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EVAPOTRANSPIRATION FROM HETEROGENEOUS MOUNTAIN MEADOWS

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ABSTRACT

The evapotranspiration rates of irrigated mountain meadow grasses were measured using non-weighing lysimeters during the 1979 and 1980 growing seasons. The lysimeters were located in a line across the Little Laramie River Valley near Laramie, Wyoming. The 1967 version of the Blaney-Criddle method for estimating evapotranspiration was calibrated using the lysimeter data (USDA, SCS, 1967).

Lysimeters 1, 2, 3, 8, and 9 were located in areas that were not irrigated. However, the E_t rates measured by lysimeters 2, 3, and 9 were as great as E_t rates measured by lysimeters in the irrigated portion of the mountain meadows. The high water table in these non-irrigated areas provided an extra source of water. The return flows from irrigated areas appeared to provide the bulk of the ground water.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

Very intense competition exists for the obvious limited water supplies in the western United States. There is every likelihood that the demand for water will continue to increase in the future. Irrigated mountain meadows are an integral part of many ranching operations and lie upstream from growing urban areas and industries. The location of irrigated mountain meadows plus the relatively low value of crops produced make water right transfers from agriculture to municipal and industrial use a common occurrence in Wyoming and Colorado. Western water laws limit these transfers to historic consumptive use or evapotranspiration. Research reported in this paper is intended to better estimate evapotranspiration from heterogeneous irrigated mountain meadows. It should be noted that the only consistent thing about irrigated meadows are their unusual variability as to soils, vegetation, and irrigated water applications.

Extent of the Problem

Mountain meadows represent a significant amount of the irrigated area in the United States. Lewis (1957) estimated that there are 5,540,000 hectares in the eleven Western states. For the purposes of this paper, mountain meadows are defined as high altitude irrigated grassland usually ranging from 1,500 meters to 3,000 meters in elevation above sea level. The grasses in these meadows are usually native and the composition depends upon long term moisture and fertility regimes maintained in the fields. Rushes and sedges tend to dominate in very wet sites and timothy, bluegrass, and other grasses appear in drier sites. Often weeds are significant in the composition (Siemer and Rumberg, 1975). Currently there are many improved mountain meadows containing such species as Garrison creeping foxtail, smooth brome, and Regar brome grasses.

Since meadows are generally located in alluvial valleys that flow out of mountainous areas, the soils are highly variable and often shallow. The shallow soils result in limited water holding capacity as well as problems if the land is not level. There are seldom up-stream storage facilities and as a result available water supplies coincide with snowmelt, with little late season water available. The water supply is diverted from streams by temporary dikes and crude diversion structures. Irrigation water is generally distributed to the field through open, unlined ditches. Field applications are generally made by the wild flood method. There has been an increase in the use of side-roll sprinkler systems for the irrigation of mountain meadows. However, the use of the popular center pivot has been limited due to the size and shapes of most fields found in mountainous areas.

Previous Research

Modern evapotranspiration measurements began in 1959 when the Agricultural Research Service (in cooperation with the Nevada State Department of Conservation and Natural Resources) installed nine plastic membrane lysimeters or tanks in the Humbolt River area near Winnemucca, Nevada. These were non-weighing tanks 10 feet square by 7 feet deep; the soil was removed and replaced for the installation.

A float system was used to maintain a desired water table and soil moisture changes above the water were evaluated by means of a neutron meter. Results are described by Dylla and Muckel (1964). Dylla and Muckel apparently had difficulty in establishing stands of dominate forage crops which were bluejoint, saltgrass, and sedges. Impure grass stands, soil moisture control, and salt accumulation were all problems.

Serious measurements did not begin until 1962 when a constant 4 foot water table was maintained. In the 1963 growing season the water table was changed to follow the surrounding field conditions. Natural water table field conditions vary from near the surface to over 7 feet in winter months. Dylla and Muckel (1964) felt that differences in water use are primarily due to the variation of plant density and growth. They then presented linear regression equations which relate water use to hay production.

During the period 1967 to 1971, major studies to better define evapotranspiration from mountain meadows were carried out in Nevada, Colorado, and Wyoming. Studies involved mountain meadows through a wide range of climatic conditions. Results from all of these studies were summarized by Burman, Rechard, and Munari (1975).

The Nevada mountain meadow studies from 1967 through 1969 appear to be a continuation of a series of evapotranspiration investigations dealing with mountain meadows and forage crops (Dylla, Stuart and Michener, 1972). The late 1960's studies involved the same three native grasses (bluejoint, saltgrasses, and sedges) which were sodded into 12 non-weighing steel tanks 5 feet in diameter and 6.5 feet deep. Weighing lysimeters were installed to measure evapotranspiration losses from two domestic forage grasses--tall wheatgrass and alta fescue.

The native grasses and domestic grasses were subjected to a variable water table regime in which a 2 foot water table was maintained in May, then a 1 foot water table for June after which the water table depth was allowed to decline to a 4 foot depth. In addition, a fairly conventional surface irrigation treatment was also imposed; irrigations were applied so that the soil moisture tension at the 9 inch depth did not exceed 9 atmospheres. Dylla, Stuart and Michener (1972) report that meadow evapotranspiration may be estimated satisfactorily by a combination theory and the Oliver methods. They did not recommend Blaney-Criddle coefficients. Fescue and wheatgrass both used more water than typical mountain meadow species, but had a higher water use efficiency because of greater forage production.

Grable et al. (1966) published results indicating that the addition of fertilizer to mountain meadows influenced evapotranspiration only to a minimal extent. Kruse and Haise (1974) used one meter square by 0.4 meter deep water table lysimeters to obtain evapotranspiration measurements at Gunnison and in the South Park areas of Colorado. Some of their studies involved both fertilized and unfertilized lysimeters. Their data do not permit making a clear distinction between evapotranspiration from fertilized and unfertilized areas. The unfertilized areas used about 96 percent of the water used by the fertilized areas if an unusually high use in 1971 is neglected. Measurements were made on lysimeters containing a sedge-rush sod mixture obtained from waterlogged areas and a bluegrass sod typical of drier sites. During summer months when the data were collected, the water table depths in the lysimeters were maintained at a constant depth throughout the season, and usually were within the top 10 inches of the ground surface. It is not possible to differentiate between vegetative types and water table depths regarding evapotranspiration. The report of Kruse and Haise (1974) is very well documented and presents considerable data. They compared measurements with estimates using the Blaney-Criddle, Jensen-Haise, and Penman methods as well as evaporation from U.S. Class A pans.

Inflow-outflow measurements were made for three years with measurements of evapotranspiration using meter square by 0.46 meter deep, galvanized metal lysimeters (Swartz, Burman, and Rechard, 1972). The lysimeters contained disturbed soil, were sodded with native sod, and had a continuous water table near the surface maintained by a float system. A pair of lysimeters was located near the upper end of the irrigated area surrounding the Medicine Bow River in Wyoming, a second pair was near the lower end, and a pair was near Laramie, Wyoming. The project report compares lysimeter evapotranspiration measurements with streamflow depletions and evapotranspiration measurements using Blaney-Criddle and Jensen-Haise methods. The report indicates the need for local calibration in estimating methods and makes recommendations for calibrations of various equations.

Objectives of Study

The overall objectives of this study were to obtain evapotranspiration data for mountain meadows under various water table conditions and to calibrate the Blaney-Criddle formula (USDA, SCS, 1967) so that it could be used to make estimates of evapotranspiration of mountain meadows in Wyoming.

These objectives were accomplished by the installation of non-weighing lysimeters in mountain meadows along a line across the Little Laramie River Valley near Laramie, Wyoming. The operation of these lysimeters used the variable water table depths actually occurring in the field and a neutron soil moisture probe to measure changes in soil moisture.

CHAPTER 2

FIELD MEASUREMENT OF EVAPOTRANSPIRATION

Nine non-weighing lysimeters were installed during the summer of 1978 along a line across the Little Laramie River approximately 20 miles west of Laramie, Wyoming (Figure 1). The lysimeter locations range from dry native prairie to improved irrigated hay meadows. The lysimeter sites were chosen so that the evapotranspiration rates measured by the lysimeters would be representative of the various field conditions in the valley.

Lysimeter Construction

The nine lysimeters used in this study were constructed of 0.5 cm fiberglass (Figure 2). They were constructed by a local fabrication shop and were tested by filling with water and found to be leak-free.

The dimensions of all the lysimeters were 1.0 m by 1.0 m by 1.3 m in depth. A 0.8 cm thick fiberglass-covered wooden reinforcement ring was built into the top outside edge of each lysimeter for increased strength. Fiberglass was used in the construction of the lysimeters because of its low cost and durability.

Soil moisture inside the lysimeters was monitored with a neutron soil moisture probe and the necessary access tubes were 4.0 cm diameter steel pipes, 1.3 m long. A 10 cm diameter PVC perforated pipe connected to a 1.3 m vertical section of 15 cm diameter PVC pipe was used as a drainage and access well system in each lysimeter. Fine mesh nylon screen was glued to the perforations to keep sand and soil out of the access well.

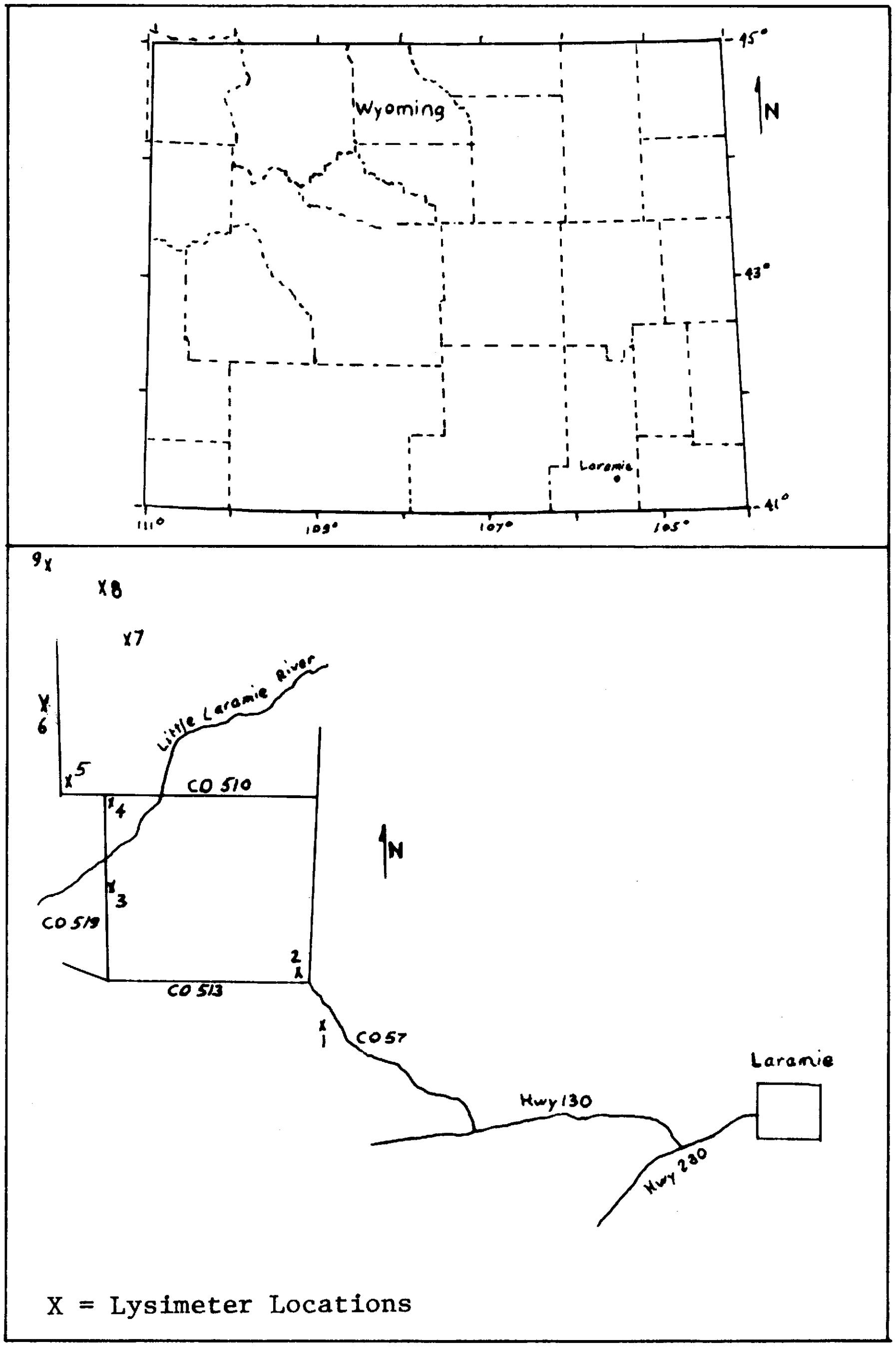

Figure 1. Lysimeter Location Maps

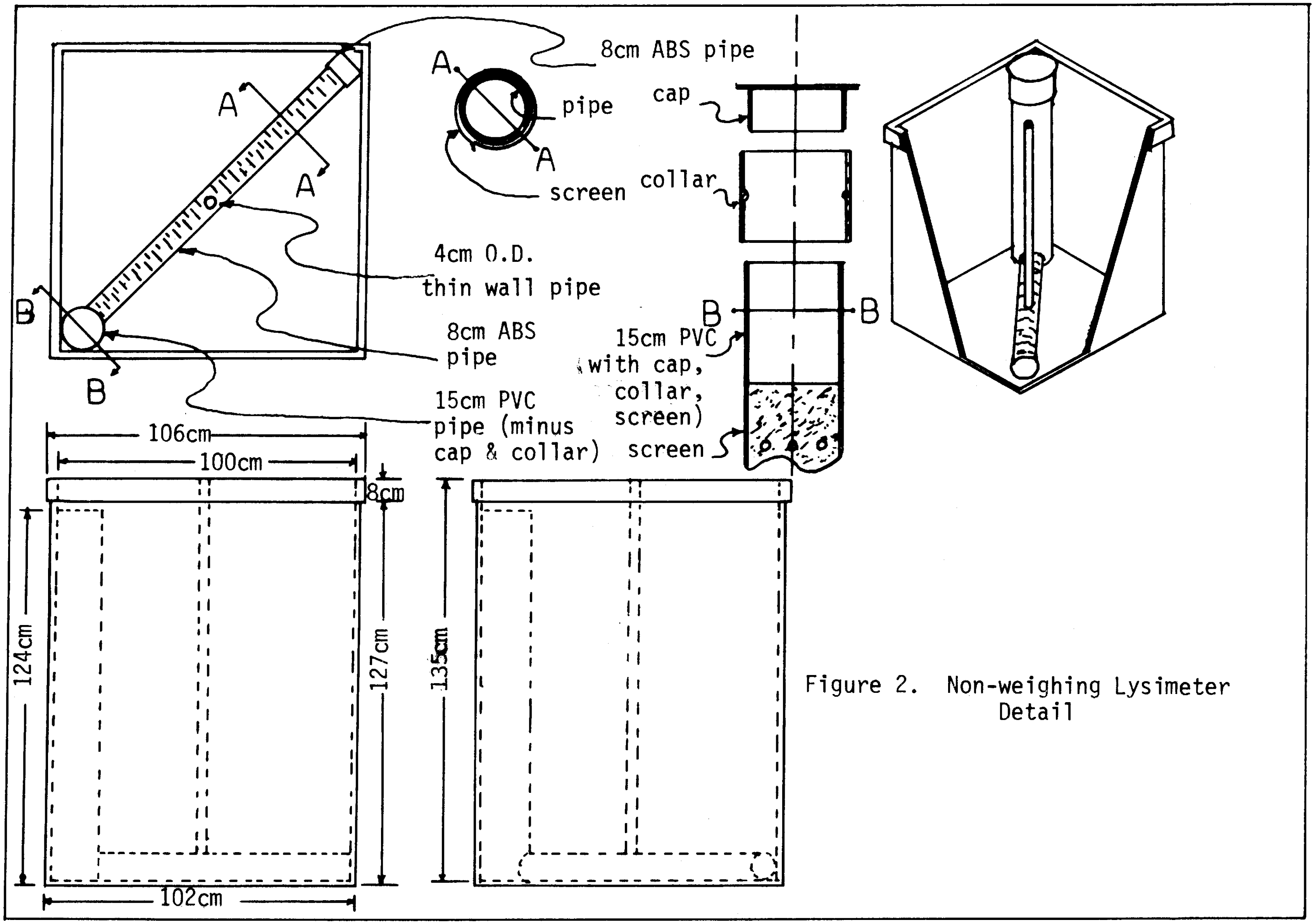

Figure 2. Non-weighing Lysimeter Detail

Lysimeter Installation

The lysimeters used in this project were installed in the field by hand excavating a hole approximately 1.3 m deep and slightly larger than the outside dimensions of the lysimeter. The vegetative cover on the installation sites was carefully removed by cutting it into blocks which extended below the root mat. These blocks were then set aside and watered daily. Plastic sheets were placed around the hole to protect the surrounding grasses from the soil removed as the hole was dug. As digging proceeded, each different soil area was placed on a separate area on plastic sheets in the order that it was removed from the hole. A portable pump was used to keep dry the holes that were dug in the high water table areas.

After a hole was excavated to the proper depth and size, an empty lysimeter was placed in it and leveled. The access well system and the neutron probe access tube were put into place in the lysimeter and were covered with layers of pea gravel and washed sand, each layer being 12 cm thick. Each lysimeter was filled with the soil which had been excavated from that hole. The layers of soil were placed in the lysimeter and carefully compacted so that surrounding natural conditions could be simulated as closely as possible. The sod blocks were then placed on top of the compacted soil in the lysimeter and kept well watered until the grass was well established. Lysimeter No. 7 (Figure 1) was seeded with Garrison's creeping meadow foxtail at the request of the rancher in whose field it was located. The sod removed from the site of Lysimeter No. 7 was not placed in the lysimeter.

Piezometers to measure the water table depths of surrounding meadows were placed in lysimeter sites 2, 3, 4, and 5 during the same summer. Monitoring of all lysimeters began in May of 1979.

<u>Lysimeter Operation</u>

Lysimeters operated during the course of this study were monitored on a weekly basis. If it was not possible to monitor during a given week, measurements were made at the beginning and end of the next. The lysimeters were operated on a weekly basis to avoid effective precipitation problems encountered by Kruse and Haise (1974) who operated lysimeters on a daily basis and to make sure they were adequately irrigated.

The first measurement taken when monitoring the lysimeter was the distance from the surface of the lysimeter to the water table inside it. The distance to the water table in the field surrounding the lysimeter was then measured at those lysimeters with outside water table piezometers. The amount of rainfall since the last time the lysimeter was monitored was then recorded.

After the water table and rainfall measurements were made, a neutron soil moisture probe was used to determine the amount of soil moisture in the lysimeter's soil above the water table. Measurements were taken every 15 cm in the lysimeter starting at 15 cm below the surface and stopping 105 cm below the surface. If the water level inside the lysimeter was above 105 cm, the soil moisture measurements were stopped at the 15 cm interval just above the water level. For example, if the water table inside one of the lysimeters was 50 cm below the surface, soil moisture measurements would be taken at 15, 30, and 45 cm.

After these soil moisture measurements were taken, water was added or removed from the lysimeter to maintain a water level the same as that in the surrounding field. The amount of water that was added or removed was estimated by finding the difference between the water depth inside the lysimeter and in the field. This difference was then multiplied by the area of the lysimeter to obtain the volume of water needed to be added or removed if the lysimeter had no soil inside it. This volume was multiplied by the appropriate specific yield of the lysimeter. This number was then converted to liters and rounded off to the nearest whole liter and that volume of water was either added or removed from the lysimeter as necessary. A small portable hand pump and a 20 liter bottle calibrated in liters was used to remove water from the lysimeters. If water was added, it was measured to the nearest whole liter and poured on the surface of the lysimeter to simulate rainfall or irrigation. The water which was added to the lysimeters in the Little Laramie River Valley was tap water from the City of Laramie. Water was brought to the lysimeters rather than using local irrigation sources which contain an excess of salts, to avoid salt build-up problems in the lysimeters. Since the lysimeters were watertight, there was no deep percolation water inside and salt concentration introduced by local irrigation water tended to build up in the soil during high water table periods.

CHAPTER 3

ANALYSES OF DATA

The research project described herein was designed to measure consumptive use on a transect across a typically irrigated mountain meadow. Lysimeters were placed in sites having the natural variations in vegetation and water table depth expected in a mountain meadow. Lysimeters were installed in sites ranging from a dryland range site with no discernible water table to one located in the center of the valley having a water table of 30 cm in May. The sites are described in the Appendix. Lysimeter sites on the edge of the irrigated areas were probably influenced by advection when the surrounding rangeland was dry late in the growing season.

Calculation of Evapotranspiration

Evapotranspiration was calculated from field data by using the following water balance equation:

$$E_t = P + W_a - W_r \pm \Delta S \pm \Delta SM$$

where:

E_t = evapotranspiration during a given measurement period.

P = precipitation since the last time the lysimeter was monitored.

W_a = water added to the lysimeter the last time the lysimeter was monitored.

W_r = water removed from the lysimeter the last time the lysimeter was monitored.

ΔS = change in the amount of water in storage inside the lysimeter since the last time the lysimeter was monitored.

ΔSM = change in soil moisture inside the lysimeter since the last time the lysimeter was monitored.

The change in the amount of water in storage inside the lysimeter was determined by measuring the distance to the water table inside each time the lysimeter was monitored. The difference between two successive water level measurements multiplied by the specific yield of each lysimeter was the change in the water storage. The specific yields for each lysimeter are shown in Table 1.

The amount of soil moisture found inside a lysimeter was calculated in two parts. The first part consisted of taking readings with a Campbell Pacific Nuclear Corporation neutron probe. These readings were then converted to centimeters of soil moisture by using the factory calibration curve supplied by the probe manufacturer. The total soil moisture measured using the neutron probe was determined by summing all of the soil moisture measurements made at 15 cm intervals.

The second part of the soil moisture determination consisted of calculating the total soil moisture found in each lysimeter. This was accomplished by adding the soil moisture measurement found using the neutron probe to the soil moisture present between the lowest neutron probe reading and the water level inside the lysimeter. The amount of moisture present between the water table and neutron soil moisture probe measurements was assumed to be the same amount of moisture in the soil as when the soil was at field capacity. Field capacity and specific yield of the soil at each lysimeter was found by measuring the level of water table in the lysimeter, removing a known quantity

Table 1. Specific Yield of Lysimeter Soil

Lysimeter No.	Specific Yield
1	0.087
2	0.087
3	0.080
4	0.130
5	0.130
6	0.080
7	0.080
8	0.087
9	0.087

of water, waiting several days, and then measuring the water table again. Lysimeters were covered during the measurement period to avoid water losses due to evapotranspiration.

Evapotranspiration calculation would proceed as in the following example:

Measurement period: May 25–June 1 (seven days)

Precipitation: P = 3.35 cm

Water added: W_a = 40 L

W_a = 4.1 cm (40,000 cm^3/surface area of the lysimeters in cm^2)

Water removed: W_r = 0.0

Depth of water in lysimeter on May 25: 57 cm

Depth of water in lysimeter on June 1: 23 cm

Change in storage: ΔS = change in water x specific yield of lysimeter

$\Delta S = 23 - 57 \times 0.3 = -10.1$ cm

(storage increased)

Soil moisture in lysimeter on May 25: 9.5 cm

Soil moisture in lysimeter on June 1: 4.4 cm

Change in soil moisture: $\Delta SM = 9.5 - 4.4 = 5.1$ cm

(soil moisture decreased)

$E_t = P + W_a - W_r \pm \Delta S \pm \Delta SM$

$E_t = 3.35 + 4.1 - 0 - 10.1 + 5.1$

E_t = 2.45 cm for the measurement period

$E_t = 2.45/7 = 0.35$ cm per day

Use of Computer Program

A computer program was written to facilitate the calculation of evapotranspiration during each measurement period. The program was designed to calculate the amount of soil moisture present at the time a lysimeter was monitored and then determine the E_t rate between lysimeter monitoring periods. A data file containing the information obtained each time the lysimeters were monitored was developed as a separate part of the program. This allowed the amount of data placed in the file to expand without changing the evapotranspiration program each time more field data were added.

The methods of calculating soil moisture and evapotranspiration rates that were previously discussed were used in the computer program.

CHAPTER 4

CALIBRATION OF BLANEY-CRIDDLE COEFFICIENTS

The lysimeters were installed in the summer of 1978 and evapotranspiration data were not immediately collected because one season was needed to enable the vegetation to recover from the shock of transplanting. Data were collected during the 1979 and 1980 seasons.

Monthly values of E_t were determined from rainfall, water added or removed, and soil moisture data using a soil moisture balance. All precipitation was regarded as being 100 percent effective. The maximum weekly precipitation was 4.11 cm.

Data from the two years are presented in the following tables: (1) the general location description (Table 2); (2) the measured monthly evapotranspiration rates for 1979 and 1980 (Table 3); (3) the average water table depth in each lysimeter (Table 4) - the lysimeters were 127 cm in depth; and (4) the average monthly temperatures (Table 5).

The measured E_t rates for lysimeters 3, 4, 5, and 6 for 1979 and 1980 are shown in Table 6. The evapotranspiration rates cover the same period during each year. Presented in Table 7 are the cutting dates for those lysimeters that were harvested.

Blaney-Criddle Method

Shown in Table 8 are the calibrated crop growth stage coefficients (k_c) for the SCS (1967) version of the Blaney-Criddle method of estimating evapotranspiration. The SCS (1967) version of the

Blaney-Criddle formula is:

$$u = 2.54\ k_t k_c f \tag{1}$$

in which:

u = the consumptive use (or E_t) for the month, in centimeters;

k_t = a coefficient related to temperature;

k_c = a crop growth stage coefficient for the month; and

f = a consumptive use factor.

The coefficient k_t is related to temperature by:

$$k_t = 0.0311t + 0.240 \tag{2}$$

in which:

t = the mean temperature for the month, in degrees centigrade.

The consumptive use factor f is defined as:

$$f = \frac{(1.8t + 32)p}{100} \tag{3}$$

in which:

p = the monthly percentage of daytime hours of the year.

Calibration of the formula consisted of calculating k_c values for each month (or portion of the month) using the averages of the measured consumptive use and temperature data over one or two seasons. It should be noted that k_c also contains a meteorological component and does not totally represent the crop which in this case is various types of mountain meadow vegetation (Jensen, 1974).

Table 2. Location Descriptions

Location:	Laramie, Wyoming
Latitude:	41°19'N
Longitude:	105°41'W
Elevation (m):	2195
Mean annual precipitation (cm):	25.4
Mean annual temperature (°C):	4.9
Average frost free period (days):	113

Table 3. Measured Evapotranspiration from Lysimeters on Little Laramie River (cm)

Month	Lysimeter No. (1979 Measurements)								
	1	2	3	4	5	6	7	8	9
May 14-31	*	*	5.3	6.8	13.3	4.1	*	*	*
June			17.4	17.7	17.6	11.1			
July			14.1	20.4	16.0	16.0			
August			9.6	16.2	10.5	11.5			
September			9.0	13.7	9.2	7.1			
October 1-13			2.1	4.2	1.8	3.1			
	(1980 Measurements)								
May 2-31	7.8	2.8	12.0	6.6	8.4	7.0	8.6	14.2	15.7
June	6.0	11.0	19.0	18.0	21.2	13.5	15.0	10.8	11.3
July	1.5	27.3	18.0	13.0	19.6	14.2	19.3	9.0	16.0
August	1.5	20.2	7.0	8.0	6.7	11.0	10.9	2.8	18.2
Sept 1-18	4.9	10.0	5.0	25.0**	2.8	7.5	8.0	0.8	5.6

*Data were collected but not used because the vegetation was judged not to be representative of the surrounding vegetation.

**This data point seems unreasonably high but the error (if real) cannot be explained at this time.

Table 4. Average Monthly Lysimeter Water Table Depth (cm)

Month	Lysimeter No. (1979 Measurements)								
	1	2	3	4	5	6	7	8	9
May 14-31			44	61	45	83			
June			37	50	29	72			
July			74	63	52	103			
August			111	75	72	118			
September			115	95	82	124			
October 1-13			125	112	102	126			
	(1980 Measurements)								
May 2-31	"none"	101	46	51	32	117	63	41	36
June	"none"	116	60	69	47	104	76	72	103
July	"none"	119	92	76	60	87	86	97	106
August	"none"	117	105	103	92	101	97	105	111
Sept 1-18	"none"	114	100	102	104	99	106	105	104

Table 5. Mean Monthly Temperatures (°C)

Month	1979	1980
May	8.5	8.1
June	13.4	15.5
July	17.6	19.0
August	16.3	16.5
September	14.4	13.2
October	10.6	-

Table 6. Comparative Evapotranspiration Rates (cm)

Month	Lysimeter No.							
	3		4		5		6	
	1979	1980	1979	1980	1979	1980	1979	1980
May 14-31	5.3	7.0	6.8	3.9	13.3	4.9	4.1	4.1
June	17.4	19.0	17.7	18.0	17.6	21.2	11.1	13.5
July	14.1	18.0	20.4	13.0	16.0	19.6	16.0	14.2
August	9.6	7.0	16.2	8.0	10.5	6.7	11.5	11.0
Sept 1-18	5.4	5.0	8.2	25.0	5.5	2.8	4.3	7.5
Total	51.8	56.0	69.3	67.9	62.9	55.2	47.0	50.3

Table 7. Clipping Dates for Lysimeters

Lysimeter	3	Not Cut*
	4	9-8-79
	5	8-10-79
	6	8-10-79
Lysimeter	1	Not Cut
	2	Not Cut
	3	Not Cut
	4	7-23-80
	5	7-23-80
	6	7-9-80
	7	6-11-80
	7	7-16-80
	8	Not Cut
	9	Not Cut

*Lysimeters were cut when the surrounding fields were harvested.

Table 8. Crop Growth State Coefficients (k_c)

Month	Lysimeter No.								
	1	2	3	4	5	6	7	8	9
May	1.42	0.51	1.86*	1.63*	2.68*	1.33*	1.56	2.58	2.85
June	0.54	0.98	1.78	1.74	1.90	1.20	1.34	0.96	1.01
July	0.10	1.90	1.17	1.22	1.30	1.10	1.34	0.63	1.11
August	0.13	1.78	0.74	1.08	0.77	1.00	0.96	0.25	1.61
September**	1.31	2.15	1.07	3.42***	0.85	1.21	1.72	0.44	1.20

*For the period May 14-31.
**For the period September 1-18.
***This data point seems unreasonably high but the error (if real) cannot be explained at this time.
NOTE: Lysimeters 1, 2, 7, 8, and 9 have only one year of data and lysimeters 3, 4, 5, and 6 have two years of data.

Discussion of Results

The purpose of the detailed description of the vegetation in each lysimeter is to allow one to select k_c values that most closely approximate the vegetation for the mountain meadows of which they are concerned. Past studies of mountain meadows have considered them to be composed of "grass". Certainly they are a diverse vegetative ecosystem that must be mapped for their vegetative composition in order to refine estimates of their evapotranspiration rates. Such refinements are necessary as irrigation waters from these areas are transferred to municipal and industrial uses.

Lysimeters 1, 2, 3, 8, and 9 were located in areas that were not irrigated. However, the E_t rates measured by lysimeters 2, 3, and 9 were as great as E_t rates measured by lysimeters in the irrigated portion of the mountain meadows. The high water table in these non-irrigated areas provided an extra source of water. The return flows from irrigated areas appeared to provide the bulk of the ground water. Thus, any water transferred from these areas should consider the decrease in E_t from areas adjacent to the irrigated lands. In most western states, only the portion of the water right consumptively used can be transferred.

CHAPTER 5

SUMMARY

The main objective of this research project was to obtain evapotranspiration data for mountain meadows under various water table conditions and to calibrate the Blaney-Criddle formula (USDA, SCS, 1967) so that the data collected could be extended to other locations. Mountain meadow E_t rates were obtained through the monitoring of nine non-weighing lysimeters which were placed across the Little Laramie River Valley near Laramie, Wyoming.

Lysimeters in areas that were not irrigated showed that non-irrigated vegetation adjacent to meadows can use as much water as irrigated meadows. Even Lysimeter No. 8, which was predominantly weeds, used almost as much water as an irrigated meadow. Thus, when transferring water from mountain meadows to other uses, it is necessary to consider the water used by vegetation adjacent to the irrigated areas.

Mountain meadows are heterogeneous in their vegetative composition. Different species predominate depending on the availability of water, soil, fertility, and other factors. Each species begins rapid growth, matures, has different heights, and produces different amounts of dry matter. Thus, it is only natural that the evapotranspiration rates will vary according to vegetative composition. This paper presents the results of an experiment designed to determine the evapotranspiration rates from various vegetative compositions within an irrigated mountain meadow.

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APPENDIX

VEGETATION TYPES FOUND IN EACH LYSIMETER

Lysimeter No. 1

Western wheatgrass*	*Agropyron smithii*
Prairie junegrass	*Koeleria cristata*
Needle and thread	*Stipa comata*
Sandburgs bluegrass	*Poa secunda*
Fringe sage	*Artemesia frigidea*
Cactus	*Echinocactus*
Sweet clover	*Melilotus alba*
Blue grama	*Boutelova gracilis*

The lysimeter was located within typical rangeland pasture outside of irrigated valley.

Lysimeter No. 2

Western wheatgrass	*Agropyron smithii*
Foxtail barley	*Hordeum jubatum*
Crested wheatgrass	*Agropyron cristatum*
Fringe sage	*Artemesia frigidea*
Japanese brome	*Cosia scoperia*
Sweet clover	*Bromos japonicus*
Mustard	*Melilotus alba*
Petter grass	*Descurainia rechard sonii*
Prickly pear	*Lepidium ramosissimun*
Opuntia fragilis	

The lysimeter is at a disturbed site near the intersection of two county roads. The native prairie is found to the south and an irrigated mountain meadow is found to the northeast. A water table at about 1 m is found in the area.

Lysimeter No. 3

Slender wheatgrass	*Agropyron trachycavlum*
Sweet clover	*Melilotus alba*
Canby bluegrass	*Poa cangyi*
Foxtail barley	*Hordeum jubatum*
Nuttalls alkaligrass	*Puccinellia airoides*
Alpine timothy	*Phelum alpinum*
Dandelion	*Taraxacum lyratum*
Pepper grass	*Lepidium ramosissimun*

*The vegetation is ranked with the most numerous specie being listed first.

Lysimeter No. 3 (continued)

Pussytoes	_Antennaria alpina_
Alpine timothy	_Phelum alpinum_

The area surrounding the lysimeter receives both surface and subsurface irrigation water. Visual evidence of salt is apparent.

Lysimeter No. 4

Dandelion	_Taraxacum lyratum_
Kentucky bluegrass	_Poa pretensis_
Meadow death camas	_Zigadenus elegans_
Common timothy	_Pheum pratense_
Smooth brome	_Bromus inermis_
Sweet clover	_Melilotus officinalis_
Canada thistle	_Cirsium arvense_

This lysimeter appears to represent an improved mountain meadow with the vegetative composition having both timothy and smooth bromegrass. A good supply of water seemed to be available.

Lysimeter No. 5

Common timothy	_Phelum pratense_
Smooth brome	_Bromus inermis_
Dandelion	_Taraxacum lyratum_
Common orchardgrass	_Dactylis glomerata_
Foxtail barley	_Hordeum jubatum_

This lysimeter represents an excellent improved mountain meadow. The field produces up to 4 tons per acre compared to a county average of just over one ton per acre.

Lysimeter No. 6

Common timothy	_Phelum pratense_
Lamb's quarters	_Chenopodium album_
Kentucky bluegrass	_Poa pretensis_
Montana wheatgrass	_Agropyron albicans_
Wild iris	_Iris missouriensis_

The lysimeter represents a mountain meadow that was harvested by grazing. However, the vegetation in the lysimeter was clipped rather than grazed.

Lysimeter No. 7

Garrison creeping meadow foxtail	_Alopecurus geniculatus_
Mustard	_Descurainia richardsonii_
Foxtail barley	_Hordeum jubatum_

This lysimeter was seeded with Garrison creeping meadow foxtail.

Lysimeter No. 8

Foxtail barley	_Hordeum jubatum_
Mustard	_Taraxacum lyratum_
Lamb's quarters	_Chenopodium album_
Canby bluegrass	_Poa canbyi_
Western wheatgrass	_Agropyron smithii_
Kentucky bluegrass	_Poa pratensis_
Plantago	_Plantago eriopoda_
Nuttalls alkaligrass	_Poccinellia airoides_
Colorado wildrye	

The lysimeter site was near a hay stack. The area was generally grazed late in the season.

Lysimeter No. 9

Western wheatgrass	_Agropyron smithii_
Nuttalls alkaligrass	_Puccinella airoides_
Plantago	_Plantago eriopoda_
Pepper grass	_Lepidium ramosissimun_
Foxtail barley	_Hordeum jubatum_
Fringe sage	_Artemesia frigidea_

This lysimeter seems to represent the fringe of the irrigated valley. Irrigation is not practiced but the water table is generally about 1 m in depth.