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Unit Consumptive use of Water Studies in the Ashley and Ferron Valleys of Utah for the 1950 Growing Season

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UNIT CONSUMPTIVE USE OF WATER STUDIES
IN THE ASHLEY AND FERRON VALLEYS OF UTAH
FOR THE 1950 GROWING SEASON

by

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J. O. H.

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INTRODUCTION

For the past 2 years a project has been carried on by the Utah Agricultural Experiment Station and the United States Department of Agriculture, Soil Conservation Service, in cooperation with the Utah State Engineer, in the Ashley and Ferron valleys of Utah to determine the consumptive use of water in these areas. This report is the preliminary part of the third year of study. It includes a determination of unit consumptive use values for the major agricultural crops. These values will later be used by the Soil Conservation Service and Experiment Station in determining the valley consumptive use by the integration method. This will be compared with the valley consumptive use as determined by the inflow-outflow method.

The data which have been collected for each of the 2 areas for the 3 years will be correlated and certain average empirical constants will be determined. With the use of these constants and climatological data the consumptive use for the different valleys of the Colorado River drainage area of Utah will be estimated by the cooperating agencies.

Purpose

The primary purpose of this project is to aid in developing a basis for determining Utah's right to Colorado River water which is based on water consumptively used. Utah has been allocated by the Upper Colorado River Basin Compact of October 11, 1948, 23 percent of an estimated 7,500,000 acre-feet of water per year (average over a 10 year period) to be consumptively used. This means that the state will be allowed to divert considerably more water than the 23 percent but it will have to prove that the difference between the percent diverted and the 23 percent will not be consumptively used and will therefore eventually find its way back into the Colorado River system. If the other Upper Basin States use most of their allotted share and the Lower Basin States get less than their allotted 7,500,000 acre-feet per year over a 10 year period and insist on their full delivery, then the Upper Basin States may have conflicts among themselves. The states having the most complete consumptive use records will surely be best able to defend their position and will less likely be forced to cut their diversions. This, therefore, is the primary purpose of making these consumptive use determinations. There are many secondary purposes which include problems in planning and enlarging new irrigation areas which will come with the increased water supply.

Definition of Terms

Consumptive Use, U (Blaney's (2) definition) The sum of the volumes of water used by the vegetative growth of a given area in transpiration and building of plant tissue and that evaporated from adjacent soil, snow, or intercepted precipitation on the area in any specified time, divided by the given area. If the unit of time is small, the consumptive use 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 is expressed as acre-feet per acre or depth in feet or inches.

Consumptive Use Factor, F The sum of the products of mean monthly temperature and monthly percent of daylight hours. ($F = \sum t \cdot p$)

Empirical Coefficient, K The ratio of consumptive use, in inches, to the consumptive use factor. ($K = U/F$)

Evapo-transpiration In this report evapo-transpiration is considered synonymous with consumptive use.

Tube Constant, C This constant is the reciprocal of the volume (cubic centimeters) per inch length of a cylindrical core having the diameter of the soil tube cutter. It has the units of inches per cubic centimeter and equals $1/2D^2$ where D is the diameter of the cutter in centimeters. This constant multiplied by the weight of water in grams in a soil core gives the inches of water in the core (5).

Methods of Determining Consumptive Use

Many methods have been used to estimate consumptive use of different types of vegetation. Some are more applicable to certain types of vegetation and moisture conditions than others. Where possible more than 1 method should be used for comparison. A common practice for an over-all check is to determine the valley consumptive use by the integration method (summing the products of the unit consumptive use values for each type of vegetation times their respective areas) and comparing this with that determined by the generally reliable inflow-outflow method.

Inflow-Outflow Method

This method of determining valley consumptive use consists of measuring all the water that flows into and out of the valley, including precipitation, and the change in the amount of water stored in the valley. The algebraic sum of these amounts (giving outflow items negative signs) is the amount of water assumed to be consumptively used in the entire valley during the period. This period is generally a month, and the months totaled for a year. In equation form

$$U_v = I + P + (G_s - G_e) - R$$

where

U_v = valley consumptive use,

I = inflow into the valley during the period,

R = outflow during the period,

P = precipitation on the valley floor during the period, and

$G_s - G_e$ = change in ground water storage during the period.

Inflow in confined surface channels can be measured quite easily and accurately. Where spring runoff is not confined it should be estimated unless considered negligible. Special determinations are made to estimate underground inflow and outflow. Precipitation is measured with rain gages (preferably automatic recording type) located throughout the valley. Water table fluctuations are recorded and the specific yield of the soil is determined for estimating changes in storage. Random soil samples should be taken throughout the higher parts of the valley where the water table is low, and the change in storage in the surface soil (5 to 10 feet) should be determined. From a wet fall to a dry fall the change in surface storage could be highly significant.

The following methods are used to determine unit consumptive use values.

Soil Moisture Depletion Method

This method consists of measuring periodically the amount of soil moisture in the root zone of the crop at a particular place and plotting graphically moisture content versus time. The slope of the curve is the rate of depletion of moisture from the soil. The curve is broken during irrigations and corrected for measured precipitation. These curves are shown in figures 1 to 25 of the Appendix. Consumptive use for a given period is found by multiplying the depletion rate by the time. This method cannot be applied where the crop receives moisture from the water table. The method is discussed in detail in a later section.

Evapo-transpiration Tank Method

In this method crops are planted in water tight tanks and the amount of water which is applied to each tank to grow the crop is measured. The amount added over a given period plus or minus the change in storage is the consumptive use for that period. A more detailed description is given in a later section.

Transpiration-well Method

This method, originally devised by W. V. White (11) for estimating ground water supplies, is based on the daily fluctuations of the water table which are caused by the consumptive use of the phreatophytes. During the daytime consumptive use is high and the water table drops, but at night there is no consumptive use and the water table rises. Knowing this rise and the specific yield of the soil in which the fluctuation occurs, the consumptive use can be determined.

Transpiration Method

Transpiration can be estimated by cutting plants on a small measured area, weighing them, and noting accurately the loss in weight due to transpiration (2). This weight loss during a short period plus an estimation of evaporation from the ground surface would be the consumptive use of the small area for the short length of time.

Other Methods

Another method used in the early part of the century (9) is to establish conditions on a field plot where deep percolation losses and ground water contributions are negligible. The amount of irrigation water applied, surface runoff, and the change in storage in the root zone are measured for the season. Consumptive use is assumed to be the difference in the amount of water applied and that running off plus or minus the change in storage over a period of time. If the above conditions can be met the results should be quite accurate.

Other methods (7) which have been used for estimating consumptive use by vegetation using ground water (phreatophytes) include the seepage-run, chloride increase, and slope-seepage methods.

DETERMINATION OF UNIT CONSUMPTIVE USE VALUES

Unit consumptive use values were determined by two methods, the soil moisture depletion method and the evapo-transpiration tank method. The tanks were used mainly to determine unit consumptive use values for grass pasture and wild hay, crops which receive considerable moisture from the water table, while the soil moisture depletion method was used for determining unit consumptive use values for grains and alfalfa.

Soil Moisture Depletion

The sampling procedure here described is the same as has been used previously by other investigators. The methods of note keeping and procedure for determining the equivalent depth of water in the root zone are new and have been previously described by the writer (8).

Procedure

A temporary laboratory was set up in a room in the county agent's office in the Unitah County Court House at Vernal, Utah. The laboratory equipment consisted of an analytical balance accurate to one-tenth of a gram, an electric oven with temperature controlled at 110° Centigrade, and tongs for handling the hot cans.

Farms in the Ashley and Ferron valleys were selected for study on the following basis:

1. Indications that the water table would not be high enough to contribute to growth of the farm crops.
2. The farmer's attitude toward the project and his willingness to cooperate.
3. The farm had to be relatively free from rocks, hardpans, etc.

4. Generally, farms that had good water rights were selected so that only a few of the plots would have a partial supply.

Undoubtedly the farms selected as a whole were above average from point of view of water supply and agricultural practices. Estimates will be made to decrease the consumptive use values found for the crops of these better farms with better water rights to that of the crops of the average farm in the valley.

To get early spring data, the first samples were obtained on April 14, 1950. The field equipment consisted of soil tubes, soil tube hammer, a box of 18 consecutively numbered sampling cans, a clip board, pencil, and field note forms shown in table 16, page 80.

Samples were taken for each foot of depth. The tube was driven down to the 1 foot mark, twisted to break the soil core at the bottom, and slowly pulled from the hole. The tube was tipped up so the core would slide out of the opposite end and into a can. This is shown in figure C. The lid was placed on the can and the procedure repeated for the next foot. The core depths and corresponding can numbers were placed on the field note form, together with the date, farmer's name, and remarks. The remarks included irrigation dates, general precipitation observations, insect or frost damage if any, stage or height of growth, and notes relating to crops as sandy, hard, dry, very wet, soil falling into hole, loss of core and probable cause of the loss, and any other irregularities.

The samples were taken to the laboratory and weighed. The lids were removed, placed on the bottom of the can, and the can and contents placed in the oven. Experimentation showed that the sample would be dried to constant weight in nearly all cases in 24 hours. Therefore, after 24 hours the samples were removed from the oven and immediately weighed. These weights were recorded and the difference between the wet weight and the dry weight (weight of water) was also recorded. If this seemed too high or too low as compared to adjacent samples the dry weight was checked. This helped eliminate recording errors.

The tube constant (as previously defined and explained) for the cutter of each tube had been computed. This multiplied by the weight of water in grams gave the equivalent inches of water (uncorrected) in that foot of core. The dry weight of the core was determined by subtracting the weight of the can from the dry weight of core plus can. No further computations were made until fall when all the data had been assembled.

In Ashley valley it was attempted to sample just before each irrigation and 3 or 4 days after irrigation, when the soil moisture was assumed to be at field capacity, and also at about weekly intervals. Sampling at Ferron was done about every 8 or 10 days. The data at Ashley valley are therefore more complete.

Analysis of Data

Each step in the analysis of data was designed to make the results more accurate and consistent, and more easily interpreted. The methods have been carefully thought through and are believed to be logical. No changes in basic data were made without a written explanation of the change and a line leading from the explanation to the change.

Average dry weight of core determinations. The dry weight of core for each foot and each sampling date was recorded on a separate page for each plot. A completed page is shown in table 17, page 81, for illustration. Each dry weight had been put on the same basis by multiplying its weight by the ratio of the area of the cutter with which most of the samples had been taken to the area of the cutter with which the particular sample was taken. All the cores which had been noted as being "poor" were crossed out along with a few more which were obviously poor and the rest were totaled and averaged. These averages were then recorded on the field note forms.

The corrected equivalent depth of water was determined by multiplying the depth of water by the ratio of the average dry weight of core to the dry weight of core for the particular sample.

Corrections and checks. Errors in arithmetic were eliminated by carrying through the totals of the different lines of the field note form which gave a positive check down to line 8. The data for line 9 (average dry weight of core) were checked by adding on a tape recording machine and the tape was checked. Line 10 was checked approximately by carrying through the totals and was also checked by re-adding after all the forms had been completed.

In performing the correction there would have been a slight error if the correction had been applied only to the total core instead of to each foot of core. Corrections on a total core basis differed appreciably from the corrections on each foot basis only when the soil moisture was highly variable throughout the profile.

The tube constants and methods of computation were checked many times and in many ways. Field checks were made by duplicating samples with different tubes. The results obtained compared closely with each other (page 14).

The computations which did not have a definite check within themselves were checked by independent re-computations.

To show that the depth of sampling, 5 feet for grains and 7 feet for alfalfa, was sufficient to show most of the depletion in the root zone, progressive depletion curves for each plot were drawn. These curves show the amount of water in each foot of each sample throughout the season. They also offer a visual check on the data. Data for points not conforming with the general trend of points were closely rechecked.

Depletion curves. Depletion curves showing the inches of water in the root zone at any time throughout the growing season were made for each plot from the data collected during the summer. The slope of these curves represents the rate of depletion of moisture from the soil. A mass depletion curve, showing the accumulated depletion at any time during the growing season, was also drawn for each plot. These curves are shown in figures 1 to 25 of the Appendix. Straight lines were drawn between observation points and extended to the irrigation dates where the depletion curves were broken.

There was probably some extra evaporation during the time of irrigation and for the 3 or 4 days following before a sample could be taken. No correction for this was made. It may be deemed necessary later to add a third or so of an inch of water for each irrigation, as has been done by the Soil Conservation Service for the 2 previous years of study, to correct for this extra evaporation. Fuhriman (6) indicates that the rate of use by sugar cane is increased for the first few days after irrigation by about 17 percent above the average rate.

Precipitation was shown by a jog in the depletion curve near the day on which it fell.

When extrapolating the depletion curves for some of the alfalfa plots in Ashley valley, the first measured rate was either extended back to April 14 (when new stems 2 to 4 inches long were appearing), or the soil was assumed at field capacity on that date, or a use of 4.70 inches (that used by plot A-A-1) from April 14 to May 11 was assumed. The method which gave the least value was used, but in most cases all 3 methods gave practically the same result. All parts of curves which were estimated by the above methods are shown by broken lines instead of solid lines.

Because of rain during the April field trip, no samples were taken in Ferron valley and therefore more of the early consumptive use had to be estimated for this area than for Ashley valley. In Ferron valley where winter precipitation was low (2.71 inches from October 1, 1949, to May 1, 1950, as compared to 8.72 inches in Ashley valley during the same period) and the soil in the fields was very dry before irrigation in the spring, consumptive use as well as growth was much less than in Ashley valley. Estimates were made by observing growth, condition of soil moisture at the time of the first sample and irrigations if any, amount of precipitation falling during the period, and by comparison with measured depletion rates of other plots for late spring estimates. These methods may not have been too accurate, but they were considered the best means of estimating the early consumptive use, there being no depletion data. However, this should not effect the consumptive use for the entire growing season very much as the early spring rate of use is small and had to be estimated for only a small part of the growing season for most plots.

Statistical Discussion

Heretofore, no attempt has been made to analyze results statistically. Statistics would indicate ways of increasing accuracy, locate probable sources and amounts of error, and organize the results in a manner such that conclusions could be more accurately drawn. This would be desirable, but because of the many chances for variation and because of financial limitations much must be left to the judgement of men who have had experience in similar studies and to checks that are had by comparing results from soil moisture depletion methods with inflow-outflow results (which if properly carried out could be assumed correct).

The following shows the chances for variation in determining consumptive use by the soil moisture depletion method, and brief comments are given.

(1) Variation between samples at a given time and location. This variation would indicate the ability to determine accurately the equivalent depth of water in the soil profile. This variation is shown to be small, for the method used, by the results of an analysis of variance of 4 pairs of duplicated 5 foot samples, sampled at each foot depth, shown in table 1. The standard deviation is actually smaller between the 5 foot cores than between the 1 foot cores. This is explained by the fact that often the computed moisture content is too high in one foot and too low in the next foot, and over the whole 5 foot core these differences tend to compensate.

(2) Variation between samples at a given location but at a different time. An analysis of this variability would indicate the basic sampling error of determining depletion. This error would be greater than that described in (1) because of possible evaporation from the previous holes and the chance that the sampler would move a few feet away from the previous hole where the moisture condition was not the same at the time of the first sample and, therefore, the difference would not be entirely depletion.

(3) Variation between depletion rates within a field. This variation would be similar to that described in (4) but not as great.

(4) Variation of depletion rates between fields. This variability would be caused by differences in irrigation practices, available water supply, crop stand, agricultural practices, soil type,

Table 1. Results of an analysis of variance for comparison of soil moisture, in inches of water, between duplicated samples.

Description	Between 5 foot cores	Between 1 foot cores
S^2 (variance)	0.025	0.0306
$S^2_{\bar{x}} = S^2t/10$ and $S^2d/2$	0.0025	0.0153
$S_{\bar{x}} = \sqrt{S^2_{\bar{x}}}$	0.05	0.124
t , 0.95, for n = 4 and 16	2.776	2.12
$t \cdot S_x$ (least significant difference)	0.139	0.262
$\bar{X} = 129.3/8$ and $129.3/40$	16.2	3.24
$S = \sqrt{S^2}$ (standard deviation)	0.158	0.175
$C = 100 \cdot S/\bar{X}$ (coefficient of variation)	0.97%	5.4%

available nutrients and essential minerals, and plant pests and diseases. This variation is probably greater than any of the other chances for variation, and therefore many more fields would have to be sampled to determine a highly accurate average.

(5) Variation of consumptive use between years. This variability is caused by differences in length of growing season and differences in growing conditions during the season. Variations of precipitation, temperature, humidity and wind, water supply, and of plant pests and diseases are causes of variability in consumptive use from year to year.

(6) Variation between measured consumptive use in a valley and that determined by the empirical method. This depends upon all of the above differences as the basic assumption of the empirical method is that consumptive use varies with the mean temperature and the percent daylight hours. If enough data were available it could be analyzed by determining unit consumptive use values in different valleys and computing these values from empirical methods, then analyzing statistically the differences. This variation would be reduced by having the basic data used in the empirical method all taken from the same drainage area--in this study the Colorado River drainage area of Utah.

This discussion of statistics may leave one with the impression that the data of this study are not good. However, there are good checks between valley consumptive use by the integration and inflow-outflow methods in other valleys where statistical methods were not employed. Over a 17 year period the average consumptive use of water in Mesilla Valley, New Mexico (3), as computed by the integration method and the inflow-outflow method differed less than 1 percent. However, the average yearly difference was 15 percent. It was concluded by the committee that the inflow-outflow method was the most accurate for the valley but that "...it is likely that the integration method will produce satisfactory results."

Results

The unit consumptive use values, as determined by the soil moisture depletion method, for the major crops in the 2 areas are shown in tables 2 and 3. The 1950 values for alfalfa are higher than those shown for the 2 previous years. The yields produced in 1950 on the fields sampled were higher than the average in the valley. Also, because of high winter precipitation and warm daytime temperatures, high use began early in the spring despite setbacks by frost. Plots receiving only partial water supply were not averaged.

Before applying the integration method to determine valley consumptive use for the year, a coefficient will be determined to decrease the unit consumptive use values shown to average values for the valley. Canal flow records for 1950, supplied by Grant Christensen, deputy water commissioner for Ashley Creek, may be used later to help estimate this coefficient.

The water supply was generally good in Ashley valley. Canals on which there were no primary or storage rights were short of water toward the end of the season.

In Ferron valley the water supply was very low. There was practically no third cutting of alfalfa in the valley and many farmers got only 1 cutting. This should be kept in mind when comparing the data.

Use of water by corn (table 2) seems quite low and therefore should be used only after comparing with similar data and with good judgement. This is discussed in more detail later.

Table 2. Unit consumptive use values for the major crops as determined by the soil moisture depletion method for Ashley Valley, Utah, 1950.

Crop	Field plot designation on map	Soil Classification 1/	Water supply	Yield	Plot cons. use (in.) 2/	Average cons. use (in.) 3/
Alfalfa	A-A-1	Billings clay	Full	5.8 T/acre	34.3	
	A-A-2	Billings very fine sandy loam	Full	3.6 T/acre	36.3	
	A-A-3	Redfield clay loam	Full	6.8 T/acre	42.2	
	A-A-4	Naples fine sandy loam	Partial (seed)	2.8 T/acre	22.7	37.5
	A-A-5	Billings clay	Omit because of high water table			
	A-A-6	Redfield fine sandy loam	Full	4.0 T/acre	36.2	
Pasture	A-P-1	Mesa clay loam	Full	—	31.0	31.0
Corn	A-C-1	Billings very fine sandy loam	Full	13 T/acre	13.2	
	A-C-2	Billings clay	Full	21 T/acre	15.5	14.4
Wheat	A-W-1	Naples fine sandy loam	1 irrigation	48 Bu/acre	14.0	
	A-W-2	Redfield clay loam	2 irrigations	71 Bu/acre	24.3	19.9
	A-W-3	Redfield fine sandy loam	2 irrigations	43 Bu/acre	21.2	
Barley	A-B-1	Billings very fine sandy loam	2 irrigations	90 Bu/acre	19.8	
	A-B-2	Billings clay	2 irrigations	79 Bu/acre	17.2	18.5
Oats	A-O-1	Billings clay Omit; high water table		15 Bu/acre	—	

1. From "Soil Survey of the Ashley Valley, Utah." U. S. Dept. Agr. Bureau of Soils. 1924.

2. Includes precipitation falling between irrigation periods. (See figures 1 to 15.)

3. "Partial supply" consumptive use values not averaged.

Table 3. Unit consumptive use values for the major crops as determined by the soil moisture depletion method for Ferron valley, Utah, 1950.

Crop	Field plot designation on map	Soil classification	Water supply	Yield	Plot cons. use (in.) 1/	Average cons. use (in.) 2/
Alfalfa	F-A-1	Sandy loam	Full 3/	3.0 T/acre	31.0	33.3
	F-A-2	Fine sandy loam	Full 3/	2.7 T/acre	31.3	
	F-A-3	Sandy loam	Partial	3.7 T/acre	24.8	
	F-A-4	Fine sandy loam	Full	--	41.8	
	F-A-5	Fine sandy loam	Full 3/	3.9 T/acre	29.2	
Wheat	F-W-1	Sandy loam	Full	53 Bu/acre	15.7	15.7
Corn	F-C-1	Fine sandy loam	Full	--	20.0	20.0
Oats	F-O-1	Sandy loam	Partial	Zero yield	--	
Oats and barley	F-OB-1	Fine sandy loam	1 irrigation	--	20.0	
	F-OB-2	Fine sandy loam	Full	70 Bu/acre	17.0	18.5

1. Includes precipitation falling between irrigation periods. (See figures 16 to 25.)

2. "Partial supply" consumptive use values not averaged.

3. Could have used one more irrigation to good advantage.

Tank Studies

The evapo-transpiration tank station, shown schematically in figure A, was located at the Vernal airport. It consisted of 6 tanks (numbers 1 to 6) which had been used for the 2 previous years and 3 new tanks (numbers 7, 8, and 9) which were installed in May 1950. There is also a standard Weather Bureau evaporation pan, an anemometer, a rain gage, thermometers, and a hydrothermograph. The 6 older tanks each consisted of 2 circular concentric tanks. The inner tank was perforated and was filled with soil, and the outer tank was water tight. The annular space between the tanks was used to saturate the soil and drain it by pumping. The 3 new tanks were constructed to maintain a water table at a constant level. This was done by utilizing a side tank containing a "chicken waterer" at the desired level (see figure B). This level was determined by the type of grass in the tank, its root development, and by the approximate level of the water table in the field from which the grass in the tank was transplanted.

Procedure

The annular space between the concentric tanks was filled with water and the soil in the tanks was saturated. The water was then pumped out of the tanks and the gravitational water was allowed to drain. The tanks were pumped at least twice a day for 2 or 3 days until no more water could be pumped out. This was to eliminate any water table effect. When the plants appeared to be in need of more water the tanks were given a small irrigation from the top. The water added was measured.

The 3 tanks which had fixed water tables required less care than the other tanks. Water was added to the "chicken waterer" in the side tanks as they became nearly dry. Water was added to the top of the tanks to

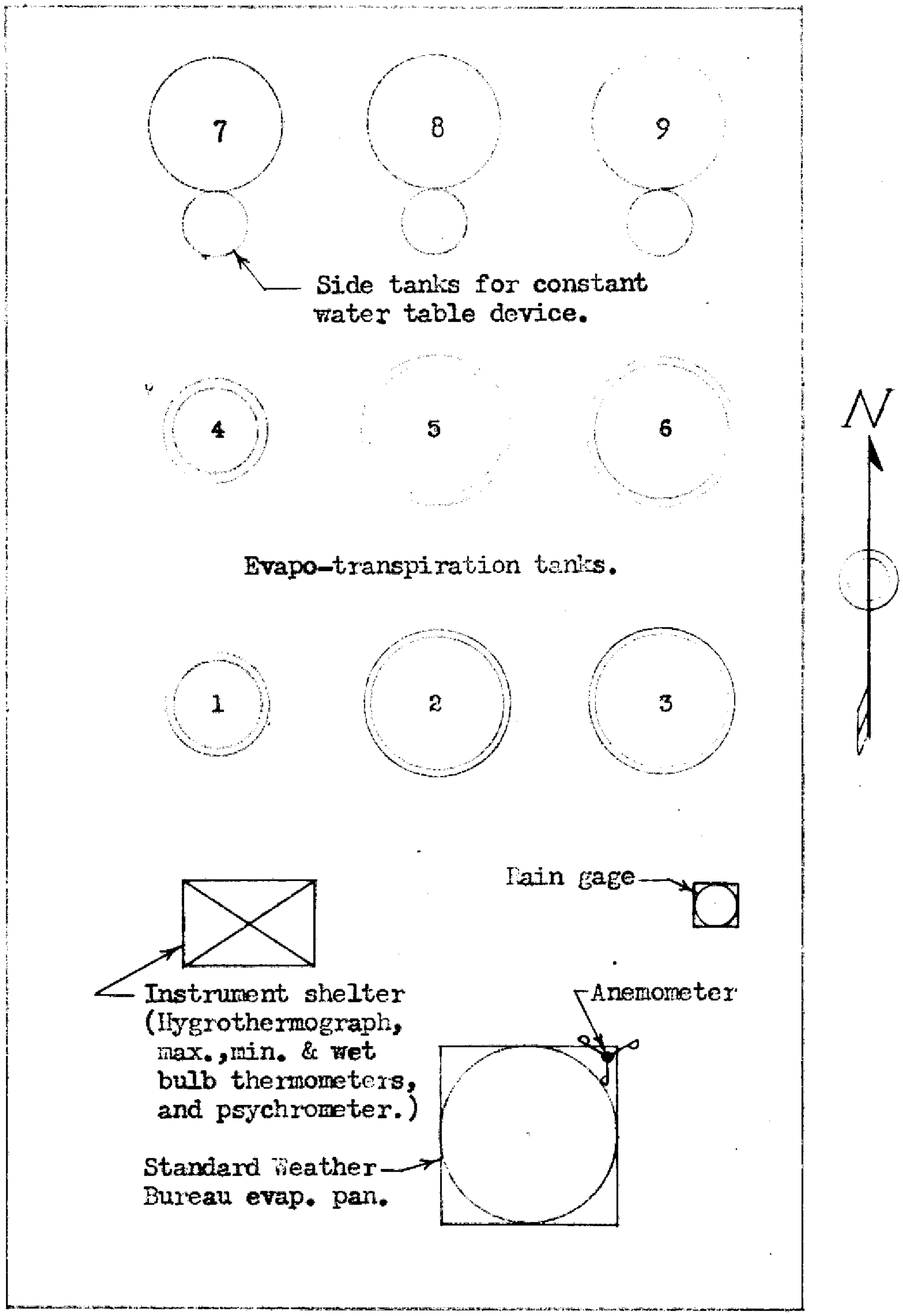

Figure A. Evapo-transpiration Station at Vernal Airport, Utah.

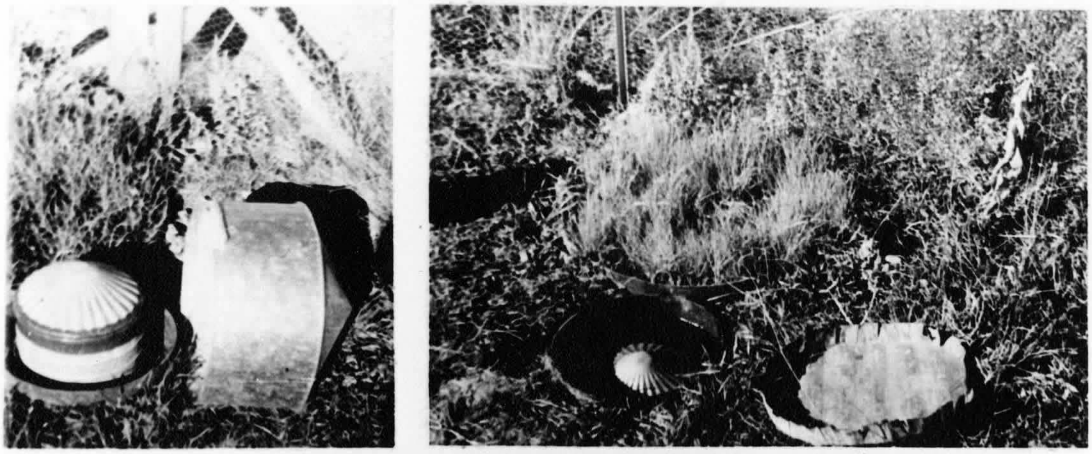

FIGURE B

Evapo-transpiration tanks located at Vernal, Utah. October 25, 1950. Side tank with constant water-table apparatus and side tank covers are shown. Left: wire grass; water-table 6 in. Right: salt grass; water-table 2 ft.

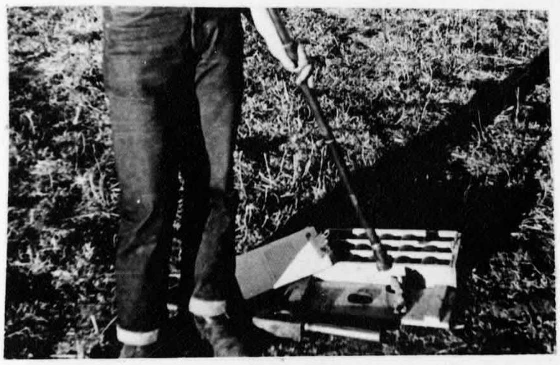

FIGURE C

Soil sampling; placing the core into an air-tight can.

FIGURE D

Weather station adjacent to evapo-transpiration station. Vernal airport, Utah.

keep the grass growing before their root systems were fully developed.

Two containers holding 11.0 and 44.0 pounds of water were used in measuring all water added to the tanks or pumped from them. Careful notes were kept in the field note book.

Analysis of Data and Results

The net pounds of water added to each tank was determined from the field notes. Knowing the diameters of the tanks, a relationship between inches of water and pounds of water added to the tank was established and the pounds of water were converted to inches of water. These data are shown graphically by the accumulated depletion curves of figures 25 to 35.

When water was added to the top of tank 7, 8, or 9, the amount that went to change the storage in the tank was not known. Consequently, the amount required for consumptive use in a given period of time was not known. Therefore, until the grass roots had developed sufficiently to get plenty of water from the water table only the total quantity used could be shown. Later when the grass was getting all of its water from the water table and there was no change in storage (water table held constant), the amount added every few days was the amount that had been used. This gave a number of accurate points from which accumulated use curves could be drawn for the latter part of the season.

Tanks numbered 1 and 4 were originally planted to wheat but a hard early frost killed most of it. The wheat in tank No. 1 which was still alive was transplanted into tank No. 4 to increase its stand, and oats about 2 inches high were later transplanted in tank No. 1. No yield data were obtained for the crops of these 2 tanks because birds took the grains as soon as the heads formed. Because of the above difficulties the results obtained from these 2 tanks may not be very useful.

Tanks numbered 2 and 5 were planted to grass pasture in 1948. The pasture contained several varieties of grass but very little clover. Yields were determined for these tanks on July 29. The growth and appearance of the grasses in these tanks seemed very much like that in the fields. None of the tank crops were artificially fertilized. Tanks numbered 3 and 6 contained alfalfa. The stand seemed quite poor, and weevil retarded growth. However, first cutting yields on July 11 were good. The second cutting was accidently destroyed by animals. All yields were taken on a cured basis, the moisture condition being about the same as when hay is stacked or hailed.

Tank No. 7 was installed and the grass transplanted on April 15, 1950. The depth to the water table was 3 feet until August 23. During this time the grass was irrigated partially from the top but did not receive enough water. The water table was raised to within 2 feet of the surface and growth was better than before. The yield was very poor.

Tank No. 8 was installed on June 15, 1950, and salt grass (Distichlis Stricta) was transplanted in it. The tank soil moisture was not brought to field capacity until May 12. From then on, and especially after about July 15, the amount of water used from this tank was accurately known. The depth to the water table was kept at 2 feet throughout the season. The growth of the salt grass seemed very similar to that growing in the salt grass pastures in the valley. This tank is shown on the right side of figure B.

Tank No. 9, shown on the left side of figure B, was installed and planted to wire grass and wet pasture grasses on May 26, 1950. Growth was poor until August 1, when the water table was raised from below 1 foot to 0.5 foot. (The water level in the side tank had been 1 foot below the soil surface in the main tank, but the hole connecting the 2 tanks was partially plugged and the water table in the main tank had dropped.) The consumptive use rate was then about 7.3 inches per month and growth was good. Because the tank was installed late, and because the wire grass received only a partial supply of water for the first month and a half, the data are inconclusive for the early part of the season. It does show, however, that consumptive use of water by wire grass is relatively high.

Results of the tank data are shown in table 4.

Comparison of Data

A comparison of the data is shown in tables 9 and 10 where both the consumptive use and empirical coefficients are tabulated for the major crops for the past 3 years. Recommended empirical coefficients are also shown for comparison.

When comparing consumptive use of water and yield values with values obtained by other methods, it is usually found that the tank use and yield values are both high. This is because the plants growing in the tank can spread out over a greater area than the tank soil surface area. When they are spread out they are better able to take advantage of the sunlight, make better growth, and use more water. If other conditions (soil type, fertility, etc.) remain the same, consumptive use would be proportional to yield. Criddle[1/] suggests plotting consumptive use against yield, and if other conditions are not too variable a curve can be fairly well defined. Then if the average yield for a crop in the valley is known or can be estimated the average consumptive use for that crop can be determined from the curve.

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1. Private conversation.

Table 4. Summary of evapo-transpiration tank data for Ashley Valley, Utah, 1950.

Tank No.	Soil depth (in.)	Area of surface (ft.^{2})	Fig. ref.	Tank crop	Growing period	Tank use (in.)	Precip. (in.)	Consumptive use (in.)	Yield[4] tons/acre
1	56	3.0	26	Oats	6/17 - 10/28	23.2	1.5	24.7	--
4	56	3.0		Wheat					
2	44	6.3	27	Pasture	4/14 - 10/27	34.8	2.7	37.5	2.45
5	44	6.3	27	Pasture	4/14 - 10/27	36.4	2.7	39.1	1.21
3	44	6.3	28	Alfalfa	4/14 - 10/27	41.1	2.7	43.8	3.34
6	44	6.3	28	Alfalfa	4/14 - 10/27	32.6	2.7	35.3	2.63
7	56 [1]	6.3	29	Native wild grasses	4/14 - 10/27	26.3	2.7	29.0	0.27
8	56 [2]	6.3	30	Salt grass	4/14 - 10/27	21.0	2.7	23.7	not cut
9	56 [3]	6.3	31	Wire grass	4/14 - 10/27	34.6	2.7	37.3	not cut

1. Depth to water table was 3 feet and water supply was short until August 23. Depth to water table was 2 feet thereafter.

2. Depth to water table 2 feet.

3. Partial supply until August 1; depth to water table 0.5 feet thereafter.

4. First cutting only.

Figure E shows all the use versus yield data available plotted for the past 3 years for Ashley and Ferron valleys. The tank data agrees with the soil moisture depletion data fairly well. The consumptive use and yield data for alfalfa which was obtained during the past 3 years for Ashley and Ferron valleys are shown in tables 5 and 6.

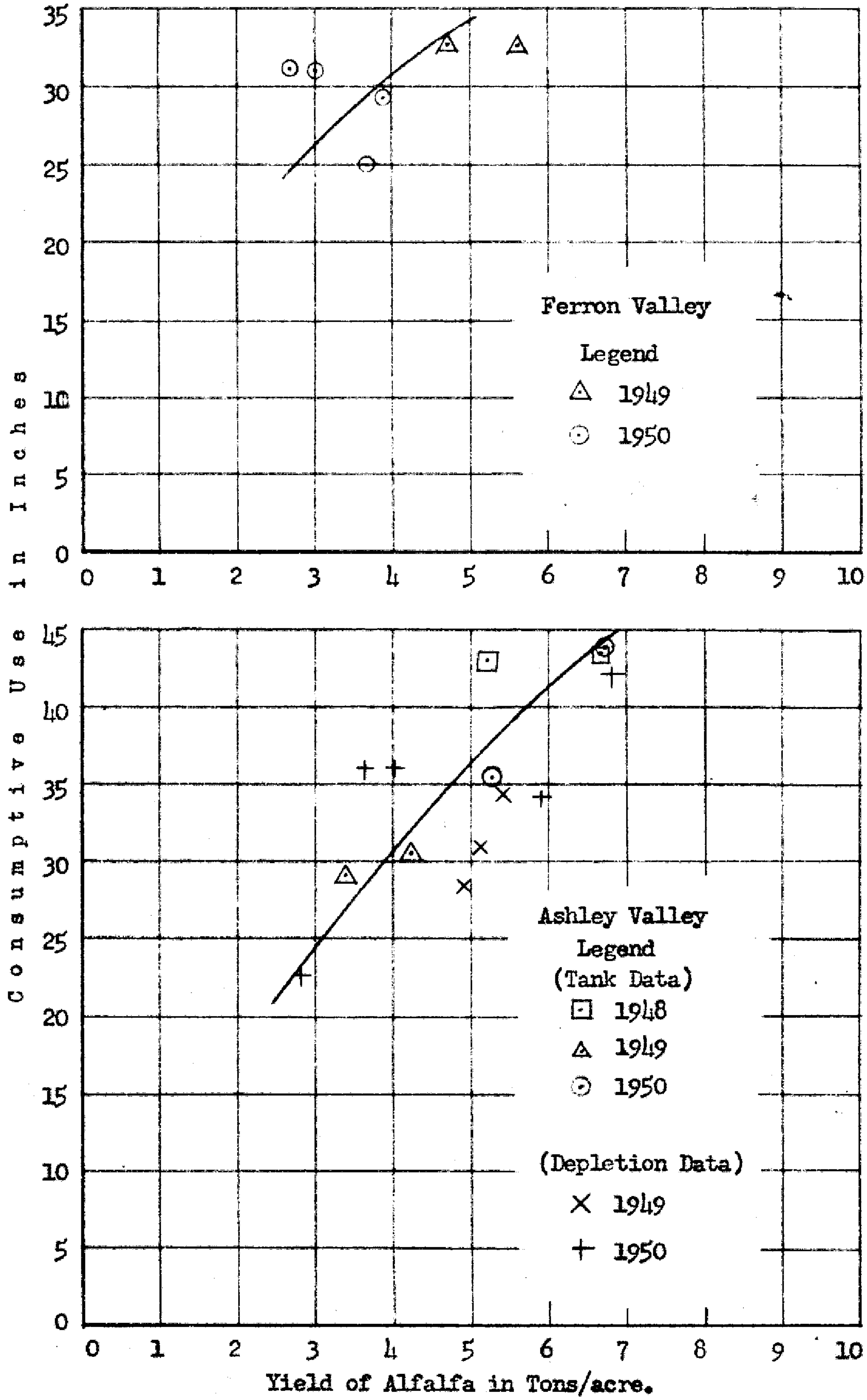

Figure E. Consumptive use of water by alfalfa versus yield for Ashley and Ferron valleys, Utah, 1948-49-50.

Table 5. Consumptive use of water (inches) by alfalfa and yield data (tons/acre) for 3 years in Ashley valley, Utah.

	1948		1949		1950	
Method Used	Use	Yield	Use	Yield	Use	Yield
	24.0	—	28.4	4.9	34.3	5.8
	24.2	—	35.8	—	36.3	3.6
Soil	22.1	—	34.5	5.4	42.2	6.8
moisture	24.3	—	31.3	5.1	22.7	2.8
depletion	22.4	—			36.2	4.0
	23.4	—				
	18.5	—				
Evapo-transpiration tanks	43.7	6.6	29.3	3.4	43.8	6.7
	43.0	5.2	30.4	4.2	35.3	5.3

Table 6. Consumptive use of water (inches) by alfalfa and yield data (tons/acre) for 3 years in Ferron valley, Utah.

	1948		1949		1950	
Method Used	Use	Yield	Use	Yield	Use	Yield
	25.5	—	28.4	—	31.0	3.0
Soil	26.2	—	32.7	4.7	31.3	2.7
moisture	22.7	—	32.7	5.6	24.8	3.7
depletion	24.3	—			41.8	—
	21.2	—			29.2	3.9

APPLICATION OF EXPERIMENTAL DATA

Because of its simplicity, the empirical method outlined by Blaney and Criddle (2) will be used to determine the consumptive use of other valleys in the Colorado River drainage area of Utah. Using this method only temperature and precipitation records for the different valleys are needed. The major assumption is that consumptive use varies directly with the consumptive use factor (F). Any differences in the over-all effect of all other factors affecting the consumptive use of water for each valley are assumed negligible. Corrections may be necessary for areas having relatively low humidity and high wind.

In applying the method, the first step is to determine the consumptive use (U) in a few areas by soil moisture depletion and inflow-outflow methods. With tables of monthly percent of daytime hours (p), and mean monthly temperatures (t) for the areas, the monthly consumptive use factor ($f = t \cdot p/100$) and the consumptive use factor for the growing season ($F = \sum f$) can be determined. This is shown for the Ashley and Ferron valleys in tables 6 and 7. The empirical consumptive use coefficient ($K = U/F$) is then found. This coefficient is assumed constant for a given crop, and recommended values are given by Blaney and Criddle(2). Tables 9 and 10 show the consumptive use coefficients for the 1950 growing season in the Ashley and Ferron valleys.

To determine unit consumptive use values in a valley where precipitation and temperature data are available the consumptive use factor (F) is determined from the percent daytime hours and mean monthly temperatures as before. This multiplied by the determined or recommended consumptive use coefficient (K) gives the unit consumptive use (U).

Table 7. Consumptive use factors for Ashley valley, Utah, 1950. Latitude 40° 30' N.

Month	% Daytime hours [1] (p)	Mean Temp. (t)	Cons. use factor (f)	Accumulated cons. use factor (F)
April	8.96	45.7	4.10 x 15/30	2.05
May	10.05	49.7	5.00	7.05
June	10.11	60.1	6.18	13.23
July	10.25	64.9	6.65	19.88
August	9.56	64.5	6.16	26.04
Sept.	8.39	58.3	4.89	30.93
Oct.	7.74	50.2	3.88	34.81

Table 8. Consumptive use factors for Ferron valley, Utah, 1950. Latitude 39° N.

Month	% Daytime hours [1] (p)	Mean Temp. (t)	Cons. use factor (f)	Accumulated cons. use factor (F)
April	8.93	48.6	4.34 x 15/30	2.17
May	9.97	53.8	5.36	7.53
June	10.02	66.3	6.65	14.18
July	10.16	69.4	7.05	21.23
August	9.51	69.7	6.62	27.85
Sept.	8.38	61.1	5.12	32.97
Oct.	7.77	55.4	4.30	37.27

1. From "Sunshine Tables." U. S. Weather Bureau Bul. 805. 1905.

Table 9. Empirical consumptive use coefficients, K, for the major crops in Ashley valley, Utah, 1950.

Crop	Plot	Growing period	Consumptive use data U	F	K	Av. K
Alfalfa	Average	4/15 - 10/31	37.5	34.8	1.08	1.08
Pasture	A-P-1	4/15 - 10/31	31.0	34.8	0.89	0.89
Corn	A-C-1	5/28 - 10/2	13.2	24.6	0.53	0.57
Corn	A-C-2	5/11 - 9/23	15.5	26.0	0.60	
Barley	A-B-1	4/15 - 8/5	19.8	20.9	0.95	0.96
Barley	A-B-2	5/3 - 8/3	17.3	17.9	0.97	
Wheat	A-W-1	4/21 - 8/17	14.0	22.5	0.62	
Wheat	A-W-2	4/15 - 8/10	24.3	21.9	1.11	0.89
Wheat	A-W-3	4/21 - 8/18	21.5	22.7	0.95	
Oats	A-O-1	High water table; omit data				

Table 10. Empirical consumptive use coefficients, K, for the major crops in Ferron valley, Utah, 1950.

Crop	Plot	Growing period	Consumptive use data U	F	K	Av. K
Alfalfa	Average	4/15 - 10/31	33.3	37.3	0.89	0.89
Corn	F-C-1	5/10 - 9/15	20.0	25.8	0.78	0.78
Oats & Barley	F-OB-1	5/15 - 8/28	20.0	22.5	0.89	0.84
Oats & Barley	F-OB-2	5/27 - 9/7	17.0	21.6	0.79	
Wheat	F-W-1	4/1 - 8/2	15.7	23.8	0.66	0.66

Comparison of Empirical Coefficients

Empirical coefficients for the major crops in Ashley and Ferron valleys are shown for the past 3 years in tables 11 and 12. Also shown are average values recommended by Blaney and Criddle (2). A discussion and comparison of these data follows.

Consumptive Use Coefficients (1948-49-50)

In comparing the empirical coefficients with those determined in the same valleys but during different years, it should be kept in mind that they vary from year to year due to seasonal differences in length of growing season, available water supply, nature and amount of precipitation, humidity, wind, and plant pests and diseases. The assumed length of growing season by the different investigators affects the coefficients appreciably.

The K value of 1.08 for the average of the alfalfa plots in Ashley valley is high compared to 0.86 and 0.90 for the 1948 and 1949 years respectively. It is explained by the high early spring use which is discussed more in detail later.

For the 2 corn plots in Ashley valley the average K value of 0.57 is low compared to that for the 2 previous years. A further discussion of this follows in a later section.

The other coefficients seemed to agree with the 1948-49 values. The coefficients for Ferron valley compared better with previous values than did those for Ashley valley.

Average and Recommended Coefficients

The consumptive use coefficients recommended by Blaney and Criddle (2) are intended to be averages over a long period of time and over many areas. They apply best to the frost free period for perennials and to the growing period for annuals which grow entirely within the frost free

Table 11. Comparison of empirical coefficients and unit consumptive use values in Ashley Valley, Utah.

Crop	1948			1949			1950			1948-49-50 Weighted average		Recommended 1/ average values of K
	Number averaged	Average U	Average K	Number averaged	Average U	Average K	Number averaged	Average U	Average K	U	K	
Alfalfa	4	23.6	0.86	4	32.5	0.90	4	37.5	1.08	31.2	0.95	.80-.85
Pasture	1	25.0	0.92	3	33.3	0.92	1	31.0	0.89	31.2	0.91	.75-.85
Corn	1	19.4	0.95	3	21.1	0.79	2	14.4	0.57	18.6	0.74	.75-.85
Wheat	3	18.7	1.00	3	20.4	0.71	3	19.9	0.89			
Barley	3	14.4	0.91	2	19.1	0.77	2	18.5	0.96	18.2	0.85	.75-.85
Oats	3	14.0	0.79	3	19.8	0.69						
Oats and Barley	2	20.5	0.96									

1. Blaney and Criddle (2).

Table 12. Comparison of empirical coefficients and unit consumptive use values in Ferron valley, Utah.

Crop	1948 Number averaged	1948 Average U	1948 Average K	1949 Number averaged	1949 Average U	1949 Average K	1950 Number averaged	1950 Average U	1950 Average K	1948-49-50 Weighted average U	1948-49-50 Weighted average K	Recommended[1] average values of K
Alfalfa	4	24.2	0.80	3	31.2	0.82	4	33.3	0.89	29.4	0.84	.80-.85
Corn				1	18.8	0.70	1	20.0	0.78	19.4	0.74	.75-.85
Barley	1	16.3	0.88	1	19.2	0.67						
Wheat	2	17.8	0.79	3	19.0	0.67	1	15.7	0.66	18.1	0.76	.75-.85
Oats and Barley							2	18.5	0.84			
Wheat and Barley	2	18.5	0.83									

1. Blaney and Criddle (2).

period. There may be variations from year to year and in different places due to influencing factors other than temperature and percent daytime hours.

The average coefficients shown for alfalfa are for periods longer than the frost free period. They also show yearly variations, so should not be expected to agree exactly with the recommended values.

The 3 year average coefficients for Ferron valley compare closely to the recommended values. However, if more water had been available, use by alfalfa would have been greater and the coefficients would also have been greater.

The 3 year average coefficients for Ashley valley are higher than those for Ferron valley. The average coefficients for alfalfa (0.95) and for irrigated pasture, generally containing alfalfa and clovers as well as grasses, (0.91) are also higher than the recommended values (0.80 - 0.85).

Discussion

A satisfactory explanation for the low consumptive use values and empirical coefficients in Ashley valley for corn has not been found. It could be because of frequent rains and high humidity or because of unequal depletion of water from the root zone due to unequal distribution of irrigation water in the row cross section, or non-uniform salt concentrations as explained by Thorne and Peterson (10) pages 139 and 140. Under those conditions the plants may get most of their water from a zone directly beneath the furrow where the salt concentration is low and the depletion beneath the shoulder of the row would be low. It is not known under which part of the row average depletion will take place. In this invesitgation all row crop data were taken directly below the shoulder of the row.

In comparing consumptive use for alfalfa as found by the soil moisture depletion method with that found by the empirical equation, u = k•f, curves were drawn showing monthly consumptive use from April to October by each of the 2 methods. For comparison, k was given the value of 1. (A higher or lower value would raise or lower the entire curve.) During the early and late parts of the season, consumptive use by the empirical method was much higher than that found experimentally, but they were about the same during June, July, and August. This indicates that the consumptive use coefficient is not constant throughout the season and an average value would be high before and after the frost free period. Israelsen (9) table 46, shows monthly coefficients for alfalfa in the Upper Salinas Valley which are lower at the beginning and end of the growing season than during the middle part.

This suggests breaking down the season into 3 periods for valleys having a relatively short growing season: an early period (before May 31), a summer period (June, July, and August), and a late period (September and October). The winter period would also be added if consumptive use was to be found on a yearly basis.

Table 13 shows alfalfa consumptive use coefficients for Ashley and Ferron valleys for the 3 periods. This table may be compared with tables 2, 3, 9, and 10. The coefficient for the early period for Ashley valley is almost double that for Ferron valley. This is mainly because of the drouth condition in Ferron valley and above normal moisture condition in Ashley valley.

Most of the consumptive use would come in the summer period, the period for which the method is probably the most accurate. Growing conditions could be specially studied during the early and late periods

Table 13. Empirical consumptive use coefficients for alfalfa. Growing season divided into 3 periods. Ashley and Ferron valleys, Utah, 1950.

Period	Plot 1/	Consumptive use (U)	Use factor (F)	Use coefficient (K)	Average use coefficient (Av. K)
April 15 to May 31	A-A-1	8.8	7.05	1.25	
	A-A-2	7.3	7.05	1.04	
	A-A-3	10.0	7.05	1.42	1.30
	A-A-6	10.5	7.05	1.49	
	F-A-1	4.8	7.53	0.64	
	F-A-2	5.6	7.53	0.74	
	F-A-4	5.1	7.53	0.68	0.67
	F-A-5	4.7	7.53	0.62	
June, July, and August	A-A-1	18.9	19.0	1.00	
	A-A-2	24.7	19.0	1.30	
	A-A-3	26.6	19.0	1.40	1.17
	A-A-6	18.8	19.0	0.99	
	F-A-1	22.0	20.32	1.09	
	F-A-2	18.8	20.32	0.93	
	F-A-4	27.8	20.32	1.37	1.07
	F-A-5	18.0	20.32	0.89	
September and October	A-A-1	6.6	8.77	0.75	
	A-A-2	4.5	8.77	0.51	
	A-A-3	5.6	8.77	0.64	0.70
	A-A-6	7.7	8.77	0.88	
	F-A-1	4.2	9.42	0.45	
	F-A-2	6.6	9.42	0.70	
	F-A-4	9.1	9.42	0.96	0.70
	F-A-5	6.3	9.42	0.67	

1. A and F refer to Ashley valley and Ferron valley respectively.

where consumptive use is generally small but where large variations occur. It seems that this would considerably increase the accuracy of estimating consumptive use for areas having a short frost free period.

Criddle[2] suggests that in the West consumptive use of water by alfalfa, in inches, can be roughly estimated for the frost free period by multiplying the number of days in the period by 0.17 or dividing by 6.

In this study all the precipitation which fell between irrigation periods was added to the depletion to get consumptive use. Small rains are almost entirely evaporated and only larger rains contribute sufficiently to the soil moisture to be transpired by the plants. However, small rains do increase the humidity and decrease the temperature, thereby causing a condition of more growth with relatively less water use. It seems, therefore, that this method of handling precipitation is entirely satisfactory. Irrigation requirement would be the consumptive use minus the total amount of precipitation added.

The 1950 climatological data for Ashley and Ferron valleys are shown in tables 15 and 16 of the Appendix. These data are shown because of their direct effect on consumptive use of water. Curves showing accumulated rainfall throughout the growing season are shown in figures 32 and 33 for the Ashley and Ferron valleys respectively.

All basic data and curves which were obtained during this study and not shown in this thesis are in the files of the Irrigation Department of the Utah State Agricultural College.

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2. Private conversation.

RECOMMENDATIONS

The following suggestions and recommendations are supplemental to those outlined by Christiansen (4). They pertain mainly to problems which were encountered during the past season.

1. A thorough study of previous consumptive use studies should be made by the investigator before he starts his field study.
2. More complete early spring data should be obtained.
3. Field plots should be well located. Where possible experienced supervision should be employed. The owner of the field should be consulted. Trial sampling tests should be made.
4. The samples within each plot should be located systematically. They should proceed up or down the rows, not laterally.
5. At least 2 plots of grain and/or corn should be sampled with a 7 foot tube, an alfalfa plot sampled with a 9 foot tube, and the water used from each foot should be computed. If the water used in the bottom 2 feet is significant, previously collected data could be corrected.
6. A fallow field should be sampled to see if moisture moves down significantly after the so-called field capacity has been reached, and to check evaporation from the soil surface.
7. Samples should be taken for a corn plot on the row and down in the furrow to determine any difference in depletion.
8. The alfalfa plot which seems the best (soil homogeneous, free draining, good irrigation practice, and good stand of alfalfa) should be sampled every 3 or 4 days or less throughout the season, and samples taken just before and a few days after irrigation should be duplicated.

9. Tanks should be installed early and only grass and clover pastures should be planted. The tanks simulating a water table should have a good filter in the bottom.

10. Good yield data should be obtained for alfalfa especially and for other crops where practicable.

11. The King soil samplers with 0.880 inch diameter cutters, designed by the writer and submitted to the Irrigation Department of the Utah State Agricultural College, should be built and used. They have the advantage that the tube constant would be 0.1 and computations would be simplified.

SUMMARY

1. Consumptive use of water studies are important and basic to modern agriculture. Distribution of Colorado River water between the Upper Basin States will be based on consumptive use. This was the primary purpose for making this study.

2. The soil moisture depletion and evapo-transpiration tank methods of determining unit consumptive use values were used. These values will be used to determine valley consumptive use by the integration method, which will be compared with that obtained by the inflow-outflow method.

3. Considerable study was devoted to increasing the accuracy of soil moisture determinations. Various methods of correcting and checking were found.

4. A brief statistical study indicated that accurate determinations of soil moisture could be made. However, other factors leading to consumptive use may be quite variable.

5. Unit consumptive use values for Ashley valley were generally higher for 1950 than those for 1948 and 1949. Average use by alfalfa was 37.5 inches. However, the plots studied were known to be better than the average in the valley. Unit consumptive use values for Ferron valley were near the average of those for the 2 preceeding years. Use in 1950 (33.3 inches) by alfalfa was slightly higher than for the 2 preceeding years, and the water supply in 1950 was at least 1 irrigation short for 3 of the 4 plots averaged.

6. The 1950 tank results compared closely to those obtained in 1948 but were higher than those for 1949.

7. Consumptive use was plotted versus yield for alfalfa for the 3 years of data. The curve obtained was fairly well defined.

8. The empirical method of applying the experimental data obtained to other valleys, which was developed by Blaney and Criddle, was employed and empirical coefficients were determined. They were in general slightly higher than those recommended by Blaney and Criddle and those obtained during the 2 previous years.

9. The growing season was divided into 3 periods, early, summer, and late. Comsumptive use coefficients were determined for alfalfa for each period. The average coefficient for the early period was very high for Ashley valley and very low for Ferron valley.

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For further reference material see the bibliography sections of Christiansen (4) and Fisher (5).

APPENDIX

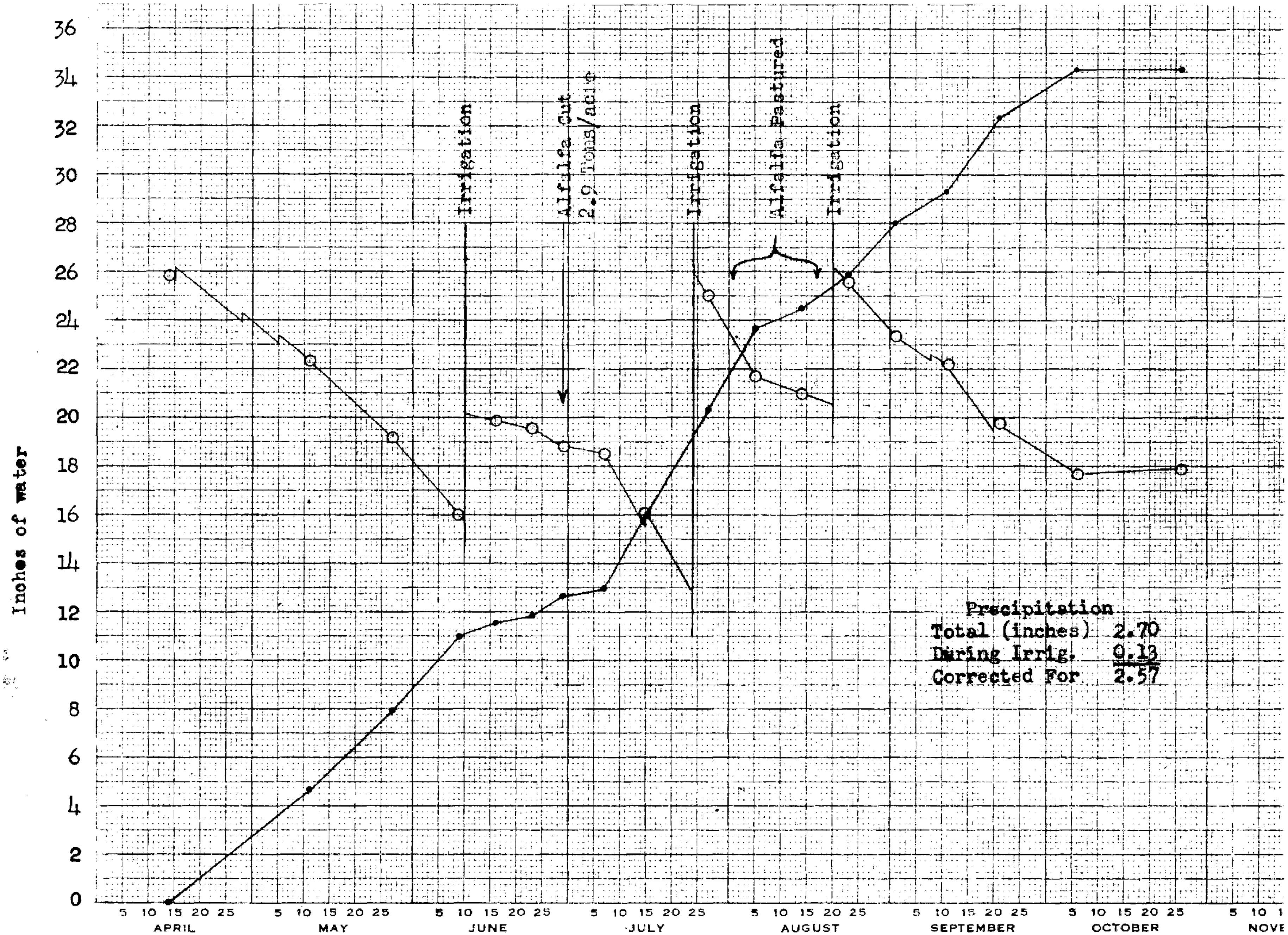


Fig. 1 . Consumptive Use of Water by Alfalfa , 1950. Area: Ashley Valley, Utah Plot: A-A-1

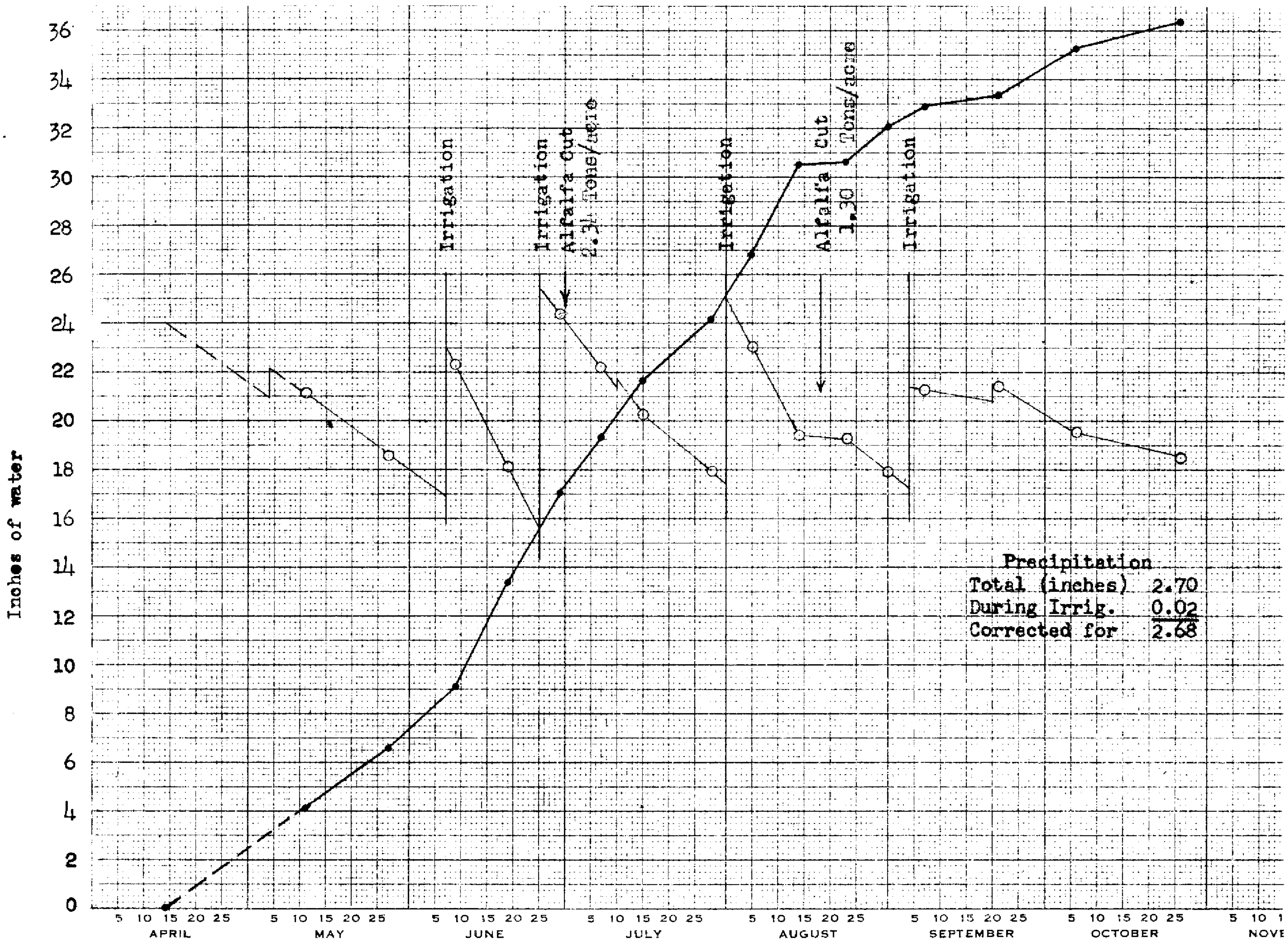


Fig. 2 . Consumptive Use of Water by Alfalfa , 1950. Area: Ashley Valley, Utah Plot: A-A-2

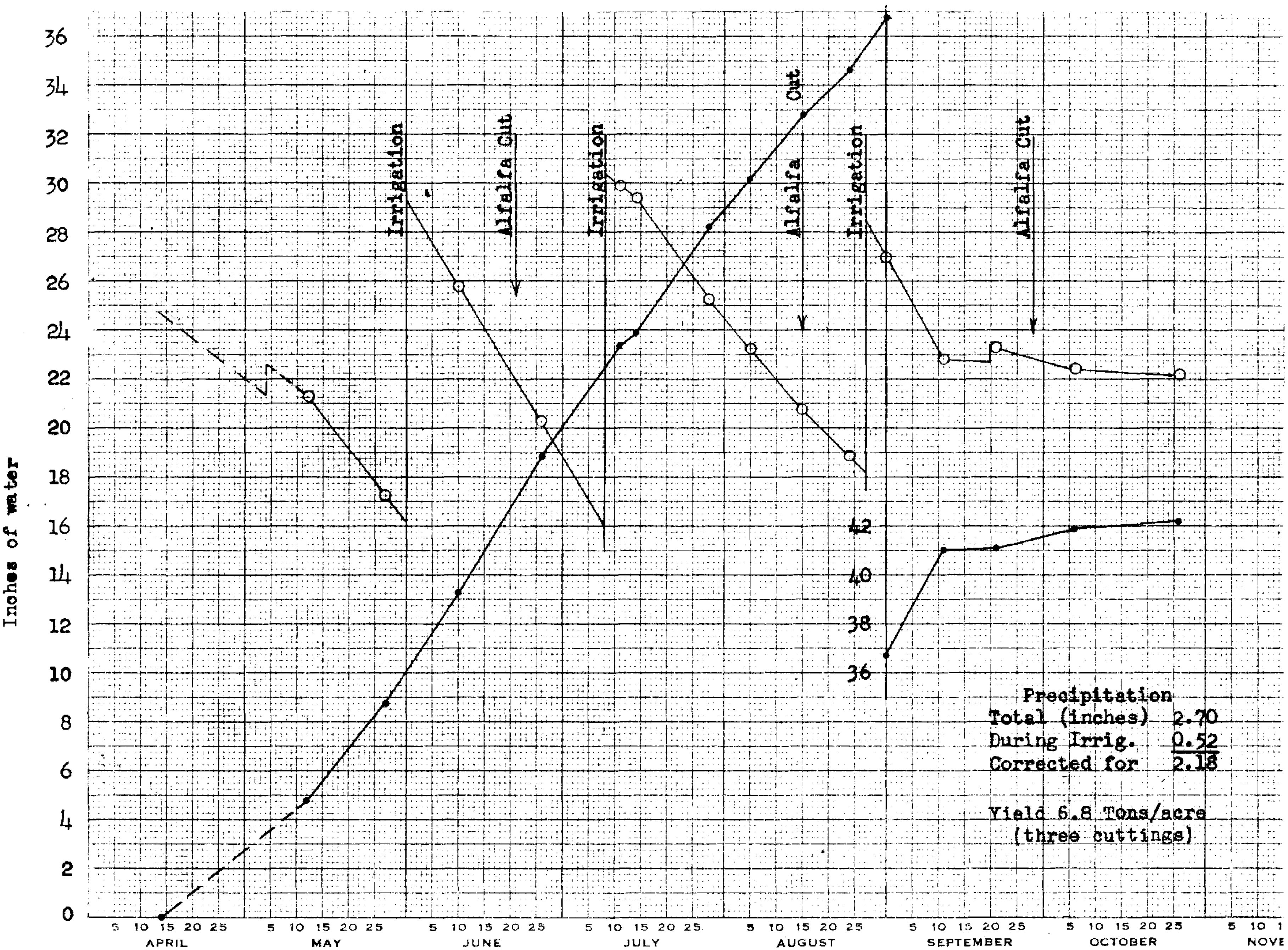


Fig. 3 . Consumptive Use of Water by Alfalfa , 1950. Area: Ashley Valley, Utah Plot: A-A-3

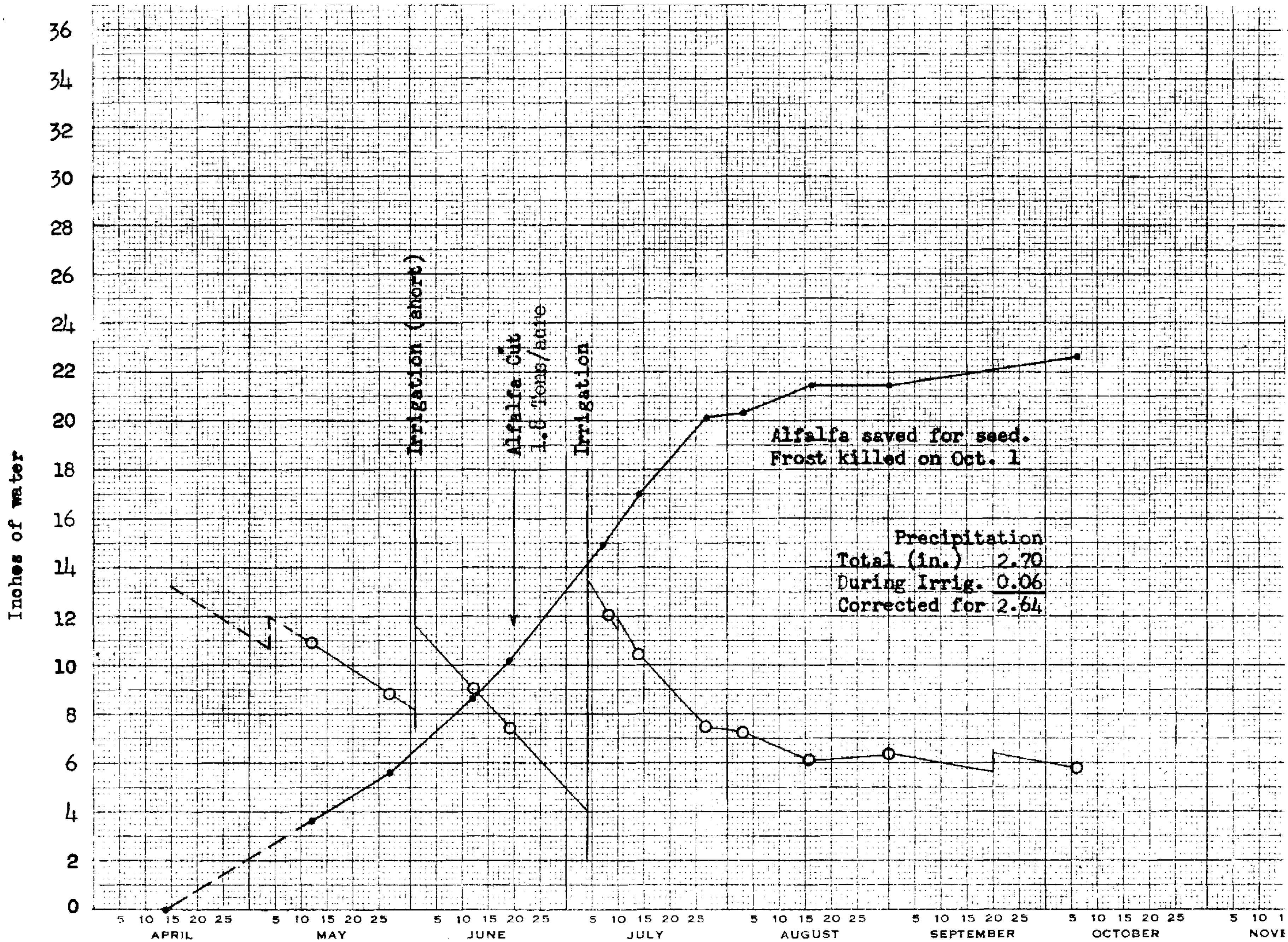


Fig. 4 . Consumptive Use of Water by Alfalfa , 1950. Area: Ashley Valley, Utah. Plot: A-A-4

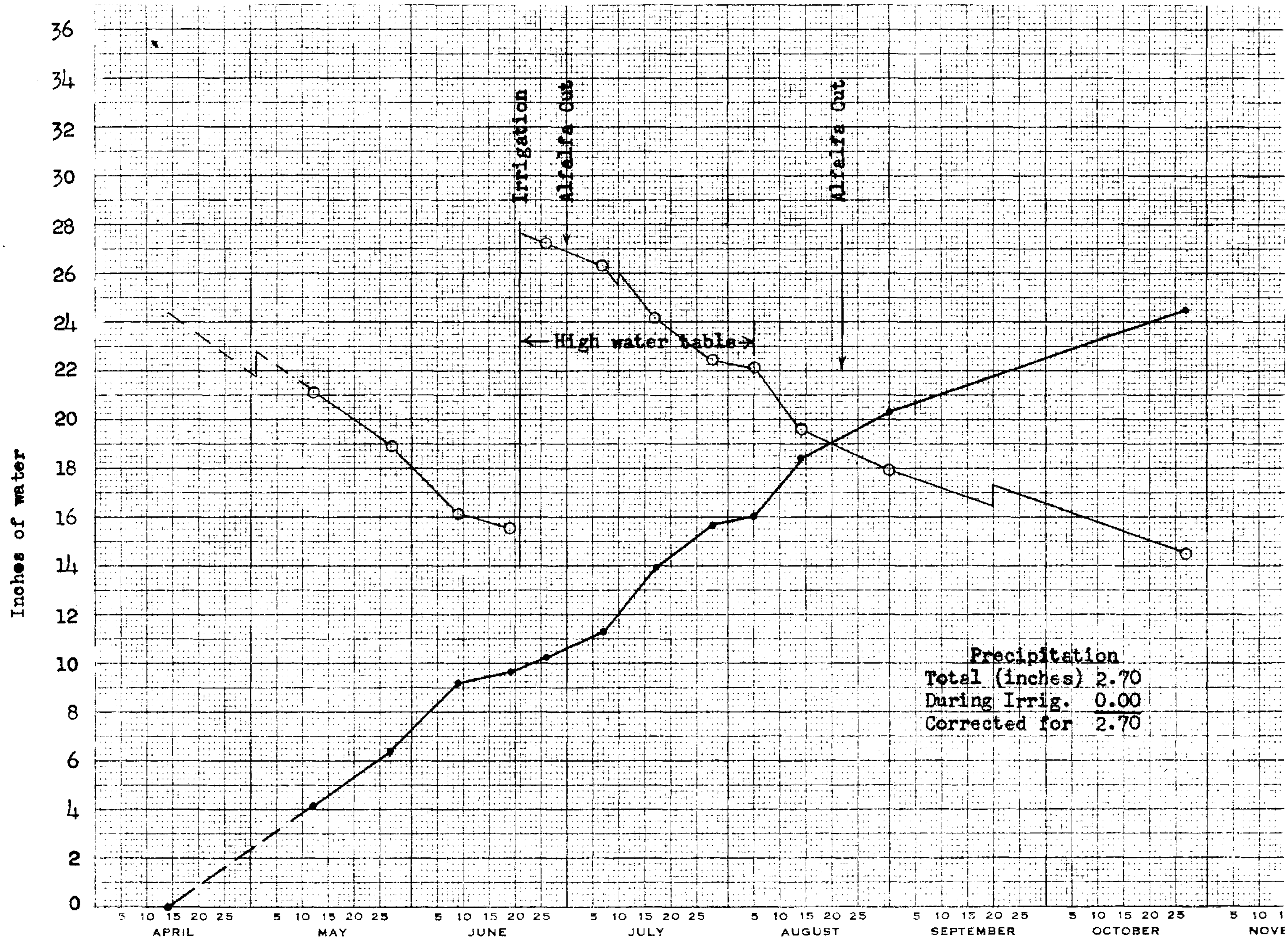


Fig. 5 . Consumptive Use of Water by Alfalfa , 1950. Area: Ashley Valley, Utah Plot: A-A-5

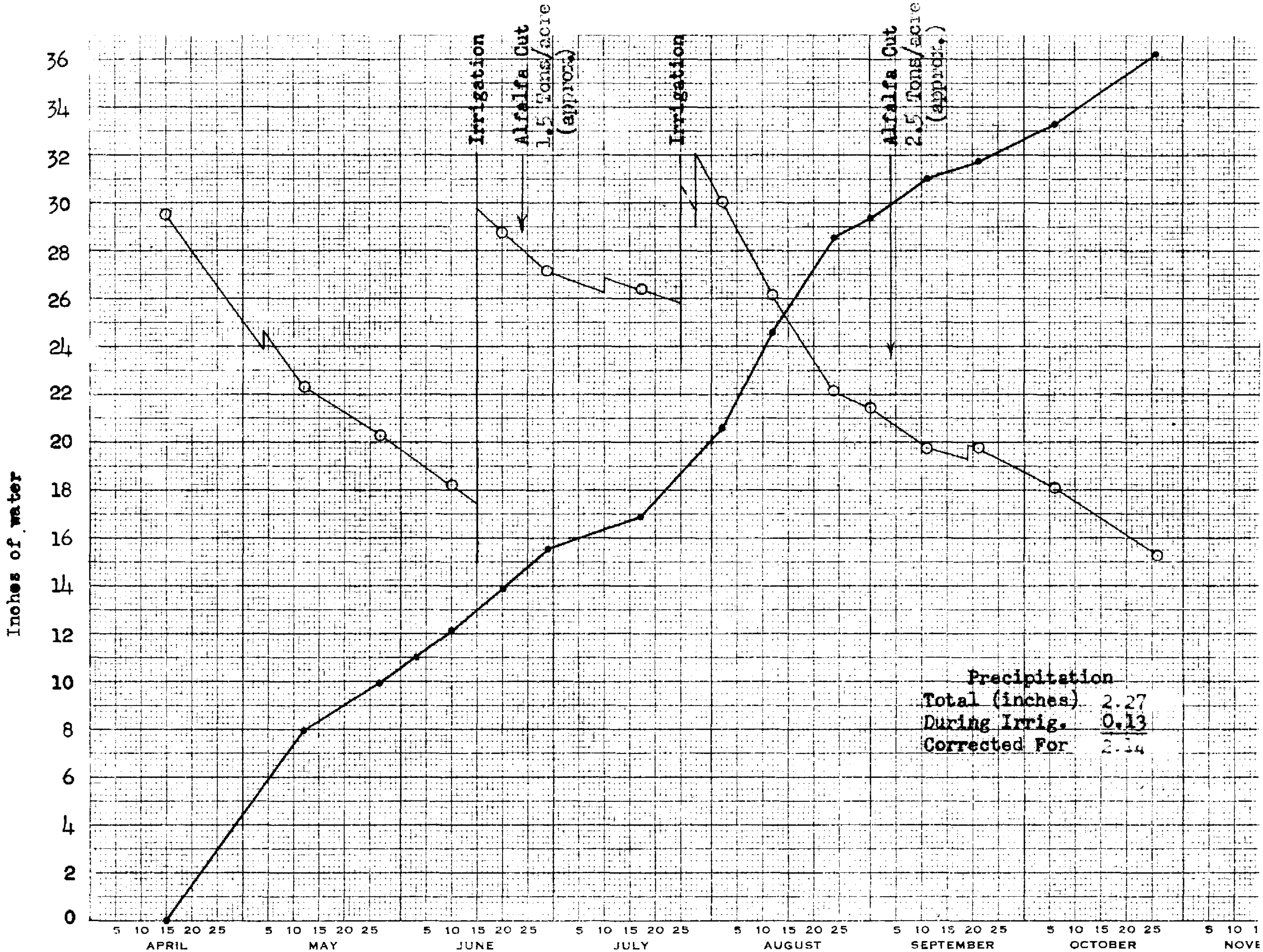


Fig. 6 . Consumptive Use of Water by Alfalfa , 1950. Area: Ashley Valley Utah Plot: A-A-6

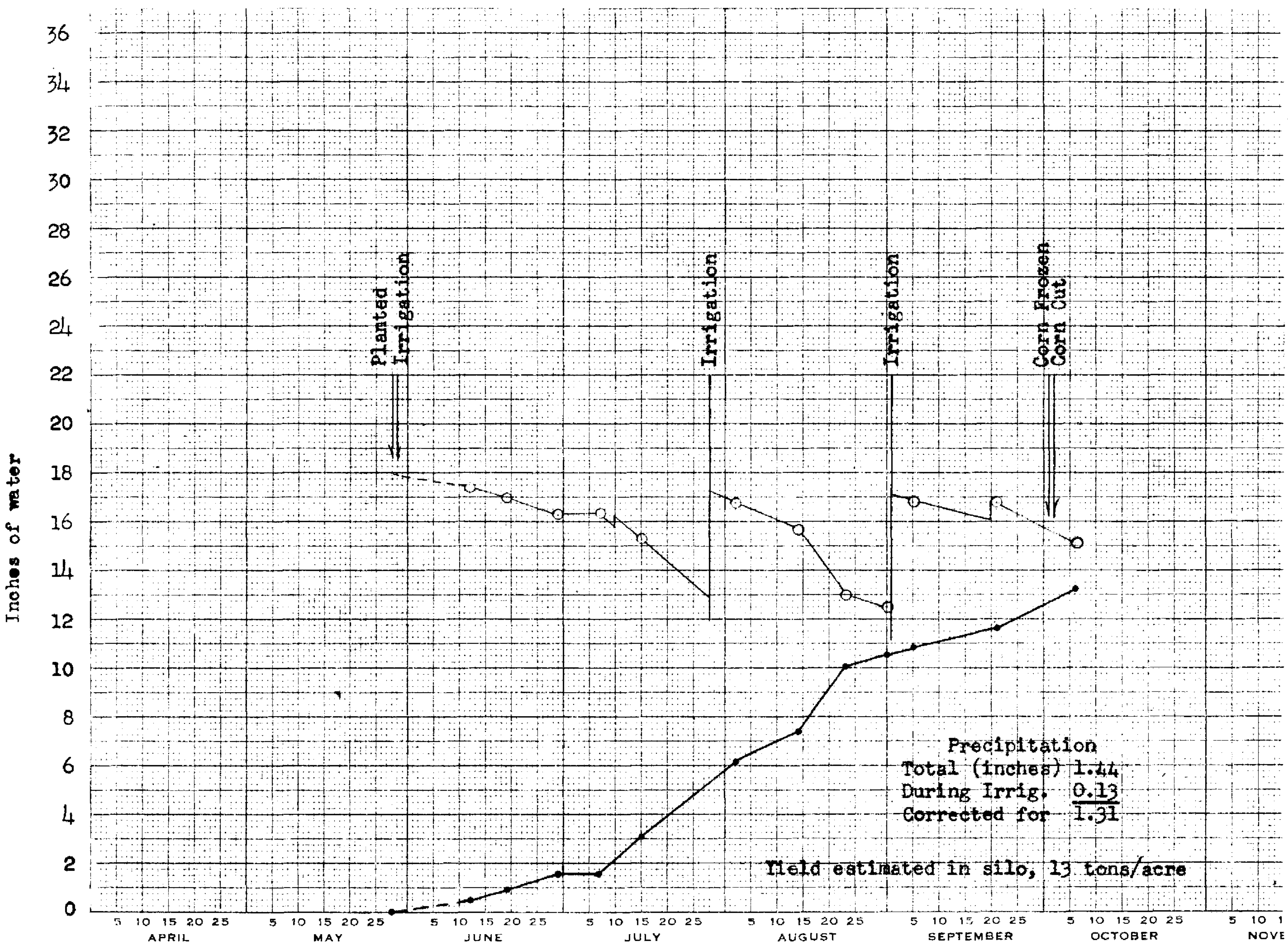


Fig. 7 . Consumptive Use of Water by Corn , 1950. Area: Ashley Valley, Utah . Plot: A-C-1

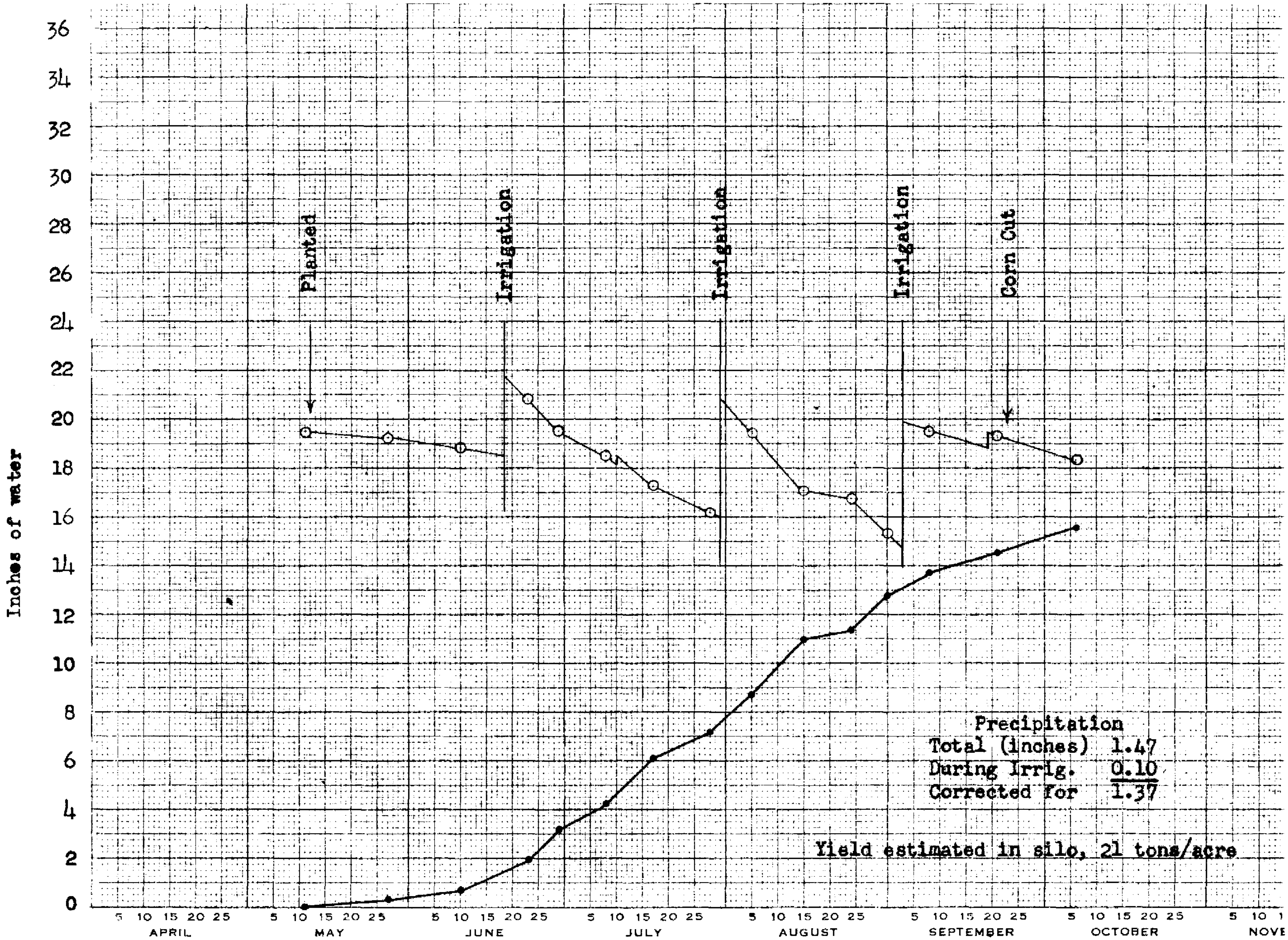


Fig. 8 . Consumptive Use of Water by Corn , 1950. Area: Ashley Valley, Utah. Plot: A-C-2

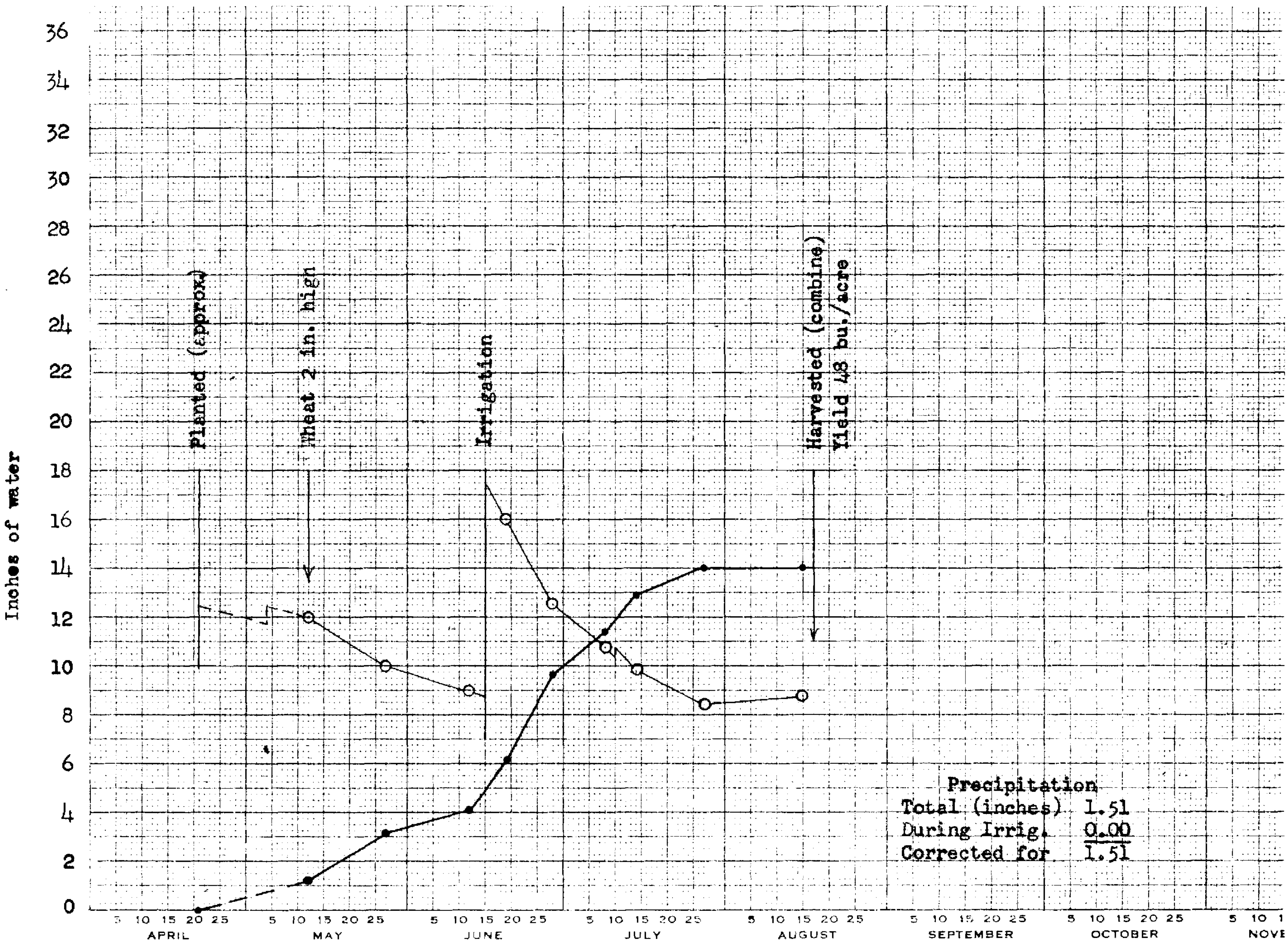


Fig. 9 . Consumptive Use of Water by Wheat , 1950. Area: Ashley Valley, Utah. Plot: A-W-1

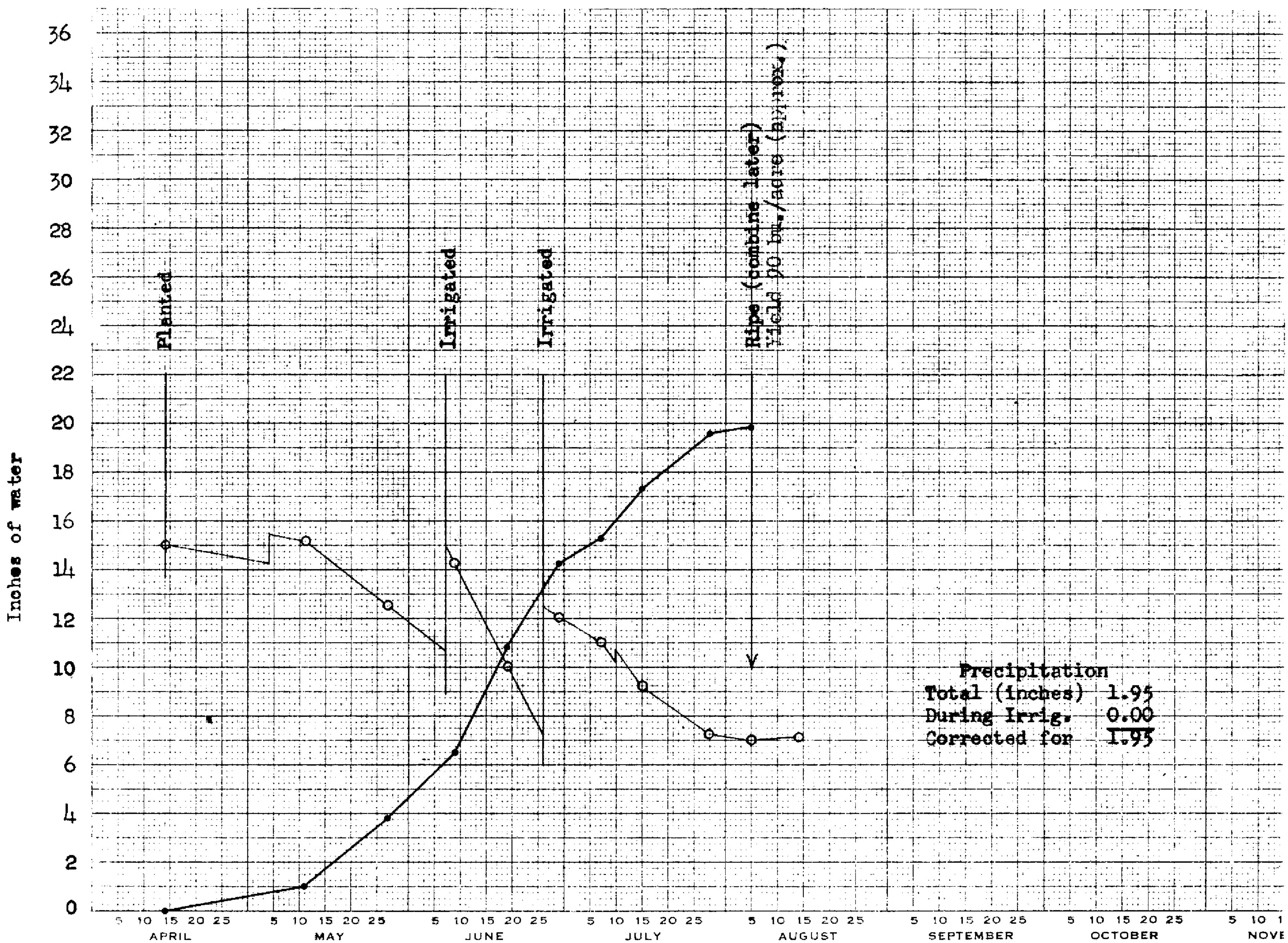


Fig. 10. Consumptive Use of Water by Barley, 1950. Area: Ashley Valley Utah. Plot: A-B-1

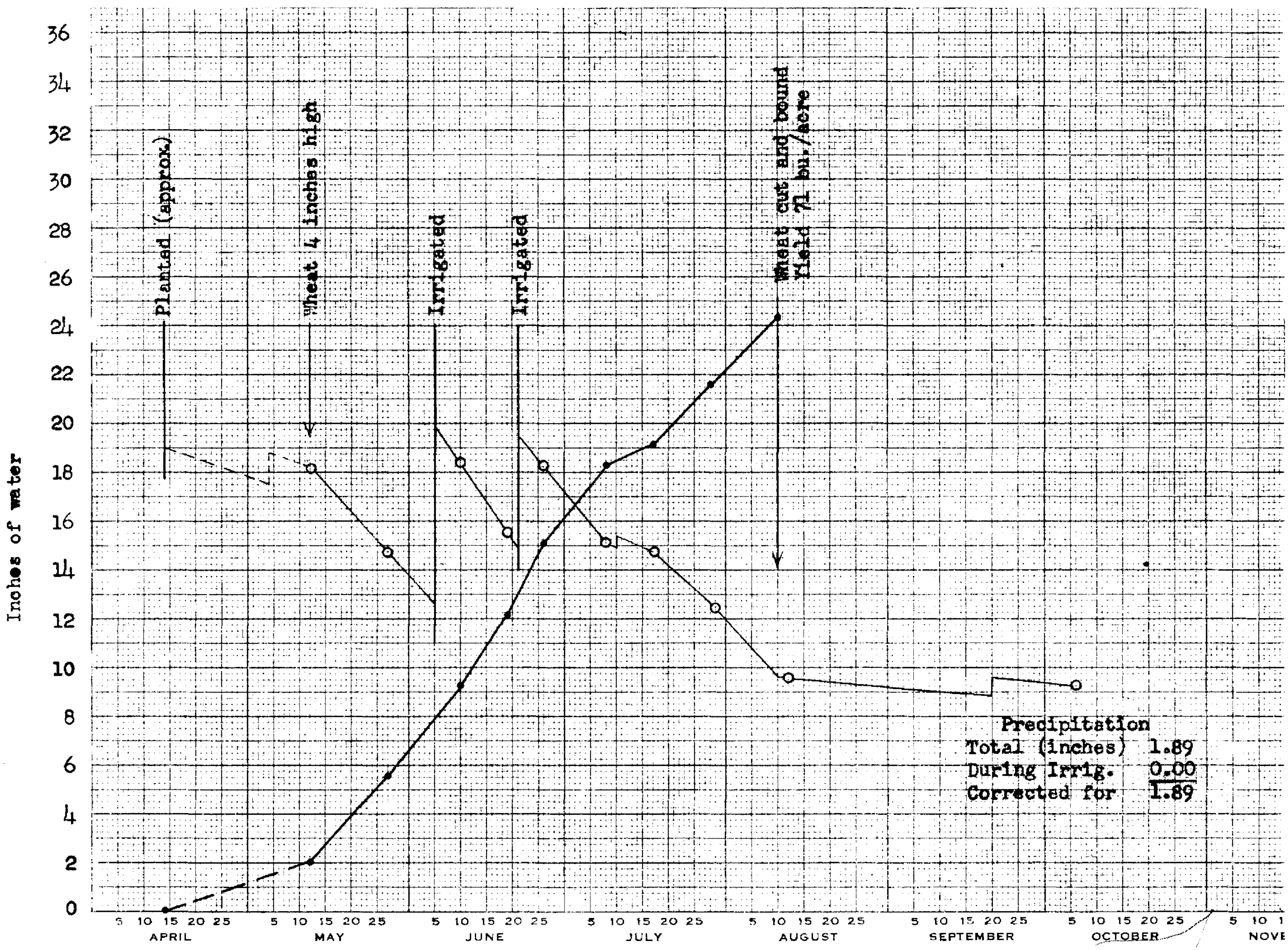


Fig. 11. Consumptive Use of Water by Wheat, 1950. Area: Ashley Valley, Utah. Plot: A-W-2

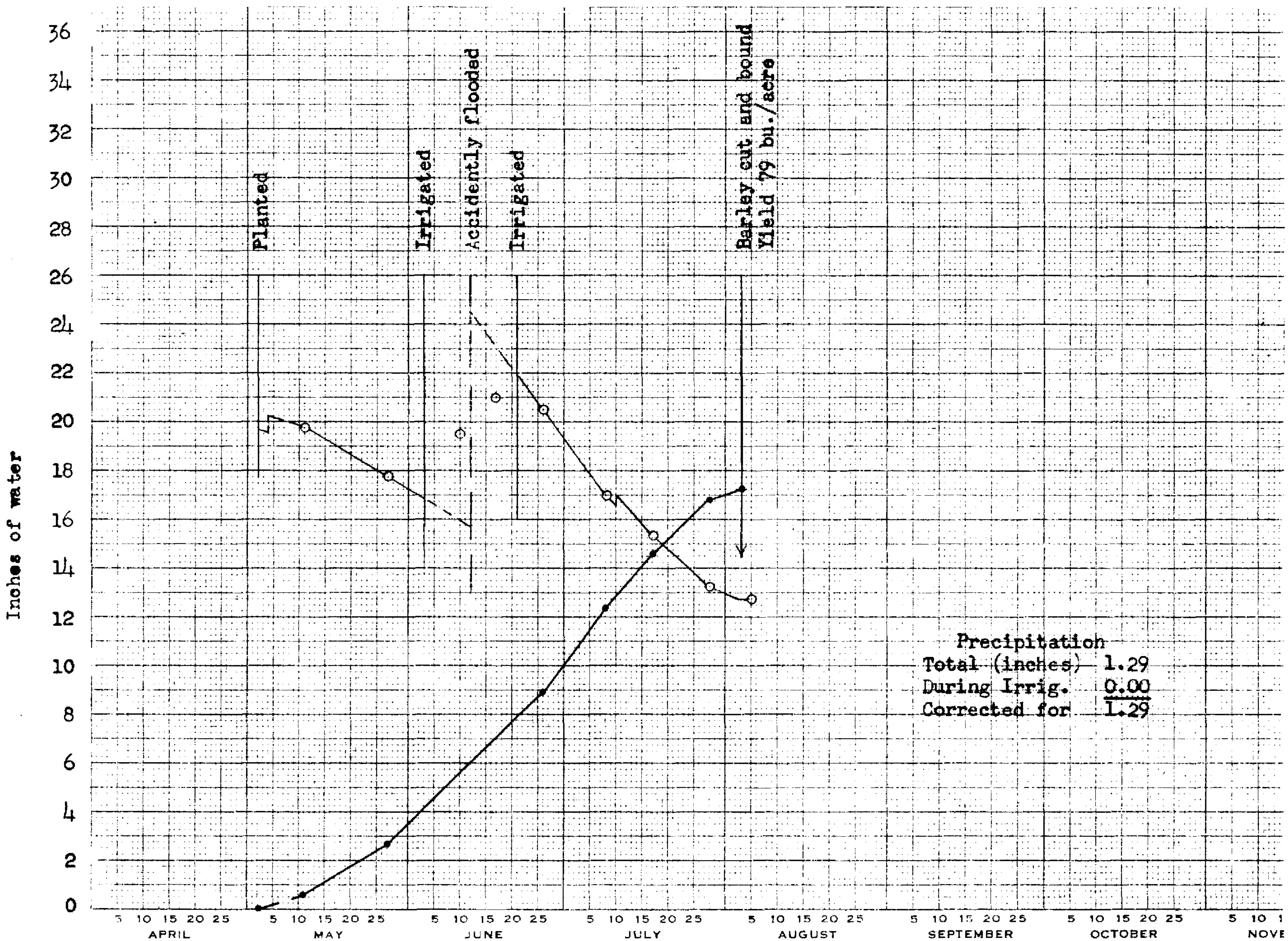


Fig. 12 . Consumptive Use of Water by Barley , 1950. Area: Ashley Valley, Utah . Plot: A-B-2

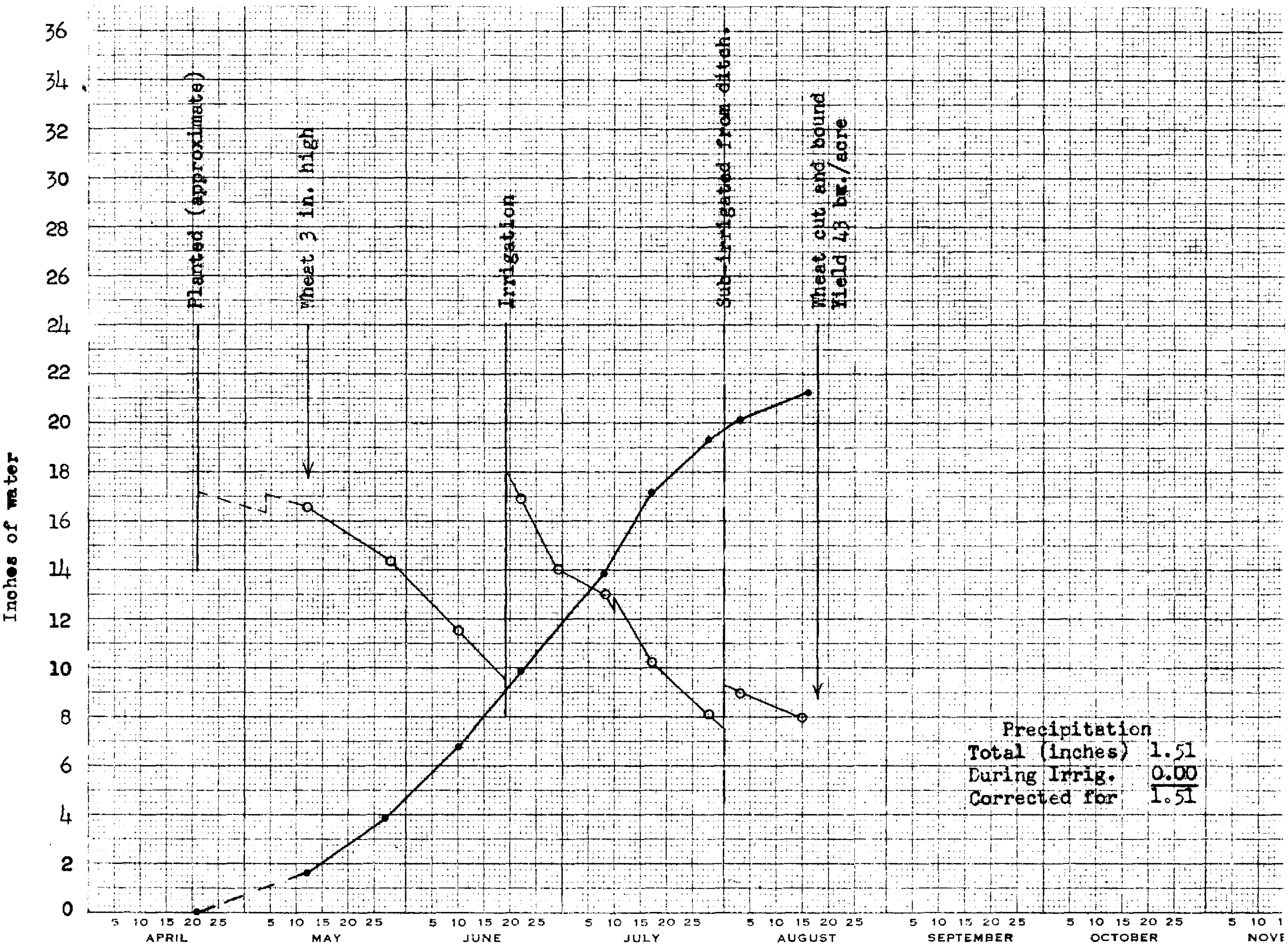


Fig. 13 . Consumptive Use of Water by Wheat , 1950. Area: Ashley Valley, Utah. Plot: A-W-3

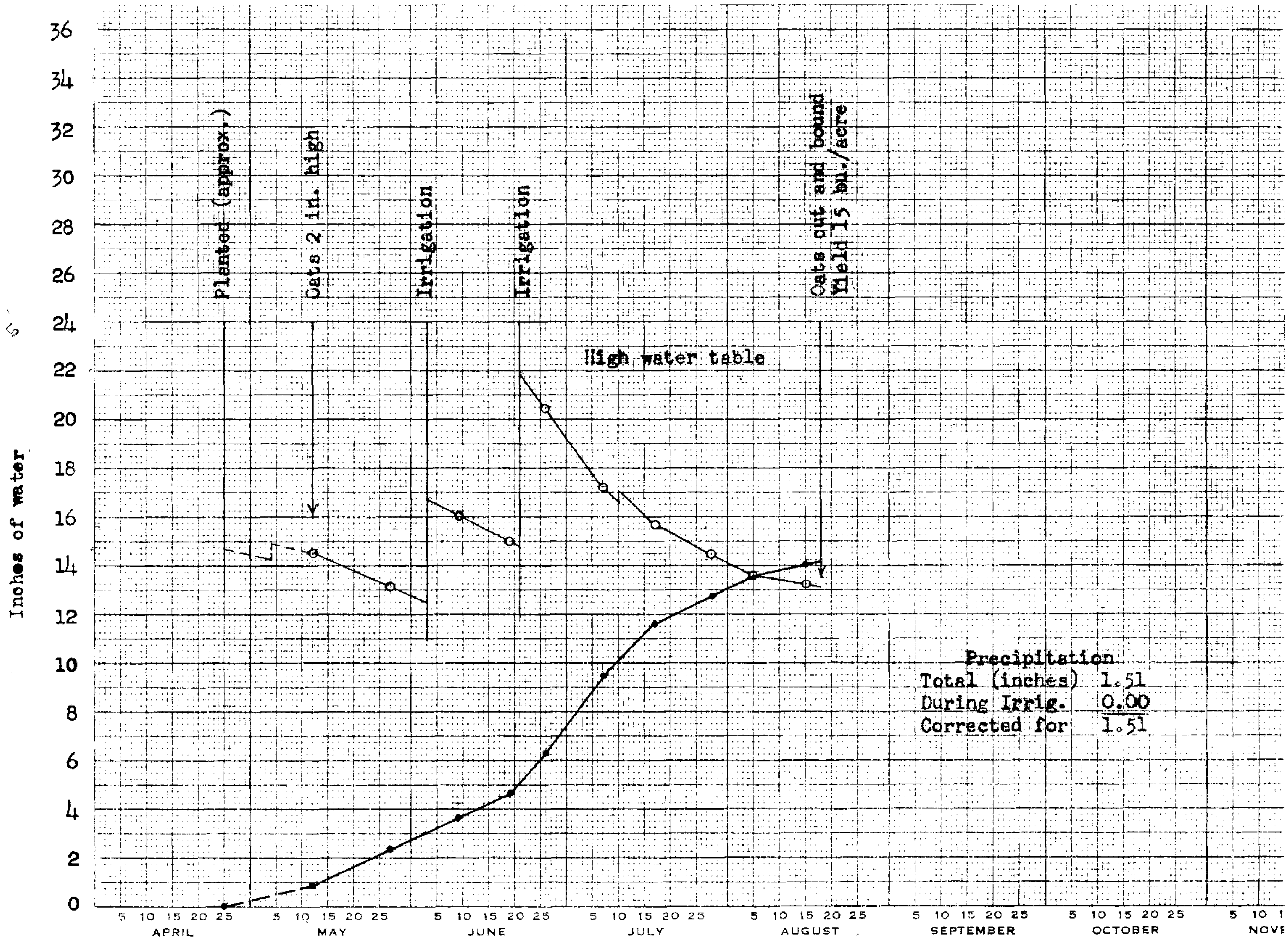


Fig. 14. Consumptive Use of Water by Oats, 1950. Area: Ashley Valley, Utah. Plot: A-O-1

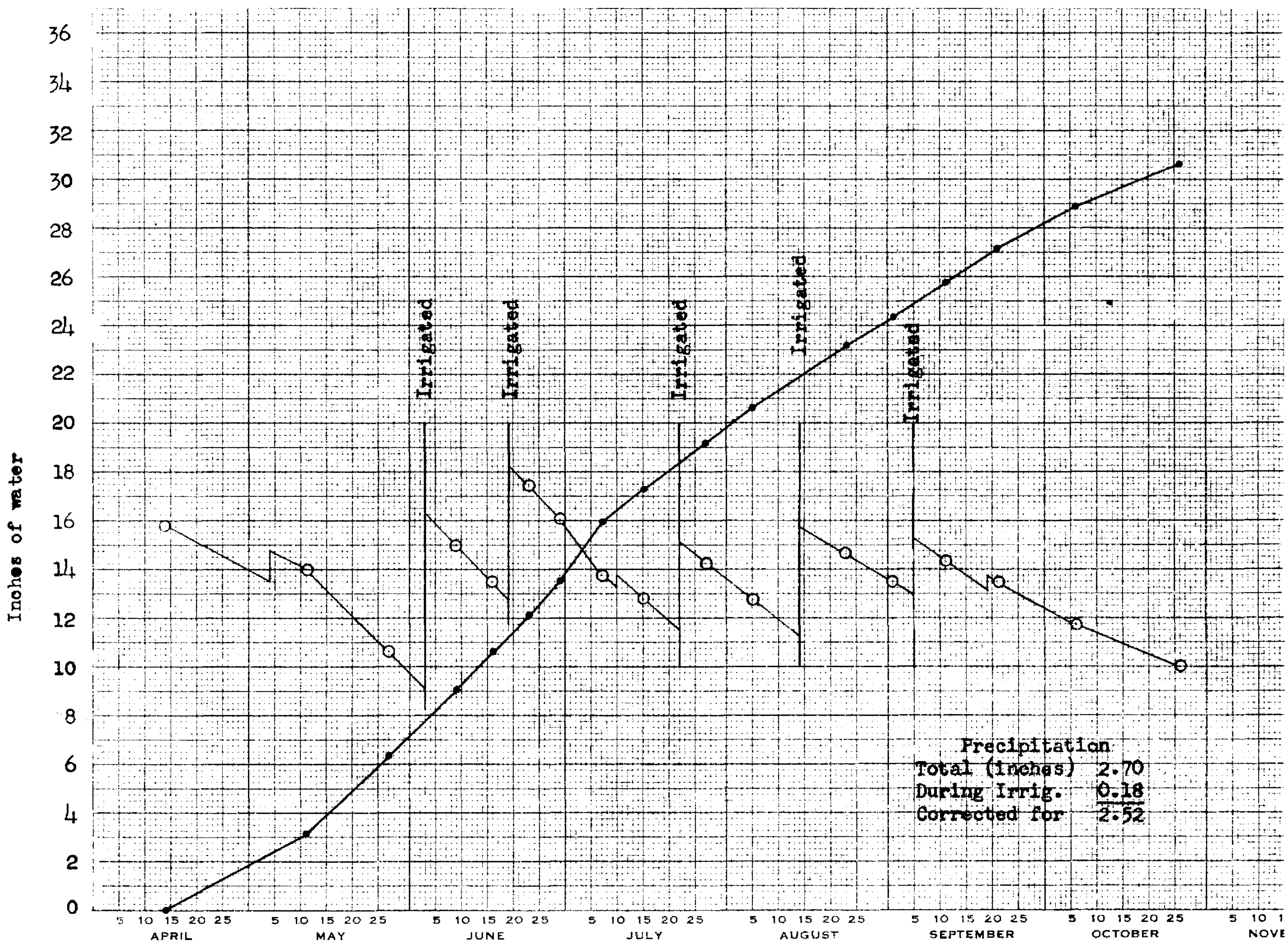


Fig. 15 . Consumptive Use of Water by Pasture , 1950. Area: Ashley Valley, Utah . Plot: A-P-1

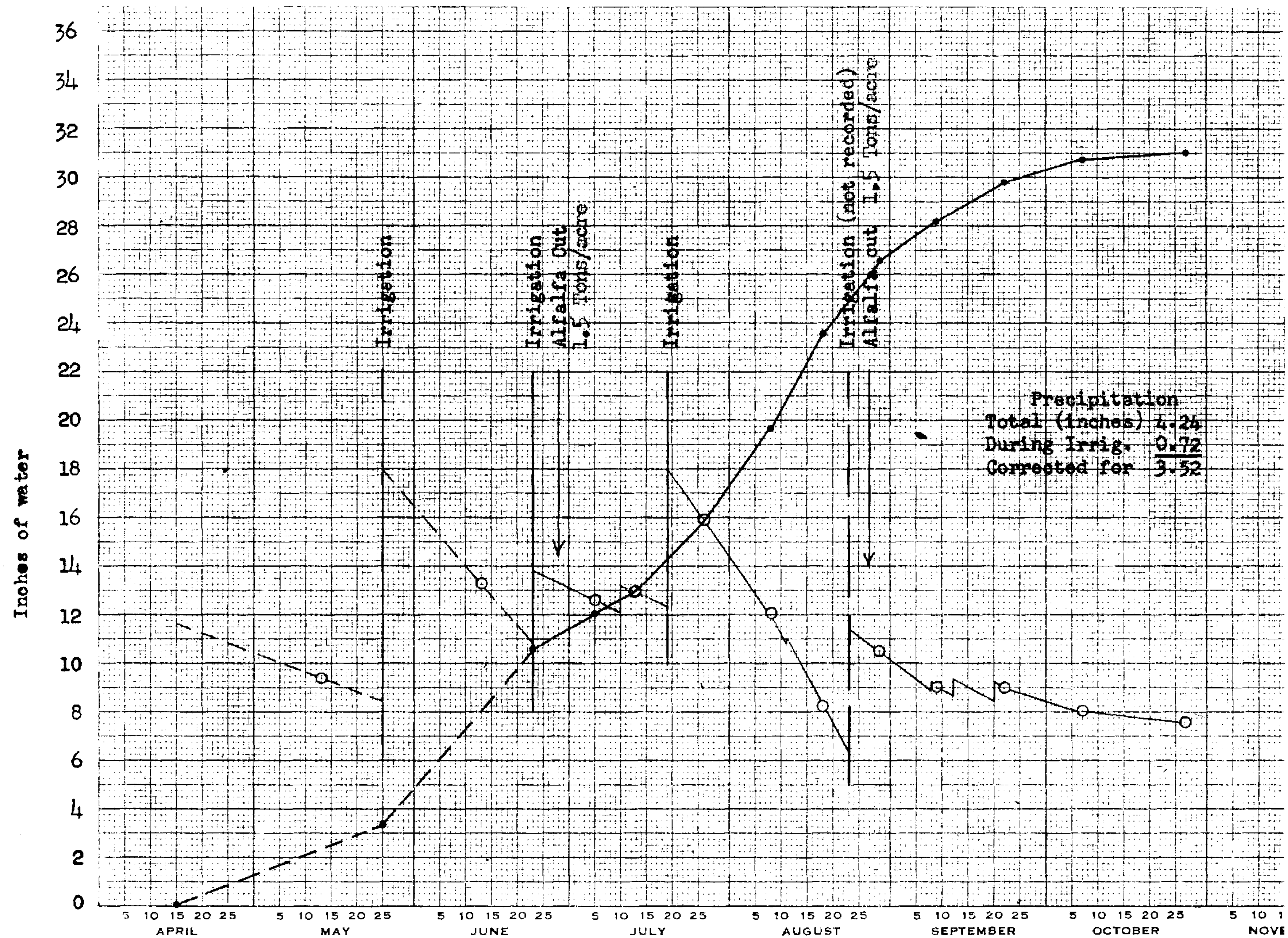


Fig. 16 . Consumptive Use of Water by Alfalfa , 1950. Area: Ferron Creek, Utah. Plot: F-A-1

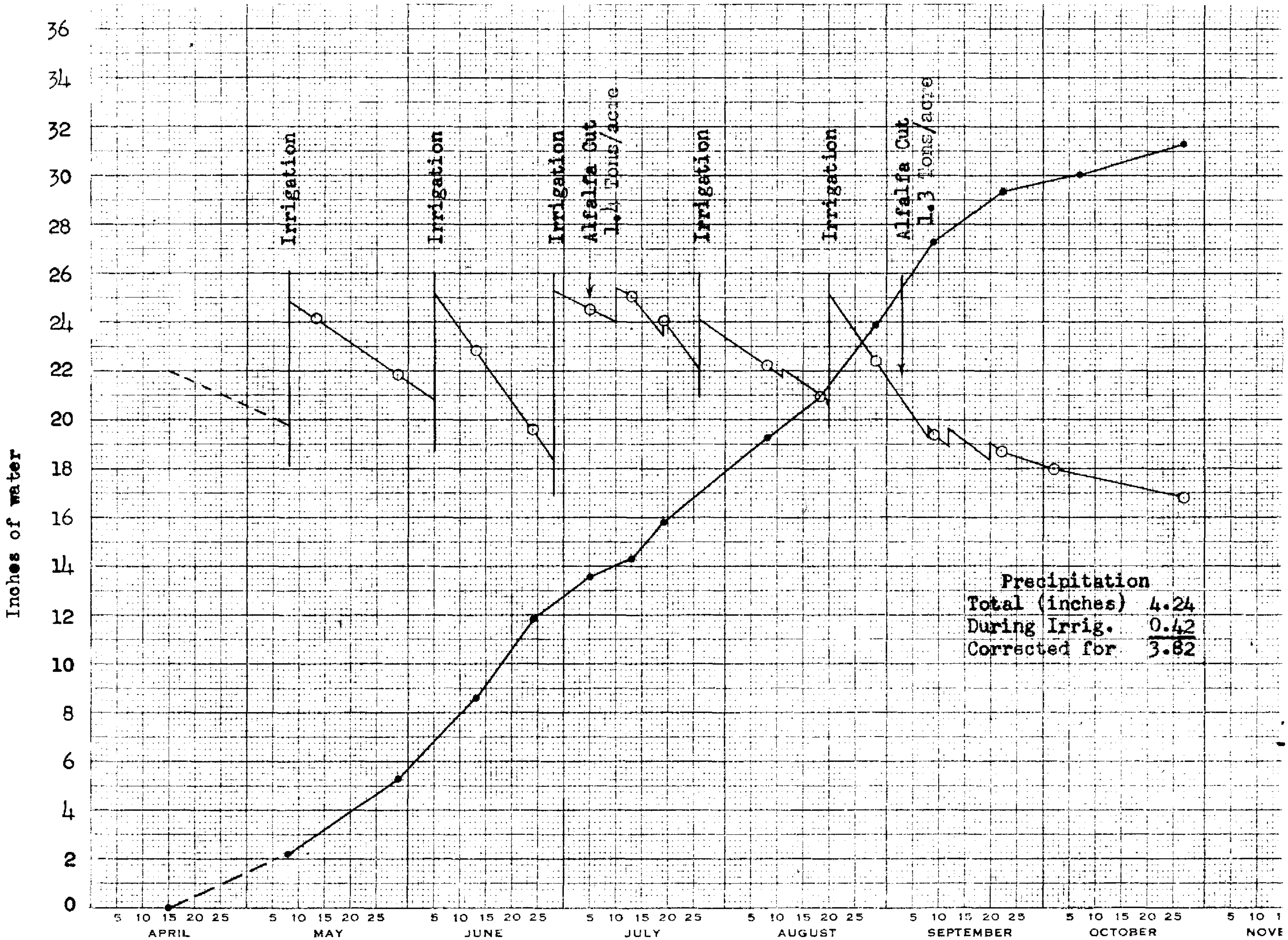


Fig. 17 . Consumptive Use of Water by Alfalfa **, 1950. Area:** Ferron Creek, Utah **. Plot:** F-A-2

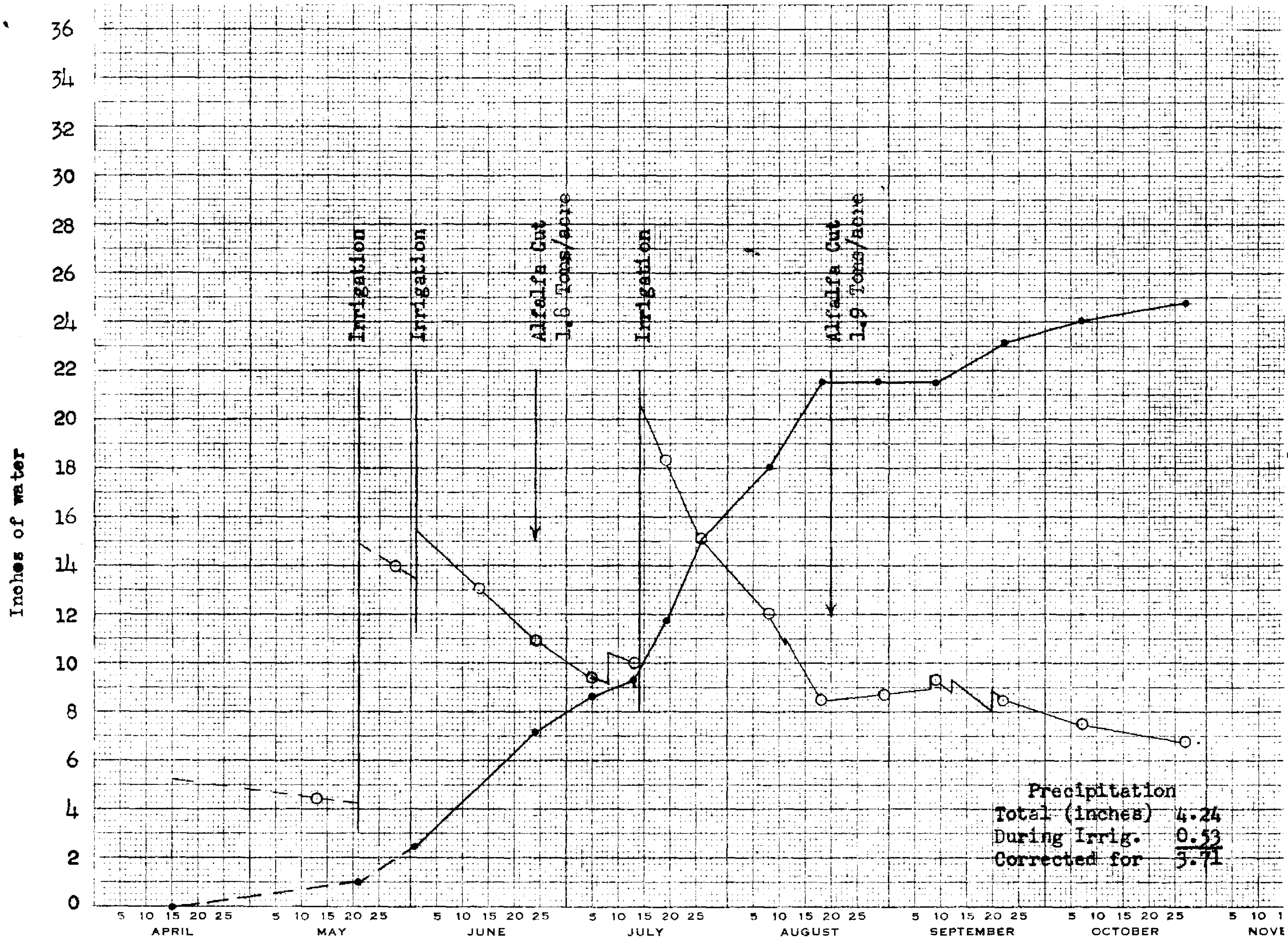


Fig. 18 . Consumptive Use of Water by Alfalfa , 1950. Area: Ferron Creek, Utah . Plot: F-A-3

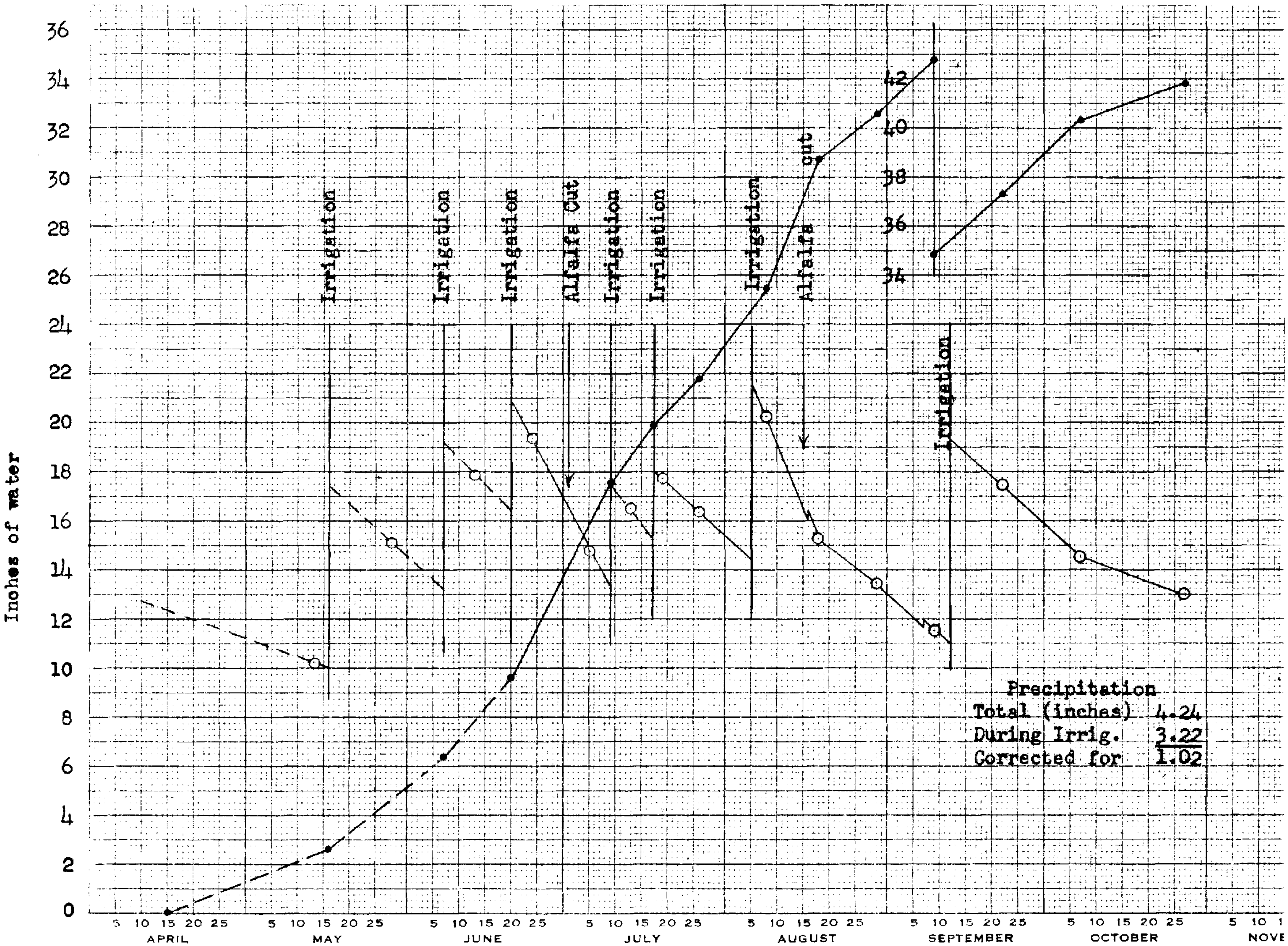


Fig. 19 . Consumptive Use of Water by Alfalfa , 1950. Area: Ferron Creek, Utah . Plot: F-A-4

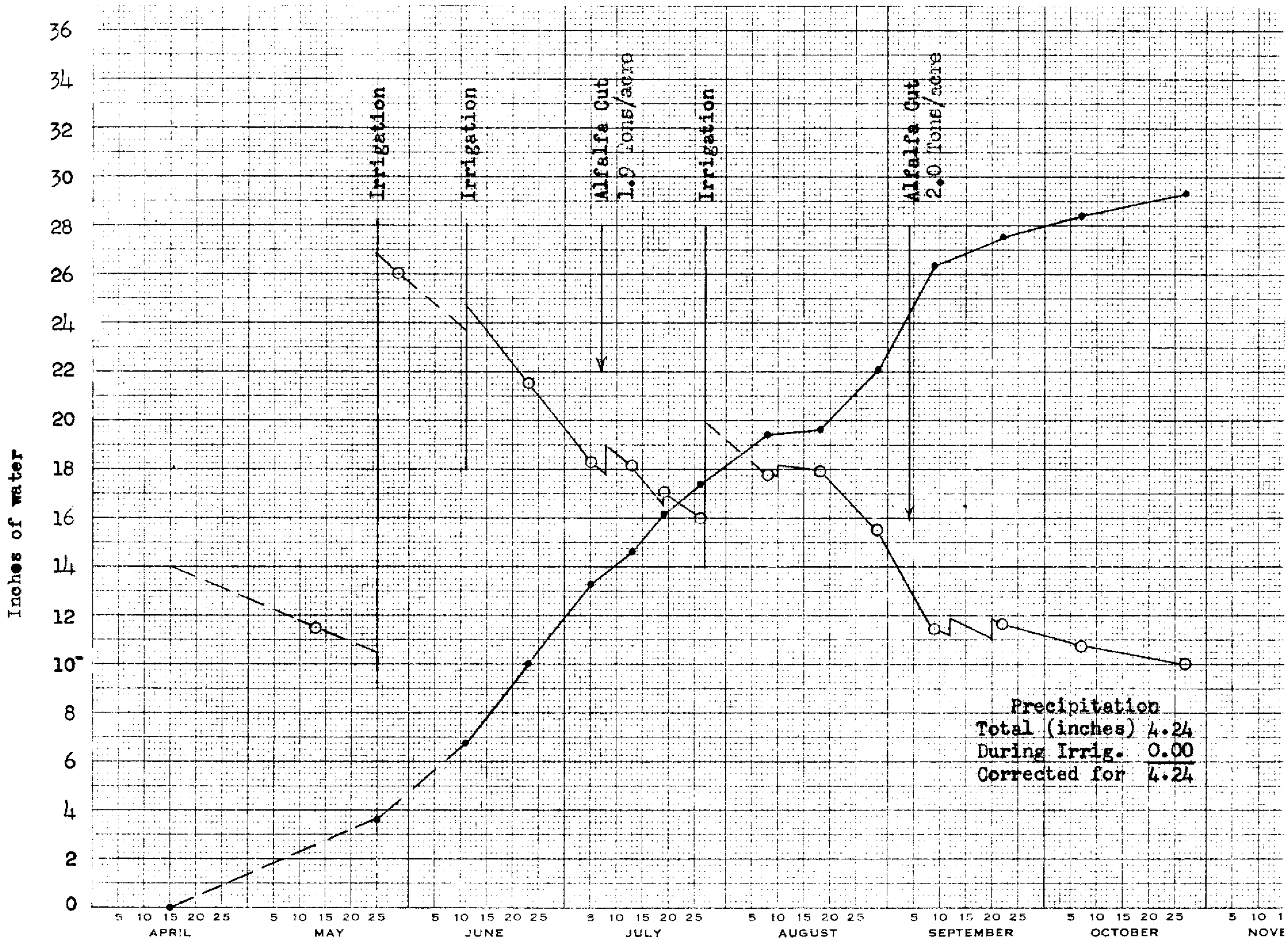


Fig. 20 . Consumptive Use of Water by Alfalfa , 1950. Area: Ferron Creek, Utah . Plot: F-A-5

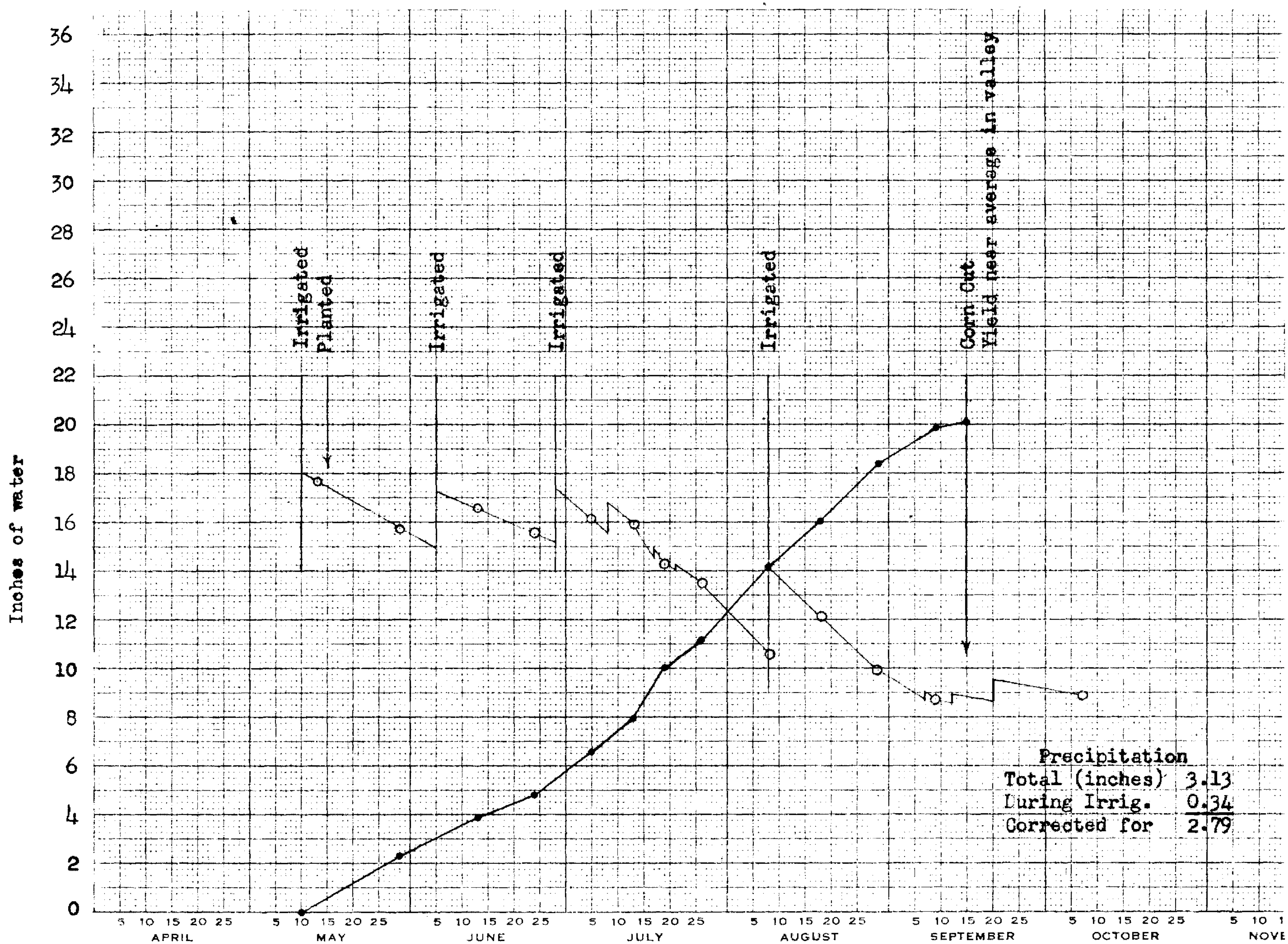


Fig. 21 . Consumptive Use of Water by Corn , 1950. Area: Ferron Creek, Utah . Plot: F-C-1

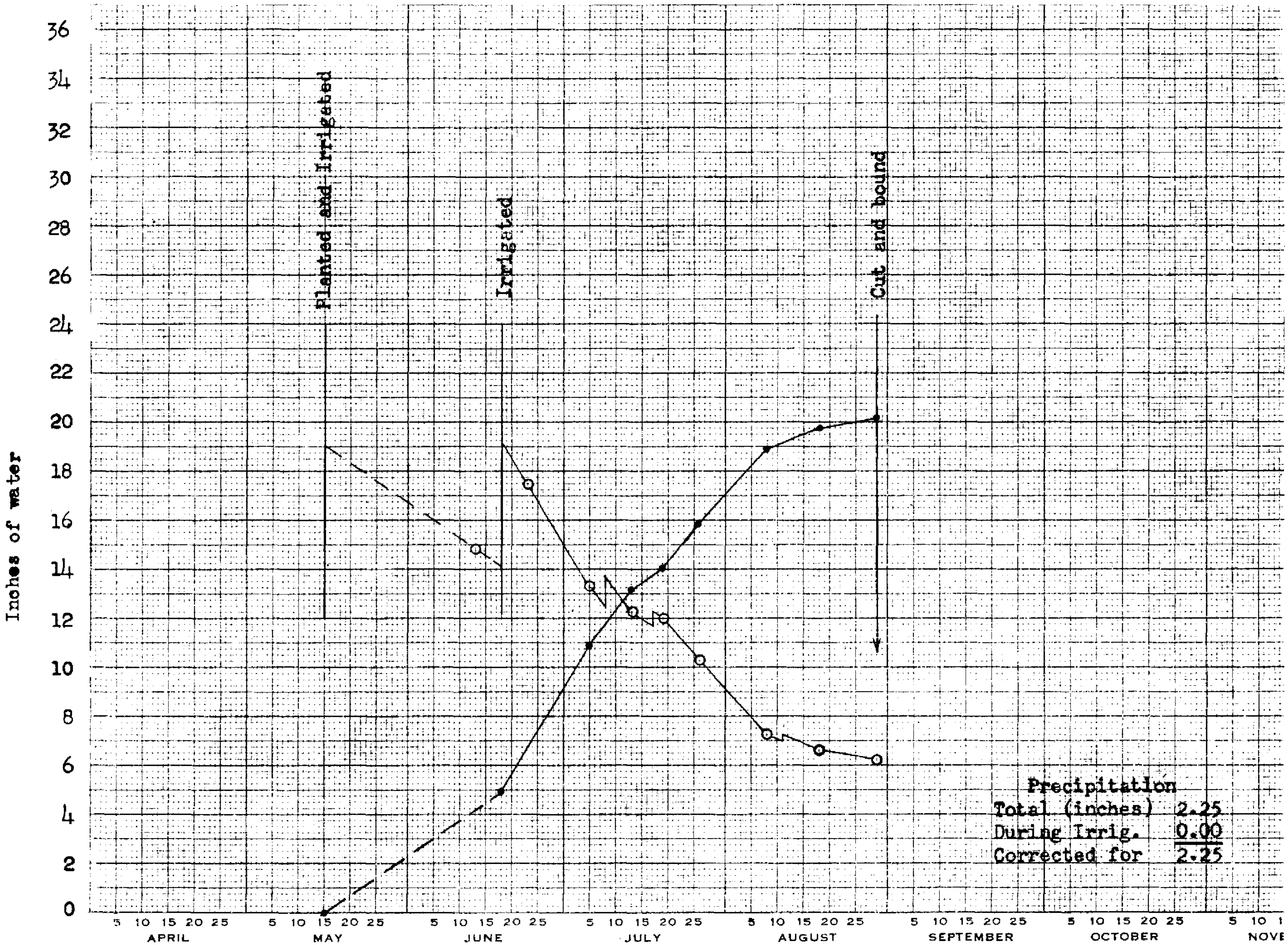


Fig. 22 . Consumptive Use of Water by Oat & Barley 1950. Area: Ferron Creek, Utah . Plot: F-OB-1

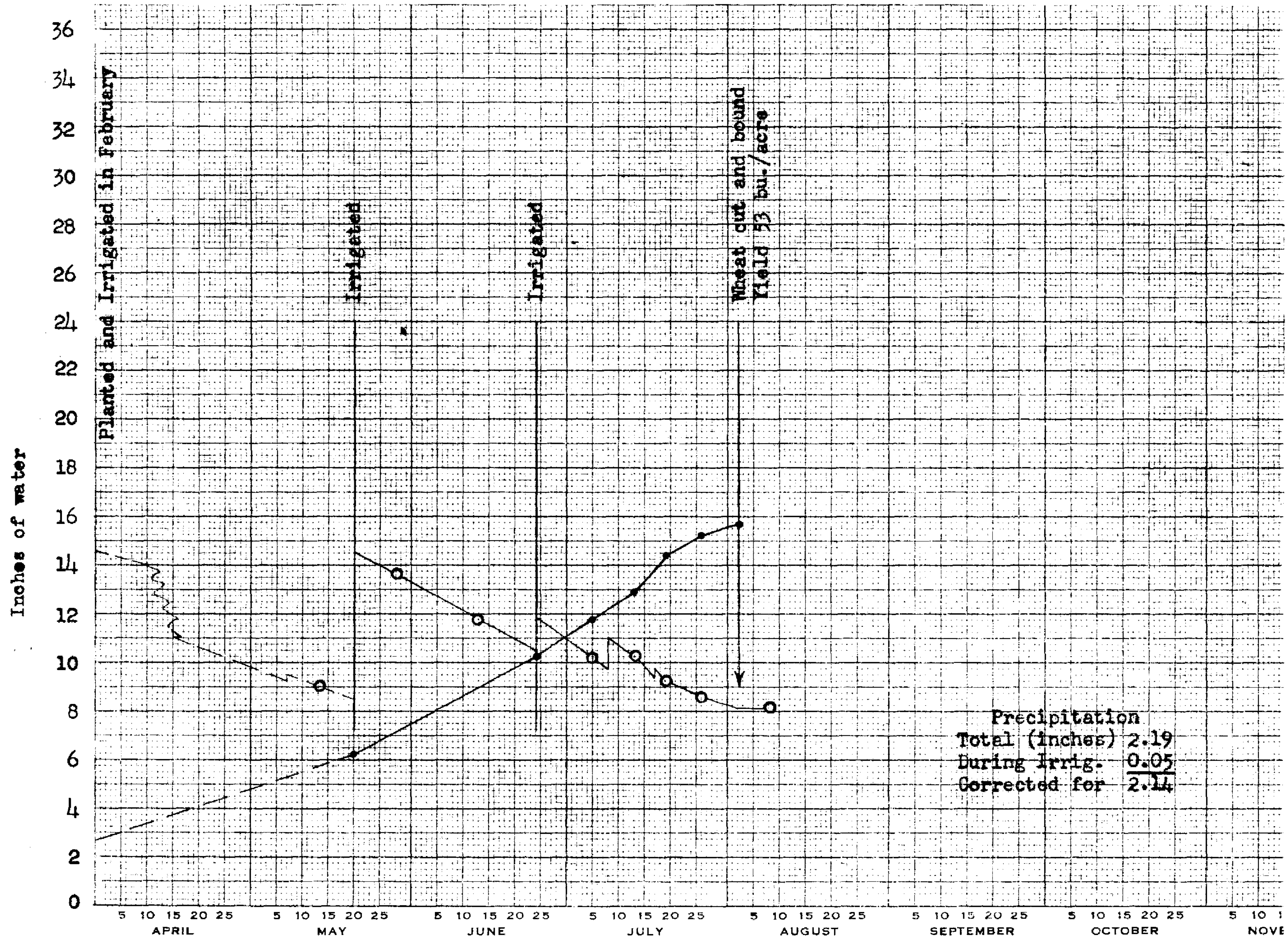


Fig. 23 . Consumptive Use of Water by Wheat , 1950. Area: Ferron Creek, Utah . Plot: F-W-1

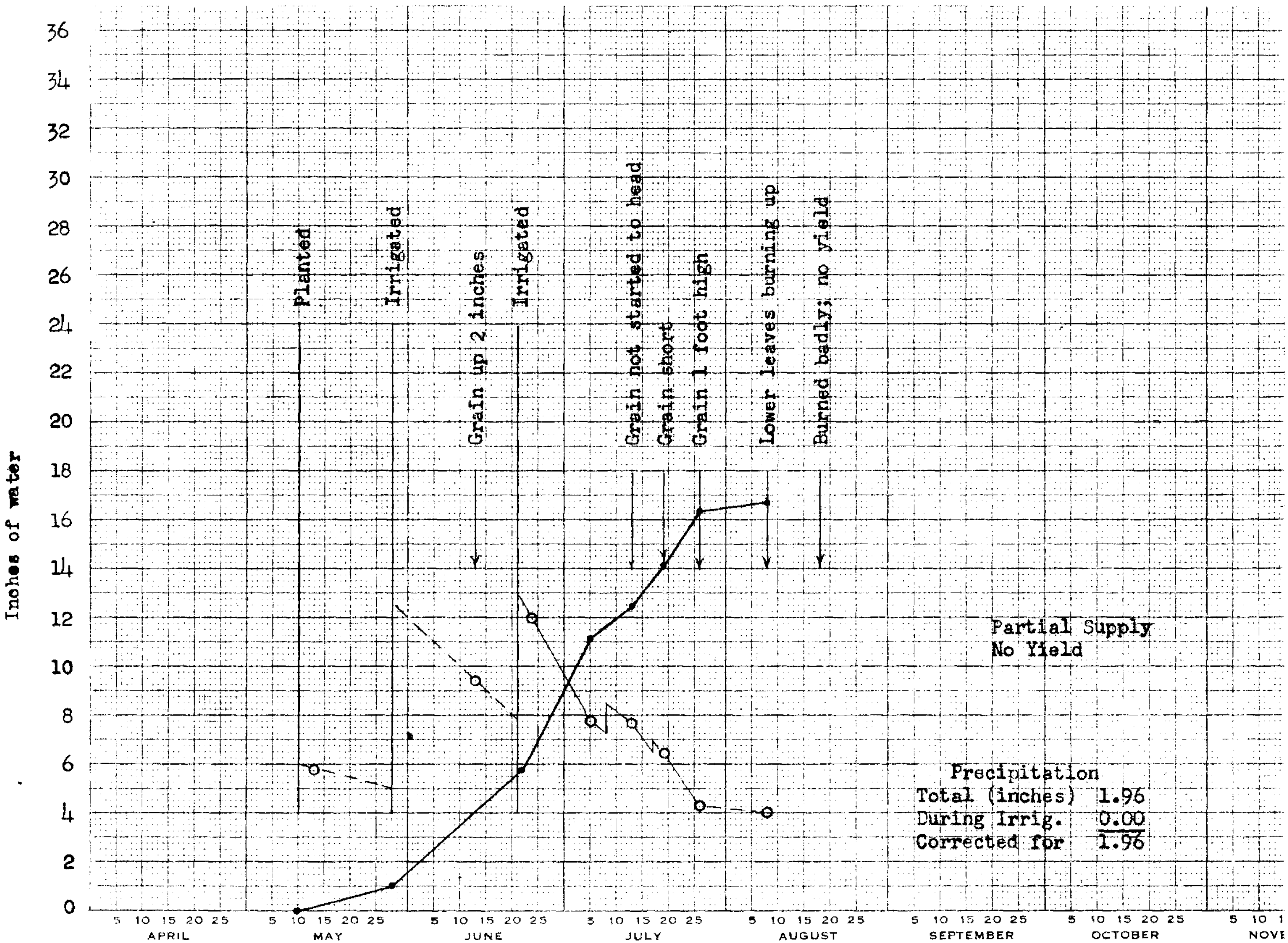


Fig. 24. Consumptive Use of Water by Oats, 1950. Area: Ferron Creek, Utah. Plot: F-O-1

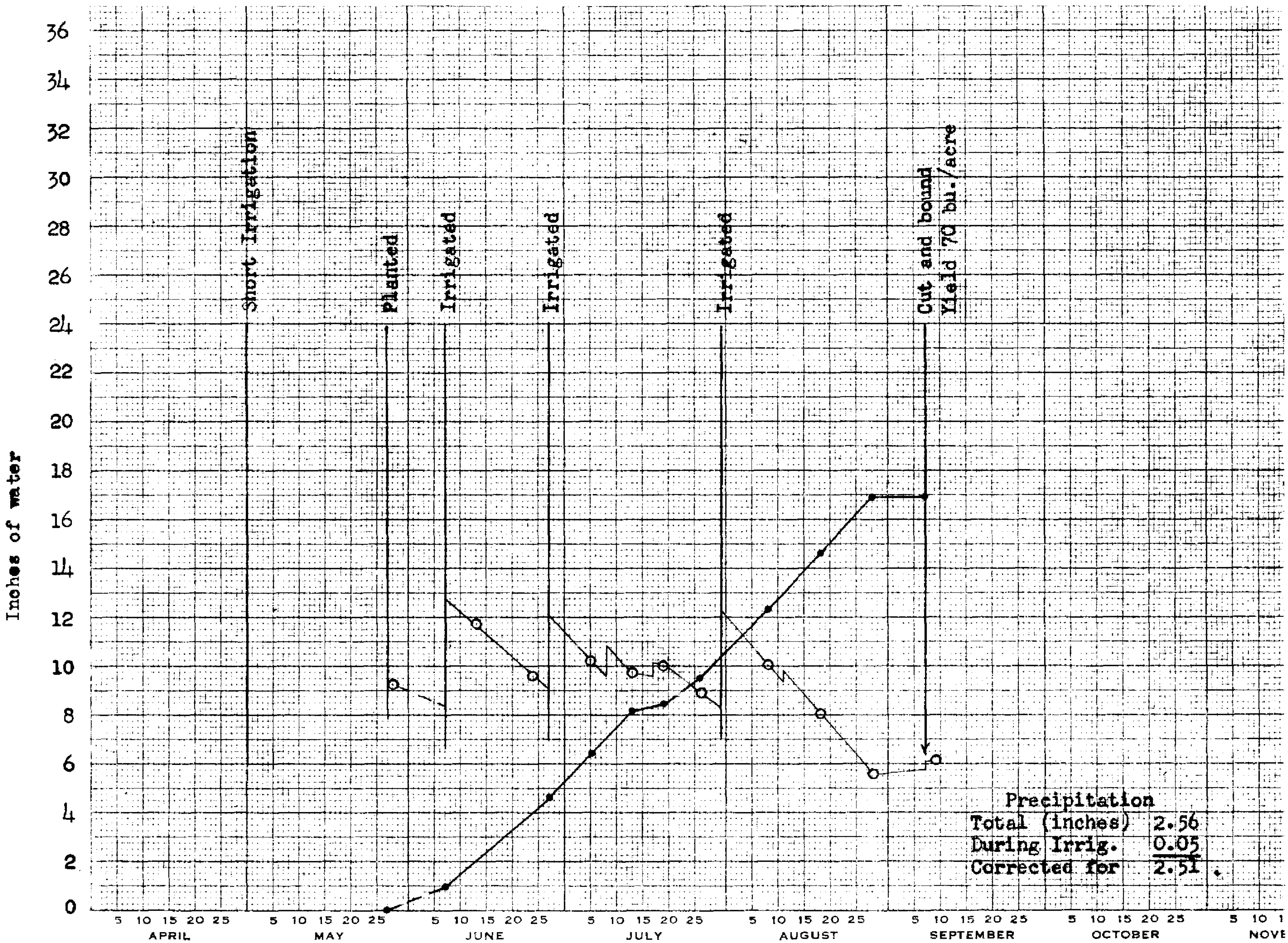


Fig. 25 . Consumptive Use of Water by Oats & Bay**.1950. Area:** Ferron Creek, Utah **. Plot:** F-Op-2

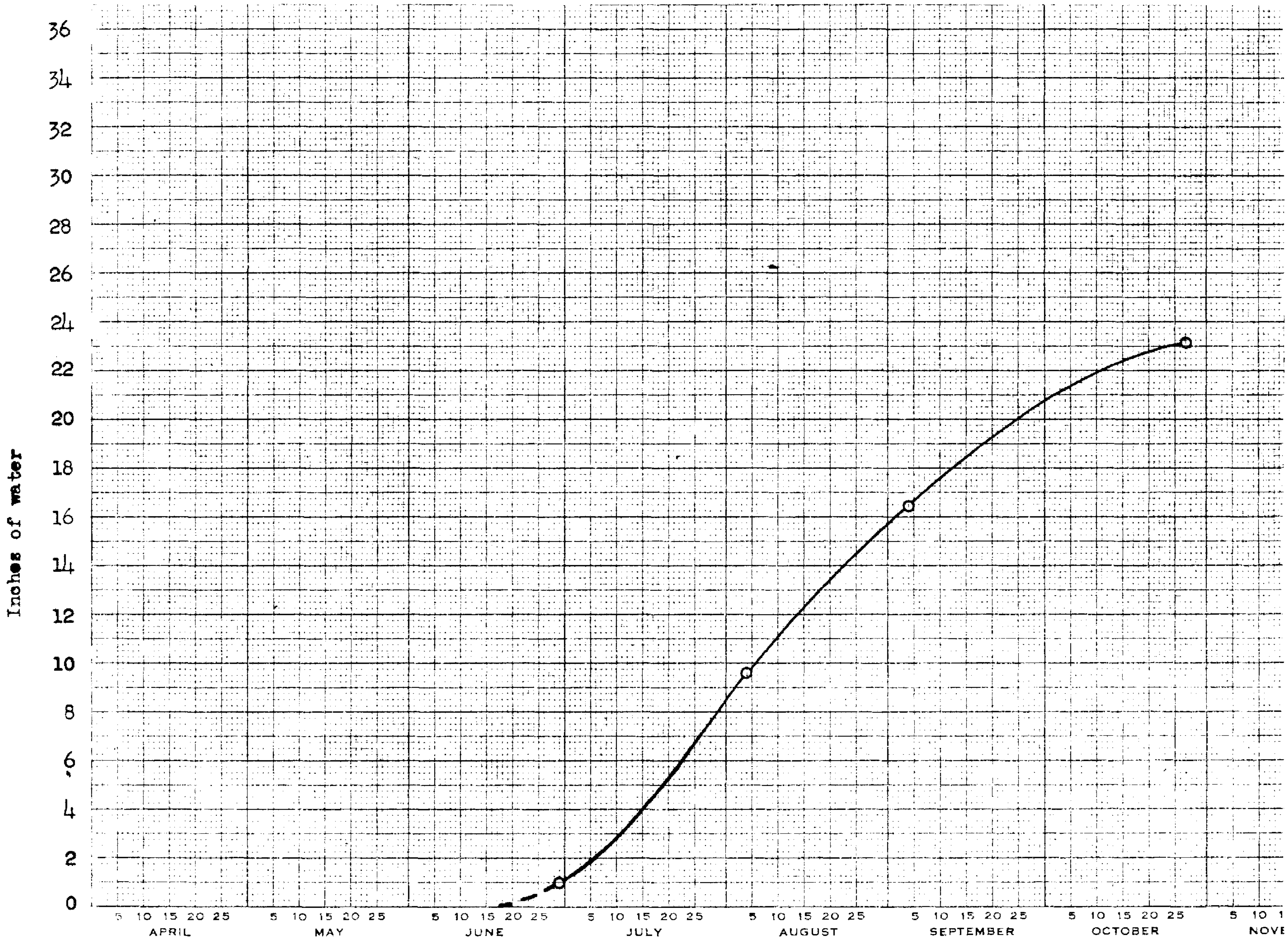


Fig. 26 . Consumptive Use of Water by Oats , 1950. Area: Ashley Valley, Utah. Plot: Tank No. 1

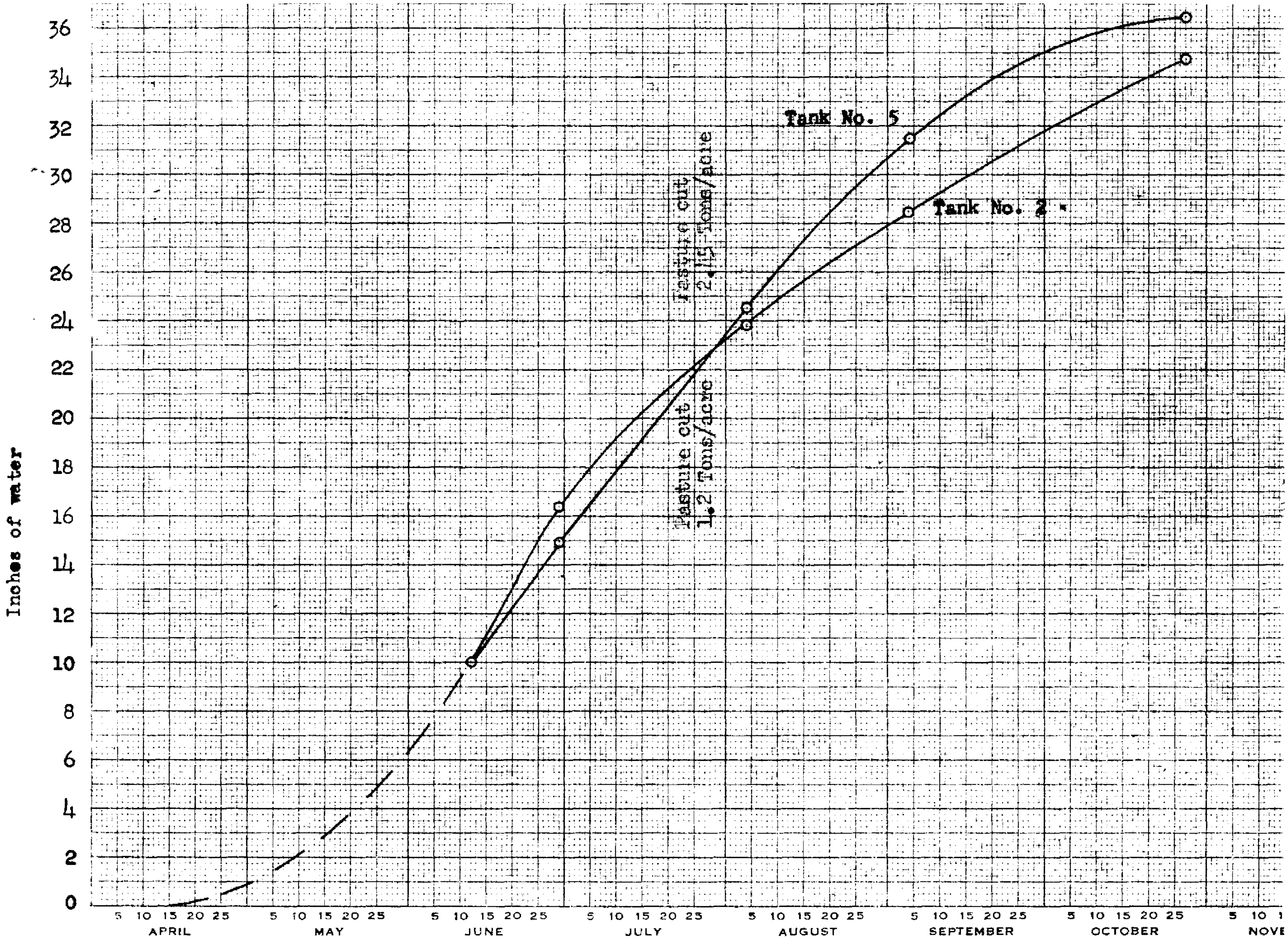


Fig. 27 . Consumptive Use of Water by Pasture , 1950. Area: Ashley Valley, Utah. Plot: Tanks No. 2 & 5

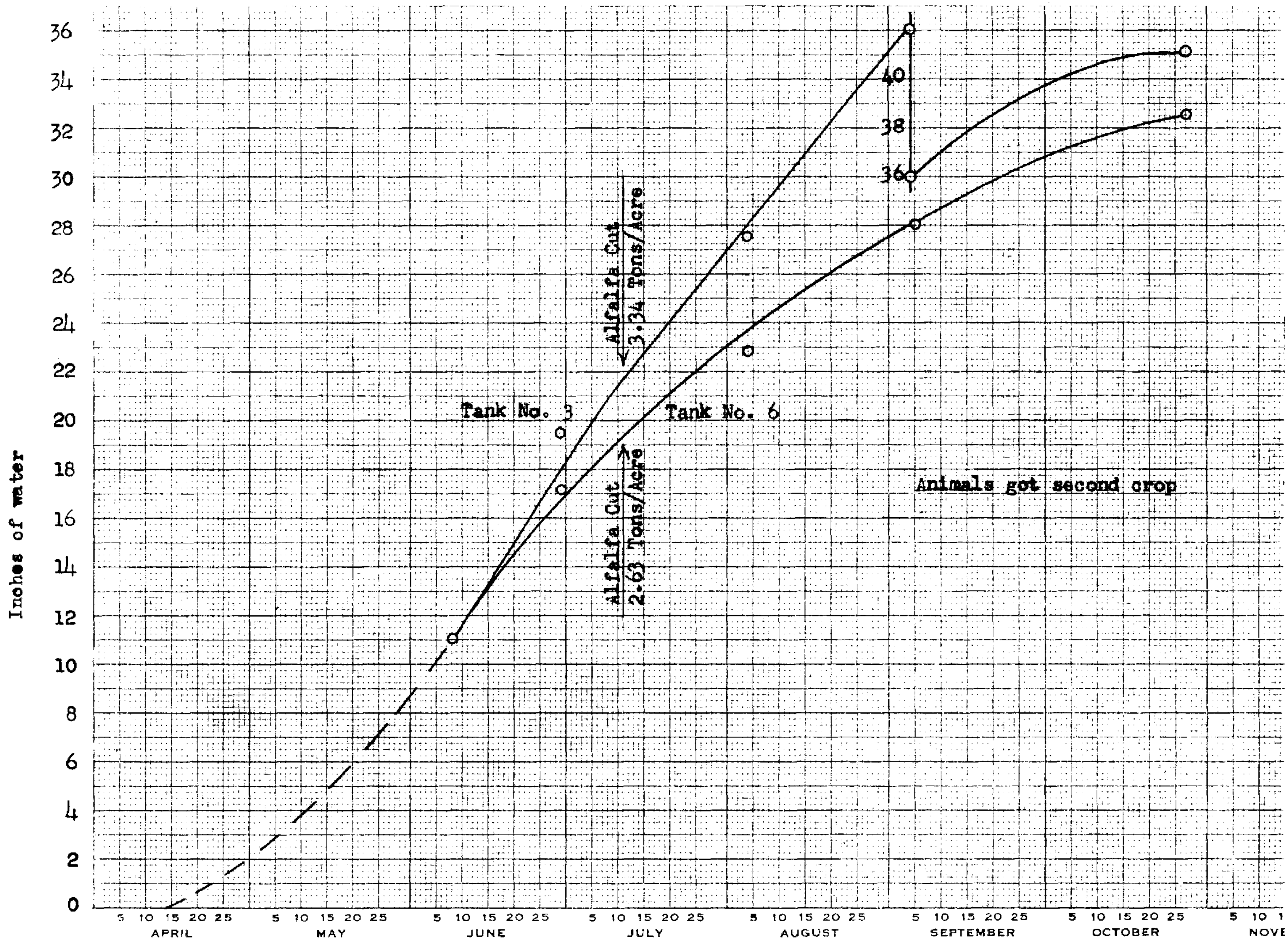


Fig. 28 . Consumptive Use of Water by Alfalfa , 1950. Area: Ashley Valley, Utah. Plot: Tanks No. 3 & 6

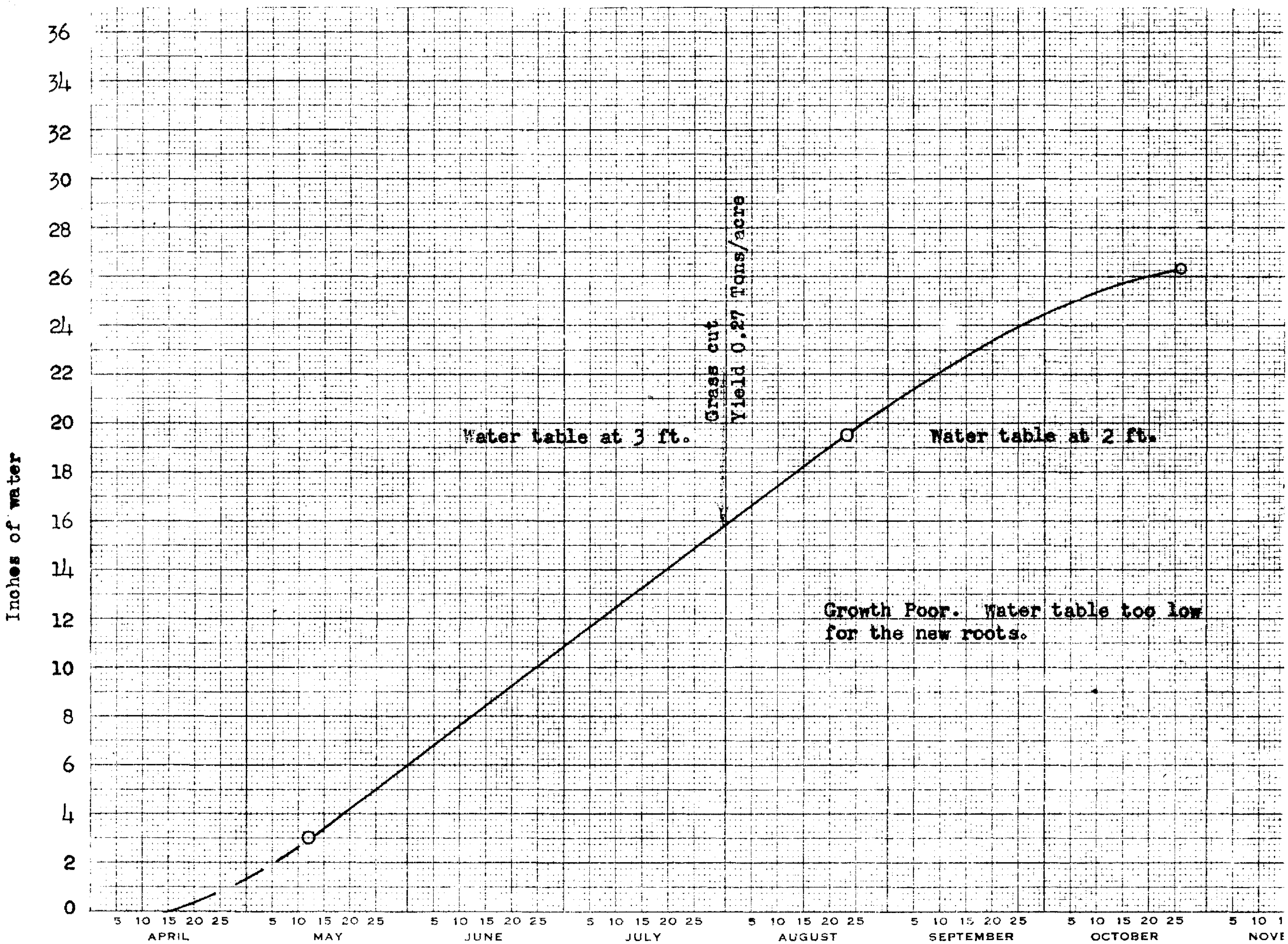


Fig. 29 . Consumptive Use of Water by Pasture , 1950. Area: Ashley Valley, Utah. Plot: Tank No. 7
(native wild)

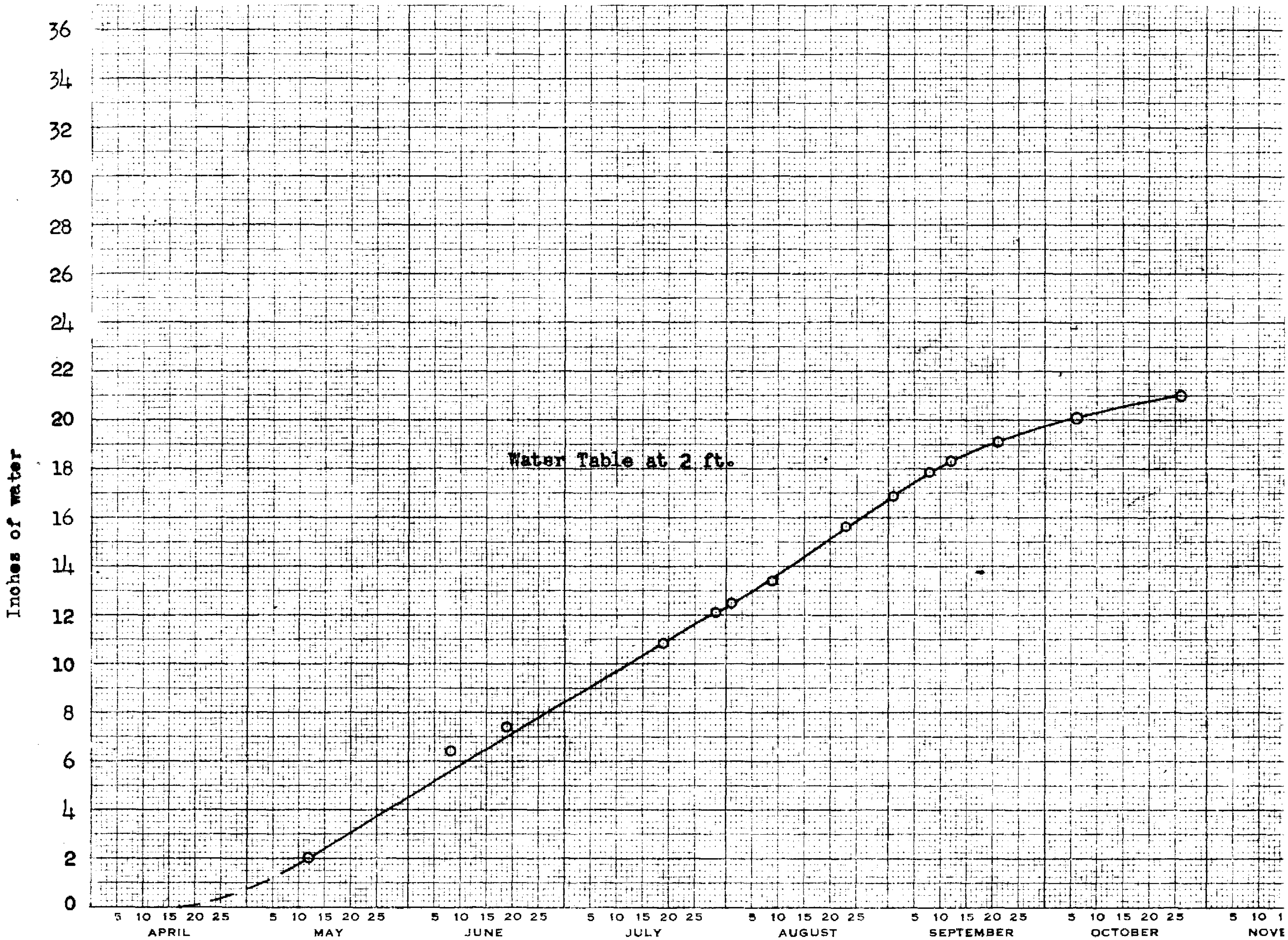


Fig. 30 . Consumptive Use of Water by Pasture , 1950. Area: Ashley Valley, Utah. Plot: Tank No. 8
(Salt grass)

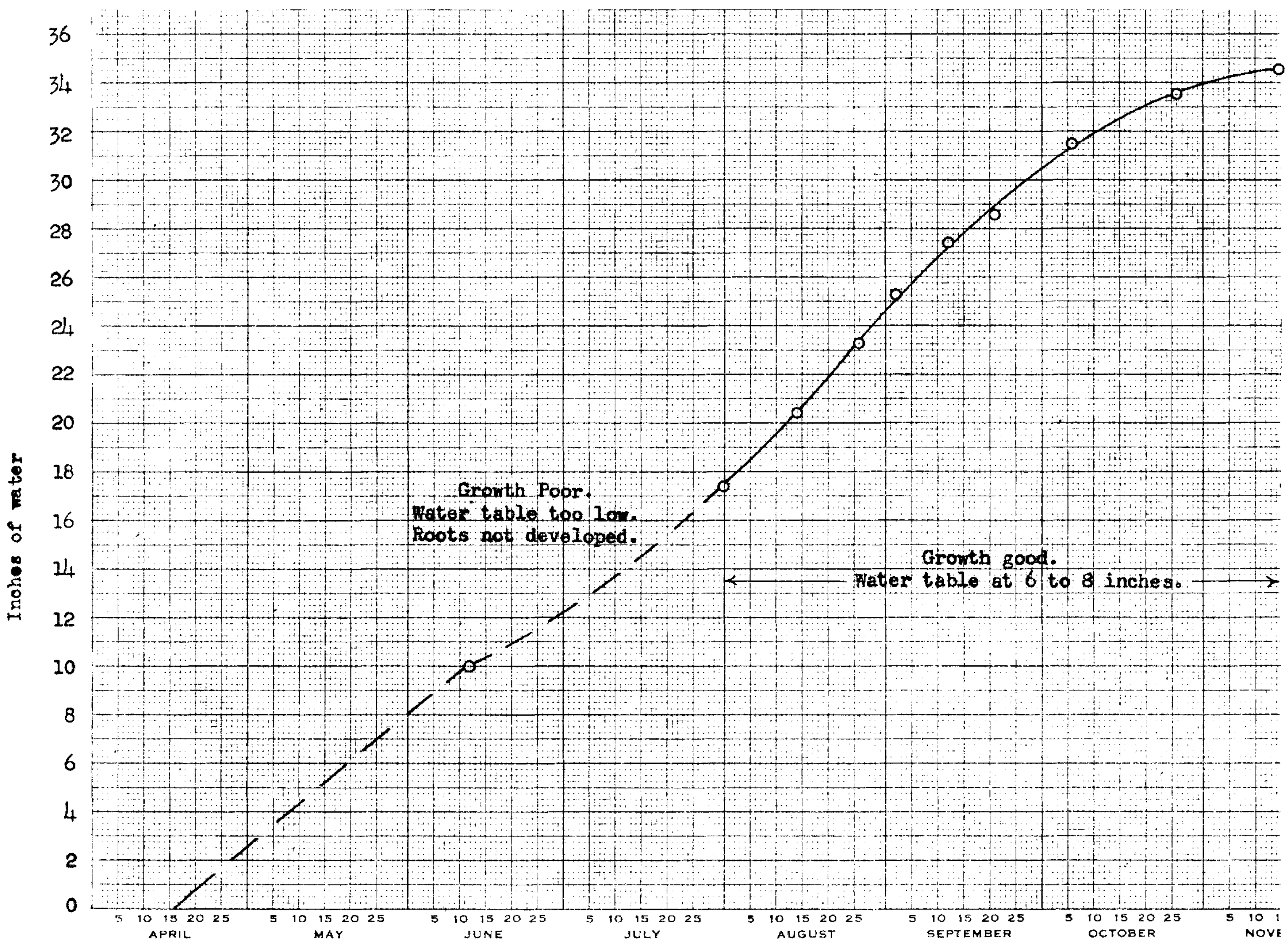


Fig. 31. Consumptive Use of Water by Pasture, 1950. Area: Ashley Valley, Utah. Plot: Tank No. 9
(Wire grass)

Table 14. Summary of climatological data in Ashley valley, Utah, 1950.

Half month ending	Precipitation in inches	Evaporation in inches	Average temperature, °F	Wind in miles	Humidity Max.	Humidity Min.
April 15	1.23	2.70	44.7	1,169		
April 30	0.17	3.52	46.8	1,192	100	43
May 15	0.65	2.43	44.6	906	100	55
May 31	0.01	3.95	54.3	1,060	100	44
June 15	0	4.24	56.5	1,073	100	46
June 30	0	4.38	63.8	680	100	47
July 15	0.50	3.82	66.7	351	100	57
July 31	0.13	3.06	63.3	296	100	49
August 15	0.05	3.00	63.8	222	100	45
August 31	0.03	3.40	65.2	222	100	42
September 15	0.19	2.29	61.8	118	100	51
September 30	0.53	2.31	54.6	107	99	53
October 15	0	1.76	51.5	104	100	40
October 31	0.02	1.99	50.8	275	100	43
November 15	0.02	--	34.2	535	100	54
Total	3.53	42.85		8,310		

Table 15. Summary of climatological data in Ferron valley, Utah, 1950.

Half month ending	Precipitation in inches	Evaporation in inches	Average temperature, °F	Wind in miles	Humidity Max.	Humidity Min.
April 15	0	2.92	46.5	--	93	37
April 30	0	3.32	50.5	--	82	37
May 15	0.23	2.57	47.8	1,102	85	41
May 31	0	3.83	59.3	1,038	80	36
June 15	0	5.41	62.8	844	70	39
June 30	0	4.96	69.7	598	70	43
July 15	1.52	3.27	70.4	208	89	56
July 31	0.44	3.87	68.5	364	86	41
August 15	0.29	3.78	67.4	374	78	41
August 31	0	4.57	71.6	--	64	32
September 15	0.88	3.51	66.1	386	89	44
September 30	0.88	2.53	56.2	548	92	42
October 15	0	2.75	55.7	573	84	35
October 31	0	2.55	55.0	582	81	42
November 15	0	--	38.4	--	90	51
Total	4.24	49.84		6,617		

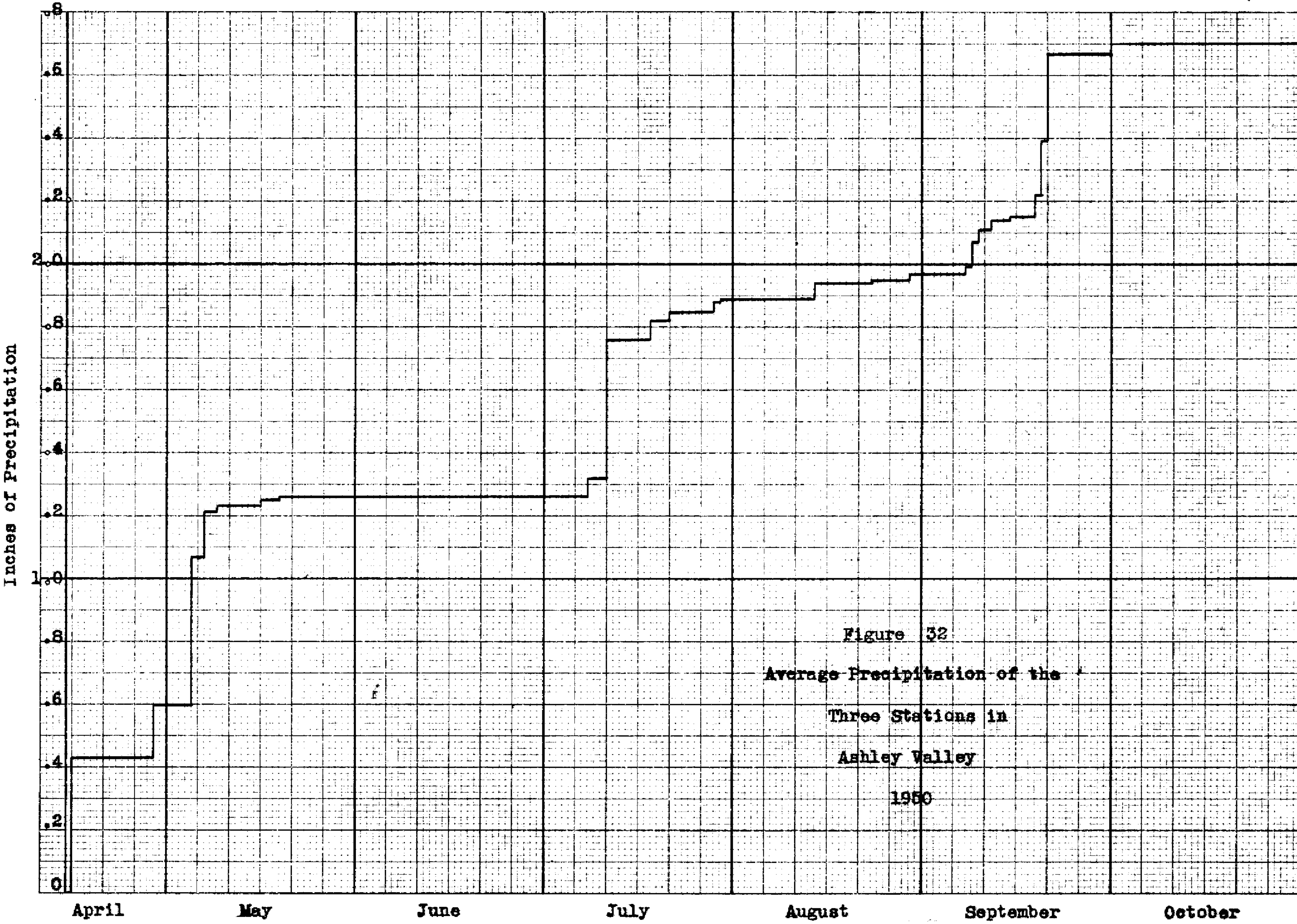


Figure 32

Average Precipitation of the

Three Stations in

Ashley Valley

1950

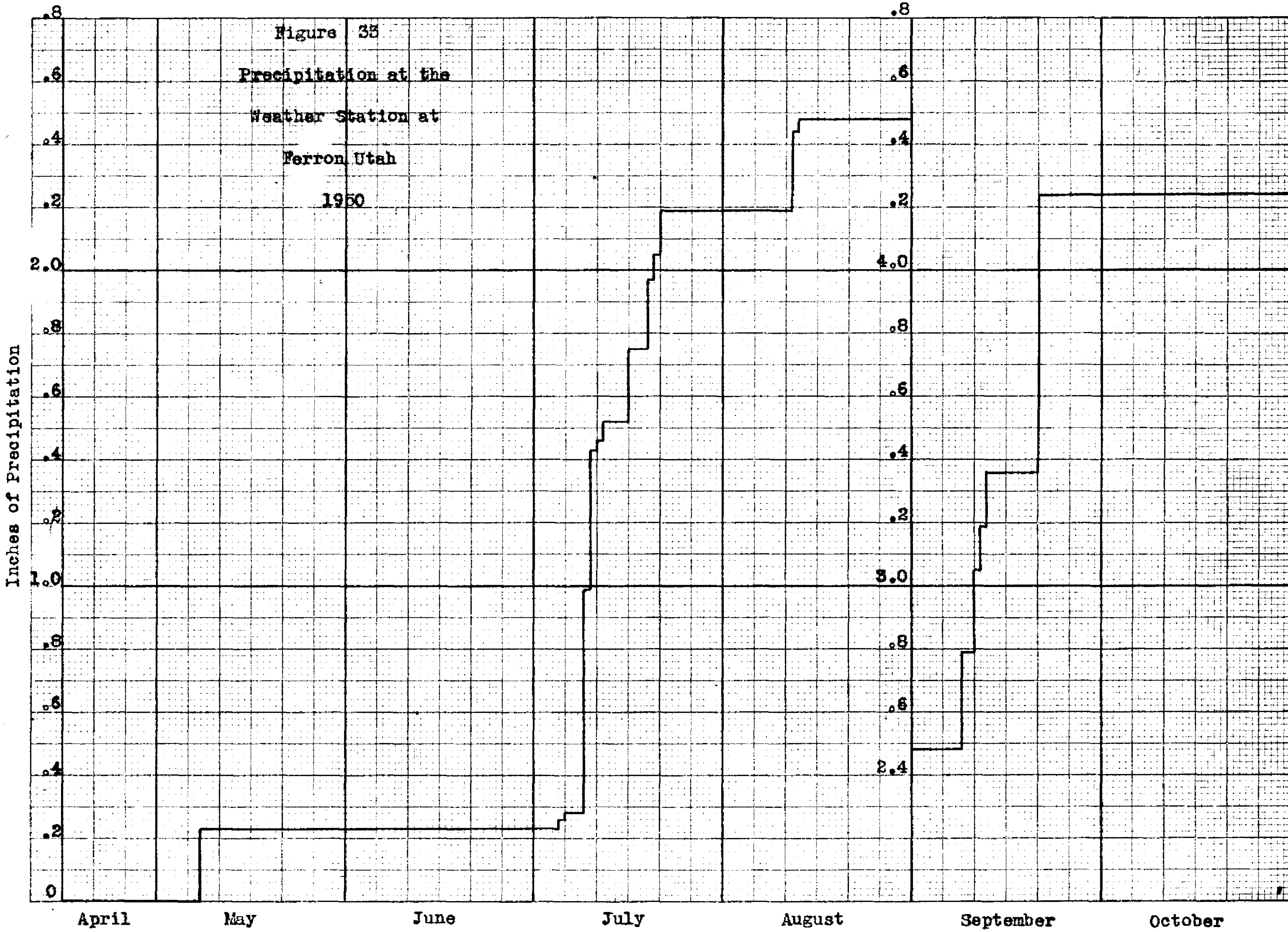


Figure 33
Precipitation at the
Weather Station at
Ferron Utah
1950
Inches of Precipitation
.8
.6
.4
.2
2.0
.8
.6
.4
.2
1.0
.8
.6
.4
.2
0
.8
.6
.4
.2
4.0
.8
.6
.4
.2
3.0
.8
.6
2.4
April
May
June
July
August
September
October

Table 16. Sample field notes.

Field Data, Computations, and Corrections of Moisture Content

Date: May 11, 19[illegible] Farm: [illegible]

Area: [illegible] Crop: Alfalfa

Tube Number: [illegible] Tube Constant, C, $\frac{1}{2D^2}$: .127

Depth of Sample	0–1	1–2	2–3	3–4	4–5	5–6	6–7	7–8	Total
(1) Can Number	[illegible]	[illegible]	12	[illegible]	[illegible]	[illegible]	[illegible]		
(2) Wt. Wet Soil + Can	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
(3) Wt. Dry Soil + Can	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
(4) Wt. of Moisture (2)-(3)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
(5) In. of Water (4) x C	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
(6) Wt. Dry Soil + Can	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		452.7
(7) Weight of Can	44.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
(8) Dry Wt. of Soil (6)-(7)	127.8	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
(9) Average Dry Wt. of Core	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]
(10) Corrected Inches of Water (9)/(8) x (5)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		[illegible]

Field Notes: (Irrigations, moisture conditions, changes in sampling procedure, loss of core, etc.)

Loss of cores 4, [illegible], 7.
Sandy layer down about a foot.
Core [illegible] out around tube.
Alfalfa about 6" high; growing well.
A few indications of frost [illegible].
No irrigations yet this year.

Table 17. Sample "Correction of Data" sheet for determining the average dry weight of core.

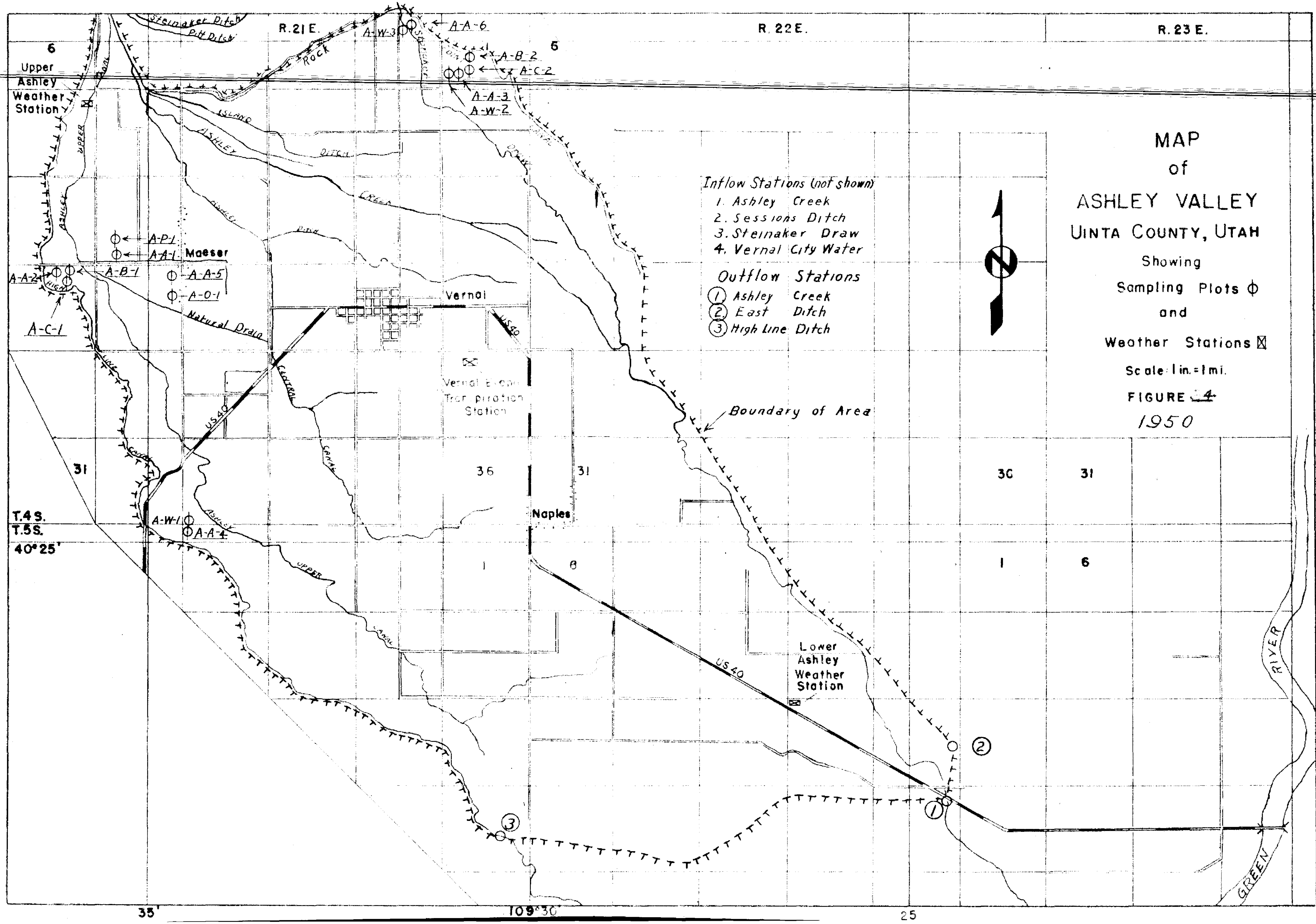
CORRECTION OF DATA

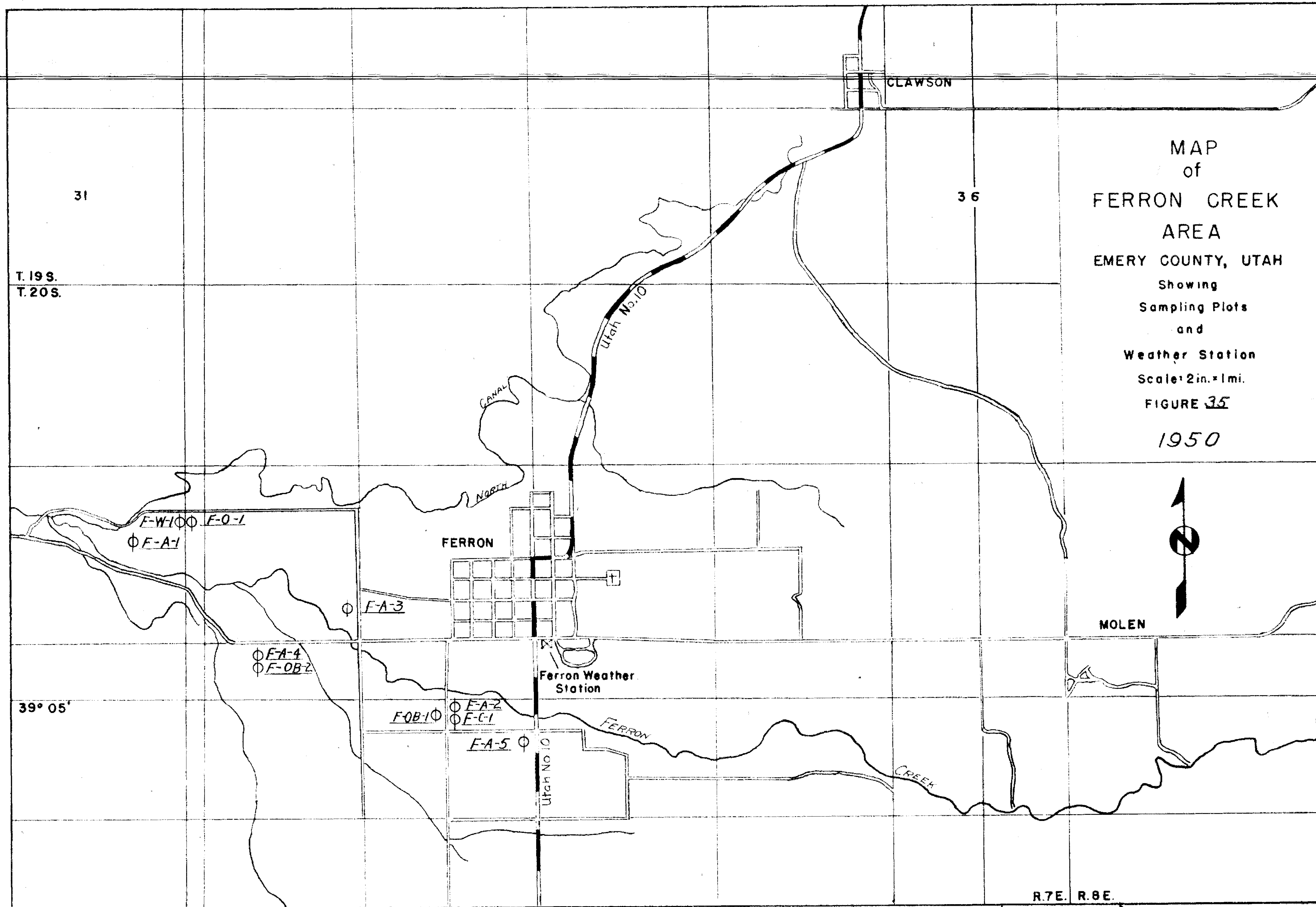
Date: October [illegible] Farm: [illegible]

Area: [illegible] Crop: [illegible]

Converted to tube No.: [illegible] Map Symbol: A-A-1

Date Sampled	Tube No. Used	CONVERTED DRY WEIGHT OF CORE								Obser-vations
		0-1	1-2	2-3	3-4	4-5	5-6	6-7	Total	
April [illegible]	[illegible]A	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
May 11	5	[illegible]	117.5	[illegible]	[illegible]	[illegible]	121.4	[illegible]	[illegible]	Poor
" 27	5	1[illegible]2.5	[illegible]	117.5	[illegible]	[illegible]	[illegible]	1[illegible]7.4	[illegible]	Good
June [illegible]	5	[illegible]	1[illegible]1.5	1[illegible]1.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" 1[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]9	5	[illegible]	116.7	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
July 7	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Good
" 15	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	129.1	[illegible]	Good
" [illegible]7	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	144.4	[illegible]	[illegible]	Good
Aug. 5	5	[illegible]	117.4	[illegible]	[illegible]	[illegible]	142.1	[illegible]	[illegible]	Good
" 1[illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Fair [illegible]
Sept. 1	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" 11	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
" [illegible]1	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Good
Oct. [illegible]	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	Good
TOTAL		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]		
Average	5	[illegible]	[illegible]	1[illegible]2.4	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
Average	[illegible]A	[illegible]	[illegible]	113.3	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	


MAP
of
ASHLEY VALLEY
UINTA COUNTY, UTAH
Showing
Sampling Plots ϕ
and
Weather Stations ⊠
Scale: 1 in. = 1 mi.
FIGURE 4
1950
Inflow Stations (not shown)
1. Ashley Creek
2. Sessions Ditch
3. Steinaker Draw
4. Vernal City Water
Outflow Stations
(1) Ashley Creek
(2) East Ditch
(3) High Line Ditch
R. 21 E.
R. 22 E.
R. 23 E.
T. 4 S.
T. 5 S.
40°25'
35'
109°30'
25
Upper Ashley Weather Station
Lower Ashley Weather Station
Vernal Evapo Transpiration Station
Vernal
Maeser
Naples
Boundary of Area
Steinaker Ditch
Pitt Ditch
Rock
Island Ditch
Ashley Creek
Natural Drain
Central Canal
Upper Canal
High Line Canal
US 40
Green River
A-A-6
A-W-3
A-B-2
A-C-2
A-A-3
A-W-2
A-P-1
A-A-1
A-B-1
A-A-5
A-O-1
A-A-2
A-C-1
A-W-1
A-A-4
6
31
36
1
30


MAP
of
FERRON CREEK
AREA
EMERY COUNTY, UTAH
Showing
Sampling Plots
and
Weather Station
Scale: 2 in. = 1 mi.
FIGURE 35
1950
CLAWSON
31
36
T. 19 S.
T. 20 S.
Utah No. 10
CANAL
NORTH
FERRON
F-W-1
F-O-1
F-A-1
F-A-3
F-A-4
F-OB-2
Ferron Weather Station
39° 05'
F-OB-1
F-A-2
F-C-1
F-A-5
FERRON
CREEK
MOLEN
R.7E. R.8E.
111° 10'
111° 05'