

CONSUMPTIVE USE OF WATER
the **IRRIGATED AREAS**
of the
UPPER COLORADO RIVER BASIN
(Provisional)

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IRRIGATION ENGINEER
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April 1949

ed under the direction of George D. Clyde, Chief
Division of Irrigation and Water Conservation

UNITED STATES DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE-Research
H. H. BENNETT, Chief SOIL CONSERVATION SERVICE M. L. NICHOLS, Chief of RESEARCH

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TABLE OF CONTENTS

	<u>Page</u>
INTRODUCTION	1
GENERAL CHARACTERISTICS OF UPPER COLORADO RIVER BASIN	2
Agriculture	2
Soils	3
Climate	4
OTHER INVESTIGATIONS	4
Studies in Other Areas	5
Upper Colorado River Basin Studies	6
Current Studies in Utah	7
GENERAL PROCEDURE	7
Consumptive Use Coefficients	8
Climatological Data	8
IRRIGATION PRACTICES	10
Method of Obtaining Data	13
General Description of Practices	13
Arizona	14
Colorado	14
New Mexico	15
Utah	15
Wyoming	15
ESTIMATES OF RATES OF CONSUMPTIVE USE	16
Irrigated Crops	16
Native Vegetation and Incidental Areas	27
APPLICATION OF CONSUMPTIVE USE RATES	28
Valley Areas	28
Farm Irrigation Requirements	33
REFERENCES	37
APPENDIX	39
Upper Colorado River Basin Compact	48

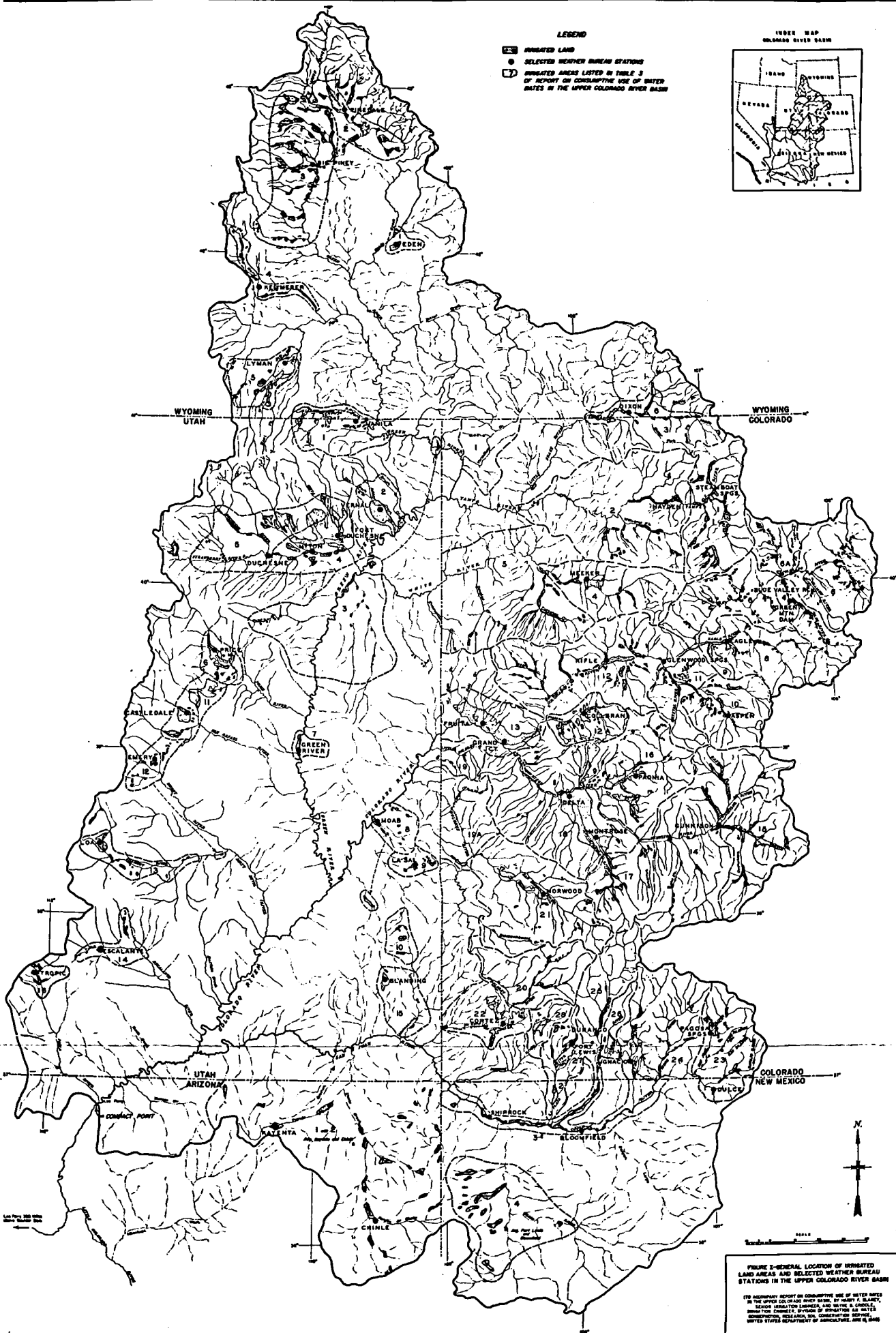
LIST OF TABLES

	<u>Page</u>
1. Coefficients used in computing consumptive use of water in the Upper Colorado River Basin	9
2. Average annual precipitation, mean annual temperature and frost-free period at Weather Bureau stations used in computing consumptive use in the Upper Colorado River Basin	11
3. Irrigated areas, Weather Bureau stations, and irrigation periods utilized in computing consumptive use of irrigation water in Arizona, Colorado, New Mexico, Utah and Wyoming	18
4. Example of observed monthly temperatures, precipitation percent of daytime hours and calculated consumptive use factor in the Upper Yampa and Elk River areas of the Upper Colorado River Basin	21
5. Example of computations of rates of consumptive use of water in the Upper Yampa and Elk River areas of the Upper Colorado River Basin	22
6. Summary of estimates of normal unit consumptive use of water rates for irrigated crops during the irrigation period for areas in the Upper Colorado River Basin	23
7. Summary of estimates of normal unit consumptive use of water rates minus precipitation by irrigated crops through the irrigation period for areas in the Upper Colorado River Basin	25
8. Summary of estimates of normal unit consumptive use of water rates for native vegetation and areas receiving water incidentally to irrigation in the Upper Colorado River Basin	29
9. Summary of estimates of normal unit consumptive use of water rates minus precipitation for native vegetation and areas receiving water incidentally to irrigation in the Upper Colorado River Basin	31
10. Average consumptive use of water in the Lower Uncompahgre Valley, Colorado, 1938-41, computed by the integration method	34
11. Application of results of consumptive use calculations to a determination of water requirement of a typical farm, Grand Junction Area, Colorado	35
12. Application of results of consumptive use calculations to a determination of water requirement of a typical ranch, Pinedale Area, Wyoming	36

LIST OF TABLES

APPENDIX

	<u>Page</u>
A. Consumptive use coefficients for alfalfa based on measured consumptive use and temperature records, and percent of daytime hours and growing season in Western States.	40
B. Examples of consumptive use coefficients for native vegetation and evaporation based on measured consumptive use and temperature records, and percent of daytime hours and growing season	41
C. Average monthly evaporation and meteorological data, Montrose Colorado 1939 to 1943	42
D. Mean monthly temperatures in degrees Fahrenheit at stations in the Upper Colorado River Basin, recorded or estimated from Weather Bureau records for the period 1914 to 1945	43
E. Mean monthly precipitation, in inches, at stations in the Upper Colorado River Basin, recorded or estimated from Weather Bureau records, for the period 1914 to 1945	45
F. Daytime hours in mean solar time, (Sunrise to Sunset) with percentages for each month of the year for latitudes within the Upper Colorado River Basin	47



LEGEND

- IRRIGATED LAND
- SELECTED WEATHER BUREAU STATIONS
- IRRIGATED AREAS LISTED IN TABLE 3 OF REPORT ON COMPARATIVE USE OF WATER DATES IN THE UPPER COLORADO RIVER BASIN

INDEX MAP
COLORADO RIVER BASIN



FIGURE 2—GENERAL LOCATION OF IRRIGATED LAND AREAS AND SELECTED WEATHER BUREAU STATIONS IN THE UPPER COLORADO RIVER BASIN

FOR NECESSARY REPORT ON COMPARATIVE USE OF WATER DATES IN THE UPPER COLORADO RIVER BASIN, BY HARVEY S. BLANCH, SENIOR CONSULTING ENGINEER, AND WALTER B. LINDLEY, SENIOR CONSULTING ENGINEER'S ASSISTANT, IN WATERS, IRRIGATION, RECLAMATION, SOIL CONSERVATION SERVICE, UNITED STATES DEPARTMENT OF AGRICULTURE, APRIL 1948

Consumptive Use of Water in the Irrigated Areas of the Upper Colorado River Basin

INTRODUCTION

One of the important elements in the cycle of water movement from the time it falls on the land as rain or snow until it reaches the ocean, is evapo-transpiration or consumptive use of water. This subject is increasingly significant, particularly in the irrigated regions of the West. It involves problems of the water supply, both surface and underground, as well as those of the management and general economics of irrigation projects. It has become a highly important factor in the arbitration of controversies over major stream systems where the public welfare of valleys, States, Federal projects, and even nations is involved. One such stream is the Colorado River, which drains parts of seven western states and flows into Lower California, Mexico.

Before the available water resources and an equitable division of the use of the waters of a drainage basin can be satisfactorily ascertained, careful consideration must be given to the consumptive-use requirements for water in various sub-basins. At the request of the Upper Colorado River Basin Compact Commission, representing the states of Arizona, Colorado, New Mexico, Utah and Wyoming and the Federal government, a brief study was made of water consumption in the Upper Colorado River Basin. After a field inspection of the irrigated areas in the Basin with representatives of the Engineering Advisory Committee of the Commission, and numerous conferences with local leaders and water users in each area, a preliminary report was submitted on consumptive use of water rates (8). Information contained in this report was used in drafting the compact which has been ratified by the legislatures of the respective states and the U. S. Congress (20). The assistance rendered by this committee, the United States Bureau of Reclamation, State and other agencies and by individuals is hereby gratefully acknowledged.

From a valley-wide standpoint, consumptive use includes all transpiration and evaporation losses from lands on which there is growth of vegetation of any kind, whether agricultural crops or native vegetation, plus evaporation from bare land and from water surfaces (4) (2). The term "consumptive use" is considered synonymous with the term "evapo-transpiration" and is defined (2) as: The sum of the volumes of water used by the vegetative growth of a given area in transpiration or building of plant tissue and that evaporated from adjacent soil, snow, or intercepted precipitation on the area in any specified time. If the unit of time is small, such as a week or a month, the consumptive-use rate is expressed in acre-inches per acre or depth in inches; whereas, if the unit of time is large, such as a crop-growing season or a 12-month period, the consumptive use rate is usually expressed as acre-feet per acre or depth in feet. The sources of water to supply consumptive use are precipitation, surface and ground water.

The purpose of this report is to present the results of the study of the rates of water consumption at sites of use by

agricultural crops and natural vegetation in various irrigated areas of Arizona, Colorado, New Mexico, Utah and Wyoming in the Upper Basin. The authors were confronted with the problem of determining, within a limited time, the unit normal consumptive use of water in valley areas extending several thousand miles along the Upper Colorado River and its tributaries. Procedures developed in the Pecos River Joint Investigation (2) and other studies throughout the West were employed. Because of the limited measurements of consumptive use in the Upper Colorado River Basin, estimates of unit consumptive use by various agricultural crops and natural vegetation and evaporation from water surfaces, are based primarily on studies in other areas of the West, transferred to the Upper Colorado River Basin through relationships established empirically between measured consumptive use and climatological data. (7) (5).

GENERAL CHARACTERISTICS OF UPPER COLORADO RIVER BASIN

The Upper Colorado River Basin is that area tributary to the Colorado River above Lee Ferry. This area is larger than New York, Pennsylvania and New Jersey combined. It includes parts of five Rocky Mountain States (Arizona, Colorado, New Mexico, Utah and Wyoming), as shown in figure 1.

Rimmed by some of the highest mountains in America that are snowcapped throughout the year, it is the source of the greater part of the water reaching the Colorado River.

Agriculture

In the Upper Basin livestock farms predominate. According to the Bureau of the Census, in 1939, livestock and livestock products accounted for 75 percent of the total value of the products sold and traded in the Upper Basin.

Farming without irrigation is generally unsuccessful in most areas of the Upper Basin because of the uncertain rainfall. It is practiced, however, to some extent in the Yampa and White River Basins, and favorable climatic conditions in the past few years, together with high prices, have encouraged expansion of dry farming in the Dry Side area of the La Plata River Basin and on the upland mesa between Cortez, Colorado and Monticello, Utah. In general, at altitudes where rainfall is sufficient during the summer to grow crops without irrigation, the season is too short for crops to mature.

According to a report of the Bureau of Reclamation (17) there are 70,696,000 acres of land in the Upper Colorado River Basin, of which 1,325,000 acres are irrigated and 272,000 are farmed without irrigation. The crops include alfalfa, wild hay, wheat, barley, corn, oats, deciduous fruits, potatoes, sugar beets, and dry beans. The following tabulation shows the area irrigated in the Upper Basin as reported by the Bureau in 1946.

<u>Division</u>	<u>Arizona</u> <u>Acres</u>	<u>Colorado</u> <u>Acres</u>	<u>New Mexico</u> <u>Acres</u>	<u>Utah</u> <u>Acres</u>	<u>Wyoming</u> <u>Acres</u>
Green		105,870		229,120	247,540
Grand		564,670		8,000	
San Juan	6,000	132,300	38,000	37,700	
Total	<u>6,000</u>	<u>802,840</u>	<u>38,000</u>	<u>274,820</u>	<u>247,540</u>

The following tabulation shows the average irrigated areas for the period 1914-45 as determined by representatives of the Upper Basin States.

Crops	Irrigated areas, Upper Colorado River Basin					
	Arizona	Colorado	New Mexico	Utah	Wyoming	Total
	Acres	Acres	Acres	Acres	Acres	Acres
Alfalfa	180	309,522	12,681	107,220	17,320	446,923
Grass, hay and pasture	---	244,054	6,889	103,430	201,910	556,283
Grain and beans	620	178,047	7,277	69,234	9,470	264,648
Corn and other annuals	2,970	33,333	9,521	8,345	---	54,169
Orchard	---	25,650	2,632	291	---	28,573
Total	3,770	790,606	39,000	288,520	228,700	1,350,596

The irrigated areas as determined by the states in 1948 are as follows: Arizona, 9,840 acres; Colorado, 790,600 acres; New Mexico, 43,620 acres; Utah, 303,977 acres and Wyoming, 236,675 acres.

Soils

The Bureau of Reclamation reports (17) that:

"The entire upper basin is underlain with sandstones, limestones, and shales composing the parent rock from which the soil forming material has been derived. Four types of soil are found: (1) alluvial soils made up from stream-deposited materials; (2) glacial soils in the form of glacial deposits on out-wash plains derived partly from granites and other igneous material of the higher mountains; (3) residual soils formed in place by the weathering of surface rocks but altered in places through deposition from higher residual lands; and (4) aeolian, or wind deposited soils, appearing in a few places as sand dunes and other formations.

"In the upper valleys lands suitable to agricultural development are largely composed of alluvial soils and are confined to the bottom lands, terraces, and valley fills. These soils are high in organic matter and are inherently fertile. They are generally of sandy loam to loam in texture. Most of these soils have good natural drainage provided by light textured soil over gravelly subsoil and a moderate slope. With the exception of small localized areas the soils in the upper valleys are free from harmful accumulations of alkali. The depth of the soil and the amount of rock on the surface usually determine the suitability of the lands for agriculture.

"Mesas, plateaus, basin-like depressions caused through erosion, and narrow valleys along the various streams characterize the lower sections of the upper basin. The broader valleys and depressions that

have been covered with alluvial soils are more suitable for cultivation where soil is of sufficient depth. Vast areas of residual soils are too shallow or too alkaline for agricultural development. Extensive drainage is often necessary in the lower valleys where irrigation is practiced.

"Wind formed soils are not extensive. Some are found in small areas south of the San Juan River along the northeastern sides of ridges or other topographic uplifts which break the winds and harbor the deposited materials. The largest areas of arable aeolian soil is east of Chaco River on the high benches south of Farmington, New Mexico."

Climate

Climatologically, the upper Colorado River Basin has the extremes of year-round snow cover and heavy precipitation on the high peaks of the Rockies which are snow-capped eight to 10 months a year, and arid conditions, with less than six inches of annual rainfall, in the southern part.

In general, the basin is arid except in the high altitudes of the headwater areas. Rainfall is insufficient in most valley areas for the profitable production of crops without irrigation.

Extremes of temperatures range from 50° below zero to 113° above zero. The northern portion is characterized by short, warm summers and long, cold winters, many mountain areas being blanketed by deep snow all winter. The southern portion has hot summers.

The frost-free period varies from about 60 days in the higher elevations of the northern mountainous sections to almost 200 days in the lower valleys of the upper Basin.

The annual precipitation on the irrigated areas ranges from above six inches at Green River, Utah to 24 inches at Pagosa Springs, Colorado and the summer precipitation ranges from three inches in the lower valleys to nine inches in the high areas. Precipitation and temperature records are available from 85 stations in the areas. (See appendix).

OTHER INVESTIGATIONS

Those responsible for planning irrigation projects or administering the waters of the West have, for many years, been attempting to define more clearly the amounts of water required to satisfy crop needs. It has been recognized that in addition to the water consumed through transpiration by the plants and evaporation from the water and soil surfaces during and after an irrigation, an allowance must be made for reasonable and necessary losses incident to irrigation. However, from an overall project standpoint or on a complete drainage basin, these conveyance and application losses may be relatively unimportant because surface waste and percolation losses can frequently be picked up and reused lower down on the project or stream.

Because of this return flow phenomenon, there have been some concentrated studies to determine the amounts of water consumptively

used by agricultural crops and the native vegetation found in the West. Additional work is necessary to determine soil; the use in the various areas taking into consideration climatological, water supply, soil, topographic and other data.

Studies in Other Areas

Various methods have been used throughout the West to determine the amount of water consumed by agricultural crops and native vegetation (6). Regardless of the method, the problems encountered are numerous and considerable time is required to make satisfactory measurements of consumptive use. The source of water used by plant life, whether from precipitation alone, irrigation plus rainfall, ground water plus precipitation, or irrigation plus ground water plus rainfall, is a factor influencing the selection of a method. Unit values of consumptive use may be determined for different kinds of native vegetation and agricultural crops by soil moisture studies, lysimeter or tank measurements, analysis of irrigation data, analysis of climatological data, and other methods (2). For irrigated crops, data on depth of irrigation water applied, number of irrigations per year, irrigation efficiency, water-holding capacity (field capacity) of soil and length of growing season may be used in estimating unit values of consumptive use (3). Unit values observed in one area may be used in estimating consumptive use for other areas having somewhat similar climatic conditions, provided temperature and precipitation records are available for both areas (2).

The effect of sunshine and heat in stimulating transpiration was studied (8) as early as 1691, according to a review of the literature by Abbe (1). Measurements of transpiration of various kinds of plants by Briggs and Shantz indicate a close correlation between transpiration and evaporation from free-water surfaces, air temperature, solar radiation, and wet-bulb depression readings (9).

Many formulas have been developed in the past for determining evaporation from meteorological observations. Formulas for estimating consumptive use are not so numerous. A few suggested methods of determining consumptive use, based on climatic factors, have been found to give reasonable results. For many years irrigation engineers have used temperature data in estimating annual valley consumptive use of water in arid and semi-arid areas of the West (4). Hedke developed the effective heat method on the Rio Grande (15). By this method, consumptive use is estimated from a study of the heat units available to the crops of a particular valley (14). It assumes that there is a linear relation between the amount of water consumed and the quantity of available heat. From studies of the Bureau of Reclamation, conducted intermittently from 1937 to 1940 by Lowry and Johnson (16), a similar method was suggested which has been adopted quite generally by the Bureau of Reclamation in making its estimates of valley consumptive use. This method also assumes a direct relationship between temperatures and consumptive use. It assumes a linear relation between consumptive use and accumulated daily maximum temperatures above 32° Fahrenheit during the growing season.

Studies conducted by the Division of Irrigation, Soil Conservation Service, in 1939-41, in connection with the Pecos River Joint

Investigation of the National Resources Planning Board, indicated that evaporation, evapo-transpiration, mean monthly temperature, monthly percent of daytime hours, growing season, monthly precipitation and efficiency of irrigation data could be used to estimate irrigation requirements (2). Later Blaney and Morin (5) developed empirical formulas from the Pecos River studies for estimating unit annual values of evaporation from free-water surfaces and consumptive use by native vegetation subsisting on ground water. This method gives consideration to temperature, daytime hours, and humidity records and is applicable to those areas in which there is ample water to take care of evaporation and transpiration. Blaney and Morin also show how the formulas might be applied in estimating consumptive use by irrigated crops having access to an ample water supply. Various methods of determining consumptive use of water have been described by Blaney (6). In 1945 Blaney and Criddle simplified the Pecos formulas by eliminating the humidity factor (7).

Upper Colorado River Basin Studies

Studies of consumptive use in the Upper Colorado River area in the past have been limited. Some estimates have been made over the years for various purposes, but these estimates have been based largely on unmeasured observations. However, several careful studies have been made on existing irrigation projects or small areas which give results applicable to limited portions of the basin.

In connection with water-supply investigations made by the United States Reclamation Service in 1920-21, Conkling (10) estimated that future consumption of water for irrigation would vary from one foot in depth for wild hay in the higher areas to probably two to 2.5 feet in the warmer climate of the southern portion of the Upper Colorado River Basin. Estimates were made of duty of water and consumptive use in the Green River, Grand (Colorado) River, Uinta and San Juan basins and other areas. The average annual water consumption in the Upper Basin for the years 1902, 1903 and 1904 was estimated as 1.54 acre-foot per acre. This was a period of low run-off.

During a four year investigation, 1938-1941, Erickson (13) measured the consumptive use of water in the Lower Uncompahgre Project in the Upper Colorado River Basin by the inflow-outflow method (4), for the Colorado Water Conservation Board.

Annual consumptive use was determined by the Bureau of Reclamation by inflow-outflow and the effective heat methods in New Fork Valley, Wyoming in the Upper Colorado River Basin and in the Michigan-Illinois area, Colorado (16) adjacent to the basin.

The 1946 report on the Colorado River prepared by the Bureau of Reclamation presents the results of a study of present irrigation developments and estimates of stream depletions (17). Consideration was given to the amounts of water being used for irrigation in each of the irrigable areas of the Basin. This report gives an estimated total present average annual stream depletion or water consumed in the Upper Basin of 2,016,000 acre-feet.

Current Studies in Utah

In 1948, detailed studies of consumptive use were begun for two drainages of the Upper Colorado River area in Utah. This investigation is being conducted cooperatively by the Utah State Engineer, the Utah Agricultural Experiment Station and the Division of Irrigation and Water Conservation, Soil Conservation Service. Measurements of consumptive use are being made by the inflow-outflow and integration methods in the Ashley Valley and in the Ferron Creek Area. Rates of consumptive use of water by the more important crops are being determined by soil moisture depletion studies and with evapo-transpiration tanks. Preliminary data are presented in a 1948 progress report of the studies. (11)

GENERAL PROCEDURE

Because of the limited measurements of consumptive use in the Upper Colorado River Basin, estimates of unit use by the various agricultural crops and native vegetation in this Basin are based largely on studies in other areas of the West, transferred to the Upper Colorado River Basin by the method suggested by Blaney and Criddle (7). Briefly, the procedure is to correlate existing consumptive use data with monthly temperature, percent of daytime hours and precipitation for the frost-free period or irrigation season and for the entire year. The coefficients so developed for different crops are used to transfer consumptive use data from one section to other areas where only climatological data are available.

Neglecting the unmeasured factors, consumptive use varies with the temperature and the daytime hours, and available moisture (precipitation, irrigation and/or ground-water). By multiplying the mean monthly temperature (t) by the monthly percent of daytime hours of the year (p), there is obtained a monthly consumptive use factor (f). Then it is assumed that the consumptive use varies directly as this factor when an ample water supply is available. Expressed mathematically,
 $U = KF = \text{sum of } kf \text{ where}$

U = Consumptive use of crop (or evaporation) in inches for any period.

F = Sum of the monthly consumptive use factors for the period
(sum of the products of mean monthly temperature and monthly percent of annual daytime hours) ($t \times p$).

K = Empirical coefficient (annual or irrigation season).

t = Mean monthly temperature in degrees Fahrenheit.

p = Monthly percent of daytime hours of the year.

$f = \frac{t \times p}{100}$ = Monthly consumptive use factor.

k = Monthly coefficient.

$u = kf$ = monthly consumptive use in inches.

By knowing the consumptive requirement of water by a particular crop in some locality an estimate of the use by the same crop in some other area may be made by application of the formula $U = KF$.

Consumptive Use Coefficients

The consumptive use coefficients (K) for the more important irrigated crops grown in the Upper Colorado River area and native vegetation and evaporation are shown in table 1. These coefficients were developed from actual measurements of consumptive use in tank and soil moisture field studies and inflow-outflow measurements made throughout the West over a period of years by the Division of Irrigation and Water Conservation and other agencies. These coefficients are based on the assumption that the crops receive a full water supply throughout the growing season or frost-free period (7). If the water supply is short during the latter part of the irrigation period some correction should be made.

Climatological Data

For many years climatological data, such as temperature, precipitation and frost-free period (growing season) have been kept by the U. S. Weather Bureau in the Upper Colorado River Basin and other areas throughout the United States (12). The 1941 "Yearbook of Agriculture: Climate and Man" states:

"The growing season of crops susceptible to frost damage -the so-called warm weather crops - is restricted by the number of days between the last killing frost in the spring and the first in the fall."

Table 1 - Coefficients used in computing consumptive use of water in the Upper Colorado River Basin.

Classification	Growing season or period	Consumptive use coefficient (K) 1/
		Growing period: Annual

IRRIGATED LAND

Alfalfa	Frost-free period	0.85
Alfalfa	Pre-frost free period	.70
Grass, hay and pasture	Frost-free period	.75
Grass, hay and pasture	Pre-frost free period	.60
Beans and small grains	3 months	.75
Corn and other annuals	4 months	.75
Orchard (deciduous)	Frost-free period	.65

INCIDENTAL AREAS

Water surfaces ^{2/}	Frost-free period	0.95	0.85
Native vegetation	Frost-free period		
Very dense ^{3/}	" " "	1.35	1.10
Dense ^{4/}	" " "	1.20	1.00
Medium ^{5/}	" " "	1.00	.90
Light ^{6/}	" " "	.80	.65
Sparse ^{7/}	" " "	(Precipitation only)	
Seeped areas ^{8/}	" " "	.90	.75

1/ $K = \frac{U}{F}$ = $\frac{\text{Consumptive use}}{\text{Consumptive use factor}}$ = Consumptive use coefficient.

2/ Based on four-year record at Montrose, Colorado (13).

3/ Large cottonwood trees, willows and grass. Adequate moisture available from high water table (or ground water).

4/ Willows, tamarisk, or small cottonwood trees, Adequate moisture available from high water table (or ground water).

5/ Small willows or tamarisk. Moisture available from high water table (or ground water).

6/ Salt grass, brush or weeds. Moisture available from ground water.

7/ Sage brush, grass and weeds. Moisture available from precipitation only. (Rainfall during the growing season plus 50 percent of winter precipitation stored in the root zone, not to exceed 3 inches.)

8/ Moist areas caused by seepage from canals, over-irrigation, ground water, or poor drainage.

The average annual precipitation, mean annual temperature, and frost-free period for various stations in the Upper Colorado River Basin are shown in table 2. These data were compiled or estimated from U. S. Weather Bureau records by the Engineering Advisory Committee to the Upper Colorado River Basin Compact Commission for the period 1914 to 1945 (18). Mean monthly temperature and precipitation at stations in the Upper Basin are shown for the period 1914 to 1945 in the Appendix.

IRRIGATION PRACTICES

The discussion thus far has assumed an adequate irrigation water supply properly distributed throughout the irrigation season and applied under normal irrigation practices. However, it was realized that these conditions do not exist in every irrigated area within the Upper Colorado River Basin. A field study was therefore made to determine the adequacy of the supply and the irrigation practices in each area before the estimates were applied to actual field conditions.

Some of the factors considered as influencing the rate of consumptive use and on which data were obtained are: The beginning date and length of irrigation season, number of irrigations applied each year, amounts of water applied each year, planting and harvesting dates, average yields, soil textures and root zone depths, rates at which water percolates into the soil, and several others considered of lesser importance. First-hand knowledge was obtained on as many of these factors as possible in the limited time allotted to the field investigations.

Table 2. - Average annual precipitation, mean annual temperature and frost-free period at Weather Bureau stations used in computing consumptive use in the Upper Colorado River Basin.

(Based on Weather Bureau records from 1914-1945, except as noted.)

Station		Average annual precipitation Inches	Mean annual temperature °F.	Elevation Feet	Average frost-free period			
No.	Location				Years of record	From-	To-	Total Days
<u>ARIZONA</u>								
1	Chinle	9.50	51.3	5,538	22	May 16	Oct. 7	144
4	Kayenta	8.35	52.9	5,640	21	Apr. 28	Oct. 13	168
<u>COLORADO</u>								
5	Aspen	19.11	39.8	7,913	17	June 10	Sep. 15	97
7	Collbran	15.90	45.6	6,200	31	May 26	Sep. 29	126
8	Cortez 1/	13.34	48.1	6,177	28	May 26	Sep. 29	126
11	Delta 1/	8.45	50.4	5,115	32	May 5	Oct. 6	154
13	Durango 1/	19.70	45.5	6,554	32	June 1	Sep. 26	127
New	Eagle 2/	14.44	42.0	6,598	8	June 19	Sep. 6	79
16	Fruita	9.75	50.9	4,525	32	May 6	Oct. 10	157
17	Glenwood Sprgs.	18.37	47.3	5,823	30	May 17	Sep. 29	135
18	Grand Junction	9.07	52.8	4,668	32	Apr. 13	Oct. 26	196
19	Gunnison 1/	10.52	37.4	7,683	28	June 18	Sep. 2	76
20	Hayden 1/	15.62	42.2	6,337	24	June 11	Sep. 13	94
21	Ignacio 1/	16.36	45.7	6,425	32	June 5	Sep. 23	110
25	Montrose	9.76	48.9	5,830	32	May 6	Oct. 6	153
27	Norwood	17.94	45.2	7,017	14	June 8	Sep. 26	110
28	Pagosa Sprgs. 1/	24.22	41.1	7,108	15	June 23	Sep. 13	82
30	Paonia	16.04	48.4	6,200	31	May 5	Oct. 12	160
31	Rifle 1/	1/11.00	47.9	5,300	28	May 15	Oct. 3	141
33	Steamboat Springs	24.07	38.4	6,770	31	June 27	Aug. 25	59
<u>NEW MEXICO</u>								
37	Bloomfield	9.11	50.9	5,794	28	May 7	Oct. 11	157
41	Dulce	18.83	43.6	6,767	26	June 11	Sep. 20	101
47	Shiprock	7.96	53.1	4,945	14	May 3	Oct. 15	165
<u>UTAH</u>								
50	Blanding	13.46	49.4	6,035	32	May 11	Oct. 13	155
52	Castledale	8.63	45.2	5,500	27	May 22	Sep. 27	128
53	Duchesne	9.66	44.0	5,520	32	May 26	Sep. 23	120
54	Emery	7.61	45.8	6,260	30	May 24	Sep. 27	126
55	Escalante	12.56	47.5	5,258	24	May 15	Oct. 1	139
56	Ft. Duchesne	7.01	44.3	4,941	28	May 23	Sep. 24	124
58	Green River	6.45	52.3	4,087	31	May 2	Oct. 9	160
59	Hanksville	5.16	52.4	4,200	29	May 2	Oct. 4	155

Table 2 (continued). - Average annual precipitation, mean annual temperature and frost-free period at Weather Bureau stations used in computing consumptive use in the Upper Colorado River Basin. (Based on Weather Bureau records from 1914-1945, except as noted.)

Station		Average annual precipitation	Mean annual temperature	Elevation	Average frost-free period			
No	Location				Years of record	From	To	Total
		Inches	°F.	Feet				Days
<u>UTAH (Cont.)</u>								
61	La Sal	12.82	46.6	6,775	21	May 25	Oct. 1	129
62	Loa	7.85	43.3	7,000	19	June 12	Sep. 9	89
63	Manila	10.35	43.5	6,225	15	June 13	Sep. 14	93
64	Moab	9.94	54.6	4,000	31	Apr. 18	Oct. 17	182
67	Myton	6.90	46.2	5,030	28	May 17	Sep. 30	136
68	Price	10.39	48.8	5,500	24	May 18	Oct. 1	136
71	Tropic	12.69	47.7	6,296	15	May 25	Oct. 6	134
72	Vernal	8.77	44.3	5,335	25	June 1	Sep. 18	109
<u>WYOMING</u>								
75	Dixon ^{3/}	12.00	41.2	6,359	24	June 4	Sep. 11	99
76	Eden ^{4/}	7.34	37.9	6,665	27	June 11	Sep. 11	92
79	Kemmerer ^{5/}	7.94	39.4	6,954		June 7	Sep. 15	100
81	Lyman	11.49	40.7	6,800	16	June 9	Sep. 17	100
82	Pinedale	11.42	35.7	7,180	20	June 22	Aug. 29	68
	New Big Piney	9.25	34.8	6,820	10	June 22	Aug. 29	68

^{1/} Based on some unpublished data.
^{2/} Average for period of record, 1905-1910 and 1944-45.
^{3/} Year 1932 estimated from temperature data.
^{4/} Year 1931 and 1932 estimated from temperature data.
^{5/} Estimated 32-year average for the period 1914-1945.

Method of Obtaining Data:

Through the courtesy of the various state representatives of the Engineering Advisory Committee to the Upper Colorado River Basin Compact Commission, interviews were arranged with representative farmers, water masters, state river commissioners, United States Bureau of Reclamation Engineers, County Extension Agents, Soil Conservation Service technicians and others acquainted with water supplies and irrigation practices in each area. In addition, information was obtained by the authors from personal observation of the areas and a study of various published and unpublished reports. All the data obtained through interviews, personal observation, or otherwise were systematically recorded. Numerous pictures were taken to record conditions found to exist in the basin. Photographs were made of natural vegetation as well as agricultural crops and irrigation practices. Figures 2 to 17 show typical areas inspected by the authors in May 1948.

As indicated in Figures 2 to 4, the beginning of the growing season varies widely within the Upper Colorado River Basin. Near Big Piney, Wyoming, alfalfa had hardly shown any signs of growth by the middle of May 1948. Irrigation had not yet started in that area. At Lake Fork, Utah, alfalfa had "greened up" and the new shoots were approximately four inches high. Irrigation here was just beginning. At Rogers Mesa, Colorado, alfalfa was knee high and the irrigation season was well advanced.

Low lying pastures and meadow hay land naturally overflowed because of swollen rivers are shown in Figures 5, 6, 7 and 9. This overflow is an annual occurrence and usually lasts from 4 to 8 weeks. After the streams subside, diversion dams are thrown across the channels and the lands receive irrigation water almost until haying time when they are allowed to dry sufficiently to support the harvesting equipment. Figures 10 to 17 in the series show river channels, native vegetation and irrigated crops at various locations throughout the basin.

General Description of Practices

In some studies of water use in areas of the West, the growing season has been considered as the time between killing frosts, and the irrigation period has generally coincided fairly well with this growing period. However, for most perennial crops, growth starts as soon as the maximum temperature stays well above the freezing point for any extended period of days and continues so throughout the season in spite of later freezes. Sometimes growth persists even after the first so-called killing frost. Grasses may mature even though summer temperatures drop below freezing repeatedly.

In the Upper Colorado River Basin it was found that in the higher areas irrigation water is applied early in the spring, in some instances even before growth begins but certainly before the beginning of the frost-free period. Irrigation water is thus consumed through evaporation and some transpiration before the beginning of the frost-free period.



FIGURE 2
Alfalfa field, near Big Piney, Wyoming,
May 22, 1948.



FIGURE 6
Yampa River overflowing bottom lands about
eight miles below Steamboat Springs, Colo.
May 19, 1948.



FIGURE 3
Alfalfa growing on bench lands two miles
east of Lake Park, Utah, May 13, 1948.



FIGURE 7
Flood irrigation of pasture about four
miles from Bayfield, Colorado, on Pine
River, May 10, 1948.



FIGURE 4
Alfalfa growing on Rogers Mesa, Colorado;
May 15, 1948.



FIGURE 8
Peach orchard growing along Colorado River
near Palisades, Colorado, May 17, 1948.



FIGURE 5
Flooded river bottom, irrigated pasture,
and very dense vegetation below Slater,
Wyoming, May 20, 1948.



FIGURE 9
Grain field, flooded pasture, cottonwood
trees in background along Colorado River
West, Utah, May 12, 1948.



FIGURE 10
 Farm in Green River Valley, Wyoming, near junction of East Fork and Green River. Sparse native vegetation in foreground, irrigated pasture and dense native vegetation in background, May 22, 1948.



FIGURE 14
 Very dense native vegetation (cottonwoods) (willows) growing along Green River above irrigated lands Green River, Utah. May 12, 1948



FIGURE 11
 Sage brush growing between Parson and Pinedale, Wyoming, May 21, 1948.



FIGURE 15
 Dense Tamarisk (salt-cedar) growing along Colorado River near Moab, Utah, May 12, 1948.



FIGURE 12
 Little Snake River at high stage, Wyoming-Colorado. Cottonwood trees and willows are typical and very dense riparian vegetation, May 20, 1948.



FIGURE 16
 Dense willows growing along Animas River two miles above Durango, Colorado. May 11, 1948.



FIGURE 13
 White River valley about 10 miles above Rangely, Colorado. Medium native vegetation growing in river channel. May 14, 1948.



FIGURE 17
 San Juan River Valley about five miles below Blanco, New Mexico. Willows, Tamarisk and Cottonwood trees growing along river. May 8, 1948.

As between States, irrigation practices do not differ materially from place to place under conditions of similar water supply, climatic conditions and elevation. Total water supply as well as its distribution throughout the irrigation season is probably the major reason for variance in irrigation practices applying to any one crop. It was found quite generally that those areas having the shortest late season water supply begin irrigation earliest in the spring in an attempt to supplement the soil moisture supply while water is available.

Following is a general discussion of the irrigation practices in each state of the Upper Colorado River Basin:

Arizona.- A large portion of the Arizona irrigated land within the Upper Colorado River Basin is located in the vicinity of Chinle and Kayenta and is farmed by Indians. Reports indicate that in recent years between 3,800 and 9,800 acres have been irrigated, the area varying with the seasonal water supply. Some lands have an adequate water supply, while other areas are irrigated only when flood waters are available. (18) The crops consist of corn, small cereals, beans, and alfalfa. The frost-free period varies from about 140 days to over 200 days.

Colorado.- The characteristics of irrigated areas in the Colorado River Area of Colorado are widely variant. The elevation of the irrigated lands ranges from about 4,600 feet near Grand Junction to almost 8,000 feet in areas such as Aspen. The Weather Bureau frost-free period varies from about 60 days to almost 200 days. The mean annual temperature varies from about 35 degrees to 53 degrees. Water supplies are also extremely variable. Some areas, such as the Florida project near Durango, have extremely short water supplies and a medium-long growing season. Agriculture varies from a highly diversified and orchard type of farming in the vicinity of Grand Junction to a wild hay and pasture type toward the head of many of the streams. Some areas which are used for growing wild hay are naturally flooded each year and the irrigation period extends through only a month or less. See figures 6 and 7. This is particularly true on the Upper Yampa River, White River, the Upper Main Colorado, Blue River and the Upper Gunnison areas. This natural flooding causes a considerable lowering in the irrigation water demand.

In the Grand Valley, which has a large percentage of its irrigated area in orchard, irrigation of alfalfa begins about the middle of April and continues until the first part of October. Orchards are irrigated approximately eight times each year, the first irrigation occurring about May 5 and the last one October 25. It is the common practice to plant grain as a nurse crop for alfalfa in this valley. The grain and alfalfa combined require five irrigations or more each year and the irrigation season extends from about April 5 until well toward fall. A large part of the irrigated area in Colorado depending upon the flow of the main streams, seems to have a full water supply. However, some of the smaller tributaries of the main rivers do not furnish an adequate late-season water supply for numerous small areas.

New Mexico.- The greater part of the New Mexico irrigated land within the Upper Colorado River Basin is irrigated from the San Juan and Animas Rivers and has a water supply adequate to mature crops. Elevation of this area is slightly over 5,000 feet and the frost-free growing period about 160 days. Alfalfa is irrigated at least four or five times a year and the hay yields vary between four and five tons per acre. Irrigation ordinarily begins by April 10 and continues until the middle of September. Small grains receive two or more irrigations per year, the first one the middle of May and the second toward the end of June. Orchards receive five or more irrigations each year beginning the middle of May and extending pretty well through September, with some farmers irrigating even later. The only other two areas in New Mexico considered were the La Plata and the Dulce, in each of which the irrigation supply is extremely short in the latter part of the summer. This shortage tends to move the beginning date of irrigation ahead and to increase the amount of water applied per application while the high flows are still in the rivers.

Utah.- Elevations of irrigated areas in the Utah part of the Colorado River Basin vary from 4,000 feet to nearly 7,000 feet. The Weather Bureau frost-free growing period for these areas varies from about 90 to 182 days. However, the majority of the irrigated areas have a growing season of about 125 days. Mean annual temperatures vary from 43 to 52 degrees. In most of the irrigated areas alfalfa, small grains and grass hay and pasture are the important irrigated crops. In a few small local areas, such as Green River and Moab, a large proportion of the irrigated land is in orchard, melons, potatoes, etc. A considerable acreage of sugar beets is grown in the Price area. There is a relatively small percentage of the irrigated land in Utah that has an adequate water supply for full crop production. However, it is believed that for most of the land the shortage is not serious, although for some of the smaller areas, such as Blanding, the supplies are extremely deficient. In most cases inadequacy applies to late-season water. In Ashley Valley, one of the large contiguous irrigated areas in this State, alfalfa is ordinarily irrigated five times, the first application being made about the middle of May and the last one the latter part of August. Small grains receive two or more irrigations each year between the period May 15 and June 5. In the Blanding area there are seldom more than two irrigations each year for alfalfa, the first one being about March 1 and the last later than the middle of June. Grains and beans get by with one irrigation.

Wyoming.- Most of the irrigated land in the Colorado River Area of Wyoming is used in growing grass hay and pasture. The growing season is relatively short. Elevation of practically all the land is above 6,000 feet. According to Weather Bureau records, the frost-free period varies from about 100 days at the south end to less than 70 days in the vicinity of Pinedale. Mean annual temperatures vary from about 35° to 41°F. The harvesting of the wild hay usually begins between the first and 15th of August and irrigation water must be taken off the meadows early enough to allow harvesting operations. Irrigation begins from May 5 at the lower end of the area to June 1 at the upper end. The major streams head high in the mountains, so that the irrigation period corresponds fairly well

with the period of high streamflow. As a result, most of the ranchers manage fairly well with very little reservoir storage water, especially at the upper end of the basin.

Considerable areas that are classed as irrigated land receive natural overflow water when the rivers and streams are high as shown in figure 5. After the streamflow drops, these areas receive irrigation water until such time as they must be prepared for harvesting. Apparently, these areas have always been naturally flooded, and man in his farming operations has merely lengthened the period during which adequate water is available for good plant growth. The larger areas of the naturally overflowed lands are found in the vicinity of Fine-dale and Big Piney and on Ham's Fork and Black's Fork.

The only major variation from the above described irrigation practices and crop distribution is the Eden Valley Irrigation Project located approximately 40 miles north of Rock Springs. About one-half of the irrigated area of this project is in alfalfa, an additional third is in small grains and the balance is in pasture and grass hay. The farmers on the Eden Project are able to make two cuttings of alfalfa each year with average yields of between 1.5 and 2.0 tons per acre. An adequate supply of storage water is available and the farmers apply an average of four irrigations per year to their alfalfa the first application being made between May 25 and 31 and the last one August 15. Small grains are irrigated two to three times, the irrigation period beginning the middle of June and extending through July.

ESTIMATES OF RATES OF CONSUMPTIVE USE

In computing rates of consumptive use of water, the Blaney-Criddle method and formula $U = KF$ are used (7). The values of coefficient (K) are shown in table 1. A consumptive use factor (F) for the growing, frost-free or irrigation period is used. Mean monthly temperature and precipitation records are shown in the appendix.

Irrigated Crops

Rates of consumptive use of water by alfalfa and grass hay are established for three types of irrigation practice, which are different because of the character of the water supply; thus one or more is applicable to each area. These three types of irrigation practice are: (1) A water supply adequate to satisfy the requirements of crops and acreages now irrigated. (2) A definitely short late-season irrigation water supply, usually found on the smaller unregulated streams. It is assumed that the period of use of irrigation water is from the date of first irrigation to the date of last irrigation, plus two weeks for grass hay and pasture and three weeks for alfalfa. These periods after the last irrigation are added to take care of residual soil moisture which is used by the crops. However, in no case has the period been extended beyond the end of the frost-free period. (3) Irrigation of crop lands normally flooded during the period of high run-off each year. This practice generally applies only to grass hay or pasture land. After the flow in the rivers declines, irrigation water is applied throughout the remainder of the season. Man-made consumption of irrigation water occurs only after the high water recedes and irrigation begins.

The irrigated areas, Weather Bureau stations and irrigation periods for alfalfa and grass hay used in computing water consumption

rates are shown in table 3. It is assumed that the growing seasons for orchard and native vegetation are the same as the frost-free periods, that small grains and beans will grow for three months beginning at the last frost in the spring and that corn and other annuals will grow for four months. For an area having a growing season longer than that shown as its average frost-free period, it is assumed that the crop will not always mature.

A sample of computations for rates of water consumption by irrigated crops in the Upper Yampa and Elk River areas, Colorado is shown in tables 4 and 5. The results of similar computations for normal water consumption rates for irrigated crops during the growing period for areas in the entire Upper Colorado River Basin are summarized in table 6. These estimates are based on the assumption that a water supply ample to satisfy the water requirement of the plants is available from precipitation and irrigation.

The estimates of rates of consumptive use shown in table 6 include moisture supplied by both irrigation and rainfall. By subtracting the growing-period rainfall from the rates of use, the rates of consumption at the point of use, as the result of irrigation, may be obtained provided this land was not naturally irrigated, ~~under virgin conditions.~~ For example, the consumptive use for alfalfa in the Montezuma Area, Colorado is computed as 24.5 inches during the irrigation season with a full water supply. The normal rainfall during this period is 5.6 inches. Then $24.5 - 5.6 = 18.9$ inches, or 1.58 feet (acre-feet per acre), which is the consumption of irrigation water at point of use for alfalfa land during the irrigation season. Table 7 summarizes the results of computations of rates of consumptive use minus rainfall during the growing or irrigation season.

~~Under virgin conditions some of this land may have received moisture from a high water table or it may have received water from precipitation only. Also, land which formerly may have had a high water table may now be drained. It is necessary to make allowances for such circumstances in each area when estimating the consumption of irrigation water, but it may be assumed that average consumptive use during the winter period under present conditions has not changed materially from what it was under virgin conditions.~~

Table 3.- Irrigated areas, Weather Bureau stations, and irrigation periods utilized in computing consumptive use of irrigation water in Arizona, Colorado, New Mexico, Utah and Wyoming

Unit		Weather Bureau station	Water <u>1</u> / supply	Frost-free ² / period	Alfalfa ³ / irrigation season
No.	Area				
<u>ARIZONA</u>					
1	Chinle	Chinle	F	5/16 - 10/7	5/1 - 10/7
			S		5/1 - 7/15
2	Kayenta	Kayenta	F	4/28 - 10/13	4/10 - 10/13
					4/10 - 7/15
<u>COLORADO</u>					
1	Upper Yampa and Elk River	Steamboat Springs	F	6/27 - 8/5	5/10 - 8/25
			S		5/10 - 7/31
			N.O.		7/8 - 7/31
2	Lower Yampa and tributaries	Hayden	S	6/11 - 9/13	5/5 - 7/31
3	Little Snake River	Dixon	S	6/4 - 9/11	5/15 - 8/20
4	White River direct	Meeker	F	6/10 - 9/11	5/15 - 9/11
			N.O.		7/12 - 9/11
5	White River tributaries	Meeker	S	6/10 - 9/11	5/15 - 7/20
			N.O.		7/12 - 7/13
6	Colorado River above Glenwood	Green Mt. Dam & Blue Valley Ranch	F	6/15 - 9/6	5/20 - 9/6
6a	Muddy Troublesome	Green Mt. Dam & Blue Valley Ranch	S	6/15 - 9/6	5/10 - 8/10
			N.O.		7/18 - 8/3
7	Blue River	Green Mt. Dam & Blue Valley Ranch	F	6/15 - 9/6	5/20 - 9/6
			N.O.		7/18 - 9/6
8	Eagle River and Upper Eagle River	Eagle	F	6/19 - 9/6	5/5 - 9/6
			N.O.		7/18 - 9/6
9	Gypsum Creek	Eagle	S		5/1 - 7/21
10	Roaring Fork above Basalt	Aspen	F	6/10 - 9/15	6/1 - 9/15
			S		6/1 - 9/1
11	Roaring Fork - Glenwood Sprgs. to Basalt	Glenwood Sprgs.	F	5/17 - 9/29	5/10 - 9/29
			S		5/10 - 8/15
12	Rifle (Silt to Glenwood Springs)	Rifle	S	5/15 - 10/3	5/25 - 8/1
12a	Plateau Creek	Collbran	S	5/26 - 9/29	5/1 - 7/15

Table 3 (cont'd).- Irrigated areas, Weather Bureau stations, and irrigation periods utilized in computing consumptive use of irrigation water in Arizona, Colorado, New Mexico, Utah and Wyoming

No.	Unit	Weather Bureau station	Water <u>1</u> / supply	Frost-free ² / period	Alfalfa ³ / irrigation season
	Area				
<u>COLORADO (cont'd)</u>					
13	Grand Valley	Fruita and Grand Junction	F	4/24 - 10/18	4/15 - 10/18
14	Upper Gunnison	Gunnison	F N.O.	6/18 - 9/2	5/20 - 9/2 7/1 - 9/2
15	Tomichi and Cochetopa	Gunnison	S N.O.	6/18 - 9/2	5/20 - 8/10 7/1 - 7/26
16	North Fork Gunnison	Paonia	S	5/5 - 10/12	4/20 - 7/15
17	Upper Uncompahgre	Montrose and	F	5/28 - 9/19	5/15 - 9/20
	Cimarron and Dallas	Gunnison			
18	Uncompahgre Project	Montrose and Delta	F	5/5 - 10/6	5/1 - 10/6
19	Little Dolores	Grand Junction	S	4/13 - 10/26	4/15 - 9/1
19a	Lower Dolores	Fruita and Grand Junction	F	4/24 - 10/18	4/15 - 10/18
20	Dolores River	Cortez	S	5/26 - 9/29	6/10 - 9/1
21	San Miquel, Tilly lands, Disappointment	Norwood	S	6/8 - 9/26	5/8 - 8/1
22	Montezuma Area	Cortez	F	5/26 - 9/29	5/5 - 9/29
23	Upper San Juan Valley	Pagosa Springs	F	6/23 - 9/13	5/15 - 9/13
24	Pine River and Podra Area	Ignacio	F	6/5 - 9/23	5/5 - 9/23
25	Animas River	Durango	F	6/1 - 9/26	5/1 - 9/26
26	Florida Area	Durango	S	6/1 - 9/26	5/1 - 7/21
27	La Plata (Colorado Area)	Cortez and Lewis	S	5/30 - 9/26	5/15 - 8/8
28	Mancos Area	Cortez	S	5/26 - 9/29	5/1 - 7/21
<u>NEW MEXICO</u>					
1	Dulce - Upper Navajo	Dulce	S	6/11 - 9/20	5/15 - 9/13
2	La Plata	Ft. Lewis and Bloomfield	S	5/21 - 10/1	5/15 - 8/8
3	Bloomfield - Shiprock	Bloomfield and Shiprock	F	5/5 - 10/13	4/10 - 10/13

Table 3 (cont'd).- Irrigated areas, Weather Bureau stations, and irrigation periods utilized in computing consumptive use of irrigation water in Arizona, Colorado, New Mexico, Utah and Wyoming

Unit		Weather Bureau station	Water ¹ / supply	Frost-free ² / period	Alfalfa ³ / Irrigation season
Area					
<u>UTAH</u>					
1	Henry's Fork	Manila	S	6/13 - 9/14	5/15 - 8/20
2	Ashley Valley and Brush Creek	Vernal	F	6/1 - 9/18	5/10 - 9/18
3	Ouray	Myton	S	5/17 - 9/30	4/10 - 7/21
4	Valley lands - Uinta Basin	Myton) Ft. Duchesne)	S	5/20 - 9/27	4/15 - 9/15
5	Bench lands - Uinta Basin	Duchesne)	S	5/26 - 9/23	4/20 - 9/15
6	Price River	Price	F	5/18 - 10/1	5/1 - 10/1
7	Green River	Green River	F	5/2 - 10/9	4/10 - 10/9
8	Moab	Moab	S	4/18 - 10/17	4/1 - 8/31
9	La Sal	La Sal	S	5/25 - 10/1	4/15 - 7/25
10	Monticarlo	La Sal	S	5/25 - 10/1	4/15 - 7/31
11	Huntington, Castle Dale, Ferron	Castle Dale	S	5/22 - 9/27	4/15 - 8/31
12	Emery - Hanksville	Emery	S	5/24 - 9/27	4/15 - 8/31
13	Loa	Loa	S	6/12 - 9/9	5/1 - 8/15
14	Escalante	Escalante	S	5/15 - 10/1	4/15 - 8/15
15	Blanding	Blanding	S	5/11 - 10/13	4/15 - 7/31
16	Paria River	Tropic	S	5/25 - 10/6	4/15 - 8/15
<u>WYOMING</u>					
1	Eden Valley	Eden	F	6/11 - 9/11	5/25 - 9/11
2	Pinedale	Pinedale	F	6/22 - 8/29	5/20 - 8/29
			N.O.		6/22 - 8/29
3	Big Piney	Big Piney	S	6/22 - 8/29	5/10 - 8/15
			N.O.		6/22 - 8/15
4	Ham's Fork	Kemmerer	F	6/7 - 9/15	5/15 - 9/15
			N.O.		6/20 - 9/15
5	Black's Fork	Lyman	S	6/9 - 9/17	5/10 - 8/15
			N.O.		6/20 - 8/15
6	Little Snake	Dixon	S	6/4 - 9/11	5/5 - 8/15
7	Henry's Fork	Manilla	S	6/13 - 9/14	5/15 - 8/20

¹/ F = Full water supply for all crops.

S = Short water supply for alfalfa, grass hay and pasture.

N.O. = Natural overflow on grass hay meadows and pasture during flood stage of river or stream provides moisture before irrigation begins.

²/ From U. S. Weather Bureau records.

³/ From interviews with farmers, county agents, water masters, river commissioners, and others. The end of the irrigation season is assumed to be the end of the frost-free period in areas of full water supply. Where the water supply is short it is assumed that alfalfa would continue to use residual moisture in the soil for three weeks after the last irrigation. Grass hay and pasture are assumed to use residual irrigation water from the soil two weeks after the last irrigation.

Table 4.- Example of observed monthly temperatures, precipitation, percent of daytime hours and calculated consumptive use factor in the Upper Yampa and Elk River areas of the Upper Colorado River Basin.

W. B. Station Steamboat Springs County Routt State Colorado
 Sta. No. 33 Elevation 6,770 Ft. Latitude 40° 30 'N.

Month or Period	Water Supply				Full 1/ 5/10 - 8/25		Short 2/ 5/10 - 7/31		Natural Over-Flow 3/ 7/8 - 7/31	
	t	p	f	R	f	R	f	R	f	R
	°F.	Percent	Inches		Inches		Inches		Inches	
January	13.9	6.72	0.93	2.31						
February	18.6	6.71	1.25	2.43						
March	26.2	8.33	2.18	2.39						
April	38.2	8.96	3.42	2.27						
May	48.2	10.05	4.84	2.23	3.23	1.49	3.23	1.49		
June	55.2	10.15	5.60	1.38	- - -	- - -	5.60	1.38		
1-27	- - -	- - -	- - -	- - -	5.04	1.24				
28-30	- - -	- - -	- - -	- - -	0.56	0.14				
July	61.6	10.26	6.32	1.58	6.32	1.58	6.32	1.58	4.74	1.18
August	59.4	9.56	5.68	1.76	4.58	1.42				
September	52.1	8.38	4.37	1.78						
October	41.7	7.73	3.22	1.99						
November	28.7	6.71	1.93	1.69						
December	16.9	6.48	1.10	2.26						
Total	38.4	100.00	40.84	24.07	- - -	- - -	15.15	4.45	4.74	1.18
5/10-6/27	- - -	- - -	- - -	- - -	8.27	2.73				
6/28-8/25	- - -	- - -	- - -	- - -	11.46	3.14				

t = Mean monthly temperature in degrees.
 p = Monthly percent of daytime hours.
 f = $\frac{t \times p}{100}$ = Monthly consumptive use factor

R = Precipitation in inches.

1/ Full water supply for all crops.

2/ Short water supply for alfalfa, grass hay, and pasture.

3/ Natural overflow on grass hay, meadows and pasture during flood stage of river or streams.

Table 5.- Example of computations of rates of consumptive use of water in the Upper Yampa and Elk River areas of the Upper Colorado River Basin.

Classification	Water supply	K	F (total f)	U	R	U minus R
				<u>Inches</u>	<u>Inches</u>	<u>Inches</u>
<u>Irrigated crops</u>						
Alfalfa	Full <u>1/</u>	0.70	8.27	5.79	2.73)	9.66
	Full <u>1/</u>	0.85	11.46	9.74	3.14)	
Alfalfa	Short <u>2/</u>	0.85	15.15	12.88	4.45	8.43
Grass hay	Full <u>1/</u>	0.60	8.27	4.96	2.73)	7.69
	Full <u>1/</u>	0.75	11.46	8.60	3.14)	
	Short <u>2/</u>	0.75	15.15	11.36	4.45	6.91
	N. O. <u>3/</u>	0.75	4.74	3.56	1.18	2.38
<u>Incidental areas</u>						
Water surfaces		0.95	11.46	10.89	3.14	7.75
Native vegetation						
Very dense		1.35	11.46	15.47	3.14	12.33
Dense		1.20	11.46	13.75	3.14	10.61
Medium		1.00	11.46	11.46	3.14	8.32
Light		0.80	11.46	9.16	3.14	6.02
Sparse				(Precipitation only)		
Seeped areas		0.90	11.46	10.31	3.14	7.17

$K = \frac{U}{F}$ = Empirical consumptive use coefficient determined experimentally

F = Sum of the monthly consumptive use factors for the period.

U = KF = consumptive use, in inches.

R = Precipitation, in inches.

1/ Full water supply for all crops.

2/ Short water supply for alfalfa, grass hay, and pasture.

3/ Natural overflow on grass hay, meadows and pasture during flood stage of river or streams.

Table 6.- Summary of estimates of normal unit consumptive use of water rates for irrigated crops during the irrigation period for areas in the Upper Colorado River Basin.

Unit		Water supply	Normal rate consumptive use 1/				
			Alfalfa	Grass Hay and pasture	Grains and beans	Corn and other annuals	Orchard
No.	Area		Inches	Inches	Inches	Inches	Inches
<u>ARIZONA</u>							
1	Chirle	F	28.3	24.2	15.4	20.1	-
	Chirle	S	13.9	10.8	15.4	20.1	-
2	Kayenta	F	32.5	28.7	15.2	20.5	-
	Kayenta	S	16.9	13.5	15.2	20.5	-
<u>COLORADO</u>							
1	Upper Yampa and Elk River	F	15.5	13.6	8.6	8.6	-
	Upper Yampa and Elk River	S	12.9	11.4	8.6	8.6	-
	Upper Yampa and Elk River	N.O.	-	3.6	-	-	-
2	Lower Yampa and Tributaries	S	14.6	11.7	14.0	-	-
3	Little Snake River	S	16.9	13.8	13.9	-	-
	Little Snake River	N.O.	-	4.9	-	-	-
4	White River, direct	F	18.9	13.9	13.8	-	-
	White River, direct	N.O.	-	8.9	-	-	-
5	White River tributaries	S	11.2	8.9	-	-	-
	White River tributaries	N.O.	-	0.0	-	-	-
6	Colorado River above Glenwood	F	16.3	14.3	11.7	-	-
6a	Kremmling, Muddy, Troublesome	S	14.4	11.6	11.7	11.7	-
	Kremmling, Muddy, Troublesome	N.O.	-	2.4	-	-	-
7	Blue River	F	16.3	14.3	11.7	-	-
	Blue River	N.O.	-	7.0	-	-	-
8	Eagle River and Upper Eagle R.	F	18.5	16.2	11.6	11.6	-
	Eagle River and Upper Eagle R.	N	-	7.1	-	-	-
9	Gypsum Creek	S	12.7	10.4	11.6	11.6	-
10	Roaring Fork, above Basalt	F	16.3	14.4	12.7	13.3	-
	Roaring Fork, above Basalt	S	14.7	13.0	12.7	13.3	-
11	Roaring Fork Glenwood Springs to Basalt	F	24.2	21.4	14.6	19.0	17.8
		S	17.5	14.2	14.6	19.0	17.8
12	Rifle-Silt to Glenwood Springs	S	12.8	9.9	15.0	19.4	18.7
12a	Plateau Creek	S	12.8	11.3	14.5	18.5	16.3
13	Grand Valley	F	32.4	28.6	15.2	20.6	24.0
14	Upper Gunnison (excluding Tomichi and Cochetopa)	F	15.8	13.8	10.9	10.9	-
		N.O.	-	9.2	-	-	-
15	Tomichi and Cochetopa	S	13.0	9.9	10.9	10.9	-
	Tomichi and Cochetopa	N.O.	-	3.9	-	-	-
16	North Fork Gunnison	S	14.5	11.5	14.6	19.3	20.5
17	Upper Uncompahgre, Cimarron and Dallas	F	21.2	18.7	14.9	19.7	20.2
18	Uncompahgre Project	F	27.9	24.6	15.2	20.0	20.6
19	Little Dolores	S	26.3	21.8	14.6	20.3	26.2
19a	Lower Dolores	F	32.4	28.6	15.2	20.6	24.0
20	Dolores River	S	15.1	11.9	14.8	18.9	16.7
21	San Miguel, Lilylands, Disappointment	S	14.3	11.1	14.1	-	-
22	Montezuma Area	F	24.5	21.5	14.8	18.9	16.7
23	Upper San Juan Valley	F	17.8	15.6	-	-	-

Table 6 (cont'd).- Summary of estimates of normal unit consumptive use of water rates for irrigated crops during the irrigation period for areas in the Upper Colorado River Basin.

No.	Unit Area	Water supply	Normal rate consumptive use 1/				
			Alfalfa	Grass hay and pasture	Grains and beans	Corn and other annuals	Orchard
			Inches	Inches	Inches	Inches	Inches
<u>COLOPADO (Continued)</u>							
24	Pine River and Piedra Area	F	22.4	19.6	14.2	18.6	14.2
25	Animas River	F	22.9	20.1	14.0	17.1	14.8
26	Florida Area	S	13.2	10.8	14.0	17.1	14.8
27	La Plata (Colorado portion)	S	14.4	11.6	14.2	17.2	15.1
28	Mancos Area	S	14.0	11.5	14.8	18.9	16.7
<u>NEW MEXICO</u>							
1	Dulce	S	20.1	16.8	13.8	-	-
2	La Plata	S	15.0	12.0	12.0	-	-
3	Bloomfield-Shiprock	F	32.1	28.4	15.3	20.4	21.9
<u>UTAH</u>							
1	Henry's Fork	S	16.8	14.0	14.0	-	-
2	Ashley Valley and Brush Creek	F	21.8	19.2	14.9	-	-
3	Ouray	S	17.1	14.2	-	-	-
4	Benchlands - Uinta Basin	S	23.4	20.6	14.6	18.2	15.0
5	Valleylands - Uinta Basin	S	25.0	22.1	15.1	19.3	17.6
6	Price River	F	26.7	23.5	15.4	19.9	18.0
7	Green River	F	32.5	28.6	16.2	21.7	23.0
8	Moab	S	28.8	24.2	15.3	20.9	25.0
9	La Sal	S	16.4	13.3	14.7	18.7	16.8
10	Monticello	S	17.6	14.3	14.7	18.7	16.8
11	Huntington, Castle Dale Ferron	S	23.1	19.3	14.6	18.7	16.0
12	Emery-Hanksville	S	22.5	18.8	14.2	18.2	18.0
13	Loa	S	17.7	14.5	13.3	-	-
14	Escalante	S	20.3	16.8	14.4	18.7	17.0
15	Blanding	S	18.2	14.8	14.8	19.4	20.0
16	Paria River	S	20.1	16.6	14.5	18.5	17.0
<u>WYOMING</u>							
1	Pinedale	F	14.8	13.0	-	-	-
	Pinedale	N.O.	-	9.8	-	-	-
2	Big Piney	S	14.7	11.9	-	-	-
	Big Piney	N.O.	-	6.8	-	-	-
3	Eden Valley	F	17.2	15.1	13.4	-	-
4	Ham's Fork	F	18.6	16.3	13.2	-	-
	Ham's Fork	N.O.	-	12.2	-	-	-
5	Black's Fork	S	16.2	13.0	13.6	-	-
	Black's Fork	N.O.	-	7.5	-	-	-
6	Henry's Fork	S	16.8	14.0	14.0	-	-
7	Little Snake	S	16.9	13.8	13.9	-	-
	Little Snake	N.O.	-	4.9	-	-	-

1/ Includes irrigation water plus precipitation.

F = Full water supply for all crops.

S = Short water supply for alfalfa, grass hay, and pasture.

N.O.=Natural over-flow on grass hay, meadows and pasture during flood stage of river or streams, provides moisture for crops before irrigation period begins consumptive use rate is for irrigation period only.

Table 7.- Summary of estimates of normal unit consumptive use of water rates minus precipitation by irrigated crops through the irrigation period for areas in the Upper Colorado River Basin

Unit		Water supply	Normal rate consumptive use 1/				
No.	Area		Alfalfa	Grass hay and pasture	Grains and beans	Corn and other annuals	Orchard
			Inches	Inches	Inches	Inches	Inches
<u>ARIZONA</u>							
1	Chinle	F	23.0	19.2	12.5	15.8	-
	Chinle	S	12.3	9.7	12.5	15.8	-
2	Kayenta	F	27.5	23.6	13.3	17.0	-
	Kayenta	S	15.3	12.2	13.3	17.0	-
<u>COLORADO</u>							
1	Upper Yampa and Elk River	F	9.7	7.7	5.5	5.5	-
	Upper Yampa and Elk River	S	8.4	6.9	5.5	5.5	-
	Upper Yampa and Elk River	N.O.	-	2.4	-	-	-
2	Lower Yampa and Tributaries	S	11.0	8.4	10.1	-	-
3	Little Snake River	S	13.8	10.9	10.7	-	-
4	White River - Direct	F	13.2	10.9	9.2	-	7.4
	White River - Direct	N.O.	-	5.6	-	-	-
5	White River Tributaries	S	8.4	6.4	9.2	-	7.4
6	Colorado River above Glenwood	F	11.8	9.8	8.1	-	-
6a	Kremmling, Muddy, Troublesome	S	10.6	8.2	8.1	8.1	-
	Kremmling, Muddy, Troublesome	N.O.	-	1.7	-	-	-
7	Blue River	F	11.8	9.8	8.1	-	-
	Blue River	N.O.	-	4.7	-	-	-
8	Eagle River and Upper Eagle R.	F	13.3	11.0	8.2	8.2	-
	Eagle River and Upper Eagle R.	N.O.	-	4.8	-	-	-
9	Gypsum Creek	S	9.4	7.3	8.2	8.2	-
10	Roaring Fork above Basalt	F	11.5	9.6	8.5	8.5	-
	Roaring Fork above Basalt	S	10.7	9.0	8.5	-	-
11	Roaring Fork Glenwood Springs to Basalt	F	17.1	14.3	10.4	12.9	11.1
	Roaring Fork Glenwood Springs to Basalt	S	13.0	10.1	10.4	10.4	-
12	Rifle-Silt to Glenwood Springs	S	11.0	8.4	12.4	15.7	14.3
12a	Plateau Creek	S	10.0	8.5	11.1	13.4	11.0
13	Grand Valley	F	28.3	24.5	13.2	17.6	19.2
14	Upper Gunnison (excluding Tomichi and Cochetopa)	F	11.7	9.7	7.5	7.5	-
	Tomichi and Cochetopa	N.O.	-	6.1	-	-	-
15	Tomichi and Cochetopa	S	10.1	7.4	7.5	-	-
	Tomichi and Cochetopa	N.O.	-	2.6	-	-	-
16	North Fork Gunnison	S	11.3	8.5	11.4	14.8	14.2
17	Upper Compahgre Cimarron and Dallas	F	16.8	14.3	12.5	16.0	15.5
18	Uncompahgre Project	F	23.2	20.0	13.0	16.6	16.2
19	Little Dolores	S	22.8	18.6	12.6	17.5	21.0
19a	Lower Dolores	F	28.3	24.5	13.2	17.6	19.2
20	Dolores River	S	11.9	9.2	11.6	13.9	11.6
21	San Miguel - Lily Lands - Disappointment	S	10.5	8.0	8.8	-	-
22	Montezuma Area	F	18.9	16.0	11.6	13.9	11.6
23	Upper San Juan Valley	F	11.0	8.8	-	-	-

Table 7 (cont'd).- Summary of estimates of normal unit consumptive use of water rates minus precipitation by irrigated crops through the irrigation period for areas in the Upper Colorado River Basin

Unit		Water supply	Normal rate consumptive use ^{1/}				
No.	Area		Alfalfa	Grass hay and pasture	Grains and beans	Corn and other annuals	Orchard
			Inches	Inches	Inches	Inches	Inches
<u>COLORADO (Continued)</u>							
24	Pine River and Piedra Area	F	15.5	12.7	9.3	12.6	8.3
25	Animas River	F	14.9	12.1	8.8	10.2	7.9
26	Florida Area	S	9.8	7.8	8.8	10.2	7.9
27	La Plata - (Colorado Portion)	S	11.2	8.8	9.9	11.4	9.2
28	Mantos Area	S	12.0	9.7	11.6	13.9	11.6
<u>NEW MEXICO</u>							
1	Dulce	S	13.1	10.3	7.9	-	-
2	La Plata	S	11.8	9.3	10.5	-	-
3	Bloomfield Shiprock	F	27.0	23.2	13.4	17.2	17.2
<u>UTAH</u>							
1	Henry's Fork	S	13.9	11.3	11.3	-	-
2	Ashley Valley and Brush Creek	F	18.7	16.1	13.1	-	-
3	Ouray	S	15.1	12.3	13.2	-	-
4	Benchlands-Uinta Basin	S	19.0	15.7	11.6	14.2	11.7
5	Valleylands-Uinta Basin	S	21.9	18.9	13.2	16.3	14.6
6	Price River	F	21.7	18.5	12.7	15.8	14.1
7	Green River	F	28.8	25.0	14.7	19.3	19.7
8	Moab	S	24.8	20.4	13.1	17.8	20.3
9	La Sal	S	13.0	10.3	11.1	-	-
10	Monticello	S	13.9	11.0	11.1	-	-
11	Huntington-Castle Dale-Ferron	S	19.6	16.1	12.1	15.1	13.0
12	Emery-Hanksville	S	19.1	15.6	11.8	14.7	14.2
13	Loa	S	15.0	12.9	10.3	-	-
14	Escalante	S	16.3	13.3	11.0	13.6	12.1
15	Blanding	S	15.4	12.2	12.3	15.6	14.8
16	Paria River	S	16.4	13.3	11.1	13.5	12.0
<u>WYOMING</u>							
1	Pinedale	F	11.4	9.6	-	-	-
	Pinedale	N.O.	-	7.5	-	-	-
2	Big Piney	S	11.9	9.3	-	-	-
	Big Piney	N.O.	-	5.7	-	-	-
3	Eden Valley	F	14.5	12.4	11.1	-	-
4	Ham's Fork	F	15.6	13.4	11.0	-	-
	Ham's Fork	N.O.	-	10.2	-	-	-
5	Black's Fork	S	12.9	9.9	10.9	-	-
	Black's Fork	N.O.	-	5.8	-	-	-
6	Henry's Fork	S	13.8	10.9	11.3	-	-
7	Little Snake	S	13.3	10.5	10.7	-	-
	Little Snake	N.O.	-	3.8	-	-	-

^{1/} Includes irrigation water only (consumptive use minus rainfall)

F = Full water supply for all crops.

S = Short water supply for alfalfa, grass hay and pasture

N.O. = Natural over-flow on grass hay, meadows and pasture during flood stage of river or streams.

Native Vegetation and Incidental Areas

Native or natural vegetation generally has first use of the water of a region. The consumption of water by native vegetation thus becomes of increasing importance as greater land areas are irrigated, and during periods of drought. Careful consideration must be given to the consumptive water requirements of native vegetation before a complete inventory can be made of the water resources of the Upper Colorado River Basin (2).

Consumptive use of water by native vegetation varies according to the quantity of moisture available (19). Plants adapted to an extreme economy of water do not continue the same low rate of use during periods of more abundant supply. Precipitation, varying widely from year to year, produces a more vigorous growth that has a greater consumptive use in wet years than in dry. Drought periods are seldom so severe that there is a widespread destruction of vegetation from lack of moisture.

Adaptation of plants to natural moisture conditions has distributed vegetation in more or less dominant communities which may be roughly classified as drought-resistant plants, ground-water plants, and plants that grow with roots submerged. Neither group is confined to any particular geographical area but is governed by local conditions. There are no fixed boundary lines between groups, for as ground-water conditions change with increased or decreased precipitation, the dominant communities advance or recede according to moisture available in the soil.

Much of the arid region has ground water only at depths beyond reach of plant roots, and in these areas plants depend entirely upon the scanty rainfall and the moisture that is held in the upper soil horizon. Desert sage, sage brush, creosote bush, desert grass, and cacti are a few desert growths which subsist upon a meager rainfall. (See figures 10 and 11).

Ground-water plants are those sending their roots to the water table or into the adjoining region of capillary moisture. Thus they are a middle group between desert growth that has no connection with ground water and plants that grow with their roots submerged. These comprise a great variety, ranging from small ground plants to large trees. Salt grass, scepweed, salt bush and some species of sacaton are in this group.

Riparian or river-bottom growths, such as salt cedars (tamarisk), willows, and cottonwoods, consume more water per given area than irrigated crops. (See figures 12 to 17).

Plants growing in water, such as tules, cattails, and sedges, are users of large quantities of water.

Meteorological conditions influencing evaporation from water surfaces likewise affect transpiration from vegetation and evaporation from soils. Both evaporation and transpiration freely respond to temperature, wind movement, and humidity (4).

Seeped lands are moist areas within irrigation projects. These areas are the result of high ground water due to seepage from canals, over-irrigation, or both, and poor drainage. Seeped lands are generally in greasewood, rabbit-brush, willows, and tules depending on the degree of moisture present. In some areas, where alkali is concentrated, no vegetation grows.

Evaporation and meteorological observations made from April 1939 to March 1943 at Montrose, Colorado (13) are shown in the appendix. These are used to establish coefficients applicable in estimating evaporation rates from free water surfaces in the Upper Colorado River Basin.

The results of computations of normal water consumption rates for native vegetation, seeped land and water surface during the frost-free period are summarized in table 8. The estimates for native vegetation are based on the assumption that a water supply ample to satisfy the water requirements of the plants is available.

The estimates of rates of consumptive use shown in table 8 include moisture supplied from all sources. By subtracting the frost-free period precipitation from these rates of use, the rates of consumption of ground water at point of use may be estimated. Table 9 summarizes the results of computations of normal unit consumptive use of water rates minus precipitation for native vegetation and areas receiving water incidentally to irrigation in the Upper Colorado River Basin during the frost-free period.

APPLICATION OF CONSUMPTIVE USE RATES

Consumptive use rates shown in this report may be used in estimating the amounts of water consumed in an entire valley, on an irrigation project, or on an individual farm, when the acreage of different crops is known. By making allowances for application and conveyance losses, the water that must be delivered to the farm headgate adequately to irrigate a farm or tract of land may also be estimated from consumptive use rates (7). Methods of application of the rates to valley areas and individual farms are presented here.

Valley Areas

The unit consumptive use rates shown in tables 6, 7, 8 and 9, may be applied to large valley areas by the integration method (2) (3) to compute the total amount of water normally consumed for a given area in acre-feet. Briefly stated, consumptive use for a specified time, as determined by the integration method, is the summation of the products of consumptive use for each crop times its area, plus the consumptive use of native vegetation times its area, plus water surface evaporation times water surface area, plus evaporation from land times its area. Before this method can be used it is necessary to know the areas of agricultural crops, native vegetation, water surfaces and other classifications, as well as the unit consumptive use for each classification.

Table 8.- Summary of estimates of normal unit consumptive use of water rates for native vegetation and areas receiving water incidentally to irrigation in the Upper Colorado River Basin.

No.	Unit Area	Normal rate consumptive use 1/						Seeped 3/land
		Water sur- face	Native vegetation 2/					
		Very dense	Dense	Medi- um	Light	Spars ^e		
		Inches	Inches	Inches	Inches	Inches	Inches	
<u>ARIZONA</u>								
1	Chinle	28.7	40.8	36.2	30.2	24.2	7.2	27.2
2	Kayenta	33.5	47.6	42.3	35.2	28.2	6.6	31.7
<u>COLORADO</u>								
1	Upper Yampa and Elk River	10.9	15.5	13.8	11.5	9.2	6.1	10.3
2	Lower Yampa and tributar- ies	18.0	25.5	22.7	18.9	15.1	7.0	17.0
3	Little Snake River	18.6	26.4	23.5	19.6	15.6	6.4	17.6
4	White River Direct	17.6	25.0	22.2	18.5	14.8	7.6	16.6
5	White River tributaries	17.6	25.0	22.2	18.5	14.8	7.6	16.6
6	Colo. River above Glenwood	14.9	21.1	18.8	15.6	12.5	-	14.1
6a	Kremmling, Muddy, and Troublesome	14.9	21.1	18.8	15.6	12.5	-	14.1
7	Blue River	14.9	21.1	18.8	15.6	12.5	-	14.1
8	Eagle River and Upper Eagle River	14.7	20.9	18.5	15.4	12.4	6.4	13.9
9	Gypsum	14.7	20.9	18.5	15.4	12.4	6.4	13.9
10	Roaring River above Basalt	16.8	23.9	21.3	17.7	14.2	7.5	15.9
11	Roaring Fork-Glenwood Springs to Basalt	26.0	36.9	32.8	27.3	21.9	9.7	24.6
12	Rifle-Silt to Glenwood Springs	27.3	38.8	34.5	28.8	23.0	7.4	25.9
13	Grand Valley	35.0	49.8	44.2	36.9	29.5	7.3	33.2
14	Upper Gunnison	13.8	19.7	17.5	14.6	11.7	6.4	13.1
15	Tomichi and Cochetopa	13.8	19.7	17.5	14.6	11.7	6.4	13.1
16	North Fork Gunnison	30.0	42.6	37.9	31.6	25.2	9.3	28.4
17	Upper Uncompahgre, Cimmar- ron and Dallas	21.7	30.8	27.4	22.8	18.3	6.8	20.6
18	Uncompahgre Project	30.2	42.9	38.1	31.8	25.4	6.8	28.6
19	Little Dolores	38.4	54.5	48.4	40.4	32.3	7.7	36.3
20	Dolores River	24.4	34.6	30.8	25.6	20.5	8.1	23.1
21	San Miguel, Lilylands, Disappointment	20.6	29.3	26.0	21.7	17.4	9.4	19.5
22	Montezuma Area	24.4	34.6	30.8	25.6	20.5	8.1	23.1
23	Upper San Juan Valley	14.7	20.9	18.7	15.5	12.4	8.5	13.9
24	Pine River and Piedra Area	20.8	29.6	26.3	21.9	17.5	9.0	19.7
25	Animas River	21.6	30.7	27.3	22.7	18.2	9.9	20.5
26	Florida Area	21.6	30.7	27.3	22.7	18.2	9.9	20.5
27	La Plata (Colorado Area)	22.1	31.4	27.9	23.2	18.6	8.8	20.9
28	Mancos Area	24.4	34.6	30.8	25.6	20.5	8.1	23.1

Table 8 (cont'd).- Summary of estimates of normal unit consumptive use of water rates for native vegetation and areas receiving water incidentally to irrigation in the Upper Colorado River Basin.

Unit		Normal rate consumptive use 1/						Seeped land
No.	Area	Water surface	Native vegetation 2/				Sparse 3/	
			Very dense	Dense	Med-ium	Light		
		Inches	Inches	Inches	Inches	Inches	Inches	
<u>NEW MEXICO</u>								
1	Dulce	18.8	26.7	23.8	19.8	15.8	9.5	17.8
2	La Plata Area	25.3	35.9	31.9	26.6	21.3	8.3	24.0
3	Bloomfield Shiprock	31.9	45.3	40.3	33.6	26.9	6.5	30.2
<u>UTAH</u>								
1	Henry's Fork	17.8	25.4	22.6	18.8	15.0	5.7	16.9
2	Ashley Valley and Brush Creek	21.5	30.6	27.2	22.7	18.1	5.5	20.4
3	Ouray Area	27.3	38.8	34.5	28.7	23.0	5.1	25.9
4	Benchlands, Uinta Basin	23.0	32.7	29.0	24.2	19.4	6.8	21.8
5	Valley lands, Uinta Basin	25.7	36.5	32.4	27.0	21.6	5.0	24.3
6	Price River	27.3	38.8	34.4	28.7	23.0	7.5	25.8
7	Green River	33.5	47.7	42.4	35.3	28.2	4.9	31.8
8	Moab	36.9	52.5	46.6	38.9	31.1	7.5	35.0
9	La Sal	23.7	33.6	29.9	24.9	19.9	8.3	22.4
10	Monticello	23.7	33.6	29.9	24.9	19.9	8.3	22.4
11	Huntington Castledale Ferron	24.4	34.7	30.9	25.7	20.6	6.2	23.2
12	Emery-Hanksville	27.1	38.6	34.3	28.6	22.9	6.0	25.7
13	Loa	16.9	24.0	21.3	17.8	14.2	5.4	16.0
14	Escalante	26.1	37.1	33.0	27.5	22.0	8.8	24.8
15	Blanding	29.3	41.7	37.1	30.9	24.7	8.2	27.8
16	Paria River	24.9	35.3	31.4	26.2	20.9	8.4	23.6
<u>WYOMING</u>								
1	Pinedale	12.4	17.6	15.6	13.0	10.4	5.2	11.7
2	Big Piney	12.4	17.6	15.6	13.0	10.4	5.0	11.7
3	Eden Valley	17.0	24.1	21.4	17.8	14.3	4.8	16.1
4	Ham's Fork	17.8	25.3	22.5	18.8	15.0	5.2	16.9
5	Black's Fork	18.4	26.1	23.2	19.4	15.5	6.0	17.4
6	Henry's Fork	18.6	26.4	23.5	19.6	15.6	5.7	17.6
7	Little Snake	17.8	25.4	22.6	18.8	15.0	6.4	16.9

1/ For frost free period only. Includes precipitation.

2/ See table 1 for types of native vegetation.

3/ Precipitation during the frost free period plus 50 percent of winter precipitation not to exceed 3 inches.

Table 9. - Summary of estimates of normal unit consumptive use of water rates minus precipitation for native vegetation and areas receiving water incidentally to irrigation in the Upper Colorado River Basin

Unit		Normal rate consumptive use 1/					Seeped land
		Water surface	Native vegetation 2/				
No.	Area		Very Dense	Dense	Medium	Light	
		Inches	Inches	Inches	Inches	Inches	Inches
<u>ARIZONA</u>							
1	Chinle	23.7	35.7	31.2	25.2	19.1	22.2
2	Kayente	28.7	42.8	37.5	30.5	23.4	27.0
<u>COLORADO</u>							
1	Upper Yampa and Elk River	7.7	12.3	10.6	8.3	6.0	7.2
2	Lower Yampa and Tributaries	14.0	21.6	18.7	15.0	11.2	13.1
3	Little Snake River	15.2	23.0	20.0	16.1	12.2	14.2
4	White River Direct	13.0	20.4	17.6	13.9	10.2	12.0
5	White River Tributaries	13.0	20.4	17.6	13.9	10.2	12.0
6	Colo. River above Glenwood	11.2	17.5	15.1	12.0	8.9	10.4
6a	Kremmling, Muddy, Troublesome	11.2	17.5	15.1	12.0	8.9	10.4
7	Blue River	11.2	17.5	15.1	12.0	8.9	10.4
8	Eagle River and Upper Eagle River	11.3	17.4	15.1	12.0	8.9	10.5
9	Gypsum	11.3	17.4	15.1	12.0	8.9	10.5
10	Roaring River above Basalt	12.3	19.4	16.8	13.2	9.7	11.4
11	Roaring Fork - Glenwood Springs	19.3	30.2	26.1	20.6	15.2	17.9
12	Rifle-Silt to Glenwood Springs	22.9	34.4	30.1	24.4	18.6	21.5
13	Grand Valley	30.2	45.0	39.4	32.1	24.7	28.4
14	Upper Gunnison	10.5	16.3	14.1	11.2	8.3	9.7
15	Tomichi and Cochetopa	10.5	16.3	14.1	11.2	8.3	9.7
16	North Fork Gunnison	23.7	36.3	31.6	25.3	19.0	22.1
17	Upper Uncompahgre, Cimarron and Dallas	17.7	26.8	23.4	18.8	14.2	16.5
18	Uncompahgre Project	25.7	38.4	33.7	27.3	21.0	24.1
19	Little Dolores	33.1	49.2	43.2	35.1	27.0	31.0
20	Dolores River	19.3	29.5	25.7	20.5	15.4	18.0
21	San Miguel, Lilylands, Disappointment	14.2	22.9	19.7	15.3	11.0	13.1
22	Montezuma Area	19.3	29.5	25.7	20.5	15.4	18.0
23	Upper San Juan Valley	9.2	15.4	13.1	10.0	6.9	8.4
24	Pine River and Piedra Area	24.8	23.6	20.3	15.9	11.6	13.7
25	Animas River	14.7	23.8	20.4	15.9	11.3	13.6
26	Florida Area	14.7	23.8	20.4	15.9	11.3	13.6
27	La Plata - (Colorado Area)	21.2	24.5	21.0	16.3	11.7	14.0
28	Mancos Area	19.3	29.5	25.7	20.5	15.4	18.0
<u>NEX MEXICO</u>							
1	Dulce	12.3	20.3	17.3	13.3	9.4	11.4
2	La Plata Area	19.6	30.2	26.2	20.9	15.6	18.3
3	Bloomfield Shiprock	27.4	40.8	35.8	29.0	22.3	25.7

Table 9 (cont'd).- Summary of estimates of normal unit consumptive use of water rates minus precipitation for native vegetation and areas receiving water incidentally to irrigation in the Upper Colorado River Basin

Unit		Normal rate consumptive use 1/					Scaped land
		Water surface	Native vegetation 2/				
No.	Area		Inches	Very dense Inches	Dense Inches	Medium Inches	Light Inches
<u>UTAH</u>							
1	Henry's Fork	15.1	22.6	19.8	16.1	12.3	14.2
2	Ashley Valley and Brush Creek	19.0	28.1	24.7	20.2	15.6	17.9
3	Curay Area	24.0	34.5	31.2	25.4	19.7	22.5
4	Benchlands, Uintah Basin	19.0	28.7	25.0	20.2	15.4	17.8
5	Valley lands, Uinta Basin	22.7	33.5	29.4	24.0	18.6	21.3
6	Price River	22.7	34.2	29.8	24.1	18.4	21.2
7	Greenriver	30.3	44.4	39.1	32.0	25.0	28.5
8	Moab	31.9	47.5	41.6	33.9	26.1	30.0
9	La Sal	18.4	28.4	24.6	19.6	14.6	17.1
10	Monticello	18.4	28.4	24.6	19.6	14.6	17.1
11	Huntington Castle-Dale Ferron	20.7	31.0	27.2	22.0	16.9	19.4
12	Emery-Hanksville	22.8	34.2	30.0	24.2	18.5	21.4
13	Loa	13.9	21.0	18.3	14.8	11.2	13.0
14	Escalante	20.3	31.3	27.2	21.7	16.2	18.9
15	Blanding	24.1	36.4	31.8	25.6	19.5	22.6
16	Paria River	19.4	30.0	26.0	20.8	15.5	18.1
<u>Wyoming</u>							
1	Pinedale	10.1	15.3	13.4	10.8	8.2	9.5
2	Big Piney	10.4	15.6	13.6	11.0	8.4	9.7
3	Edin Valley	14.6	21.8	19.1	15.5	12.0	13.8
4	Ham's Fork	15.4	23.0	20.1	16.4	12.6	14.5
5	Black's Fork	15.4	23.1	20.2	16.4	12.5	14.4
6	Henry's Fork	15.2	23.0	20.0	16.1	12.2	14.2
7	Little Snake	15.1	22.6	19.8	16.1	12.3	14.2

1/ For frost-free or growing season. Does not include precipitation.
 2/ See table 1 for types of native vegetation.

After acreages of irrigated crops and other water-consuming areas have been determined by members of the Engineering Advisory Committee to the Upper Colorado River Basin Compact Commission, the normal valley consumptive use for the areas shown in table 3 may be computed from these acreages and the unit rates of use shown in table 6, 7, 8 and 9. Again it is emphasized that not all use of water by native vegetation is the result of man's activities in the Upper Basin and only those areas using water because of man should be considered in determining the man-made consumptive use.

Erickson in a four-year (1938-41) study of consumptive use of irrigation water in the Lower Uncompahgre Valley, made a survey of water-using areas for the Colorado Water Conservation Board and by inflow and outflow measurements calculated the average consumptive use, exclusive of precipitation at 195,200 acre-feet (13). The average rates of consumptive use minus precipitation determined for the period 1938-41 by the methods described in this report were applied to the same area. The use of water thus determined was 202,187 acre-feet, as shown in table 10, or 3.6 percent greater than Erickson measured by the inflow-outflow method. Similar comparisons were made in other areas with like results. These comparisons serve to validate the rates of use computed herein.

Farm Irrigation Requirements

The amounts of water required fully to irrigate a farm in the Upper Colorado River Basin may be estimated from the consumptive use rates established in this report. The irrigation water required $\frac{1}{}$ to satisfy the consumptive use for each crop growing or to be grown on a farm in the area is obtained from table 7, and rates for native vegetation are drawn from table 9. The net consumptive requirement of the crop divided by the farm irrigation efficiency gives the annual amount of water required at the farm headgate for each acre of the crop. (7).

The summation of the headgate requirements for each crop times its acreage plus other water consumed incidental to the farming operations produces the total amount of water that must be delivered to the farm headgate for satisfactory crop production. This method of analysis is illustrated for two typical farms in tables 11 and 12.

$\frac{1}{}$ Consumptive use minus effective rainfall.

Table 10.- Average consumptive use of water in the Lower Uncompahgre Valley, Colorado, 1938-41, computed by the integration method

Classification	Area <u>1/</u>		Consumptive use		Consumptive use minus precipitation	
	Percent	Acres	Unit rate	Quantity	Unit rate	Quantity
	Percent	Acres	Feet	Acre feet	Feet	Acre feet
<u>Irrigated crops <u>2/</u></u>						
Alfalfa	30	21,704	2.60	56,430	2.12	46,012
Hay and pasture	15	10,852	2.29	24,851	1.81	19,642
Small grain and beans	30	21,703	1.21	26,261	1.07	23,222
Corn	10	7,234	1.65	11,936	1.44	10,417
Potatoes	5	3,617	1.65	5,968	1.44	5,208
Sugar beets	3	2,170	1.65	3,580	1.44	3,125
Orchard and truck	7	5,065	1.93	9,775	1.46	7,395
Total or weighted average	100	72,345	1.92	138,801	1.59	115,021
<u>Incidental areas</u>						
Cropped land (seeped) <u>2/</u>	38.5	14,180	2.67	37,861	2.20	31,196
Seeped land and moist <u>2/</u>	43.0	15,815	2.67	42,226	2.20	34,793
River bottom and willows <u>3/</u>	14.0	5,060	4.40	22,264	3.53	17,862
Towns <u>3/</u>	3.0	1,020	1.92	1,958	1.59	1,622
Stream surfaces <u>3/</u>	1.5	590	3.74	2,207	2.87	1,693
Total or weighted average	100.0	36,665	2.91	106,516	2.38	87,166
Total		109,010	2.25	245,317	1.85	202,187

1/ The area does not include 5,875 acres of arable non-cropped land 15,980 acres of non-arable, non-cropped land and 38,135 acres of dry land. Survey by Erickson (12).

2/ Consumptive use for irrigation season only.

3/ Consumptive use for entire year.

Table 11.- Application of results of consumptive use calculations to a determination of water requirement of a typical farm, Grand Junction Area, Colorado

Crop	Growing period	Area	Irrigation required for consumptive use	Farm irrigation efficiency ^{1/}	Headgate require- ment ^{2/}	Total water ^{3/} required
		Acres	Ac. ft./ac.	Per cent	Ac.ft./ac	Ac. ft.
<u>Irrigated</u>						
Alfalfa	4/15-10/18	50	2.36	60	3.64	182
Small grain	4/24-7/24	20	1.10	55	2.00	40
Pasture	4/15-10/18	25	2.04	60	3.40	85
Potatoes	4/24-8/24	15	1.47	50	2.95	44
Orchard	4/24-10/18	40	1.60	60	2.67	107
<u>Incidental land use</u>						
Roads and lanes		4/ 8	0.00	-	-	0
Dense native vegetation		2	3.28	-	3.28	7
Total or Average		160	1.72	61	2.90	465

- ^{1/} Considered reasonable efficiencies for irrigation in this area.
- ^{2/} Amount of water that must be delivered at the farm headgate to satisfy the crop needs.
- ^{3/} Total water required at farm headgate during normal irrigation season.
- ^{4/} Receives water incidental to irrigation such as low land that receives surface runoff or seepage.

Table 12.- Application of results of consumptive use calculations to a determination of water requirement of a typical ranch Pinedale Area, Wyoming

Crop	Growing period	Area Acres	Irrigation	Farm	Headgate	Total
			required for consumptive use Ac. ft./ac.	irrigation efficiency 1/ Per cent	require- ment 2/ Ac.ft./ac	water 3 required Ac. ft.
<u>Irrigated:</u>						
Alfalfa	5/20-8/29	40	0.95	40	2.38	95
Wild hay	5/20-8/29	450	0.80	25	3.20	1440
<u>Incidental land use</u>						
Roads, lanes, yards		35	0.00	-	-	0
Native vegetation ^{4/}						
Medium dense		20	0.90	-	-	18
Light		35	0.68	-	-	24
Sparse		80	0.00	-	-	0
Total or Average		660			2.39	1577

1/ Considered reasonable efficiencies for irrigation in this area.

2/ Amount of water that must be delivered at the farm headgate to satisfy the crop needs.

3/ Total water required at farm headgate during normal irrigation season.

4/ Receives water incidental to irrigation such as low land that receives surface runoff or seepage.

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APPENDIX

Table A - Consumptive use coefficients for alfalfa based on measured consumptive use and temperature records, and percent of daytime hours and growing season in Western States

Location	Year	Growing season or period	Consumptive use (U) <u>Inches</u>	Consumptive use factor (F)	Coefficient (K)
		<u>Alfalfa</u>			
Carlsbad, New Mexico	1940	4/18 - 11/10	38.6	43.59	0.885
Carlsbad, New Mexico	Normal	3/28 - 11/3	36.8	47.39	.778
Fort Stockton, Texas	1940	4/13 - 11/11	40.5	46.28	.875
Fort Stockton, Texas	Normal	3/31 - 11/12	39.7	48.97	.811
San Fernando, Calif.	1939	5/26 - 9/9	19.3	23.35	.827
San Fernando, Calif.	1940	4/1 - 10/31	37.4	43.73	.855
Bonnars Ferry, Idaho	1940-44	5/4 - 9/19	22.8	27.18	.839
Scottsbluff, Nebr.	1932-35	5/11 - 9/26	26.7	29.70	.899
Bozeman, Montana	-	5/24 - 9/16	18.9	22.60	.836
Prosser, Washington	1940-41	4/28 - 10/14	29.65	35.24	.841
Logan, Utah	1902-11	5/12 - 10/9	26.9	31.66	.850
Vale, Oregon	1941-42	5/17 - 9/18	24.0	26.82	.895
Vernal, Utah	1948	5/17 - 10/6	23.6	27.42	.86
Ferron, Utah	1948	5/9 - 10/6	24.2	28.70	.84

Table B. - Examples of consumptive use coefficients for native vegetation and evaporation based on measured consumptive use and temperature records, and percent of daytime hours and growing season

Location	Classification	Year	Depth to water table	Growing season or period	Consumptive use factor (F)	Consumptive use (U)	Coefficient (K) growing season	Annual		
								F	U	K
			Feet	Inches						
Carlsbad, New Mexico	Salt Cedar	1940	2	April to Sept.	40.72	48.61	1.19	63.75	62.9	0.99
Carlsbad, New Mexico	Salt Cedar	1940	3	April to Sept.	40.72	43.95	1.08	63.75	57.2	.90
Carlsbad, New Mexico	Sacaton	1940	2	April to Sept.	40.72	37.93	.93	63.75	48.1	.75
Carlsbad, New Mexico	Sacaton	1940	4	April to Sept.	40.72	32.32	.81	63.75	41.4	.65
San Luis Rey, Calif.	Cotton and willows	1940-43	4	April to Sept.	36.27	48.99	1.35	61.38	62.5	1.02
San Luis Rey, Calif.	Tules	1940-43	0	April to Sept.	41.89	47.03	1.12	62.16	58.9	.95
Montrose, Colorado	Water surface	1939-43	0	Apr. 23 to Oct. 15	34.93	33.26	.95	52.23	43.7	.84

Table C - Average monthly evaporation and meteorological data,
Montrose, Colorado 1939 to 1943 (13)

Month	Mean temperature F°	Percent daytime hours Percent	Consumptive use factor (F)	Evaporation		Coefficient Reservoir evaporation (K)
				Fan Inches	Reservoir (U) Inches	
January	26.8	6.84	1.83	1.30	0.86	0.47
February	32.2	6.78	2.18	1.37	.95	.44
March	39.5	8.34	3.29	3.32	2.39	.73
April	48.8	8.92	4.35	4.95	3.46	.80
May	59.3	9.94	5.89	7.83	5.64	.96
June	67.1	9.98	6.70	10.29	7.51	1.12
July	73.4	10.13	7.44	10.41	7.60	1.02
August	71.0	9.49	6.74	8.55	6.24	.93
September	62.5	8.38	5.24	5.64	4.23	.81
October	50.6	7.78	3.94	3.53	2.54	.64
November	38.2	6.80	2.60	1.84	1.38	.53
December	30.7	6.62	2.03	1.23	.86	.42
Annual	50.0	100.00	52.23	60.26	43.66	0.84

$$K = \frac{U}{F} = \frac{43.66}{52.33} = 0.84, \text{ annual coefficient.}$$

$$K = \frac{U}{F} = \frac{33.26}{34.93} = 0.95, \text{ growing season coefficient.}$$

Table D. - Mean monthly temperatures in degrees Fahrenheit at stations in the Upper Colorado River Basin, recorded or estimated from Weather Bureau records for the period 1914 to 1945.

No.	Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean annual
ARIZONA														
1	Chinle	28.4	34.4	41.9	49.5	58.9	69.0	74.6	72.6	64.3	52.3	39.6	30.1	51.3
4	Kayenta	27.9	37.6	44.1	51.9	61.5	70.9	76.3	73.5	66.0	54.2	40.7	30.2	52.9
New	Lees Ferry	35.0	42.8	52.0	60.2	70.1	79.4	86.2	83.7	75.5	61.5	46.8	37.0	60.9
COLORADO														
5	Aspen	18.4	22.0	28.5	38.8	46.9	54.8	60.8	59.5	52.8	42.6	29.8	22.6	39.8
7	Collbran	21.8	27.6	36.1	45.6	53.7	62.4	68.4	66.5	58.5	47.2	35.2	24.1	45.6
8	Cortez	26.5	31.5	38.5	46.1	55.0	64.0	70.1	68.4	60.7	49.9	37.6	28.7	48.1
10	Crested Butte	13.1	16.5	22.7	32.8	43.5	51.9	57.0	55.6	47.9	37.5	25.0	15.3	34.9
11	Delta	24.6	32.6	41.8	51.0	59.9	68.4	74.5	72.3	63.5	51.5	37.9	26.7	50.4
12	Dillon	13.3	16.0	21.0	31.7	41.7	49.1	54.8	53.4	46.8	36.3	24.0	15.2	33.6
13	Durango	24.3	29.5	36.8	44.5	51.9	60.1	66.1	65.0	57.8	47.5	36.2	26.3	45.5
New	Eagle	19.5	25.1	34.4	41.9	49.1	56.3	63.5	62.6	55.0	44.0	32.2	20.8	42.0
15	Fraser	11.7	15.2	21.3	32.0	40.9	49.1	54.1	52.6	45.9	35.6	23.0	13.5	32.9
16	Fruita	23.4	32.3	42.4	51.4	60.5	69.4	76.3	74.0	64.6	51.7	38.2	26.7	50.9
17	Glenwood Springs	23.9	29.2	38.1	47.1	56.2	63.1	69.5	68.1	60.3	49.6	36.4	26.3	47.3
18	Grand Junction	25.3	33.9	42.9	52.3	62.2	72.1	78.5	75.6	66.8	54.3	40.0	29.1	52.8
19	Gunnison	7.9	13.9	26.0	39.7	48.0	56.0	61.8	60.3	52.6	41.7	27.9	13.0	37.4
20	Hayden	16.9	21.4	29.7	42.0	51.2	59.9	66.6	64.9	55.9	45.8	31.7	20.5	42.2
21	Ignacio	22.2	28.6	36.6	44.7	53.0	61.5	67.6	66.3	58.8	47.8	35.8	26.3	45.7
25	Montrose	24.6	31.7	39.8	48.4	57.3	66.5	72.2	69.8	62.0	50.0	37.6	26.8	48.9
27	Norwood	22.5	27.7	35.3	43.7	52.5	61.7	67.4	65.3	58.1	47.8	34.9	25.6	45.2
28	Pagosa Springs	17.8	22.5	31.0	41.4	48.4	56.7	63.2	61.7	54.3	43.5	31.3	21.6	41.1
29	Palisade	26.5	34.8	43.2	53.2	62.4	71.8	78.0	75.5	67.0	54.5	41.4	30.6	53.2
30	Paonia	25.0	31.7	38.6	47.4	56.0	64.8	71.0	69.0	60.9	50.6	38.6	27.3	48.4
31	Rifle	22.4	30.1	38.8	48.5	57.0	65.4	72.0	67.6	60.8	49.0	37.1	26.2	47.9
32	Sapinero	17.0	20.8	28.1	37.1	46.0	54.6	59.9	58.6	51.7	41.4	29.8	19.4	38.7
33	Steamboat Springs	13.9	18.6	26.2	38.2	48.2	55.2	61.6	59.4	52.1	41.7	28.7	16.9	38.4

Table D. (cont'd.) - Mean monthly temperatures in degrees Fahrenheit at stations in the Upper Colorado River Basin, recorded or estimated from Weather Bureau records for the period 1914 to 1945.

No.	Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Mean annual
NEW MEXICO														
37	Bloomfield	26.0	34.1	41.1	49.6	58.9	63.2	74.9	72.6	64.6	52.2	38.9	29.0	50.9
41	Dulce	17.8	25.7	34.5	43.7	51.8	60.7	66.6	64.6	57.2	45.6	33.4	21.5	43.6
47	Shiprock	28.6	35.4	44.7	53.1	61.7	69.6	76.3	74.4	67.0	55.0	41.2	30.2	53.1
UTAH														
50	Blanding	26.6	32.5	39.7	47.8	55.9	65.8	71.9	70.3	62.1	51.4	39.1	29.1	49.4
52	Castledale	18.5	26.2	36.9	45.3	54.3	63.3	69.2	67.1	58.3	46.8	34.9	22.0	45.2
53	Duchesne	15.6	23.4	35.3	45.2	54.0	61.7	68.9	66.8	57.8	46.5	32.5	20.6	44.0
54	Emery	24.0	29.0	36.7	44.5	53.1	61.2	67.3	65.6	57.7	47.5	36.5	26.8	45.8
55	Escalante	25.5	31.3	38.8	46.2	54.4	63.5	69.1	67.2	59.2	49.1	37.5	27.9	47.5
56	Ft. Duchesne	13.2	20.5	35.3	46.6	55.1	63.7	70.3	68.2	59.4	46.7	32.8	19.4	44.3
58	Green River	21.8	32.6	43.2	53.2	62.9	72.0	79.8	76.9	67.0	53.1	38.1	27.4	52.3
59	Hanksville	23.9	34.0	44.1	53.2	62.3	71.9	78.1	74.7	65.5	53.1	39.4	26.5	52.4
61	La Sal	24.7	29.3	35.7	45.2	53.9	63.1	69.4	67.8	59.5	48.3	36.8	25.3	46.6
62	Loa	21.8	26.1	33.6	41.9	51.2	59.8	66.5	64.0	55.0	43.8	32.7	22.8	43.3
63	Manila	21.3	25.8	33.6	41.6	51.1	59.7	67.4	64.8	56.8	46.4	33.5	19.3	43.5
64	Moab	29.0	36.9	46.7	55.6	64.6	72.8	79.0	76.3	67.5	54.0	41.6	31.3	54.6
67	Nyton	15.4	24.4	27.0	47.6	57.2	65.5	72.2	70.4	61.5	49.4	33.6	20.9	46.2
68	Price	23.8	30.0	39.1	47.7	57.4	66.8	73.0	71.2	62.1	51.2	37.2	26.4	43.8
71	Tropic	28.2	31.2	33.8	45.9	53.7	62.6	68.7	66.5	59.3	49.2	33.7	30.0	47.7
72	Vernal	16.6	23.0	34.9	46.4	54.5	63.8	69.4	67.1	57.7	45.6	33.9	18.2	44.3
WYOMING														
74	Big Piney	8.8	10.9	22.7	36.6	44.5	51.7	59.9	55.9	47.4	37.9	23.0	15.0	34.5
75	Dixon	16.5	21.6	29.4	40.9	50.2	58.2	65.4	63.3	54.4	44.0	30.4	19.7	41.2
76	Eden	9.8	15.6	26.7	38.4	48.1	56.9	64.0	61.7	52.1	41.4	27.0	12.8	37.9
78	Green River	18.3	23.8	32.2	42.8	52.9	61.7	69.9	67.2	57.1	45.3	32.2	20.9	43.7
79	Kemmerer	17.2	23.4	27.1	39.1	48.1	55.1	62.4	60.6	51.8	42.5	28.5	22.1	39.4
81	Lyman	17.0	21.7	28.9	38.1	49.7	53.7	65.3	62.2	52.4	43.1	29.4	22.2	40.7
82	Pinedale	11.7	15.3	23.0	35.0	44.9	53.2	60.8	57.9	49.3	39.0	23.3	14.5	35.7

Table E. - Mean monthly precipitation, in inches, at stations in the Upper Colorado River Basin, recorded or estimated from Weather Bureau records, for the period 1914 to 1945.

No.	Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
ARIZONA														
1	Chinle	0.57	0.58	0.67	0.60	0.40	0.38	1.55	1.60	1.11	0.86	0.45	0.73	9.50
4	Kayenta	0.44	0.58	0.70	0.47	0.39	0.32	1.27	1.60	0.83	0.77	0.52	0.46	8.35
New	Lees Ferry	0.30	0.57	0.36	0.44	0.37	0.16	0.68	1.17	0.52	0.54	0.43	0.47	6.01
COLORADO														
5	Aspen	1.96	1.99	1.91	1.89	1.64	0.96	1.44	1.61	1.63	1.40	1.27	1.41	19.11
7	Collbran	1.20	1.18	1.54	1.78	1.47	0.78	1.15	1.59	1.58	1.51	1.05	1.07	15.90
8	Cortez	0.93	1.23	1.23	1.11	0.67	0.40	1.41	1.47	1.77	1.36	0.70	1.01	13.34
10	Crested Butte	2.09	2.11	1.85	1.57	1.46	1.36	2.21	2.42	2.23	1.12	1.20	1.72	21.34
11	Delta	0.59	0.49	0.56	0.71	0.94	0.44	0.63	1.12	1.03	0.89	0.55	0.50	8.45
12	Dillon	1.23	1.45	2.02	2.19	1.64	0.99	1.80	1.83	1.38	1.39	1.03	1.26	18.26
13	Durango	1.61	1.60	1.79	1.59	1.14	0.87	2.08	2.19	2.02	1.86	1.24	1.71	19.70
New	Eagle	1.27	0.87	1.11	1.56	1.47	0.95	1.21	1.57	1.45	1.27	0.74	0.97	14.44
15	Fraser	1.55	1.75	1.87	2.17	1.91	1.24	2.11	1.75	1.29	1.35	1.12	1.29	19.40
16	Fruita	0.88	0.64	0.89	0.82	0.73	0.49	0.74	1.00	1.17	0.99	0.68	0.72	9.75
17	Glenwood Springs	1.64	1.77	1.69	1.72	1.58	1.04	1.48	1.83	1.64	1.43	1.18	1.32	18.37
18	Grand Junction	0.62	0.60	0.32	0.30	0.72	0.43	0.75	1.19	1.03	0.86	0.57	0.68	9.07
19	Gunnison	0.84	0.80	0.69	0.70	0.39	0.72	1.60	1.43	0.97	0.70	0.50	0.68	10.52
20	Hayden	1.24	1.20	1.34	1.42	1.60	1.03	1.25	1.34	1.63	1.47	0.89	1.21	15.62
21	Ignacio	1.21	1.27	1.44	1.27	0.95	0.90	1.92	1.99	1.72	1.43	1.01	1.25	16.36
25	Montrose	0.55	0.47	0.76	1.00	1.05	0.47	0.79	1.31	1.11	0.96	0.60	0.69	9.76
27	Norwood	1.10	1.45	1.67	1.82	1.26	0.83	2.02	2.18	1.84	1.50	0.98	1.29	17.92
28	Pagosa Springs	2.85	2.51	2.71	1.73	0.94	1.10	2.13	2.39	1.66	2.70	1.16	2.29	24.22
29	Palisade	0.63	0.62	0.87	1.15	0.91	0.53	0.77	1.08	1.23	1.16	0.72	0.67	10.39
30	Paonia	1.39	1.38	1.46	1.73	1.41	0.73	1.01	1.38	1.36	1.57	1.22	1.40	16.04
31	Rifle	0.91	0.67	0.91	1.05	1.03	0.49	1.08	1.06	1.13	1.14	0.74	0.79	11.00
32	Sapinero	2.08	2.15	2.51	2.28	1.75	0.96	1.62	2.17	1.75	1.50	1.46	1.95	22.18
33	Steamboat Springs	2.31	2.43	2.39	2.27	2.23	1.33	1.53	1.76	1.78	1.99	1.69	2.26	24.07

Table E (cont'd.) - Mean monthly precipitation, in inches, at stations in the Upper Colorado River Basin, recorded or estimated from Weather Bureau records for the period 1914 to 1945.

No.	Station	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
NEW MEXICO														
37	Bloomfield	0.55	0.72	0.62	0.62	0.66	0.50	1.11	1.23	1.14	0.76	0.55	0.64	9.11
41	Dulce	1.40	1.58	1.63	1.39	1.24	0.91	2.49	2.09	1.95	1.36	1.21	1.58	18.83
47	Shiprock	0.34	0.55	0.73	0.67	0.59	0.29	0.74	1.02	1.49	0.52	0.46	0.56	7.96
UTAH														
50	Blanding	1.29	1.40	1.09	0.98	0.75	0.46	1.15	1.23	1.35	1.39	0.97	1.40	13.46
52	Castledale	0.71	0.66	0.57	0.55	0.53	0.52	0.95	1.23	0.95	0.84	0.50	0.62	8.63
53	Duchesne	0.58	0.63	0.81	0.76	0.81	0.70	1.05	1.30	1.07	0.95	0.48	0.52	9.66
54	Emery	0.53	0.49	0.50	0.49	0.62	0.46	0.95	1.16	0.96	0.76	0.24	0.45	7.61
55	Escalante	1.13	1.01	0.97	0.66	0.56	0.49	1.57	2.06	1.38	1.12	0.60	1.01	12.56
56	Ft. Duchesne	0.44	0.37	0.50	0.72	0.70	0.51	0.53	0.65	1.01	0.83	0.38	0.37	7.01
58	Green River	0.45	0.39	0.45	0.54	0.39	0.55	0.60	0.78	0.75	0.76	0.35	0.44	6.45
59	Hanksville	0.41	0.31	0.28	0.32	0.38	0.33	0.69	0.73	0.56	0.53	0.24	0.38	5.16
61	La Sal	0.90	0.91	0.82	1.14	0.89	0.69	1.52	1.51	1.36	1.30	0.74	1.04	12.82
62	Loa	0.51	0.54	0.61	0.50	0.47	0.38	1.12	1.39	0.83	0.60	0.37	0.43	7.85
63	Manila	0.36	0.61	0.85	1.46	1.23	0.69	0.98	0.96	0.86	1.28	0.65	0.42	10.35
64	Moab	0.80	0.71	0.85	0.88	0.74	0.49	1.03	0.87	0.97	1.02	0.66	0.92	9.94
67	Myton	0.32	0.32	0.45	0.66	0.58	0.43	0.80	0.93	0.91	0.79	0.37	0.34	6.90
68	Price	0.83	0.78	0.73	0.79	0.74	0.71	0.95	1.33	1.27	0.96	0.53	0.77	10.39
71	Tropic	1.20	1.08	1.14	0.81	0.58	0.40	1.47	1.75	1.50	1.03	0.63	1.10	12.69
72	Vernal	0.63	0.60	0.55	0.95	0.86	0.43	0.63	0.76	1.15	0.97	0.66	0.58	8.77
WYOMING														
74	Big Piney	0.36	0.35	0.42	0.84	1.13	0.97	0.70	0.77	1.17	1.06	0.34	0.29	8.40
75	Dixon	0.79	0.71	1.01	1.17	1.24	0.81	1.10	1.28	0.98	1.17	0.31	0.93	12.00
76	Eden	0.42	0.53	0.45	0.76	0.81	0.71	0.76	0.83	0.73	0.67	0.34	0.33	7.34
78	Green River	0.88	0.42	0.32	0.35	0.51	0.54	1.06	1.06	0.65	0.59	0.70	0.82	7.90
79	Keimarer	0.56	0.61	0.67	0.66	0.76	0.72	0.77	0.77	0.56	0.67	0.59	0.60	7.94
81	Lyman	0.45	0.82	0.79	1.31	1.40	0.57	1.35	0.79	0.80	1.26	0.80	0.65	11.49
82	Pinedale	0.88	0.87	0.71	0.94	1.21	1.13	1.04	0.95	1.08	1.04	0.71	0.36	11.42

Table F. Daytime hours in mean solar time, (Sunrise to Sunset) with percentages for each month of the year for latitudes within the Upper Colorado River Basin^{1/}

Month	Latitude in degrees north of Equator											
	34		36		38		40		42		44	
	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent	Hours	Percent
January	315.7	7.10	310.9	6.99	305.9	6.87	300.9	6.76	295.3	6.62	289.4	6.49
February	307.4	6.91	305.0	6.86	302.2	6.79	299.7	6.73	296.6	6.65	293.6	6.58
March	371.4	8.36	371.3	8.35	371.2	8.34	371.0	8.33	370.6	8.31	370.2	8.30
April	391.4	8.80	393.7	8.85	396.1	8.90	398.6	8.95	401.1	9.00	404.0	9.05
May	432.1	9.72	436.6	9.81	441.4	9.92	446.2	10.02	451.8	10.14	457.7	10.26
June	431.3	9.70	437.2	9.83	443.0	9.95	448.9	10.08	455.1	10.21	463.0	10.38
July	439.2	9.88	444.4	9.99	449.8	10.10	455.2	10.22	461.4	10.35	468.2	10.49
August	414.7	9.33	418.2	9.40	421.7	9.47	425.1	9.54	428.7	9.62	432.9	9.70
September	371.4	8.36	372.0	8.36	372.9	8.38	373.5	8.38	374.3	8.40	375.0	8.41
October	351.3	7.90	349.2	7.85	347.3	7.80	345.2	7.75	343.1	7.70	340.6	7.63
November	311.9	7.02	308.0	6.92	303.7	6.82	299.4	6.72	294.9	6.62	289.4	6.49
December	307.8	6.92	302.1	6.79	296.3	6.66	290.6	6.52	284.5	6.38	277.5	6.22
Total	4445.8	100.00	4448.6	100.00	4451.5	100.00	4454.3	100.00	4457.4	100.00	4461.5	100.00

^{1/}From "Sunshine Tables" U. S. Weather Bureau Bulletin No. 805, Edition of 1905.

For leap year to above percentages add 0.2 percent for February and subtract 0.1 percent from March and from April.

Total for leap year	4457.3	4460.0	4469.2	4465.6	4468.6	4472.7
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UPPER COLORADO RIVER BASIN COMPACT

On October 11, 1948, at Santa Fe, New Mexico, following preliminary meetings at other points in the Upper Colorado River Basin, a compact among the five states having territory in the Upper Basin was executed. These are the four "upper division" States of Colorado, New Mexico, Utah, and Wyoming, plus Arizona, which has a small area in the Upper Basin, although it is a "lower division" State.

Article I of the Compact states:

"(a) The major purposes of this Compact are to provide for the equitable division and apportionment of the use of the waters of the Colorado River System, the use of which was apportioned in perpetuity to the Upper Basin by the Colorado River Compact; to establish the obligations of each State of the Upper Division with respect to the deliveries of water required to be made at Lee Ferry by the Colorado River Compact; to promote interstate comity; to remove causes of present and future controversies; to secure the expeditious agricultural and industrial development of the Upper Basin, the storage of water and to protect life and property from floods.

"(b) It is recognized that the Colorado River Compact is in full force and effect and all of the provisions hereof are subject thereto."

Comprising 21 articles in all, the document is written around an apportionment made in Article III thereof, as follows:

"(a) Subject to the provisions and limitations contained in the Colorado River Compact and in this Compact, there is hereby apportioned from the Upper Colorado River System in perpetuity to the States of Arizona, Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use of water as follows:

- (1) To the State of Arizona the consumptive use of 50,000 acre-feet of water per annum.
- (2) To the States of Colorado, New Mexico, Utah and Wyoming, respectively, the consumptive use per annum of the quantities resulting from the application of the following percentages to the total quantity of consumptive use per annum apportioned in perpetuity to and available for use each year by Upper Basin under the Colorado River Compact and remaining after the deduction of the use, not to exceed 50,000 acre-feet per annum, made in the State of Arizona.

State of Colorado -----	51.75 percent,
State of New Mexico -----	11.25 percent,
State of Utah -----	23.00 percent,
State of Wyoming -----	14.00 percent.'

The Upper Colorado River Basin Compact was approved by the legislatures of each of the signatory States and by Congress early in 1949.