IRRIGATION SCHEDULING
Using
REAL TIME SOIL MOISTURE MEASUREMENTS

A report on methods and procedures used by the Bureau of Reclamation's Lower Colorado Region to provide field irrigation scheduling during the time period from about 1975 to about 1990

December 2003

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Preface

The Bureau of Reclamation's Lower Colorado Region (LC Region) was a pioneer in developing the neutron moisture gauge and associated procedures for scheduling irrigations. This report describes the procedures developed initially by Dr. Melvin Campbell. Some of the techniques have since been refined through years of daily use of the gauge for production irrigation scheduling by Reclamation, district, Bureau of Indian Affairs, and Tribal staff. Individuals most closely involved with development efforts have since transferred from the Lower Colorado Region or have retired. Therefore, resources of Reclamation's Upper Colorado Region, headquartered in Salt Lake City, Utah, have been used to prepare and produce this report. Three individuals closely associated with development and use of the neutron moisture gauge have contributed to the preparation of this report. They are: Stan Conway, Land Suitability and Water Quality Group, Technical Service Center, Denver, Colorado; Michael Stuver, Regional Water Management Coordinator, Upper Colorado Region, Salt Lake City, Utah; and Terry Taylor, Soil Scientist, Retired, Dillingham, Alaska. The report was compiled by Michael Stuver with material and editing provided by Stan Conway and Terry Taylor. Completion of this report has been on a time-available basis and has required several years to finish.

About This Report

This report describes how Reclamation provided field irrigation scheduling services in its Lower Colorado Region during the time period from about 1975 to about 1990. It may be helpful to organizations desiring to provide a field irrigation scheduling service. Chapter 1 gives some general background information. Chapter 2 discusses the theory and procedure used to schedule irrigations using in-place field moisture measurements. Chapter 3 describes the equipment used to conduct field irrigation scheduling programs in the LC Region. Chapter 4 discusses what is needed and describes how to begin a field irrigation scheduling service. Finally, Chapter 5 describes the day-to-day activities involved in providing a field irrigation scheduling service.

TABLE OF CONTENTS

1 - INTRODUCTION 1

2 - THEORY OF SCHEDULING IRRIGATIONS USING MOISTURE GAUGES 4
How Irrigation Scheduling Works 4
How Plant Stress is Determined 6

3 - REQUIRED EQUIPMENT 13
The Neutron Measuring Gauge 13
Description of Gauge 13
Use of Gauge 15
Standardization Barrels 18
Infrared Thermometer 19
Description of Thermometer 19
Use of Thermometer 20
Soil Auger 21
Access Tubes 21
Access Tube Driver 23

4 - GETTING STARTED 24
Starting a New Field Irrigation Scheduling Service 24
Calibrating Gauge 25
Standardizing the Neutron Moisture Gauge 26
Establishing Well-Watered Baseline 30

5 - SCHEDULING IRRIGATIONS 31
Starting Irrigation Service to a New Field 31
Locating Access Tube Site 31
Accessibility 31
Irrigation Method 31
Soil Types 31
Crop Stand 31
Installing Access Tubes 32
Determining Refill Point 32
Using Optimum Moisture Content 32
Using Crop Water Stress Index (CWSI) 33
Using Observation of Visible Stress 33
Using Farmer's Judgement 33
Establishing Full Point 34
Visiting Fields 35
Contacting Farmers 39

LIST OF TABLES

Number	Title	Page
1	Terms and Definitions	10
2	Well-Watered Base Line Coefficients for Selected Crops	12

LIST OF FIGURES

Number	Title	Page
1	Graphical Scheduling with Neutron Probe Measurements	5
2	CWSI vs. Date for Wheat	7
3	Typical Vapor Pressure Deficit vs Temperature Depression Graph	9
4	Foliage-Air Temperature vs. Vapor Pressure Deficit for Well-Watered Alfalfa	11
5	CPN Model 503 Moisture Gauge	14
6	Taking Moisture Readings With the 503	15
7	Probe Rating Table - Uniform Count Increment	16
8	Probe Rating Table - Uniform Water Content Increment	17
9	Gauge on Standardization Barrel	19
10	Infrared Thermometer	19
11	Measuring Turf Canopy Temperature with the Infrared Thermometer	20
12	Sample Plant Foliage Temperature Data	22
13	Access Tube Cap Assembly	23
14	Installing a Steel Access Tube Using the Access Tube Driver	23
15	Soil Moisture in Inches per Foot vs. Count Ratio of the Neutron Moisture Gauge	27
16	Neutron Probe Standard Count Determination	29
17	Sample Printout from Program VEGY	34
18	Data for CWSI Hand Calculation Example	35
19	Hand Calculating Crop Water Stress Index	36
20	Sample Field Graph	38
21	Sample Farmer Report Form	40
22	Sample Computer Generated Farm Irrigation Schedule	41

APPENDIX

A Relative Humidity, Percent - Centigrade Temperatures
B Vapor Pressure of Water Below 100 °C
C Equipment Drawings and Specifications
D Blank Field Data sheets
E Using Program VEGY

FIELD IRRIGATION SCHEDULING

1 - INTRODUCTION

The efficient use of water is necessary in many areas to meet existing needs. In some areas, extensive use of water for irrigation and the increasing need for municipal and industrial water is depleting available supplies. In other areas there is an abundance of water. Yet, the high cost of fertilizers and farm labor or the need to improve crop yields and quality are causing the farmer to look for ways to improve on-farm irrigation efficiency.

The Bureau of Reclamation began its involvement with on-farm field irrigation scheduling when it began its Irrigation Management Service (IMS) in the early 1970's. IMS provided a staff of one or two specialists on-site to help local irrigation districts establish an IMS. The local irrigation district also provided one or more employees. Reclamation intended to withdraw its IMS staff when the district's staff was fully trained and capable of continuing the IMS on its own.

Reclamation's Lower Colorado Region (LC Region) had been involved in the IMS program from the early 1970's to the early 1990's. The LC Region continued to provide technical support for several years after it discontinued active participation in local IMS programs. This report describes the process of scheduling irrigations using field moisture measurements that was adopted by the LC Region. The standard device for taking these measurements was the neutron moisture gauge.

This report is based upon the LC Region's efforts to provide field irrigation scheduling services. It is intended to be used by Federal and State agencies, irrigation districts, or private consultants that are supporting or providing an irrigation scheduling service. It may also be helpful to private farmers who purchase their own gauges and provide their own scheduling service. The report discusses procedures for starting a new service. Also, it describes the necessary equipment and how to use the equipment. Finally, it describes the process for conducting field activities and communicating findings to the farmer.

Improved on-farm efficiencies may require changes in present irrigation and water delivery practices. The irrigator may need better information to help him know when to irrigate a particular crop. Proper scheduling depends upon how much water is available to the plant. It also depends upon how fast that plant or crop is using water. The farmer must also know how much water to apply. This depends upon the amount of water used by the crop, the distribution uniformity (irrigation efficiency) of the irrigation system, the water holding capacity of the soil, and salt leaching requirements.

By using careful management and sound irrigation scheduling practices, the farmer can realize the direct savings in water, fertilizer, pesticide, herbicide, and farm labor. In addition, many farms have seen increases in quality and quantity of their yields.

Although irrigation scheduling helps the farmer, irrigation districts usually provide the scheduling service. Reclamation has, on occasion, also helped provide the service. In a few instances, private consultants provide the service for a fee. Some large farms buy their own equipment and provide their own service. Unless a farm is large, however, most farmers cannot justify the cost of the equipment. In the LC Region, Reclamation partnered with local irrigation districts and a Native American Tribe to provide the services.

Services provided by an irrigation district are usually more economical than similar services provided by a farmer. When a district provides the service, it spreads the cost of equipment among many individuals and can better control the quality and accuracy of the scheduling. Also, a district can better assess the success of its water management activities when the field irrigation scheduling service is a part of its water management program.

Districts have met the cost of the service in several ways. Some included the field irrigation scheduling costs with other operating costs that are covered with a variety of taxes and assessments. Other districts provided the service for a fee. Farmers paid a fee based upon the number of acres or fields enrolled in the service. A fully equipped district technician could easily serve several farms. Typically, a technician served about 5,000 acres when 40-acre fields were the norm.

The LC Region started its Water Management and Conservation (WMC) program in 1973. (In 1996, the WMC Program became officially known as the Water Conservation Field Services Program (WCFSP) with little or no emphasis on providing field irrigation scheduling with the neutron moisture gauge.) This was about the same time the program was being introduced in other areas of the western United States. The program was originally known as the Irrigation Management Service (IMS) and initially provided field irrigation scheduling service to participating project water users.

The IMS used a computer model to schedule irrigations. The model utilized used weather data to compute crop water use and a soil water budget to determine timing and amount of water to apply. The IMS computer programs were developed by Reclamation's Technical Services Center (formerly known as the Engineering and Research Center) staff for use on Reclamation's CYBER computer system. Participating projects accessed the CYBER with computer terminals and dedicated telephone lines. Eventually, the IMS service was expanded to provide a gravity distribution scheduling program. As Reclamation's IMS program expanded and contemplated providing additional services, the program was renamed the Water Management and Conservation Program.

The IMS Program was introduced simultaneously to three irrigation projects in the LC Region. These were:

(1) Wellton-Mohawk Irrigation District, near Wellton, Arizona;
(2) Palo Verde Irrigation District, near Blythe, California; and
(3) Colorado River Indian Irrigation Project, at Poston (near Parker),

Arizona.

All three IMS programs began using the IMS computer programs with varying degrees of success. Three major problems became obvious. First, terminal connections with the CYBER computer in Denver were unreliable. Second, the computer model would not duplicate observed field conditions to an acceptable level of accuracy. Finally, farmers lacked confidence in the IMS schedules. Farmers' lack of confidence caused some sponsoring districts to consider dropping the programs.

To improve reliability and acceptability of the IMS programs, Reclamation specialists in the LC Region worked with a company that manufactured neutron moisture/density gauges for the construction industry. Together, they developed a neutron moisture gauge suitable for measuring agricultural soil moisture content. Prototype models were developed, tested in the field, and refined until models suitable for production field scheduling were available. Procedures were then developed and implemented for scheduling irrigations with the newly developed neutron moisture gauge (often called the neutron probe). Eventually, use of the IMS programs on the CYBER computer was discontinued by the LC Region in favor of the more precise method of scheduling irrigations with the neutron moisture gauge.

The procedures and techniques described here have been used successfully by several irrigation districts for over 25 years. Improvements and refinements have evolved during these years. Several types of non-nuclear moisture sensing devices are being developed and tested. Some of these devices may eventually replace the neutron moisture gauge. However, this report does not address these latest developments.

2 - THEORY OF SCHEDULING IRRIGATIONS USING MOISTURE GAUGES

How Irrigation Scheduling Works

The neutron moisture gauge, commonly called a "neutron probe," is a practical tool for making rapid and accurate measurements of soil moisture. This real time measurement of soil moisture makes possible quick and accurate determinations of the projected irrigation dates and the amounts of water to apply and eliminates the need for extensive computations required to determine crop water use. This field irrigation scheduling process assumes the plant will use as much water from the soil as possible without impairing crop production and causing water stress. When the soil moisture content (SMC) reaches a predetermined minimum allowable moisture content, the crop should be irrigated. The irrigation scheduling procedures described below refer to the neutron moisture gauge but are equally applicable to any soil moisture sensing device that can be calibrated to indicate soil moisture content.

Gauge readings should be taken biweekly during the summer and weekly during the winter if crops are grown throughout the year. This provides sufficient information to determine the rate of moisture depletion in the soil. The readings can be plotted on a field graph. The amount of water required to refill the soil profile to field capacity can be accurately determined. The next irrigation date can be predicted as much as a week in advance. If a computer is available, it can use the gauge readings and compute the next irrigation date automatically. (The IMS staff at Parker, AZ developed an IBM-compatible computer software package for MS-DOS that makes these computations and print the reports.)

In graphical irrigation scheduling, the SMC is measured with a neutron moisture gauge and the measurements are plotted on a graph. The x-axis on the graph represents the dates readings are taken. The y-axis represents the SMC in each foot of soil in the profile where a reading is taken. Readings are usually taken from the first-foot, second-foot, and third-foot increments of the soil profile. In some deep-rooted, permanent crops, readings may be taken as deep as 5 feet. The readings taken from the first or top foot of the profile are used to determine the next irrigation date. Combined readings from the entire profile are used to determine plant water consumption and the amount of water needed to replenish the root zone. The irrigation efficiency and the leaching requirement are needed to adjust the irrigation amount.

Figure 1 shows a typical graph of plotted gauge readings. The minimum allowable SMC occurring in the first foot of the profile is marked on the graph as a horizontal line. This is called the refill line or refill point. The refill line is shown as the dashed horizontal line in Figure 1.

At least two sets of gauge readings must be taken on different days to determine the next irrigation date. If evapotranspiration rates are changing rapidly, additional readings will be required. To determine the date, the first-foot SMC readings are plotted

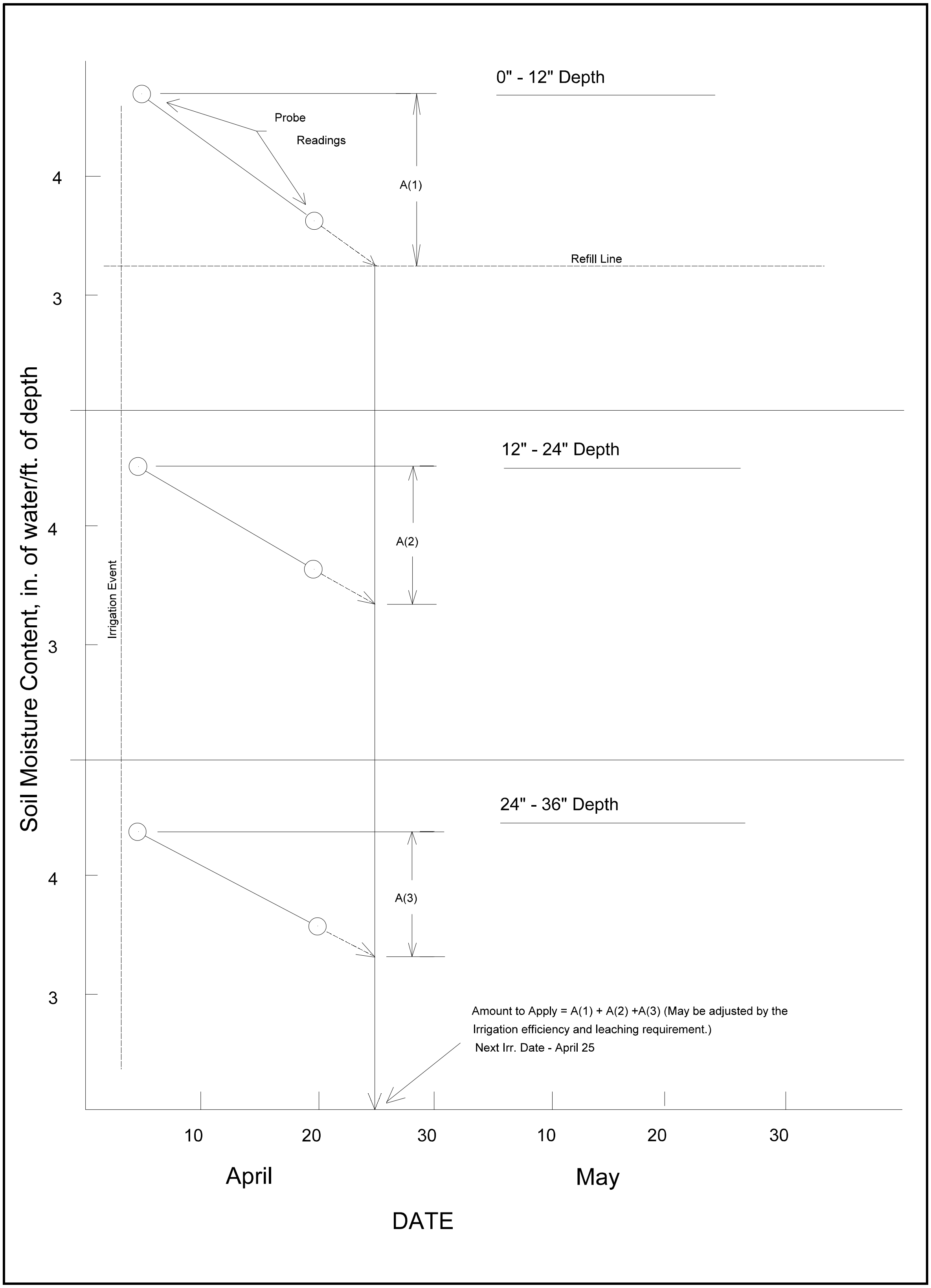


Figure 1 - Graphical Scheduling with the Neutron Probe

the graph (see the 0" - 12" Depth portion of Figure 1). A line is drawn through the two points and extended downward to the horizontal refill line. The date on which the extended line intersects the refill line is the projected date of the next irrigation. In some instances, only one reading will be available after an irrigation.

However, the one reading can still be used to predict the next irrigation date, provided two or more readings were taken before the irrigation and the evapotranspiration rate is relatively constant. A line having the same slope as the line through the prior readings can be passed through the single point and extended downward to the refill line. Again, the date on which the line intersects the refill line is the projected date of the next irrigation. This prediction will be refined with the next set of readings.

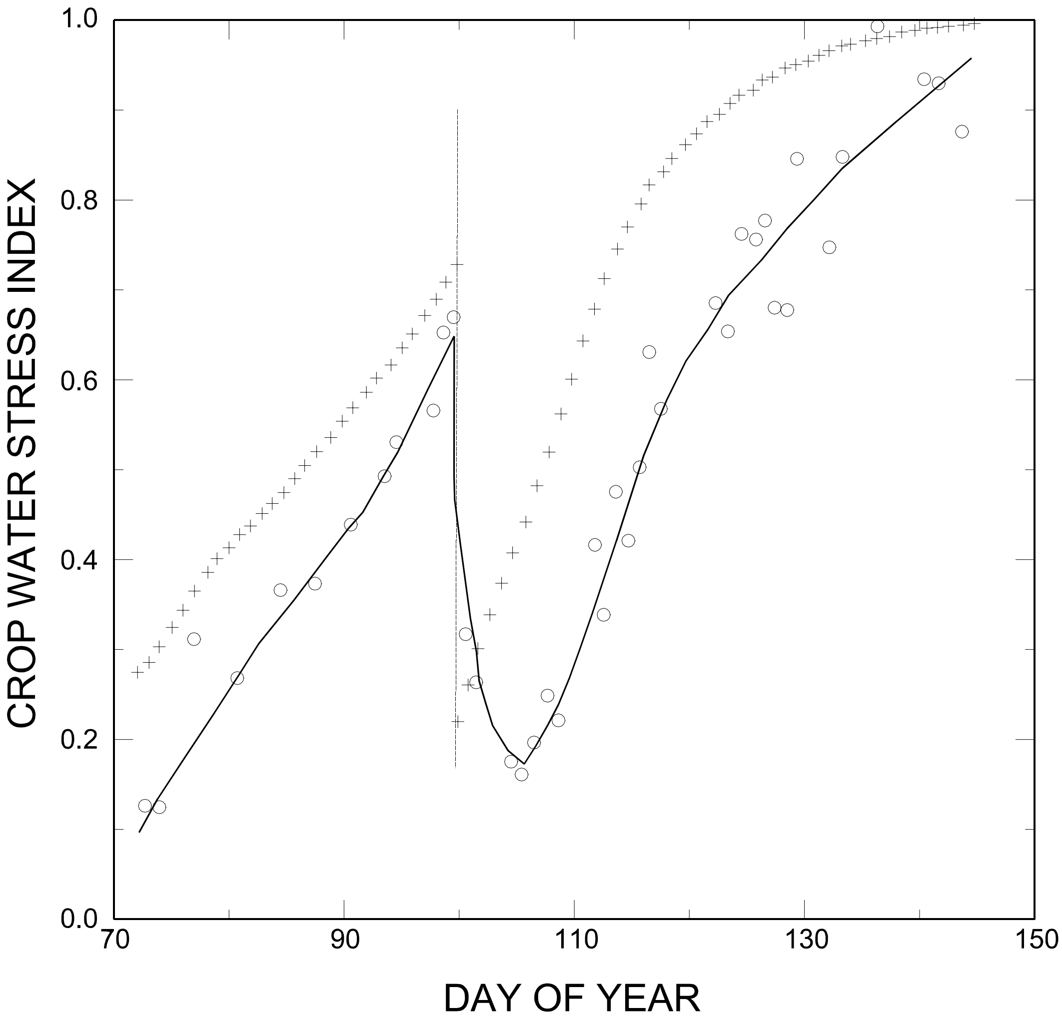
The amount of water used by the crop (includes evaporation) is the total of the depletions in each foot of the profile. These are shown as A(1), A(2), and A(3) in Figure 1. The amount to apply is the total of A(1), A(2), and A(3) divided by the irrigation efficiency.

How Plant Stress is Determined

An essential element in the scheduling process is determining the minimum allowable SMC. One method for establishing the minimum allowable SMC is to identify the point at which the plant is no longer adequately watered. A plant's temperature is directly related to its transpiration rate. Under similar atmospheric conditions, a healthy, well-watered plant will be cooler than an unhealthy plant. There will be more evaporative cooling at the leaf surface in the healthy case. It follows then that, by measuring the plant temperature and comparing it to the air temperature it is possible to tell if the plant is under stress. Stress would be due to anything that would interfere with the transpiration process: lack of soil moisture, insect infestations, and other causes. However, this discussion assumes that the cause of plant stress is due only to lack of adequate soil moisture.

Plants that have been stressed require some time to recover after an irrigation. The length of this recovery period is influenced by several factors. These include the degree of stress the plant has undergone, the species of the plant, its stage of growth, and its root depth. The more often the crop must recover from stress, the greater the impact to crop production and yield. Thus, minimizing or eliminating water stress will improve crop production and yield.

Figure 2 illustrates this stress recovery process. A wheat plot received an irrigation on day 100. This figure shows the changing Crop Water Stress Index (CWSI) during a portion of the growth period. The CWSI is a measure of water stress ranging from 0.0 shortly after an irrigation to 1.0 at the wilting point.



The CWSI is shown as a function of day of the year for wheat. Circles represent the CWSI data points and the solid line was drawn in by eye to show the trend. The Plus (+) symbols represent the fraction of extractable water used from the 0- to 1.1-m depth. Values on the ordinate also represent extractable water used.

Figure 2
CWSI vs. Day of Year for Wheat

Beginning on day 72, the CWSI increased with time, reaching a value of +0.67 before irrigation. The CWSI did not drop to zero immediately after the irrigation but decreased to a minimum on day 106. The 5 to 6 days required to reach the minimum are necessary to allow the plant to recover from a stressed condition. Time is needed for the water to move throughout the root zone and rehydrate the leaves. Roots, previously in dry soil, need time to grow new root hairs to extract soil water at a normal rate. Thus, too much water stress retards growth and reduces crop production.

Irrigating too frequently has the same impact on crop production and yield as stress. Roots are without air after each irrigation until the free water has drained from the soil profile. During this time, plant growth and development nearly stops.

Research has shown that for any given crop, plant stress can be quantified using three easily measured parameters. These include the foliage temperature measured with the infrared thermometer; air temperature; and vapor pressure deficit. The vapor pressure deficit is commonly called the evaporative demand of the atmosphere. The vapor pressure deficit is calculated from dry- and wet-bulb air temperatures taken in the field at approximately the same time as the infrared thermometer readings. Figure 3 is a graphical representation of the relationship between the crop's foliage-air temperature differential and the vapor pressure deficit of the atmosphere. The lower bound or baseline represents the relationship for a healthy, actively transpiring, well-watered crop. The upper bound is the non-transpiring or wilted crop.

Some terms and definitions about the baselines used in calculating the CWSI are shown in Table 1.

From these baselines one is able to derive the CWSI. If the foliage-air temperature differential for a given vapor pressure deficit falls on the lower baseline, such as at point C on Figure 3, the crop is said to be non-stressed or well-watered (transpiring at the potential rate). If the point is on the upper bound (point A), the crop is at maximum stress (non-transpiring or wilted). Any point between these limits (point B for instance) indicates that the plant is under some stress. As point B gets closer to point A, the level of water stress increases. CWSI is defined as the distance ratio BC/AC.

The CWSI provides a measure of how the crop is responding to existing soil moisture conditions. A CWSI of near zero (0) indicates the crop is in a well watered condition. This well watered condition will continue for as long as the soil moisture can meet the plant's water needs. A CWSI of one (1) indicates insufficient soil moisture to sustain plant life. A CWSI value below 0.1 would probably not represent stress but could be a fluctuation about the baseline. Research has shown that the critical CWSI, where crop production begins to falter is at 0.3 and 0.45 for wheat and cotton, respectively. Thus, a small amount of stress is acceptable before irrigation becomes necessary. Research is continuing to determine the critical CWSI for other crops. Considerable data has been collected to compute the slopes and intercepts defining the well watered baseline for several crops.

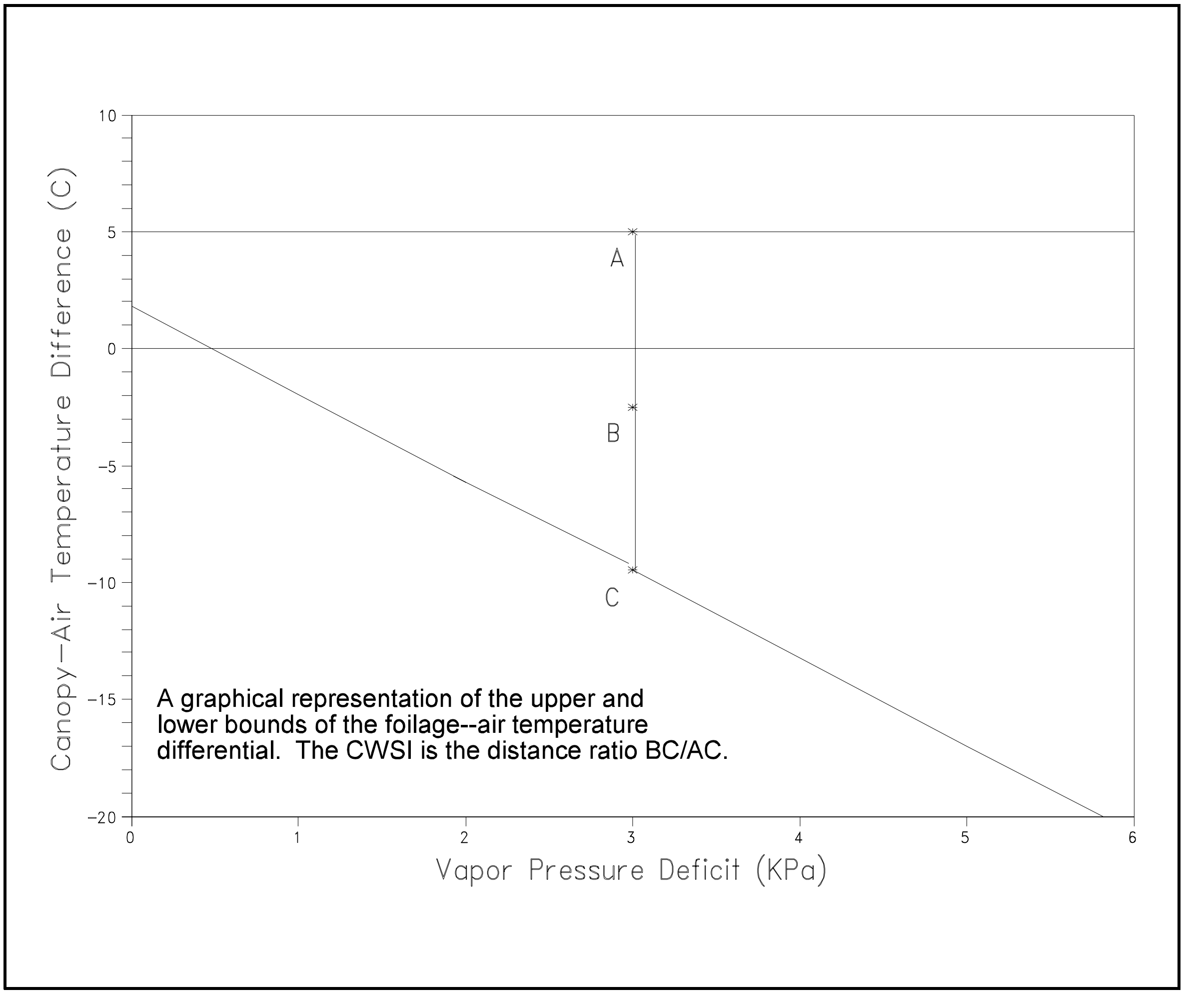


Figure 3
Typical Vapor Pressure vs. Temperature Depression Graph

Early in the growing season, infrared measurements may not represent true canopy temperatures. When there is incomplete canopy cover, the measurement with an infrared thermometer from a distance of 30 to 45 feet results in an observed surface temperature that combines both foliage and soil temperatures. The resulting "canopy" temperature is usually higher than the true foliage temperature. The calculated CWSI is not a true crop water stress index.

The baseline slope and intercept for any given crop are established by collecting data while the crop is in a non-stress state. This is usually 4 to 5 days after irrigation. Data collection should be done at different times of the day. This gives a good spread of data points due to changes in temperature and humidity. A linear regression on these data points will give the slope and intercept for the well-watered baseline. An example of data collected on alfalfa is shown in Figure 4.

Term	Definition
Crop-air temperature differential (Tc-Ta)	Crop canopy temperature as measured with the infrared thermometer minus the ambient air temperature (dry-bulb temperature psychrometer).
Vapor Pressure Deficit (VPD)	Potential saturation vapor pressure at the measured ambient air temperature minus the calculated existing vapor pressure.
Upper Limit	Potential saturation vapor pressure at the measured ambient air temperature minus the calculated existing vapor pressure. This is the canopy-ambient air temperature at which transpiration has ceased.
Crop Water Stress Index	A measure of plant moisture stress which cannot be greater than one; calculated by the following formula: $CWSI = \frac{B - C}{A - C}$ where A = upper limit (Tc-Ta) B = actual measured (Tc-Ta) C = value of Tc-Ta if crop were well-watered

Table 1
Terms and Definitions

Suggested slopes and intercepts for several crops are shown in Table 2. These may vary slightly according to region and climate.

Thus, the CWSI can be used to initially set the refill point. Using wheat as an example, the critical CWSI is about 0.3. Soil moisture reading are taken in the field at the same time as when the CWSI is determined. When the CWSI reaches approximately 0.3, the corresponding soil moisture reading in the first-foot interval is noted. This is the moisture reading that will be plotted as the refill line on the field graph.

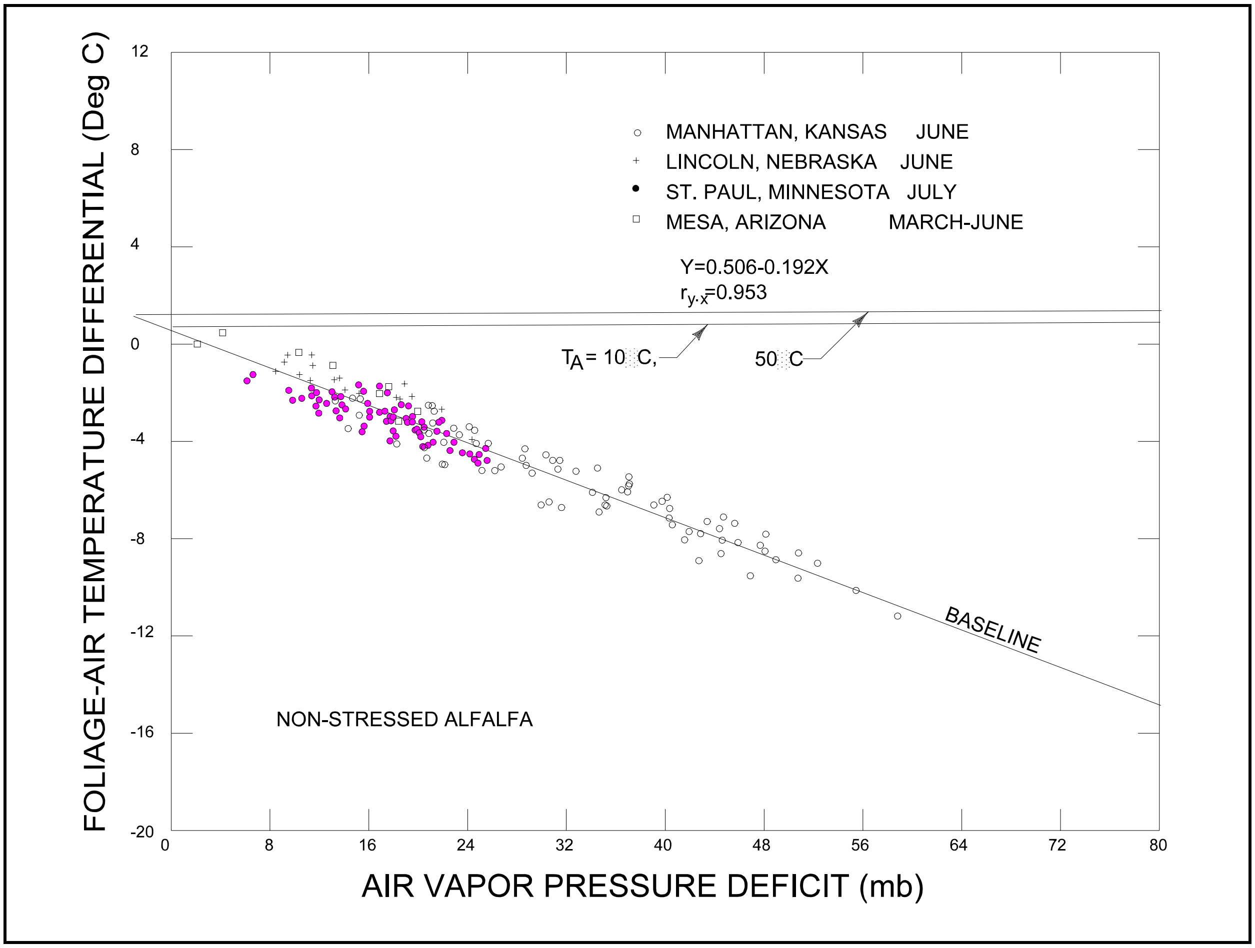


Figure 4
Foliage-air Temperature vs. Air Vapor Pressure Deficit for Well-watered Alfalfa Grown at a Variety of Specified Sites and Dates During 1980

Common Name	Scientific Name	Conditions	Intercept	Slope
Alfalfa	Medicago sativa L.	Sunlit	0.51	-1.92
Barley	Hordeum vulgare L.	Sunlit, Pre-heading	2.01	-2.25
		Sunlit, Post-heading	1.72	-1.23
Bean	Phaseolus vulgaris L.	Sunlit	2.91	-2.35
		Shaded	-1.57	-2.11
Beet	Beta vulgaris L.	Sunlit	5.16	-2.30
Chard	Beta vulgaris L.	Sunlit	2.46	-1.88
Corn	Zea mays L.	Sunlit, no tassels	3.11	-1.97
Cotton	Gossypium hirsutum L.	Sunlit	2.00	-2.24
Cowpea	Vigna catjang Walp.	Sunlit	1.32	-1.84
Cucumber	Cucumis sativus L.	Sunlit	4.88	-2.52
		Shaded	-1.28	-2.14
Fig tree	Ficus carica L.	Sunlit	4.22	-1.77
Guayule	Parthenium argentatum	Sunlit	1.87	-1.75
Kohlrabi	Brassica oleracea caulorapa communis DC.	Sunlit	2.01	-2.17
Lettuce, Leaf	Lactuca scariola L.	Sunlit	4.18	-2.96
Pea	Pism sativam L.	Sunlit	2.74	-2.13
Potato	Solanum tuberosum L.	Sunlit	1.17	-1.83
Pumpkin	Cucurbita pepo L.	Sunlit	0.95	-1.93
		Shaded	-1.32	-2.10
Rutabaga	Brassica napo-brassica	Sunlit	3.75	-2.66
Soybean	Glycine max L. Merr.	Sunlit	1.44	-1.34
Squash, Hubbard	Curbita pepo L.	Sunlit	6.91	-3.09
		Shaded	2.12	-2.38
Squash, Zucchini	Cucurbita pepo L.	Sunlit	2.00	-1.88
Sugar Beet	Beta vulgaris L.	Sunlit	2.50	-1.92
Sunflower	Helianthus annuus L.	Sunlit	2.86	-1.96
Tomato, Mill.	Lycopersicum esculentum	Sunlit	2.86	-1.96
Turnip	Brassica rapa L.	Sunlit	1.94	-2.26
Wheat, Podura	Triticum durum Desf.	Sunlit, pre-heading	3.38	-3.25
		Shaded, post-heading	2.88	-2.11

Table 2. Well-Watered Base Line Coefficients
for Selected Crops

3 - REQUIRED EQUIPMENT

Only a limited amount of equipment is needed to provide irrigation scheduling services to local farmers. The following section describes the equipment used by the LC Region and suggests proper usage procedures.

In addition to normal office space, vehicle, and miscellaneous hand tools, specialized equipment include:

(1) Neutron moisture gauge
(2) Infrared thermometer
(3) Standardization barrels
(4) 2-inch diameter soil auger (preferably power driven)
(5) Access tubes w/bottom seal and caps (steel or aluminum are preferred)
(6) Access tube driver

The following sections describe the specialized equipment:

The Neutron Measuring Gauge

Description of Gauge

The gauge is the instrument used to measure the moisture in the soil. It is portable and can be carried from field to field. However, an access tube must be installed wherever a measurement is to be made.

The gauge uses a high energy source to detect the presence of hydrogen atoms in the soil. When the high energy source of the gauge is lowered into the access tube, fast neutrons are emitted. Neutron emission occurs when an alpha particle emitter (americium) is mixed with beryllium powder in a tightly compressed pellet. Fast neutrons ricochet strongly from large atoms like a golf ball does when it collides with a bowling ball. Very little energy is lost. Neutrons are dramatically slowed down, however, if they collide with hydrogen atoms. Since the hydrogen atoms are the same mass as the neutron, the neutrons lose energy. The detector tube of the moisture gauge can then count the slow moving neutrons as they pass through the tube.

In most soils the major source of hydrogen is water; hence, the only major moderator of fast neutrons would be water. Therefore, when a soil has a high moisture content (such as at field capacity), the gauge readings would be high. On the other hand, soils that are dry or are approaching the wilting point would show low readings. Thus, a relationship can be established between the gauge counts and the amount of water in the soil.

Several gauges are on the market now. However, primary experience in the LC Region has been with the Campbell Pacific Nuclear 503 Moisture Gauge (503 gauge).

If other makes of gauges are in use, consult the owner's manual for a complete description and operating instructions.

Two models of the 503 gauge have been used. The Standard 503 gauge (S-503) displays raw counts that must be converted to the desired units of measure. The Direct Readout 503 gauge (DR-503) contains a microprocessor that converts raw counts to any of several desired units of measure.

The primary parts of the 503 gauge are: The case, the display, and the probe containing the radioactive source and detector electronics. The case is a rectangular box approximately 7 inches (18 cm) square by 14 inches (36 cm) length. A tube for holding the probe is located in the center of the case. The readout display is attached to one side. The lower portion of the case is a neutron shield filled with a high hydrocarbon paraffin-based wax. The wax will partially absorb the neutrons emitting from the source. This also helps shield the user from stray neutron radiation. Figure 5 is a manufacturer's photo showing gauge with the probe locked in its housing. In this configuration, the gauge is ready to be carried into the field.

Figure 5
CPN Model 503 Moisture Gauge

The display unit is contained in a 7-inch by 7-inch by 2-inch box. The display unit contains the display circuitry, the battery pack, and a liquid crystal display (LCD) or light emitting diode readout. The back of the display has a fuse holder and the cable attachment block.

The probe unit has four main parts: the external stainless steel case, the radioactive source permanently secured in the lower part of the probe tube, the neutron detector tube, and the detector electronics. The probe, containing the radioactive source and display electronics, is attached to the display by a cable.

A cable is used to lower the probe tube into the access tube and to transmit electrical pulses to the display unit. Cable stops are placed on the cable to permit lowering the probe to predetermined depths in the access tubes. The setting of the cable stops depends upon the adaptor used to support the gauge on top of the access tubes. Specifications for the adaptor used in the LC Region are shown in Appendix C.

With this particular adaptor, the first cable stop should be 26 inches (66 cm) from the bottom of the detector tube to the base of the first stop. All additional stops are set in increments of 12 inches (30.5 cm) from the base of the first cable stop. The stop placement should be checked weekly because the insulation on the cable stretches and slides over time. Heat and rough handling accelerate this process. Changes in stop placement may cause inconsistent readings.

Use of Gauge

Soil moisture measurements are taken by placing the gauge on top of the access tube and lowering the probe to the desired depth. Figure 6 shows the gauge positioned on the access tube to take readings. Readings are taken by pressing **START**, and recording the displayed number in the field book. The normal sampling time is 30 seconds for the S-503 and 16 seconds for the DR-503. Therefore, the numbers will not be displayed immediately after **START** has been pressed. (Consult the operator's manual if other intervals are desired.) The S-503 displays raw counts that must be converted to moisture content using a rating table similar to the tables shown in Figures 7 and 8. The DR-503 displays the moisture content in several preselected units of measure. The normal unit of measure used in the United States for agricultural applications is inches of water per foot of soil depth (in/ft).

The DR-503 can directly display the moisture content and store readings as they are taken in the field. Some additional steps are needed to initialize the gauge before taking field measurements. Place the gauge on the shipping case with the probe tube in the retracted position. Press the key marked **UNITS**. If the LCD does not display **IF** (in/ft), press the **STEP** key until **IF** is displayed. When **IF** is displayed, press the **ENTER** key to record desired unit of measure. Now press the key marked **TIME**. Press the **STEP** key until **16 seconds** appears. Press the **ENTER** key to record desired sampling interval.

Next take a new standard count. Press the key marked **STD**. The probe will display the old standard count if one has been recorded. A new 32-count standard will be taken automatically when the **START** key is pressed. Be patient, this will take several minutes. When the 32-count standard has been taken, make a note of the new standard count displayed. Press the **STEP** key and this will display the previous standard count. Press the **STEP** key again and the Chi value will be displayed. The Chi value is the standard deviation of the 32 counts divided by the square root of the 32-count average. This value should be

Figure 6
Taking Moisture readings with the 503.

WATER CONT, IN/FT 06/25/92 PROBE NO 1 (SN=4503)

1000'S	0	100	200	300	400	500	600	700	800	900
					HUNDREDS					
6	0.40	0.41	0.42	0.43	0.44	0.46	0.47	0.48	0.49	0.50
7	0.51	0.52	0.53	0.54	0.55	0.57	0.58	0.59	0.60	0.61
8	0.62	0.63	0.64	0.65	0.67	0.68	0.69	0.70	0.71	0.72
9	0.73	0.74	0.75	0.77	0.78	0.79	0.80	0.81	0.82	0.83
10	0.84	0.85	0.86	0.88	0.89	0.90	0.91	0.92	0.93	0.94
11	0.95	0.96	0.98	0.99	1.00	1.01	1.02	1.03	1.04	1.05
12	1.06	1.08	1.09	1.10	1.11	1.12	1.13	1.14	1.15	1.16
13	1.17	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27
14	1.29	1.30	1.31	1.32	1.33	1.34	1.35	1.36	1.37	1.39
15	1.40	1.41	1.42	1.43	1.44	1.45	1.46	1.47	1.48	1.50
16	1.51	1.52	1.53	1.54	1.55	1.56	1.57	1.58	1.60	1.61
17	1.62	1.63	1.64	1.65	1.66	1.67	1.68	1.70	1.71	1.72
18	1.73	1.74	1.75	1.76	1.77	1.78	1.79	1.81	1.82	1.83
19	1.84	1.85	1.86	1.87	1.88	1.89	1.91	1.92	1.93	1.94
20	1.95	1.96	1.97	1.98	1.99	2.01	2.02	2.03	2.04	2.05
21	2.06	2.07	2.08	2.09	2.10	2.12	2.13	2.14	2.15	2.16
22	2.17	2.18	2.19	2.20	2.22	2.23	2.24	2.25	2.26	2.27
23	2.28	2.29	2.30	2.31	2.33	2.34	2.35	2.36	2.37	2.38
24	2.39	2.40	2.41	2.43	2.44	2.45	2.46	2.47	2.48	2.49
25	2.50	2.51	2.53	2.54	2.55	2.56	2.57	2.58	2.59	2.60
26	2.61	2.62	2.64	2.65	2.66	2.67	2.68	2.69	2.70	2.71
27	2.72	2.74	2.75	2.76	2.77	2.78	2.79	2.80	2.81	2.82
28	2.84	2.85	2.86	2.87	2.88	2.89	2.90	2.91	2.92	2.93
29	2.95	2.96	2.97	2.98	2.99	3.00	3.01	3.02	3.03	3.05
30	3.06	3.07	3.08	3.09	3.10	3.11	3.12	3.13	3.15	3.16
31	3.17	3.18	3.19	3.20	3.21	3.22	3.23	3.24	3.26	3.27
32	3.28	3.29	3.30	3.31	3.32	3.33	3.34	3.36	3.37	3.38
33	3.39	3.40	3.41	3.42	3.43	3.44	3.46	3.47	3.48	3.49
34	3.50	3.51	3.52	3.53	3.54	3.55	3.57	3.58	3.59	3.60
35	3.61	3.62	3.63	3.64	3.65	3.67	3.68	3.69	3.70	3.71
36	3.72	3.73	3.74	3.75	3.76	3.78	3.79	3.80	3.81	3.82
37	3.83	3.84	3.85	3.86	3.88	3.89	3.90	3.91	3.92	3.93
38	3.94	3.95	3.96	3.98	3.99	4.00	4.01	4.02	4.03	4.04
39	4.05	4.06	4.07	4.09	4.10	4.11	4.12	4.13	4.14	4.15
40	4.16	4.17	4.19	4.20	4.21	4.22	4.23	4.24	4.25	4.26
41	4.27	4.29	4.30	4.31	4.32	4.33	4.34	4.35	4.36	4.37
42	4.38	4.40	4.41	4.42	4.43	4.44	4.45	4.46	4.47	4.48
43	4.50	4.51	4.52	4.53	4.54	4.55	4.56	4.57	4.58	4.60
44	4.61	4.62	4.63	4.64	4.65	4.66	4.67	4.68	4.69	4.71
45	4.72	4.73	4.74	4.75	4.76	4.77	4.78	4.79	4.81	4.82
46	4.83	4.84	4.85	4.86	4.87	4.88	4.89	4.91	4.92	4.93
47	4.94	4.95	4.96	4.97	4.98	4.99	5.00	5.02	5.03	5.04
48	5.05	5.06	5.07	5.08	5.09	5.10	5.12	5.13	5.14	5.15
49	5.16	5.17	5.18	5.19	5.20	5.22	5.23	5.24	5.25	5.26
50	5.27	5.28	5.29	5.30	5.31	5.33	5.34	5.35	5.36	5.37

COUNT INTERVAL = 0.001 IN/FT PER 10 COUNTS
EQUATION: W=0.0001107 x C -.264

Figure 7
Probe Rating Table - Uniform Count Increment

COUNT	INCHES	COUNT	INCHES	COUNT	INCHES
3037	.50	10819	2.55	18601	4.60
3227	.55	11009	2.60	18791	4.65
3417	.60	11199	2.65	18981	4.70
3606	.65	11389	2.70	19171	4.75
3796	.70	11578	2.75	19361	4.80
3986	.75	11768	2.80	19551	4.85
4176	.80	11958	2.85	19740	4.90
4366	.85	12148	2.90	19930	4.95
4555	.90	12338	2.95	20120	5.00
4745	.95	12528	3.00	20310	5.05
4935	1.00	12717	3.05	20500	5.10
5125	1.05	12907	3.10	20689	5.15
5315	1.10	13097	3.15	20879	5.20
5505	1.15	13287	3.20	21069	2.25
5694	1.20	13477	3.25	21259	5.30
5884	1.25	13666	3.30	21449	5.35
6074	1.30	13856	3.35	21638	5.40
6264	1.35	14046	3.40	21828	5.45
6454	1.40	14236	3.45	22208	5.55
6643	1.45	14615	3.55	22398	5.60
7023	1.55	14805	3.60	22588	5.65
7213	1.60	14995	3.65	22777	5.70
7403	1.65	15185	3.70	22967	5.75
7592	1.70	15375	3.75	23157	5.80
7782	1.75	15564	3.80	23347	5.85
7972	1.80	15754	3.85	23537	5.90
8162	1.85	15944	3.90	23726	5.95
8352	1.90	16134	3.95	23916	6.00
8541	1.95	16324	4.00	24106	6.05
8731	2.00	16514	4.05	24296	6.10
8921	2.05	16703	4.10	24486	6.15
9111	2.10	16893	4.15	24675	6.20
9301	2.15	17083	4.20	24865	6.25
9491	2.20	17273	4.25	25055	6.30
9680	2.25	17463	4.30	25245	6.35
9870	2.30	17652	4.35	25435	6.40
10060	2.35	17842	4.40	25624	6.45
10250	2.40	18032	4.45	25814	6.50
10440	2.45	18222	4.50		
10629	2.50	18412	4.55		

Figure 8. Probe Rating Table
Uniform Moisture Content Increment

between 0.75 and 1.25. If the Chi value is within these limits, press the **ENTER** key and the new standard count will be entered into the probe. If the Chi value is out of range, press the **CLEAR** key, and initiate the standard count procedure again. If the Chi value is still out of range after the third try, the probe will require servicing.

If site locations and readings are to be stored in the gauge's memory, the memory area must be formatted. To do this, press the **FMT** key. The gauge will display **K Data 1**. Key in a **1** if the gauge does not display a **1**. Press the **ENTER** key. The gauge will display **Depths**. The gauge can record up to 15 depths but measurements are normally taken at three depths per tube site. However, the gauge will expect the same number of depths at each site. When the number of depths is keyed in, press the **ENTER** key. The gauge will store the number of depths to be read and will display **Set FMT?**. Press the **ENTER** key and the gauge should display **Ready**. To clear all stored gauge readings, press the **FMT** key; then press **ENTER** until **Ready** appears in the display.

The following procedure should be used when storing readings in the DR-503 memory. Place the gauge on the access tube. Press **LOG**, key in the farm number, and press **ENTER**. Key in the field number and press **ENTER**. **M3** will be displayed. Lower the probe to the first cable stop and press **START**. In about 16 seconds the measurement is displayed. Press **ENTER** to store the measurement if the measurement appears correct. Otherwise, press **START** and repeat the reading. **M2** will then be displayed after the gauge has stored the reading. Lower the probe to the next stops repeating the **START** and **ENTER** sequence at each stop. Three readings <u>must</u> be recorded for each site. If readings are to be taken at only two depths, key in **0**, and press **ENTER** in place of the third reading. After the third reading has been entered, the total moisture will be displayed. Press **ENTER** if correct. The gauge will then display **IS DATA OK?**. Press **ENTER** to store all data for the site. The gauge is now ready to take readings at the next site.

The above procedures assume that the gauge has been properly standardized. (See "Standardizing Gauge.")

Standardization Barrels

Standardization barrels are used to verify correct calibration of each gauge and to insure that all gauges are calibrated to the same standard. Some gauges change calibration gradually from season to season, especially in hot climates. The set of standardization barrels consists of two, large 30- or 55-gallon barrels. One is filled with air-dried sand and the other with saturated sand. The air-dry sand approximates the lower limit of the moisture contents encountered in the field and the saturated sand approximates the upper limit. Local soils with high silt and clay contents may be used in place of saturated sand. These soils should be near field-capacity when used.

Both barrels are fitted with access tubes centered in the barrels. The access tubes should be of the same material as the access tubes used in the field. Each tube extends far enough above the top of the barrel so the probe detector tube will be suspended in the center of barrel when hanging on the second cable stop. Figure 9 shows a moisture gauge set up on a standardization barrel ready to take a measurement.

Be careful when placing sand in the barrels so that the sand is adequately compacted to eliminate future settling. The barrels should be filled with sand to within 1-inch of the top. Water is added to the sand in one barrel until the sand is saturated and water stands freely above the sand. A lid with a 2-3/16-inch diameter hole to accommodate the access tube is placed on the top of each barrel. The lid should be sealed on the dry barrel with silicone or rubber adhesive sealant as soon as the sand has been compacted. The lid is not sealed on the wet barrel. An inspection hole could be provided to facilitate maintaining the water at a constant level above the sand. Otherwise, provide an external filling tube as shown in Figure 9.

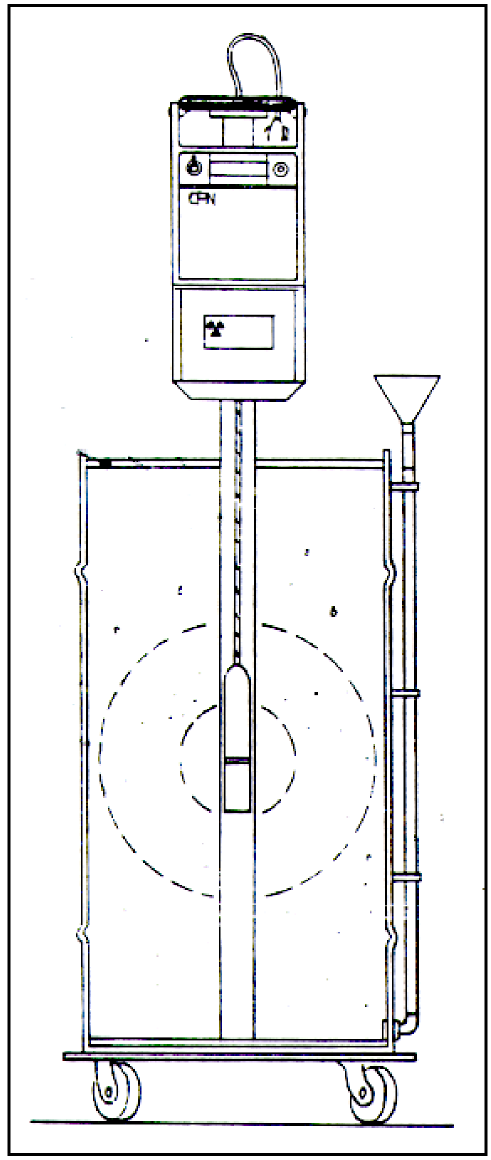


Figure 9
Gauge On Standardization Barrel

The <u>apparent</u> moisture content of each barrel is measured with a gauge accurately calibrated to local soil conditions. Twenty moisture measurements are taken and averaged to determine the apparent moisture content of each barrel. Outside influences can affect gauge readings, especially the dry barrel readings. This can be minimized by maintaining the barrels and surrounding area in a constant configuration.

Alternately, sand samples can be taken from each barrel. The samples should be analyzed in the laboratory to determine actual moisture content of each barrel.

Infrared Thermometer

Description of Thermometer

Figure 10
Infrared Thermometer

Soil water content can be inferred from tensiometers or measured with the neutron moisture gauge, but just knowing how much water is in the soil is not enough. One must also know the minimum amount of water that must remain in the soil without reducing crop production. The infrared thermometer (Figure 10) provides a means of determining the degree of crop water stress by measuring crop foliage temperature. The complete infrared thermometer includes a Bendix psychrometer for measuring wet and dry-bulb temperatures. The kit also contains a reference temperature black body for calibrating the infrared thermometer. Newer models of the infrared thermometers have the necessary built-in sensors and microprocessor to determine the CWSI directly.

Use of Thermometer

Crop foliage temperatures (and associated relative humidity) are measured to develop the well-watered baseline curves and to determine plant water stress conditions. The infrared thermometer measures the temperature of the crop foliage, while the Bendix psychrometer measures wet-bulb and dry-bulb temperatures needed to determine relative humidity.

Data for the well-watered baseline may be collected anytime from about 9 a.m. to 3 p.m. When using the infrared thermometer for detecting stress, readings are preferably taken between noon and 2 p.m., when the sun is usually higher overhead. During these hours, shadows are the smallest and transpiration is at its peak. It is more effective to read each field at approximately the same time each day when checking for stress.

The temperature readings should all be taken in an area of the field where the largest percentage of the whole field will be represented. Readings should be taken approximately 50 feet into the field so temperatures will not be influenced by the edge effect of the field. Edges of the field may not receive as much water or may be dried out faster by winds. Taking temperatures from eight directions is necessary to give a good average of the canopy or foliage temperature. Figure 11 illustrates the procedure for measuring canopy temperatures with an infrared thermometer.

Figure 11
Measuring canopy temperature with an infrared thermometer.

The wet-bulb and dry-bulb temperatures should be taken as soon as possible after taking the infrared thermometer readings. First, apply distilled water to the sock of the wet-bulb. Be careful not to get water in the fan mechanism. Shake off the excess, then turn on the fan. Hold the psychrometer approximately 1 meter from the ground and upwind from body temperature influences. The wet-bulb reaches its lowest temperature in 1 minute or less. Read both the wet- and dry-bulb temperatures together. Newer versions of the infrared thermometer compute and display the vapor pressure deficit and the crop temperature differential directly. In this case, a psychrometer is not necessary to determine wet-bulb and dry-bulb temperatures.

Data collected at any given site should be recorded on a form similar to the one in Figure 12. The top half of this form contains information regarding the site and data quality. Data quality refers to the existing climatic conditions when the data is taken and should either be a 1, 2, or 3. If sunny, with light winds, data quality is 1 for **GOOD**. If slight overcast or just windy, data quality is 2 for **FAIR**. If cloudy or high winds, readings probably should not be taken, but the data quality is 3 for **POOR**. Be sure to enter the crop name to the top right of **TEMPERATURE MEASUREMENTS**. Under the heading **TEMPERATURE MEASUREMENTS**, fill in the time of the readings and the field number or other reference to the area where readings are taken. Then record the dry-bulb, wet-bulb, and eight infrared thermometer readings.

Periodic checks should be made with the infrared thermometer against a calibration source or black body to see that it is reading correctly. Normally, the Bendix psychrometer need only be watched for loss of power due to low batteries. Fluctuating fan speeds, due to low batteries, cause the wet-bulb temperature to descend slowly and result in inaccurate or variable readings.

Soil Auger

A 2-inch diameter soil auger is needed to bore holes to permit the installation of access tubes. Any type of auger capable of boring a 2-inch diameter hole deep enough to accept the longest access tube in use is acceptable. However, a power-driven, continuous-flite auger is preferred. The power-driven auger drills holes much faster and speeds installation of access tubes. However, extra care must be taken to ensure that the auger does not over-bore the hole diameter.

Access Tubes

Probe access tubes must be installed at each location where soil moisture measurements will be taken. These tubes may be steel, aluminum, or PVC pipe for the nuclear gauge. Steel tubes are preferred because of better durability and lower cost.

The steel access tubes are 2-inch (50 cm) inside diameter, thin walled, rigid steel conduit. The conduit is purchased in 10-foot sections and then cut to the desired length. The tube is sealed on the bottom with a 1⅞-inch chain link fence post cap and water repellent adhesive. The top is covered with a removable cap to protect the tube and to keep out irrigation water and debris. The cap consists of a 2½- by 2½- by ¼-inch steel plate bolted on top of a No. 11 rubber stopper. The cap should be painted with a highly visible color of paint for ease in locating the tube. If a tube cannot be located in a field, the steel plate on the cap helps a good metal detector locate the tube. Figure 13 shows a typical cap assembly.

PLANT FOLIAGE TEMPERATURE DATA SHEET

LOCATION *Double Bar Ranch*

YEAR DAY - DATE *4/22/95* BY *LM* DATA QUALITY *1*

INSTRUMENT

MODEL No. - SERIAL No. -

CALIBRATION CHECK:

TIME	INST.	REF.
1400	*24.6*	*24.6*

WEATHER

SUN *X* HAZE - CLOUD TYPE - CLOUD COVER - WIND SPEED *4* WIND DIRECTION *SE*

PRECIP.______ IRRIGATION *Field S10 4/18*

COMMENTS: *Plants are in the milky dough stage*

TEMPERATURE MEASUREMENTS CROP______

SITE	TIME	FLD	DRY BULB	WET BULB	DIRECTION OF VIEW							
					N	NE	E	SE	S	SW	W	NW
1	*1410*	*S10*	*24.7*	*15.0*	*23.5*	*23.7*	*23.7*	*23.4*	*23.6*	*23.2*	*23.2*	*22.8*
2												
3												
4												
5												
6												
7												

Figure 12
Sample Plant Foliage Temperature Data

The length of the access tube is determined by the root structure of the crop being scheduled. For most field crops, a 44-inch (112 cm) tube will be long enough. It will permit readings down to 3 feet and provide extra clearance below the probe. This tube length is adequate for crops like cereal grains, alfalfa, cotton, and most vegetables.

A longer tube is preferred for citrus, grapes, dates, and other tree crops. Also, the longer tube will allow early identification of water table problems.

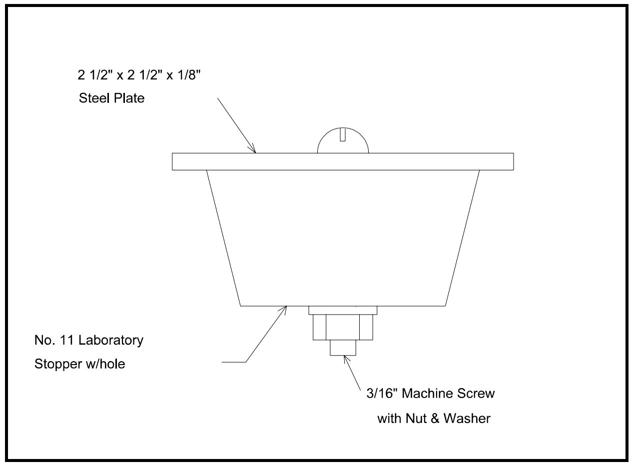


Figure 13. Access Tube Cap Assembly

Tube installation requires drilling a 2-inch diameter hose several inches deeper that the tube length. The extra depth accommodates some soil sloughing that usually occurs when the tube is driven into the hole.

Access Tube Driver

A specially designed driver is used to install steel access tubes in holes that have been previously bored in the ground. The driver consists of a drop-hammer, guide rod, and anvil. The anvil is specifically designed to protect the top of the tube and prevent tube deformation during the driving process. The guide rod is attached to the anvil to center the force of the drop-hammer.

In operation, the driver works much like a steel fence-post driver. The anvil is inserted in the top of the tube. The drop-hammer is repeatedly raised to the top of the guide rod and released. The force of the falling drop-hammer drives the tube into the ground. Figure 14 shows a photograph of an access tube driver.

PVC access tubes do not require a specially designed driver. A hard rubber mallet is adequate for driving these access tubes.

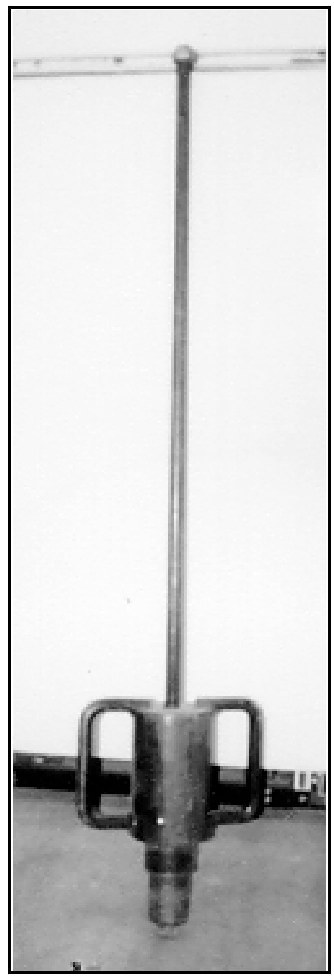


Figure 14.
Access Tube Driver

4 - GETTING STARTED

The LC Region started its field irrigation scheduling services on a demonstration basis at the two previously mentioned irrigation districts and on the Native American Indian Reservation. The initial staff provided at each site consisted of a hydraulic engineer and a soil scientist provided by Reclamation and a soil scientist or soil conservationist provided by the partner. The partners provided office space for each team. Reclamation provided furniture, equipment, and supplies. Reclamation and the partners provided vehicles for their own employees. As the programs expanded beyond the initial acreage enrollment, the partners provided additional field technicians. The ultimate intent was to withdraw Reclamation employees after 3 to 5 years when the partners could sustain the programs on their own. Lessons learned and insight gained by Reclamation through these demonstration activities have resulted in the following suggestions for starting a new field irrigation scheduling service.

Starting a New Field Irrigation Scheduling Service

Starting a new field irrigation scheduling service involves several activities. These include recruiting field technicians; obtaining office space, equipment, and vehicles; preparing the equipment; and enrolling participating farmers.

Local procedures will govern the recruiting of field technicians. However, the technicians should have some knowledge of irrigated agriculture. They also should have the skills to use the specialized equipment used for irrigation scheduling. Finally, they should be able to communicate effectively with the farmers.

Similarly, local conditions will govern the availability of office and work space. The neutron moisture gauge will require special provisions for licensing, storage, and transportation. The technicians also must be trained and certified by a qualified Radiation Safety Officer.

Local policies will determine how participating farmers will be recruited and enrolled. Enrollment should be open to all local farmers. However, program success is the greatest when first consideration is given to the most progressive and cooperative farmers. Experience has also demonstrated that the program is the most successful when all of a participating farmer's fields are receiving scheduling services. Farmers cannot assess the benefits of the service fully when just a few "demonstration" fields are receiving the service. The farmer must still schedule the irrigations on the non-enrolled fields. The demonstration fields are just considered a curiosity.

Compliance with regulations governing the possession and use of neutron moisture gauges is essential. The use of these gauges is regulated by Federal or State agencies because the devices contain radioactive sources. Federal agencies usually are under the jurisdiction of the Nuclear Regulatory Commission (NRC). Irrigation districts and private owners are under the jurisdiction of the State regulatory agency.

The owner must first obtain a license from the NRC and/or appropriate State agency before purchasing and taking delivery of nuclear moisture gauges. To get a license, the owner must meet conditions for storage and use of the nuclear gauge as set by either a state or federal regulatory agency. The owner should consult with the appropriate regulatory agency for specific requirements. Typically, the storage area must be a specified distance away from areas frequented by people and animals. It must always be locked and must be properly marked. Again, all operators must be trained and certified by a certified training instructor. Each person operating or servicing the gauges must be supplied with a dosimeter film badge to monitor radiation exposure. These badges must be replaced and analyzed periodically. Finally, a record keeping system must be set up to maintain film badge and leak test reports and other correspondence. The NRC and/or State agency will periodically inspect the site to insure that the owners and operators are in compliance with the regulations. The inspection includes an examination of the record keeping system. Finally, Department of Transportation guidelines must be observed when the nuclear gauge is transported.

The remainder of the discussion on getting the service started concentrates on setting up the equipment and compiling the necessary information needed to operate the service.

Calibrating Gauge

The neutron moisture gauges must be initially calibrated so the readings (counts) can be related to actual soil moisture. Soils have different chemical and physical properties that may affect the gauge readings. Calibration curves should be developed for local conditions. The gauge, thus calibrated, can be used to measure the equivalent moisture content of the standardization barrels.

To calibrate the gauge, select representative sites of the soils in the area to be monitored. As the access tube hole is being bored, take soil samples at different depths. Use a soil sampler capable of taking a sample of a known volume. Seal the samples in cans for later moisture determination in the laboratory. After installing the access tube, take gauge readings at the same depths where the samples were taken and record the measurements. Enough sites should be selected to give readings for a range of different moisture levels (wet, moist, and dry). The soil samples taken during access tube installation are analyzed in the laboratory to determine the amount of moisture contained in the different soils.

A graph is prepared with the gauge readings on one axis. The moisture content of the soil, as determined in the laboratory, is on the other. The curves are then developed and plotted on a graph similar to Figure 15. A straight line is then fitted to the plotted points and the coefficients of the line are determined. A graph or table is then prepared which relates the amount of moisture in the soil to a given gauge reading. This table also can be developed on the computer. The coefficients of the line also may be entered into the gauge if the gauge is capable of displaying readings in actual moisture content.

Some people contend that a calibration curve must be developed for each soil type to be monitored. This is true if detailed research is involved. However, for the practical use of the gauge for predicting and scheduling irrigations, experience shows that one calibration curve is normally sufficient. There may be some instances when two curves are necessary, due to an extreme difference in local soil types.

Standardizing the Neutron Moisture Gauge

Ideally, the calibration procedure described above should be repeated each time a new gauge is put in service. The process also should be repeated at frequent intervals to insure continued accurate operation of each gauge. Unfortunately, the process is very time consuming.

An alternate procedure involves the use of standardization barrels. These barrels were previously described in the "Required Equipment" chapter. The barrels with known moisture content simulate typical "wet" and "dry" conditions in the field. Calibration curves are developed using gauge readings from the two barrels. This replaces the process of taking readings in the field and determining the soil moisture in the laboratory.

Standardization procedures are somewhat different for the S-503 and the DR-503 gauges. Coefficients for the calibration curve must be computed manually for the S-503. Coefficients are computed automatically by the DR-503.

To standardize the S-503, take sets of 20 measurements with the probe lowered to the center each the barrel. For each set, the readings (counts) are recorded in a notebook, totaled, and averaged. The standard deviation is also computed.

The calibration equation is of the form: M=aC+b

where: M= Moisture content in inches of water per foot of soil depth
C= Counts shown on display
a= Slope coefficient
b= Intercept coefficient

and: $a = \frac{(M_w - M_D)}{(C_w - C_D)}$ and $b = M_w - aC_w$

where: M_w= Moisture content of wet barrel (in/ft)
C_w= Average for 20 readings on wet barrels (counts)
M_D= Moisture Content of Dry barrel (in/ft)
C_D= Average for 20 readings on Dry barrel (counts).

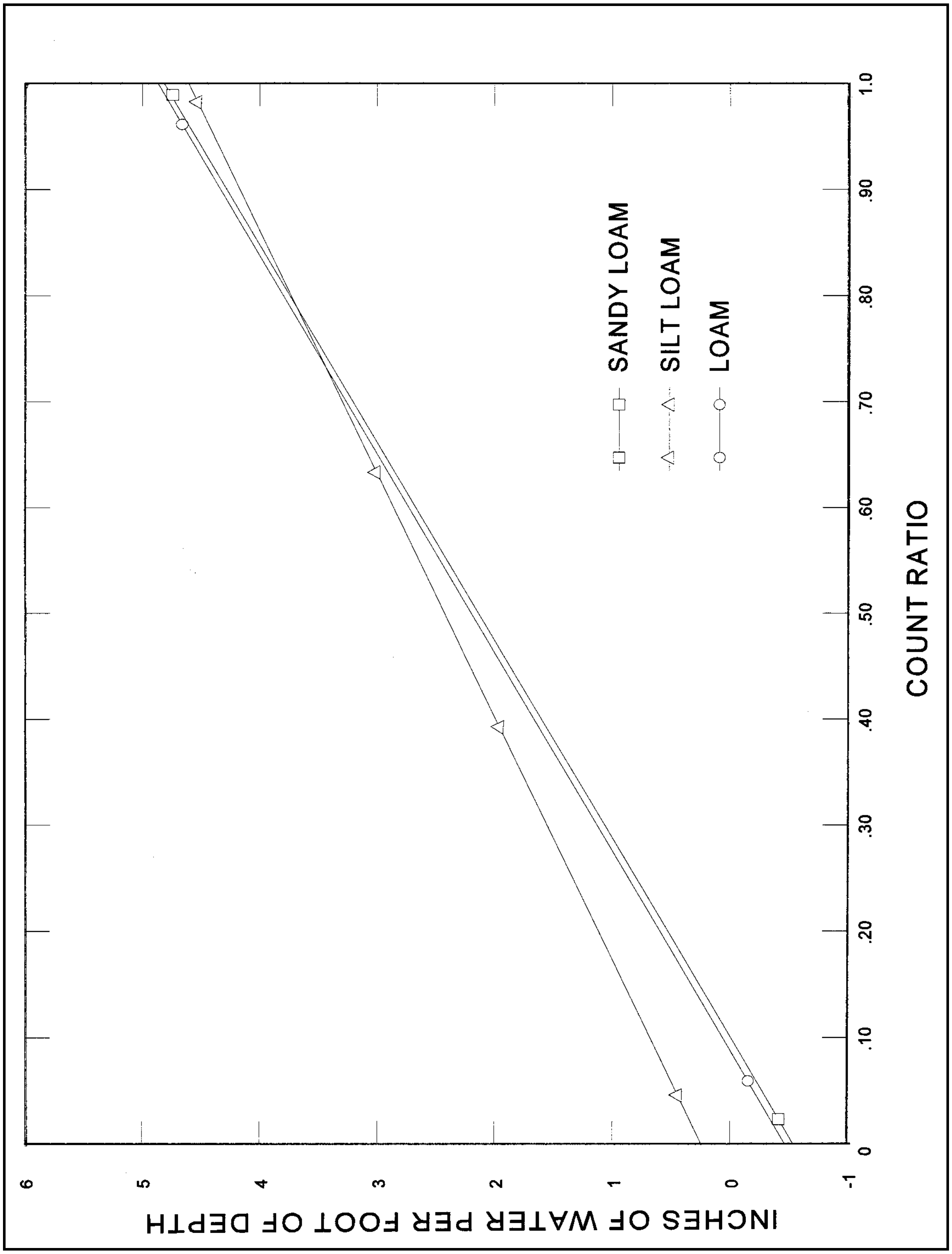


Figure 15. Soil Moisture in Inches per Foot of Depth vs. Count Ratio of the Neutron Moisture Gauge

Coefficients "a" and "b" are used in the calibration equation to develop rating tables used by field personnel to convert displayed counts to equivalent moisture contents. Samples of two typical rating tables were previously shown in Figures 7 and 8.

Data recorded during the standardization process also can be used to verify proper operation of the gauge. No more than 6 of the 20 readings should be outside the acceptable range. The acceptable range is plus or minus the square root of the average count above and below the average count. The Chi value obtained by dividing the square root of the average count by the standard deviation should be between 0.75 and 1.25 (see Figure 16). If either of the above tests fail, additional sets of 20 readings should be taken on the appropriate barrel. Several additional failures indicate the gauge is defective and should be repaired.

To standardize the DR-503, place the gauge on the wet barrel and lower the probe to the center of the barrel. Press the key marked **CALIB** and the gauge will display **Cal 1 IF**. This is the first of eight calibrations that can be stored in the gauge. Only one calibration is needed for most agricultural soils. Now press the **ENTER** key. The gauge will display **COEFFS?**. Press the **STEP** key until **SLFCAL** is displayed. Press the **ENTER** key. The gauge will display **M2 0.0---** and will wait for entry of the moisture equivalent of the wet barrel (inches of moisture per foot of soil). Key in wet barrel moisture content and press the **ENTER** key. The gauge will display **C 2 0---**. (It is waiting for entry of the average count for the wet barrel.) Press the **START** key and the gauge will determine the average count for the wet barrel. The gauge will take about 4 minutes to complete the measurement. When the measurements are completed, press the **ENTER** key. Place the gauge on the dry barrel. If the gauge is now displaying **M1 0.00**, it is waiting for the moisture equivalent of the dry barrel to be keyed in. Key in this number and press the **ENTER** key. The gauge will display **C1 0---** and wait for the average count of the dry barrel to be keyed in. By pressing the **START** key, the gauge will determine the average counts in about 4 minutes. When the gauge is finished counting, press the **ENTER** key. The LCD will flash the word **COMPUTE** on the display screen and then will show **READY**. Calibration is complete.

Correct operation can be verified by taking a measurement on one of the barrels. Lower the probe to the center of the barrel and press **START**. The displayed reading should be within ±0.05 in/ft of the barrel's equivalent moisture content. If the test fails for repeated measurements, repeat the standardization process and try the test again. The previously described tests for the S-503 should be used if the gauge still cannot measure the equivalent moisture content within ±0.05 in/ft.

As shown above, the barrels provide a quick means of verifying proper gauge operation. Simply measure the moisture content of one or both barrels before taking the gauge into the field each day. All gauges should be more extensively checked out on the barrels to identify changes caused by electrical breakdown or drift at least weekly. Standardization procedures should be followed any time drift is apparent.

NEUTRON PROBE
STANDARD COUNT DETERMINATION

Probe No. H32074503

DATE: 6-10-85 OPERATOR: LM

Reading No.	Count Rates	
1.	29248	
2.	29543	
3.	29416	
4.	29386	
5.	29280	
6.	29725	High
7.	29245	
8.	29133	Low
9.	29603	High
10.	29330	
11.	29100	Low
12.	29391	
13.	29382	
14.	29648	High
15.	29401	
16.	29422	
17.	29370	
18.	29417	
19.	29190	Low
20.	29339	

Total = 587629
Average = 29381 $\sqrt{Avg}$ = 171.4

Average + $\sqrt{Avg}$ = 29552
{Acceptable Range
Average - $\sqrt{Avg}$ = 29210

STD DEV = 161.6

Chi or RATIO = $\sqrt{Avg}$ / STD DEV = 1.06
(Acceptable range = 0.75 - 1.25)

REMARKS: Probe is demonstrating good performance.

Figure 16
Neutron Probe Standard Count Determination

Establishing Well-Watered Baseline

The well-watered baseline has been established for many common crops. Baseline coefficients for these crops have been shown previously in Table 2. Unfortunately, a desired crop may not be included in the table. In this event, a new baseline must be developed.

The data needed to develop the new baseline for a crop must be collected in the field. Infrared thermometer and Bendix psychrometer temperature measurements should be taken from as many recently irrigated fields as practical. Several readings should be made between 9 a.m. and 3 p.m. in each field to sample a range of temperature and humidity conditions.

Analysis of the data requires computing the temperature depression (Tc-Ta) and the vapor pressure deficit (VPD) for each set of measurements (see [B] and [C] in the hand calculation example to follow). New versions of the infrared thermometer display these measurements directly. A graph similar to Figure 4 is next prepared. Plot the VPD and (Tc-Ta) values for each set of measurements. The coefficients of the well-watered baseline are then determined using a standard linear regression process. The coefficients can now be used for making future CWSI computations.

5 - SCHEDULING IRRIGATIONS

Starting Irrigation Service to a New Field

Once a field has been enrolled to receive irrigation scheduling services, several preliminary activities are required before active scheduling can begin. This discussion assumes that the necessary equipment and technicians are available to provide the scheduling service. Preliminary activities include selecting a site for the access tube, installing an access tube, and determining the "refill and full points."

Locating Access Tube Site

Selecting the proper site for tube installation requires analysis of several factors including (1) accessibility to the tube, (2) method of irrigation, (3) soil type, and (4) crop stand and crop cover.

Accessibility. The tube should be located where it is readily accessible from normally traveled roadways. If possible, tubes should be located away from areas that may cause frequent hindrances to vehicle or foot travel. Tube accessibility will have a bearing on the number of sites that can be read in a day by a technician.

Irrigation Method. With any type of flood irrigation system, the tube should be located in the third quarter of the field below the head ditch. The first and second quarters may be over irrigated and should be avoided. The fourth quarter of the field, furthest from the head ditch, may receive insufficient water or may have excess water ponded. Tube location is not critical with drip or sprinkler irrigation systems except that tubes should not be placed directly under a sprinkler head or adjacent to an emitter. Theoretically, all parts of the field receive the same amount of water from these systems. The extreme edges, high or low spots, or obvious dry spots in the field should be avoided.

Soil Types. The access tube should be located in the area containing the predominate or representative soil in the field to achieve most uniform results. Extremely sandy or clay soils should be avoided, if possible. Adjustments can be made in the refill point to accommodate these soil types if they represent significant portions of the field.

Crop Stand. The tubes should be located where crop stands are uniform and healthy. Stunted, bare, or weedy areas should be avoided. These areas do not represent normal consumptive use or soil conditions.

Installing Access Tubes

The installation of access tubes is a simple procedure, if the proper equipment is available and good work methods are employed. A 2-inch hole is bored several inches deeper than the length of the tube to be installed. The extra depth collects any soil that might slough off the sides of the hole as the tube is driven into the ground. A hand auger is adequate but a power auger is preferred for boring the hole. Be careful to avoid over-sizing the hole diameter when using the power auger. There should be no air spaces around the tube. Loose soil deposited around the mouth of the hole should be carefully cleaned away from the hole before inserting the tube.

The tube is inserted into the hole, sealed end first. It is pushed down by hand and driven in flush with the ground surface using the tube driver. In some installations, tubes are not susceptible to equipment damage and do not need to be installed flush with the ground. However, uniformly installing all tubes flush with the ground surface will insure that all measurements are taken at consistent depths. Any loose soil around the top of the tube can be compacted. A brightly painted cap should be placed on the tube as soon as the installation is complete.

The tube location can be marked with a stake and flagging for easy location by the technician. In some situations the stake would disrupt cultural operations (like cutting alfalfa). In this case, the stake should be placed at the edge of the field. It should be marked with the number of paces between the stake and the tube.

Determining Refill Point

The refill point, or minimum allowable SMC at the time of irrigation, is established in the top foot of the soil profile using one or a combination of three criteria: (1) at what depletion should irrigation result in optimum yields; (2) at what depletion would the crop show water stress; and (3) how dry would the farmer allow the soil to become before irrigating.

Using Optimum Moisture Content. Most crops can tolerate some stress before yields are affected. The moisture content at which irrigation should result in optimum yield, can be identified by measuring the water content using the gauge and the soil moisture tension using a tensiometer. Research has identified an optimum moisture tension for many crops. Irrigating before reaching the optimum tension can waste water and retard plant growth. Delaying irrigations beyond the optimum tension reduces crop yield. The refill point is the moisture content that occurs at the optimum soil moisture tension. Unfortunately, the tensiometer has been unsatisfactory for large-scale irrigation scheduling activities. It has limited reliability and requires too much labor to keep the tensiometer operating properly. The accuracy of this method depends upon the reliability of the tensiometers and how closely local conditions duplicate conditions where optimum tensions were determined.

Using Crop Water Stress Index (CWSI). The infrared thermometer is showing promise in identifying the optimum moisture content. The CWSI, determined with the infrared thermometer, is compared to the SMC measured with the gauge. The refill point is the moisture content that is measured when the optimum CWSI occurs. As previously mentioned, the optimum CWSI for cotton and wheat are 0.45 and 0.3, respectively. Research is continuing to determine the optimum CWSI for other crops. This optimum value may vary depending upon the stage of growth. This is the most accurate method for determining the refill point.

The CWSI is computed using data collected with infrared thermometer and Bendix psychrometer. The computations can be made using a computer or by hand. Newer versions of the infrared thermometer display the CWSI directly.

The computer program VEGY, developed by the Bureau of Reclamation, Yuma Area Office, can be used to make the computations. (Instructions for using VEGY along with a program listing can be found in Appendix E.) Field readings from the Plant Foliage Temperature Data Sheet (see Figure 12) are entered into Program VEGY to compute the CWSI. Final output for two fields, S10 and 9, is shown in Figure 15. Note that field S10 is still well-watered with a CWSI of only 0.02. Field 9 is considered in a stress state with a CWSI of 0.45. Remember, CWSI ranges from 0.0 to 1.0.

Hand calculating the CWSI is a rather lengthy procedure, where errors are easily made. The field data used in the calculations are shown in Figure 18. Other values required in the computation are determined from Appendixes A and B. The procedure is illustrated in Figure 19 to show how the CWSI is derived.

Using Observation of Visible Stress. The soil moisture depletion at which the crop shows water stress can also be used to establish the refill point. The refill point would be the moisture content measured at the time stress is first noted. Salt or similar influences are accommodated by minor upward adjustments of the refill point until such stress is not observable. Setting the refill point by this method is not as accurate as previously discussed methods. However, it will produce acceptable results that can improve irrigation efficiency and crop yields.

Using Farmer's Judgement. Finally, the farmer's judgement and experience can be used to set the refill point. The refill point would be the moisture content measured just before the beginning of a normal irrigation. This is usually the least accurate method for determining refill points.

The refill points established using observed stress or the farmer's judgement are the easiest to obtain and often the most agreeable to the farmer. The other methods can be used to refine these refill points. These refinements may have to be made gradually over a period of several irrigations to be acceptable to the farmer.

```
                         CROP WATER STRESS INDEX COMPUTATIONS
                                      11/15/90
                                      Page  1

    SAMPLE    SAMPLE
     DATE      TIME     CROP            FIELD
    4/22/95    1410     WHEAT           S10

DRY BULB  WET BULB              SAMPLE TEMPERATURES                      DATA
  TEMP      TEMP    (1)  (2)  (3)  (4)  (5)  (6)  (7)  (8)   WIND  QUALITY
  24.7      15.0    23.5 23.7 23.7 23.4 23.6 23.2 23.2 22.8  4 SE   GOOD

        SLOPE:                                                -3.25

        OFFSET:                                                3.38

        TC-TA                                                 -1.31 C

        VAPOR PRESSURE DEFICIT:                                2.04 KPA

        UPPER LIMIT:                                           5.61 C

        CROP WATER STRESS INDEX:                               0.22

        RELATIVE HUMIDITY:                                    34.28%

                             - - - - - - - - - -
    SAMPLE    SAMPLE
     DATE      TIME     CROP            FIELD
    4/22/95    1410     WHEAT           9

DRY BULB  WET BULB            SAMPLE TEMPERATURES                        DATA
  TEMP      TEMP    (1)  (2)  (3)  (4)  (5)  (6)  (7)  (8)  WIND   QUALITY
  27.7      14.2    28.9 29.0 28.4 26.4 27.5 27.5 27.2 27.3 10 N     GOOD

        SLOPE:                                               -3.25

        OFFSET:                                               3.38

        TC-TA                                                  .07 C

        VAPOR PRESSURE DEFICIT:                               2.98 KPA

        UPPER LIMIT:                                          4.30 C

        CROP WATER STRESS INDEX:                              0.45

        RELATIVE HUMIDITY:                                   19.73%
```

Figure 17
Sample Printout from Program VEGY

Establishing Full Point

Both the refill and full points must be identified to establish the soil moisture holding capacity of any field. The full point, an approximation of field capacity, is the amount of moisture in the soil after initial drainage has removed the excess water. It is the total of the moisture contents in each foot of soil profile. This measurement is taken 1 or 2 days after the irrigation. The technician must be able to walk on the field without sinking into the soil or causing damage to the crop.

```
                      CROP WATER STRESS INDEX COMPUTATIONS
                                    11/15/90
                                    Page  1

    SAMPLE    SAMPLE
     DATE      TIME      CROP            FIELD
    ------    ------     ----            -----
    7/25/95     1215     COTTON          S10

DRY BULB  WET BULB             SAMPLE TEMPERATURES                DATA
  TEMP      TEMP    (1)  (2)  (3)  (4)  (5)  (6)  (7)  (8) WIND QUALITY
--------  -------- ---- ---- ---- ---- ---- ---- ---- ---- ---- -------
  37.0      20.0   30.0 31.7 32.1 32.3 32.2 32.3 32.8 32.1 5 SSE  GOOD

        SLOPE:                                             -2.24

        OFFSET:                                             2.00

        TC-TA                                              -5.06 C

        VAPOR PRESSURE DEFICIT:                             5.06 KPA

        UPPER LIMIT:                                        3.09 C

        CROP WATER STRESS INDEX:                            0.17

        RELATIVE HUMIDITY:                                 19.33%
```

Figure 18
Data for CWSI Hand Calculation Example

Visiting Fields

Once access tube installation is complete and the refill point has been established, field irrigation scheduling can be started. Biweekly readings are taken at predetermined depths. Cool-climate crops require less frequent readings. The readings, in inches of moisture, are plotted on a graph or entered into a computer. Usually, three measurements are taken in the first 3 feet of depth. Crops, such as fruit trees, that have deeper penetrating roots will require additional readings at greater depths. Each set of readings will give the current moisture content. Consecutive readings will give the rate of water use by the crop.

Accurate moisture readings are essential to schedule irrigations precisely. The technician must ensure that the equipment works properly, readings are taken correctly, and the site is protected. Before going to the field, the technician should verify the proper operation of the gauge. This is done by taking a measurement on one of the standardization barrels. The reading should be within ±0.05 in/ft of the barrel's moisture content, if using the DR-503. The reading with an S-503 should be within plus or minus one standard deviation of the average count. (The average count was determined during standardization of the gauge).

Sample Date:	7-25-83	Crop:	Cotton
Field:	5	USBR Slope	-1.70
C = Centigrade		USBR Intercept	1.90

(Tc-Ta) = -1.70 (VPD) + 1.92 (Equation of Well-Watered Baseline)

[B]. (Tc-Ta) = 31.94 C - 37.0 C db = -5.06 C (Actual Temperature Depression)

[A]. Upper Limit Value

Saturation Vapor Pressure of db Temp. (Appendix A)	47.067
Saturation Vapor Pressure of (db Temp. + 1.92)	-52.161
Vapor Pressure Difference in MM Hq	- 5.094
VPD in mm Hq = -5.094 x constant 1.3331 = VPD in mb	- 6.791
VPD in mb = 6.791 ÷ constant 10 = VPD in Kpa	- .679
(Tc - Ta) ul = -.679 x slope -1.70 + offset +1.92	+ 3.07

[C]. Well-Watered Value

Saturation Vapor Pressure of db Temp. (Appendix A)	47.067
Relative Humidity in Field from Wet- and Dry-Bulb	x .193
Existing Vapor Pressure in mm Hg	9.084
Saturation Vapor Pressure of db Temp.	47.067
Existing Vapor Pressure in mm Hg	- 9.084
Vapor Pressure Deficit in mm Hg	37.983
Vapor Pressure Deficit in mm Hg	37.983
Constant	x 1.3331
Vapor Pressure Deficit in mb	50.635
Vapor Pressure Deficit in mb ÷ 10 = Vapor Pressure Deficit in Kpa =	5.063
Vapor Pressure Deficit in Kpa =	5.063
$(Tc\text{-}Ta)_{ww}$ = 5.063 x (-1.70) + 1.92	- 6.687

$$CWSI = \frac{[B] - [C]}{[A] - [C]} = \frac{(-5.06) - (-6.687)}{(3.07) - (-6.687)} = .167 \text{ or } .17 \text{ (rounded)}$$

Note: If B is a larger number than C and they are both negative, the CWSI will be negative.

Figure 19
Hand Calculating Crop Water Stress Index

Upon arriving at the field, the technician should exercise caution when approaching the site, placing the gauge on the access tube, and taking readings. This is to insure that the crop growth around the tube is not trampled. Otherwise, the consumptive use measured at the site will not represent healthy crop stands in the remainder of the field. Protecting the crop is essential in maintaining good relations with the farmer.

Moisture readings are taken at about the 6-inch, 18-inch, and 30-inch depths. These readings will be centered in the 1st-foot, 2nd-foot, and 3rd-foot zones. Fewer reading intervals may be required for shallow-rooted crops while deep-rooted crops may require more reading intervals. Readings are taken according to previously described procedures. The reading, read directly from the display or determined from a conversion table, should be written in the space provided and plotted immediately on a field graph. A sample field graph is shown in Figure 20. The reading can be plotted while the gauge is measuring the next depth so plotting does not require much additional time. (Note: Appendix D contains a blank field graph that can be duplicated as needed for use in the field.)

Plotting readings as they are taken serves several purposes. The chance of an occasional stray reading or error in interpretation can be quickly spotted and the measurement retaken. If needed, the next irrigation can be immediately determined at the site. Use a straight edge to project a line through the last two readings to the refill line. Read the date where the projected line and the refill line intersect. By noting the date and the surrounding conditions, the technician may identify unusual conditions. Anything unusual should be brought to the farmer's attention. Several crops have been saved by the alert observations of field technicians.

Before leaving the site, the technician should insure that the probe has been retracted and securely locked in place in the gauge case. The cap should also be securely replaced on the tube. Otherwise, irrigation water could fill the tube and damage the probe the next time a reading is taken.

Field technicians have noted that readings taken at the access tube site may, in some cases, not always represent conditions found throughout the majority of the field. The most frequently occurs when the field is not uniformly irrigated. As a result, some parts of the field may be under irrigated while other parts are over irrigated. When the technician suspects that this may be the case, a hand soil probe should be used to sample several locations in the field and use the "feel method" to determine and compare moisture contents. When this condition is noted, the farmer should be advised. This effort may help save a portion of the crop and offers an opportunity to consult with the farmer on ways to improve the efficiency of the irrigation program.

After measuring all the sites on the assigned route, the technician should submit the data for computer preparation of schedules, if a computer is being used. Otherwise, the technician should transfer projected dates and amounts to a summary report sheet that can be given to the farmer. If printed irrigation schedules are used, the technician should compare projected dates shown on the printout with the graphs in the field book. Any corrections should be entered into the computer. A new schedule should be

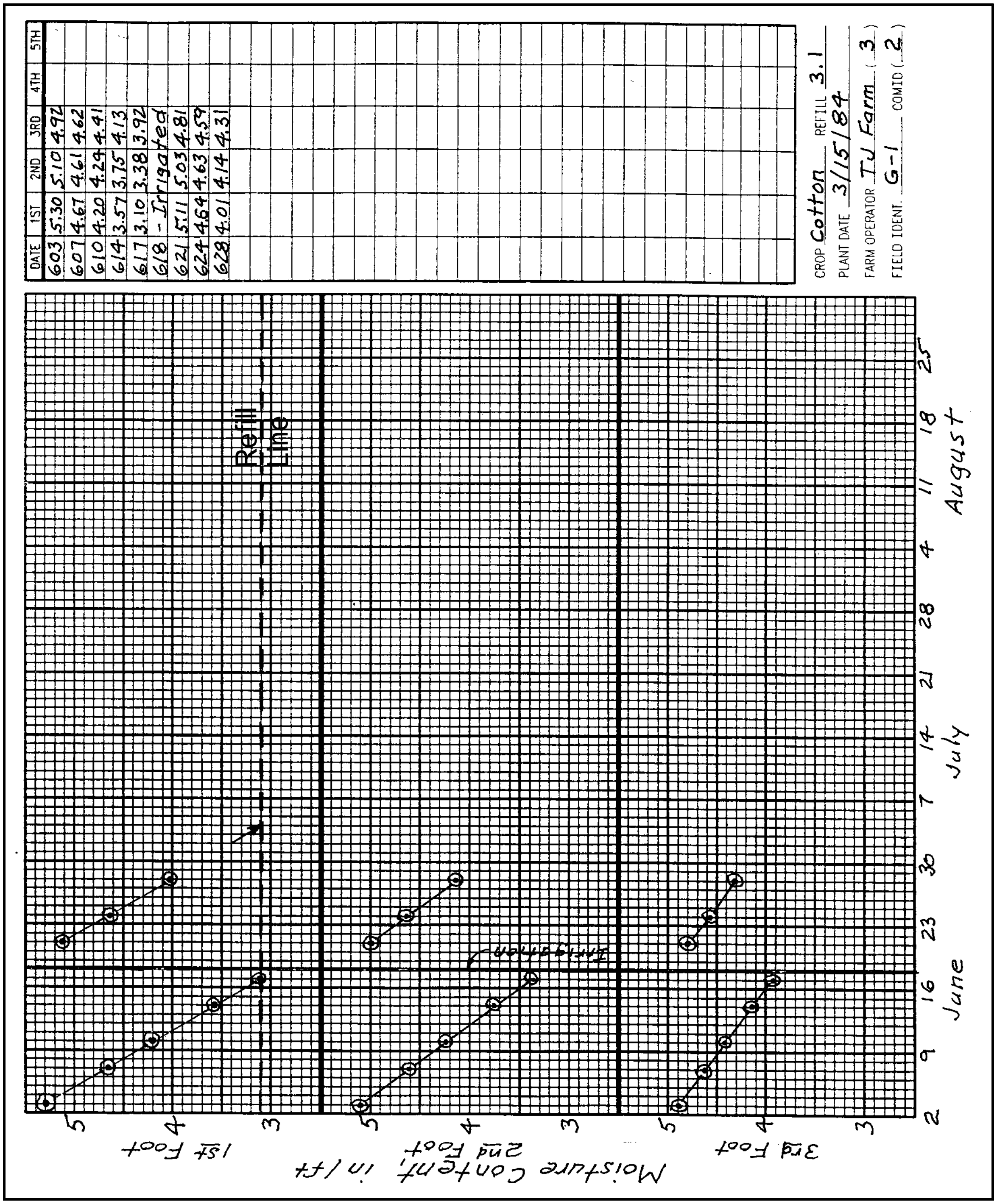


Figure 20
Sample Field Graph

printed so the printed dates and amounts agree with the field graphs. A simple summary form that can be given to the farmers is shown in Figure 21. A blank form is in Appendix D. A computer-generated irrigation schedule is shown in Figure 22.

Contacting Farmers

Several methods are available to get the completed report or schedule to the farmer. The report or schedule can be sent by mail, delivered to the secretary or a family member, put in farmer's truck, etc. However, the most effective method is by direct contact. Experience has repeatedly shown in the LC Region that the farmers who most closely follow the recommendations have received the most frequent personal contact by the field technicians. Personal contacts can include a walk through the field with the farmer, a roadside discussion, a meeting at the local coffee shop, or a visit to the farmer's home or office. Any other means where the technician and farmer can discuss the farmer's irrigation activities, field and crop conditions, and any other information about the farmer's overall operation are also appropriate. Regular meeting schedules are often impossible to establish with farmers. Other means to get scheduling reports to the farmer in a timely manner will beneficially supplement personal contacts.

Remember, good personal contacts are essential to effective irrigation scheduling.

DATE___________________________

WATER USER ____________________

CONTRACT NO. __________________

FIELD NO.	PROJECTED IRRIG. DATE	REFILL AMOUNT

303-41 (Rev. 5-92)
(File Copy)

DATE___________________________

WATER USER ____________________

CONTRACT NO. __________________

FIELD NO.	PROJECTED IRRIG. DATE	REFILL AMOUNT

303-41 (Rev. 5-92)
(Farmer's Copy)

Figure 21
Sample Farmer Report Form

BUREAU OF INDIAN AFFAIRS
Route 1 Box 9c
Parker, AZ 85344
662-4358

DATE: APR 26

CRIT FARMS
P O BOX 1028
PARKER AZ 85344

FIELD, CROP AND ACRES			IRRIGATIONS NEXT DATE	NEXT AMT IN.	NEXT AMT AC-FT	LAST DATE	LAST AMT IN.	LAST AMT AC-FT
12	ALF	38	5/ 3	5.7	18.0	4/19	4.2	13.3
16	ALF	37	5/ 3	5.7	17.6	4/19	5.4	16.7
17	ALF	37	5/ 9	5.7	17.6	4/21	3.0	9.3
21	ALF	36	4/29	4.0	12.0	4/16	.0	.0
22	ALF	37	5/ 9	5.6	15.4	4/21	6.8	21.0
26	ALF	36	5/ 7	5.6	16.8	4/16	11.9	35.7
27	ALF	36	5/ 7	4.2	12.6	4/18	10.8	32.4
30	ALF	35	5/ 7	4.0	11.9	4/18	8.7	25.4
31	ALF	35	5/ 7	5.3	15.5	4/18	11.1	32.4
41	ALF	38	4/30	4.2	13.2	4/18	6.3	20.0
45	ALF	37	*****			4/20	.0	.0
46	ALF	35	5/ 3	4.0	12.0	4/18	.0	.0
48	ALF	35	4/29	4.6	13.8	4/18	.0	.0
49	ALF	38	4/29	3.5	10.9	4/18	.0	.0
56	ALF	35	4/23*	3.5	10.5	4/14	7.4	21.6
2- 2	ALF	32	4/27	3.4	9.1	4/14	17.3	46.1
2- 3	ALF	25	4/26	5.0	10.4	4/13	3.2	6.7
2- 8	ALF	16	4/26	3.4	4.2	4/14	5.0	6.7
2-11	ALF	21	4/25*	5.1	8.9	4/13	4.5	7.9
2-13	ALF	52	4/28	4.2	16.2	4/12	4.2	18.2
2-16	ALF	29	4/27	4.5	10.9	4/10	8.1	19.6
2-17	ALF	30	4/27	4.6	11.5	4/10	3.9	9.8

* - FIELD OVERDUE FOR IRRIGATION
***** - IRRIGATION NOT REQUIRED BEFORE MAY 10

Figure 22
Sample Computer Generated Farm Irrigation Schedule

APPENDIX A

Relative Humidity, Percent – Centigrade Temperatures

Appendix A

Relative Humidity, Percent - Centigrade Temperatures

[Pressure=29.24 in.]

Air temperature(t)	Depression of wet-bulb thermometer(t-t')														
	7.6	7.7	7.8	7.9	8.0	8.1	8.2	8.3	8.4	8.5	8.6	8.7	8.8	8.9	9.0
8.................	12	11	10	9	8	7	6	5							
9.................	16	15	14	13	12	11	10	9	8	7	6	5			
10................	19	18	17	16	15	14	13	12	11	10	9	8	7	7	6
11................	22	21	20	19	18	17	16	15	14	13	13	12	11	10	9
12................	24	23	22	22	21	20	19	18	17	16	16	15	14	13	13
13................	27	26	25	24	23	22	22	21	20	19	18	17	17	16	15
14................	29	28	27	27	26	25	24	23	22	22	21	20	19	18	18
15................	31	30	29	28	27	27	26	25	24	24	23	22	22	21	20
16................	33	32	32	31	30	29	29	28	27	26	26	25	24	23	23
17................	35	34	34	33	32	31	31	30	29	28	28	27	26	26	25
18................	37	36	35	35	34	33	33	32	31	30	30	29	28	28	27
19...............	39	38	37	36	36	35	34	34	33	32	32	31	30	30	29
20................	40	39	39	38	37	37	36	35	35	34	33	33	32	31	31
21................	42	41	40	40	39	38	38	37	36	36	35	34	34	33	32
22................	43	42	42	41	40	40	39	39	38	37	37	36	35	35	34
23................	44	44	43	42	42	41	41	40	39	39	38	38	37	36	36
24................	46	45	44	44	43	43	42	41	41	40	40	39	38	38	37
25................	47	46	46	45	44	44	43	43	42	41	41	40	40	39	39
26................	48	47	47	46	46	45	44	44	43	43	42	42	41	40	40
27................	49	48	48	47	47	46	46	45	44	44	43	43	42	42	41
28................	50	49	49	48	48	47	47	46	46	45	44	44	43	43	42
29...............	51	50	50	49	49	48	48	47	47	46	46	45	44	44	43
30................	52	51	51	50	50	49	49	48	48	47	47	46	45	45	44
31................	53	52	52	51	51	50	50	49	49	48	48	47	47	46	45
32................	54	53	52	52	51	51	50	50	49	49	48	48	47	47	46
33................	54	54	53	53	52	52	51	51	50	50	49	49	48	48	47
34................	55	55	54	54	53	53	52	52	51	51	50	50	49	49	48
35................	56	55	54	54	54	53	53	52	52	51	51	50	50	49	49
36................	56	56	55	55	54	54	53	53	53	52	52	51	51	50	50
37................	57	57	56	56	55	55	54	54	53	53	52	52	51	51	51
38................	58	57	57	56	56	55	55	55	54	54	53	53	52	52	51
39................	58	58	57	57	57	56	56	55	55	54	54	53	53	52	52
40................	59	59	58	58	57	57	56	56	55	54	54	54	54	53	53
41................	60	59	59	58	58	57	57	56	56	56	55	55	54	54	53
42................	60	60	59	59	58	58	57	57	57	56	56	55	54	54	54
43................	61	60	60	59	59	58	58	58	57	57	56	56	55	55	55
44................	61	61	60	60	59	59	58	58	58	57	57	56	56	56	55

Appendix A

Relative humidity, percent-centigrade temperatures-Continued

[Pressure=29.24 in.]

Air tempreature(t)	Depression of wet-bulb thermometer(t-t')														
	9.1	9.2	9.3	9.4	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.2	10.3	10.4	10.5
10....................	5														
11....................	8	7	6	6	5										
12....................	11	10	10	9	8	7	6	5	5						
13..................	14	13	13	12	11	10	9	9	8	7	6	6	5		
14..................	17	16	15	15	14	13	12	11	11	10	9	8	8	7	6
15..................	20	19	18	17	16	16	15	14	13	13	12	11	11	10	9
16..................	22	21	20	20	19	18	17	17	16	15	15	14	13	13	12
17..................	24	23	23	22	21	21	20	19	18	18	17	16	16	15	14
18..................	26	26	25	24	23	23	22	21	21	20	19	19	18	17	17
19..................	28	28	27	26	26	25	24	24	23	22	22	21	20	20	19
20..................	30	29	29	28	28	27	26	26	25	24	24	23	22	22	21
21..................	32	31	31	30	29	29	28	28	27	26	26	25	24	24	23
22..................	34	33	32	32	31	30	30	29	29	28	28	27	26	26	25
23..................	35	34	34	33	33	32	32	31	30	30	29	29	28	27	27
24..................	37	36	35	35	34	34	33	33	32	31	31	30	30	29	29
25..................	38	37	37	36	36	35	35	34	33	33	32	32	31	31	30
26..................	39	39	38	38	37	37	36	35	35	34	34	33	33	32	32
27..................	41	40	39	39	38	38	37	37	36	36	35	35	34	34	33
28..................	42	41	41	40	40	39	39	38	38	37	36	36	35	35	34
29..................	43	42	42	41	41	40	40	39	39	38	38	37	37	36	36
30..................	44	43	43	42	42	41	41	40	40	39	39	38	38	37	37
31..................	45	44	44	43	43	42	42	41	41	40	40	40	39	39	38
32..................	46	45	45	44	44	43	43	42	42	41	41	41	40	40	39
33..................	47	46	46	45	45	44	44	43	43	42	42	42	41	41	40
34..................	48	47	47	46	46	45	45	44	44	43	43	43	42	42	41
35..................	49	48	48	47	47	46	46	45	45	44	44	44	43	43	42
36..................	49	49	48	48	48	47	47	46	46	45	45	44	44	44	43
37..................	50	50	49	49	48	48	47	47	47	46	46	45	45	44	44
38..................	51	50	50	50	49	49	48	48	47	47	46	46	46	45	45
39..................	52	51	51	50	50	49	49	48	48	48	47	47	46	46	46
40..................	52	52	51	51	51	50	50	49	49	48	48	48	47	47	46
41..................	53	52	52	52	51	51	50	50	50	49	49	48	48	47	47
42..................	53	53	53	52	52	51	51	51	50	50	49	49	48	48	48
43..................	54	54	53	53	52	52	52	51	51	50	50	50	49	49	48
44..................	55	54	54	53	53	53	52	52	51	51	51	50	50	49	49

Appendix A

Relative humidity, percent-centigrade temperatures-Continued

[Pressure=29.24 in.]

Air tempreature(t)	Depression of wet-bulb thermometer(t-t')														
	10.6	10.7	10.8	10.9	11.0	11.1	11.2	11.3	11.4	11.5	11.6	11.7	11.8	11.9	12.0
14........................	6	5													
15........................	8	8	7	6	6	5									
16........................	11	10	10	9	8	8	7	6	6	5					
17......................	14	13	12	12	11	10	10	9	8	8	7	6	6	5	
18......................	16	15	15	14	14	13	12	12	11	10	10	9	8	8	7
19......................	18	18	17	17	16	15	15	14	13	13	12	12	11	10	10
20......................	21	20	19	19	18	18	17	16	16	15	15	14	13	13	12
21......................	23	22	22	21	20	20	19	19	18	17	17	16	16	15	14
22......................	25	24	23	23	22	22	21	20	20	19	19	18	18	17	17
23......................	26	26	25	25	24	24	23	22	22	21	21	20	20	19	19
24......................	28	27	27	26	26	25	25	24	24	23	23	22	21	21	20
25......................	30	29	29	28	28	27	26	26	25	25	24	24	23	23	22
26......................	31	31	30	30	29	28	28	27	27	26	26	25	25	24	24
27......................	33	32	32	31	31	30	30	29	29	28	28	27	27	26	26
28......................	34	33	33	32	32	31	31	30	30	29	29	28	28	27	27
29......................	35	35	34	34	33	33	32	32	31	31	30	30	29	29	28
30......................	36	36	35	35	35	34	34	33	33	32	32	31	31	30	30
31......................	38	37	37	36	36	35	35	34	34	33	33	32	32	32	31
32......................	39	38	38	37	37	36	36	36	35	35	34	34	33	33	32
33......................	40	39	39	38	38	37	37	36	36	36	35	35	34	34	33
34......................	41	40	40	39	39	39	38	38	37	37	36	36	35	35	35
35......................	42	41	41	40	40	40	39	39	38	38	37	37	37	36	36
36......................	43	42	42	41	41	40	40	40	39	39	38	38	38	37	37
37......................	44	43	43	42	42	41	41	41	40	40	39	39	38	38	38
38......................	44	44	44	43	43	42	42	41	41	41	40	40	39	39	39
39......................	45	45	44	44	43	43	43	42	42	42	41	41	40	40	39
40......................	46	46	45	45	44	44	44	43	43	42	42	42	41	40	40
41......................	47	46	46	45	45	45	44	44	43	43	43	42	42	41	41
42......................	47	47	46	46	46	45	45	45	44	44	43	43	43	42	42
43......................	48	48	47	47	46	46	46	45	45	44	44	44	43	43	43
44......................	49	48	48	47	47	47	46	46	46	45	45	44	44	44	43

Appendix A

Relative humidity, percent-centigrade temperatures-Continued

[Pressure=29.24 in.]

Air Temperature (t)	Depression of wet-bulb thermometer(t-t')														
	12.1	12.2	12.3	12.4	12.5	12.6	12.7	12.8	12.9	13.0	13.1	13.2	13.3	13.4	13.5
18...............	7	6	5	5											
19...............	9	9	8	7	7	6	6	5							
20...............	12	11	10	10	9	9	8	7	7	6	6	5	5		
21...............	14	13	13	12	12	11	10	10	9	9	8	8	7	7	6
22...............	16	15	15	14	14	13	13	12	12	11	10	10	9	9	8
23...............	18	17	17	16	16	15	15	14	14	13	13	12	12	11	11
24...............	20	19	19	18	18	17	17	16	16	15	15	14	14	13	13
25...............	22	21	21	20	20	19	19	18	18	17	17	16	16	15	15
26...............	23	23	22	22	21	21	20	20	19	19	19	18	18	17	17
27...............	25	25	24	24	23	23	22	22	21	21	20	20	19	19	18
28...............	27	26	26	25	25	24	24	23	23	22	22	21	21	20	20
29...............	28	28	27	27	26	26	25	25	24	24	23	23	22	22	22
30...............	29	29	28	28	28	27	27	26	26	25	25	24	24	24	23
31...............	31	30	30	29	29	28	28	28	27	27	26	26	25	25	25
32...............	32	31	31	31	30	30	29	29	28	28	28	27	27	26	26
33...............	33	32	32	32	31	31	30	30	30	29	29	28	28	28	27
34...............	34	34	33	33	32	32	32	31	31	30	30	30	29	29	28
35...............	35	35	34	34	34	33	33	32	32	32	31	31	30	30	30
36...............	36	36	35	35	35	34	34	33	33	33	32	32	31	31	31
37...............	37	37	36	36	36	35	35	34	34	34	33	33	33	32	32
38...............	38	38	37	37	37	36	36	35	35	35	34	34	33	33	33
39...............	39	39	38	38	38	37	37	36	36	36	35	35	34	34	34
40...............	40	40	39	39	38	38	38	37	37	36	36	36	35	35	35
41...............	41	40	40	40	39	39	39	38	38	37	37	37	36	36	36
42...............	42	41	41	40	40	40	39	39	39	38	37	37	37	37	36
43...............	42	42	42	41	41	40	40	40	39	39	39	38	38	38	37
44...............	43	43	42	42	42	41	41	40	40	40	39	39	39	38	38

APPENDIX B

Vapor Pressure of Water Below 100 ^{o}C

VAPOR PRESSURE OF WATER BELOW 100°

Pressure of aqueous vapor over water in mm of Hg for temperatures from -15.8 to 100° C
Values for fractional degrees between 50 and 89 were obtained by interpolation.

Temp °C	0.0	0.2	0.4	0.6	0.8	Temp °C	0.0	0.2	0.4	0.6	0.8
-15	1.436	1.414	1.390	1.368	1.345	12	10.518	10.658	10.799	10.941	11.085
-14	1.500	1.534	1.511	1.483	1.460	13	11.231	11.379	11.528	11.680	11.833
-13	1.691	1.685	1.637	1.611	1.585	14	11.987	12.444	12.302	12.462	12.624
-12	1.834	1.804	1.776	1.748	1.720	15	12.788	12.953	13.121	13.290	13.461
-11	1.987	1.955	1.924	1.893	1.863	16	13.643	13.809	13.897	14.166	14.347
-10	2.149	2.116	2.084	2.050	2.018	17	14.530	14.715	14.903	15.092	15.284
- 9	2.326	2.289	2.254	2.219	2.184	18	15.477	15.673	15.871	16.071	16.272
- 8	2.514	2.475	2.437	2.399	2.362	19	16.477	16.685	16.894	17.105	17.319
- 7	2.715	2.674	2.633	2.593	2.553	20	17.535	17.753	17.974	18.197	18.422
- 6	2.931	2.887	2.843	2.800	2.757	21	18.650	18.880	19.113	19.349	19.587
- 5	3.163	3.115	3.069	3.022	2.976	22	19.827	20.070	20.316	20.565	20.815
- 4	3.410	3.359	3.309	3.259	3.211	23	21.068	21.234	21.583	21.845	22.110
- 3	3.673	3.620	3.567	3.514	3.461	24	22.377	22.648	22.922	23.198	23.476
- 2	3.956	3.808	3.841	3.785	3.730	25	23.756	24.039	24.326	24.617	24.912
- 1	4.258	4.196	4.135	4.075	4.016	26	25.209	25.509	25.812	26.117	26.426
- 0	4.579	4.513	4.448	4.385	4.320	27	26.739	27.055	27.374	37.696	28.021
0	4.579	4.647	4.715	4.785	4.855	28	28.349	28.680	29.015	29.354	29.697
1	4.296	4.998	5.070	5.144	5.219	29	30.043	30.392	30.745	31.102	31.461
2	5.294	5.370	5.447	5.525	5.605	30	31.824	32.191	32.561	32.934	33.312
3	5.685	5.766	5.848	5.931	6.015	31	33.695	34.082	34.471	34.864	35.261
4	6.101	6.187	6.274	6.363	6.453	32	35.663	36.068	36.477	36.891	37.308
5	6.543	6.635	6.728	6.822	6.917	33	37.729	38.155	38.584	39.018	39.457
6	7.013	7.111	7.209	7.309	7.411	34	39.898	40.344	40.796	41.251	41.710
7	7.513	7.617	7.722	7.828	7.936	35	42.175	42.644	43.117	43.595	44.078
8	8.045	8.155	8.267	8.380	8.494	36	44.563	45.054	45.549	46.050	46.556
9	8.609	8.727	8.845	8.965	9.086	37	47.067	47.582	48.102	48.627	49.157
10	9.209	9.333	9.458	9.585	9.714	38	49.692	50.231	50.774	51.323	51.879
11	9.844	9.976	10.109	10.244	10.380	39	52.442	53.009	53.580	54.156	54.737

VAPOR PRESSURE OF WATER BELOW 100°-Continued
Pressure of aqueous vapor over water in mm of Hg for temperatures from -15.8 to 100° C
Values for fractional degrees between 50 and 89 were obtained by interpolation.

Temp °C	0.0	0.2	0.4	0.6	0.8	Temp °C	0.0	0.2	0.4	0.6	0.8
40	55.324	55.91	56.51	57.11	57.72	71	243.9	246.0	248.2	250.3	252.4
41	58.34	58.96	59.58	60.22	60.86	72	254.6	256.8	259.0	261.2	263.4
42	61.50	62.14	62.80	63.46	64.12	73	265.7	268.0	270.2	272.6	274.8
43	64.80	65.48	66.16	66.86	67.56	74	277.2	279.4	281.8	284.2	286.6
44	68.26	68.97	69.69	70.41	71.14	75	289.1	291.5	294.0	296.4	298.8
45	71.88	72.62	73.36	74.12	74.88	76	301.4	303.8	306.4	308.9	311.4
46	75.65	76.43	77.21	78.00	78.80	77	314.1	316.6	319.2	322.0	324.6
47	79.60	80.41	81.23	82.05	82.87	78	327.3	330.0	332.8	335.8	338.2
48	83.71	84.56	85.42	80.28	87.14	79	341.0	343.8	346.6	349.4	352.2
49	88.02	38.90	39.90	90.69	91.59	80	355.1	358.0	361.0	363.8	366.8
50	92.51	93.5	94.4	95.3	96.3	81	369.7	372.6	375.6	378.8	381.8
51	97.20	98.2	99.1	100.1	101.1	82	384.9	388.0	391.2	394.4	397.4
52	102.09	103.1	104.1	105.1	106.2	83	400.6	403.8	407.0	410.2	413.6
53	107.20	108.2	109.3	110.4	111.4	84	416.8	420.2	423.6	426.8	430.2
54	112.51	113.6	114.7	115.8	116.9	85	433.6	437.0	440.4	444.0	447.5
55	118.04	119.1	120.3	121.5	122.6	86	450.9	454.4	458.0	461.6	465.2
56	123.80	125.0	126.2	127.4	128.6	87	468.7	472.4	476.0	479.8	483.4
57	129.82	131.0	132.3	133.5	134.7	88	487.1	491.0	494.7	498.5	502.2
58	136.08	137.3	138.5	139.9	141.2	89	506.1	510.0	513.9	517.8	521.8
59	142.60	143.9	145.2	146.6	148.0	90	525.76	529.77	533.80	537.86	541.95
60	149.38	150.7	152.1	153.5	155.0	91	546.05	550.18	554.35	558.53	562.75
61	156.43	157.8	159.3	160.8	162.3	92	566.99	571.26	575.55	579.87	584.22
62	163.77	165.2	166.8	168.3	169.8	93	538.60	593.00	597.43	601.89	600.38
63	171.38	172.9	174.5	176.1	177.7	94	610.90	615.44	620.01	624.61	629.24
64	179.31	180.9	182.5	184.2	185.8	95	633.90	638.58	643.30	648.05	652.82
65	187.54	189.2	190.9	192.6	194.3	96	657.62	662.45	667.31	672.20	677.12
66	196.09	197.8	199.5	201.3	203.1	97	682.07	687.04	692.05	697.10	702.17
67	204.96	206.8	208.6	210.5	212.3	98	707.27	712.40	717.56	722.75	727.98
68	214.17	216.0	218.0	219.9	221.8	99	733.24	738.24	743.85	749.20	754.58
69	223.73	225.7	227.7	229.7	231.7	100	760.00	765.45	770.93	776.44	782.00
70	233.7	235.7	237.7	239.7	241.8	101	787.57	793.18	798.82	804.50	810.21

APPENDIX C

Equipment Drawings and Specifications

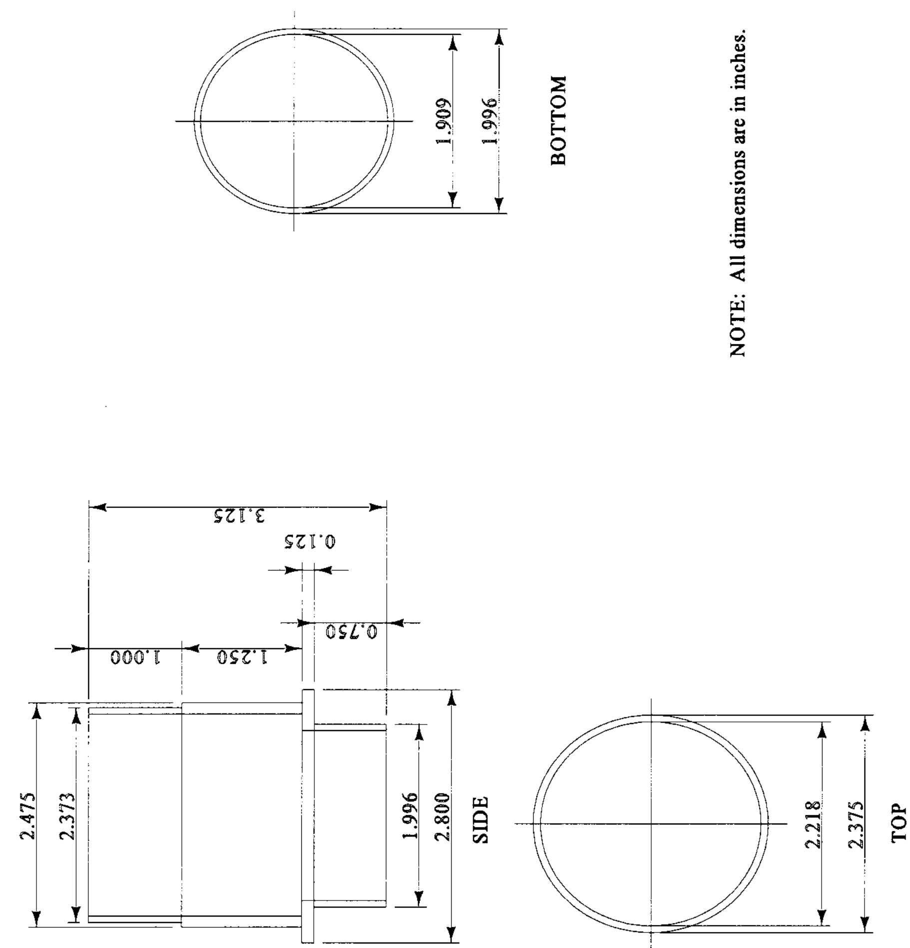


Figure C-1. Neutron Moisture Gauge Access Tube Adapter

APPENDIX D

Blank Field Data Sheets

PLANT FOLIAGE TEMPERATURE DATA SHEET

LOCATION________________________________

YEAR DAY________ DATE__________ BY_________ DATA QUALITY_____

INSTRUMENT

MODEL No.____________ SERIAL No.____________

CALIBRATION CHECK:

TIME	INST.	REF.

WEATHER

SUN_______ HAZE_______ CLOUD TYPE_______ CLOUD COVER_______ WIND SPEED______ WIND DIRECTION____

PRECIP.______________________ IRRIGATION______________________________

COMMENTS:____

TEMPERATURE MEASUREMENTS CROP__________________________

SITE	TIME	FLD	DRY BULB	WET BULB	DIRECTION OF VIEW							
					N	NE	E	SE	S	SW	W	NW
1												
2												
3												
4												
5												
6												
7												
8												
9												

DATE ____________________

WATER USER ____________________

CONTRACT NO. ____________________

FIELD NO.	PROJECTED IRRIG. DATE	REFILL AMOUNT

303-41 (Rev. 5-92)
(File Copy)

DATE ____________________

WATER USER ____________________

CONTRACT NO. ____________________

FIELD NO.	PROJECTED IRRIG. DATE	REFILL AMOUNT

303-41 (Rev. 5-92)
(Farmer's Copy)

DATE	1ST	2ND	3RD	4TH	5TH

CROP ______________ REFILL __________

PLANT DATE ___________________________

FARM OPERATOR _________________ (____)

FIELD IDENT. ___________ COMID (____)

APPENDIX E

Using Program VEGY

USING PROGRAM VEGY

Program VEGY is intended to assist in the computation of the Crop Water Stress Index (CWSI). VEGY was originally written in FORTRAN by the Yuma Area Office in about 1985 for use on the VAX computer. The version discussed here has been converted to BASIC for use on IBM-compatible, personal computers. It can be run with GWBASIC or QBASIC on MS-DOS computers. The program listing is also included for those venturesome individuals who wish to enter the program by hand or convert it to Visual Basic so that it can be run on MS-Windows computers.

Program VEGY is a menu-driven program that presents the user with fill-in-the-blanks screen images for data entry. From the main menu, the user can do the following:

1. Create a new data file,
2. Add data to an existing data file,
3. Correct data in an existing data file,
4. Compute the CWSI,
5. Compute the slope and offset for a crop, and
6. Exit the program.

Program VEGY and its accompanying crop name file, CROPS.DAT, can be located in any convenient subdirectory on the hard drive. It can also be run from a floppy disk if desired. If other Reclamation WMC software programs are in use, VEGY should be located in the same subdirectory.

To start Program VEGY, use the appropriate commands under the following circumstances:

GWBASIC (early versions of MS-DOS) - Type: **GWBASIC VEGY**
QBASIC (MS-DOS ver. 5.0 & later) - Type: **QBASIC /R VEGY**
Compiled Program - Type: **VEGY**

VEGY will display a main menu showing the options listed above. After selecting an option, VEGY will ask for the name of the data file containing existing data or the name of a new file being created. Use an easily understood and remembered name like VEGYDATA.DAT. You may want to use separate files for each batch of data being processed, separate files for different crops, etc. A word of caution here. Data from various crops can be mixed when computing the CWSI but should not be mixed when computing new a slope and offset for a crop. Use a separate file for each crop.

Program Listing - VEGY.BAS

```
10 ' - PROGRAM VEGY.BAS
20 '   DATA ENTRY PROGRAM CREATED BY DATASYS
30 '   AUTHOR:  Michael Stuver
40 '   DATE:    October 24, 1995
50 DIM SL$(30),DL$(50),CROP$(100),VALID$(16),SKEY$(50),RPOINTER(50)
60 FF$=CHR$(12)
70 NP=1
80 SCREEN 0
90 COLOR 15,1
100 FOR I=1 TO 20
110   READ SL$(I)
120 NEXT I
130 FOR I=1 TO 16
140   READ VALID$(I)
150 NEXT I
160 DATA "                         Program VEGY Data Entry Form"
170 DATA ""
180 DATA ""
190 DATA "Sampling Date (7/21/95 = 072195):  .......   "
200 DATA ""
210 DATA "Sampling Time (8:15am = 0815 & 2:15pm = 1415):  ...."
220 DATA ""
230 DATA "Crop Code:  ..                        Field designation: .........."
240 DATA ""
250 DATA "Dry-Bulb Temperature (Deg C):  .....  Wet-Bulb Temperature (Deg C):  ....."
260 DATA ""
270 DATA "                              Temperatures (Deg C)"
280 DATA "        (1):  .....    (2):  .....    (3):  .....    (4):  .....  "
290 DATA "        (5):  .....    (6):  .....    (7):  .....    (8):  ....."
300 DATA ""
310 DATA "Wind Speed:  ..                       Wind Direction:  ..."
320 DATA ""
330 DATA "Slope:  .....                         Offset:  ....."
340 DATA ""
350 DATA "Data Quality Code (1=good, 2=fair, 3=poor):  .."
360 DATA "N  ","NNE","NE ","ENE","E  ","ESE","SE ","SSE"
370 DATA "S  ","SSW","SW ","WSW","W  ","WNW","NW ","NNW"
380 RESTORE
390 OPEN "I",1,"CROPS.DAT"
400 IF EOF(1) THEN 430
410 INPUT#1,I,CROP$(I),Z$
420 GOTO 400
430 CLOSE(1)
440 CLS
450 PRINT "PROGRAM VEGY               PC Ver. 1.0                25 October 1995"
460 PRINT
470 PRINT "                               MAIN MENU"
480 PRINT
490 PRINT "     1 - Start new data file"
500 PRINT "     2 - Add data to existing file"
510 PRINT "     3 - Correct data in existing file"
520 PRINT "     4 - Compute and print CWSI reports"
530 PRINT "     5 - Compute new Slope and Offset"
540 PRINT "           (Do not mix data for several crops in"
550 PRINT "           the same data file.  Use separate Files.)"
560 PRINT "     6 - Exit"
570 PRINT
580 PRINT "     Please Enter your choice:  ";
590 COLOR 14,1
600 LINE INPUT A$
610 COLOR 15,1
620 SEL=VAL(A$)
```

```
630 IF SEL>0 AND SEL<=9 THEN 660
640 PRINT CHR$(7):GOSUB 10120
650 GOTO 580
660 ON SEL GOTO 680,870,1120,1490,1650,1780
670 '
680 '   CHOICE 1 - START NEW DATA FILE
690 '
700 K=1
710 PRINT
720 PRINT "Enter name of data file:  ";
730 COLOR 14,1
740 LINE INPUT D$
750 COLOR 15,1
760 CLS
770 FOR I=1 TO 20
780 PRINT SL$(I)
790 NEXT I
800 'OPEN "O",3,D$
810 GOSUB 1830      '  CALL DATA ENTRY SUBROUTINE
820 IF QUIT=1 THEN 830 ELSE 810
830 NR=K-1
840 'GOSUB 10030     '  PRINT UPDATED DATA FILE
845 GOSUB 10200      '  SORT AND PRINT UPDATED DATA FILE
850 GOTO 440
860 '
870 '   CHOICE 2 - ADD DATA TO EXISTING FILE
880 '
890 PRINT
900 PRINT "Enter name of data file:  ";
910 COLOR 14,1
920 LINE INPUT D$
930 COLOR 15,1
940 OPEN "I",#1,D$
950 K=0
960 IF EOF(1) THEN 1000
970 K=K+1
980 LINE INPUT#1,DL$(K)
990 GOTO 960
1000 CLS
1010 K=K+1
1020 FOR I=1 TO 20
1030 PRINT SL$(I)
1040 NEXT I
1050 QUIT =0
1060 GOSUB 1830      '  CALL DATA ENTRY SUBROUTINE
1070 IF QUIT=1 THEN 1080 ELSE 1060
1080 CLOSE
1081 NR=K-1
1082 'LPRINT NR
1090 'GOSUB 10030     '  PRINT UPDATED DATA FILE
1091 GOSUB 10200     '  SORT AND PRINT UPDATED DATA FILE
1100 GOTO 440
1110 '
1120 '  CHOICE 3 - SUBROUTINE TO CORRECT EXISTING DATA
1130 '
1140 IF D$>"" THEN 1200
1150 PRINT
1160 PRINT "Enter name of data file:  ";
1170 COLOR 14,1
1180 LINE INPUT D$
1190 COLOR 15,1
1200 OPEN "I",1,D$
1210 K=0
1220 IF EOF(1) THEN 1260
1230 K=K+1
```

```
1240 LINE INPUT#1,DL$(K)
1250 GOTO 1220
1260 CLOSE
1270 NR=K
1280 CLS
1290 FOR I=1 TO 20
1300 PRINT SL$(I)
1310 NEXT I
1320 FOR K=1 TO NR
1330 GOSUB 6790
1340 LOCATE 23,1:PRINT "Is this record correct (Y/N)? Y  ";
1350 LOCATE 23,31
1360 COLOR 14,1
1370 LINE INPUT B$
1380 COLOR 15,1
1390 LOCATE 23,1:PRINT "                                      "
1400 IF B$="y" OR B$="Y" THEN 1450
1410 IF B$="" THEN 1450
1420 QUIT=0
1430 GOSUB 1830
1440 IF QUIT=1 THEN 1460
1450 NEXT K
1460 'GOSUB 10030     '  PRINT UPDATED DATA FILE
1461 GOSUB 10200      '  SORT AND PRINT UPDATED DATA FILE
1470 GOTO 440
1480 '
1490 '  CHOICE 4 - COMPUTE AND PRINT CWSI
1500 '
1510 IF D$<="" THEN
1520   PRINT
1530   PRINT "Enter name of data file:  ";
1540   COLOR 14,1
1550   LINE INPUT D$
1560   COLOR 15,1
1570 END IF
1580 GOSUB 7230
1590 LPRINT FF$
1600 LOCATE 23,1,1
1610 PRINT "                                "
1620 CLOSE
1630 GOTO 440
1640 '
1650 '  CHOICE 5 - COMPUTE NEW SLOPE AND OFFSET
1660 '
1670 IF D$>"" THEN 1730
1680 PRINT
1690 PRINT "Enter name of data file:  ";
1700 COLOR 14,1
1710 LINE INPUT D$
1720 COLOR 15,1
1730 OPEN "I",2,D$
1740 GOSUB 8760
1750 CLOSE
1760 GOTO 440
1770 '
1780 '   CHOICE 6 - EXIT PROGRAM
1790 '
1800 LOCATE 23,1,1
1810 PRINT "                             "
1820 SYSTEM
1830 '
1840 ' --- SUBROUTINE TO ENTER OR CORRECT ONE LINE OF DATA
1850 '
1860 ' - Sampling Date
1870 ' - FIELD 1      INTEGER, SIZE I 7      REPEATED WITH 'ENTER'
```

```
1880 '
1890 LOCATE 23,1:PRINT "ENTER '\' TO END DATA ENTRY                      ";
1900 LOCATE 4,1:PRINT MID$(SL$(4),1,42);
1910 LOCATE 4, 36,1
1920 COLOR 14,1
1930 LINE INPUT I$
1940 COLOR 15,1
1950 IF LEFT$(I$,1)="\" THEN 1960 ELSE 1980
1960 QUIT=1
1970 RETURN
1980 Z=LEN(I$):IF Z=0 THEN 2140
1990 Z=LEN(I$)
2000 FOR J=1 TO Z
2010 IF MID$(I$,J,1)= CHR$(45) THEN 2040
2020 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 2040
2030 PRINT CHR$(7):GOSUB 10120:GOTO 1830
2040 NEXT J
2050 IF Z=5 THEN
2060   F1$=" 0"+I$
2070   GOTO 2140
2080 END IF
2090 IF Z=6 THEN
2100   F1$=" "+I$
2110   GOTO 2140
2120 END IF
2130 GOTO 2030
2140 IF MID$(F1$,2,2)<"01" OR MID$(F1$,2,2)>"12" THEN 2030
2150 IF MID$(F1$,4,2)<"01" OR MID$(F1$,4,2)>"31" THEN 2030
2160 COLOR 14,1
2170 LOCATE 4,36,1:PRINT USING"\     \";F1$
2180 COLOR 15,1
2190 LOCATE 22,1:PRINT "                                  "
2200 '
2210 ' - Sampling Time
2220 ' - FIELD 2      INTEGER, SIZE I 4      REPEATED WITH 'ENTER'
2230 '
2240 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD             ";
2250 LOCATE 6,1:PRINT MID$(SL$(6),1,52);
2260 LOCATE 6, 49,1
2270 COLOR 14,1
2280 LINE INPUT I$
2290 COLOR 15,1
2300 IF LEFT$(I$,1)="\" THEN 1830
2310 Z=LEN(I$):IF Z=0 THEN 2390
2320 Z=LEN(I$)
2330 FOR J=1 TO Z
2340 IF MID$(I$,J,1)= CHR$(45) THEN 2370
2350 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 2370
2360 PRINT CHR$(7):GOSUB 10120:GOTO 2200
2370 NEXT J
2380 F2=VAL(I$)
2390 IF F2<500 OR F2>2000 THEN 2360
2400 COLOR 14,1
2410 LOCATE 6,49,1:PRINT USING"####";F2
2420 COLOR 15,1
2430 LOCATE 22,1:PRINT "                                  "
2440 F2$="    "
2450 RSET F2$=STR$(F2)
2460 '
2470 ' - Crop Code
2480 ' - FIELD 3      INTEGER, SIZE I 2      REPEATED WITH 'ENTER'
2490 '
2500 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD             ";
2510 LOCATE 8,1:PRINT MID$(SL$(8),1,36);
2520 LOCATE 8, 13,1
```

```
2530 COLOR 14,1
2540 LINE INPUT I$
2550 COLOR 15,1
2560 IF LEFT$(I$,1)="\" THEN 2200
2570 Z=LEN(I$):IF Z=0 THEN 2650
2580 Z=LEN(I$)
2590 FOR J=1 TO Z
2600 IF MID$(I$,J,1)= CHR$(45) THEN 2630
2610 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 2630
2620 PRINT CHR$(7):GOSUB 10120:GOTO 2460
2630 NEXT J
2640 F3=VAL(I$)
2650 IF F3<1 OR F3>99 THEN 2620
2660 COLOR 14,1
2670 LOCATE 8,13,1:PRINT USING"##   \        \";F3,CROP$(F3)
2680 COLOR 15,1
2690 LOCATE 22,1:PRINT "                                   "
2700 F3$="    "
2710 RSET F3$=STR$(F3)
2720 F3$=MID$(F3$,3,2)
2730 '
2740 ' - Field Number
2750 ' - FIELD 4      ALPHA, SIZE A 10      REPEATED WITH 'ENTER'
2760 '
2770 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
2780 LOCATE 8,37:PRINT MID$(SL$(8),37,32);
2790 LOCATE 8, 58,1
2800 COLOR 14,1
2810 LINE INPUT I$
2820 COLOR 15,1
2830 IF LEFT$(I$,1)="\" THEN 2460
2840 Z=LEN(I$):IF Z=0 THEN 2870
2850 F4$="          "
2860 LSET F4$=I$
2870 COLOR 14,1
2880 LOCATE 8,58,1:PRINT F4$
2890 COLOR 15,1
2900 LOCATE 22,1:PRINT "                                   "
2910 '
2920 ' - Dry-bulb Temp
2930 ' - FIELD 5      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
2940 '
2950 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
2960 LOCATE 10,1:PRINT MID$(SL$(10),1,36);
2970 LOCATE 10, 32,1
2980 COLOR 14,1
2990 LINE INPUT I$
3000 COLOR 15,1
3010 IF LEFT$(I$,1)="\" THEN 2730
3020 Z=LEN(I$):IF Z=0 THEN 3100
3030 Z=LEN(I$)
3040 FOR J=1 TO Z
3050 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 3080
3060 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 3080
3070 PRINT CHR$(7):GOSUB 10120:GOTO 2910
3080 NEXT J
3090 F5=VAL(I$)
3100 IF F5<2 OR F5>54 THEN 3070
3110 COLOR 14,1
3120 LOCATE 10,32,1:PRINT USING"###.#";F5
3130 COLOR 15,1
3140 LOCATE 22,1:PRINT "                                   "
3150 F5$="    "
3160 RSET F5$=STR$(F5*10)
3170 '
```

```
3180 ' - Wet-bulb Temp
3190 ' - FIELD 6      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
3200 '
3210 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD             ";
3220 LOCATE 10,37:PRINT MID$(SL$(10),37,38);
3230 LOCATE 10, 70,1
3240 COLOR 14,1
3250 LINE INPUT I$
3260 COLOR 15,1
3270 IF LEFT$(I$,1)="\" THEN 2910
3280 Z=LEN(I$):IF Z=0 THEN 3360
3290 Z=LEN(I$)
3300 FOR J=1 TO Z
3310 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 3340
3320 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 3340
3330 PRINT CHR$(7):GOSUB 10120:GOTO 3170
3340 NEXT J
3350 F6=VAL(I$)
3360 IF F6<2 OR F6>54 THEN 3330
3370 COLOR 14,1
3380 LOCATE 10,70,1:PRINT USING"###.#";F6
3390 COLOR 15,1
3400 LOCATE 22,1:PRINT "                                  "
3410 F6$="    "
3420 RSET F6$=STR$(F6*10)
3430 '
3440 ' - Temp 1
3450 ' - FIELD 7      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
3460 '
3470 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD             ";
3480 LOCATE 13,1:PRINT MID$(SL$(13),1,19);
3490 LOCATE 13, 15,1
3500 COLOR 14,1
3510 LINE INPUT I$
3520 COLOR 15,1
3530 IF LEFT$(I$,1)="\" THEN 3170
3540 Z=LEN(I$):IF Z=0 THEN 3620
3550 Z=LEN(I$)
3560 FOR J=1 TO Z
3570 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 3600
3580 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 3600
3590 PRINT CHR$(7):GOSUB 10120:GOTO 3430
3600 NEXT J
3610 F7=VAL(I$)
3620 IF F7<2 OR F7>54 THEN 3590
3630 COLOR 14,1
3640 LOCATE 13,15,1:PRINT USING"###.#";F7
3650 COLOR 15,1
3660 LOCATE 22,1:PRINT "                                  "
3670 F7$="    "
3680 RSET F7$=STR$(F7*10)
3690 '
3700 ' - Temp 2
3710 ' - FIELD 8      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
3720 '
3730 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD             ";
3740 LOCATE 13,20:PRINT MID$(SL$(13),20,15);
3750 LOCATE 13, 30,1
3760 COLOR 14,1
3770 LINE INPUT I$
3780 COLOR 15,1
3790 IF LEFT$(I$,1)="\" THEN 3430
3800 Z=LEN(I$):IF Z=0 THEN 3880
3810 Z=LEN(I$)
3820 FOR J=1 TO Z
```

```
3830 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 3860
3840 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 3860
3850 PRINT CHR$(7):GOSUB 10120:GOTO 3690
3860 NEXT J
3870 F8=VAL(I$)
3880 IF F8<2 OR F8>54 THEN 3850
3890 COLOR 14,1
3900 LOCATE 13,30,1:PRINT USING"###.#";F8
3910 COLOR 15,1
3920 LOCATE 22,1:PRINT "                                  "
3930 F8$="    "
3940 RSET F8$=STR$(F8*10)
3950 '
3960 ' - Temp 3
3970 ' - FIELD 9      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
3980 '
3990 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
4000 LOCATE 13,35:PRINT MID$(SL$(13),35,15);
4010 LOCATE 13, 45,1
4020 COLOR 14,1
4030 LINE INPUT I$
4040 COLOR 15,1
4050 IF LEFT$(I$,1)="\" THEN 3690
4060 Z=LEN(I$):IF Z=0 THEN 4140
4070 Z=LEN(I$)
4080 FOR J=1 TO Z
4090 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 4120
4100 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 4120
4110 PRINT CHR$(7):GOSUB 10120:GOTO 3950
4120 NEXT J
4130 F9=VAL(I$)
4140 IF F9<2 OR F9>54 THEN 4110
4150 COLOR 14,1
4160 LOCATE 13,45,1:PRINT USING"###.#";F9
4170 COLOR 15,1
4180 LOCATE 22,1:PRINT "                                  "
4190 F9$="    "
4200 RSET F9$=STR$(F9*10)
4210 '
4220 ' - Temp 4
4230 ' - FIELD 10      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
4240 '
4250 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
4260 LOCATE 13,50:PRINT MID$(SL$(13),50,15);
4270 LOCATE 13, 60,1
4280 COLOR 14,1
4290 LINE INPUT I$
4300 COLOR 15,1
4310 IF LEFT$(I$,1)="\" THEN 3950
4320 Z=LEN(I$):IF Z=0 THEN 4400
4330 Z=LEN(I$)
4340 FOR J=1 TO Z
4350 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 4380
4360 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 4380
4370 PRINT CHR$(7):GOSUB 10120:GOTO 4210
4380 NEXT J
4390 F10=VAL(I$)
4400 IF F10<2 OR F10>54 THEN 4370
4410 COLOR 14,1
4420 LOCATE 13,60,1:PRINT USING"###.#";F10
4430 COLOR 15,1
4440 LOCATE 22,1:PRINT "                                  "
4450 F10$="    "
4460 RSET F10$=STR$(F10*10)
4470 '
```

```
4480 ' - Temp 5
4490 ' - FIELD 11      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
4500 '
4510 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
4520 LOCATE 14,1:PRINT MID$(SL$(14),1,19);
4530 LOCATE 14, 15,1
4540 COLOR 14,1
4550 LINE INPUT I$
4560 COLOR 15,1
4570 IF LEFT$(I$,1)="\" THEN 4210
4580 Z=LEN(I$):IF Z=0 THEN 4660
4590 Z=LEN(I$)
4600 FOR J=1 TO Z
4610 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 4640
4620 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 4640
4630 PRINT CHR$(7):GOSUB 10120:GOTO 4470
4640 NEXT J
4650 F11=VAL(I$)
4660 IF F11<2 OR F11>54 THEN 4630
4670 COLOR 14,1
4680 LOCATE 14,15,1:PRINT USING"###.#";F11
4690 COLOR 15,1
4700 LOCATE 22,1:PRINT "                                  "
4710 F11$="    "
4720 RSET F11$=STR$(F11*10)
4730 '
4740 ' - Temp 6
4750 ' - FIELD 12      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
4760 '
4770 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
4780 LOCATE 14,20:PRINT MID$(SL$(14),20,15);
4790 LOCATE 14, 30,1
4800 COLOR 14,1
4810 LINE INPUT I$
4820 COLOR 15,1
4830 IF LEFT$(I$,1)="\" THEN 4470
4840 Z=LEN(I$):IF Z=0 THEN 4920
4850 Z=LEN(I$)
4860 FOR J=1 TO Z
4870 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 4900
4880 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 4900
4890 PRINT CHR$(7):GOSUB 10120:GOTO 4730
4900 NEXT J
4910 F12=VAL(I$)
4920 IF F12<2 OR F12>54 THEN 4890
4930 COLOR 14,1
4940 LOCATE 14,30,1:PRINT USING"###.#";F12
4950 COLOR 15,1
4960 LOCATE 22,1:PRINT "                                  "
4970 F12$="    "
4980 RSET F12$=STR$(F12*10)
4990 '
5000 ' - Temp 7
5010 ' - FIELD 13      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
5020 '
5030 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
5040 LOCATE 14,35:PRINT MID$(SL$(14),35,15);
5050 LOCATE 14, 45,1
5060 COLOR 14,1
5070 LINE INPUT I$
5080 COLOR 15,1
5090 IF LEFT$(I$,1)="\" THEN 4730
5100 Z=LEN(I$):IF Z=0 THEN 5180
5110 Z=LEN(I$)
5120 FOR J=1 TO Z
```

```
5130 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 5160
5140 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 5160
5150 PRINT CHR$(7):GOSUB 10120:GOTO 4990
5160 NEXT J
5170 F13=VAL(I$)
5180 IF F13<2 OR F13>54 THEN 5150
5190 COLOR 14,1
5200 LOCATE 14,45,1:PRINT USING"###.#";F13
5210 COLOR 15,1
5220 LOCATE 22,1:PRINT "                                  "
5230 F13$="    "
5240 RSET F13$=STR$(F13*10)
5250 '
5260 ' - Temp 8
5270 ' - FIELD 14      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
5280 '
5290 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
5300 LOCATE 14,50:PRINT MID$(SL$(14),50,15);
5310 LOCATE 14, 60,1
5320 COLOR 14,1
5330 LINE INPUT I$
5340 COLOR 15,1
5350 IF LEFT$(I$,1)="\" THEN 4990
5360 Z=LEN(I$):IF Z=0 THEN 5440
5370 Z=LEN(I$)
5380 FOR J=1 TO Z
5390 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 5420
5400 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 5420
5410 PRINT CHR$(7):GOSUB 10120:GOTO 5250
5420 NEXT J
5430 F14=VAL(I$)
5440 IF F14<2 OR F14>54 THEN 5410
5450 COLOR 14,1
5460 LOCATE 14,60,1:PRINT USING"###.#";F14
5470 COLOR 15,1
5480 LOCATE 22,1:PRINT "                                  "
5490 F14$="    "
5500 RSET F14$=STR$(F14*10)
5510 '
5520 ' - Wind Speed
5530 ' - FIELD 15      INTEGER, SIZE I 2      REPEATED WITH 'ENTER'
5540 '
5550 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
5560 LOCATE 16,1:PRINT MID$(SL$(16),1,15);
5570 LOCATE 16, 14,1
5580 COLOR 14,1
5590 LINE INPUT I$
5600 COLOR 15,1
5610 IF LEFT$(I$,1)="\" THEN 5250
5620 Z=LEN(I$):IF Z=0 THEN 5700
5630 Z=LEN(I$)
5640 FOR J=1 TO Z
5650 IF MID$(I$,J,1)= CHR$(45) THEN 5680
5660 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 5680
5670 PRINT CHR$(7):GOSUB 10120:GOTO 5510
5680 NEXT J
5690 F15=VAL(I$)
5700 IF F15<0 OR F15>99 THEN 5670
5710 COLOR 14,1
5720 LOCATE 16,14,1:PRINT USING"##";F15
5730 COLOR 15,1
5740 LOCATE 22,1:PRINT "                                  "
5750 F15$="  "
5760 RSET F15$=MID$(STR$(F15),2,2)
5770 '
```

```
5780 ' - Wind Direction
5790 ' - FIELD 16      ALPHA, SIZE A 3      REPEATED WITH 'ENTER'
5800 '
5810 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
5820 LOCATE 16,16:PRINT MID$(SL$(16),16,43);
5830 LOCATE 16, 56,1
5840 COLOR 14,1
5850 LINE INPUT I$
5860 COLOR 15,1
5870 IF LEFT$(I$,1)="\" THEN 5510
5880 Z=LEN(I$):IF Z=0 THEN 5910
5890 F16$="   "
5900 MID$(F16$,1, 3 )=I$
5910 FOR I=1 TO 16
5920 IF F16$=VALID$(I) THEN 5960
5930 NEXT I
5940 PRINT CHR$(7):GOSUB 10120
5950 GOTO 5770
5960 COLOR 14,1
5970 LOCATE 16,56,1:PRINT MID$(F16$,1,3)
5980 COLOR 15,1
5990 LOCATE 22,1:PRINT "                                  "
6000 '
6010 ' - Slope
6020 ' - FIELD 17      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
6030 '
6040 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
6050 LOCATE 18,1:PRINT MID$(SL$(18),1,13);
6060 LOCATE 18, 9,1
6070 COLOR 14,1
6080 LINE INPUT I$
6090 COLOR 15,1
6100 IF LEFT$(I$,1)="\" THEN 5770
6110 Z=LEN(I$):IF Z=0 THEN 6190
6120 Z=LEN(I$)
6130 FOR J=1 TO Z
6140 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 6170
6150 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 6170
6160 PRINT CHR$(7):GOSUB 10120:GOTO 6000
6170 NEXT J
6180 F17=VAL(I$)
6190 COLOR 14,1
6200 LOCATE 18,9,1:PRINT USING"##.##";F17
6210 COLOR 15,1
6220 LOCATE 22,1:PRINT "                                  "
6230 F17$=STR$(F17*100)
6240 '
6250 ' - Offset
6260 ' - FIELD 18      DECIMAL, SIZE F 5.1      REPEATED WITH 'ENTER'
6270 '
6280 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
6290 LOCATE 18,14:PRINT MID$(SL$(18),14,39);
6300 LOCATE 18, 48,1
6310 COLOR 14,1
6320 LINE INPUT I$
6330 COLOR 15,1
6340 IF LEFT$(I$,1)="\" THEN 6000
6350 Z=LEN(I$):IF Z=0 THEN 6430
6360 Z=LEN(I$)
6370 FOR J=1 TO Z
6380 IF MID$(I$,J,1)= CHR$(45) OR MID$(I$,J,1)=CHR$(46) THEN 6410
6390 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 6410
6400 PRINT CHR$(7):GOSUB 10120:GOTO 6240
6410 NEXT J
6420 F18=VAL(I$)
```

```
6430 COLOR 14,1
6440 LOCATE 18,48,1:PRINT USING"##.##";F18
6450 COLOR 15,1
6460 LOCATE 22,1:PRINT "                                   "
6470 F18$=STR$(F18*100)
6480 '
6490 ' - Data Quality Code
6500 ' - FIELD 19      INTEGER, SIZE I 2      REPEATED WITH 'ENTER'
6510 '
6520 LOCATE 23,1:PRINT "ENTER '\' TO BACKSPACE ONE FIELD              ";
6530 LOCATE 20,1:PRINT MID$(SL$(20),1,47);
6540 LOCATE 20, 46,1
6550 COLOR 14,1
6560 LINE INPUT I$
6570 COLOR 15,1
6580 IF LEFT$(I$,1)="\" THEN 6240
6590 Z=LEN(I$):IF Z=0 THEN 6670
6600 Z=LEN(I$)
6610 FOR J=1 TO Z
6620 IF MID$(I$,J,1)= CHR$(45) THEN 6650
6630 IF MID$(I$,J,1)>CHR$(47) AND MID$(I$,J,1)<CHR$(58) THEN 6650
6640 PRINT CHR$(7):GOSUB 10120:GOTO 6480
6650 NEXT J
6660 F19=VAL(I$)
6670 IF F19<1 OR F19>3 THEN 6640
6680 COLOR 14,1
6690 LOCATE 20,46,1:PRINT USING"##";F19
6700 COLOR 15,1
6710 LOCATE 22,1:PRINT "                                   "
6720 F19$=STR$(F19)
6730 LOCATE 23,1,1
6740 PRINT" "
6750 DL$(K)=F1$+F2$+F3$+F4$+F5$+F6$+F7$+F8$+F9$+F10$+F11$+F12$+F13$+F14$
6760 DL$(K)=DL$(K)+F15$+F16$+F17$+F18$+F19$
6761 K=K+1
6770 RETURN
6780 '
6790 '----- SUBROUTINE TO DISPLAY DATA FOR CORRECTION
6800 '
6810 COLOR 7,1
6820 F1$=MID$(DL$(K),1,7)
6830 LOCATE 4,36,1:PRINT USING"\     \";F1$
6840 F2=VAL(MID$(DL$(K),9,4))
6850 LOCATE 6,49,1:PRINT USING"####";F2
6860 F3=VAL(MID$(DL$(K),13,2))
6870 LOCATE 8,13,1:PRINT USING"##   \         \";F3,CROP$(F3)
6880 F4$=MID$(DL$(K),15,10)
6890 LOCATE 8,58,1:PRINT F4$
6900 F5=VAL(MID$(DL$(K),25,4))/10
6910 LOCATE 10,32,1:PRINT USING"###.#";F5
6920 F6=VAL(MID$(DL$(K),29,4))/10
6930 LOCATE 10,70,1:PRINT USING"###.#";F6
6940 F7=VAL(MID$(DL$(K),33,4))/10
6950 LOCATE 13,15,1:PRINT USING"###.#";F7
6960 F8=VAL(MID$(DL$(K),37,4))/10
6970 LOCATE 13,30,1:PRINT USING"###.#";F8
6980 F9=VAL(MID$(DL$(K),41,4))/10
6990 LOCATE 13,45,1:PRINT USING"###.#";F9
7000 F10=VAL(MID$(DL$(K),45,4))/10
7010 LOCATE 13,60,1:PRINT USING"###.#";F10
7020 F11=VAL(MID$(DL$(K),49,4))/10
7030 LOCATE 14,15,1:PRINT USING"###.#";F11
7040 F12=VAL(MID$(DL$(K),53,4))/10
7050 LOCATE 14,30,1:PRINT USING"###.#";F12
7060 F13=VAL(MID$(DL$(K),57,4))/10
```

```
7070 LOCATE 14,45,1:PRINT USING"###.#";F13
7080 F14=VAL(MID$(DL$(K),61,4))/10
7090 LOCATE 14,60,1:PRINT USING"###.#";F14
7100 F15=VAL(MID$(DL$(K),65,2))
7110 LOCATE 16,14,1:PRINT USING"##";F15
7120 F16$=MID$(DL$(K),67,3)
7130 LOCATE 16,56,1:PRINT F16$
7140 F17=VAL(MID$(DL$(K),70,4))/100
7150 LOCATE 18,9,1:PRINT USING"##.##";F17
7160 F18=VAL(MID$(DL$(K),74,4))/100
7170 LOCATE 18,48,1:PRINT USING"##.##";F18
7180 F19=VAL(MID$(DL$(K),78,2))
7190 LOCATE 20,46,1:PRINT USING"##";F19
7200 COLOR 15,1
7210 RETURN
7220 '
7230 '      SUBROUTINE TO COMPUTE CWSI
7240 '
7250   DIM TEMP(8),X(100),Y(100),YC(100), QUAL$(3)
7260   QUAL$(1)="GOOD"
7270   QUAL$(2)="FAIR"
7280   QUAL$(3)="POOR"
7290   OPEN "I",2,D$
7300   OPEN "O",3,"OUTPUT"
7310   E=2.7182818#
7320   NO=0
7330   IPAGE=0
7340   IF EOF(2) THEN 8750
7350   LINE INPUT#2,B$
7360   IDATE=VAL(MID$(B$,1,7))
7370   IHOUR=VAL(MID$(B$,9,4))
7380   ICROP=VAL(MID$(B$,13,2))
7390   IFIELD$=MID$(B$,15,10)
7400   TA=VAL(MID$(B$,25,4))/10
7410   TWB=VAL(MID$(B$,29,4))/10
7420   FOR I=1 TO 8
7430     M=33+(I-1)*4
7440     TEMP(I)=VAL(MID$(B$,M,4))/10
7450   NEXT I
7460   WINDS$=MID$(B$,65,2)
7470   WINDD$=MID$(B$,67,3)
7480   SLOPE=VAL(MID$(B$,70,4))/100
7490   OFFSET=VAL(MID$(B$,74,4))/100
7500   IQUAL=VAL(MID$(B$,78,2))
7510   '
7520   '   CHECK FOR BAD DATA
7530   '
7540   IF IQUAL=0 THEN
7550     LPRINT " *****ERROR:  BAD DATA QUALITY ON THE FOLLOWING RECORD.  ";
7560     LPRINT "MUST BE 1, 2 OR 3"
7570     LPRINT DATE;IHOUR;ICROP;IFIELD$;TA;TWB;TEMP;WINDS$;WINDD$;SLOPE;OFFSET;IQUAL
7580     GOTO 7340
7590   END IF
7600   '
7610   '   CALCULATE MEAN TEMPERATURE OF PLANT
7620   '
7630   TMPAVG=(TEMP(1)+TEMP(2)+TEMP(3)+TEMP(4)+TEMP(5)+TEMP(6)+TEMP(7)+TEMP(8))
7640   TMPAVG=TMPAVG/8!
7650   '
7660   '   CALCULATE TEMPERATURE DIFFERENTIAL
7670   '   TEMP DIFF = TEMP AVG. - DRY BULB TEMP.
7680   '
7690   TMPDIF = TMPAVG-TA
7700   '
7710   '   CALCULATE THE SATURATION VAPOR PRESSURE
```

```
7720   '
7730   XP=18.7209-(3806.41/(TA+273.16))-(222153!/(TA+273.16)^2)
7740   EO1=E^XP
7750   XP=18.7209-(3806.41/(TWB+273.16))-(222153!/(TWB+273.16)^2)
7760   EO2=E^XP
7770   EA=EO2-((.00066*(.00115*TWB+1!))*(980!*(TA-TWB)))
7780   VPD1=(EO1-EA)/10!
7790   IF (SLOPE=0! AND OFFSET=0!) THEN
7800     '
7810     '    DEVELOPING THE REGRESSION EQUATION.  STORE VPD AND TC-TA VALUE
7820     '
7830     PRINT
7840     PRINT DL$(K)
7850     PRINT "Record skipped, no slope of offset provided."
7860     GOTO 7340
7870   END IF
7880   '
7890   '   NOW CALCULATE THE UPPER LIMIT.
7900   '
7910   TC=TA+OFFSET
7920   XP=18.7209-(3806.41/(TC+273.16))-(222153!/(TC+273.16)^2)
7930   VPD2=E^XP
7940   VPDIFF=(EO1-VPD2)/10!
7950   UPLMT=OFFSET+(SLOPE*VPDIFF)
7960   '
7970   '   CALCULATE THE CROP WATER STRESS INDEX
7980   '
7990   CWSI=(TMPDIF-(SLOPE*VPD1+OFFSET))/(UPLMT-(SLOPE*VPD1+OFFSET))
8000   '
8010   '   CALCULATE RELATIVE HUMIDITY
8020   '
8030   RH=EA/EO1*100!
8040   '
8050   '   ALL DONE WITH THIS SAMPLE.  PRINT ANSWERS
8060   '
8070   NO=NO+1
8080   IF NO=0 GOTO 8290   '------LOOKS FOR BLANK DATE?
8090   '
8100   '   WRITE HEADINGS.
8110   '
8120   IF NP=1 THEN 8130 ELSE 8230
8130     IPAGE= IPAGE + 1
8140     LPRINT CHR$(12);TAB(22);"CROP WATER STRESS INDEX COMPUTATIONS"
8150     D$=DATE$
8160     TODAY$=MID$(D$,1,2)+"/"+MID$(D$,4,2)+"/"+MID$(D$,9,2)
8170     LPRINT TAB(36);TODAY$
8180     LPRINT TAB(37);"Page ";IPAGE
8190     LPRINT
8200     LPRINT
8210     NP=2
8220   GOTO 8280
8230     LPRINT
8240     LPRINT TAB(30);"- - - - - - - - - -"
8250     LPRINT
8260     LPRINT
8270     NP=1
8280   NO=1
8290   LPRINT TAB(7);"SAMPLE";TAB(17);"SAMPLE"
8300   LPRINT TAB(8);"DATE";TAB(18);"TIME";TAB(28);"CROP";TAB(44);"FIELD"
8310   LPRINT TAB(7);"------";TAB(17);"------";TAB(28);"----";TAB(44);"-----"
8320   MO=INT(IDATE/10000)
8330   DY=INT(IDATE/100)-MO*100
8340   YR=IDATE-DY*100-MO*10000
8350   LPRINT USING"     ##/##/##   ######";MO,DY,YR,IHOUR;
8360   LPRINT USING"     \        \      \        \";CROP$(ICROP),IFIELD$
```

```
8370   LPRINT
8380   LPRINT "  DRY BULB";TAB(13);"WET BULB";TAB(36);"SAMPLE TEMPERATURES";
8390   LPRINT TAB(75);"DATA"
8400   LPRINT TAB(5);"TEMP";TAB(15);"TEMP";
8410   LPRINT TAB(24);"(1)  (2)  (3)  (4)  (5)  (6)  (7)  (8)     WIND";
8420   LPRINT TAB(73);"QUALITY"
8430   LPRINT "  --------";TAB(13);"--------";TAB(24);
8440   LPRINT "---- ---- ---- ---- ---- ---- ---- ----    ----";
8450   LPRINT TAB(73);"-------"
8460   LPRINT USING"    ##.#      ##.#    ";TA,TWB;
8470   LPRINT USING" ##.# ##.# ##.# ##.#";TEMP(1),TEMP(2),TEMP(3),TEMP(4);
8480   LPRINT USING" ##.# ##.# ##.# ##.#";TEMP(5),TEMP(6),TEMP(7),TEMP(8);
8490   LPRINT USING"   \\ \ \   \  \";WINDS$,WINDD$,QUAL$(IQUAL)
8500   LPRINT
8510   LPRINT "          SLOPE:                                       ";
8520   LPRINT USING"          #####.##";SLOPE
8530   LPRINT
8540   LPRINT "          OFFSET:                                      ";
8550   LPRINT USING"          #####.##";OFFSET
8560   LPRINT
8570   LPRINT "          TC-TA                                        ";
8580   LPRINT USING"          #####.## C";TMPDIF
8590   LPRINT
8600   LPRINT "          VAPOR PRESSURE DEFICIT:                      ";
8610   LPRINT USING"          #####.## KPA";VPD1
8620   LPRINT
8630   LPRINT "          UPPER LIMIT:                                 ";
8640   LPRINT USING"          #####.## C";UPLMT
8650   LPRINT
8660   LPRINT "          CROP WATER STRESS INDEX:                     ";
8670   LPRINT USING"          #####.##";CWSI
8680   LPRINT
8690   LPRINT "          RELATIVE HUMIDITY:                           ";
8700   LPRINT USING"          #####.##%";RH
8710   GOTO 7340
8720   '
8730   '   END OF FILE.
8740   '
8750 RETURN
8760 '
8770 '      SUBROUTINE TO COMPUTE SLOPE AND OFFSET
8780 '
8790   E=2.7182818#
8800   NO=0
8810   IPAGE=0
8820   XCROP=0
8830   IF EOF(2) THEN 9250
8840   NO=NO+1
8850   LINE INPUT#2,B$
8860   ICROP=VAL(MID$(B$,13,2))
8870   'PRINT XCROP,ICROP
8880   IF XCROP=0 OR XCROP=ICROP THEN 8930
8890   LPRINT B$
8900   LPRINT "DATA SKIPPED, CROP NOT ";CROP$(XCROP)
8910   NO=NO-1
8920   GOTO 8830
8930   XCROP=ICROP
8940   TA=VAL(MID$(B$,25,4))/10
8950   TWB=VAL(MID$(B$,29,4))/10
8960   FOR I=1 TO 8
8970     M=33+(I-1)*4
8980     TEMP(I)=VAL(MID$(B$,M,4))/10
8990   NEXT I
9000   '
9010   '   CALCULATE MEAN TEMPERATURE OF PLANT
```

```
9020    '
9030    TMPAVG=(TEMP(1)+TEMP(2)+TEMP(3)+TEMP(4)+TEMP(5)+TEMP(6)+TEMP(7)+TEMP(8))
9040    TMPAVG=TMPAVG/8!
9050    '
9060    '   CALCULATE TEMPERATURE DIFFERENTIAL
9070    '   TEMP DIFF = TEMP AVG. - DRY BULB TEMP.
9080    '
9090    TMPDIF = TMPAVG-TA
9100    '
9110    '   CALCULATE THE SATURATION VAPOR PRESSURE
9120    '
9130    XP=18.7209-(3806.41/(TA+273.16))-(222153!/(TA+273.16)^2)
9140    EO1=E^XP
9150    XP=18.7209-(3806.41/(TWB+273.16))-(222153!/(TWB+273.16)^2)
9160    EO2=E^XP
9170    EA=EO2-((.00066*(.00115*TWB+1!))*(980!*(TA-TWB)))
9180    VPD1=(EO1-EA)/10!
9190    X(NO)=VPD1
9200    Y(NO)=TMPDIF
9210    ISW=1
9220    JCROP$=CROP$(ICROP)
9230    GOTO 8830
9240    ' CALCUALTE SLOPE AND OFFSET
9250    XSUM=0!
9260    X2SUM=0!
9270    YSUM=0!
9280    XYSUM=0!
9290    Y2SUM=0!
9300    '
9310    '   SUM UP THE X VALUES
9320    '
9330    FOR J=1 TO NO
9340      XSUM=XSUM+X(J)
9350    NEXT J
9360    '
9370    '   SUM UP X SQUARED VALUES
9380    '
9390    FOR J=1 TO NO
9400      X2SUM=X2SUM + X(J)^2
9410    NEXT J
9420    '
9430    '   SUM UP THE Y VALUES
9440    '
9450    FOR J=1 TO NO
9460      YSUM=YSUM+Y(J)
9470    NEXT J
9480    '
9490    '   SUM THE PRODUCT OF X*Y
9500    '
9510    FOR J=1 TO NO
9520      XYSUM=XYSUM+(X(J)*Y(J))
9530    NEXT J
9540    '
9550    '   SUM UP THEE Y SQUARED VALUES
9560    '
9570    FOR J=1 TO NO
9580      Y2SUM=Y2SUM + Y(J)^2
9590    NEXT J
9600    '
9610    '   DETERMINE THE ARITHMETIC MEAN FOR X AND Y
9620    '
9630    XMEAN=XSUM/NO
9640    YMEAN=YSUM/NO
9650    '
9660    '   COMPUTE THE M(11),M(12), AND M(22) VALUES
```

```
9670   '
9680   M11=Y2SUM-(NO*(YMEAN)^2)
9690   M12=XYSUM-(NO*YMEAN*XMEAN)
9700   M22=X2SUM-(NO*(XMEAN^2))
9710   '
9720   '   NOW THE 'B' AND 'A' VALUES
9730   '
9740   B=M12/M22
9750   A=YMEAN-B*XMEAN
9760   SLOPE=B
9770   OFFSET=A
9780   '
9790   '   NOW CALCULATE THE R SQUARED VALUE AND WE ARE DONE.
9800   '
9810   SST=M11
9820   SSR=ABS(B)^2*M22
9830   R2=SSR/SST
9840   'IF ISW=0 THEN 6560
9850   LPRINT CHR$(12);TAB(26);"SLOPE AND OFFSET CALCULATIONS"
9860   LPRINT
9870   LPRINT
9880   LPRINT USING" VPD AND TC-TA DATA PAIRS FOR WELL-WATERED \
\";CROP$(XCROP)
9890   LPRINT
9900   LPRINT TAB(21);"TC-TA     TC-TA"
9910   LPRINT "  POINT     VPD     (ACTUAL)  (CALC)"
9920   LPRINT
9930   FOR J=1 TO NO
9940     YC(J)=SLOPE*X(J)+OFFSET
9950     LPRINT USING"   ###    ####.#    ####.#    ####.#
####.#";J,X(J),Y(J),YC(J)
9960   NEXT J
9970   LPRINT
9980   LPRINT USING"     REGRESSION EQUATION:  #####.## + #####.## X";OFFSET,SLOPE
9990   LPRINT USING"     R SQUARED= ###.##";R2
10000   LPRINT CHR$(12)
10010 RETURN
10020 '
10030 '   SUBROUTINE TO PRINT DATA FILE
10040 '
10050   OPEN "O",1,D$
10060   FOR I=1 TO 50
10070   IF MID$(DL$(I),1,7)<="       " THEN 10100
10080   PRINT#1,DL$(I)
10090   NEXT I
10100   CLOSE
10110 RETURN
10120 '
10130 '  SUBROUTINE TO DISPLAY BAD DATA MESSAGE
10140 '
10150 COLOR 12,1
10160 LOCATE 22,1,1
10170 PRINT "BAD DATA, TRY AGAIN.              "
10180 COLOR 15,1
10190 RETURN
10200 '
10201 '   SUBROUTINE TO SORT DATA BY FIELD NUMBER AND SAMPLING DATE
10202 '
10210 '   Build Sort Key
10220 '
10230     X2$ = ""
10231     'NR=K
10232     'LPRINT NR,CHR$(12)
10240     For L = 1 To NR
10242       X2$=MID$(DL$(L),15,10)
```

```
10244       X2$=X2$+MID$(DL$(L),6,2)
10246       X2$=X2$+MID$(DL$(L),2,2)
10248       X2$=X2$+MID$(DL$(L),4,2)
10250       X2$=X2$+MID$(DL$(L),9,4)
10460 '
10470 '     Locate Record Position in File
10480 '
10490        If L = 1 Then
10500            RPointer(L) = L
10510          skey$(L) = X2$
10520            NumRec = L
10530            GoTo 11330   'loop3
10540        End If
10550        LL = 1
10560        UL = NumRec
10570      If X2$ < skey$(LL) Then
10580        'Print #F2, X2$; "<"; skey(LL), LL
10590            RN = 1
10600            GoTo 11150    'InsertRcd
10610        End If
10620      If X2$ = skey$(LL) Then
16030        'Print #F2, X2$; "="; skey(LL), LL
10640            RN = LL
10650 'Loop1:
10660            RN = RN + 1
16070            If RN > NumRec Then
16080                RN = NumRec
10690                GoTo 11290   'AppendRecord
10700            End If
10710          If X2$ = skey$(RN) Then
10720                GoTo 10650   'Loop1
10730            Else
10740                RN = RN - 1
10750                If RN <= 0 Then RN = 1
10760                GoTo 11150   'InsertRcd
10770            End If
10780        End If
10790      If X2$ > skey$(UL) Then
10800        'Print #F2, X2$; ">"; skey(UL), UL
10810            GoTo 11290    'AppendRecord
10820        End If
10830      If X2$ = skey$(UL) Then
10840        'Print #F2, X2$; "="; skey(UL), UL
10850            RN = UL
10860 'Loop2:
10870            RN = RN + 1
10880            If RN > NumRec Then
10890                RN = NumRec
10900                GoTo 11290    'AppendRecord
10910            End If
10920          If X2$ = skey$(RN) Then
10930                GoTo 10860    'Loop2
10940            Else
10950 '                RN = RN - 1
10960                If RN <= 0 Then RN = 1
10970                GoTo 11150    'InsertRcd
10980            End If
11000        End If
11010 'LBL4091:
11020        X = Int((UL + LL) / 2 + .5)
11030        'Print #F2, X2$, skey(X), X
11040      If X2$ > skey$(X) Then
11050            LL = X
11060        Else
11070            UL = X
```

```
11080        End If
11090        'Print #F2, L, LL; X; UL, LLX$; X2$; ULX$
11100        If (UL - LL) = 1 Then
11110            RN = UL
11120            GoTo 11150    'InsertRcd
11130        End If
11140        GoTo 11010    'LBL4091
11150 'InsertRcd:
11160        For J = NumRec To RN Step -1
11170            If J <= 0 Then
11180                GoTo 11240    'Loop5
11190            End If
11200            'Print #F2, J, NumRec, RN
11210          skey$(J + 1) = skey$(J)
11220            RPointer(J + 1) = RPointer(J)
11230        Next J
11240 'Loop5:
11250      skey$(RN) = X2$
11260        RPointer(RN) = L
11270        NumRec = NumRec + 1
11280        GoTo 11330    'loop3
11290 'AppendRecord:
11300        NumRec = NumRec + 1
11310      skey$(NumRec) = X2$
11320        RPointer(NumRec) = L
11330 'loop3:
11340 '
11350    Next L
11560    'Close #F1
11370 '     All Records sorted, create new file.
11430    Open D$ For Output As 1
11440    'Open FILEIN$ For Random As F1 Len = RL
11450    For I = 1 To NR
11460        'Print #F3, rpointer(I)
11500        Print #1, DL$(RPOINTER(I))
11510    Next I
11520    Close
11580 RETURN
```

INDEX

Access tube
- Accessibility . . . 31
- adapter . . . C-1
- Driver . . . 13, 23
- location . . . 31, 32
- Site . . . 31, 37

Access tubes . . . 13, 14, 18, 21, 23, 32
Acres . . . 2, 41
Adapter . . . C-1
Amount to apply . . . 6
Apparent Moisture Content . . . 19
Black body . . . 20, 21
Calibration . . . 18, 21, 22, 25, 26, 28
Consumptive Use . . . 31, 37
Crop . . . 1, 2, 4, 6, 8-10, 20-23, 30-37, 39, 41, E-1, E-2, E-5, E-6, E-12, E-14-17
Crop Name . . . 21, E-1
Crop stand . . . 31
Crop water Stress . . . 6, 9, 10, 20, 33-36, E-1, E-14, E-15
Crop Water Stress Index . . . 6, 9, 10, 33-36, E-1, E-14, E-15
CWSI . . . 6-10, 20, 30, 33, 35, 36, E-1, E-2, E-4, E-13-15
Data Sheet . . . 22, 33
- Plant foliage temperature data sheet . . . 22, 33

Date . . . 4, 6, 22, 29, 34-37, 40, 41, E-2, E-5, E-13-15, E-18
Dosimeter . . . 25
DR-503 . . . 14, 15, 18, 26, 28, 35
Dry Barrel . . . 19, 26-28
Dry-Bulb . . . 20, 21, 36
Efficiency . . . 1, 4, 6, 33, 37
Errors . . . 33
Excess water . . . 31, 34
Farm irrigation schedule . . . 41
Farm number . . . 18
Field data . . . 33, C-2
Field Irrigation Scheduling . . . 1-2, 4, 24, 35
Film badge . . . 25
Gauge . . . 1-4, 13-15, 18, 19, 21, 24-28, 32, 33, 35, 37, C-1
Infrared thermometer . . . 8-10, 13, 19-21, 30, 33
Initialize the gauge . . . 15
Irrigation Method . . . 31
License . . . 25
Memory . . . 18
Name . . . 12, 21, E-1, E-3, E-4
Neutron Moisture Gauge . . . 1-4, 13, 19, 24, 26, 27, C-1
Neutron Probe . . . ii-5, 29
Next irrigation date . . . 4, 6
NRC . . . 24, 25
Nuclear Regulatory Commission . . . 24
Plant foliage temperature . . . 22, 33
Plant foliage temperature data sheet . . . 22, 33
Probe . . . ii-5, 14-19, 21, 23, 26, 28, 29, 37
Psychrometer . . . 10, 20, 21, 30, 33
Recovery . . . 6
Refill Line . . . 4, 6, 10, 37
Refill point . . . 4, 10, 31-33, 35
Run . . . E-1
S-503 . . . 14, 15, 26, 28, 35

Schedules 2, 37, 39
Scheduling irrigations 1, 3, 4, 26, 31
Soil Moisture 1-4, 6, 8, 10, 15, 21, 25-27, 32-34
Soil Moisture depletion 33
Soil Type 26, 31
Standard count 15, 18, 29
Standardization Barrel 19
Summary report sheet 37
Technicians 24, 31, 37, 39
Temperature 6, 8-11, 20-22, 30, 33, 36, A-1, A-5, E-2, E-14, E-16
Tube location 31, 32
Type 21, 22, 26, 31, E-1
VEGY 33, 34, 7, E-1, E-2
Visible stress 33
Water user 40
Wet Barrel 19, 26, 28
Wet-bulb 8, 20, A-1, A-2, A-4, A-5