53.1	88	4.2
83	8	22	.04	544	71.6	39.	55.6	76	3.5
83	8	23	.04	571	72.9	41.	56.1	72	3.7
83	8	24	.00	594	76.3	34.	55.7	64	3.2
83	8	25	.00	542	77.0	37.	56.4	68	2.6
83	8	26	.00	581	79.6	34.	55.5	64	3.0
83	8	27	.00	568	81.2	31.	55.1	62	3.2
83	8	28	.00	447	77.2	31.	54.3	63	3.7
83	8	29	.00	480	77.5	36.	54.1	69	3.4
83	8	30	.00	497	79.1	35.	55.5	66	2.9
83	8	31	.00	523	80.5	34.	56.5	64	3.0

Table 1B. Climatic Data for July 1983 from Lower Horse Creek.

LOCATION	ID NO.	DATE YR/MO/DY	PRECIP (IN)	NET H2O ADDED (IN)	DEPTH TO WATER TABLE (IN)	PERIOD ET (IN)	PERIOD ET (CM)	AVG DAILY ET (IN)	AVG DAILY ET (CM)	SUM ET (IN)	SUM ET (CM)	MOISTURE DEPL (%)
FARSON	2A	83 6 3	0.00	0.00	33.25	0.00	0.00	0.00	0.00	0.00	0.00	-.02
	2A	83 6 18	.71	-1.40	44.00	1.33	3.39	.09	.23	1.33	3.39	10.74
	2A	83 6 25	0.00	0.00	46.75	.83	2.10	.12	.30	2.16	5.49	17.72
	2A	83 7 2	.36	.51	48.00	.78	1.98	.11	.28	2.94	7.47	13.26
	2A	83 7 9	.32	2.98	33.00	.50	1.26	.07	.18	3.44	8.73	-.40
	2A	83 7 15	.16	.76	30.75	.85	2.17	.14	.36	4.29	10.90	5.07
	2A	83 7 21	.12	1.50	28.13	1.27	3.23	.21	.54	5.56	14.13	5.37
	2A	83 7 30	.08	0.00	33.00	1.36	3.47	.15	.39	6.93	17.59	19.60
	2A	83 8 5	0.00	1.49	32.88	1.49	3.79	.25	.63	8.42	21.39	20.10
	2A	83 8 12	0.00	1.49	33.50	1.69	4.30	.24	.61	10.11	25.69	22.51
	2A	83 8 19	1.93	1.49	33.50	2.30	5.83	.33	.83	12.41	31.52	-3.03
	2A	83 8 25	.12	0.00	35.25	1.13	2.88	.19	.48	13.54	34.40	14.09
	2A	83 9 3	0.00	1.49	37.00	1.99	5.05	.22	.56	15.53	39.46	19.01
	2A	83 9 11	.47	1.63	39.25	2.43	6.17	.30	.77	17.96	45.63	18.71
	2A	83 9 16	0.00	1.49	40.50	1.85	4.70	.37	.94	19.81	50.33	21.80
	2A	83 9 24	.08	.60	44.25	1.31	3.32	.16	.41	21.12	53.64	22.39
	2B	83 6 3	0.00	0.00	23.25	0.00	0.00	0.00	0.00	0.00	0.00	.01
	2B	83 6 18	.71	-1.79	37.25	1.60	4.06	.11	.27	1.60	4.06	16.37
	2B	83 6 25	0.00	0.00	41.13	.70	1.78	.10	.25	2.30	5.84	18.25
	2B	83 7 2	.36	.66	41.25	1.03	2.61	.15	.37	3.33	8.45	18.00
	2B	83 7 9	.32	0.00	43.75	.26	.65	.04	.09	3.58	9.10	10.61
	2B	83 7 15	.16	1.27	41.50	2.00	5.08	.33	.85	5.58	14.18	26.07
	2B	83 7 21	.12	1.35	40.38	1.35	3.44	.23	.57	6.93	17.61	27.38
	2B	83 7 30	.08	0.00	47.00	1.56	3.95	.17	.44	8.49	21.57	32.89
	2B	83 8 5	0.00	1.50	48.25	1.69	4.29	.28	.72	10.18	25.86	32.51
	2B	83 8 12	0.00	2.99	46.25	2.46	6.24	.35	.89	12.64	32.10	29.67
	2B	83 8 19	1.93	2.99	44.13	3.49	8.87	.50	1.27	16.13	40.97	12.39
	2B	83 8 25	.12	1.50	39.75	1.08	2.74	.18	.46	17.21	43.71	14.33
	2B	83 9 3	0.00	1.50	47.50	2.91	7.40	.32	.82	20.12	51.11	18.18
	2B	83 9 11	.47	1.67	42.63	1.37	3.48	.17	.43	21.49	54.59	17.99
	2B	83 9 16	0.00	1.50	37.50	.71	1.81	.14	.36	22.21	56.40	18.23
	2B	83 9 24	.08	.60	40.63	1.19	3.02	.15	.38	23.39	59.42	18.64
TODD'S	3A	83 5 26	0.00	0.00	12.50	0.00	0.00	0.00	0.00	0.00	0.00	-5.61
	3A	83 6 18	.36	2.89	9.25	2.68	6.81	.12	.30	2.68	6.81	-6.69
	3A	83 6 25	0.00	0.00	16.25	1.21	3.07	.17	.44	3.89	9.88	-5.09
	3A	83 7 2	.43	1.72	5.00	1.51	3.82	.22	.55	5.40	13.71	0.00
	3A	83 7 9	.60	-.39	14.00	-.02	-.05	-.00	-.01	5.38	13.65	-19.98
	3A	83 7 16	.32	1.07	13.50	1.53	3.90	.22	.56	6.91	17.55	-13.49
	3A	83 7 22	.04	0.00	19.38	1.04	2.64	.17	.44	7.95	20.19	-10.66
	3A	83 7 30	.39	1.49	12.13	.78	1.97	.10	.25	8.73	22.16	-10.12
	3A	83 8 5	.11	.75	12.75	.92	2.34	.15	.39	9.65	24.51	-11.11
	3A	83 8 11	.37	.75	14.13	1.32	3.35	.22	.56	10.97	27.85	-11.40
	3A	83 8 19	1.30	0.00	6.00	-.20	-.50	-.02	-.06	10.77	27.35	-29.18
	3A	83 8 25	.75	-.75	11.88	1.11	2.81	.18	.47	11.88	30.16	-13.21
	3A	83 9 3	.32	-.75	27.00	.61	1.55	.07	.17	12.49	31.72	-32.08
	3A	83 9 10	.55	0.00	31.25	2.90	7.37	.41	1.05	15.39	39.08	-6.36
	3A	83 9 16	.15	0.00	35.25	.78	1.99	.13	.33	16.17	41.07	-6.68
	3A	83 9 24	.03	.30	38.13	1.45	3.67	.18	.46	17.62	44.74	.44

Table 2a. Preliminary Results for 1983 Green River Basin Evapotranspiration Study.

LOCATION	ID NO.	DATE YR/MO/DY	PRECIP (IN)	NET H2O ADDED (IN)	DEPTH TO WATER TABLE (IN)	PERIOD ET (IN)	PERIOD ET (CM)	AVG DAILY ET (IN)	AVG DAILY ET (CM)	SUM ET (IN)	SUM ET (CM)	MOISTURE DEPL (%)
	3B	83 5 26	0.00	0.00	11.25	0.00	0.00	0.00	0.00	0.00	0.00	-.01
	3B	83 6 18	.36	3.12	12.00	3.40	8.63	.15	.38	3.40	8.63	-5.91
	3B	83 6 25	0.00	0.00	19.88	1.43	3.64	.20	.52	4.83	12.27	2.85
	3B	83 7 2	.43	1.13	9.75	-.10	-.25	-.01	-.04	4.73	12.02	-3.82
	3B	83 7 9	.60	0.00	18.50	1.48	3.77	.21	.54	6.22	15.79	-9.14
	3B	83 7 16	.32	1.28	17.50	1.82	4.62	.26	.66	8.03	20.41	-1.72
	3B	83 7 22	.04	0.00	24.00	1.23	3.12	.21	.52	9.26	23.53	3.24
	3B	83 7 30	.70	1.50	16.25	.95	2.41	.12	.30	10.21	25.95	.87
	3B	83 8 5	.11	.75	17.63	1.12	2.86	.19	.48	11.34	28.80	2.36
	3B	83 8 11	.37	.75	21.00	1.66	4.21	.28	.70	13.00	33.02	3.22
	3B	83 8 19	1.30	0.00	11.75	-.29	-.74	-.04	-.09	12.71	32.27	-4.00
	3B	83 8 25	.75	-.75	19.25	1.25	3.17	.21	.53	13.95	35.44	1.52
	3B	83 9 3	.32	-.60	34.50	2.37	6.03	.26	.67	16.33	41.47	6.64
	3B	83 9 10	.55	0.00	41.00	1.67	4.23	.24	.60	17.99	45.70	7.52
	3B	83 9 16	.15	1.50	27.00	-.67	-1.69	-.11	-.28	17.33	44.01	6.35
	3B	83 9 24	.03	0.00	33.00	1.27	3.23	.16	.40	18.60	47.25	9.90
KANSKI	3C	83 5 26	0.00	0.00	39.63	0.00	0.00	0.00	0.00	0.00	0.00	-.29
	3C	83 6 18	.36	7.90	10.25	1.56	3.97	.07	.17	1.56	3.97	-23.80
	3C	83 6 25	0.00	-1.67	19.75	.57	1.44	.08	.21	2.13	5.42	-5.03
	3C	83 7 2	.43	1.70	12.50	.33	.85	.05	.12	2.47	6.27	-23.73
	3C	83 7 9	.60	.74	13.25	1.32	3.34	.19	.48	3.78	9.61	-36.39
	3C	83 7 16	.32	0.00	17.13	1.64	4.17	.23	.60	5.42	13.78	-1.28
	3C	83 7 22	.04	-1.48	25.63	.43	1.10	.07	.18	5.86	14.88	-.74
	3C	83 7 30	.70	0.00	27.75	1.52	3.87	.19	.48	7.38	18.75	11.99
	3C	83 8 5	0.00	0.00	31.50	.76	1.93	.13	.32	8.14	20.68	8.55
	3C	83 8 11	.65	0.00	35.63	1.57	3.98	.26	.66	9.71	24.66	7.82
	3C	83 8 19	1.74	0.00	34.25	.94	2.38	.12	.30	10.65	27.04	-6.25
	3C	83 8 25	.42	0.00	31.38	.20	.51	.03	.08	10.85	27.55	6.06
	3C	83 9 3	.44	0.00	34.50	1.35	3.43	.15	.38	12.19	30.98	11.89
	3C	83 9 10	1.11	0.00	34.75	.96	2.44	.14	.35	13.15	33.41	5.96
	3C	83 9 16	.57	0.00	34.75	.83	2.11	.14	.35	13.98	35.52	13.31
	3C	83 9 24	0.00	.30	34.88	.48	1.22	.06	.15	14.46	36.73	17.63
	3D	83 5 26	0.00	0.00	41.63	0.00	0.00	0.00	0.00	0.00	0.00	-.08
	3D	83 6 18	.36	5.63	20.50	1.65	4.20	.07	.18	1.65	4.20	-31.44
	3D	83 6 25	0.00	0.00	24.75	1.02	2.59	.15	.37	2.67	6.79	-16.93
	3D	83 7 2	.43	1.63	18.75	.58	1.49	.08	.21	3.26	8.27	-40.85
	3D	83 7 9	.60	1.21	16.50	.99	2.50	.14	.36	4.24	10.77	-65.19
	3D	83 7 16	.32	.65	19.00	1.66	4.22	.24	.60	5.90	14.99	-46.45
	3D	83 7 22	.04	0.00	23.13	1.01	2.57	.17	.43	6.92	17.57	-29.13
	3D	83 7 30	.70	-.76	29.50	1.86	4.72	.23	.59	8.78	22.29	-2.57
	3D	83 8 5	0.00	0.00	33.25	.96	2.44	.16	.41	9.74	24.73	4.98
	3D	83 8 11	.65	0.00	37.25	1.47	3.73	.24	.62	11.20	28.46	7.63
	3D	83 8 19	1.74	0.00	39.25	1.18	2.99	.15	.37	12.38	31.45	-7.80
	3D	83 8 25	.42	0.00	36.63	.36	.92	.06	.15	12.74	32.37	-1.77
	3D	83 9 3	.44	0.00	38.75	1.01	2.55	.11	.28	13.75	34.92	2.22
	3D	83 9 10	1.11	1.63	31.00	1.06	2.70	.15	.39	14.81	37.62	-6.60
	3D	83 9 16	.57	0.00	31.25	1.14	2.89	.19	.48	15.95	40.52	4.77
	3D	83 9 24	0.00	.30	31.75	.54	1.37	.07	.17	16.49	41.89	8.02

Table 2b. Preliminary Results for 1983 Green River Basin Evapotranspiration Study.

LOCATION	ID NO.	DATE YR/MO/DY	PRECIP (IN)	NET H2O ADDED (IN)	DEPTH TO WATER TABLE (IN)	PERIOD ET (IN)	PERIOD ET (CM)	AVG DAILY ET (IN)	AVG DAILY ET (CM)	SUM ET (IN)	SUM ET (CM)	MOISTURE DEPL (%)
	3E	83 5 26	0.00	0.00	35.13	0.00	0.00	0.00	0.00	0.00	0.00	-.08
	3E	83 6 18	.36	5.01	10.75	1.79	4.55	.08	.20	1.79	4.55	4.81
	3E	83 6 25	0.00	-1.35	22.00	.59	1.51	.08	.22	2.38	6.06	10.97
	3E	83 7 2	.43	2.64	8.50	.42	1.06	.06	.15	2.80	7.12	-25.51
	3E	83 7 9	.60	0.00	14.75	1.45	3.68	.21	.53	4.25	10.80	-19.05
	3E	83 7 16	.32	1.10	14.50	1.52	3.86	.22	.55	5.77	14.66	-12.34
	3E	83 7 22	.04	0.00	18.38	.78	1.99	.13	.33	6.56	16.65	-3.31
	3E	83 7 30	.70	.75	17.75	1.70	4.33	.21	.54	8.26	20.98	10.91
	3E	83 8 5	0.00	0.00	25.00	1.09	2.77	.18	.46	9.35	23.75	7.86
	3E	83 8 11	.65	0.00	32.38	1.91	4.86	.32	.81	11.26	28.61	9.57
	3E	83 8 19	1.74	0.00	26.13	.29	.72	.04	.09	11.55	29.33	-2.60
	3E	83 8 25	.42	0.00	22.63	.20	.52	.03	.09	11.75	29.85	6.97
	3E	83 9 3	.44	0.00	27.50	1.45	3.69	.16	.41	13.20	33.54	13.22
	3E	83 9 10	1.11	0.00	32.25	1.66	4.22	.24	.60	14.87	37.76	7.61
	3E	83 9 16	.57	0.00	32.50	.93	2.36	.15	.39	15.79	40.11	14.75
	3E	83 9 24	0.00	.30	33.75	.56	1.43	.07	.18	16.36	41.55	15.84
	3F	83 5 26	0.00	0.00	24.75	0.00	0.00	0.00	0.00	0.00	0.00	-.17
	3F	83 6 18	.36	4.72	10.50	1.83	4.65	.08	.20	1.83	4.65	-25.96
	3F	83 6 25	0.00	-1.38	22.00	.94	2.40	.13	.34	2.78	7.05	-11.61
	3F	83 7 2	.43	1.68	13.50	.16	.41	.02	.06	2.94	7.46	-31.35
	3F	83 7 9	.60	0.00	20.00	1.46	3.71	.21	.53	4.40	11.17	-35.79
	3F	83 7 16	.32	1.66	16.00	1.42	3.61	.20	.52	5.82	14.78	-34.59
	3F	83 7 22	.04	0.00	20.75	1.21	3.07	.20	.51	7.03	17.86	-19.61
	3F	83 7 30	.70	-1.50	32.75	2.69	6.84	.34	.86	9.72	24.70	9.83
	3F	83 8 5	0.00	0.00	38.13	1.20	3.05	.20	.51	10.92	27.74	10.60
	3F	83 8 11	.65	0.00	43.25	2.43	6.18	.41	1.03	13.35	33.92	21.07
	3F	83 8 19	1.74	0.00	46.00	1.02	2.59	.13	.32	14.37	36.51	1.35
	3F	83 8 25	.42	0.00	39.00	-.47	-1.18	-.08	-.20	13.91	35.33	10.42
	3F	83 9 3	.44	1.50	31.00	.36	.92	.04	.10	14.27	36.25	13.65
	3F	83 9 10	1.11	0.00	34.63	1.69	4.30	.24	.61	15.96	40.55	9.48
	3F	83 9 16	.57	0.00	34.50	.92	2.34	.15	.39	16.88	42.89	16.81
	3F	83 9 24	0.00	0.00	37.50	.89	2.25	.11	.28	17.77	45.14	20.58
BEARD'S	4A	83 5 26	0.00	0.00	21.63	0.00	0.00	0.00	0.00	0.00	0.00	-.11
	4A	83 6 17	.75	-.50	33.00	3.19	8.11	.15	.37	3.19	8.11	28.76
	4A	83 6 24	0.00	.46	32.50	.49	1.24	.07	.18	3.68	9.34	30.20
	4A	83 7 1	.16	.37	33.50	.73	1.85	.10	.26	4.41	11.19	30.91
	4A	83 7 9	.56	1.51	23.63	-.33	-.83	-.04	-.10	4.08	10.36	11.91
	4A	83 7 15	.24	.83	22.25	1.18	3.00	.20	.50	5.26	13.37	17.29
	4A	83 7 22	.04	.76	24.38	1.11	2.81	.16	.40	6.37	16.18	18.51
	4A	83 7 29	.20	0.00	29.25	1.32	3.35	.19	.48	7.69	19.53	27.10
	4A	83 8 4	.16	1.51	22.25	-.01	-.02	-.00	-.00	7.68	19.51	12.03
	4A	83 8 10	0.00	1.51	20.50	1.39	3.54	.23	.59	9.07	23.05	13.61
	4A	83 8 19	1.58	.76	10.38	1.08	2.75	.12	.31	10.16	25.80	6.95
	4A	83 8 24	.36	-1.21	30.00	2.14	5.43	.43	1.09	12.30	31.23	24.55
	4A	83 9 2	.31	.76	33.75	1.68	4.27	.19	.47	13.98	35.51	26.24
	4A	83 9 11	.91	.83	34.25	1.90	4.83	.21	.54	15.88	40.34	27.47
	4A	83 9 16	0.00	0.00	36.63	.63	1.60	.13	.32	16.51	41.94	31.33
	4A	83 9 24	0.00	0.00	41.88	1.43	3.62	.18	.45	17.94	45.56	38.67

Table 2c. Preliminary Results for 1983 Green River Basin Evapotranspiration Study.

LOCATION	ID NO.	DATE YR/MO/DY	PRECIP (IN)	NET H2O ADDED (IN)	DEPTH TO WATER TABLE (IN)	PERIOD ET (IN)	PERIOD ET (CM)	AVG DAILY ET (IN)	AVG DAILY ET (CM)	SUM ET (IN)	SUM ET (CM)	MOISTURE DEPL (%)
	4B	83 5 26	0.00	0.00	23.13	0.00	0.00	0.00	0.00	0.00	0.00	.11
	4B	83 6 17	.75	-1.26	44.25	3.50	8.88	.16	.40	3.50	8.88	22.69
	4B	83 6 24	0.00	0.00	49.50	1.14	2.88	.16	.41	4.63	11.77	26.79
	4B	83 7 1	.16	.41	51.75	.80	2.03	.11	.29	5.43	13.79	25.68
	4B	83 7 9	.56	1.51	35.63	-1.08	-2.74	-.13	-.34	4.35	11.06	14.60
	4B	83 7 15	.24	.45	36.00	1.30	3.31	.22	.55	5.66	14.37	22.94
	4B	83 7 22	.04	.60	36.13	.57	1.44	.08	.21	6.22	15.81	21.64
	4B	83 7 29	.20	0.00	39.50	.96	2.45	.14	.35	7.19	18.26	25.50
	4B	83 8 4	.16	1.50	35.63	1.00	2.54	.17	.42	8.19	20.80	24.31
	4B	83 8 10	0.00	1.50	29.75	.71	1.80	.12	.30	8.90	22.60	25.60
	4B	83 8 19	1.58	1.50	20.63	.81	2.07	.09	.23	9.71	24.67	2.36
	4B	83 8 24	.36	0.00	21.50	.57	1.44	.11	.29	10.28	26.11	5.17
	4B	83 9 2	.31	.75	24.50	1.72	4.38	.19	.49	12.00	30.48	12.41
	4B	83 9 11	.91	.81	21.00	.97	2.46	.11	.27	12.97	32.95	4.50
	4B	83 9 16	0.00	-1.05	35.00	1.68	4.28	.34	.86	14.66	37.23	22.79
	4B	83 9 24	0.00	0.00	39.00	.82	2.09	.10	.26	15.48	39.32	26.19
	4C	83 5 26	0.00	0.00	14.25	0.00	0.00	0.00	0.00	0.00	0.00	.01
	4C	83 6 17	.75	2.17	19.75	3.75	9.52	.17	.43	3.75	9.52	2.68
	4C	83 6 24	0.00	.85	25.00	2.06	5.23	.29	.75	5.81	14.76	12.05
	4C	83 7 1	.16	1.59	22.00	1.06	2.70	.15	.39	6.87	17.45	7.18
	4C	83 7 9	.56	1.50	16.00	.53	1.35	.07	.17	7.40	18.81	-12.18
	4C	83 7 15	.24	1.04	22.00	2.78	7.07	.46	1.18	10.19	25.88	6.81
	4C	83 7 22	.04	0.00	30.00	2.07	5.27	.30	.75	12.26	31.14	20.72
	4C	83 7 29	.20	0.00	35.50	1.84	4.67	.26	.67	14.10	35.81	29.82
	4C	83 8 4	.16	1.48	31.38	.50	1.26	.08	.21	14.59	37.07	24.59
	4C	83 8 10	0.00	.74	34.50	1.60	4.06	.27	.68	16.19	41.13	28.61
	4C	83 8 19	1.58	.74	36.00	2.33	5.92	.26	.66	18.53	47.06	25.04
	4C	83 8 24	.36	0.00	35.38	.31	.77	.06	.15	18.83	47.83	25.82
	4C	83 9 2	.31	.74	36.00	1.50	3.81	.17	.42	20.33	51.64	30.24
	4C	83 9 11	.91	.83	34.25	1.31	3.32	.15	.37	21.64	54.96	28.91
	4C	83 9 16	0.00	-.59	41.00	.01	.04	.00	.01	21.65	54.99	21.01
	4C	83 9 24	0.00	0.00	44.38	2.15	5.45	.27	.68	23.80	60.45	37.64
	4D	83 5 26	0.00	0.00	23.75	0.00	0.00	0.00	0.00	0.00	0.00	-.00
	4D	83 6 17	.75	1.96	17.50	2.33	5.92	.11	.27	2.33	5.92	1.67
	4D	83 6 24	0.00	.95	20.00	1.28	3.24	.18	.46	3.61	9.16	5.57
	4D	83 7 1	.16	.80	22.50	1.15	2.93	.16	.42	4.76	12.10	5.47
	4D	83 7 9	.56	1.45	17.25	1.06	2.69	.13	.34	5.82	14.78	-10.92
	4D	83 7 15	.24	.76	21.50	1.85	4.70	.31	.78	7.67	19.48	5.10
	4D	83 7 22	.04	0.00	32.13	1.53	3.88	.22	.55	9.20	23.37	15.81
	4D	83 7 29	.20	0.00	38.25	1.30	3.31	.19	.47	10.50	26.68	22.73
	4D	83 8 4	.16	1.48	34.38	1.21	3.08	.20	.51	11.72	29.76	22.89
	4D	83 8 10	0.00	.74	38.25	1.24	3.16	.21	.53	12.96	32.91	23.83
	4D	83 8 19	1.58	1.48	32.13	1.84	4.67	.20	.52	14.80	37.58	15.21
	4D	83 8 24	.36	0.00	32.13	.38	.95	.08	.19	15.17	38.54	15.47
	4D	83 9 2	.31	.74	31.25	.92	2.35	.10	.26	16.10	40.88	14.83
	4D	83 9 11	.91	.81	29.88	1.86	4.73	.21	.53	17.96	45.62	19.72
	4D	83 9 16	0.00	-.59	39.00	.65	1.65	.13	.33	18.61	47.27	23.37
	4D	83 9 24	0.00	0.00	43.50	.94	2.39	.12	.30	19.55	49.66	28.66

Table 2d. Preliminary Results for 1983 Green River Basin Evapotranspiration Study.

LOCATION	ID NO.	DATE YR/MO/DY	PRECIP (IN)	NET H2O ADDED (IN)	DEPTH TO WATER TABLE (IN)	PERIOD ET (IN)	PERIOD ET (CM)	AVG DAILY ET (IN)	AVG DAILY ET (CM)	SUM ET (IN)	SUM ET (CM)	MOISTURE DEPL (%)
SEEDSKADEE	6A	83 6 2	0.00	0.00	17.75	0.00	0.00	0.00	0.00	0.00	0.00	.02
	6A	83 6 17	.87	-1.73	33.25	2.74	6.96	.18	.46	2.74	6.96	22.00
	6A	83 6 24	0.00	-.42	37.00	.86	2.19	.12	.31	3.60	9.15	28.88
	6A	83 7 1	.32	.37	38.00	1.20	3.04	.17	.43	4.80	12.19	32.17
	6A	83 7 8	.16	1.50	32.50	.27	.69	.04	.10	5.07	12.88	28.33
	6A	83 7 16	.48	.38	34.00	1.19	3.03	.15	.38	6.26	15.91	29.05
	6A	83 7 21	0.00	1.50	41.13	2.44	6.20	.49	1.24	8.71	22.11	25.51
	6A	83 7 29	0.00	0.00	41.00	.88	2.24	.11	.28	9.59	24.35	34.03
	6A	83 8 4	0.00	1.50	42.00	2.31	5.86	.38	.98	11.89	30.21	39.67
	6A	83 8 10	.08	2.24	38.63	1.30	3.31	.22	.55	13.20	33.52	36.63
	6A	83 8 18	.32	1.80	40.38	2.53	6.44	.32	.80	15.73	39.95	37.21
	6A	83 8 24	.44	1.50	38.63	1.35	3.43	.22	.57	17.08	43.38	34.95
	6A	83 9 2	.12	2.24	40.88	2.63	6.68	.29	.74	19.71	50.06	33.21
	6A	83 9 10	1.22	1.56	30.50	.18	.45	.02	.06	19.89	50.51	25.98
	6A	83 9 16	0.00	0.00	33.75	-.86	-2.19	-.14	-.36	19.02	48.32	9.51
	6A	83 9 23	0.00	0.00	39.75	3.48	8.83	.50	1.26	22.50	57.15	35.47
	6B	83 6 2	0.00	0.00	12.13	0.00	0.00	0.00	0.00	0.00	0.00	-.08
	6B	83 6 17	.87	-.51	29.00	3.55	9.01	.24	.60	3.55	9.01	19.10
	6B	83 6 24	0.00	0.00	34.50	1.06	2.70	.15	.39	4.61	11.71	21.55
	6B	83 7 1	.32	.37	35.50	1.10	2.80	.16	.40	5.71	14.51	24.20
	6B	83 7 8	.16	1.50	30.50	1.25	3.17	.18	.45	6.96	17.68	29.21
	6B	83 7 16	.48	.44	29.50	.81	2.07	.10	.26	7.77	19.75	30.16
	6B	83 7 21	0.00	1.49	31.63	2.04	5.19	.41	1.04	9.82	24.93	32.07
	6B	83 7 29	0.00	0.00	48.75	4.64	11.79	.58	1.47	14.46	36.72	43.08
	6B	83 8 4	0.00	1.49	50.00	2.06	5.23	.34	.87	16.52	41.95	45.30
	6B	83 8 10	.08	2.24	48.25	1.54	3.90	.26	.65	18.05	45.85	42.29
	6B	83 8 18	.32	2.68	46.25	1.51	3.85	.19	.48	19.57	49.70	33.78
	6B	83 8 24	.44	2.98	30.25	-.24	-.60	-.04	-.10	19.33	49.10	26.41
	6B	83 9 2	.12	.75	42.38	3.54	8.99	.39	1.00	22.87	58.09	31.62
	6B	83 9 10	1.22	1.76	34.63	1.01	2.57	.13	.32	23.88	60.65	25.90
	6B	83 9 16	0.00	0.00	47.00	3.04	7.71	.51	1.29	26.92	68.37	33.28
	6B	83 9 23	0.00	.94	53.50	4.31	10.96	.62	1.57	31.23	79.33	48.13

Table 2e. Preliminary Results for 1983 Green River Basin Evapotranspiration Study.