THESIS

LETTUCE IRRIGATION SCHEDULING USING

ATMOMETERS AND COMPUTERS

Submitted by

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Horticulture

In partial fulfillment of the requirements

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Colorado State University

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED

UNDER OUR SUPERVISION BY ANN EMERY McSAY ENTITLED

LETTUCE IRRIGATION SCHEDULING USING ATMOMETERS AND

COMPUTERS BE ACCEPTED AS FULFILLING IN PART REQUIRE-

MENTS FOR THE DEGREE OF MASTER OF SCIENCE.

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ABSTRACT OF THESIS

LETTUCE IRRIGATION SCHEDULING USING
ATMOMETERS AND COMPUTERS

Linear relationships between soil matric potential (SMP) and
evaporative power of the air (EPA) were developed in order to schedule
irrigation of lettuce in arid or semi-arid regions. The irrigation sched-
uling model is based on the assumption that SMP i.e. soil moisture "need"
is a function of stage of growth, EPA, soil texture and root zone recharge.
Root zone recharge may be due to an irrigation which brings the effective
root zone to field capacity or a rainfall event which accomplishes the same
purpose. Four linear equations similar to stage of growth coefficients are
modified by soil coefficients which account for variation in hydraulic con-
ductivities due to soil texture.

Information required on a daily basis for daily output consists of
milliliters of water lost from standardized Bellani plant atmometers and
inches of rainfall from 8 inch diameter USWS rain gauges.

The irrigation scheduling output is in 2 forms. One is graphic.
Graphic analysis allows the user to visualize the progression of SMP
(converted from ΣEPA) as a function of days from last recharge. The
observer simply compares this plotted line to the SMP horizontal
(constant) line, one for each of the 4 growth stages. An obvious

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reminder of tardiness occurs after the two lines intersect. This graphic form of output results from a program written in assembly language for a programmable calculator.

The other form of output is digital. A FORTRAN program for a large scale computer was written. The program fits, by the least squares method; linear, quadratic and cubic regression equations to ΣEPA versus days from last recharge data. The program solves each of the 3 polynomials for days to next recharge and converts the end of the interval to a calendar date. The user then selects the most imminent of the 3 predicted dates with the aid of associated coefficients of determination. A tardiness reminder is also provided. The program is used in the interactive mode and will permit rapid daily update and query of 400 different plantings.

A method was developed to protect the Bellani plate assemblies from freezing.

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INTRODUCTION

Irrigation consumes 13% of all energy used in agriculture. A much higher percentage is devoted to irrigated farms in the arid west.

Agricultural irrigation accounts for about 79% of Colorado's 650,000 hectare-meters (5.3 million acre feet) per year of water depletion. The greatest potential for water savings appears to lie within the science of farm irrigation efficiency. Thus, the greatest need is to help growers become aware of optimal irrigation through additional research on irrigation practices. Application methods are associated with certain inefficiencies but applying irrigation water only when the crop requires it usually results in a water savings and therefore an energy savings while preventing yield and quality decrease due to unnecessarily frequent irrigation. Unlike most agronomic crops, lettuce is grown primarily under arid conditions and is irrigated frequently. The challenge is to decide correctly, perhaps 9 to 10 times within 60 days, when to irrigate.

At present, there are more than 100,000 hectares (250,000 acres) of western iceberg lettuce grown each year in the United States. Currently, no irrigation scheduling techniques are being used. It has been estimated that irrigation cost for a lettuce crop in the Imperial Valley comprises at least 10% of the total pre-harvest cost. An irrigation scheduling model is needed to aid the less experienced but

better educated field person now replacing the "old hands." Also, a model will aid in conserving water and nitrogen fertilizer which is so readily leached from the porous soils where much of the western iceberg lettuce is normally produced. Conservation of nitrogen fertilizer also results in energy conservation.

Lettuce is grown by farmers who contract with large companies, many of which have access to computers; these could be used as a tool for scheduling lettuce irrigation.

The purpose of this research was: 1. to develop a relationship between evaporative power of the air, stage of growth, root zone recharge, soil type and soil matric potential for western iceberg lettuce; and 2. to computerize the model so that the most effective irrigation scheduling may be readily calculated.

The work presented in this thesis was initiated by Moore and Workman (36). The assembly language coding was done by A. C. Cameron. The FORTRAN coding was done by D. M. Arns. This thesis is a contribution to Regional Project W-127, "Stand Establishment of Small Seeded Vegetable Crops."

LITERATURE REVIEW

Irrigation Scheduling

Irrigation is defined as an artificial means of maintaining water
availability in the root zone at an optimal level for plant growth.
Irrigation was an ancient art but now a modern science. Irrigation
scheduling normally refers to the proper timing and amount of
water applied. Why attempt to schedule irrigation? As the demand
for food increases, we must learn to manage our natural resources
including water. In the arid west, water has become our most
critical resource. Also, the person who has the experience of
knowing when to irrigate is becoming a rarity and is being replaced
by the better educated but less experienced individual.

Some (15) feel that although both timeliness and amount of water
applied affect irrigation efficiency, timing has the greatest effect on
crop yield and quality. Studies have been done which show stress
during certain stages of growth and plant development will reduce
yield and quality (21, 46, 47). Prior to the mid-1960's, very little if
any scheduling was done on any crop. In fact, various methods such
as a fixed calendar with no latitude for climatic variation, a fixed
crop rotation, when the neighbor irrigates, and digging with a shovel
have been and are currently being used for determining when to

irrigate. Jensen (23) feels the major reasons irrigation scheduling has not changed substantially in recent years are that the needs of managers of irrigated farms and acceptability of suggested scheduling procedures have not been adequately evaluated. More importantly, the increase in cost of irrigation water has not been significant and indirect costs are not easily quantified. Today, the cost of energy to pump water is becoming more of a limiting factor than the cost of water itself.

Before irrigation scheduling can be attempted, some indication of how much water the crop is using must be quantified. There are several ways to estimate the amount of available soil moisture in the root zone.

The methods used include gravimetric, neutron probes, electrical resistance blocks, tensiometers, lysimeters and estimation of evapotranspiration (15).

Evapotranspiration

Actual evapotranspiration (ET), sometimes called consumptive use, is the sum of evaporation; water loss from the soil and other surfaces and transpiration; water loss due to processes within the plant tissue. Potential ET may be estimated by water balance methods, micrometeorological methods or by empirical methods (15).

Water balance (sometimes called water budget) methods include catchments, soil water depletion sampling and lysimetry. Catchments are used primarily for large irrigation and drainage districts. Soil water depletion sampling, either by gravimetric or by using neutron moisture probes or tensiometers, is difficult to employ for periods shorter than 1 week. Also, errors may result from inadequate drainage and many sub-samples must be taken to insure an unbiased sample. Lysimetry is frequently used to check micro-meteorological methods and for calibrating empirical formulae used to estimate potential ET. When using lysimeters, care must be taken that the lysimeter is placed in a representative area of the fields and that the soil moisture status in the lysimeter is maintained in a manner similar to the field.

Micrometeorological measurements are used to provide a measurement of the flux density of water vapor in the boundary layer of the atmosphere primarily for time periods of a few minutes. Micro-meteorological measurements are made using profile methods, energy balance methods or combinations of the two. The micrometeorological methods have limitations as to where and how they can be used. Instrumentation difficulties also limit micrometeorological measurements (15).

Empirical methods include formulae which have been developed to relate climatological measurements and ET. Empirical methods

may be divided into 4 classes: 1. formulae depending primarily on the relation of ET to radiation; 2. formulae dependent upon temperature such as Blaney-Criddle; 3. humidity dependent formulae; and 4. evaporimeters such as pans and atmometers (15). There are other empirical formulae which do not fall into one of the above classes because they are combinations of the classes. Among these formulae are those by Penman, Thornthwaite, Makkink, Jensen-Haise and Christiansen (14, 15, 24). Penman's is probably the most widely known and used.

All empirical method formulae are concerned with potential ET. All assume complete ground cover with an unlimited water supply (14). These formulae based on climatic data as a manifestation of the drying power of the air will give realistic potential ET estimates only for the local areas and for the time period for which the coefficients used in the equations were developed (2). Generally, the empirical formulae are conservative in their estimate of ET (15, 24, 36).

The use of evaporimeters to estimate potential ET through correlation with the measured evaporation was one of the earliest approaches to estimating potential ET. The correlation should be relatively high because both ET and evaporation (E) are influenced by the same micrometeorological conditions (15). Care must be taken in selection of the site for evaporimeters. They must be placed in an area which is homogeneous with the crop which they are monitoring.

Several different theories have been proposed to explain the relationship of actual ET to potential ET. Actual ET may be defined as the actual amount of water lost through processes of evaporation and transpiration. While potential ET may be defined as the maximum amount of water which could be lost through the evaporation and transpiration processes. Penman has defined potential ET as the amount of water transpired in a unit time by a short green crop which completely shades the ground and is of uniform height and never short of water (24). The ratio of ET/potential ET for soils and plants will differ in time because of root proliferation, stage of development and crop species (15).

ET is affected by the air temperature, relative humidity, day length, wind velocity, irrigation method, degree of plant development, amount of foliage and nature of leaf surface. The ratio between ET and E must be calculated separately for each crop and set of climatic conditions. The difference in ET among crops results from the roughness of crop and soil surfaces, foliage color, degree of ground cover, amount of root proliferation and the soil water regime (frequency of irrigation and drainage properties). The ratio (ET/E) changes during the growing season in accordance with the stage of plant growth. In general, in the beginning of the season the ratio (ET/E) is small, about 0.3. Thereafter, a rapid increase occurs in the ratio (ET/E) with maximum values reached during maximum growth. At maximum, the

ET/E ratio approaches 1.0. During maturation and senescence, the ratio decreases. The main factor responsible for the changes in the ratio (ET/E) is the extent of the ground cover by the canopy. Of the crop species investigated, the increase in the ET is linear with the increase in ground cover until approximately 80% cover is reached (14).

The curve of the ratio between cumulative ET and cumulative E is almost sigmoidal for the entire season. However, during the major part of the growing season, after about 1/3 of the ground is covered by foliage, a linear relationship with time is described by the ratio. The slope of the linear part of the sigmoidal curve then represents the average ratio between ET and E (14). Ritchie (42) calculated daily ET from a row crop surface with incomplete cover by using such parameters as leaf area index, potential ET, rainfall and net radiation above the canopy. He considers E from the soil surface to be in two stages. The first being the constant rate stage or atmosphere dependent phase where the drying process is limited only by the supply of energy to the surface. The amount of drying which occurs is dependent on soil depth, hydraulic properties of the soil and evaporative conditions. The hydraulic properties seem to cause the major difference among soils in the amount of drying during the constant rate stage before transformation to the falling rate stage. The second stage known as the falling rate stage (soil dependent phase) is controlled by the hydraulic properties of

the soil. This stage is more dependent on hydraulic properties of the soil and less dependent on the available energy. ET from the plant surface is predicted using an empirical relation for local data which shows the relationship of transpiration to potential ET using leaf area index. Tanner and Jury (51) modeled ET for a crop with incomplete cover by estimating the E separately from the transpiration. Miller and Aarstad (33) studied the relationship of the rate of effective available water as a function of the rate of ET. They used effective available water because in their opinion it is more easily defined than field capacity. They defined effective available water as the amount of water remaining in a given depth of soil plus the ET from that depth until the time drainage ceases or the water from that depth becomes unavailable.

Some have used soil moisture budgets combined with computer calculation to schedule irrigation, primarily for agronomic crops. The programs begin when the soil water depletion level is known or can be calculated. Modifications of the Penman formula are commonly used to calculate the potential ET (10, 17, 26). Kincaid and Heerman (26) use a Jensen modified Penman equation with a crop coefficient which depends on crop species, planting date and effective cover date for use in scheduling irrigation of agronomic crops. Their computer program is written for a Wang model 600 or 700 with modifications for 700A and 700B. It is interesting to note that W. Trimmer (District

Irrigation Engineer, Panhandle Station Scottsbluff, Nebraska -

Personal communication) adapted the Kincaid-Heerman program

to a hand-held Hewlett-Packard model 67 programmable calculator.

Computer programs as normally used, output the irrigation schedule

no more than twice weekly because the consensus is that this fre-

quency is adequate for agronomic crops. However, the use of pro-

grammable calculators as opposed to large scale computers allows

"on-spot" same day calculations without the need for mail service

or expensive telephone communications (26).

Hydraulic Conductivity and Soil Texture

Hydraulic conductivity has been defined as the ratio of the flow

velocity to the driving force for the viscous flow of water. The con-

ductivity of soil for liquid water depends on the cross sectional

area of the soil pores.

During conditions of saturation, flow increases as the fourth

power of the radius of the soil pore. Normally, the coarse-textured

soils have higher hydraulic conductivity near saturation than the finer-

textured soils near saturation. However, during periods of unsatura-

tion the hydraulic conductivity depends on the degree of unsaturation.

That is, the rate of unsaturated flow depends on the size of the soil pores

which are active and on the tension (matric potential) with which the

water is held. The tighter the water is held by the soil, the slower its

movement under the influence of a tension gradient. Unsaturated flow ceases in sand at a higher soil matric potential than in finer-textured soils since the water films lose continuity sooner between the larger particles of sand (27). Therefore, unsaturated flow occurs at lower matric potentials in fine textured soils because at the lower matric potentials, the fine-textured soils have higher hydraulic conductivities than the coarse-textured ones. A soil having a high hydraulic conductivity such as a fine-textured soil would move water faster and farther than one with a low hydraulic conductivity given the same hydraulic gradient. Given the same evaporative energy, the fine-textured soil e. g. a clay will be irrigated less frequently not only because of its greater hydraulic conductivity but also because of its greater moisture holding capacity.

<center>Evaporimeters</center>

Measurement of E from a free water surface such as with a Class A USWS pan has been used as an estimate of potential ET. Jensen (21) used a pan combined with on-site inspection to schedule irrigation of potatoes. A Class A pan is simply one type of evaporimeter. Other evaporimeters known as atmometers include carborundum blocks, Piche atmometers, spherical atmometers, Bellani plates and others.

Bellani plates were designed in 1820 by Bellani who used them primarily in plant ecology studies. Essentially, they involve a flat, black, porous porcelain plate surface (5.0 to 7.5 cm in diameter) attached to a glazed ceramic hemisphere which is connected to a water supply. They are quite fragile since the wall is only 3 mm thick (31). Bellani plate assemblies are normally used in pairs and they are standardized by the manufacturer (C & M Meteorological Supply, see Appendix A).

Carder (7) set forth some basic requirements which an atmometer must satisfy to be acceptable. He tested five different types of atmometers including the Bellani plate. He measured consistency by the mean absolute difference and the average deviation. The Bellani plate met all requirements except one, that of resistance to freezing.

Bellani plate evaporation has been compared with potential ET as measured by lysimeters containing brome grass, alfalfa, and ladino clover. Measurements weekly, daily and every 2 hours of wind, air temperature, solar radiation and dewpoint were also made. Partial correlations showed all four weather factors to have highly significant effect on E and potential ET even though the factors are interdependent. Measured on a daily or weekly basis, air temperature gave the highest correlation with potential ET. Solar radiation measured every 2 hours was the dominant factor influencing potential ET as determined by the lysimeter. Radiation also was more influential on the potential ET/E

ratio than all other factors combined. The four weather factors together accounted for 93, 88 and 60 percent of the variation in E, potential ET and potential ET/E ratio, respectively, when measurements were made every two hours. The correlations of E as well as potential ET with the Bellani plate on a weekly and daily basis were 0.98 and 0.90, respectively, as determined by use of second degree polynomial regressions.

The Bellani plate appears to be as reliable as the Class A pan and more convenient (40, 56, 57).

Several other tests have been done with the Bellani plates. Wilcox (58) tested the effects of negative water pressure on the evaporation from the Bellani plates. This experiment relates directly to the question: Does the level of the water in the Bellani plate reservoir influence the evaporation rate of the Bellani plate? The suction principle of the Bellani plate has some features similar to that of plant leaves. The smaller the pores of the evaporimeter, the greater the suction. The Bellani plates have proved to retain their suction powers at an elevation of at least 4 m above the reservoir. At water pressures of 0 to -4 cm, dripping occurred from the upper plate surface. At pressures of -4 to -64 cm of water in the laboratory, no beading of water occurred. However, there was a slight tendency for the rate of evaporation to decrease with the decreasing water pressure but the effect was not statistically significant. In routine field

recording there was no apparent effect of mean daily water pressure on the rate of evaporation when the range of water pressure was restricted to -5 to -34 cm. It is quite possible with the procedures used in routine recording, effects of water pressure were small enough to be masked by other sources of variability. Thus, it can be concluded that the level of the water in the Bellani plate reservoir has a negligible effect on the rate of evaporation from the plate.

Wilcox (55, 59) performed some tests on the effects of shielding Bellani plates. In Canada, the plates are used without check valves which prevent input during rainfall. Clear glass shields, 30 cm in diameter, are used for protection from rainfall. They are placed 7.6 cm above the plates. The use of the shields increased the rate of evaporation by approximately 5%. However, Wilcox feels the use of the transparent shield is justified because absolute values are not required in most applications of the instrument.

Desjardins and Hansen (9) conducted tests in a wind tunnel at speeds of 0 to 21.6 km/hr (0 to 13.4 mph) comparing the Bellani plates with other atmometers. The evaporation from the Bellani plate varies almost linearly with the wind speed if the effects of air temperature, solar radiation and vapor pressure are accounted for.

Soil moisture budgets and balance sheet methods employing Bellani plates have been used for orchard irrigation in Canada (25, 28).

Lettuce Irrigation Studies

Very little work has been done with irrigation scheduling for lettuce. Schwalen and Wharton (47) did some early work in Arizona. They concluded a relatively high and uniform soil moisture supply was conducive to the production of the highest yield of quality head lettuce. Veihmeyer and Holland (52) worked in the bay area of California. They essentially used a fixed calendar by deciding prior to planting how many and when irrigations would occur throughout the season. Sale (45, 46) worked with butterhead lettuce in England in order to determine critical stages of soil moisture demand. His experiments used both transplants and direct seeding. For the first set of experiments, he watered whenever the soil moisture deficit reached a given level. For the second set of experiments, the irrigation water was applied or withheld at different stages of growth of an 11 week crop which he determined prior to planting. He used combinations of 3, $5\frac{1}{2}$, 7, 8 and 9 weeks post planting for the different stages of growth. He concluded that the most critical stage of need for replenishing the soil moisture to field capacity was during the last one to two weeks before harvest. Irrigation at 3 weeks or $5\frac{1}{2}$ weeks after planting gave a slight increase in fresh weight at harvest but the crop matured slightly earlier.

The greatest water requirement of a crop occurs when a large portion of the soil surface is covered with plant leaves. For lettuce this is primarily the last three weeks of growth. Zink and Yamaguchi

(62) concluded that lettuce makes 70% of its growth during the last three weeks prior to harvest. Robinson (43, 44) reports observations of commercial plantings of head lettuce under sprinkler irrigation. After the germination period, water was applied at weekly intervals in amounts equal to the evaporation from a Class A pan. However, Moore and Soltanpour (35) found, for their conditions in the San Luis Valley, the mean ET/E pan ratio to be 0.87. In the arid west, it is common practice to provide a dryback period following stand establishment, a period of high soil moisture status. It is also common practice to maintain a relative high moisture status during the heading period. It is felt that in the arid west that the most critical stages of need for water are the stand establishment and heading stages (Personal communication, F. D. Moore).

Moore and Soltanpour (35) studied ET from a lettuce field in the San Luis Valley of Colorado. They found the consumptive use of western iceberg lettuce to be approximately 49 centimeters (19 inches) per growing season for early June planted lettuce. However, Robinson (44) reports consumptive use of lettuce in the Imperial Valley of California to be approximately 36 centimeters (14 inches). Other reports of consumptive use values include those by Singh and Alderfer (49) of 29 centimeters (11.25 inches) for April planted lettuce in New Jersey; Veihmeyer and Holland (52) of 10 cm (4 inches) in the Monterey Bay area for a summer crop during the period of thinning to maturity; and

Larkman (29) of 43 cm (17 inches) for head lettuce in New South Wales, Australia. Estimates for the eastern U.S. range from 13 to 20 cm (5 to 8 inches) (53).

Why the difference in consumptive use between these areas? It has been said that evaporation may increase or decrease according to elevation depending on the climatic factors of the area. Longacre and Blaney (32) cite an example where evaporation at 2800 m (9194 ft) was almost 4 times that at 125 m (410 ft) with temperature the same at both sites. This apparent increase in evaporation rate at the higher elevation was due to an increased vapor pressure gradient between water surface and air at the higher elevation, according to the authors. The diffusion rate of water molecules should be greater at higher elevations due to less interference by gas molecules. The diffusion rate hypothesis as well as the vapor pressure gradient hypothesis are both supported by the fact that barometric pressure decreases with increasing elevation. Note that in the Monterey Bay area, cool ocean fogs would reduce the ET.

MATERIALS AND METHODS

The rate of evaporation is governed by the incident radiant energy and the temperature, humidity and motion of the air immediately above the evaporating surface. Atmometers, in this case the Bellani plate type, were used to evaluate the evaporative power of the air (EPA). Germane to this study is the relationship among EPA, soil matric potential (SMP), and time. Since SMP was measured as cumulative parameter to correspond with days from last recharge, atmometer water loss (EPA) was expressed as a cumulative parameter. Atmometer water loss and EPA terms will be used interchangeably throughout the remainder of this thesis. When the programmable calculator program is discussed, "Need" is synonymous with SMP. The unit for SMP is negative centibars while the unit for atmometer water loss and therefore EPA is milliliters. Each Bellani plate has a designated coefficient which is used to standardize all EPA readings. Lactuca sativa L. 'Mesa 659' was used for all plantings.

Sandy Loam Soil Investigations

It was assumed in the studies presented here that the effective lettuce root zone (0-25 cm) would be filled at each irrigation. In

making this assumption, the experiments could be devoted to the timing aspect of irrigation scheduling.

The first experiment was initiated to determine the relationship between the root zone soil matric potential and atmometer water loss for a sandy loam soil. The research plot was located at the Colorado State University San Luis Valley Horticultural Research Center near Center, Colorado. The research center is surrounded by more than 2000 hectares (5000 acres) of commercially grown western iceberg lettuce each summer. The elevation is 2316 m and sporadic rainfall occurs at a rate of 1.0 to 2.8 cm (0.4 to 1.1 inches) per month during the growing season.

Lettuce beds in 0.2 hectare (0.5 acre) plots were oriented east-west and were planted to commercial specifications using furrow irrigation, with 102 cm wide raised beds with 2 rows 33 cm apart on the beds. The lettuce was thinned approximately $3\frac{1}{2}$ weeks after planting to 30 cm between plants within the row. Plots were surrounded by other irrigated research plots.

Tensiometers to monitor SMP were placed at 2.5, 15.0 and 25.0 cm depths (1, 6 and 10 inches) in 2 areas of the plot. The first monitoring area was about one-third of the distance down the field from the head ditch. The second area was about one-third of the distance of the field up from the tail ditch. Each area had 4 tensiometers at each depth for a total of 24 tensiometers. Tensiometers were placed within the row

midway between plants. The type of tensiometers used were Irrometer Soil Moisture Indicators.[1] Model 'S', with a special seed bed tip, was used for the shallow depth (2.5 cm). Each of these instruments was supported with a small steel tripod. Model 'R' 15 and 30 cm lengths were used for the other two depths, 15 and 25 cm.

A pair of Bellani plate atmometers with black surfaces were used to monitor evaporative power of the air (EPA). These were placed within irrigated fetch and surrounds in a surface irrigated agricultural weather station located at the research center. The Bellani plate assembly is illustrated in Figure 1. The 2 plate surfaces were positioned parallel to and 1 meter above the soil surface. Distilled water was used to replenish the 250 ml reservoir when necessary.

All instruments were read daily between 8 and 9 A.M. The cumulative average of the standardized tensiometer readings was plotted as a function of the accumulated average of the standardized Bellani plate readings. Both cumulative values began at zero when a significant recharge or irrigation occurred.

Irrigation was scheduled when the mean of the tensiometer readings reached a predetermined soil matric potential as previously determined by the literature (Personal communication, Irrometer Company) and prior experience with tensiometers in conjunction with moisture release curves. The matric potentials chosen were -16 cb from

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[1]Irrometer Company, Riverside, California 92506.

Figure 1. Bellani plate assembly including the standardized
plate, air vent and one way check valve.
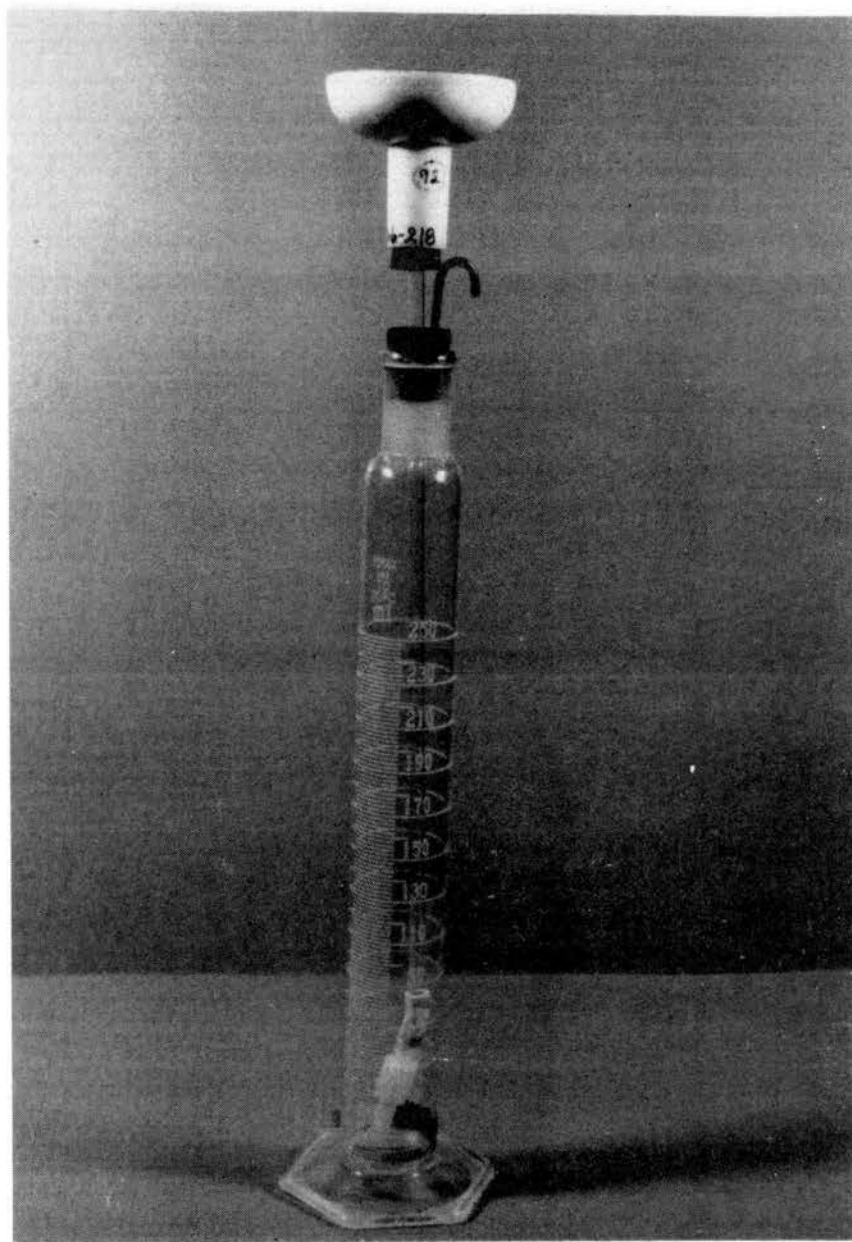
planting through 10 days, -28 cb for 11 to 30 days, -33 cb for 31 to 50 days and -39 cb for 51 days to the first commercial harvest. The exception to this was an irrigation which took place immediately after thinning. The amount of rainfall which would constitute a recharge if runoff was minimal was as follows: 0.64 cm (0.25 inches) for 0 to 30 days, 0.89 cm (0.35 inches) for 31 to 50 days and 1.27 cm (0.50 inches) for 51 days to harvest. The rainfall was accumulated for 24 hour periods in a standard USWS 8 inch diameter rain and snow gauge.

The first experiment was repeated for a second and third growing season, again planting in June. A growth curve based on plant dry weight was established during each of these 3 trials.

A test to determine the response of the Bellani plates to position placement in different crop species was initiated. Paired plate assemblies were placed in the surface irrigated agricultural weather station, a surface irrigated lettuce field and a surface irrigated potato field all located at the research center. These were monitored for 30 days.

Another test was conducted in order to determine the monitoring range of the Bellani plate atmometers. A pair of plate assemblies were placed in a surface irrigated potato field at the research center. The second pair of plates were placed in a grower's surface irrigated potato field 13 km (8 miles) distant. All readings were taken between 8 and 9 A.M. daily for 30 days.

Another experiment was designed to test the effect of planting date on the relationship developed for SMP as a function of EPA. This was accomplished by planting on April 27, May 27 and June 27 in a single season at the San Luis Valley Research Center. As before, the plots were planted to commercial specifications. A plot area of six beds 91 m long for a total area of 0.05 ha (0.13 acre) was used. Tensiometers were not used. However, the irrigations were scheduled by monitoring the EPA with the previously described Bellani plate assemblies. The irrigations took place when accumulated milliliters lost corresponded to the previously determined SMP constants. Therefore, the EPA constants used were 229 ml for 0 to 10 days, 488 ml for 11 to 30 days, 278 ml for 31 to 50 days and 227 ml for 51 days to the first commercial harvest. Yield records were taken in a single harvest at the time each of the plantings reached maturity. The harvests were taken 87, 75 and 83 days after planting for the April 27, May 27 and June 27 plantings, respectively.

Clay Soil Investigations

An experiment was designed to test the influence of a different soil classification, that is, a heavier textured soil on the relationship developed for the sandy loam soil. The 0.05 ha (0.13 acre) plots were planted to the commercial specifications (previously described) at the Horticulture Department's farm located 13 km (8 miles) northeast of

the Colorado State University campus. The farm is surrounded by surface irrigated agronomic crops including alfalfa, barley, corn, pinto beans and sugar beets. The plots were surrounded by other surface irrigated vegetable research plots and field corn. The elevation is 1524 m and sporadic rainfall occurs on the order of 2.8 to 3.8 cm (1.1 to 1.7 inches) per month during the growing season.

Tensiometers were placed at 2.5, 15.0 and 25.0 cm depths and correlated with the Bellani plate readings in a similar manner as the first experiment in the San Luis Valley. The Bellani plates were located in an area of surface irrigated pasture grass.

Irrigations occurred at approximately the same soil matric potentials used for the sandy loam soil. The amount of effective rainfall considered to provide a significant recharge was also the same as that for the sandy loam soil.

The experiment was conducted for two consecutive seasons. During the first season, planting occurred on August 4. The lettuce was planted July 12 during the second season. During the first season, the lettuce suffered frost damage on October 10, 65 days post planting, before the heads reached maturity. The lettuce during the second season reached a marketable harvest maturity 70 days after planting. During the second season, a growth curve was established.

Bellani Plate Freezing

Two tests were conducted to determine the effectiveness of a 250 w heat lamp in preventing ice formation in a Bellani plate assembly. The system was positioned as illustrated in Figure 2. Testing took place in a walk-in cooler. Copper-constantan thermocouples measured plate water temperature and ambient air temperature.

A Versatherm electronic controller model 2158[1] was used to control the temperature of deionized water in the plate and simulated graduated cylinder. The simulated graduated cylinder was a 2 cm I. D. piece of tygon tubing with a volume of approximately 250 ml. A Cole-Parmer Series 8400, Yellow Springs Instrument Series 400 thermistor probe[2] was used in conjunction with the controller to sense the temperature in the Bellani plate. The controller was used in the range B mode. Dial settings for coarse and fine adjustment were 58 and 70, respectively. The upper (black) surface of the Bellani plate was sealed with a polyurethane varnish to prevent moisture loss.

The first test was conducted by placing the components in the cooler at an ambient temperature of $-2^{\circ}C$. This temperature was maintained for a 12-hour period.

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[1] Horizon Ecology Company, Chicago, Illinois 60648.

[2] Ibid.

Figure 2. Diagram of the positioning of the Bellani plate assembly relative to the heat lamp used in the freezing protection study in a low temperature controlled room.

BELLANI
PLATE

57.4 cm (23")

32°

90°

SEALED
WATER
FILLED
TEMPERATURE
SENSOR

THERMISTOR

68.6 cm (27")

36.8 cm
(14.5")

SIMULATED
GRADUATED
CYLINDER

58°

HEAT LAMP

CONTROLLER

COARSE   FINE

110 VAC
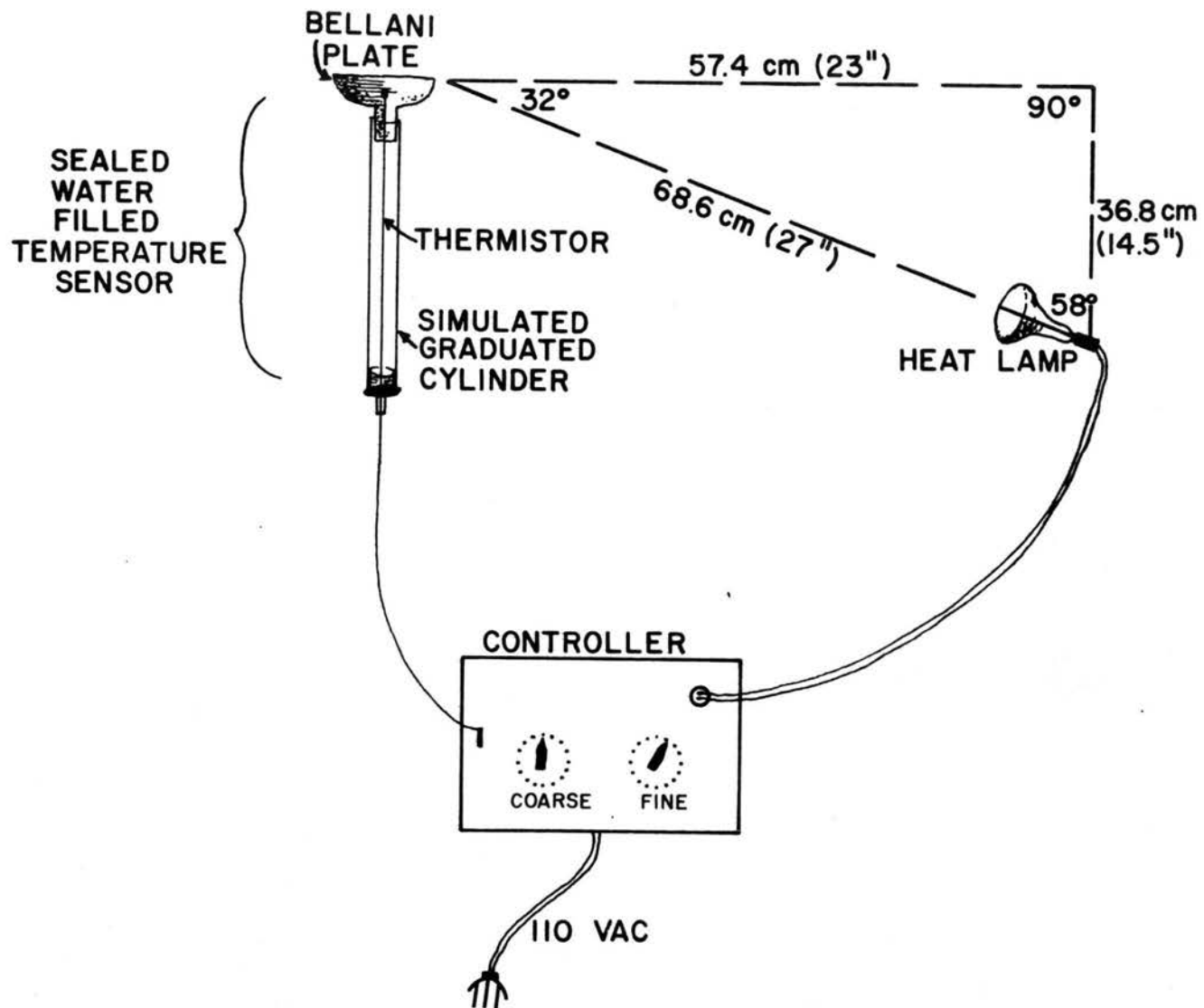
The second test began with an ambient air temperature of $18^{\circ}C$ and corresponding water temperature. The air temperature was then lowered to $-3^{\circ}C$ over a period of $1\frac{1}{2}$-hours. The ambient air temperature subsequently dropped to $-4^{\circ}C$ and was stable for a 12-hour period.

RESULTS

Sandy Loam Soil Investigations

Three equations were developed using the least squares regression method for the relationship for SMP as a function of EPA as indicated by atmometer water depletion. Figure 3 shows 2 scatter plots, regression curves and confidence bands representing the 95% level of probability. Confidence bands at the 95% level of probability indicate that 95 times out of 100, the regression line will fall within the area bounded by the bands.

Since the data appeared to fall into 2 subsets relative to days from planting, the "I" serves for approximately the first 30 days of the growing season and "III" for 51 days from planting to the first commercial harvest.

When used for scheduling, period I is divided in 2 parts. IA is for stand establishment usually by 10 days after planting. Irrigation should occur after 229 ml of water have been lost from the atmometers. IB serves for approximately 11 to 30 days, normally through thinning. Water loss of 488 ml should occur before irrigation takes place. Period IB is arbitrarily termed root establishment. The increase in the value (water loss before irrigation occurs) for IB provides a more optimum seedling root environment. Period III is

Figure 3. Data points, regression lines and 95% confidence
bands for irrigation periods I and III established
for a sandy loam soil. Data for 3 successive
seasons are combined.

BELLANI ATMOMETER H₂0 DEPLETION (ml)
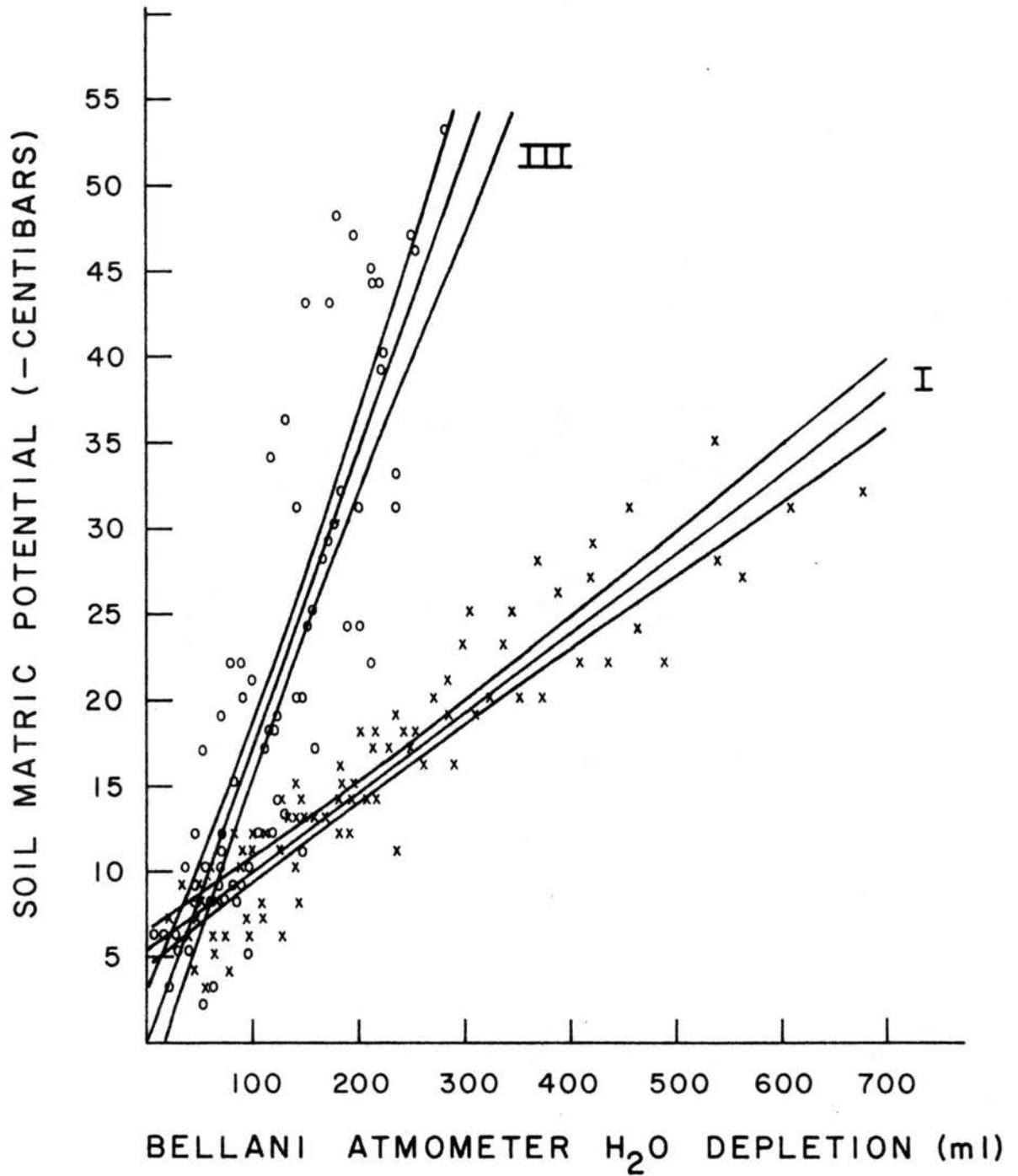
termed heading and canopy closure stage. The milliliters of

atmometer water loss for irrigation to occur is 227. Note the

intercepts are the same for both periods.

The growth curve for the lettuce for the sandy loam soil is

illustrated in Figure 4. The three irrigation periods are indicated

by Roman numerals. The initial segments which relate to the first

period (I) are indicated by A and B.

Figure 5 illustrates the three regression lines and correspond-

ing linear equations used for the sandy loam soil. Also indicated on the

X axis are the atmometer water loss levels (EPA constants) at which

irrigation should take place for each of the four growth periods. The

values for the regression coefficients in equation II were estimated by

calculating the arithmetic means of the respective regression coeffi-

cients in equations I and III that is:

$$\frac{_0\beta_I + {_0\beta_{III}}}{2} = {_0\beta_{II}} \quad \text{and} \quad \frac{_1\beta_I + {_1\beta_{III}}}{2} = {_1\beta_{II}}$$

F tests for regression with regard to the analysis of the equations

representing growth periods I and III were both highly significant.

The behavior of the Bellani plate pairs located during the vege-

tative phase in 2 crop species and in a weather observation station

are depicted in Figure 6. The observations are plotted as the mean

Figure 4.   Growth curve for lettuce during 3 seasons on a
           sandy loam soil in the San Luis Valley.
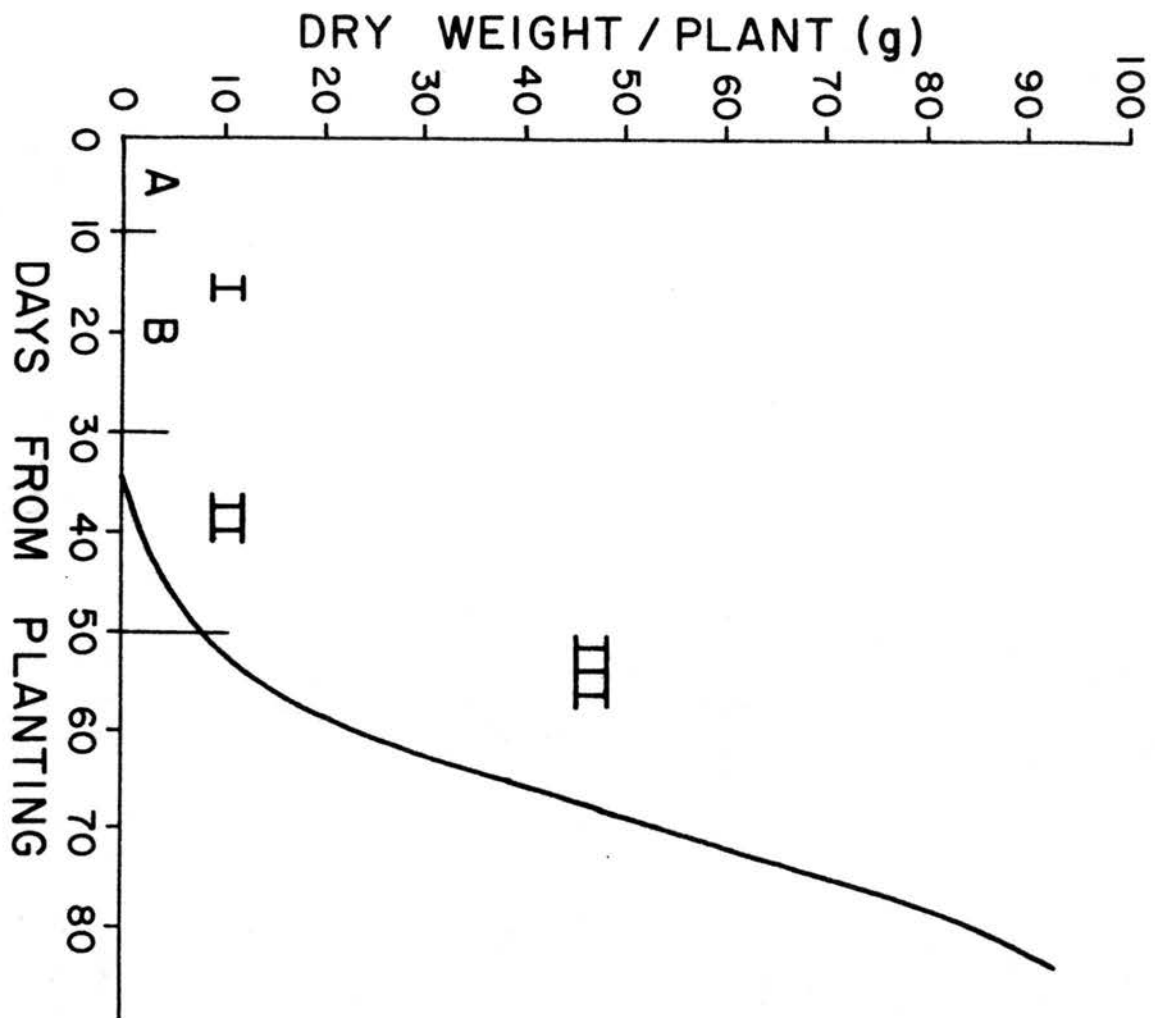
Figure 5. Three linear regression equations and four irrigation periods used for irrigation scheduling for western iceberg lettuce on a sandy loam soil. Note that the same equation is used for stages A and B but the EPA constants differ.

SOIL MATRIC POTENTIAL (−CENTIBARS)

BELLANI ATMOMETER H2O DEPLETION (ml)

A

B

51 DAYS → HARVEST
0 → 10 DAYS
31 → 50 DAYS

11 → 30 DAYS

III
$\hat{Y} = -0.279319 + 0.172731X$
$r^2 = 0.74**$

II
$\hat{Y} = 2.545283 + 0.109547X$

I
$\hat{Y} = 5.369884 + 0.046362X$
$r^2 = 0.87**$
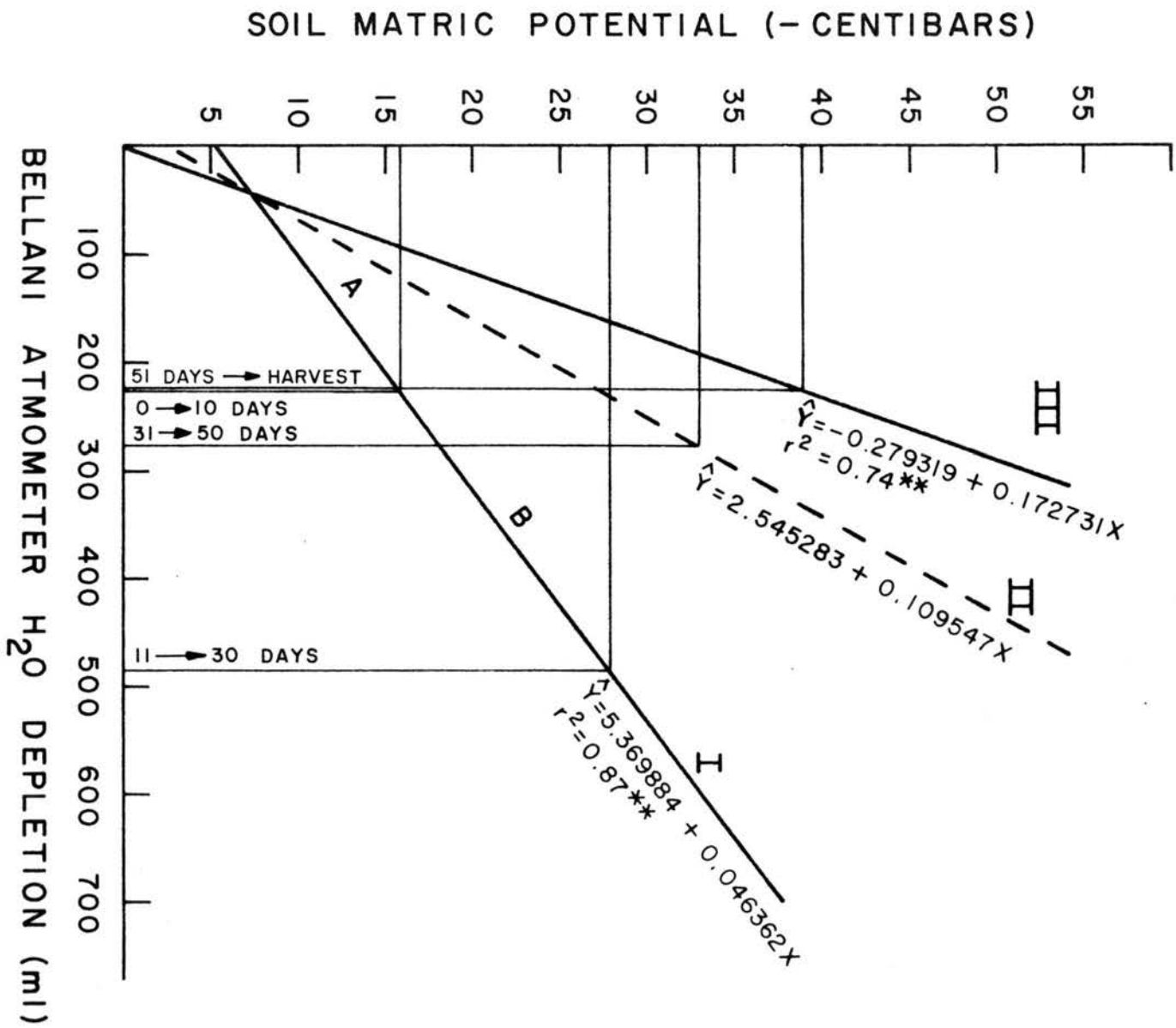
Figure 6. Behavior of the Bellani plate atmometers located in
three different surface irrigated crop species on the
same farm.
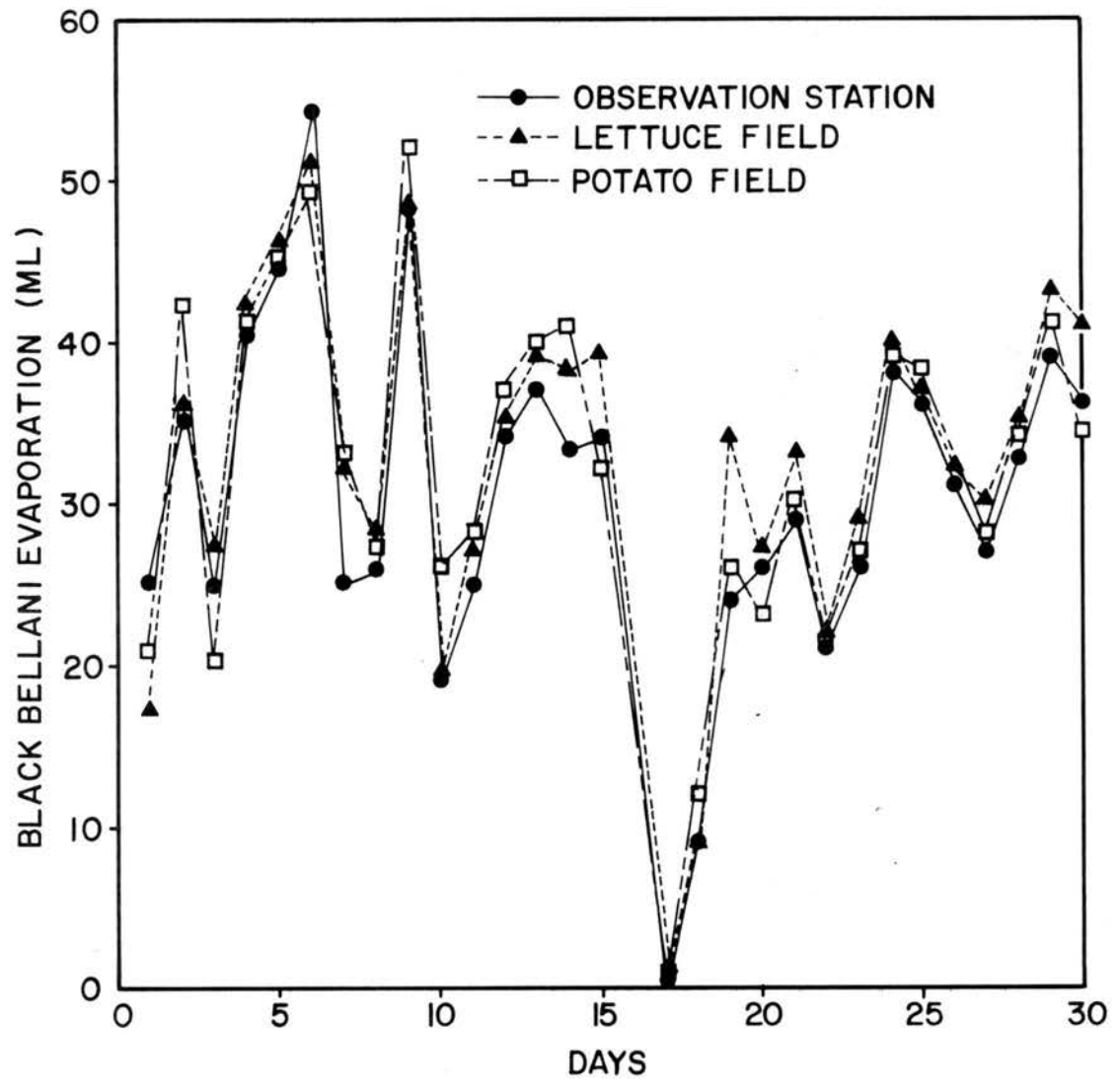
standardized plate loss per day for 30 days for each of the 3 crop species.

The similarities of evaporative loss from the two pairs of plates 13 km (8 miles) distant can be seen in Figure 7. Again, the observations are plotted as the mean standardized plate loss per day for 30 days for each pair of plates. The period monitored corresponded to the vegetative growth phase for potatoes.

The yields for the three plantings in a single season ranged from 26, 880 to 41, 440 kg per ha (250 to 370 cwt per acre). The cut-out varied from 54 to 80 percent. These yields are in the range of a once over commercial harvest. The April 27 planting was harvested 87 days from planting. The May 27 planting was harvested 75 days following planting. The June 27 planting was harvested 83 days after planting.

Clay Soil Investigations

The growth curve established for the clay soil is shown in Figure 8. The figure also includes the growth curve for the sandy loam soil. It can be seen that the initial log phases of growth are essentially the same for both soils. The relationship for SMP as a function of EPA for the clay soil during a 70 day season is shown in Figure 9. The data points and confidence bands at the 95% level of probability are included. The data were first divided into subsets

Figure 7. Behavior of two pairs of Bellani plate atmometers with one pair located in each of two furrow irrigated potato fields 13 km (8 miles) apart.
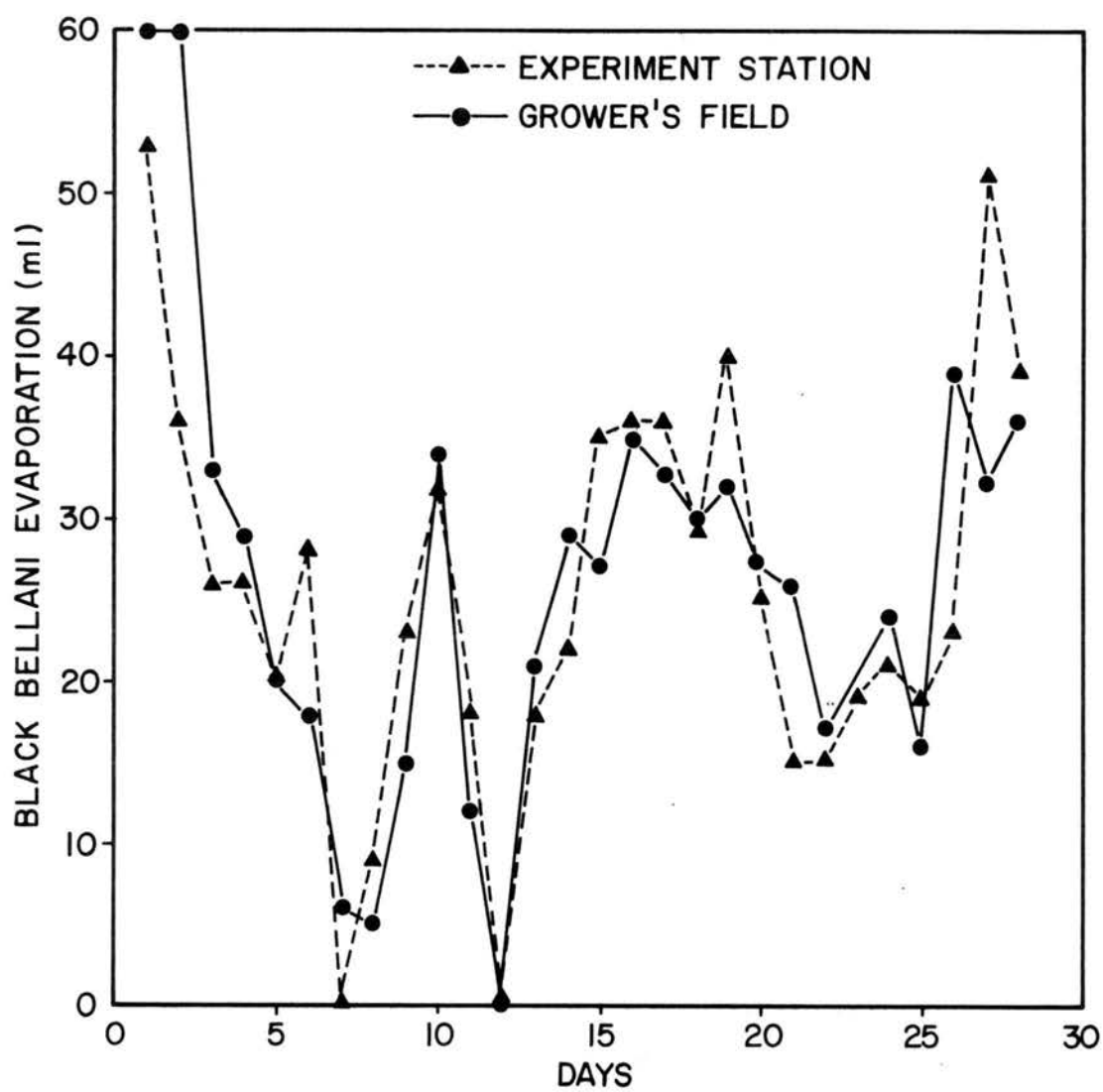
Figure 8. Comparison of lettuce growth curves for sandy
loam and clay soils. The sandy loam soil curve
represents 3 seasons ranging from 78 to 88 days
while the clay soil was a 70 day season.
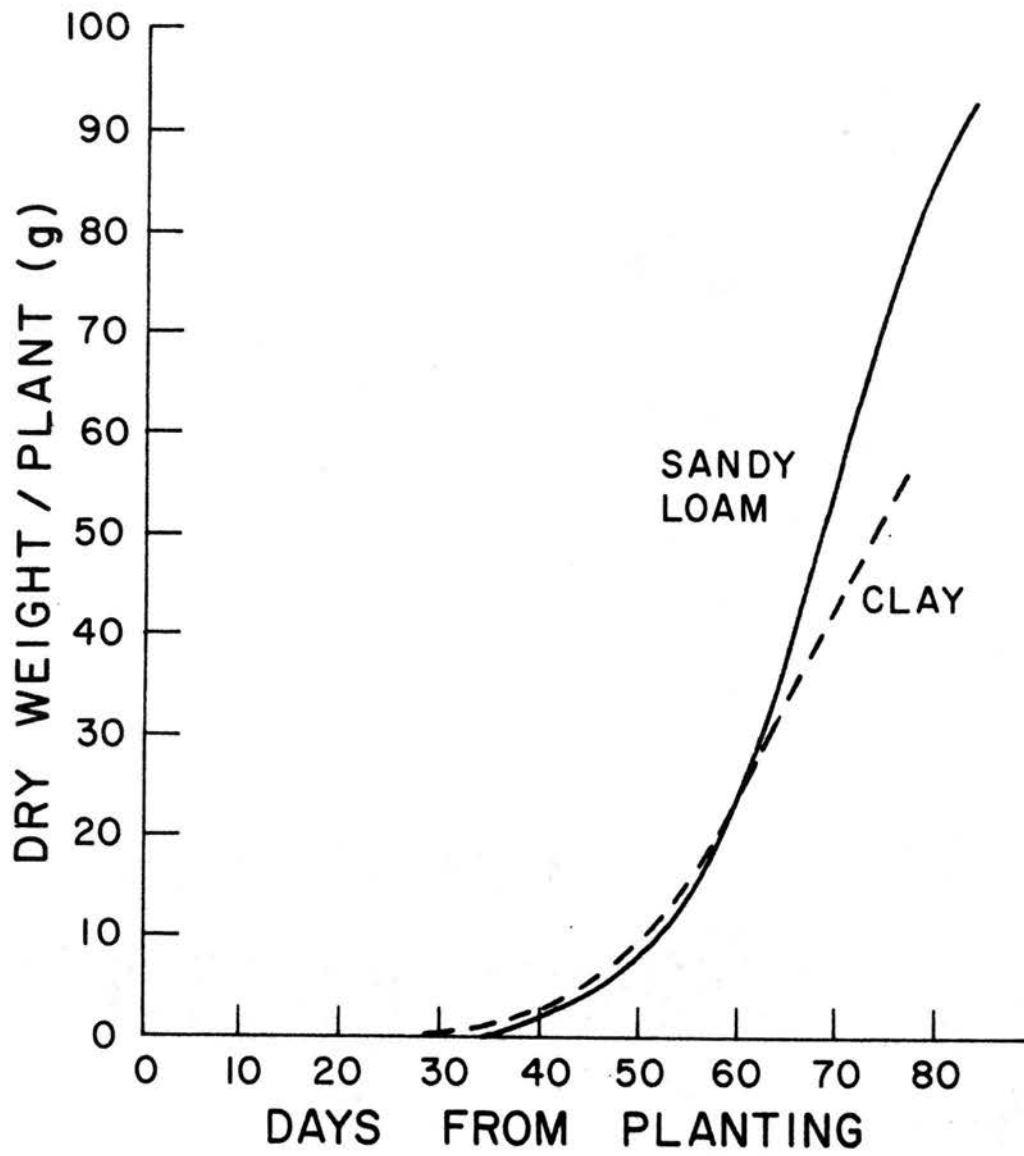
Figure 9. Data points, regression line and 95% confidence
bands for a 70 day season for SMP as a function
of EPA established for the clay soil during 2
seasons. The R^2 is 0.78.
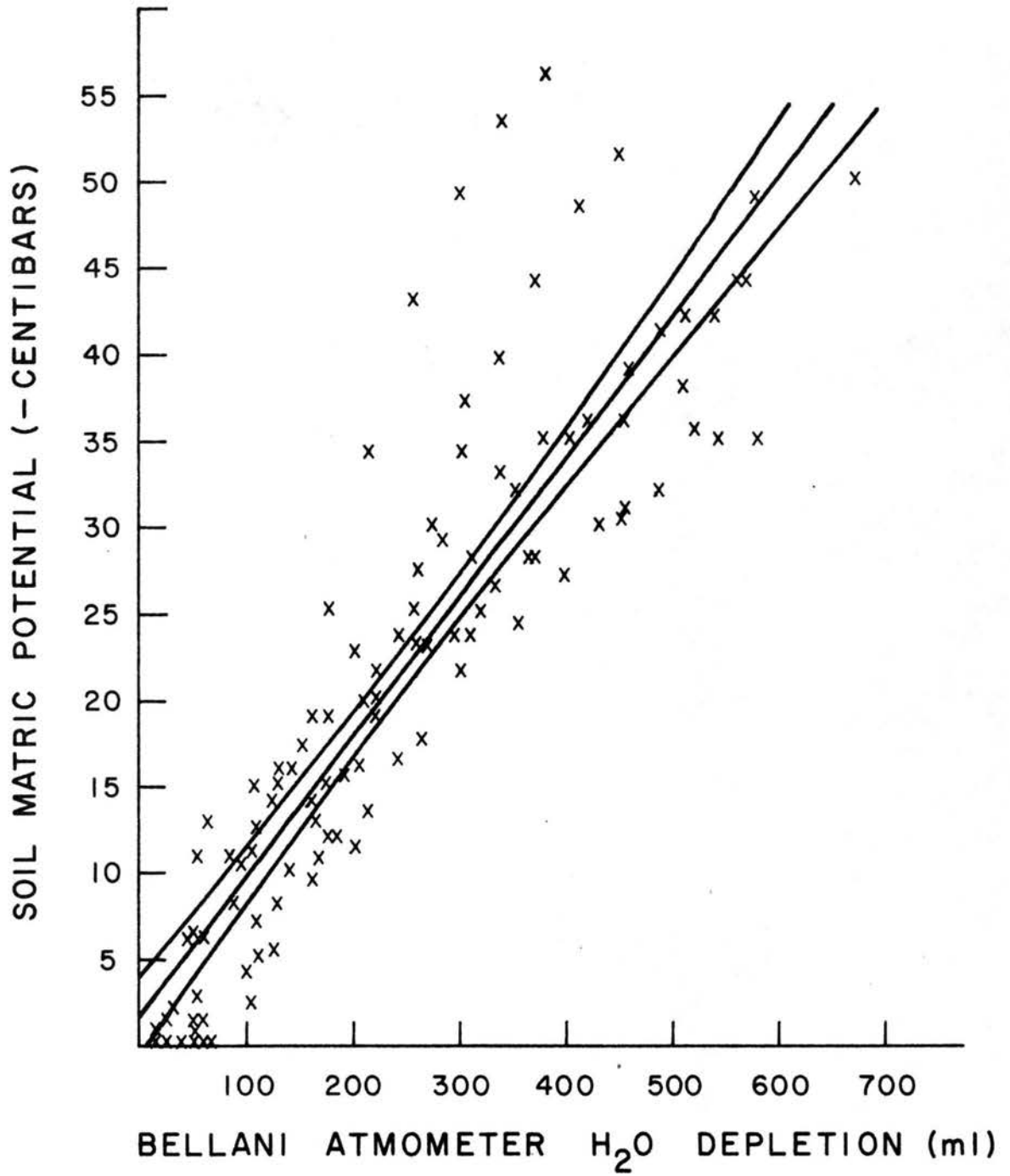
corresponding to the three time periods established for the sandy

loam soil, however, the three regression lines for the clay soil were

not significantly different as determined by examining the confidence

bands for each of the 3 regressions. The examination showed the

three sets of confidence bands overlapping.

Figure 10 compares the linear relationships I and III for the

sandy loam soil to the linear relationship for the clay soil and includes

their respective confidence bands. Note that the intercepts are essen-

tially the same for all 3 regression lines. Therefore, the 2 different

soils are behaving in a similar linear fashion with regard to SMP as

a function of EPA.

The soil coefficient (K) to be applied to the slopes of the equations

for the sandy loam soil in order to use these equations when irrigating

a clay soil is 0.72. The coefficient was derived by using the soil moisture

desorption curves for the two soils illustrated in Figure 11. The values

for the soil moisture contents in percent by volume are indicated in the

figure. The change in soil moisture content from -10 to -50 centibars

for the sandy loam was multiplied by the reciprocal of the change over

the same range for the clay soil. That is, the value of 15.5% (sandy

loam at -50 cb) is subtracted from 27.3% (sandy loam at -10 cb) to give

an 11.8% change. The value of 35.9% (clay at -50 cb) is subtracted

from 52.3% (clay at -10 cb) to give a 16.4% difference. The sandy

loam change (11.8%) multiplied by the reciprocal of the clay change

Figure 10. SMP as a function of EPA including the 95% confidence
bands for the sandy loam period I (0-30 days), sandy
loam period III (51-90 days) and clay (0-70 days).
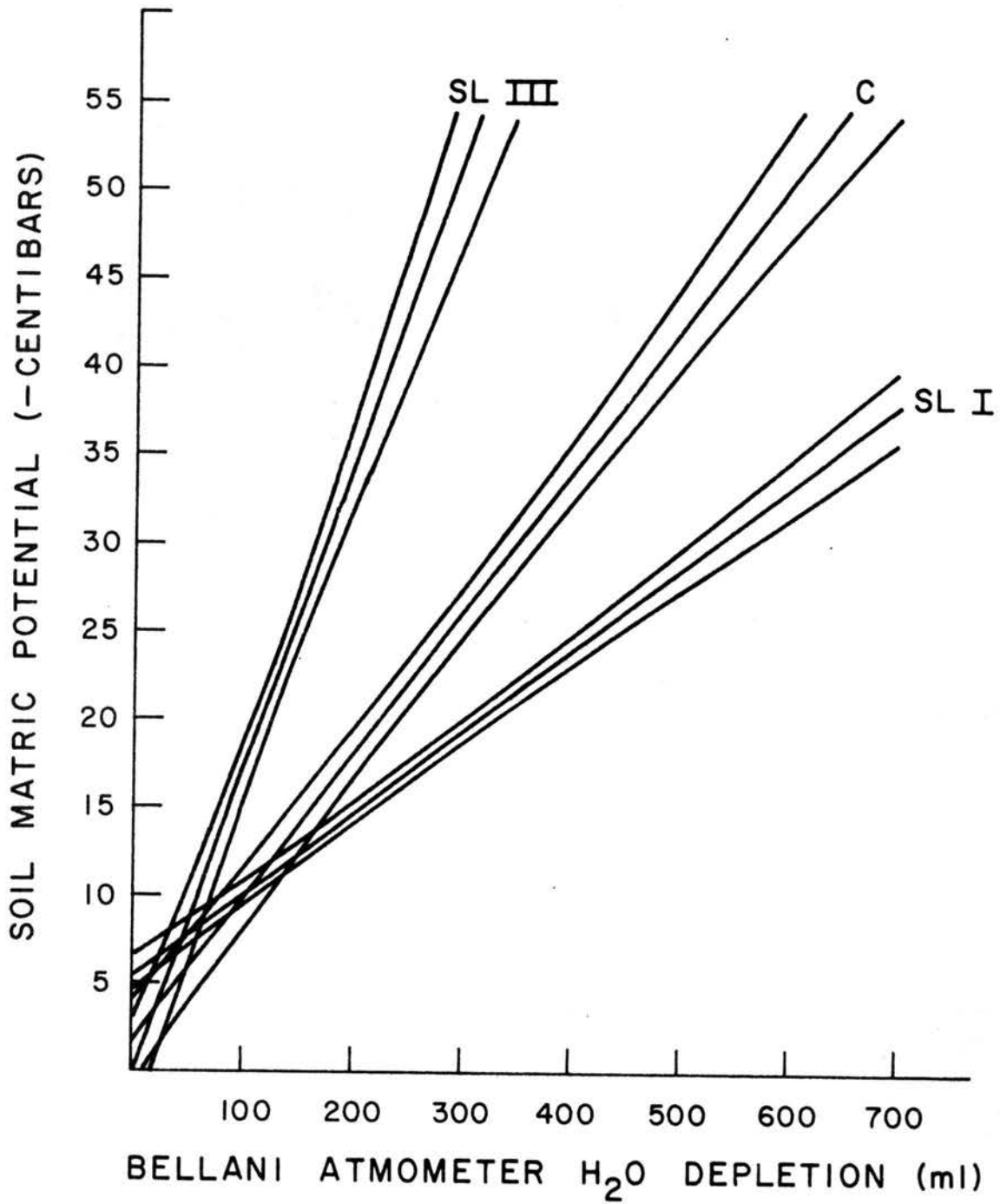
Figure 11. Desorption curves for the sandy loam and clay soils used in the field investigations for developing the soil coefficient. Samples represent an effective root zone of 0-25 cm (0-10 inches). Bulk densities are from literature (15). Soil moisture content at saturation (percent pore space at 0 matric potential) was calculated using the respective bulk densities and a real specific gravity of 2.65 (19).

PARTICLE SIZE ANALYSIS

TEXTURE	C	SL
% SAND	26	72
% SILT	31	16
% CLAY	43	12
BULK DENSITY	1.25	1.40
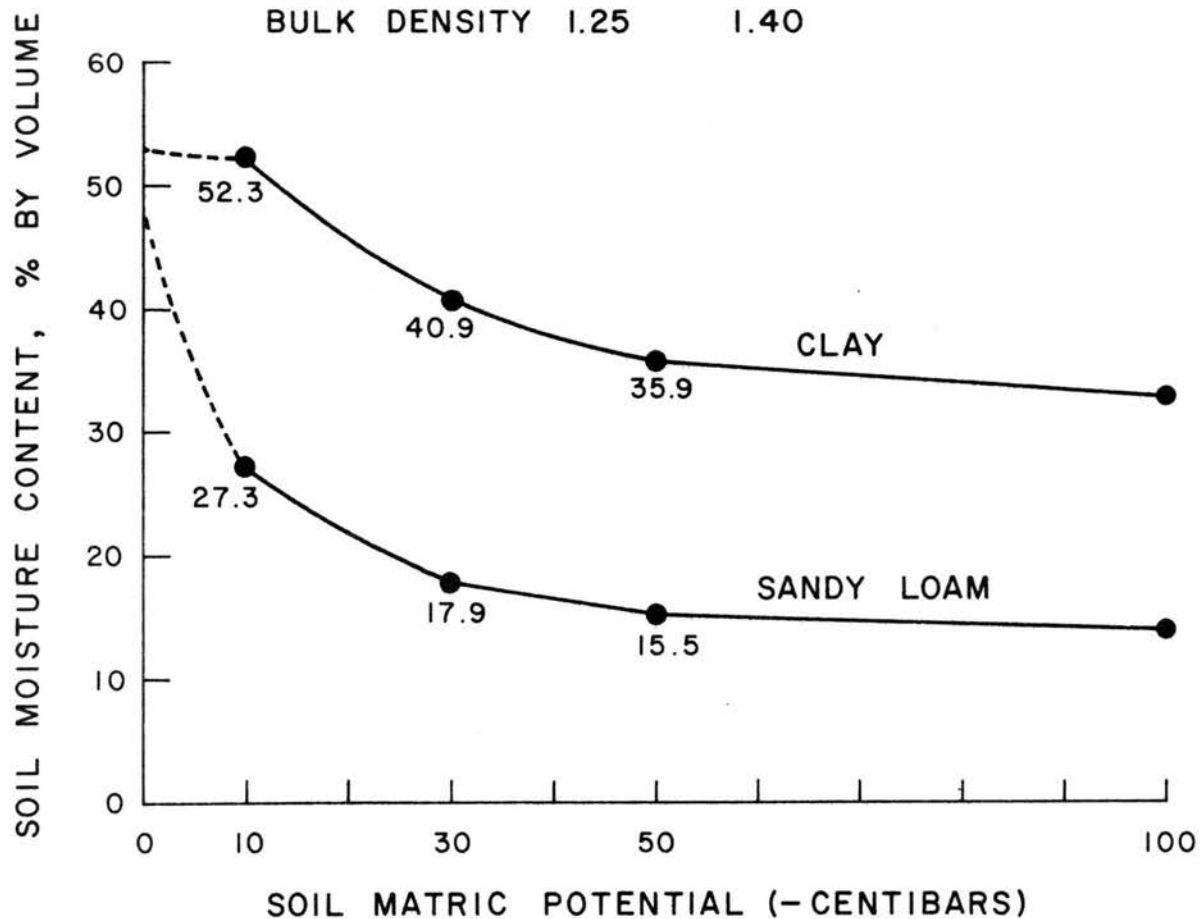
(1/16.4%) provides a clay soil coefficient of 0.72. The smaller the soil coefficient, the greater the predicted time interval for a given EPA value (constant). In calculating future soil coefficients, the 11.8 is seen as a constant to be multiplied by the reciprocal of the change in moisture content (-10 to -50 cb) of the unknown soil for which irrigation scheduling is desired. This adjusts the model for soil type.

Figure 12 presents the 3 regression lines and corresponding linear equations for the sandy loam soil along with the 3 regression lines and corresponding linear equations for the clay soil. Note that the clay soil equations differ from the sandy loam equations only in the value representing K, the soil coefficient. The sandy loam coefficient is set at 1.00 and the clay soil coefficient was determined empirically to be 0.72. Thus, the slopes of the equations used for the clay soil have decreased compared to those used for the sandy loam soil. This supports the fact that more evaporative energy is required to reach a given SMP for a clay soil than for a sandy loam soil. In other words, for a given evaporative loss there is a smaller change in the SMP for the clay soil than for the sandy loam soil. In a situation where cumulative evaporative power (Σ EPA) was the same for a clay and sandy loam soil during the same time interval, irrigation would be predicted sooner with regard to the sandy loam soil.

The yield for the clay soil in 1978, 70 days after planting, was 10,750 kg per ha (95 cwt per acre) with a 43% cutout of marketable heads.

Figure 12. Three regression lines and corresponding linear equations for the sandy loam soil along with the 3 regression lines and corresponding linear equations for the clay soil. Note the clay soil coefficient applied to the slope.
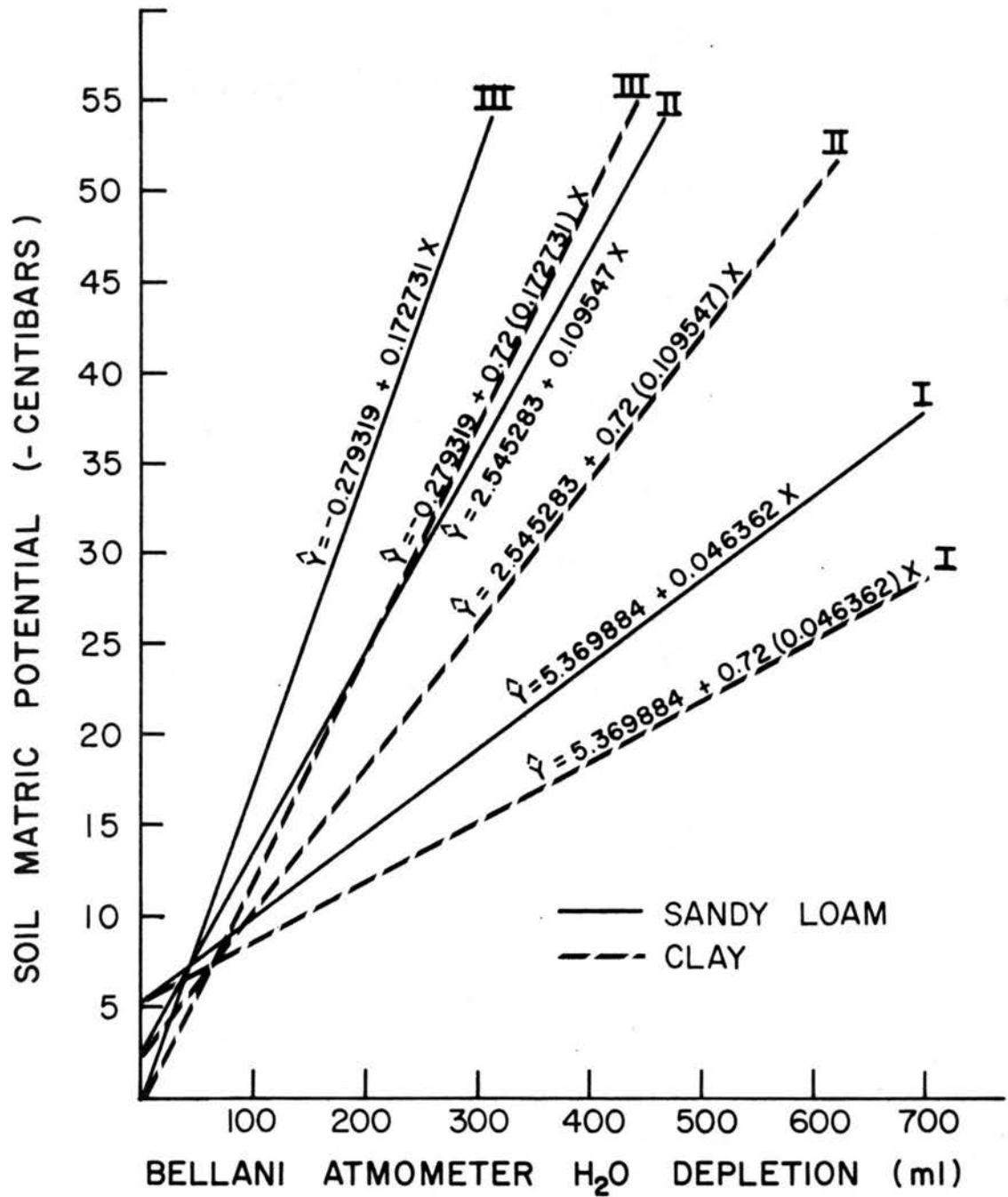
The plants for 1977 did not produce marketable heads before they were frozen 65 days after planting.

Bellani Plate Freezing

For the first test, the ambient air temperature was maintained at -2°C for a 12-hour period. During this time, the Bellani plate water temperature was approximately 1°C. The heat lamps became activated 50% of the time.

For the second test, the beginning ambient air temperature was 18°C. The air temperature then lowered rapidly to -3°C and gradually to -4°C where it was stable for a 12-hour period. During this 12-hour period, the Bellani plate water temperature was 0.5°C. The heat lamp was activated essentially all of the time.

The Irrigation Scheduling Model

Since SMP constants for growth stages have been developed for many crops including lettuce, the model first pictures SMP as a function of cumulative evaporative power of the air (Σ EPA) as indicated by atmometer water depletion for each of 4 lettuce growth stages. The influence of soil type is accounted for by a soil coefficient (K) applied to each of the slope values (β_1) in the linear equations involving SMP as a function of EPA.

$$SMP = \beta_0 + K \beta_1 (\Sigma EPA) \qquad [1]$$

The value of K is assumed to be 1.00 for the initial sandy loam soil. The reciprocal of the change in the soil moisture content from -10 to -50 cb for the soil in question times 11.8 (the corresponding change for the original sandy loam) will be the value for the coefficient (K) for any soil in question.

The Programmable Calculator Program

The computer program uses equation [1] at each update for each lettuce field to convert ΣEPA to SMP as the field progresses through intervals between recharges and 4 growth stages. It was written in assembly language for a programmable calculator. The calculator has the capability of 2036 program steps plus 111 storage registers or approximately 3K capacity. The data is stored on a digital cassette. Each digital cassette has the data storage capacity for a maximum of 50 individual lettuce plantings. The program produces a graphic output for each day for each lettuce field.

A flow chart of the irrigation scheduling program is shown in Figure 13. The flow chart was used as an aid in writing the programmable calculator program and also as an aid in converting the program to a large scale computer program. The circles represent entrance and exits from the program. The trapezoids represent information entered by the computer operator. The diamonds represent branches where decisions must be made. The solid line rectangles are

Figure 13.   Flow chart for the programmable calculator irriga-
tion scheduling program.

START

FIELD NO.

Descriptive
Field Info.

Planting Date
1st Irrigation Date
Plate Coefficients
Soil Coefficient

Need
Calculation

No. of Days
Calculation

TODAY'S
DATE

Irrigate
Line

Clears
Stored
Data

Yes

RECHARGE?

No

ml LOST
PLATE #1

Plate
Coeff X ml

ml LOST
PLATE #2

Plate
Coeff X ml

CALCULATES
AVG. ml
LOST

Need
Calculation
And Applies
Soil
Coefficient

PLOTS AXES

DAILY FIELD
INFO

Descriptive
Field Info.

Plot
Irrigate
Line

PLOTS DATA
FROM LAST
RECHARGE

STORES
UPDATE
INFO.

STOP

subroutines the computer performs. The dashed line rectangles represent internal calculations done with information which was stored initially.

The program stores for individual lettuce plantings, data which include the descriptive field information, Bellani plate coefficients, soil coefficient, cumulative days from planting, cumulative EPA since the last significant recharge which is transformed to SMP and SMP constants at which a significant recharge should occur. The descriptive field information includes the company name, grower name, field description, soil classification and planting date or date of the first irrigation.

The graphic output is updated daily for individual plantings. The reported EPA loss for the previous day is entered. The program adds this value to that value representing cumulative loss since the last significant recharge. The accumulated EPA is then transformed to a SMP value, by solving one of the three linear equations, which is then plotted.

In order for a daily output for individual plantings to be created, it is necessary for information to be supplied to the computer operator on a daily basis. It is preferable that the information pertaining to yesterday be supplied to the computer operator in the early morning of the report day for the necessary short turn-around. The daily information necessary for mathematical calculations to be accomplished by the

program include the field number, today's date, whether a significant recharge occurred (either by irrigation or rainfall) and the Bellani plate readings for yesterday and today for each of the plate assemblies. If necessary, the stored Bellani plate coefficients may be changed at this time. The daily information required to complete each plot includes yesterday's date, the amount of rainfall, the maximum temperature, whether irrigation took place and if the rainfall was considered to be equal to a significant recharge.

Examples of the graphic output for the desk top calculator are seen on pages 61-69. The output is presented with "NEED" a function of "DAYS FROM LAST IRRIGATION." "NEED" is actually negative centibars of SMP corresponding to the milliliters of Bellani plate loss for each of the respective irrigation intervals. Days from the last irrigation are simply summed since the last recharge. The "IRRIGATE!" line moves up during the season as a function of stage of growth. Therefore, the "IRRIGATE!" line can be thought of as a SMP constant effective during each of the 4 growth stages. If the report is issued in the early morning, "YESTERDAY" is the date for the most recent day for which evaporation and irrigation information is complete.

The information on the left, see examples pages 61-69, is dynamic and changes daily. "RAIN" indicates the amount of rainfall received for the past 24 hours. "TEMP" is the maximum temperature for yesterday. Temperature plays no part in the model, it only serves as a weather

YESTERDAY   7/ 12/78

    RAIN   0.02   CSU-SLV

    TEMP   76   NELSON

    IRR?   NO   SL

    R=1?   NO   JUNE 10/1978

                                    IRRIGATE!

NEED →

0. 2. 4. 6. 8. 10. 12. 14. 16. 18. 20. 22. 24.

DAYS FROM LAST IRRIGATION
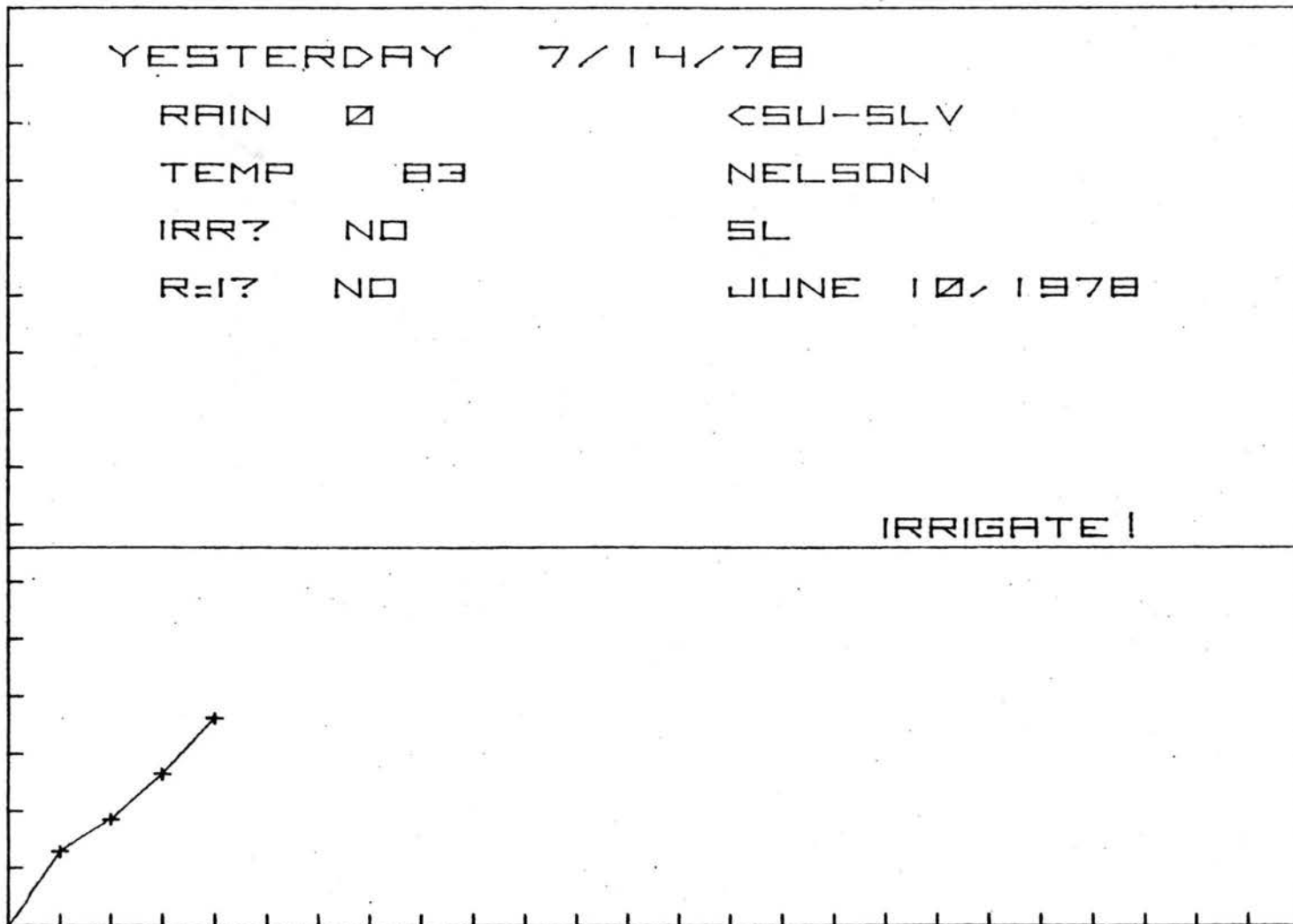
YESTERDAY   7/14/78

RAIN   0   CSU-SLV

TEMP   83   NELSON

IRR?   NO   SL

R=I?   NO   JUNE 10, 1978

↑ NEED

IRRIGATE!

DAYS FROM LAST IRRIGATION

YESTERDAY   7/17/78

RAIN   0.03   CSU-SLV

TEMP   73   NELSON

IRR?   NO   SL

R=I?   NO   JUNE 10, 1978
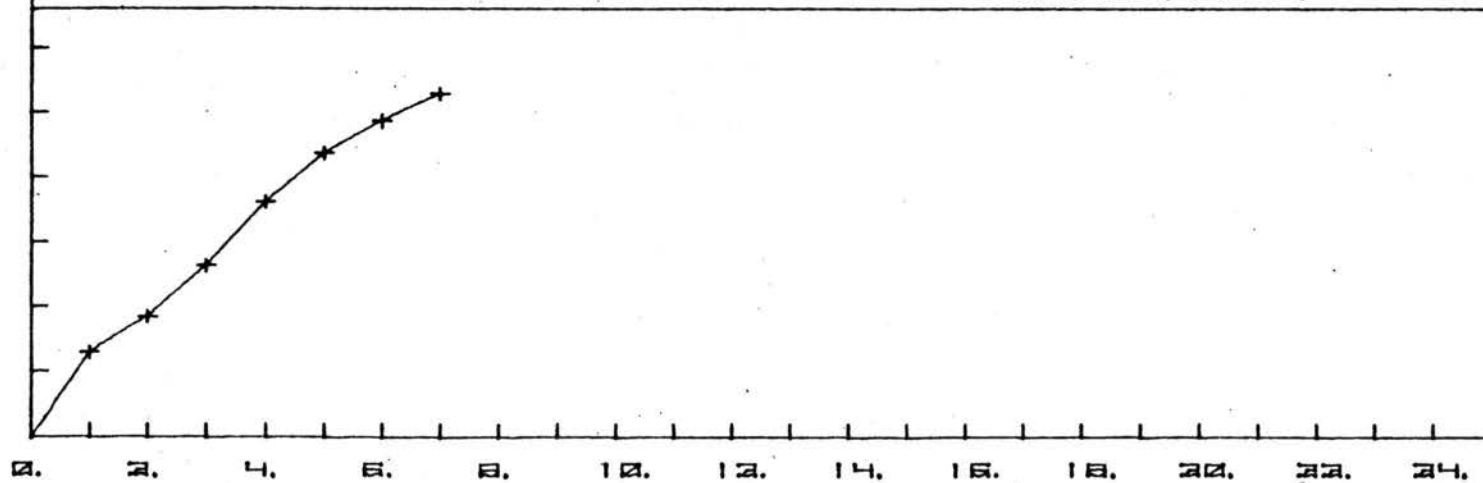
IRRIGATE!

NEED →

DAYS FROM LAST IRRIGATION

YESTERDAY   7/20/78

RAIN   0.08   CSU-SLV

TEMP   75   NELSON

IRR?   NO   SL

R=I?   NO   JUNE 10/1978
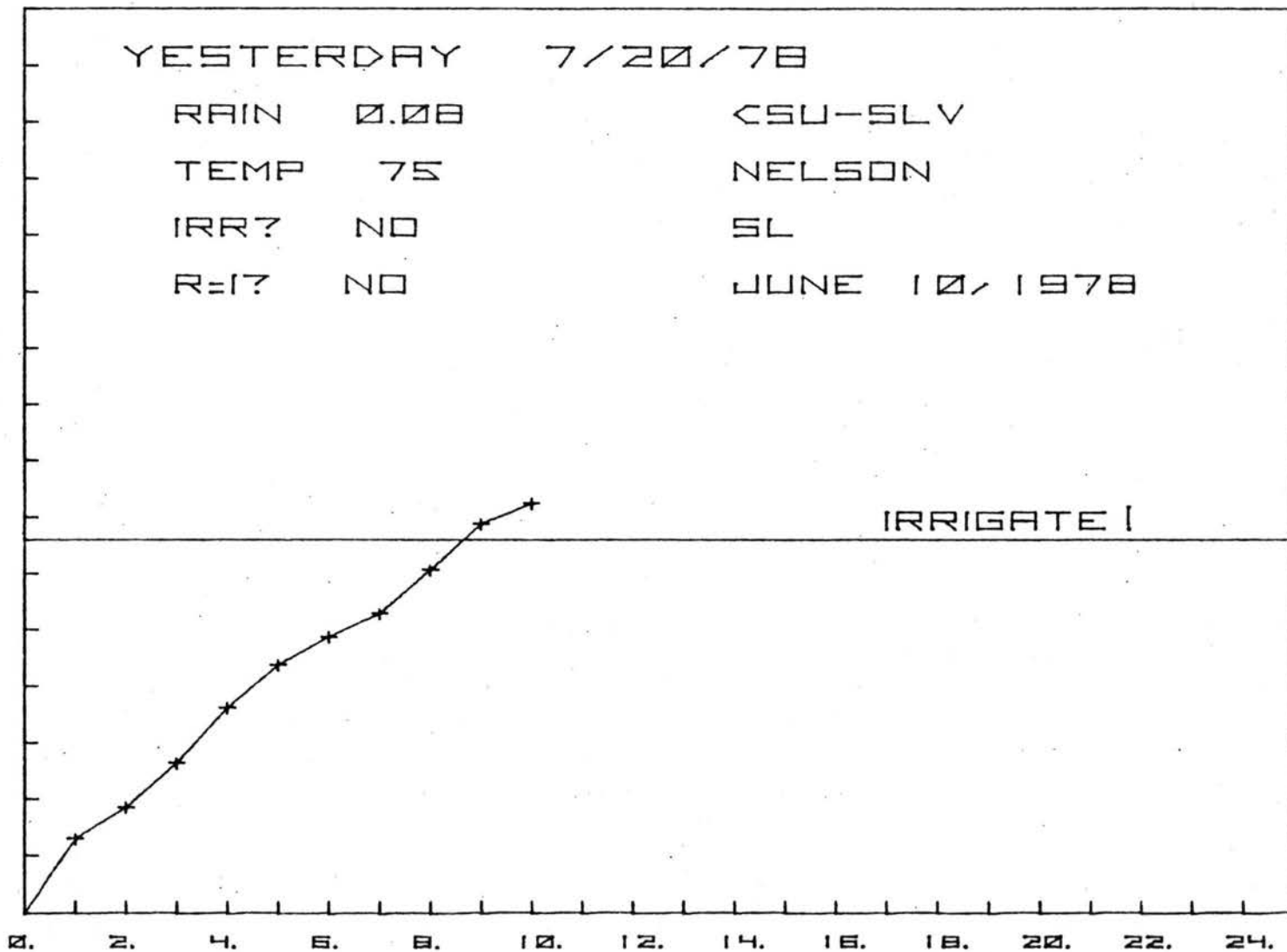
IRRIGATE!

NEED →

DAYS FROM LAST IRRIGATION

YESTERDAY   7/21/78

RAIN   0.08   <SU-SLV

TEMP   75   NELSON

IRR?   NO   SL

R=1?   NO   JUNE 10/1978
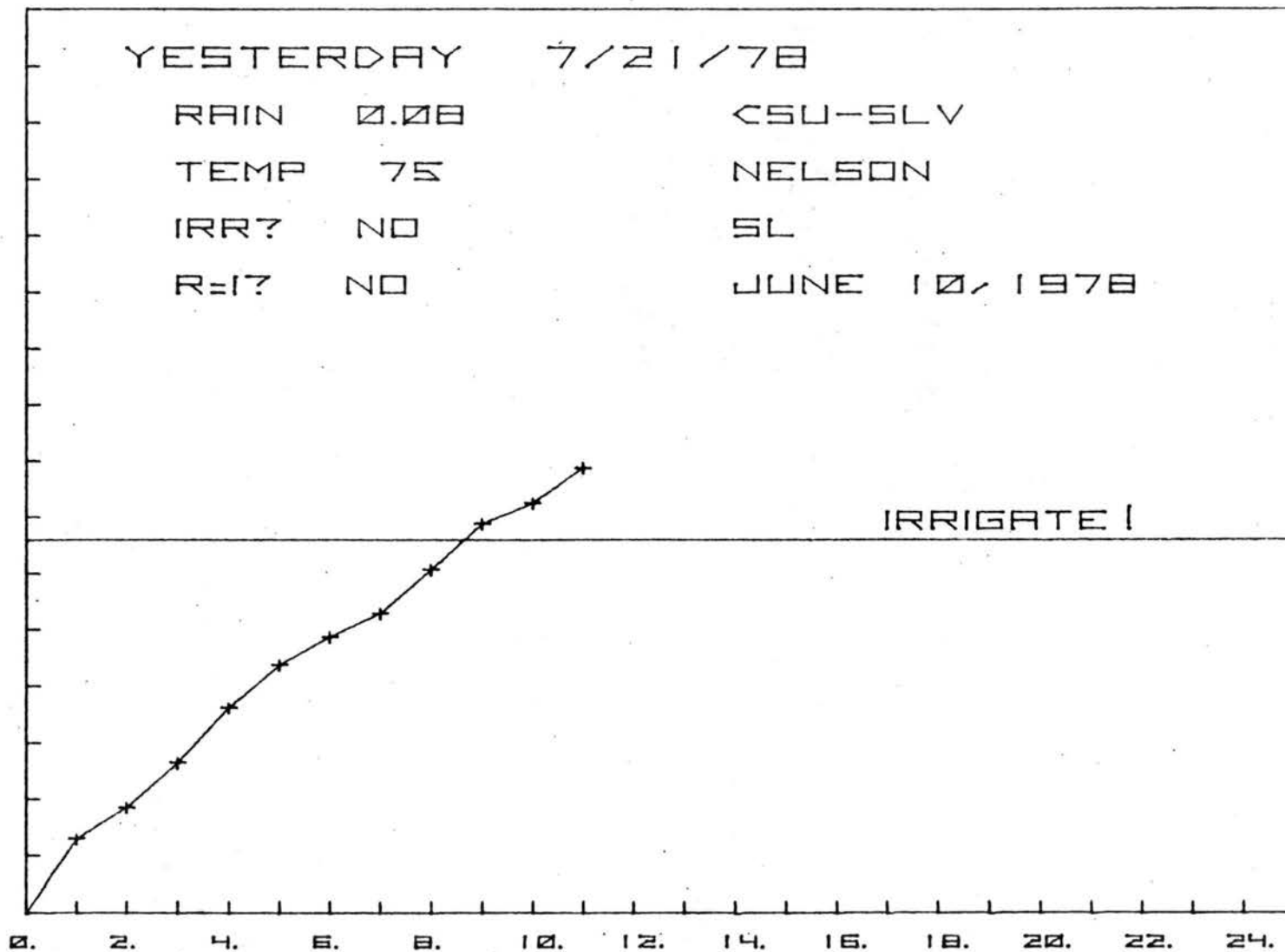
NEED →

IRRIGATE !

DAYS FROM LAST IRRIGATION

YESTERDAY   7/22/78

RAIN   Ø.19   CSU-SLV

TEMP   76   NELSON

IRR?   NO   SL

R=I?   NO   JUNE 1Ø/1978

IRRIGATE!

NEED →

Ø.   2.   4.   6.   8.   1Ø.   14.   16.   18.   2Ø.   22.   24.
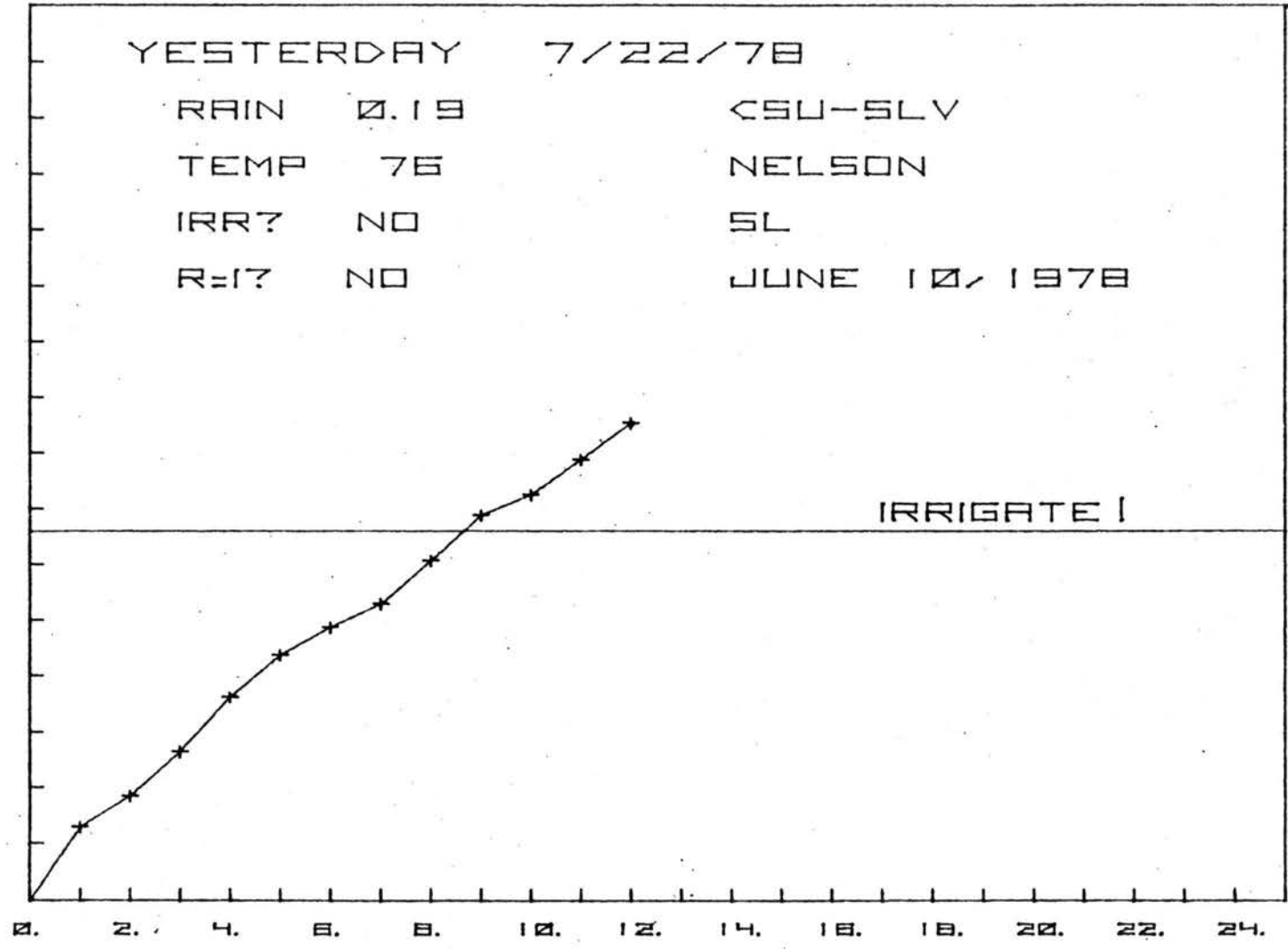
DAYS FROM LAST IRRIGATION

reminder. "IRR?" reveals if a significant recharge occurred.

"R=I?" indicates whether the amount of rainfall was adequate to

equal an irrigation (significant recharge). This also provides the

grower an opportunity to inform the computer operator of whether

the rate of rainfall was sufficient to cause runoff. If it was, the

computer operator answers no to "R=I?". Runoff is merely a subjec-

tive judgement by the observer i. e. the percentage of rainfall which

infiltrates the soil may vary from 0 to 100 depending upon rainfall

intensity and other factors. Therefore, the assumption is, if runoff

is observed, the root zone does not contain enough water to reach field

capacity, however, when irrigation occurs, the assumption is that

field capacity will be obtained. Obviously, when runoff occurs the

scheduling accuracy is in some jeopardy. However, it is felt that

any remedy would reduce the simplicity of the scheduling system

greatly.

The information on the right is entered when the crop is planted

and does not change. The first line represents the company name.

Next is the grower name and field description. The soil classification

is indicated by standard abbreviation on the third line. The final line

indicates the planting date, usually the date of the first irrigation for

the field.

The line which connects the pluses (+) is the daily line. Each of

the pluses actually represents the soil matric potential (NEED) relative

to days from last recharge. When the daily line intersects the "IRRIGATE!" line, irrigation should take place. Irrigation is over-due if the daily line crosses and exceeds the "IRRIGATE!" line. The daily line begins again at zero (the origin) when a significant recharge either by irrigation or rainfall occurs.

The user instructions and the annotated program listing may be found in Appendix B.

Large Scale Computer Program

In addition to the programmable calculator program, a program was written for the Control Data Corporation Cyber 171 computer at Colorado State University. A NOS version 1 management system is employed. The program was designed to be used independently of the programmable calculator program. The program uses 43K octal words of core to create and maintain files for the individual plantings. The program is written in FORTRAN IV with exceptions to ANSI stand-ard noted in Appendix C. It was designed to be used as an interactive program accessible by a remote hard copy and/or soft copy (CRT) time sharing terminal. A flow chart of the program is shown in Figure 14.

The program outputs predicted irrigation dates instead of graphic analysis. Internally, it fits by means of the least squares regression method; linear, quadratic and cubic polynomial models to EPA versus days from the last recharge data. The program then solves each of the

Figure 14. Flow chart for the large scale computer irrigation scheduling program. "Field" refers to a single lettuce planting.

START

DIRECTIONS ? —— YES → WRITES DIRECTIONS

NO

FILE OPERATIONS? —— YES → CALLS FIELD FILES →

LIST FIELDS?
ADD FIELDS?
DELETE FIELDS?
EDIT FIELDS?

NO

CALCULATIONS? —— YES →

ENTER DATA
CALCULATES NO. OF DAYS FROM PLANTING
DECIDES IF PRECIPITATION EQUALS A SIGNIFICANT RECHARGE
DECIDES IF ACCUMULATED ml EQUALS EPA CONSTANT
FITS BY LEAST SQUARES METHOD LINEAR, QUADRATIC & CUBIC REGRESSIONS
CONVERTS SOLUTION OF REGRESSIONS TO CALENDAR DATE
WRITES REPORT
NO ←—— ANOTHER FIELD? ——→ YES

NO

END

3 polynomials for days to next irrigation and converts the end of the interval to calendar date. This program does not repeatedly solve equation [1] for SMP as does the programmable calculator program. It merely uses the equation to convert SMP constants for the 4 growth stages to EPA constants.

A report is written by the computer each day for each field. Information required daily by the computer operator in order to create the output includes the field number, the date for which data processing is to occur, the amount of rainfall and whether runoff occurred and the evaporation loss for each of the Bellani plate assemblies. If new Bellani plates are being used, the new plate coefficients must be entered once into the program at the appropriate time.

The general format of the daily output for the large scale computer program includes the "Date of Report" and "Date of Last Report." The "ml accumulated" (Σ EPA) and "ml necessary for irrigation" (EPA constant) are also output. The "Last recharge date" and the "amount of rainfall" are provided prior to the predicted dates for irrigation. Along with the predicted dates for irrigation for each of the 3 polynomial equations are the coefficients of determination for each regression.

Examples of reports written by the computer are presented on pages 75-77. Note that the user is made aware of recharge and limited data plus information permitting a logical decision on when to irrigate. The user is also reminded when irrigation is overdue.

***** DATE OF REPORT: TUESDAY, JUL 11, 1978 *****
***** DATE OF LAST REPORT: MONDAY, JUL 10, 1978
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
RAIN: .40 INCHES--RECHARGE OCCURRED.

***** DATE OF REPORT: WEDNESDAY, JUL 12, 1978 *****
***** DATE OF LAST REPORT: TUESDAY, JUL 11, 1978
ML ACCUMULATED: 25; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: .02 INCHES--NO RECHARGE.
NO CURVE FITS AVAILABLE--ONLY ONE DAY'S DATA ENTERED SINCE LAST RECHARGE.

***** DATE OF REPORT: THURSDAY, JUL 13, 1978 *****
***** DATE OF LAST REPORT: WEDNESDAY, JUL 12, 1978
ML ACCUMULATED: 61; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: 1.000   WEDNESDAY, JUL 19, 1978
NOT ENOUGH POINTS FOR PARABOLIC OR CUBIC CURVE FITS.

***** DATE OF REPORT: FRIDAY, JUL 14, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUL 13, 1978
ML ACCUMULATED: 106; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .996   TUESDAY, JUL 18, 1978
     QUAD: 1.000   MONDAY, JUL 17, 1978
NOT ENOUGH POINTS FOR CUBIC CURVE FIT.

***** DATE OF REPORT: SATURDAY, JUL 15, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUL 14, 1978
ML ACCUMULATED: 141; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .998   TUESDAY, JUL 18, 1978
     QUAD: .998   WEDNESDAY, JUL 19, 1978
     CUB: .999   WEDNESDAY, JUL 19, 1978

***** DATE OF REPORT: MONDAY, JUL 17, 1978 *****
***** DATE OF LAST REPORT: SUNDAY, JUL 16, 1978
ML ACCUMULATED: 183; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: .03 INCHES--NO RECHARGE.
     LIN: .978   THURSDAY, JUL 20, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.

***** DATE OF REPORT: THURSDAY, JUL 20, 1978 *****
***** DATE OF LAST REPORT: WEDNESDAY, JUL 19, 1978
ML ACCUMULATED: 273; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: .08 INCHES--NO RECHARGE.
     LIN: .990   THURSDAY, JUL 20, 1978
    QUAD: .994   THURSDAY, JUL 20, 1978
     CUB: .994   THURSDAY, JUL 20, 1978

***** DATE OF REPORT: FRIDAY, JUL 21, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUL 20, 1978
ML ACCUMULATED: 302; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: .08 INCHES--NO RECHARGE.
IRRIGATE TODAY!

***** DATE OF REPORT: SATURDAY, JUL 22, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUL 21, 1978
ML ACCUMULATED: 332; ML NECESSARY FOR IRRIGATION: 278
FIELD NUMBER 5
COMPANY NAME: CSU
GROWER: NELSON
FIELD DESCRIPTION: SLV
LAST RECHARGE: TUESDAY, JUL 11, 1978
RAIN: .19 INCHES--NO RECHARGE.
*** IRRIGATION 1 DAYS OVERDUE.

The program user instructions and listing are found in Appendix C.

DISCUSSION

Sandy Loam Soil Investigations

The growth periods in this discussion will be referred to as:

0-10 days; stand establishment, 11-30 days; root establishment, 31-50 days; transition, and 51 days to the first commercial harvest; heading and canopy closure.

Equation I as shown in Figure 5 is divided in two parts corresponding to the periods indicated on the growth curve in Figure 4. A, or stand establishment, is for 0 to 10 days from planting. This is during the time when there is essentially a free water surface and seedlings are emerging. B, or root establishment, is for 11 to 30 days from planting, normally through thinning. During this period, the grower tends to reduce the irrigation frequency in order to encourage root growth by providing more aeration at greater depth after stand establishment (IA). The plants are small, thus the transpiration is trivial compared to the evaporation from the soil surface during the entire first 30 days of the growing season.

Equation II or the transition stage (Figure 5) was constructed using the arithmetic mean of the regression coefficients in equations I and III.

$$\frac{{}_0\beta_I + {}_0\beta_{III}}{2} = {}_0\beta_{II} \quad \text{and} \quad \frac{{}_1\beta_I + {}_1\beta_{III}}{2} = {}_1\beta_{II} \, .$$

The original regression analyses indicated that during each of the 3 seasons from approximately 31 to 50 days, no relationship between SMP and atmometer water loss existed. The growth curve indicated that this was the period when growth rate was not constant but increasing. Therefore, the arithmetic mean of each of the pairs of coefficients was arbitrarily chosen as an equation to represent this period. The judgement was made that little scheduling inaccuracy would result, if during the relative short transition stage (31 to 50 days from planting), it was assumed that SMP = $f(\Sigma \text{EPA})$ was linear. It is interesting to note the regression line (II) does not fall on a line which would bisect the angle between I and III (Figure 5).

The last equation (III) applies to 51 days after planting until the first commercial harvest (heading and canopy closure stage). This period represents maximum ground cover by the canopy. Therefore, more plant transpiration than evaporation occurs during this period (Figure 5).

The growth curve illustrated in Figure 4 is divided into three major sections which correspond to the 3 equations being used for irrigation scheduling. The two initial segments (A and B) of the first major section (I) represent the stand and root establishment periods

or the lag phase of growth. Section II is the portion which relates to the transition stage as previously discussed. The heading and canopy closure stage is depicted in section III.

The three equations shown in Figure 5 are used for the sandy loam soil. The right angle lines indicate the soil matric potential and the corresponding Bellani atmometer water depletion when irrigation should occur for each of the respective periods. The slope and intercept values are the same for IA and IB, however, the EPA constant for IA was arbitrarily increased for IB to provide an irrigation delay. The delay irrigation promotes root growth extension after stand establishment as experienced growers do.

Crop coefficients used in agronomic irrigation scheduling models account for adapting the original model to other crop species and also account for various stages of growth. The use of my three linear equations for the different stages of growth takes the place of crop coefficients used in other models.

The division of the growing season into four stages of growth for the purpose of irrigation scheduling has precedence regarding another leafy vegetable crop. Nelson and Hwang (38) studied the consumptive use of water in cabbage. They arrived at four growth periods. They defined their growth periods as: 1. emergence to the start of head development, 2. a short transition stage, 3. head development, and 4. maturity and senescence.

No differences in the behavior of the Bellani plate atmometers was found due to their respective locations within various crop species (Figure 6). Others have reported that the maintenance of the plate surface a uniform distance from the soil surface is more important than the crop species in which the Bellani plates are located (48).

The monitoring range of a pair of Bellani plates appears to be at least 13 km (8 miles) in the San Luis Valley of Colorado (Figure 7). Ranges greater than 13 km have not been tested. The greater the monitoring area, the more effective the system becomes. The homogeneous flat topography of the San Luis Valley involves few trees and therefore no wind barriers.

The yields for the 3 planting dates in the San Luis Valley sandy loam indicate that the time of planting did not influence the model used for the irrigation scheduling. The time of planting seems to have no influence on the ability of the Bellani plates to estimate evapotranspiration. The various climatic changes within a season can be accounted for by the irrigation scheduling method. This seems logical because as the weather is cooler, such as for April and May plantings, there is less energy available for plant growth as well as for the evaporative processes. In June the weather is warmer, therefore, more energy is available for plant growth as well as the evaporative processes.

The length of the growing season does not seem to influence the capability of the model to schedule irrigation. My investigations were

concerned with growth periods of 75 to 87 days from planting until first harvest. Zink and Yamaguchi (62) reported on lettuce growing seasons as varying from 61 to 78 days for summer and fall crops and a variation of 91 to 145 days for a spring crop in California. Depending on the length of the growing season, more or less time will be spent in period III of the irrigation model. That is, if the season is longer than 61 days, the irrigation would be scheduled by equation III a proportionately longer time. Actually, the EPA constant values required to be reached before a significant recharge should occur are relatively close for three of the four irrigation periods. That is, for periods IA, II and III the milliliter loss required is 229, 278 and 227, respectively, for the sandy loam soil, while the loss for period IB, the root establishment stage, is 488 ml. This might lead one to believe that a maximum of three irrigation periods with two EPA constants could possibly be used for scheduling irrigation. That is, a period for stand establishment, a period for root establishment and a period for post root establishment with the EPA constants for the period before and after the root establishment stage being the same. However, the average difference (50 ml) in EPA constant values between periods II and IA and II and III could mean a difference of 1 to 10 or more days in the irrigation interval depending on the climatological variation for the period in question.

Clay Soil Investigations

The clay soil was used to test the effectiveness of the model under a different soil regime. If the model is valid for two soils which are at either end of the soil classification scale, it should be valid for intermediate soils. Lettuce is not normally grown in clay soils and the Fort Collins area is not a commercial lettuce producing area. However, the area is close to the University and provided easy access to the researcher.

The growth curve for lettuce in the clay soil (July planted 70 day season) is seen in Figure 8 along with the sandy loam soil growth curve (June planted; 78, 84 and 88 day seasons combined and for practical pur-poses a 90 day season). The clay curve follows essentially the same pattern as the sandy loam curve. Thus, the four major growth periods being used for the sandy loam appear appropriate for the clay soil.

Figure 9 shows the scatter pattern of the data points, regression line and confidence bands for the soil matric potential as a function of the Bellani atmometer water depletion for the clay soil for the entire growing season (65 and 70 day seasons combined). The data were first divided into the three periods used in the earlier work done on the sandy loam soil. However, the confidence intervals overlapped enough so that they were considered one line. Some of the points which seem to be outliers are most likely due to the hysteresis effect of the wetting followed by drying of the soil after individual irrigations.

The relative similarities for the relationships developed for the SMP as a function of the EPA for the clay (entire growing season) and for the first and third periods for the sandy loam are shown in Figure 10. The confidence bands for the respective lines are also indicated. The regression line for the clay is not far from where the calculated line for the middle period (II) for the sandy loam soil would be. But more importantly, the intercepts are the same. It was decided because of the growth curve similarities and the similar linear relationships between the SMP and EPA to rely on using the linear regression equations developed for the sandy loam soil with modification for use with the clay soil for irrigation scheduling purposes. The modification used is provided by the soil coefficient.

The desorption curves for the sandy loam soil and the clay soil are shown in Figure 11. The percent moisture by volume for the various soil matric potentials are indicated for the respective soils. The desorption curves were constructed to a maximum of -100 centibars because most vegetable crops including lettuce are watered at potentials of less than -100 centibars. The soil coefficient for the clay, 0.72, was calculated using the -10 to -50 centibars inclusive. These values were used because all of the work presented here was scheduled for irrigation at less than -50 centibars of SMP. Furthermore, little change in moisture retention is observed from -50 to -100 cb. The respective bulk densities of the 2 soils were extracted from the literature in order

to provide averages within each of the 2 classifications (15). The effective root zone of concern was 0 to 25 cm. In this profile, the clay holds 13.3 and 9.1 total available cm of water at -10 and -50 cb of matric potential, respectively. The sandy loam soil holds total available water of 6.9 and 3.9 cm at -10 and -50 cb of matric potential, respectively (19). Thus, in order to convert the sandy loam soil equations to another soil, a moisture release curve which includes -10 and -50 cb for the new soil is needed. For the new soil, the difference between the soil moisture content percent by volume for the range -10 to -50 centibars should be calculated. The reciprocal of the value should be multiplied times the change (11.8) found for the sandy loam over the same range. The result obtained would be the soil coefficient to be applied to the appropriate regression equations.

Figure 12 shows the regression lines and corresponding linear equations for the original sandy loam compared to the regression lines and corresponding linear equations for the clay soil. The difference between the two sets of equations is the application of the soil coefficient (0.72) to the slopes for the clay soil. The application of the correction factor (K) makes the interval longer between significant recharges for the clay soil than for the sandy loam soil. The literature supports the longer intervals between irrigations for the clay soil due to the increased amount of total available water held and the increased hydraulic conductivity. During the period between significant recharges,

the soil is in a drying phase, therefore, an unsaturated condition.
It is expected that in fine textured soils liquid water will move more
rapidly than in the coarse textured soils due to the hydraulic conduc-
tivity. The increased hydraulic conductivity of the clay compared to
the sandy loam increases the rate of movement of the soil water and
the distance which the water moves from the layers below the effective
root zone and within the effective root zone.

As irrigation scheduling progresses from period IA through
period III, the SMP constants increase for the programmable calculator
program. However, for the large scale computer program, the pro-
gression does not have increasing EPA constants. The lack of always
increasing EPA constants is due to the solving of the linear equations
(Figures 5 and 12) for milliliters of water loss. That is, if one holds
SMP constant for each of the 4 growth stages and solves for the EPA
constants, the constants do not increase for each period, IA through
III, because of the different slopes for the linear equations for the 3
major growth periods. The use of one linear equation for both
periods IA and IB serves to create an actual delay of irrigation for
period IB as has been discussed.

The irrigation delay for the clay soil compared to the sandy loam
soil is provided by reducing the rate of the EPA accumulation. This is
done by multiplying the slope of the 3 linear equations by K (0.72) for

the programmable calculator program. For the large scale computer program, the K (0. 72) is multiplied times the ΣEPA.

Bellani Plate Freezing

Based on long term temperature records, extreme minimum temperatures expected in the San Luis Valley during the latter part of April and the latter part of September are approximately -4°C.

It is realized that the heat loss from the Bellani plates in the field at night cannot be duplicated by a test conducted in a cooler. However, the results presented suggested the use of a field assembly, shown in Appendix A, for the prevention of instrument destruction when ambient air temperatures of 0°C or lower are expected during the irrigation season. A list of parts for the assembly is found in Appendix A. Some preliminary field studies indicate that the heat lamps will prevent ice formation in the Bellani plate assemblies at -3.3°C (26°F) but not at -6.1°C (21°F). However, temperatures much below -3.3 are not expected since the long term weather records for lettuce growing areas show extreme minimums during the growing season to be approximately -4°C. Also, an important factor which should be considered is the duration of time for which the temperature is at its minimum.

The coarse and fine dial settings for the controller previously mentioned are merely suggestions of where the dials might be set.

Because of instrument variability, each controller should be cali-

brated to achieve the proper dial settings. The controller can easily

be calibrated by using the thermistor with one heat lamp plugged

into the system. The system can then be subjected to a $0^{\circ}C$ tempera-

ture and the dials adjusted so that the heat lamp activates. There are

at least two methods to achieve a $0^{\circ}C$ environment. One is the use of

a low temperature controlled walk-in room. The second and most

likely the easier, is to put the thermistor in an ice bath.

A word of caution: since there is variability among thermistors,

it is probably best to use the same thermistor for calibrating the

controller as well as for sensing the temperature in the field environ-

ment.

The Irrigation Scheduling Model

In both programs, the model pictures "NEED" as a function of

SMP or EPA. In the programmable calculator program, the EPA is

converted to SMP using the appropriate linear equations at each update

and is plotted as "NEED" (SMP) = f(days from last recharge). Each

of the four growth stages is represented by a SMP constant. In the

large scale computer program, EPA (cumulative water loss) is a

different constant for each of the 4 growth stages. In the large scale

computer program, a predicted date of irrigation based on solving

each of 3 polynomial regression equations for time until EPA

constant - $\Sigma EPA = 0$ is given.

The Programmable Calculator Program

The graphic output provided by the programmable calculator

program allows the irrigation scheduler to observe the daily pro-

gress of the "daily" line between significant recharges. By antici-

pating the next irrigation, cultural operations which need to be done

prior to irrigation can be scheduled. When the "daily" line exceeds

the "IRRIGATE!" line, it should serve as an obvious reminder that

irrigation should be done as soon as possible.

The ordinate of the graph is labeled "NEED" by the program

when in reality -cbs of SMP are plotted. It was felt that the growers

and their irrigators could more closely identify with the former.

Negative centibars were plotted as a function of time from last re-

charge instead of ΣEPA due to the direct relationship of the former to

tensiometer readings and soil moisture release curves.

Actually, the programmable calculator program follows the

instructions provided by the Irrometer Company in that tensiometer

SMP is plotted (by hand) as a function of time since last recharge with

irrigation scheduled to occur when SMP reaches a critical value for a

particular soil type and growth stage.

The use of the programmable calculator to schedule irrigation was also seen as a way for an irrigation scheduler to conveniently schedule irrigation with an "on site" device as opposed to interacting with a large scale computer possibly via expensive phone lines.

Once the field information is stored on the digital cassette, the daily update for individual plantings requires approximately 4 to 5 minutes. This time includes the creation of graphic output for each field.

<center>The Large Scale Computer Program</center>

The large scale computer program assumes that: accumulated water loss from Bellani plates (ΣEPA) is either a linear, quadratic or cubic function of time. This assumption was based on experience with the programmable calculator graphs i. e., observing how the daily line approaches the irrigate line.

Let y represent cumulative EPA and t, time <u>from last</u> recharge then:

$$y = \beta_0 + \beta_1 t \quad \underline{viz}$$

$$y = \beta_0 + \beta_1 t \pm \beta_2 t^2 \quad \underline{viz}$$
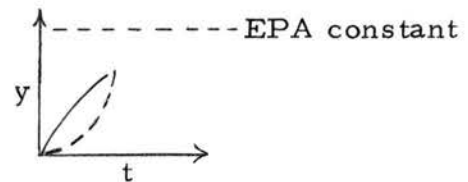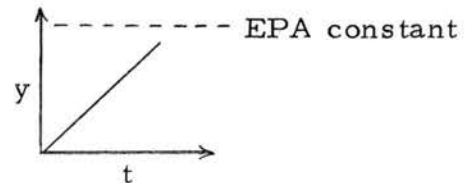
$$y = \beta_0 + \beta_1 t \pm \beta_2 t^2 \pm \beta_3 t^3 \quad \underline{viz}$$
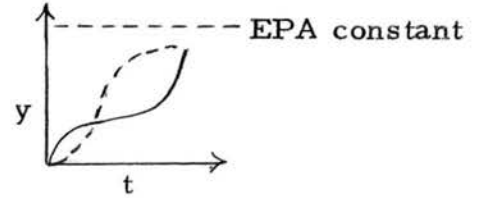
If we redefine y as y' and let y' = EPA constant - ΣEPA_i , we can then predict t' which now represents time to <u>next</u> irrigation.

$$\hat{t'} = \frac{y'}{\beta_0 + \beta_1} \quad \text{or} \quad \frac{y'}{\beta_0 + \beta_1 \pm \beta_2} \quad \text{or} \quad \frac{y'}{\beta_0 + \beta_1 \pm \beta_2 \pm \beta_3}$$

Since t' is an interval expressed in days, a calendar function was added to the program in order to convert the end of the interval to calendar date. Note that t' is some linear function of y' itself dependent upon which of the 3 regression models best fits the t_i , y_i data. If the independent variable ΣEPA is held constant, $\hat{t'}$ is decreased as the algebraic sum of the appropriate regression coefficient values increase. In the case where a heavier soil is employed and/or the size of the EPA constant may be increased due to crop advancement, the predicted date of irrigation is advanced.

The large scale computer program requires fewer input variables for the creation of the daily update for individual plantings than the programmable calculator program requires. Also, the time required for the update of each field is less, approximately 2 minutes.

The daily output for the large scale computer program includes the "Date of Report" and "Date of Last Report." If the individual plantings are updated daily, "Date of Report" should be the current

day's date while, the "Date of Last Report" should be the date for yesterday. If it is not yesterday's date and the report was updated yesterday, it is possible that yesterday's field file information was lost due to a computer malfunction. This error may occur because of the use of the direct access files as opposed to indirect access files. However, the direct access files were chosen over the indirect access files because it is estimated that 400 fields can be scheduled with the direct access files while only 100 fields using the indirect access files could be scheduled. This difference is related to the Colorado State University's NOS management system and limits placed on various account categories.

The report (page 75) also shows "ml accumulated" which is simply the plate coefficient and soil coefficient corrected evaporative loss since the last significant recharge. The statement "ml necessary for irrigation" is the EPA constant necessary for irrigation to occur for each of the 4 growth stages.

An explanation of the criteria used in making the choice among the 3 predicted dates is necessary. We have the situation where 3 models are being fitted to the same data and therefore, one of the components of lack of fit, that is data variability, can be eliminated. The other component, model appropriateness, is the one we hope to evaluate. The coefficient of determination (R^2) has been used for this purpose and has been developed using the following rationale:

$$\text{Regression SS} = \text{Total SS} - \text{Residual SS} \qquad \text{and}$$

$$R^2 = \frac{\text{Regression SS}}{\text{Total SS}} \quad \text{or} \quad 1 - \frac{\text{Residual SS}}{\text{Total SS}} \qquad \text{since}$$

$\dfrac{\text{Regression SS}}{\text{Total SS}}$ is the proportion of variation in Y <u>explained</u> by the regression of Y on X   [2]

$\dfrac{\text{Residual SS}}{\text{Total SS}}$ is the proportion of the variability in Y <u>unexplained</u> by the regression of Y on X   [3]

$$R^2 = 1 - \frac{\text{Residual SS}/ \, n-1}{\text{Total SS}/ \, n-1} \qquad [4]$$

Equation [4] provides us with a scale free single quantity with the same explanation as [2]. The R^2 statistic provides a measure of the variation in Σ EPA explained by time or time + time squared or time + time squared + time cubed i. e. a linear, quadratic or cubic model. It is realized that examination of residuals, F ratio for overall regression or F tests for lack of fit or F tests for adding quadratic and cubic terms to the linear model might be more valid than comparing the magnitudes of R^2's among the 3 models. Furthermore, the size of the coefficient of determination increases when we add terms to the linear model if the coefficient of determination is not adjusted for degrees of freedom (12, 39). With this in mind, the most imminent date should be noted first and heeded if the corresponding R^2 is arbitrarily greater than 0.95. All R^2's should be relatively high since all data

are cumulative values, i. e. no ΣEPA value can be less than a preceding value which makes for "smoothness."

The purpose of using the coefficient of determination statistic in the large scale computer output is to use it in conjunction with, but subordinate to, the most imminent date in order to decide when irrigation should take place. If recharge has recently occurred, the coefficient of determination will have absolutely no meaning. The program, however, will make the user aware of any prediction based on less than 3 ΣEPA versus time observations (see page 75). The idea is that if enough time has passed, enough data will have been accumulated for validation of the linear, quadratic and cubic relationship(s).

Examples of the daily output for the large scale computer program can be seen on pages 75-77. The corresponding examples for the assembly language program can be seen on pages 61-69. The output for both programs changes daily. The changes occur due to a combination of the number of days from the last recharge and the evaporative loss. Pages 61 and 75 show the output for a field which has just been recharged (July 11). This recharge was the result of a significant rainfall. Pages 62 and 75 show the output for the day (July 12) immediately following the recharge day. Pages 63 and 75 are for the second day following recharge (July 13). The output for the third day (July 14) following recharge can be seen on pages 64 and 76. Pages 65 and 76 are the output for the fourth day following recharge (July 15). This output

illustrates the predicted time to irrigation for all the polynomial regression equations. The output illustrated on pages 66 and 76 are similar to that illustrated on pages 65 and 76. However, in this case (July 17), the predicted irrigation date for the "QUAD:" and "CUB:" functions is more than 40 days away. This message was built into the program for the cases where the daily line is asymptotic to the irrigate line. The report for July 20, pages 67 and 77, indicate the predicted irrigation should take place July 20. It can be seen on pages 68 and 77 that the only message given is "IRRIGATE TODAY!" (July 21). The report for July 22, pages 69 and 77, indicate the irrigation is one day overdue. This overdue message will continue to accumulate days until a recharge takes place.

There appears to be some differences in the predicted time of irrigation between the two programs. These differences are primarily due to the two different methods of handling the recharge day. That is, for the assembly language program the day of recharge was considered the first day of the new irrigation interval. While, for the large scale computer program (FORTRAN IV), the day of recharge was considered the last day of the previous irrigation interval or the day following recharge is the first day of the new irrigation interval. Also, some of the differences may be due to rounding errors. For the graphic analysis, it is possible to interpolate partial days to irrigation. For the digital analysis, the partial days are rounded to the nearest day which is then

converted to calendar date for the predicted irrigation date. One other difference exists between the two programs. The programmable calculator uses equation [1] to repeatedly, at each update, convert the ΣEPA to SMP where the SMP constants were determined as previously described. However, the large scale computer program uses [1] solely to provide one time the EPA constants by converting the SMP negative cb to ml.

It is probably more convenient to use the large scale computer program by interacting with the CSU Cyber system rather than struggling with the transfer of the program to another system. However, costs must be considered. If a cooperator in the Salinas Valley of California wanted to use the program by interacting with the CSU Cyber system via telephone, the cost per field for telephone charges would range from approximately 30¢ to 70¢ per field depending on the time of day. An additional charge of approximately 4¢ per field would be for computer time charges. Thus, for a theoretical situation of 400 fields being scheduled from California via telephone, the cost at 2 minutes per field per day would range from $136.00 to $296.00 and would require about 13 hours of computer operator time. If it is assumed that the fields are 20 acres each and the irrigation season is 100 days, the cost of scheduling irrigation for each field for the season will range from $1.70 to $3.50 per acre. A cost which is minimal compared to other production costs for lettuce. A leased telephone line would be helpful in reducing these costs.

There is an alternative which might be used to reduce the amount of connect time, the time used for inputing data interactively and receiving the report for each field. If major program modifications were made to accept data from a stored source such as tape, the data could be entered on the tape "off-line." The transmission of the stored data would require less time than the process of answering the questions "on-line." However, use of this alternative would mean the deletion of the several error detection and subsequent correction routines which are incorporated in the program.

An example of the information which may be listed at any time for the data stored on the field files of the large scale computer is seen in Figure 15. The figure illustrates the information stored in field files for 4 individual plantings. It is not possible to get a similar listing from the programmable calculator program without calling each of the field numbers.

It should be kept in mind for both programs, that the grower should not be planting more lettuce in a 24-hour period than can be irrigated in a 24-hour period i. e. a field code not only represents a location but the amount of lettuce which can be irrigated in one day.

Figure 15. Example of the information stored for individual plantings on field files for the large scale computer irrigation scheduling program.

```
FIELD NO.   5    COMPANY: CSU                    GROWER: NELSON
FIELD DESCRIPTION: SLV                   SOIL CLASSIFICATION: SL
DATE OF PLANTING: JUN 10, 1978
DATE OF LAST REPORT: JUN 23, 1978       SOIL COEFFICIENT:  1.00
BELLANI PLATE COEFFICIENTS #1 AND #2:    .95,  .97

FIELD NO.   6    COMPANY: FINNERMAN              GROWER: HAASS
FIELD DESCRIPTION: -5                    SOIL CLASSIFICATION: SL
DATE OF PLANTING: JUN 16, 1978
DATE OF LAST REPORT: JUN 23, 1978       SOIL COEFFICIENT:  1.00
BELLANI PLATE COEFFICIENTS #1 AND #2:    .95,  .97

FIELD NO.   7    COMPANY: SKYVIEW               GROWER: BUTLER
FIELD DESCRIPTION: -G                    SOIL CLASSIFICATION: SL
DATE OF PLANTING: JUN 17, 1978
DATE OF LAST REPORT: JUN 23, 1978       SOIL COEFFICIENT:  1.00
BELLANI PLATE COEFFICIENTS #1 AND #2:    .95,  .97

FIELD NO. 101    COMPANY: CSU                  GROWER: ANDERSON
FIELD DESCRIPTION: HORT FARM             SOIL CLASSIFICATION: C
DATE OF PLANTING: JUL 13, 1978
DATE OF LAST REPORT: JUL 13, 1978       SOIL COEFFICIENT:   .72
BELLANI PLATE COEFFICIENTS #1 AND #2:    .95,  .95
```

SUMMARY

It was shown that very close linear relationships between soil matric potential (SMP) and the evaporative power of the air (EPA) existed for 4 lettuce growth stages. The Bellani plate atmometer was used to reflect the EPA with tensiometers monitoring the SMP. SMP constants or EPA constants corresponding to previously established SNP irrigation guidelines are in effect during each of the 4 established stages: IA, 0-10 days, stand establishment; IB, 11-30 days, root establishment; II, 31-50 days, transition; III, 51 days to harvest, heading and canopy closure.

Effects of different planting dates and different soils on the relationship established were tested. It was found that the relation-ship was versatile enough to account for climatic conditions encoun-tered during early through late season plantings. A soil coefficient was developed for a clay soil (0.72) with the original sandy loam assumed to have the coefficient value of 1.00. Soils of intermediate texture would, therefore, be assigned coefficients having intermed-iate values.

The irrigation scheduling model is based on the assumption that SMP is a function of stage of growth, EPA, root zone recharge and soil texture. Soil texture is constant for the duration of the crop and EPA

varies between significant recharges. Equations relating SMP to EPA for 4 growth periods are substituted in place of crop coefficients commonly used in other models.

The irrigation scheduling output is in two forms. The first form is graphic analysis. The program was written for a desk top programmable calculator in assembly language. The program converts Σ EPA to SMP and plots SMP ("NEED" in the output) as a function of days from last recharge every day for any planting for which scheduling is being provided. The irrigation scheduler simply inspects the plotted function (line) and extrapolates it to the SMP constant (line) in order to estimate how soon an irrigation should occur. An obvious reminder of tardiness is provided after the two lines cross.

The second form of output is digital. The program was written in FORTRAN IV for a CDC Cyber 171 employing the NOS management system. It fits, by means of the least squares regression method; linear, quadratic and cubic models to the cumulative EPA versus days from last recharge data. The program then solves each of the 3 polynomials for days to next irrigation and converts the end of the interval to calendar date. The user simply selects the most imminent of the 3 dates while using the associated coefficient of determination as a measure of confidence in the choice of when to irrigate. Interactive computing is employed and softcopy output seems to be the most efficient.

The evaporative power of the air should not change with irrigation method. Therefore, the model as presented should be valid for use not only for surface irrigated lettuce but also for sprinkler and drip irrigation if the occasion should require it.

It seems quite possible to adapt the programs presented here to other crops with minimal effort. The necessary task would be to develop the relationship between root zone soil matric potential and the evaporative power of the air for the different stages of growth, expressed by the crop species in question.

Bellani plate atmometers are not completely free of problems. Prior to the present study, the major problem was freezing of the plates at either end of the growing season. The other minor problems include algae buildup in the system, priming, dust and hail. It has been found that zephrian chloride at concentrations of 1 to 5000 or 1 to 10000 parts water will control the algae growth (Personal communication, Tracy E. Sulzbach). In the work here, once the suction was started, it was found that maintenance of the prime caused no problem if caution was exercised when the reservoir was replenished. Dust which accumulates on the plates was easily taken care of by gentle dusting with a camel hair brush at the time of the daily readings. The only solution to damage by hail is to maintain a pair of operating Bellani plate assemblies in reserve which can easily be pressed into service.

The maximum monitoring range of a single pair of plates will depend indirectly on local topography. The cost in actual dollars and manpower of using the Bellani plates to schedule irrigation is certainly less than that of using tensiometers, neutron probes or climatic data.

It can be argued that weaknesses in the model are lack of dependence on weather event probabilities and energy for growth and development. If the predictive model were dependent upon weather probability, its use would be limited to only those areas where long term data are available. Furthermore, the weather data is composed of that which the atmometer provides. It is felt that this integration is necessary. The Bellani plate readings could not only provide an evaluation of the EPA as it currently does in the model, but it could also provide cumulative energy values which might be used to determine growth stages instead of relying on real time as the model currently does. This approach might possibly result in more accuracy and provide more biological rationale. It is felt however, for the practical task of scheduling irrigation, neither high degree of accuracy nor extensive biological rationale is warranted.

When a runoff event occurs due primarily to unusually intense precipitation, some inaccuracy may be sacrificed for simplicity. The scheduling scheme presented should be most accurate in regions of sparse rainfall during a growing season.

Single experimental plot size lettuce and spinach fields have been successfully scheduled from a distance of 488 km (300 miles) by using the field sheet (Figure 16) and the values provided in Appendix B. Two commercial fields were successfully irrigated by means of the programmable calculator program during the summer of 1978.

Figure 16. One example of a field form used for collecting input data for the programmable calculator program.

RECORD FOR BELLANI ATMOMETERS

IDENTIFICATION_____   YEAR_____

DAY*	DATE	PLATE COEFF		INSTRUMENT READING		EVAPORATION			TEMPERATURE			IRRIGATION		RAINFALL
		No. 1	No. 2	No. 1	No. 2	3 x 5	4 x 6	mean	Max	Min	Mean	Yes	No	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15

*Day 1 is first day of irrigation.

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APPENDICES

APPENDIX A

ATMOMETER ASSEMBLY

Accessories and suppliers for Bellani plate assembly

1. No. 9-C Standardized Black Bellani Plate.

   Available from: C and M Meteorological Supply
   P. O. Box 5723
   Riverside, California 92507

2. Cylinder, graduate with an opening to accommodate 5
   pennyhead stopper. Pyrex (Corning 2982) 250 ml with
   hexagonal base.

   Available from: A laboratory supply company

3. Valve, check, linear polyethylene (Nalge 6120-0010) in place
   of a wool and mercury valve available from C & M Meteoro-
   logical Supply.

   Available from: A laboratory supply company

4. Copper J tube, air vent.

   Available from: C & M Meteorological Supply

5. Glass tubing 6-7mm O. D., 35 cm long.

   Available from: A laboratory supply company

6. No. 2 rubber stopper.

   Available from: A laboratory supply company

7. No. 5 rubber stopper

   Available from: A laboratory supply company

8. Tygon or latex tubing.

   Available from: A laboratory supply company

Accessories for the Bellani plate freezing protection assembly

The following electrical items may be purchased from an electrical wholesale supplier:

1. 3-Stonco #25A Boxes

2. 3-Steber #S-506 Covers

3. 3-Stonco #1501 Lampholders

4. 3-250 watt PAR 38 heat lamps

5. 4'-$\frac{1}{2}$'' liquid tight flux conduit

6. 6-90° liquid tight connectors

7. 1-handy box

8. 1-handy box duplex receptacle plate

9. 3-duplex receptacles

10. 1'-#14-3 SO cord

11. 1-cord grip connector

12. 5-Herbbill #5276 plug caps

13. 1-4'' square box

14. 1-2 gang industrial cover

15. 1-3/8'' romex box connector

16. 1-3/4'' chase nipple and locknut

17. 8'-#16-3 SJ cord

The following metal items may be purchased from an iron and sheetmetal supplier:

1. 16 gauge cold roll sheetmetal for electrical control housing

2. 3/8" X 4" flat bar

3. 2" I. D. Black iron pipe

4. $1\frac{1}{2}$" I. D. Black iron pipe

5. $1\frac{1}{2}$" I. D. Black iron couplings

6. 3/8" thumb screws

7. 3/8" rod

Figure 17. Wiring diagram for the field assembly used to protect the Bellani atmometers from frost damage.

HEAT LAMPS

CONTROLLER

CONTROLLED OUTLET

4 SQUARE BOX WITH 2 DUPLEX RECEPTACLES

HANDY BOX

14-3 SO CORD

110 VAC
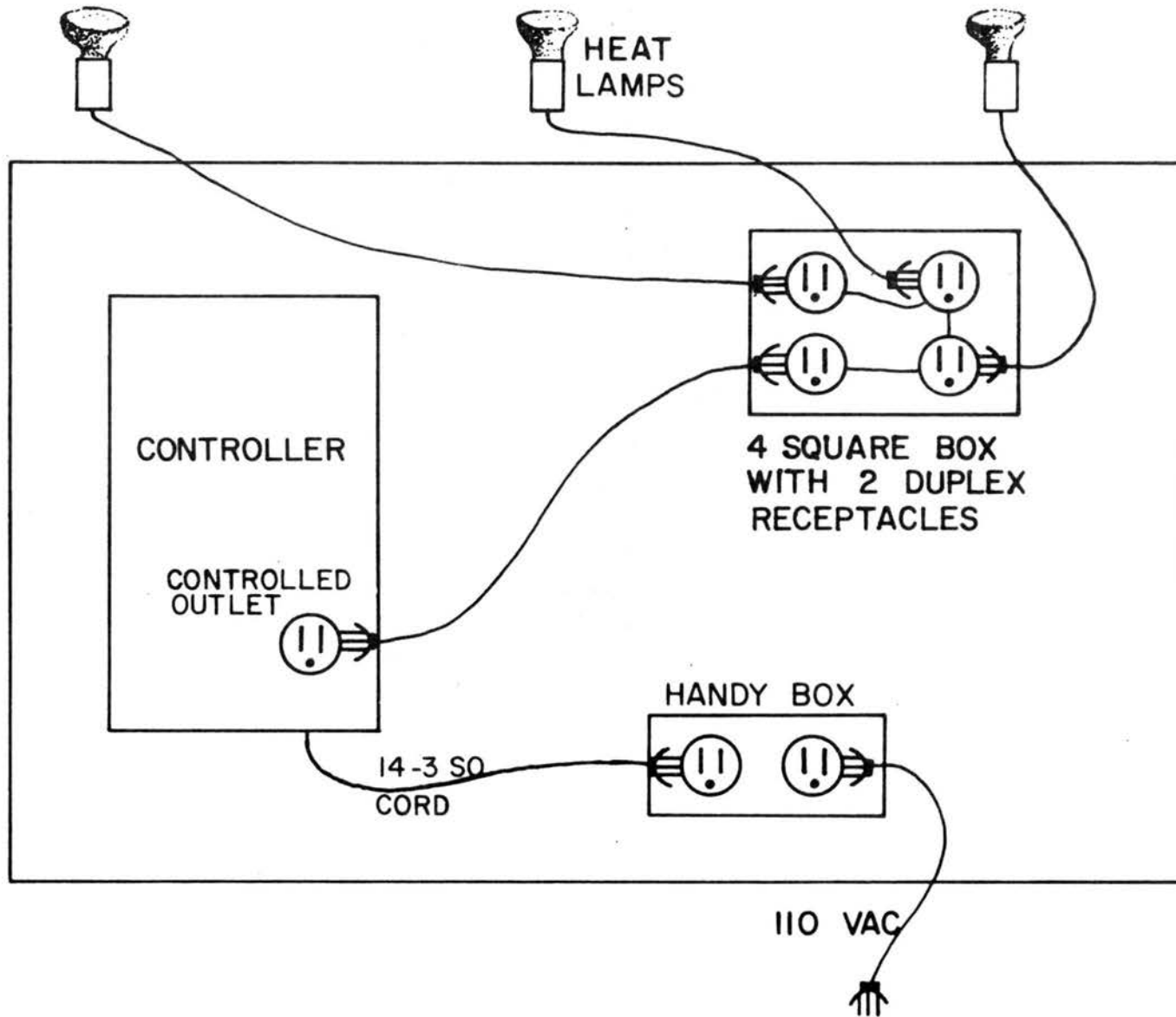
Figure 18. Field assembly used to protect the Bellani atmometers from frost damage.
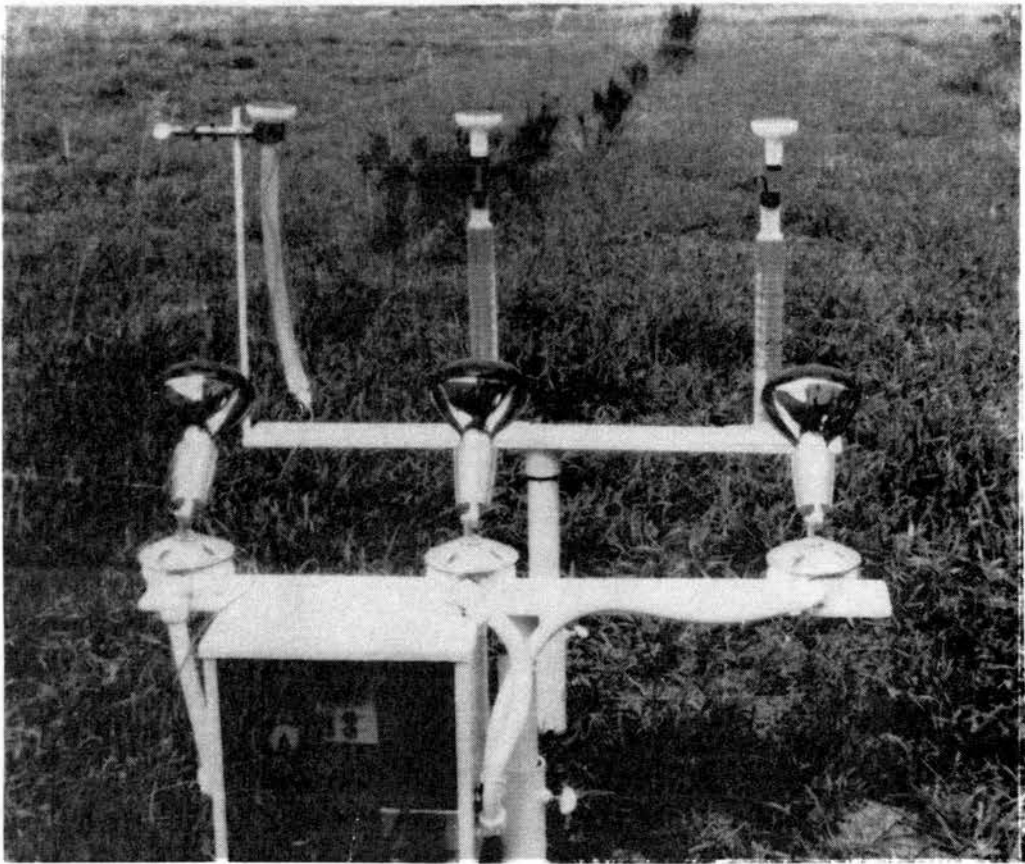
APPENDIX B

PROGRAMMABLE CALCULATOR PROGRAM

User Documentation for Programmable Calculator Program

This program enables the computer operator to store information for a maximum of 50 individual plantings per data cassette for use in scheduling irrigations for each planting. The program stores information for each planting which is constant for the planting for the entire growing season. This information includes the company name, grower name and field description, the soil type and the planting date. Also stored for each planting is the atmometer information between significant recharges which is automatically cleared when a significant recharge takes place. Stored for access by all plantings are the SMP constants at which a significant recharge should occur for each of the four growth stages. The program, given daily information concerning Bellani plate loss with the proper plate coefficients, date and amount of rainfall, produces a graphic output for use by the irrigation scheduler.

The graphic output includes such information as: yesterday's date, the amount of rainfall received for the previous 24 hours, the maximum temperature for the previous 24 hours, whether a recharge occurred either by rainfall or irrigation, whether the rainfall was considered to be equal to a significant recharge and the stored field information. The temperature acting only as a weather reminder plays no part in the model. The option of whether rainfall was equal to a recharge was put in the program for the cases of runoff.

To use the programmable calculator program a HP9810A programmable calculator equipped with a Statistics ROM (HP11214A), a Cassette Memory ROM (HP11265A) and a Plotter Printer Alpha ROM (HP11261A) and interfaced with a HP9865A Cassette Memory and a HP9862A Calculator Plotter are necessary. Hewlett-Packard Digital Cassettes (HP9162-0050) are required for use in the cassette memory.

Field information must be stored before the program can be run. The descriptive information for the paper tape printout is stored in program steps 1800-1849. Use the following steps to store information on the digital cassette for each field. User response is under-lined in the following instructions.

1. Go to step 1800 by pressing GOTO 1800

   Then switch to the program mode

   Enter FMT at 1800

   Enter FMT at 1801

   Enter any information from step 1802 to 1847 inclusive

   Enter FMT at 1848

   Enter S/R (Sub Return) at 1849

The information for the plot is stored in steps 1850-1949 as follows:

1. Company name for the plot is stored in steps 1850-1874

   Enter FMT at 1850

   Enter 1 at 1851

Enter FMT at 1852

Enter any information from step 1853 to 1872 inclusive

Enter FMT at 1873

Enter S/R at 1874

2. Grower name and field description for plot is stored in steps 1875-1899.

Enter FMT at 1875

Enter 1 at 1876

Enter FMT at 1877

Enter any information from step 1878 to 1897 inclusive

Enter FMT at 1898

Enter S/R at 1899

3. Soil classification for plot is stored in steps 1900-1924

Enter FMT at 1900

Enter 1 at 1901

Enter FMT at 1902

Enter any information from step 1903 to 1922 inclusive

Enter FMT at 1923

Enter S/R at 1924

4. Planting date for plot is stored in steps 1925-1949

Enter FMT at 1925

Enter 1 at 1926

Enter FMT at 1927

Enter any information from step 1928 to 1947 inclusive

Enter FMT at 1948

Enter S/R at 1949

5. Return to run mode

6. Position tape by entering the assigned field number into X register

7. Press FMT 5 CLX (Clear X)

8. To record general field information above, press 1800 FMT 5 X^2 then press 1800 FMT 5 S/R

9. Also to be stored are the planting date, date of first irrigation, soil coefficient and Bellani plate coefficients. They should be stored in the following storage registers:

Enter the planting date into the X register

press X →( ) 041

Enter the irrigation date into the X register

press X →( ) 042

Enter the soil coefficient into the X register

press X →( ) 043

Enter Bellani plate coefficient #1 into the X register

press X →( ) 044 (New coefficients may be stored at any time)

Enter Bellani plate coefficient #2 into the X register

press X →( ) 045

10. Position tape at field number + 50 by pressing field number into X register then FMT 5 CLX.

11. To store constants enter 60 into Y register

Enter 40 into X register

Press FMT 5 X⟶( )

Press FMT 5 S/R

Programmable Calculator Program - Example of stored
information for a sample field

1800	-- FMT	--- 42	
1801	-- FMT	--- 42	
1802	-- C	--- 61	
1803	-- YTO	--- 40	CSU SLV EXPT STA
1804	-- 1/X	--- 17	
1805	-- CNT	--- 47	
1806	-- YTO	--- 40	
1807	-- L	--- 72	
1808	-- INT	--- 64	
1809	-- CNT	--- 47	
1810	-- E	--- 60	
1811	-- YE	--- 24	
1812	-- π	--- 56	
1813	-- XTO	--- 23	
1814	-- CNT	--- 47	
1815	-- YTO	--- 40	
1816	-- XTO	--- 23	
1817	-- A	--- 62	
1818	-- CLR	--- 20	
1819	-- F	--- 16	
1820	-- I	--- 65	
1821	-- E	--- 60	
1822	-- L	--- 72	
1823	-- D	--- 63	FIELD # 1
1824	-- CNT	--- 47	
1825	-- GTO	--- 44	
1826	-- 1	--- 01	
1827	-- CLR	--- 20	
1828	-- CNT	--- 47	
1829	-- A	--- 62	
1830	-- π	--- 56	
1831	-- α	--- 13	APRIL 27, 1977
1832	-- I	--- 65	
1833	-- L	--- 72	
1834	-- CNT	--- 47	
1835	-- 2	--- 02	
1836	-- 7	--- 07	
1837	-- CLX	--- 37	
1838	-- 1	--- 01	
1839	-- 9	--- 11	
1840	-- 7	--- 07	

1841	--	7	---	07	
1842	--	FMT	---	42	
1843	--	S/R	---	77	
1844	--	CNT	---	47	
1845	--	CNT	---	47	
1846	--	CNT	---	47	
1847	--	CNT	---	47	
1848	--	CNT	---	47	
1849	--	CNT	---	47	
1850	--	FMT	---	42	
1851	--	1	---	01	
1852	--	FMT	---	42	
1853	--	C	---	61	
1854	--	YTO	---	40	CSU
1855	--	1/X	---	17	
1856	--	FMT	---	42	
1857	--	S/R	---	77	
1858	--	CNT	---	47	
1859	--	CNT	---	47	
1860	--	CNT	---	47	
1861	--	CNT	---	47	
1862	--	CNT	---	47	
1863	--	CNT	---	47	
1864	--	CNT	---	47	
1865	--	CNT	---	47	
1866	--	CNT	---	47	
1867	--	CNT	---	47	
1868	--	CNT	---	47	
1869	--	CNT	---	47	
1870	--	CNT	---	47	
1871	--	CNT	---	47	
1872	--	CNT	---	47	
1873	--	CNT	---	47	
1874	--	0	---	00	
1875	--	FMT	---	42	
1876	--	1	---	01	
1877	--	FMT	---	42	
1878	--	YTO	---	40	
1879	--	L	---	72	
1880	--	INT	---	64	SLV-1
1881	--	-	---	34	
1882	--	1	---	01	
1883	--	FMT	---	42	
1884	--	S/R	---	77	
1885	--	CNT	---	47	

1886	-- CNT	--- 47
1887	-- CNT	--- 47
1888	-- CNT	--- 47
1889	-- CNT	--- 47
1890	-- CNT	--- 47
1891	-- CNT	--- 47
1892	-- CNT	--- 47
1893	-- CNT	--- 47
1894	-- CNT	--- 47
1895	-- CNT	--- 47
1896	-- CNT	--- 47
1897	-- CNT	--- 47
1898	-- CNT	--- 47
1899	-- 0	--- 00
1900	-- FMT	--- 42
1901	-- 1	--- 01
1902	-- FMT	--- 42
1903	-- YTO	--- 40
1904	-- L	--- 72
1905	-- FMT	--- 42
1906	-- S/R	--- 77
1907	-- CNT	--- 47
1908	-- CNT	--- 47
1909	-- CNT	--- 47
1910	-- CNT	--- 47
1911	-- CNT	--- 47
1912	-- CNT	--- 47
1913	-- CNT	--- 47
1914	-- CNT	--- 47
1915	-- CNT	--- 47
1916	-- CNT	--- 47
1917	-- CNT	--- 47
1918	-- CNT	--- 47
1919	-- CNT	--- 47
1920	-- CNT	--- 47
1921	-- CNT	--- 47
1922	-- CNT	--- 47
1923	-- CNT	--- 47
1924	-- 0	--- 00
1925	-- FMT	--- 42
1926	-- 1	--- 01
1927	-- FMT	--- 42
1928	-- A	--- 62
1929	-- π	--- 56
1930	-- α	--- 13

SL

APRIL 27, 1977

```
1931  -- I     --- 65
1932  -- L     --- 72
1933  -- CNT   --- 47
1934  -- 2     --- 02
1935  -- 7     --- 07
1936  -- CLX   --- 37
1937  -- 1     --- 01
1938  -- 9     --- 11
1939  -- 7     --- 07
1940  -- 7     --- 07
1941  -- FMT   --- 42
1942  -- S/R   --- 77
1943  -- CNT   --- 47
1944  -- CNT   --- 47
1945  -- CNT   --- 47
1946  -- END   --- 46
```

Programmable Calculator Program - Daily Usage

1. Insert digital cassette into Cassette memory

2. Press O FMT 5 CLX and wait for tape to stop

3. Press O FMT 5 S/R and wait for tape to stop

4. Press END CONTINUE

5. Enter field number into X register

6. Press CONTINUE and wait for tape to stop

7. Field information is printed

8. Enter today's date, i. e. the date of the report as a decimal into X register e. g. May 1 = 5.01 or March 16 = 3.16

9. Press CONTINUE

10. IRRIGATE?   NO-press CONTINUE

     YES-press SFL (set flag)

11. Enter yesterday's unstandardized reading (Plate 1) into the Y register

12. Enter today's unstandardized reading (Plate 1) into the X register

13. Press CONTINUE

14. Repeat steps 11, 12 and 13 for plate 2

15. A plot will be made at this time. The plotter will stop after printing YESTERDAY for information from the keyboard. All information from the keyboard must be prefaced by FMT 1 FMT. The

information must be followed by <u>FMT</u> <u>CONTINUE</u> when finished before the plotter will continue. The operator fills in the following blanks on the plot from the keyboard.

16. YESTERDAY - ___date___

17. RAIN   -   ___amount___

18. TEMP   -   ___$^\circ$F or $^\circ$C___

19. IRR?   enter <u>YES</u> or <u>NO</u>

20. R=I?   enter <u>YES</u> or <u>NO</u>

21. Following this the plotter will finish the rest of the plot including the field information, the irrigate line (SMP constant line) and the daily line. The data will be stored on the cassette as the plot is finished.

22. Press <u>END</u> <u>CONTINUE</u> in order to schedule irrigation for another field.

Programmable Calculator Program - Example of Printout

ENTER FIELD #
CSU SLV EXPT STA   } Field information from
                            program steps 1800-1849
FIELD #1
   APRIL 27, 1977

TODAY S DATE
IRRIGATE?   Waits for response
ENTER READING   Waits for response
     YES → Y
     TOD → X   Enter yesterday's unstand-
PLATE 2   ardized plate number 1
     YES ⟶ Y   reading into Y register
     TOD ⟶ X   Enter today's reading into
                           X register

Programmable Calculator Program - Algorithms

1. The planting and irrigation dates must be entered into storage as day number where January 1 is day 0.

COMMON YEAR			BISSEXTILE YEAR		
Jan.	1-31	0-30	Jan.	1-31	0-30
Feb.	1-28	31-58	Feb.	1-29	31-59
March	1-31	59-89	March	1-31	60-90
April	1-30	90-119	April	1-30	91-120
May	1-31	120-150	May	1-31	121-151
June	1-30	151-180	June	1-30	152-181
July	1-31	181-211	July	1-31	182-212
Aug.	1-31	212-242	Aug.	1-31	213-243
Sept.	1-30	243-272	Sept.	1-30	244-273
Oct.	1-31	273-303	Oct.	1-31	274-304
Nov.	1-30	304-333	Nov.	1-30	305-334
Dec.	1-31	334-364	Dec.	1-31	335-365

2. The algorithms for the calculation of the EPA constants for the four growth periods are as follows:

IA, 0-10 days, $y=5.369884 + 0.046362x$

or 229 ml = 16 cb

IB, 11-30 days, $y=5.369884 + 0.046362x$

or 488 ml = 28 cb

II, 31-50 days, $y = 2.545283 + 0.109547x$

or 278 ml = 33 cb

III, 51-harvest, $y = -0.279319 + 0.172731x$

or 227 ml = 39 cb

3. The amounts of rainfall predetermined to be equal to a significant recharge if runoff is minimal for each of the growth periods:

IA 0.25 inches

IB 0.25 inches

II 0.35 inches

III 0.50 inches

Programmable Calculator Program - General Program Storage Map

STEPS	DESCRIPTION
0-16	Enter field number
17-50	Retrieves stored information
60-282	Data calculation
	Days from zero stored in register 005
	Days from planting stored in register 006
283-344	Irrigate?
	Date of last stored in 042
	If YES stored data is erased
345-417	Data calculation of Bellani atmometer loss
418-475	Calculates average ml loss stores in register 007
500-648	Calculates number of days from planting then stores slope in 008 intercept in 009 irrigate line in 010
721-1283	Plot routine

Programmable Calculator Program - Program Listing

0000	-- CLR	---	20
0001	-- FMT	---	42
0002	-- FMT	---	42
0003	-- E	---	60
0004	-- N	---	73
0005	-- XTO	---	23
0006	-- E	---	60
0007	-- α	---	13
0008	-- CNT	---	47
0009	-- F	---	16
0010	-- I	---	65
0011	-- E	---	60
0012	-- L	---	72
0013	-- D	---	63
0014	-- CNT	---	47
0015	-- GTO	---	44
0016	-- FMT	---	42
0017	-- STP	---	41
0018	-- XTO	---	23
0019	-- 0	---	00
0020	-- FMT	---	42
0021	-- 5	---	05
0022	-- CLX	---	37
0023	-- 1	---	01
0024	-- 8	---	10
0025	-- 0	---	00
0026	-- 0	---	00
0027	-- FMT	---	42
0028	-- 5	---	05
0029	-- S/R	---	77
0030	-- CNT	---	47
0031	-- XFR	---	67
0032	-- 0	---	00
0033	-- UP	---	27
0034	-- 5	---	05
0035	-- 0	---	00
0036	-- +	---	33
0037	-- DN	---	25
0038	-- FMT	---	42
0039	-- 5	---	05
0040	-- CLX	---	37

ENTER FIELD NO. - Enter field number for which processing is to occur.

Retrieves stored information from field file.

0041	-- CNT	--- 47
0042	-- 4	--- 04
0043	-- 0	--- 00
0044	-- FMT	--- 42
0045	-- 5	--- 05
0046	-- XFR	--- 67
0047	-- CNT	--- 47
0048	-- CNT	--- 47
0049	-- CNT	--- 47
0050	-- CNT	--- 47
0051	-- CNT	--- 47
0052	-- CNT	--- 47
0053	-- GTO	--- 44
0054	-- S/R	--- 77
0055	-- 1	--- 01
0056	-- 8	--- 10
0057	-- 0	--- 00
0058	-- 0	--- 00
0059	-- CNT	--- 47
0060	-- FMT	--- 42
0061	-- FMT	--- 42
0062	-- CLR	--- 20
0063	-- XTO	--- 23
0064	-- O	--- 71
0065	-- D	--- 63
0066	-- A	--- 62
0067	-- XFR	--- 67
0068	-- CNT	--- 47
0069	-- YTO	--- 40
0070	-- CNT	--- 47
0071	-- D	--- 63
0072	-- A	--- 62
0073	-- XTO	--- 23
0074	-- E	--- 60
0075	-- FMT	--- 42
0076	-- STP	--- 41
0077	-- XTO	--- 23
0078	-- 3	--- 03
0079	-- UP	--- 27
0080	-- INT	--- 64
0081	-- -	--- 34
0082	-- YTO	--- 40
0083	-- 4	--- 04
0084	-- UP	--- 27
0085	-- 1	--- 01

TODAY'S DATE - Enter the date for which processing is to occur.

Calculates number of days from zero and calculates number of days from planting.

```
0086 -- X=Y  --- 50
0087 -- GTO  --- 44
0088 -- LBL  --- 51
0089 -- 1    --- 01
0090 -- CNT  --- 47
0091 -- 2    --- 02
0092 -- X=Y  --- 50
0093 -- GTO  --- 44
0094 -- LBL  --- 51
0095 -- 2    --- 02
0096 -- CNT  --- 47
0097 -- 3    --- 03
0098 -- X=Y  --- 50
0099 -- GTO  --- 44
0100 -- LBL  --- 51
0101 -- 3    --- 03
0102 -- CNT  --- 47
0103 -- 4    --- 04
0104 -- X=Y  --- 50
0105 -- GTO  --- 44
0106 -- LBL  --- 51
0107 -- 4    --- 04
0108 -- CNT  --- 47
0109 -- 5    --- 05
0110 -- X=Y  --- 50
0111 -- GTO  --- 44
0112 -- LBL  --- 51
0113 -- 5    --- 05
0114 -- CNT  --- 47
0115 -- 6    --- 06
0116 -- X=Y  --- 50
0117 -- GTO  --- 44
0118 -- LBL  --- 51
0119 -- 6    --- 06
0120 -- CNT  --- 47
0121 -- 7    --- 07
0122 -- X=Y  --- 50
0123 -- GTO  --- 44
0124 -- LBL  --- 51
0125 -- 7    --- 07
0126 -- CNT  --- 47
0127 -- 8    --- 10
0128 -- X=Y  --- 50
0129 -- GTO  --- 44
0130 -- LBL  --- 51
```

```
0131  -- 8      --- 10
0132  -- CNT    --- 47
0133  -- 9      --- 11
0134  -- X=Y    --- 50
0135  -- GTO    --- 44
0136  -- LBL    --- 51
0137  -- 9      --- 11
0138  -- 9      --- 11
0139  -- CNT    --- 47
0140  -- 1      --- 01
0141  -- 0      --- 00
0142  -- X=Y    --- 50
0143  -- GTO    --- 44
0144  -- LBL    --- 51
0145  -- a      --- 13
0146  -- CNT    --- 47
0147  -- 1      --- 01
0148  -- 1      --- 01
0149  -- X=Y    --- 50
0150  -- GTO    --- 44
0151  -- LBL    --- 51
0152  -- b      --- 14
0153  -- CNT    --- 47
0154  -- 3      --- 03
0155  -- 3      --- 03
0156  -- 4      --- 04
0157  -- GTO    --- 44
0158  -- LBL    --- 51
0159  -- A      --- 62
0160  -- CNT    --- 47
0161  -- LBL    --- 51
0162  -- 1      --- 01
0163  -- CLX    --- 37
0164  -- GTO    --- 44
0165  -- LBL    --- 51
0166  -- A      --- 62
0167  -- CNT    --- 47
0168  -- LBL    --- 51
0169  -- 2      --- 02
0170  -- CNT    --- 47
0171  -- 3      --- 03
0172  -- 1      --- 01
0173  -- GTO    --- 44
0174  -- LBL    --- 51
0175  -- A      --- 62
```

```
0176  -- CNT  --- 47
0177  -- LBL  --- 51
0178  -- 3    --- 03
0179  -- CNT  --- 47
0180  -- 5    --- 05
0181  -- 9    --- 11
0182  -- GTO  --- 44
0183  -- LBL  --- 51
0184  -- A    --- 62
0185  -- CNT  --- 47
0186  -- LBL  --- 51
0187  -- 4    --- 04
0188  -- CNT  --- 47
0189  -- 9    --- 11
0190  -- 0    --- 00
0191  -- GTO  --- 44
0192  -- LBL  --- 51
0193  -- A    --- 62
0194  -- CNT  --- 47
0195  -- LBL  --- 51
0196  -- 5    --- 05
0197  -- CNT  --- 47
0198  -- 1    --- 01
0199  -- 2    --- 02
0200  -- 0    --- 00
0201  -- GTO  --- 44
0202  -- LBL  --- 51
0203  -- A    --- 62
0204  -- CNT  --- 47
0205  -- LBL  --- 51
0206  -- 6    --- 06
0207  -- CNT  --- 47
0208  -- 1    --- 01
0209  -- 5    --- 05
0210  -- 1    --- 01
0211  -- GTO  --- 44
0212  -- LBL  --- 51
0213  -- A    --- 62
0214  -- CNT  --- 47
0215  -- LBL  --- 51
0216  -- 7    --- 07
0217  -- CNT  --- 47
0218  -- 1    --- 01
0219  -- 8    --- 10
0220  -- 1    --- 01
```

```
0221  -- GTO  --- 44
0222  -- LBL  --- 51
0223  -- A    --- 62
0224  -- CNT  --- 47
0225  -- LBL  --- 51
0226  -- 8    --- 10
0227  -- CNT  --- 47
0228  -- 2    --- 02
0229  -- 1    --- 01
0230  -- 2    --- 02
0231  -- GTO  --- 44
0232  -- LBL  --- 51
0233  -- A    --- 62
0234  -- CNT  --- 47
0235  -- LBL  --- 51
0236  -- 9    --- 11
0237  -- CNT  --- 47
0238  -- 2    --- 02
0239  -- 4    --- 04
0240  -- 3    --- 03
0241  -- GTO  --- 44
0242  -- LBL  --- 51
0243  --·A    --- 62
0244  -- CNT  --- 47
0245  -- LBL  --- 51
0246  -- α    --- 13
0247  -- 2    --- 02
0248  -- 7    --- 07
0249  -- 3    --- 03
0250  -- GTO  --- 44
0251  -- LBL  --- 51
0252  -- A    --- 62
0253  -- CNT  --- 47
0254  -- LBL  --- 51
0255  -- b    --- 14
0256  -- CNT  --- 47
0257  -- 3    --- 03
0258  -- 0    --- 00
0259  -- 4    --- 04
0260  -- LBL  --- 51
0261  -- A    --- 62
0262  -- CNT  --- 47
0263  -- UP   --- 27
0264  -- XFR  --- 67
0265  -- 4    --- 04
```

0266	-- UP	--- 27
0267	-- 1	--- 01
0268	-- 0	--- 00
0269	-- 0	--- 00
0270	-- X	--- 36
0271	-- DN	--- 25
0272	-- +	--- 33
0273	-- YTO	--- 40
0274	-- 5	--- 05
0275	-- XFR	--- 67
0276	-- 4	--- 04
0277	-- 1	--- 01
0278	-- -	--- 34
0279	-- YTO	--- 40
0280	-- 6	--- 06
0281	-- CLR	--- 20
0282	-- CNT	--- 47
0283	-- FMT	--- 42
0284	-- FMT	--- 42
0285	-- I	--- 65
0286	-- α	--- 13
0287	-- α	--- 13
0288	-- I	--- 65
0289	-- G	--- 15
0290	-- A	--- 62
0291	-- XTO	--- 23
0292	-- E	--- 60
0293	-- IFG	--- 43
0294	-- FMT	--- 42
0295	-- STP	--- 41
0296	-- IFG	--- 43
0297	-- GTO	--- 44
0298	-- LBL	--- 51
0299	-- F	--- 16
0300	-- CNT	--- 47
0301	-- GTO	--- 44
0302	-- LBL	--- 51
0303	-- G	--- 15
0304	-- CNT	--- 47
0305	-- LBL	--- 51
0306	-- F	--- 16
0307	-- XFR	--- 67
0308	-- 5	--- 05
0309	-- XTO	--- 23
0310	-- 4	--- 04

Number of days from zero stored in register 005, number of days from planting stored in register 006.

IRRIGATE? Did a recharge either by rainfall or irrigation occur? The date of last recharge is stored in register 042.

0311	-- 2	--- 02
0312	-- CNT	--- 47
0313	-- 1	--- 01
0314	-- XTO	--- 23
0315	-- -	--- 34
0316	-- 4	--- 04
0317	-- 2	--- 02
0318	-- CNT	--- 47
0319	-- 5	--- 05
0320	-- 0	--- 00
0321	-- XTO	--- 23
0322	-- α	--- 13
0323	-- CLX	--- 37
0324	-- LBL	--- 51
0325	-- H	--- 74
0326	-- CNT	--- 47
0327	-- XTO	--- 23
0328	-- IND	--- 31
0329	-- α	--- 13
0330	-- CNT	--- 47
0331	-- 1	--- 01
0332	-- XTO	--- 23
0333	-- +	--- 33
0334	-- α	--- 13
0335	-- CNT	--- 47
0336	-- α	--- 13
0337	-- UP	--- 27
0338	-- 1	--- 01
0339	-- 0	--- 00
0340	-- 0	--- 00
0341	-- X=Y	--- 50
0342	-- GTO	--- 44
0343	-- LBL	--- 51
0344	-- G	--- 15
0345	-- CNT	--- 47
0346	-- CLX	--- 37
0347	-- GTO	--- 44
0348	-- LBL	--- 51
0349	-- H	--- 74
0350	-- CNT	--- 47
0351	-- LBL	--- 51
0352	-- G	--- 15
0353	-- CNT	--- 47
0354	-- CLR	--- 20
0355	-- FMT	--- 42

0356	-- FMT	--- 42	
0357	-- E	--- 60	ENTER READING Enter unstandardized Bellani plate number 1 reading.
0358	-- N	--- 73	
0359	-- XTO	--- 23	
0360	-- E	--- 60	
0361	-- α	--- 13	
0362	-- CNT	--- 47	
0363	-- α	--- 13	
0364	-- E	--- 60	
0365	-- A	--- 62	
0366	-- D	--- 63	
0367	-- I	--- 65	
0368	-- N	--- 73	
0369	-- G	--- 15	
0370	-- CLR	--- 20	
0371	-- CNT	--- 47	
0372	-- CNT	--- 47	
0373	-- CNT	--- 47	
0374	-- XFR	--- 67	
0375	-- E	--- 60	YES $\rightarrow$ Y Enter yesterday's reading for plate number 1 into Y register.
0376	-- YTO	--- 40	
0377	-- EEX	--- 26	
0378	-- XFR	--- 67	
0379	-- CLR	--- 20	
0380	-- CNT	--- 47	
0381	-- CNT	--- 47	
0382	-- CNT	--- 47	
0383	-- XTO	--- 23	TOD $\rightarrow$ X Enter today's reading for plate number 1 into X register.
0384	-- O	--- 71	
0385	-- D	--- 63	
0386	-- EEX	--- 26	
0387	-- YE	--- 24	
0388	-- FMT	--- 42	
0389	-- CNT	--- 47	
0390	-- CNT	--- 47	
0391	-- CNT	--- 47	
0392	-- CNT	--- 47	
0393	-- CNT	--- 47	
0394	-- CNT	--- 47	
0395	-- CNT	--- 47	
0396	-- CNT	--- 47	
0397	-- STP	--- 41	Subtracts yesterday's reading from today's reading to give evaporative loss.
0398	-- -	--- 34	
0399	-- CLX	--- 37	
0400	-- CNT	--- 47	

0401	-- CNT	---	47
0402	-- CNT	---	47
0403	-- CNT	---	47
0404	-- CNT	---	47
0405	-- CNT	---	47
0406	-- CNT	---	47
0407	-- XFR	---	67
0408	-- 0	---	00
0409	-- 4	---	04
0410	-- 4	---	04
0411	-- CNT	---	47
0412	-- CNT	---	47
0413	-- CNT	---	47
0414	-- CNT	---	47
0415	-- CNT	---	47
0416	-- X	---	36
0417	-- CLX	---	37
0418	-- FMT	---	42
0419	-- FMT	---	42
0420	-- π	---	56
0421	-- L	---	72
0422	-- A	---	62
0423	-- XTO	---	23
0424	-- E	---	60
0425	-- CNT	---	47
0426	-- 2	---	02
0427	-- CLR	---	20
0428	-- CNT	---	47
0429	-- CNT	---	47
0430	-- CNT	---	47
0431	-- XFR	---	67
0432	-- E	---	60
0433	-- YTO	---	40
0434	-- CNT	---	47
0435	-- EEX	---	26
0436	-- CNT	---	47
0437	-- XFR	---	67
0438	-- CLR	---	20
0439	-- CNT	---	47
0440	-- CNT	---	47
0441	-- CNT	---	47
0442	-- XTO	---	23
0443	-- O	---	71
0444	-- D	---	63
0445	-- CNT	---	47

Bellani plate 1 coefficient recalled from storage register 044.

Multiplies plate 1 coefficient times evaporative loss.

PLATE 2   Enter unstandardized Bellani plate number 2 reading.

YES → Y   Enter yesterday's reading for plate number 2 into Y register.

TOD → X   Enter today's reading for plate number 2 into X register.

0446	-- EEX	--- 26	
0447	-- CNT	--- 47	
0448	-- YE	--- 24	
0449	-- FMT	--- 42	
0450	-- STP	--- 41	
0451	-- -	--- 34	Subtracts yesterday's reading
0452	-- CLX	--- 37	from today's reading to give
0453	-- CNT	--- 47	evaporative loss.
0454	-- CNT	--- 47	
0455	-- CNT	--- 47	
0456	-- CNT	--- 47	
0457	-- CNT	--- 47	
0458	-- CNT	--- 47	
0459	-- CNT	--- 47	
0460	-- XFR	--- 67	
0461	-- 0	--- 00	Plate 2 coefficient recalled
0462	-- 4	--- 04	from storage register 045.
0463	-- 5	--- 05	
0464	-- CNT	--- 47	
0465	-- CNT	--- 47	
0466	-- CNT	--- 47	
0467	-- CNT	--- 47	
0468	-- X	--- 36	Multiplies plate 2 coefficient
0469	-- DN	--- 25	times evaporative loss.
0470	-- +	--- 33	
0471	-- 2	--- 02	Calculates average evaporative
0472	-- DIV	--- 35	loss and stores in register 007.
0473	-- YTO	--- 40	
0474	-- 7	--- 07	
0475	-- CLR	--- 20	
0476	-- CNT	--- 47	
0477	-- CNT	--- 47	
0478	-- CNT	--- 47	
0479	-- CNT	--- 47	
0480	-- CNT	--- 47	
0481	-- CNT	--- 47	
0482	-- CNT	--- 47	
0483	-- CNT	--- 47	
0484	-- CNT	--- 47	
0485	-- CNT	--- 47	
0486	-- CNT	--- 47	
0487	-- CNT	--- 47	
0488	-- CNT	--- 47	
0489	-- CNT	--- 47	
0490	-- CNT	--- 47	

```
0491  -- CNT  --- 47
0492  -- CNT  --- 47
0493  -- CNT  --- 47
0494  -- CNT  --- 47
0495  -- CNT  --- 47
0496  -- CNT  --- 47
0497  -- CNT  --- 47
0498  -- CNT  --- 47
0499  -- CNT  --- 47
0500  -- CNT  --- 47
0501  -- XFR  --- 67
0502  -- 6    --- 06
0503  -- UP   --- 27
0504  -- 1    --- 01
0505  -- 1    --- 01
0506  -- X>Y  --- 53
0507  -- GTO  --- 44
0508  -- LBL  --- 51
0509  -- B    --- 66
0510  -- CNT  --- 47
0511  -- 3    --- 03
0512  -- 1    --- 01
0513  -- X>Y  --- 53
0514  -- GTO  --- 44
0515  -- LBL  --- 51
0516  -- C    --- 61
0517  -- CNT  --- 47
0518  -- 5    --- 05
0519  -- 1    --- 01
0520  -- X>Y  --- 53
0521  -- GTO  --- 44
0522  -- LBL  --- 51
0523  -- D    --- 63
0524  -- CNT  --- 47
0525  -- .    --- 21
0526  -- 2    --- 02
0527  -- 7    --- 07
0528  -- 9    --- 11
0529  -- 3    --- 03
0530  -- 1    --- 01
0531  -- 9    --- 11
0532  -- XTO  --- 23
0533  -- 9    --- 11
0534  -- CNT  --- 47
0535  -- .    --- 21
```

Compares number of days from planting to each growth stage to select the proper intercept and slope and stores in temporary storage for later use.

Intercept period III

Slope period III

0536	-- 1	---	01
0537	-- 7	---	07
0538	-- 2	---	02
0539	-- 7	---	07
0540	-- 3	---	03
0541	-- 1	---	01
0542	-- XTO	---	23
0543	-- 8	---	10
0544	-- CNT	---	47
0545	-- 3	---	03
0546	-- 9	---	11
0547	-- XTO	---	23
0548	-- 1	---	01
0549	-- 0	---	00
0550	-- GTO	---	44
0551	-- LBL	---	51
0552	-- E	---	60
0553	-- CNT	---	47
0554	-- LBL	---	51
0555	-- B	---	66
0556	-- 5	---	05
0557	-- .	---	21
0558	-- 3	---	03
0559	-- 6	---	06
0560	-- 9	---	11
0561	-- 8	---	10
0562	-- 8	---	10
0563	-- 4	---	04
0564	-- XTO	---	23
0565	-- 9	---	11
0566	-- CNT	---	47
0567	-- .	---	21
0568	-- 0	---	00
0569	-- 4	---	04
0570	-- 6	---	06
0571	-- 3	---	03
0572	-- 6	---	06
0573	-- 2	---	02
0574	-- XTO	---	23
0575	-- 8	---	10
0576	-- CNT	---	47
0577	-- 1	---	01
0578	-- 6	---	06
0579	-- XTO	---	23
0580	-- 1	---	01

Intercept period IA

Slope period IA

0581	-- 0	--- 00
0582	-- GTO	--- 44
0583	-- LBL	--- 51
0584	-- E	--- 60
0585	-- CNT	--- 47
0586	-- LBL	--- 51
0587	-- C	--- 61
0588	-- CNT	--- 47
0589	-- 5	--- 05
0590	-- .	--- 21
0591	-- 3	--- 03
0592	-- 6	--- 06
0593	-- 9	--- 11
0594	-- 8	--- 10
0595	-- 8	--- 10
0596	-- 4	--- 04
0597	-- XTO	--- 23
0598	-- 9	--- 11
0599	-- CNT	--- 47
0600	-- .	--- 21
0601	-- 0	--- 00
0602	-- 4	--- 04
0603	-- 6	--- 06
0604	-- 3	--- 03
0605	-- 6	--- 06
0606	-- 2	--- 02
0607	-- XTO	--- 23
0608	-- 8	--- 10
0609	-- CNT	--- 47
0610	-- 2	--- 02
0611	-- 9	--- 11
0612	-- XTO	--- 23
0613	-- 1	--- 01
0614	-- 0	--- 00
0615	-- CNT	--- 47
0616	-- GTO	--- 44
0617	-- LBL	--- 51
0618	-- E	--- 60
0619	-- CNT	--- 47
0620	-- LBL	--- 51
0621	-- D	--- 63
0622	-- 2	--- 02
0623	-- .	--- 21
0624	-- 5	--- 05
0625	-- 4	--- 04

Intercept period IB

Slope period IB

Intercept period II

0626	-- 5	--- 05	
0627	-- 2	--- 02	
0628	-- 8	--- 10	
0629	-- 3	--- 03	
0630	-- XTO	--- 23	
0631	-- 9	--- 11	
0632	-- CNT	--- 47	
0633	-- .	--- 21	
0634	-- 1	--- 01	Slope period II
0635	-- 0	--- 00	
0636	-- 9	--- 11	
0637	-- 5	--- 05	
0638	-- 4	--- 04	
0639	-- 7	--- 07	
0640	-- XTO	--- 23	
0641	-- 8	--- 10	
0642	-- CNT	--- 47	
0643	-- 3	--- 03	
0644	-- 3	--- 03	
0645	-- XTO	--- 23	
0646	-- 1	--- 01	
0647	-- 0	--- 00	
0648	-- CNT	--- 47	
0649	-- LBL	--- 51	
0650	-- E	--- 60	
0651	-- CNT	--- 47	
0652	-- CNT	--- 47	
0653	-- CNT	--- 47	
0654	-- CNT	--- 47	
0655	-- CNT	--- 47	
0656	-- CNT	--- 47	
0657	-- CNT	--- 47	
0658	-- CNT	--- 47	
0659	-- XFR	--- 67	
0660	-- 7	--- 07	Recalls average evaporative
0661	-- XTO	--- 23	loss both plates.
0662	-- 1	--- 01	
0663	-- 1	--- 01	
0664	-- CNT	--- 47	
0665	-- CNT	--- 47	
0666	-- CNT	--- 47	
0667	-- CNT	--- 47	
0668	-- CNT	--- 47	
0669	-- 5	--- 05	
0670	-- 0	--- 00	

0671	-- XTO	---	23
0672	-- α	---	13
0673	-- 7	---	07
0674	-- 5	---	05
0675	-- XTO	---	23
0676	-- b	---	14
0677	-- CNT	---	47
0678	-- LBL	---	51
0679	-- J	---	75
0680	-- CNT	---	47
0681	-- XFR	---	67
0682	-- IND	---	31
0683	-- α	---	13
0684	-- UP	---	27
0685	-- 0	---	00
0686	-- X=Y	---	50
0687	-- GTO	---	44
0688	-- LBL	---	51
0689	-- I	---	65
0690	-- CNT	---	47
0691	-- 1	---	01
0692	-- XTO	---	23
0693	-- +	---	33
0694	-- α	---	13
0695	-- XTO	---	23
0696	-- +	---	33
0697	-- b	---	14
0698	-- GTO	---	44
0699	-- LBL	---	51
0700	-- J	---	75
0701	-- CNT	---	47
0702	-- LBL	---	51
0703	-- I	---	65
0704	-- GTO	---	44
0705	-- S/R	---	77
0706	-- 1	---	01
0707	-- 3	---	03
0708	-- 7	---	07
0709	-- 5	---	05
0710	-- XFR	---	67
0711	-- 5	---	05
0712	-- UP	---	27
0713	-- XFR	---	67
0714	-- 4	---	04
0715	-- 2	---	02

Recalls number of days
from zero.

Recalls date of last
recharge.

0716	-- -	---	34
0717	-- YTO	---	40
0718	-- IND	---	31
0719	-- b	---	14
0720	-- CNT	---	47
0721	-- CNT	---	47
0722	-- CNT	---	47
0723	-- FMT	---	42
0724	-- 1	---	01
0725	-- 8	---	10
0726	-- 0	---	00
0727	-- CNT	---	47
0728	-- 2	---	02
0729	-- 5	---	05
0730	-- UP	---	27
0731	-- 3	---	03
0732	-- CHS	---	32
0733	-- FMT	---	42
0734	-- 1	---	01
0735	-- 2	---	02
0736	-- CNT	---	47
0737	-- 8	---	10
0738	-- 0	---	00
0739	-- UP	---	27
0740	-- 1	---	01
0741	-- 0	---	00
0742	-- CHS	---	32
0743	-- FMT	---	42
0744	-- 1	---	01
0745	-- 3	---	03
0746	-- CNT	---	47
0747	-- 0	---	00
0748	-- UP	---	27
0749	-- FMT	---	42
0750	-- 1	---	01
0751	-- UP	---	27
0752	-- CLR	---	20
0753	-- 1	---	01
0754	-- XTO	---	23
0755	-- b	---	14
0756	-- CNT	---	47
0757	-- LBL	---	51
0758	-- K	---	55
0759	-- CNT	---	47
0760	-- CLX	---	37

Plot routine

0761	-- UP	--- 27
0762	-- α	--- 13
0763	-- FMT	--- 42
0764	-- 1	--- 01
0765	-- DN	--- 25
0766	-- b	--- 14
0767	-- UP	--- 27
0768	-- α	--- 13
0769	-- FMT	--- 42
0770	-- 1	--- 01
0771	-- DN	--- 25
0772	-- CLX	--- 37
0773	-- UP	--- 27
0774	-- α	--- 13
0775	-- FMT	--- 42
0776	-- 1	--- 01
0777	-- DN	--- 25
0778	-- α	--- 13
0779	-- UP	--- 27
0780	-- 2	--- 02
0781	-- 5	--- 05
0782	-- X=Y	--- 50
0783	-- GTO	--- 44
0784	-- LBL	--- 51
0785	-- L	--- 72
0786	-- CNT	--- 47
0787	-- 1	--- 01
0788	-- XTO	--- 23
0789	-- +	--- 33
0790	-- α	--- 13
0791	-- GTO	--- 44
0792	-- LBL	--- 51
0793	-- K	--- 55
0794	-- CNT	--- 47
0795	-- LBL	--- 51
0796	-- L	--- 72
0797	-- CNT	--- 47
0798	-- 5	--- 05
0799	-- XTO	--- 23
0800	-- b	--- 14
0801	-- CNT	--- 47
0802	-- .	--- 21
0803	-- 2	--- 02
0804	-- 5	--- 05
0805	-- XTO	--- 23

```
0806  -- a      --- 13
0807  -- CNT    --- 47
0808  -- 8      --- 10
0809  -- 0      --- 00
0810  -- UP     --- 27
0811  -- 2      --- 02
0812  -- 5      --- 05
0813  -- FMT    --- 42
0814  -- 1      --- 01
0815  -- DN     --- 25
0816  -- CNT    --- 47
0817  -- 0      --- 00
0818  -- UP     --- 27
0819  -- FMT    --- 42
0820  -- 1      --- 01
0821  -- UP     --- 27
0822  -- CNT    --- 47
0823  -- LBL    --- 51
0824  -- M      --- 70
0825  -- CNT    --- 47
0826  -- b      --- 14
0827  -- UP     --- 27
0828  -- CLX    --- 37
0829  -- FMT    --- 42
0830  -- 1      --- 01
0831  -- DN     --- 25
0832  -- b      --- 14
0833  -- UP     --- 27
0834  -- a      --- 13
0835  -- FMT    --- 42
0836  -- 1      --- 01
0837  -- DN     --- 25
0838  -- b      --- 14
0839  -- UP     --- 27
0840  -- CLX    --- 37
0841  -- FMT    --- 42
0842  -- 1      --- 01
0843  -- DN     --- 25
0844  -- b      --- 14
0845  -- UP     --- 27
0846  -- 8      --- 10
0847  -- 0      --- 00
0848  -- X=Y    --- 50
0849  -- GTO    --- 44
0850  -- LBL    --- 51
```

```
0851  --  N    --- 73
0852  --  CNT  --- 47
0853  --  5    --- 05
0854  --  XTO  --- 23
0855  --  +    --- 33
0856  --  b    --- 14
0857  --  GTO  --- 44
0858  --  LBL  --- 51
0859  --  M    --- 70
0860  --  CNT  --- 47
0861  --  LBL  --- 51
0862  --  N    --- 73
0863  --  CNT  --- 47
0864  --  8    --- 10
0865  --  0    --- 00
0866  --  UP   --- 27
0867  --  2    --- 02
0868  --  5    --- 05
0869  --  FMT  --- 42
0870  --  1    --- 01
0871  --  DN   --- 25
0872  --  CNT  --- 47
0873  --  CNT  --- 47
0874  --  CNT  --- 47
0875  --  CNT  --- 47
0876  --  CNT  --- 47
0877  --  CNT  --- 47
0878  --  CNT  --- 47
0879  --  CNT  --- 47
0880  --  CNT  --- 47
0881  --  CNT  --- 47
0882  --  CNT  --- 47
0883  --  CNT  --- 47
0884  --  CNT  --- 47
0885  --  CNT  --- 47
0886  --  CNT  --- 47
0887  --  CNT  --- 47
0888  --  CNT  --- 47
0889  --  CNT  --- 47
0890  --  CNT  --- 47
0891  --  CNT  --- 47
0892  --  CNT  --- 47
0893  --  CNT  --- 47
0894  --  CNT  --- 47
0895  --  CNT  --- 47
```

0896	-- CNT	---	47
0897	-- CNT	---	47
0898	-- CNT	---	47
0899	-- CNT	---	47
0900	-- .	---	21
0901	-- 1	---	01
0902	-- 8	---	10
0903	-- CNT	---	47
0904	-- FMT	---	42
0905	-- 1	---	01
0906	-- 1	---	01
0907	-- CNT	---	47
0908	-- 1	---	01
0909	-- 0	---	00
0910	-- CHS	---	32
0911	-- UP	---	27
0912	-- 4	---	04
0913	-- FMT	---	42
0914	-- 1	---	01
0915	-- UP	---	27
0916	-- FMT	---	42
0917	-- 1	---	01
0918	-- FMT	---	42
0919	-- D	---	63
0920	-- A	---	62
0921	-- XFR	---	67
0922	-- YTO	---	40
0923	-- CNT	---	47
0924	-- F	---	16
0925	-- α	---	13
0926	-- O	---	71
0927	-- M	---	70
0928	-- CNT	---	47
0929	-- L	---	72
0930	-- A	---	62
0931	-- YTO	---	40
0932	-- XTO	---	23
0933	-- CNT	---	47
0934	-- I	---	65
0935	-- α	---	13
0936	-- α	---	13
0937	-- I	---	65
0938	-- G	---	15
0939	-- A	---	62
0940	-- XTO	---	23

Writes DAYS FROM LAST IRRIGATION. Note LAST IRRIGATION can refer to a rainfall recharge.

```
0941  -- I      --- 65
0942  -- O      --- 71
0943  -- N      --- 73
0944  -- FMT    --- 42
0945  --  .     --- 21
0946  -- 1      --- 01
0947  -- 0      --- 00
0948  -- FMT    --- 42
0949  -- 1      --- 01
0950  -- 1      --- 01
0951  -- CNT    --- 47
0952  --  .     --- 21
0953  -. 3      --- 03
0954  -- CHS    --- 32
0955  -- XTO    --- 23
0956  -- a      --- 13
0957  -- 0      --- 00
0958  -- XTO    --- 23
0959  -- b      --- 14
0960  -- CNT    --- 47
0961  -- LBL    --- 51
0962  -- O      --- 71
0963  -- 3      --- 03
0964  -- CHS    --- 32
0965  -- UP     --- 27
0966  -- a      --- 13
0967  -- FMT    --- 42
0968  -- 1      --- 01
0969  -- UP     --- 27
0970  -- b      --- 14
0971  -- FMT    --- 42
0972  -- 1      --- 01
0973  -- PNT    --- 45
0974  -- CNT    --- 47
0975  -- b      --- 14
0976  -- UP     --- 27
0977  -- 2      --- 02
0978  -- 4      --- 04
0979  -- X=Y    --- 50
0980  -- GTO    --- 44
0981  -- LBL    --- 51
0982  -- π      --- 56
0983  -- CNT    --- 47
0984  -- 2      --- 02
0985  -- XTO    -- 23
```

0986	-- +	--- 33
0987	-- α	--- 13
0988	-- XTO	--- 23
0989	-- +	--- 33
0990	-- b	--- 14
0991	-- GTO	--- 44
0992	-- LBL	--- 51
0993	-- O	--- 71
0994	-- CNT	--- 47
0995	-- LBL	--- 51
0996	-- π	--- 56
0997	-- CNT	--- 47
0998	-- .	--- 21
0999	-- 2	--- 02
1000	-- FMT	--- 42
1001	-- 1	--- 01
1002	-- 1	--- 01
1003	-- CNT	--- 47
1004	-- FMT	--- 42
1005	-- 1	--- 01
1006	-- 9	--- 11
1007	-- CNT	--- 47
1008	-- 2	--- 02
1009	-- 5	--- 05
1010	-- UP	--- 27
1011	-- 1	--- 01
1012	-- CHS	--- 32
1013	-- FMT	--- 42
1014	-- 1	--- 01
1015	-- UP	--- 27
1016	-- FMT	--- 42
1017	-- 1	--- 01
1018	-- FMT	--- 42
1019	-- N	--- 73
1020	-- E	--- 60
1021	-- E	--- 60
1022	-- D	--- 63
1023	-- CNT	--- 47
1024	-- EEX	--- 26
1025	-- FMT	--- 42
1026	-- CNT	--- 47
1027	-- FMT	--- 42
1028	-- 1	--- 01
1029	-- 9	--- 11
1030	-- CNT	--- 47

Writes <u>NEED</u>.

1031	-- 7	--- 07
1032	-- 5	--- 05
1033	-- UP	--- 27
1034	-- 2	--- 02
1035	-- FMT	--- 42
1036	-- 1	--- 01
1037	-- UP	--- 27
1038	-- .	--- 21
1039	-- 1	--- 01
1040	-- 8	--- 10
1041	-- FMT	--- 42
1042	-- 1	--- 01
1043	-- 1	--- 01
1044	-- FMT	--- 42
1045	-- 1	--- 01
1046	-- FMT	--- 42
1047	-- XFR	--- 67
1048	-- E	--- 60
1049	-- YTO	--- 40
1050	-- XTO	--- 23
1051	-- E	--- 60
1052	-- α	--- 13
1053	-- D	--- 63
1054	-- A	--- 62
1055	-- XFR	--- 67
1056	-- CNT	--- 47
1057	-- CNT	--- 47
1058	-- FMT	--- 42
1059	-- STP	--- 41
1060	-- .	--- 21
1061	-- 1	--- 01
1062	-- 6	--- 06
1063	-- FMT	--- 42
1064	-- 1	--- 01
1065	-- 1	--- 01
1066	-- CNT	--- 47
1067	-- 7	--- 07
1068	-- 0	--- 00
1069	-- UP	--- 27
1070	-- 3	--- 03
1071	-- FMT	--- 42
1072	-- 1	--- 01
1073	-- UP	--- 27
1074	-- CNT	--- 47
1075	-- FMT	--- 42

Writes <u>YESTERDAY</u> waits for response.

1076	-- 1	--- 01	
1077	-- FMT	--- 42	
1078	-- α	--- 13	Writes <u>RAIN</u> waits for
1079	-- A	--- 62	response.
1080	-- I	--- 65	
1081	-- N	--- 73	
1082	-- CNT	--- 47	
1083	-- CNT	--- 47	
1084	-- FMT	--- 42	
1085	-- STP	--- 41	
1086	-- 6	--- 06	
1087	-- 5	--- 05	
1088	-- UP	--- 27	
1089	-- 3	--- 03	
1090	-- FMT	--- 42	
1091	-- 1	--- 01	
1092	-- UP	--- 27	
1093	-- FMT	--- 42	
1094	-- 1	--- 01	
1095	-- FMT	--- 42	
1096	-- XTO	--- 23	
1097	-- E	--- 60	Writes <u>TEMP</u> waits for
1098	-- M	--- 70	response.
1099	-- π	--- 56	
1100	-- CNT	--- 47	
1101	-- CNT	--- 47	
1102	-- FMT	--- 42	
1103	-- STP	--- 41	
1104	-- 6	--- 06	
1105	-- 0	--- 00	
1106	-- UP	--- 27	
1107	-- 3	--- 03	
1108	-- FMT	--- 42	
1109	-- 1	--- 01	
1110	-- UP	--- 27	
1111	-- FMT	--- 42	
1112	-- 1	--- 01	
1113	-- FMT	--- 42	
1114	-- I	--- 65	Writes <u>IRR?</u> waits for
1115	-- α	--- 13	response.
1116	-- α	--- 13	
1117	-- IFG	--- 43	
1118	-- CNT	--- 47	
1119	-- CNT	--- 47	
1120	-- FMT	--- 42	

1121	-- STP	--- 41
1122	-- 5	--- 05
1123	-- 5	--- 05
1124	-- UP	--- 27
1125	-- 3	--- 03
1126	-- FMT	--- 42
1127	-- 1	--- 01
1128	-- UP	--- 27
1129	-- FMT	--- 42
1130	-- 1	--- 01
1131	-- FMT	--- 42
1132	-- a	--- 13
1133	-- SFL	--- 54
1134	-- I	--- 65
1135	-- IFG	--- 43
1136	-- CNT	--- 47
1137	-- CNT	--- 47
1138	-- FMT	--- 42
1139	-- STP	--- 41
1140	-- 7	--- 07
1141	-- 0	--- 00
1142	-- UP	--- 27
1143	-- 1	--- 01
1144	-- 4	--- 04
1145	-- FMT	--- 42
1146	-- 1	--- 01
1147	-- UP	--- 27
1148	-- GTO	--- 44
1149	-- S/R	--- 77
1150	-- 1	--- 01
1151	-- 8	--- 10
1152	-- 5	--- 05
1153	-- 0	--- 00
1154	-- CNT	--- 47
1155	-- 6	--- 06
1156	-- 5	--- 05
1157	-- UP	--- 27
1158	-- 1	--- 01
1159	-- 4	--- 04
1160	-- FMT	--- 42
1161	-- 1	--- 01
1162	-- UP	--- 27
1163	-- GTO	--- 44
1164	-- S/R	--- 77
1165	-- 1	--- 01

Writes R=I? waits for response. (at line 1133)

Goes to field files for stored information such as: company name (at line 1151)

1166	-- 8	--- 10	grower name and field
1167	-- 7	--- 07	description
1168	-- 5	--- 05	
1169	-- CNT	--- 47	
1170	-- 6	--- 06	
1171	-- 0	--- 00	
1172	-- UP	--- 27	
1173	-- 1	--- 01	
1174	-- 4	--- 04	
1175	-- FMT	--- 42	
1176	-- 1	--- 01	
1177	-- UP	--- 27	
1178	-- GTO	--- 44	
1179	-- S/R	--- 77	
1180	-- 1	--- 01	soil classification
1181	-- 9	--- 11	
1182	-- 0	--- 00	
1183	-- 0	--- 00	
1184	-- CNT	--- 47	
1185	-- 5	--- 05	
1186	-- 5	--- 05	
1187	-- UP	--- 27	
1188	-- 1	--- 01	
1189	-- 4	--- 04	
1190	-- FMT	--- 42	
1191	-- 1	--- 01	
1192	-- UP	--- 27	
1193	-- GTO	--- 44	
1194	-- S/R	--- 77	
1195	-- 1	--- 01	
1196	-- 9	--- 11	planting date.
1197	-- 2	--- 02	
1198	-- 5	--- 05	
1199	-- CNT	--- 47	
1200	-- XFR	--- 67	
1201	-- 1	--- 01	
1202	-- 0	--- 00	
1203	-- UP	--- 27	
1204	-- 0	--- 00	
1205	-- FMT	--- 42	
1206	-- 1	--- 01	
1207	-- UP	--- 27	
1208	-- CNT	--- 47	
1209	-- XFR	--- 67	
1210	-- 1	--- 01	

1211	-- 0	--- 00	Recalls SMP constant line.
1212	-- UP	--- 27	
1213	-- 2	--- 02	
1214	-- 5	--- 05	
1215	-- FMT	--- 42	
1216	-- 1	--- 01	
1217	-- DN	--- 25	Plots SMP constant line.
1218	-- CNT	--- 47	
1219	-- XFR	--- 67	
1220	-- 1	--- 01	
1221	-- 0	--- 00	
1222	-- UP	--- 27	
1223	-- 1	--- 01	
1224	-- +	--- 33	
1225	-- 1	--- 01	
1226	-- 7	--- 07	
1227	-- FMT	--- 42	
1228	-- 1	--- 01	
1229	-- UP	--- 27	
1230	-- FMT	--- 42	
1231	-- 1	--- 01	
1232	-- FMT	--- 42	
1233	-- I	--- 65	Writes <u>IRRIGATE!</u>
1234	-- a	--- 13	
1235	-- a	--- 13	
1236	-- I	--- 65	
1237	-- G	--- 15	
1238	-- A	--- 62	
1239	-- XTO	--- 23	
1240	-- E	--- 60	
1241	-- FMT	--- 42	
1242	-- XFR	--- 67	
1243	-- 1	--- 01	
1244	-- 0	--- 00	
1245	-- UP	--- 27	
1246	-- 1	--- 01	
1247	-- .	--- 21	
1248	-- 5	--- 05	
1249	-- +	--- 33	
1250	-- 2	--- 02	
1251	-- 1	--- 01	
1252	-- .	--- 21	
1253	-- 7	--- 07	
1254	-- 5	--- 05	
1255	-- FMT	--- 42	

```
1256  -- 1     --- 01
1257  -- UP    --- 27
1258  -- FMT   --- 42
1259  -- 1     --- 01
1260  -- FMT   --- 42
1261  -- I     --- 65
1262  -- FMT   --- 42
1263  -- XFR   --- 67
1264  -- 1     --- 01
1265  -- 0     --- 00
1266  -- UP    --- 27
1267  -- 1     --- 01
1268  -- +     --- 33
1269  -- 2     --- 02
1270  -- 1     --- 01
1271  --  .    --- 21
1272  -- 7     --- 07
1273  -- 5     --- 05
1274  -- FMT   --- 42
1275  -- 1     --- 01
1276  -- UP    --- 27
1277  -- FMT   --- 42
1278  -- 1     --- 01
1279  -- FMT   --- 42
1280  --  .    --- 21
1281  -- FMT   --- 42
1282  -- CNT   --- 47
1283  -- 0     --- 00
1284  -- UP    --- 27
1285  -- FMT   --- 42
1286  -- 1     --- 01
1287  -- UP    --- 27
1288  -- CNT   --- 47
1289  -- CNT   --- 47
1290  -- 5     --- 05
1291  -- 0     --- 00
1292  -- XTO   --- 23
1293  -- a     --- 13
1294  -- 7     --- 07
1295  -- 5     --- 05
1296  -- XTO   --- 23
1297  -- b     --- 14
1298  -- CNT   --- 57
1299  -- LBL   --- 51
1300  -- YTO   --- 40
```

1301	-- XFR	--- 67	
1302	-- IND	--- 31	
1303	-- α	--- 13	
1304	-- UP	--- 27	
1305	-- 0	--- 00	
1306	-- X=Y	--- 50	
1307	-- GTO	--- 44	
1308	-- LBL	--- 51	
1309	-- XTO	--- 23	
1310	-- CNT	--- 47	
1311	-- XFR	--- 67	
1312	-- 4	--- 04	Recalls previously stored
1313	-- 3	--- 03	soil coefficient.
1314	-- X	--- 36	
1315	-- XFR	--- 67	
1316	-- 8	--- 10	Recalls slope from temporary
1317	-- X	--- 36	storage.
1318	-- XFR	--- 67	
1319	-- 9	--- 11	Recalls intercept from
1320	-- +	--- 33	temporary storage.
1321	-- XFR	--- 67	
1322	-- IND	--- 31	
1323	-- b	--- 14	Calculates daily line.
1324	-- FMT	--- 42	
1325	-- 1	--- 01	
1326	-- DN	--- 25	Plots daily line.
1327	-- FMT	--- 42	
1328	-- 1	--- 01	
1329	-- 4	--- 04	
1330	-- 1	--- 01	
1331	-- XTO	--- 23	
1332	-- +	--- 33	Updates stored information.
1333	-- α	--- 13	
1334	-- XTO	--- 23	
1335	-- +	--- 33	
1336	-- b	--- 14	
1337	-- GTO	--- 44	
1338	-- LBL	--- 51	
1339	-- YTO	--- 40	
1340	-- CNT	--- 47	
1341	-- LBL	--- 51	
1342	-- XTO	--- 23	
1343	-- CNT	--- 47	
1344	-- XFR	--- 67	
1345	-- 0	--- 00	

1346	-- UP	--- 27
1347	-- 5	--- 05
1348	-- 0	--- 00
1349	-- +	--- 33
1350	-- DN	--- 25
1351	-- FMT	--- 42
1352	-- 5	--- 05
1353	-- CLX	--- 37
1354	-- CNT	--- 47
1355	-- 6	--- 06
1356	-- 0	--- 00
1357	-- UP	--- 27
1358	-- 4	--- 04
1359	-- 0	--- 00
1360	-- FMT	--- 42
1361	-- 5	--- 05
1362	-- XTO	--- 23
1363	-- CNT	--- 47
1364	-- GTO	--- 44
1365	-- 1	--- 01
1366	-- 3	--- 03
1367	-- 9	--- 11
1368	-- 8	--- 10
1369	-- CNT	--- 47
1370	-- CNT	--- 47
1371	-- CNT	--- 47
1372	-- CNT	--- 47
1373	-- CNT	--- 47
1374	-- CNT	--- 47
1375	-- 1	--- 01
1376	-- XTO	--- 23
1377	-- -	--- 34
1378	-- a	--- 13
1379	-- XFR	--- 67
1380	-- IND	--- 31
1381	-- a	--- 13
1382	-- UP	--- 27
1383	-- XFR	--- 67
1384	-- 1	--- 01
1385	-- 1	--- 01
1386	-- +	--- 33
1387	-- 1	--- 01
1388	-- XTO	--- 23
1389	-- +	--- 33
1390	-- a	--- 13

```
1391  -- DN    --- 25
1392  -- XTO   --- 23
1393  -- IND   --- 31
1394  -- α     --- 13
1395  -- S/R   --- 77
1396  -- CNT   --- 47
1397  -- CNT   --- 47
1398  -- END   --- 46
```

APPENDIX C

LARGE SCALE COMPUTER PROGRAM

User Documentation for Large Scale Computer Program

This program enables the user, in an interactive mode to schedule irrigation for approximately 400 individual lettuce plantings at a rate of 2 minutes per field per day. The program uses 43K octal words of memory with 60-bit, 10-byte words. The program stores for each planting, on field files, the information which is constant for the season. This information includes the company name, grower name and field description, soil classification, planting date, soil coefficient and Bellani plate coefficients. The field files also store the Bellani atmometer water loss between significant recharges. The predicted time to irrigation which is updated daily is also stored. The program by the least squares regression method fits the cumulative atmometer water loss versus days from the last recharge for linear, quadratic and cubic equations. The predicted time is converted to calendar date. The user with the aid of the coefficient of determination (R^2) selects the date most imminent for irrigation to occur.

The program is written in FORTRAN IV ANSI standard except for the Indexed Sequential Routines (IS). Although the concept of IS files is widespread, there is no standard to meet when writing routines for IS manipulation. As a result, most IS routine packages are different and incompatible. The set of subroutines described here were written for the CDC Cyber 171 which has a NOS version 1 operating system. More

information can be obtained from Control Data Corporation, 1977,

Fortran Extended Version 4 Reference Manual, CDC, Sunnyvale,

California.

CALL FILE IS(FET, 3LLFN, 6LFIELDS)

This routine must be the first of all IS routines to be called. It sets

up the file environment table, a user-declared array of 35 words that

is used by the IS routines to communicate with one another (see also

program listing Appendix C). The "3LLFN" is a character constant

which means "Put the three characters LFN into a word, left-justified

and fill the rest of the word with binary zeroes." LFN stands for Local

File Name, and FIELDS is the indexed-sequential file that program

IRRIGT uses for data. This is used only in program IRRIGT.

CALL ØPENM(FET, 3LI-Ø, ILR)

"ØPENM" is the routine that "opens" a file, i. e., makes it functional

and accessible from your program. This routine must be called before

any other file-manipulating IS routines (the ones shown below). "I-Ø"

means that this file will be used for both input and output-both reading

and writing. When the file is just being created, this is replaced by

"3LNEW". ILR means that the file is to be rewound before doing any-

thing else. This is used in subroutines GTDATA, ADDFLD, DLTFLD,

LSTFLD and EDIT.

CALL GET(FET, INFØ, FLDNØ, O, O, O, BØMB)

This routine will get (read) data from the IS file "FIELDS". The array INFØ will be the recipient of the data. Which field's data you get depends on the number of the field you wish to access-FLDNØ. The next three zeroes specify the default values for three other variables. BØMB is the error routine, i.e., the routine to which processing goes if an error is encountered in the GET routine, e.g., trying to get a non-existent record. This is used in subroutines GTDATA, ADDFLD and EDIT.

CALL PUT(FET, INFØ, 350, FLDNØ, O, O, BØMB)

This routine will write the data record to the IS file. INFØ is where the data to be written is stored; FLDNØ is the field number. The two zeroes are more defaults (see page 173) and BØMB is the error routine. This is used in subroutine ADDFLD.

CALL DLTE(FET, FLDNØ, O, O, BØMB)

This routine will delete field number, FLDNØ, from the IS file; the zeroes are the same two defaults as before and BØMB is the error routine. This is used in subroutines ADDFLD and DLTFLD.

CALL GETN(FET, INFØ, FLDNØ, BØMB)

This will sequence through in ascending order according to FLDNØ all the records on file. This is used in LSTFLD.

CALL REPLC(FET, INFØ, 350, FLDNØ, O, 1LC, BØMB)

This will replace record number FLDNØ (which is 350 characters

long) with the data currently in INFØ. 1LC means to replace the

current record. It is basically a combination of DLTE and a PUT.

This is used in subroutines GTDATA and EDIT.

CALL CLØSEM(FET)

This will close, or deactivate, the file associated with FET. Part

of the information in the array FET is the name of the file; it was put

in by FILE IS. This is used in GTDATA, ADDFLD, DLTFLD,

LSTFLD, and EDIT.

There are five files used with the irrigation scheduling program:

FILE	FUNCTION	PRU's	WORD SIZE	CHARACTER SIZE
1. IRRIGT	Procedure file for invoking program	1	64	640
2. IRR	Fortran source Code of program	92	5888	58880
3. IRRLGØ	Compiled object code of program	89	5696	56960
4. FIELDS	Indexed-sequential field information file	--	--	--
5. BACKUP	An extra copy of file "FIELDS"	--	--	--

The file "FIELDS" does not have a size specified because the

file size increases as fields are added. However, it does not decrease

in size as fields are deleted. This is inefficient but there is nothing to

be done about it. The general rule is: every field will add about 600

characters to the file's size, usually but not always resulting in
PRU size of the file being incremented.

The files "FIELDS" and "BACKUP" are direct access files
while the other three files are indirect access files. The advantage
of the direct access file as compared to the indirect access file for
the CSU computer system is that the direct access file has a capacity
of approximately 4 times that of the indirect access file (the capacity
is 400 to 500 plantings instead of 100 to 120). However, when using
direct access files, there is the danger that the file may be accident-
ally changed either through error by the computer operator or through
a system malfunction while the program is being used. Thus,
"BACKUP" is designed to be an extra copy of the file "FIELDS".
"BACKUP" should be updated at least weekly (preferably daily) by
using the following commands in the Batch subsystem via an interactive
terminal:

1. ATTACH, BACKUP/M=W

2. ATTACH, FIELDS

3. COPY, FIELDS, BACKUP

The file "IRR" includes not only the program but it is also a pro-
cedure file and therefore it includes the line whereby it is compiled.
The total number of lines in the file is 1151 and takes approximately
9.96 seconds to compile.

To put the program up on file from cards, two batch jobs must be run. The first deck requires the following setup:

Card 1. Job card number.

Card 2. USER, account number.

Card 3. CØPY, INPUT, IRRIGT.   } JCL

Card 4. REPLACE, IRRIGT.

Card 5. 7/8/9

Deck as described on page 196 of the program listing.

Card 6. 6/7/8/9

The second deck requires the following setup:

Card 1. Job card number.

Card 2. USER, account number.

Card 3. CØPY, INPUT, IRR.   } JCL

Card 4. REPLACE, IRR.

Card 5. 7/8/9

Deck as described on pages 196-220.

Card 6. 6/7/8/9

Once the batch jobs are run, then log on interactively to the same user number on which the batch jobs were run. If necessary, update the user number on file IRR using the text editor (performs data manipulation on a file).

Then use the commands: 1.   ØLD, IRR.

                         2.   SUBMIT, IRR.

This will cause the control cards in file IRR to compile the FORTRAN source program and save it on file IRRLG∅. The program is now ready to use (assuming you have given the computer a few minutes to do the actual compilation) by typing the command -IRRIGT. The file called FIELDS will be made by the program.

To use the irrigation scheduling program on a daily basis, an interactive, time sharing, terminal is required. The interactive terminal used may be either a soft (cathode ray tube, CRT) or a hard copy type. The use of a CRT eliminates paper but requires the computer operator to write the scheduling decisions on some other form. The hard copy type of course requires extensive use of terminal paper, however, it eliminates the need for transferring information and the associated errors. It was found that using a CRT in conjunction with a hard copy terminal was the most satisfactory. This is accomplished by connecting a CRT to a hard copy terminal with an "on-off" switch in the line. This essentially makes the hard copy terminal a slave to the CRT. In practice, the questions necessary to create the report are answered on the CRT with the switch to the hard copy terminal "off". The switch is turned "on" when the actual report is ready to be printed. This system conserves paper and eliminates the need for transferring information, however, it obviously requires a greater investment in interactive terminals. The procedure for using the program is as

follows. The user responses are underlined. The terminal responses are in capitals.

1. Sign on the terminal with a valid user number and password.

2. RECOVER/SYSTEM: -IRRIGT

3. DO YOU WANT DIRECTIONS?

4. ?   If Y the directions are those found on pages 194 and 195, Appendix C.

5. DO YOU WANT TO DO FILE OPERATIONS?

6. ?   If Y go to step 7

     If N go to step 50

7. DO YOU WANT A LIST OF FIELDS?

8. ?   If Y go to step 9

     If N go to step 14

9. HOW MANY FIELDS?

10. ?   _____

11. BEGINNING WHERE?

12. ?   _____

13. Lists the fields indicated then returns to step 7

14. DO YOU WANT TO ADD OR EDIT A FIELD (YES OR NO)?

15. ?   If Y go to step 16

     If N go to step 36

16. IS THIS TO BE THE FIRST FIELD ON THE WHOLE FILE?

17. ?   If Y go to step 18

     If N go to step 18

18. WHAT NUMBER IS THIS FIELD?

19. ? _____

20. COMPANY NAME:

21. ? _____

22. GROWER NAME:

23. ? _____

24. FIELD DESCRIPTION:

25. ? _____

26. SOIL CLASSIFICATION (UP TO 5 CHARACTERS):

27. ? _____

28. PLANTING DATE (MMDDYY):

29. ? _____

30. SOIL COEFFICIENT (NUMERICAL: "1.00" FOR SANDY LOAM):

31. ? _____

32. BELLANI PLATE COEFFICIENT #1 AND #2:

33. ? _____   _____

34. DO YOU WANT TO ADD ANOTHER FIELD:

35. ?   If Y repeat steps 18-33

     If N go to step 36

36. DO YOU WANT TO DELETE A FIELD?

37. ?   If Y go to step 38

     If N go to step 42

38. WHICH FIELD DO YOU WANT TO DELETE?

39. ? _____

40. DO YOU WANT TO DELETE ANOTHER FIELD?

41. ?   If Y repeat steps 38-39

    If N go to step 42

42. DO YOU WANT TO DELETE THE LAST DAY'S DATA
    FROM A FIELD?

43. ?   If Y go to step 44

    If N go to step 48

44. WHAT IS THE FIELD NUMBER?

45. ? _____

46. THE LAST DAY'S DATA FOR FIELD #_____ HAS BEEN
    SUCCESSFULLY DELETED. DO YOU WANT TO DELETE
    THE LAST DAY'S DATA FROM ANOTHER FIELD?

47. ?   If Y go to step 44

    If N go to step 48

48. ARE YOU DONE WITH FILE OPERATIONS?

49. ?   If Y go to step 50

    If N go to step 7

50. DO YOU WANT TO DO CALCULATIONS ON PRE-
    DEFINED DATA?

51. ?   If Y go to step 52

    If N go to step 94

52. WHAT IS THE FIELD NUMBER?

53. ? _____

54. WHAT IS THE DATE FOR WHICH PROCESSING IS TO
    OCCUR (MMDDYY)?

55. ? _____

56. WAS THE FIELD IRRIGATED ON THE ABOVE DATE?

57. ? If Y go to step 64

    If N go to step 58

58. HOW MUCH DID IT RAIN ON THE ABOVE DATE?

59. ? _____

60. RAIN= _____ CORRECT?

61. ? If Y go to step 62, if the amount was greater than 0.10
    inches other wise to step 64
    If N go to step 58

62. WAS THERE APPRECIABLE RUNOFF?

63. ? If Y go to step 64

    If N go to step 64

64. DO YOU WANT TO SPECIFY NEW BELLANI PLATE
    COEFFICIENTS?

65. ? If Y go to step 66

    If N go to step 70

66. PLATE COEFFICIENT ONE:

67. ? _____

68. PLATE COEFFICIENT TWO:

69. ? _____

70. BELLANI PLATE #1 LOSS SINCE YESTERDAY?

71. ? _____

72. BELLANI PLATE #2 LOSS SINCE YESTERDAY:

73. ? _____

74. PLATE 1'S LOSS: _____ PLATE 2'S LOSS: _____
    IS THAT OKAY?

75. ? If Y go to step 76

    If N go to step 70

76. *****DATE OF REPORT***** as illustrated on page 75

77. DO YOU WANT TO WORK WITH ANOTHER FIELD?

78. ? If Y go to step 79

    If N go to step 94

79. WHAT IS THE FIELD NUMBER?

80. ? _____

81. WAS THE FIELD IRRIGATED ON THE ABOVE DATE?

82. ? If Y go to step 83

    If N go to step 85

83. DO YOU WANT TO SPECIFY NEW BELLANI PLATE
    COEFFICIENTS?

84. ? If Y go to step 89

    If N go to step 76

85. HOW MUCH DID IT RAIN ON THE ABOVE DATE?

86. ? _____

87. RAIN= _____ CORRECT?

88. ? If Y go to step 83

    If N go to step 85

89. PLATE COEFFICIENT ONE:

90. ? _____

91. PLATE COEFFICIENT TWO:

92. ? _____

93. Goes to step 76

94. ARE YOU THROUGH WITH THE PROGRAM?

95. ?   If Y go to step 96

   If N go to step 5

96. >>> PROGRAM END <<<

NOTES ABOUT INSTRUCTIONS:

1. FIRST FIELD ON THE WHOLE FILE? - This would only be true if the file is being created.

2. MMDDYY - The month, day, and year are represented by two digits each.

3. When doing several plantings for the same day with the same atmometer loss it is not necessary to repeat the information concerning the date and atmometer loss.

4. The information will be retained on a local file and will not be filed on permanent file unless PROGRAM END is executed.

5. You may wish to answer no at step 95 if you are scheduling a group of fields associated with a different climatic area with a different pair of Bellani atmometers.

Large Scale Computer Algorithms

Constants which were stored as parameters are:

1. The ml necessary for irrigation for each of the 4 growth periods:

IA,	0-10 days,	229 ml
IB,	11-30 days,	488 ml
II,	31-50 days,	278 ml
III,	51-harvest,	227 ml

2. The amount of rainfall which is considered a significant recharge if there is minimal runoff:

IA & B,	0-30 days	0.25 inches
II,	31-50 days	0.35 inches
III,	51-harvest	0.50 inches

Precipitation intensities greater than the infiltration capacity of the soil cause runoff therefore, the amount even though falling into one of the categories above cannot be counted as a recharge. It was assumed rainfall in quantities of less than 0.10 inches would not create runoff.

3. The two soil constants as empirically derived are:

Sandy loam	1.00
Clay	0.72

Large Scale Computer Program Validation

An important part of writing a computer program is validation of the program. In an attempt to validate the large scale computer program, information for 400 hypothetical fields was entered into the program. A random sample of 20 fields was chosen for simulation of irrigation scheduling. Due to sample duplication, only 14 fields were scheduled for a period of 30 days. These 14 fields included 3 planting dates and 4 soil classifications. The planting dates were June 21, 22, and 23, 1978. The soil classifications and respective soil coefficients included: clay, 0.72; clay loam, 0.80; sandy loam, 1.00; and loamy sand, 1.10. The soil coefficients for the clay and sandy loam are those which were developed empirically from the field experiments. The soil coefficients for the clay loam and loamy sand are hypothetical. The information stored on field files for each of the 4 fields, one of each soil classification, is found on page 190. Also found on pages 190-193 are sample outputs for each of the 4 fields. The file information is presented first. The reports begin on June 30, a common day of recharge for each of the fields. The output is shown daily through July 10. The June 30 to July 10 time period is one of transition from period IA to period IB. By comparing from left to right for each of the daily outputs, the effects of soil coefficients may be seen.

July 1 for all fields indicates "No curve fits available ... ".
This occurs because it is not mathematically possible to fit polynomial
regressions with only one data pair. Also it would be illogical to sched-
ule irrigation based on this small amount of data. Note the range of
35 to 53 for the ml accumulated for the 4 fields.

July 2 for all fields gives a predicted irrigation time only for
the linear regression. With only 2 data pairs, it is not possible to fit
the quadratic and cubic regressions due to the lack of sufficient data
pairs. Note the predicted irrigation date for each of the fields is
different due to the soil moisture release properties of each of the 4
fields.

July 3 gives a predicted irrigation date for the linear regression
for each of the 4 fields. However, the quadratic regression indicates
the predicted irrigation date to be more than 40 days away. This option
was built into the program for the cases when the regression line is
asymptotic to the EPA constant line. This behavior occurred because
the atmometer water loss on July 2 was zero. This can be determined
by comparing the ml (loss) accumulated by July 3 with those for the
previous day. A predicted irrigation date for the cubic regression is
not given because of the lack of sufficient data pairs.

July 4 gives a predicted irrigation date only for the linear regres-
sion. Both the quadratic and cubic regressions give the message for the
case of asymptotic lines. Again the evaporation loss was minimal. Note

the coefficient of determination (R^2) decreased from the previous day's output.

July 5 for the 2 clay type soils (#133, #231) indicates the case of asymptotic lines for all 3 regressions. For the sandy loam (#244) and the loamy sand (#387) soils, the linear regression gives a predicted irrigation date while, the case of asymptotic lines is seen for the quadratic and cubic regressions.

July 6 gives a predicted irrigation date for each of the 3 polynomial regressions for each of the 4 fields. Note the range of predicted irrigation dates within a field and between fields.

July 7 and July 8 show similar patterns of output as that of July 6. Note that on July 8 for the loamy sand for the cubic regression that irrigation should take place on July 8. The program was designed to predict irrigation dates until the ml accumulated is equal to or greater than the ml necessary.

July 9 gives predicted irrigation dates for each of the 3 polynomial regressions for each of the first 3 fields. The loamy sand report says "IRRIGATE TODAY!" as would be expected.

July 10 report shows the clay soil fields (#133, #231) to have predicted irrigation dates for each of the 3 polynomial regressions. The sandy loam (#244) report says "IRRIGATE TODAY!" while, the loamy sand (#387) indicates irrigation is 1 day overdue. Once the message becomes irrigation overdue, the days are simply incremented.

By comparing the 4 fields, each representing a different soil classification, for the days shown, it can be seen that the program appears to be doing what it was designed to do.

CLAY Field #133

FIELD NO. 133   COMPANY: CHERYL   GROWER: CHRIS
FIELD DESCRIPTION: KAN 3   SOIL CLASSIFICATION: C
DATE OF PLANTING: JUN 21, 1978
DATE OF LAST REPORT: JUL 10, 1978   SOIL COEFFICIENT: .72
BELLANI PLATE COEFFICIENTS #1 AND #2:   .95, .97

***** DATE OF REPORT: FRIDAY, JUN 30, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUN 29, 1978
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
NO RAIN, BUT RECHARGE OCCURRED THROUGH IRRIGATION.

***** DATE OF REPORT: SATURDAY, JUL 1, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUN 30, 1978
ML ACCUMULATED: 35; ML NECESSARY FOR IRRIGATION: 229
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
NO CURVE FITS AVAILABLE--ONLY ONE DAY'S DATA ENTERED SINCE LAST RECHARGE.

***** DATE OF REPORT: SUNDAY, JUL 2, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL 1, 1978
ML ACCUMULATED: 76; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: 1.000   WEDNESDAY, JUL 12, 1978
NOT ENOUGH POINTS FOR PARABOLIC OR CUBIC CURVE FITS.

***** DATE OF REPORT: MONDAY, JUL 3, 1978 *****
***** DATE OF LAST REPORT: SUNDAY, JUL 2, 1978
ML ACCUMULATED: 76; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .750   SUNDAY, JUL 23, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
NOT ENOUGH POINTS FOR CUBIC CURVE FIT.

***** DATE OF REPORT: TUESDAY, JUL 4, 1978 *****
***** DATE OF LAST REPORT: MONDAY, JUL 3, 1978
ML ACCUMULATED: 76; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .600   SUNDAY, AUG 6, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.

CLAY LOAM Field #231

FIELD NO. 231   COMPANY: E   GROWER: F
FIELD DESCRIPTION: G 5   SOIL CLASSIFICATION: CL
DATE OF PLANTING: JUN 23, 1978
DATE OF LAST REPORT: JUL 10, 1978   SOIL COEFFICIENT: .89
BELLANI PLATE COEFFICIENTS #1 AND #2:   .95, .97

***** DATE OF REPORT: FRIDAY, JUN 30, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUN 29, 1978
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
NO RAIN, BUT RECHARGE OCCURRED THROUGH IRRIGATION.

***** DATE OF REPORT: SATURDAY, JUL 1, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUN 30, 1978
ML ACCUMULATED: 38; ML NECESSARY FOR IRRIGATION: 229
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
NO CURVE FITS AVAILABLE--ONLY ONE DAY'S DATA ENTERED SINCE LAST RECHARGE.

***** DATE OF REPORT: SUNDAY, JUL 2, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL 1, 1978
ML ACCUMULATED: 84; ML NECESSARY FOR IRRIGATION: 229
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: 1.000   WEDNESDAY, JUL 5, 1978
NOT ENOUGH POINTS FOR PARABOLIC OR CUBIC CURVE FITS.

***** DATE OF REPORT: MONDAY, JUL 3, 1978 *****
***** DATE OF LAST REPORT: SUNDAY, JUL 2, 1978
ML ACCUMULATED: 84; ML NECESSARY FOR IRRIGATION: 229
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .750   SUNDAY, JUL 9, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
NOT ENOUGH POINTS FOR CUBIC CURVE FIT.

***** DATE OF REPORT: TUESDAY, JUL 4, 1978 *****
***** DATE OF LAST REPORT: MONDAY, JUL 3, 1978
ML ACCUMULATED: 84; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .600   WEDNESDAY, AUG 2, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.

SANDY LOAM Field #244

FIELD NO. 244   COMPANY: MIKE   GROWER: LEWIS
FIELD DESCRIPTION: COLO 6   SOIL CLASSIFICATION: SL
DATE OF PLANTING: JUN 21, 1978
DATE OF LAST REPORT: JUL 10, 1978   SOIL COEFFICIENT: 1.00
BELLANI PLATE COEFFICIENTS #1 AND #2:   .95, .97

***** DATE OF REPORT: FRIDAY, JUN 30, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUN 29, 1978
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
NO RAIN, BUT RECHARGE OCCURRED THROUGH IRRIGATION.

***** DATE OF REPORT: SATURDAY, JUL 1, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUN 30, 1978
ML ACCUMULATED: 48; ML NECESSARY FOR IRRIGATION: 229
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
NO CURVE FITS AVAILABLE--ONLY ONE DAY'S DATA ENTERED SINCE LAST RECHARGE.

***** DATE OF REPORT: SUNDAY, JUL 2, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL 1, 1978
ML ACCUMULATED: 106; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: 1.000   SUNDAY, JUL 9, 1978
NOT ENOUGH POINTS FOR PARABOLIC OR CUBIC CURVE FITS.

***** DATE OF REPORT: MONDAY, JUL 3, 1978 *****
***** DATE OF LAST REPORT: SUNDAY, JUL 2, 1978
ML ACCUMULATED: 106; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .750   SUNDAY, JUL 16, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
NOT ENOUGH POINTS FOR CUBIC CURVE FIT.

***** DATE OF REPORT: TUESDAY, JUL 4, 1978 *****
***** DATE OF LAST REPORT: MONDAY, JUL 3, 1978
ML ACCUMULATED: 106; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .600   TUESDAY, JUL 25, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.

LOAMY SAND Field #387

FIELD NO. 387   COMPANY: SHIRLEY   GROWER: TWILA
FIELD DESCRIPTION: U 9   SOIL CLASSIFICATION: LS
DATE OF PLANTING: JUN 22, 1978
DATE OF LAST REPORT: JUL 10, 1978   SOIL COEFFICIENT: 1.10
BELLANI PLATE COEFFICIENTS #1 AND #2:   .95, .97

***** DATE OF REPORT: FRIDAY, JUN 30, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUN 29, 1978
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
NO RAIN, BUT RECHARGE OCCURRED THROUGH IRRIGATION.

***** DATE OF REPORT: SATURDAY, JUL 1, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUN 30, 1978
ML ACCUMULATED: 53; ML NECESSARY FOR IRRIGATION: 229
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
NO CURVE FITS AVAILABLE--ONLY ONE DAY'S DATA ENTERED SINCE LAST RECHARGE.

***** DATE OF REPORT: SUNDAY, JUL 2, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL 1, 1978
ML ACCUMULATED: 116; ML NECESSARY FOR IRRIGATION: 229
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: 1.000   TUESDAY, JUL 4, 1978
NOT ENOUGH POINTS FOR PARABOLIC OR CUBIC CURVE FITS.

***** DATE OF REPORT: MONDAY, JUL 3, 1978 *****
***** DATE OF LAST REPORT: SUNDAY, JUL 2, 1978
ML ACCUMULATED: 116; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .750   FRIDAY, JUL 14, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
NOT ENOUGH POINTS FOR CUBIC CURVE FIT.

***** DATE OF REPORT: TUESDAY, JUL 4, 1978 *****
***** DATE OF LAST REPORT: MONDAY, JUL 3, 1978
ML ACCUMULATED: 116; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .600   SUNDAY, JUL 23, 1978
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.

CLAY Field #133

CLAY LOAM Field #231

***** DATE OF REPORT: WEDNESDAY, JUL 5, 1978 *****
***** DATE OF LAST REPORT: TUESDAY, JUL 4, 1978
ML ACCUMULATED: 76; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.

***** DATE OF REPORT: THURSDAY, JUL 6, 1978 *****
***** DATE OF LAST REPORT: WEDNESDAY, JUL 5, 1978
ML ACCUMULATED: 124; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .711   SATURDAY, AUG 5, 1978
     QUAD: .715   FRIDAY, JUL 21, 1978
     CUB: .819   THURSDAY, JUL 13, 1978

***** DATE OF REPORT: FRIDAY, JUL 7, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUL 6, 1978
ML ACCUMULATED: 207; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .726   SATURDAY, JUL 22, 1978
     QUAD: .857   TUESDAY, JUL 11, 1978
     CUB: .939   MONDAY, JUL 10, 1978

***** DATE OF REPORT: SATURDAY, JUL 8, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUL 7, 1978
ML ACCUMULATED: 276; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .785   MONDAY, JUL 17, 1978
     QUAD: .939   MONDAY, JUL 10, 1978
     CUB: .976   MONDAY, JUL 10, 1978

***** DATE OF REPORT: SUNDAY, JUL 9, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL 8, 1978
ML ACCUMULATED: 338; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY NAME: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .836   SATURDAY, JUL 15, 1978
     QUAD: .967   TUESDAY, JUL 11, 1978
     CUB: .979   MONDAY, JUL 10, 1978

***** DATE OF REPORT: MONDAY, JUL 10, 1978 *****
***** DATE OF LAST REPORT: SUNDAY, JUL 9, 1978
ML ACCUMULATED: 366; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER133
COMPANY N. 'E: CHERYL
GROWER: CHRIS
FIELD DESCRIPTION: KAN 3
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .880   FRIDAY, JUL 14, 1978
     QUAD: .966   TUESDAY, JUL 11, 1978
     CUB: .961   TUESDAY, JUL 11, 1978

***** DATE OF REPORT: WEDNESDAY, JUL 5, 1978 *****
***** DATE OF LAST REPORT: TUESDAY, JUL 4, 1978
ML ACCUMULATED: 84; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     QUAD: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB: PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.

***** DATE OF REPORT: THURSDAY, JUL 6, 1978 *****
***** DATE OF LAST REPORT: WEDNESDAY, JUL 5, 1978
ML ACCUMULATED: 138; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .711   TUESDAY, AUG 1, 1978
     QUAD: .715   WEDNESDAY, JUL 19, 1978
     CUB: .816   WEDNESDAY, JUL 12, 1978

***** DATE OF REPORT: FRIDAY, JUL 7, 1978 *****
***** DATE OF LAST REPORT: THURSDAY, JUL 6, 1978
ML ACCUMULATED: 230; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .728   THURSDAY, JUL 20, 1978
     QUAD: .857   MONDAY, JUL 10, 1978
     CUB: .938   MONDAY, JUL 10, 1978

***** DATE OF REPORT: SATURDAY, JUL 8, 1978 *****
***** DATE OF LAST REPORT: FRIDAY, JUL 7, 1978
ML ACCUMULATED: 307; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .786   SATURDAY, JUL 15, 1978
     QUAD: .939   MONDAY, JUL 10, 1978
     CUB: .976   MONDAY, JUL 10, 1978

***** DATE OF REPORT: SUNDAY, JUL 9, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL 8, 1978
ML ACCUMULATED: 376; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .837   THURSDAY, JUL 13, 1978
     QUAD: .967   MONDAY, JUL 10, 1978
     CUB: .979   MONDAY, JUL 10, 1978

***** DATE OF REPORT: MONDAY, JUL 10, 1978 *****
***** DATE OF LAST REPORT: SUNDAY, JUL 9, 1978
ML ACCUMULATED: 407; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER231
COMPANY NAME: E
GROWER: F
FIELD DESCRIPTION: G 5
LAST RECHARGE: FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN: .881   THURSDAY, JUL 13, 1978
     QUAD: .966   TUESDAY, JUL 11, 1978
     CUB: .961   TUESDAY, JUL 11, 1978

SANDY LOAM Field #244

```
***** DATE OF REPORT: WEDNESDAY, JUL 5, 1978 *****
***** DATE OF LAST REPORT:  TUESDAY, JUL 4, 1978
ML ACCUMULATED: 106; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE:   FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .500      SUNDAY, AUG  6, 1978
     QUAD:   PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB:    PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.


***** DATE OF REPORT:  THURSDAY, JUL 6, 1978 *****
***** DATE OF LAST REPORT: WEDNESDAY, JUL 5, 1978
ML ACCUMULATED: 173; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE:    FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .712      TUESDAY, JUL 25, 1978
     QUAD:   .715      MONDAY, JUL 17, 1978
     CUB:    .816      TUESDAY, JUL 11, 1978


***** DATE OF REPORT:   FRIDAY, JUL 7, 1978 *****
***** DATE OF LAST REPORT:  THURSDAY, JUL 6, 1978
ML ACCUMULATED: 288; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE:    FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .728      SUNDAY, JUL 16, 1978
     QUAD:   .856      SUNDAY, JUL  9, 1978
     CUB:    .937      SUNDAY, JUL  9, 1978


***** DATE OF REPORT: SATURDAY, JUL  8, 1978 *****
***** DATE OF LAST REPORT:   FRIDAY, JUL 7, 1978
ML ACCUMULATED: 384; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE:    FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .786      WEDNESDAY, JUL 12, 1978
     QUAD:   .938      SUNDAY, JUL  9, 1978
     CUB:    .976      SUNDAY, JUL  9, 1978


***** DATE OF REPORT:  SUNDAY, JUL  9, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL  8, 1978
ML ACCUMULATED: 470; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE:    FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .837      TUESDAY, JUL 11, 1978
     QUAD:   .967      SUNDAY, JUL  9, 1978
     CUB:    .979      SUNDAY, JUL  9, 1978


***** DATE OF REPORT:   MONDAY, JUL 10, 1978 *****
***** DATE OF LAST REPORT:    SUNDAY, JUL  9, 1978
ML ACCUMULATED: 508; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER244
COMPANY NAME: MIKE
GROWER: LEWIS
FIELD DESCRIPTION: COLO 6
LAST RECHARGE:    FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
IRRIGATE TODAY!
```

LOAMY SAND Field #387

```
***** DATE OF REPORT: WEDNESDAY, JUL 5, 1978 *****
***** DATE OF LAST REPORT:  TUESDAY, JUL 4, 1978
ML ACCUMULATED: 116; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE:   FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .500      THURSDAY, AUG  3, 1978
     QUAD:   PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.
     CUB:    PREDICTED IRRIGATION DATE MORE THAN 40 DAYS AWAY.


***** DATE OF REPORT:  THURSDAY, JUL 6, 1978 *****
***** DATE OF LAST REPORT: WEDNESDAY, JUL 5, 1978
ML ACCUMULATED: 190; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE:   FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .711      SATURDAY, JUL 22, 1978
     QUAD:   .715      SATURDAY, JUL 15, 1978
     CUB:    .817      TUESDAY, JUL 11, 1978


***** DATE OF REPORT:   FRIDAY, JUL 7, 1978 *****
***** DATE OF LAST REPORT:  THURSDAY, JUL 6, 1978
ML ACCUMULATED: 317; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE:   FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .727      FRIDAY, JUL 14, 1978
     QUAD:   .857      SUNDAY, JUL  9, 1978
     CUB:    .938      SATURDAY, JUL  8, 1978


***** DATE OF REPORT: SATURDAY, JUL  8, 1978 *****
***** DATE OF LAST REPORT:   FRIDAY, JUL  7, 1978
ML ACCUMULATED: 423; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE:   FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
     LIN:    .785      TUESDAY, JUL 11, 1978
     QUAD:   .939      SUNDAY, JUL  9, 1978
     CUB:    .976      SATURDAY, JUL  8, 1978


***** DATE OF REPORT:  SUNDAY, JUL  9, 1978 *****
***** DATE OF LAST REPORT: SATURDAY, JUL  8, 1978
ML ACCUMULATED: 518; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE:   FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
IRRIGATE TODAY!


***** DATE OF REPORT:   MONDAY, JUL 10, 1978 *****
***** DATE OF LAST REPORT:   SUNDAY, JUL  9, 1978
ML ACCUMULATED: 560; ML NECESSARY FOR IRRIGATION: 488
FIELD NUMBER387
COMPANY NAME: SHIRLEY
GROWER: TWILA
FIELD DESCRIPTION: U 9
LAST RECHARGE:   FRIDAY, JUN 30, 1978
RAIN: 0.00 INCHES--NO RECHARGE.
*** IRRIGATION  1 DAYS OVERDUE.
```

Large Scale Computer Program - Directions obtained
when option for directions is chosen

THIS IS AN ICEBERG LETTUCE IRRIGATION PREDICTION PROGRAM.
THERE ARE TWO MODES IN WHICH THE PROGRAM OPERATES: FILE OP-
ERATIONS MODE AND PREDEFINED DATA MODE.
  FILE OPERATIONS MODE: IN THIS MODE, YOU ARE WORKING DI-
RECTLY WITH THE INDEXED-SEQUENTIAL FILE, DOING ONE OF THE
FOLLOWING:

1. LIST ALL THE FIELDS ON FILE. THIS WILL PRINT A LIST-
   ING OF ALL THE FIELDS ON THE FILE, WITH THE ASSOCIATED
   DATA, IN ORDER OF THE FIELD NUMBER.
2. ADDING A FIELD TO OR EDITING A FIELD ON THE IS FILE.
   THE PROGRAM WILL ASK YOU WHETHER OR NOT THIS FIELD IS
   TO BE THE FIRST ONE ON THE FILE; YOU ANSWER YES OR NO.
   NOTE: AN EMPTY FILE IS NOT THE SAME THING AS A NON-
   EXISTENT FILE--I.E. IF YOU'VE HAD FIELDS ON THE FILE
   BUT HAVE DELETED THEM ALL, YOU HAVE AN EMPTY FILE, BUT
   THE FILE DIRECTORY STILL EXISTS. THEREFORE, CONSIDER
   IT TO HAVE HAD FIELDS BEFORE--THE FIELD YOU ARE ABOUT
   TO PUT ON FILE IS NOT THE FIRST. IF, HOWEVER, YOU ARE
   RUNNING THIS PROGRAM FOR THE FIRST TIME EVER, OR THE
   FIRST TIME THIS "SEASON", OR YOU HAVE ACTUALLY PURGED
   THE "FIELDS" FILE, OR FOR ANY OTHER REASON THE FILE DOES
   NOT EXIST, THEN YOU WOULD ANSWER "YES" TO THE QUES-
   TION--THIS IS THE FIRST FIELD (BOTH LETTUCE FIELD AND
   COMPUTER FILE FIELD) ON THE FILE. THE COMPUTER WILL
   THEN SET UP THE FILE DIRECTORY AND OTHER BOOKKEEPING
   SUNDRIES.
     NOW THE PROGRAM WILL ASK YOU FOR A FIELD NUMBER.
   THIS NUMBER WILL BE NEEDED EVERY TIME YOU ACCESS THE
   FIELD. OTHER THINGS, TOO, WILL BE ASKED FOR, SUCH AS
   COMPANY, GROWER, AND FIELD DESCRIPTION (EACH OF WHICH
   HAS A MAXIMUM OF TWENTY CHARACTERS), SOIL COEFFICIENT,
   ETC.
     IF YOU INPUT A FIELD NUMBER THAT ALREADY EXISTS, THE
   PROGRAM WILL ASK YOU IF YOU WANT TO REDEFINE THE FIELD
   (AS OPPOSED TO A TYPO). ANSWER ACCORDINGLY.

3. DELETING A FIELD FROM THE FILE. THIS IS QUITE STRAIGHT-
   FORWARD; IT WILL ASK FOR A FIELD NUMBER, YOU ANSWER
   ACCORDINGLY, AND THAT FIELD IS DELETED FROM THE FILE.
   THERE IS NO WAY TO RECOVER DELETED DATA.
   ENTERING A FIELD NUMBER OF 0 WILL GET YOU OUT OF THE
   ROUTINE.
4. DELETE THE LAST DAY'S DATA FROM A PARTICULAR FIELD ON
   THE FILE. IF DATA WAS ENTERED ONTO A FIELD'S STORAGE
   MISTAKENLY, IT IS POSSIBLE TO DELETE ONLY THE ERRANT
   DATA. ANSWER THE APPROPRIATE QUESTION "YES", THEN SPEC-
   IFY THE FIELD NUMBER FROM WHICH YOU WANT TO DELETE THE
   LAST DAY ENTERED'S DATA, AND IT WILL BE DONE. IF YOU
   WANT TO DELETE SEVERAL DAYS' DATA FROM A FIELD, JUST
   INVOKE THE ROUTINE SEVERAL TIMES, SPECIFYING THE SAME
   FIELD.
   NOTHING WILL HAPPEN IF YOU TRY TO DELETE MORE DATA THAN
   EXISTS FROM THE FILE, AND IF YOU DELETE N DAYS' WORTH
   OF DATA, THE "DATE OF LAST REPORT" MAY BE OFF BY N DAYS.

   PREDEFINED DATA MODE: THIS IS THE MODE FOR WHICH THE PRO-
GRAM WAS ACTUALLY MADE. YOU WORK WITH A MIXTURE OF DATA;
SOME FROM THE FIELDS FILE--BELLANI PLATE COEFFICIENTS, SOIL
COEFFICIENT, DATE OF LAST IRRIGATION, ETC.--AND SOME FROM THE
KEYBOARD; ENTERED DAILY BY THE OPERATOR--AMOUNT OF RAIN, DATE,
PLATE LOSS, ETC.
   THE PROGRAM WILL ASK FOR A FIELD NUMBER, WHICH YOU SUPPLY.
THIS IS TO GET THE CORRECT FILE DATA WITH WHICH TO DO CAL-
CULATIONS. IT WILL LET YOU KNOW IF YOU SPECIFY A NONEXISTENT
FIELD NUMBER. AFTER OBTAINING SOME OF THE NECESSARY DATA
FROM THE FILE, YOU WILL BE ASKED SEVERAL QUESTIONS. UPON
YOUR COMPLETION OF THE QUESTION-ANSWERING, A REPORT
WILL BE PRINTED WITH THE IRRIGATION DATE PREDICTIONS.
   NOTE: ONCE A "TODAY'S DATE" IS SPECIFIED BY YOUR ANSWERING
OF THE ASSOCIATED QUESTION, IT REMAINS SPECIFIED UNTIL YOU
EXIT PREDEFINED DATA MODE. TO CHANGE THE "DATE FOR WHICH
PROCESSING IS TO OCCUR", YOU MUST EXIT AND REENTER PRE-
DEFINED DATA MODE.

Large Scale Computer Program - Listing

```
GET,IRRLGO.
SETJSL,100.
RETURN,ZZZZZEF,FIELDS.
ATTACH,FIELDS/M=W.
GOTO,1.
EXIT.
1,FILE,FIELDS,FO=IS,RT=F,FL=350,KT=I,KL=10,RB=1.
LDSET(FILES=FIELDS)
IRRLGO.
EXIT.
REWIND,ZZZZZEF.
COPY,ZZZZZEF,OUTPUT.
READY.
```

```
/JOB
TYDM,PR70,T20. DAVE ARNS
USER,GFFABM8,2264898.
ROUTE,OUTPUT,DC=LP,UN=AY,DEF.
FTN,OPT=2,R=3,EL=A,B=IRRLGO,P.
REPLACE,IRRLGO.
EXIT.
DAYFILE,DAY.
REPLACE,DAY.
/EOR
      PROGRAM IRRIGT(INPUT, OUTPUT, TAPE5=INPUT, TAPE6=OUTPUT)
C****************************************************************************
C                                                                          *
C  PROGRAM:  ICEBERG LETTUCE IRRIGATION PREDICTION, USING BELLANI          *
C     EVAPORATION PLATES AND CURVE-FITTING.                                *
C  AUTHOR:   DAVE ARNS, B.S. IN COMPUTER SCIENCE.                          *
C  DATE WRITTEN:  MAY AND JUNE, 1979.                                      *
C  INSTALLATION:  COLORADO STATE UNIVERSITY.                               *
C  COMPUTER:  CONTROL DATA CORPORATION'S CYBER 171, WITH THE NOS           *
C     VERSION 1 OPERATING SYSTEM.                                          *
C                                                                          *
```

```
C*********************************************************************
C                                                                   *
C                   CONCERNING ANSI STANDARD FORTRAN                 *
C                                                                   *
C     CONFORMITY TO ANSI STANDARDS EXISTS EXCEPT WHERE UTILITY OR SIM-*
C  PLICITY OF THE PROGRAM WOULD HAVE TO HAVE BEEN SACRIFICED.         *
C     THE NON-CONFORMITIES TO ANSI-STANDARD FORTRAN ARE:             *
C                                                                   *
C     1.  THE "PROGRAM" STATEMENT AT THE BEGINNING OF THE DECK;      *
C     2.  DATA STATEMENTS WHEN INITIALIZING ARRAYS;                  *
C     3.  THE "L" FORM (LEFT-JUSTIFIED, ZERO FILL) OF HOLLERITH CON- *
C         STANTS (NECESSARY FOR THE INDEXED-SEQUNTIAL ROUTINES) ;    *
C     4.  OCTAL CONSTANTS (A NUMBER SUFFIXED WITH A "B") FOR SENDING *
C         TERMINAL CONTROL CHARACTERS, I.E. SUBROUTINE "BEEP";       *
C     5.  LIST-DIRECTED (OR FREE-FORMAT) I/O STATEMENTS, SUCH AS     *
C         "READ(5, *)BEL1CO, BEL2CO";                                *
C     6.  HOLLERITH CONSTANTS IN "IF" STATEMENTS.                    *
C                                                                   *
C*********************************************************************
C                                                                   *
C                        VARIABLES OF INTEREST                       *
C                                                                   *
C  BEHIND:  THE NUMBER OF DAYS BEHIND IN IRRIGATING A PARTICULAR PERSON *
C           IS.  THIS IS LEFT ALONE UNTIL THE ML LOST IS GREATER THAN OR *
C           EQUAL TO THE NUMBER OF ML NEEDED FOR IRRIGATION, THEN IT IN- *
C           CREMENTS EVERY TIME SUBROUTINE "GTDATA" IS ACCESSED WITH THAT *
C           PARTICULAR FIELD.                                        *
C  BEL1CO:  THE COEFFICIENT OF POROSITY FOR BELLANI PLATE NUMBER ONE. *
C  BELL1L:  THE NUMBER OF MILLILITERS OF WATER LOST FROM BELLANI     *
C           PLATE #1 IN THE LAST DAY.                                *
C  BEL2CO:  THE COEFFICIENT OF POROSITY FOR BELLANI PLATE NUMBER TWO. *
C  BELL2L:  THE NUMBER OF MILLILITERS OF WATER LOST FROM BELLANI PLATE *
C           #2 IN THE LAST DAY.                                      *
C  CMPANY:  THIS IS A TWO-WORD (TWENTY-CHARACTER MAX.) ALPHANUMERIC  *
C           COMPANY NAME.  USED ONLY FOR THE REPORT.                 *
C  CURVE:   AN ARRAY OF TWENTY INTEGERS REPRESENTING THE AMOUNTS     *
C           OF WATER LOST (AS FIGURED WITH THE BELLANI PLATES).      *
C           THESE VALUES ARE CURVE-FITTED AGAINST THEIR INDICES;     *
C           THAT IS, CURVE(1) IS PLOTTED AGAINST 1, CURVE(2) IS      *
C           PLOTTED AGAINST 2, ETC.  SEE ALSO NCURVE.                *
C  DATE:    THIS IS THE DATE ON WHICH THE PROGRAM IS RUN.  IT IS IN THE *
C           FORMAT MMDDYY AND IT IS AN INTEGER.                      *
C  DAYPLT:  THE NUMBER OF DAYS SINCE PLANTING.                       *
C  DUMMY:   THIS IS MERELY A DUMMY VARIABLE THAT IS USED FOR THE     *
C           LOGICAL FUNCTIONS "RESPNS" AND "ENDFYL", BECAUSE IN FORTRAN, *
C           A FUNCTION MUST HAVE AT LEAST ONE INCOMING ARGUMENT.     *
C  FLDESC:  JUST LIKE "CMPANY" (Q.V.), EXCEPT THIS IS A FIELD        *
C           DESCRIPTION.                                             *
C  FLDNO:   THE NUMBER OF THE FIELD SPECIFIED; ALSO THIS IS THE      *
C           INDEXED-SEQUENTIAL RECORD KEY.                           *
```

```
C  FET:     THIS IS AN ARRAY THAT IS NECESSARY FOR THE INDEXED-SEQUENTIAL *
C           SUBROUTINES TO COMMUNICATE WITH ONE ANOTHER.  THIS "FILE       *
C           ENVIRONMENT TABLE" IS NOT USED BY ANY OF THE ROUTINES IN       *
C           THIS DECK, EXCEPT FOR BEING IN "COMMON" STATEMENTS--AGAIN      *
C           FOR COMMUNICATION.                                             *
C  GROWER:  JUST LIKE "CMPANY" (Q.V.), EXCEPT THIS IS THE GROWER'S         *
C           NAME.                                                          *
C  IRRLVL:  THIS IS A LOGICAL VARIABLE THAT IS TRUE IFF (IF AND ONLY       *
C           IF) THE IRRIGATION LEVEL (OF EVAPORATION) HAS BEEN             *
C           REACHED; I.E. "LOSTML" .GE. "NEEDED".                          *
C  LSTIRR:  A INTEGER REPRESENTING THE DATE OF THE LAST IRRIGATION         *
C           (MMDDYY).                                                      *
C  LSTRPT:  AN INTEGER REPRESENTING THE DATE (IN THE FORM MMDDYY) OF       *
C           THE LAST REPORT GENERATED FOR THAT FIELD.                      *
C  NCURVE:  THE NUMBER OF ELEMENTS IN "CURVE" THAT ARE DEFINED AT THE      *
C           PRESENT TIME; THE NUMBER OF POINTS CONSIDERED IN THE CURVE     *
C           FITS.                                                          *
C  NEEDED:  THE NUMBER OF MILLILITERS OF WATER THAT ARE NEEDED TO          *
C           EVAPORATE FROM THE BELLANI PLATES BEFORE THE IDEAL IRRIGATION  *
C           DAY.                                                           *
C  PLNTDT:  THE DATE OF PLANTING OF THE CURRENT FIELD (MMDDYY) .           *
C  RAIN:    THIS IS A REAL NUMBER THAT REPRESENTS THE AMOUNT OF RAIN       *
C           IN INCHES THAT FELL ON THE DATE SPECIFIED BY "DATE".           *
C  RUNOFF:  THIS IS A LOGICAL VARIABLE THAT IS TRUE IF THERE WAS APPRE-    *
C           CIABLE RUNOFF DURING THE LAST BIT OF PRECIPITATION.            *
C  RECHRG:  THIS IS ANOTHER LOGICAL VARIABLE, THIS ONE DEFINED BY          *
C           THE PROGRAM AFTER FINDING OUT THE NUMBER OF DAYS SINCE         *
C           PLANTING, THE AMOUNT OF PRECIPITATION, AND WHETHER THERE WAS   *
C           APPRECIABLE RUNOFF.                                            *
C  SLCLAS:  A FIVE-CHARACTER MNEMONIC SOIL CLASSIFICATION.                 *
C  SOILCO:  A REAL NUMBER REPRESENTING THE SOIL COEFFICIENT.               *
C                                                                          *
C***************************************************************************
      COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
     +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
     +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
     +IRRLVL, BEHIND, SLCLAS, LSTRPT
      COMMON /INDSEQ/ FET(35), ERROR
      INTEGER FLDNO, DATE, CURVE, CMPANY, DAYPLT, FLDESC, GROWER
      INTEGER PLNTDT, BEHIND, LSTRPT, SLCLAS
      LOGICAL RUNOFF, RECHRG, RESPNS, IRRLVL, ERROR
      RECHRG=.FALSE.
      CALL FILEIS(FET, 3LLFN, 6LFIELDS)
      WRITE(6, 7)
    7 FORMAT(23HDO YOU WANT DIRECTIONS?)
      IF(RESPNS(DUMMY))CALL DIRECT
    5 WRITE(6, 1)
    1 FORMAT(34HDO YOU WANT TO DO FILE OPERATIONS?)
      IF(RESPNS(DUMMY))CALL FIELD
      WRITE(6, 2)
```

```
    2 FORMAT(51HDO YOU WANT TO DO CALCULATIONS ON PRE-DEFINED DATA?)
      IF(RESPNS(DUMMY))CALL GTDATA
      WRITE(6, 4)
    4 FORMAT(33HARE YOU THROUGH WITH THE PROGRAM?)
      IF(.NOT.RESPNS(DUMMY))GOTO 5
      WRITE(6, 3)
    3 FORMAT(33H>>>>>>>>>> PROGRAM END <<<<<<<<<<)
      STOP
      END
      SUBROUTINE GTDATA
C**********************************************************************
C                                                                    *
C     THIS ROUTINE ASKS ALL THE QUESTIONS NEEDED FOR THE DAILY INTER- *
C  ACTION WITH THE OPERATOR.                                          *
C                                                                    *
C**********************************************************************
      COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
     +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
     +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
     +IRRLVL, BEHIND, SLCLAS, LSTRPT
      COMMON /INDSEQ/ FET(35), ERROR
      COMMON /INFORM/ INFO(35)
      INTEGER FLDNO, DATE, PLNTDT, DAYPLT, CMPANY, GROWER, SLCLAS
      INTEGER FLDESC, CURVE, BEHIND, LSTRPT
      LOGICAL RUNOFF, ERROR, RESPNS, RECHRG, IRRLVL, FIRST
      EXTERNAL BOMB
      FIRST=.TRUE.
   19 CALL OPENM(FET, 3LI-0)
      WRITE(6, 1)
    1 FORMAT(25HWHAT IS THE FIELD NUMBER?)
   15 CALL READNO(1HI, FLDNO)
      ERROR=.FALSE.
      CALL GET(FET, INFO, FLDNO, 0, 0, 0, BOMB)
      IF(.NOT. ERROR)GO TO 16
      WRITE(6, 14)FLDNO
   14 FORMAT(7HFIELD #,I3,39H IS UNDEFINED.  PLEASE SPECIFY ANOTHER:)
      GO TO 15
   16 CALL CLOSEM(FET)
      CALL TOVARS
      IF(.NOT.FIRST)GO TO 20
      WRITE(6, 2)
    2 FORMAT(59HWHAT IS THE DATE FOR WHICH PROCESSING IS TO OCCUR (MMDDY
     +Y)?)
   12 CALL READNO(1HI, DATE)
      IF(DATE.GT.10000.AND.DATE.LT.123199)GO TO 20
      WRITE(6, 26)
   26 FORMAT(34HDATE UNACCEPTABLE; PLEASE REENTER:)
      GO TO 12
   20 WRITE(6, 17)
   17 FORMAT(42HWAS THE FIELD IRRIGATED ON THE ABOVE DATE?)
      RECHRG=RESPNS(DUMMY)
      RAIN=0.
```

```
      IF(RECHRG)GO TO 5
   28 WRITE(6, 3)
    3 FORMAT(39HHOW MUCH DID IT RAIN ON THE ABOVE DATE?)
      CALL READNO(1HR, RAIN)
      WRITE(6, 27) RAIN
   27 FORMAT(6HRAIN =,F5.2,10H. CORRECT?)
      IF(.NOT.RESPNS(DUMMY))GO TO 28
      RUNOFF=.FALSE.
      IF(RAIN.LE.0.1)GO TO 5
      WRITE(6, 4)
    4 FORMAT(29HWAS THERE APPRECIABLE RUNOFF?)
      RUNOFF=RESPNS(DUMMY)
    5 WRITE(6, 6)
    6 FORMAT(54HDO YOU WANT TO SPECIFY NEW BELLANI PLATE COEFFICIENTS?)
      IF(.NOT.RESPNS(DUMMY))GO TO 7
      WRITE(6, 8)
    8 FORMAT(22HPLATE COEFFICIENT ONE:)
      CALL READNO(1HR, BEL1CO)
      WRITE(6, 13)
   13 FORMAT(22HPLATE COEFFICIENT TWO:)
      CALL READNO(1HR, BEL2CO)
    7 IF(.NOT.FIRST)GO TO 24
      WRITE(6, 9)
    9 FORMAT(38HBELLANI PLATE #1 LOSS SINCE YESTERDAY:)
      CALL READNO(1HR, BELL1L)
      WRITE(6, 11)
   11 FORMAT(38HBELLANI PLATE #2 LOSS SINCE YESTERDAY:)
      CALL READNO(1HR, BELL2L)
      WRITE(6, 25)BELL1L, BELL2L
   25 FORMAT(16HPLATE 1'S LOSS: ,F5.1,8X,16HPLATE 2'S LOSS: ,F5.1/
     +13HIS THAT OKAY?)
      IF(.NOT.RESPNS(DUMMY))GO TO 7
   24 CALL REPORT
      WRITE(6, 10)
   10 FORMAT(//)
      FIRST=.FALSE.
      IF(.NOT.RECHRG)GO TO 22
      BEHIND=-1
      NCURVE=0
      DO 23 I=1, 20
   23 CURVE(I)=0
      LSTIRR=DATE
      IRRLVL=.FALSE.
   22 CALL OPENM(FET, 3LI-0)
      CALL FRMVAR
      ERROR=.FALSE.
      CALL REPLC(FET, INFO, 350, FLDNO, 0, 1LC, BOMB)
      IF(ERROR)WRITE(6, 21)
   21 FORMAT(27H"REPLC" ERROR OF SOME KIND.)
      CALL CLOSEM(FET)
      WRITE(6, 18)
```

```
   18 FORMAT(39HDO YOU WANT TO WORK WITH ANOTHER FIELD?)
      IF(RESPNS(DUMMY))GO TO 19
      RETURN
      END
      SUBROUTINE REPORT
C*******************************************************************
C                                                                 *
C     THIS SUBROUTINE DOES SOME CALCULATIONS AND PRINTS A SMALL REPORT ON *
C THE FIELD CURRENTLY BEING WORKED ON.  MOST OF THE VARIABLES BEING    *
C WORKED ON IN THIS ROUTINE HAVE EITHER BEEN DEFINED IN "ADDFLD", WHEN *
C THE FIELD WAS BEING DEFINED, OR IN "GTDATA", FROM WHICH THIS WAS     *
C CALLED.                                                          *
C                                                                 *
C*******************************************************************
      COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
     +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
     +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
     +IRRLVL, BEHIND, SLCLAS, LSTRPT
      INTEGER DATE, DAYPLT, PLNTDT, CURVE, BEHIND, CMPANY, FLDNO
      INTEGER FLDESC, GROWER, WKDAY, DAY, YEAR, DAYOWK, LSTRPT, SLCLAS
      LOGICAL RUNOFF, RECHRG, IRRLVL
      DAYPLT=JULIAN(DATE)-JULIAN(PLNTDT)
      IDAY=MMDDYY(JULIAN(DATE), MONTH, DAY, YEAR)
      MONAM=MONAME(MONTH)
      WKDAY=DAYOWK(IDAY)
      WRITE(6, 20)WKDAY, MONAM, DAY, YEAR
   20 FORMAT(/21H***** DATE OF REPORT:,A10,2H, ,A3,I3,2H, ,I4,6H *****)
      IDAY=MMDDYY(JULIAN(LSTRPT), MONTH, DAY, YEAR)
      MONAM=MONAME(MONTH)
      WKDAY=DAYOWK(IDAY)
      WRITE(6, 27)WKDAY, MONAM, DAY, YEAR
   27 FORMAT(26H***** DATE OF LAST REPORT:,A10,2H, ,A3,I3,2H, ,I4)
      LSTRPT=DATE
      IF(DAYPLT.GE.0.AND.DAYPLT.LE.10)NEEDED=229
      IF(DAYPLT.GE.11.AND.DAYPLT.LE.30)NEEDED=488
      IF(DAYPLT.GE.31.AND.DAYPLT.LE.50)NEEDED=278
      IF(DAYPLT.GE.50)NEEDED=227
C...RECHRG MAY ALREADY BE TRUE FROM SUBROUTINE GTDATA.................
      IF(DAYPLT.GE.0.AND.DAYPLT.LE.30.AND.RAIN.GE..25.AND..NOT.RUNOFF)
     +   RECHRG=.TRUE.
      IF(DAYPLT.GE.31.AND.DAYPLT.LE.50.AND.RAIN.GE..35.AND..NOT.RUNOFF
     +)  RECHRG=.TRUE.
      IF(DAYPLT.GE.51.AND.RAIN.GE..5.AND..NOT.RUNOFF)RECHRG=.TRUE.
      IF(RECHRG)NEEDED=0
      LOSTML=IFIX(SOILCO*(BELL1L*BEL1CO+BELL2L*BEL2CO)/2.+.5)
      N=1
      IF(NCURVE.NE.0)N=NCURVE
      M=CURVE(N)+LOSTML
      IF(.NOT.RECHRG)WRITE(6, 26)M, NEEDED
   26 FORMAT(15HML ACCUMULATED:,I4,30H; ML NECESSARY FOR IRRIGATION:,I4)
      IF(NCURVE.GE.20)GO TO 18
```

```
      NCURVE=NCURVE+1
      IF(NCURVE.NE.1)GO TO 19
      CURVE(NCURVE)=LOSTML
      GO TO 18
   19 CURVE(NCURVE)=CURVE(NCURVE-1)+LOSTML
   18 IF(NEEDED-LOSTML-CURVE(N))14, 15, 16
   14 BEHIND=BEHIND+1
      IRRLVL=.TRUE.
      GO TO 17
   15 BEHIND=0
      IRRLVL=.TRUE.
      GO TO 17
   16 IRRLVL=.FALSE.
   17 WRITE(6, 1)FLDNO, (CMPANY(I), I=1, 2), (GROWER(I), I=1, 2),
     +(FLDESC(I), I=1, 2)
    1 FORMAT(12HFIELD NUMBER,I3/
     +14HCOMPANY NAME: ,2A10/
     +8HGROWER: ,2A10/
     +19HFIELD DESCRIPTION: ,2A10)
      IF(RECHRG)GO TO 4
      LSTIRR=MMDDYY(JULIAN(LSTIRR), MONTH, DAY, YEAR)
      MONAM=MONAME(MONTH)
      WKDAY=DAYOWK(LSTIRR)
      WRITE(6, 21)WKDAY, MONAM, DAY, YEAR
   21 FORMAT(14HLAST RECHARGE:,A10,2H, ,A3,I3,2H, ,I4)
      WRITE(6, 3)RAIN
    3 FORMAT(6HRAIN: ,F4.2,21H INCHES--NO RECHARGE.)
      GO TO 8
    4 IF(RAIN.EQ.0.)GO TO 6
      WRITE(6, 5)RAIN
    5 FORMAT(6HRAIN: ,F4.2,27H INCHES--RECHARGE OCCURRED.)
      GO TO 8
    6 WRITE(6, 7)
    7 FORMAT(50HNO RAIN, BUT RECHARGE OCCURRED THROUGH IRRIGATION.)
    8 IF(RECHRG)RETURN
      IF(IRRLVL)GO TO 10
      IF(NCURVE.GE.2)GO TO 13
      WRITE(6, 11)
   11 FORMAT(73HNO CURVE FITS AVAILABLE--ONLY ONE DAY'S DATA ENTERED SIN
     +CE LAST RECHARGE.)
      RETURN
   13 CALL SUMS
      CALL LINEAR(A, B, R2)
      CALL PRDICT(A, B, 0., 0., 4H LIN, R2)
      IF(NCURVE.GE.3)GO TO 25
      WRITE(6, 22)
   22 FORMAT(52HNOT ENOUGH POINTS FOR PARABOLIC OR CUBIC CURVE FITS.)
      RETURN
   25 CALL PARAB(A, B, C, R2)
      CALL PRDICT(A, B, C, 0., 4HQUAD, R2)
      IF(NCURVE.GE.4)GO TO 23
```

```
      WRITE(6, 24)
   24 FORMAT(38HNOT ENOUGH POINTS FOR CUBIC CURVE FIT.)
      RETURN
   23 CALL CUBIC(A, B, C, D, R2)
      CALL PRDICT(A, B, C, D, 4H CUB, R2)
      RETURN
   10 IF(BEHIND.EQ.0)GO TO 2
      WRITE(6, 12)BEHIND
   12 FORMAT(14H*** IRRIGATION,I3,14H DAYS OVERDUE.)
      RETURN
    2 WRITE(6, 9)
    9 FORMAT(15HIRRIGATE TODAY!)
      RETURN
      END
      SUBROUTINE FIELD
C*********************************************************************
C                                                                   *
C     THIS IS THE MASTER CONTROLLER FOR FILE OPERATIONS.  IT ASKS QUES- *
C TIONS AND DIRECTS THE EXECUTION TO THE APPROPRIATE PLACE.         *
C                                                                   *
C*********************************************************************
      LOGICAL RESPNS
    3 WRITE(6, 6)
    6 FORMAT(29HDO YOU WANT A LIST OF FIELDS?)
      IF(.NOT.RESPNS(DUMMY))GO TO 7
      CALL LSTFLD
      GO TO 3
    7 WRITE(6, 1)
    1 FORMAT(47HDO YOU WANT TO ADD OR EDIT A FIELD (YES OR NO)?)
      IF(RESPNS(DUMMY))CALL ADDFLD
      WRITE(6, 2)
    2 FORMAT(30HDO YOU WANT TO DELETE A FIELD?)
      IF(RESPNS(DUMMY))CALL DLTFLD
      WRITE(6, 5)
    5 FORMAT(55HDO YOU WANT TO DELETE THE LAST DAY'S DATA FROM A FIELD?)
      IF(RESPNS(DUMMY))CALL EDIT
      WRITE(6, 4)
    4 FORMAT(34HARE YOU DONE WITH FILE OPERATIONS?)
      IF(.NOT.RESPNS(DUMMY))GO TO 3
      RETURN
      END
      SUBROUTINE ADDFLD
C*********************************************************************
C                                                                   *
C     THIS ROUTINE ADDS NEW FIELDS TO THE FILE AND/OR EDITS EXISTING *
C ONES.  THE METHOD OF EDITING IS TO DELETE THE WHOLE RECORD, AND CREATE *
C IT AGAIN AFRESH.                                                  *
C                                                                   *
C*********************************************************************
      COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
     +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
```

```
     +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
    +IRRLVL, BEHIND, SLCLAS, LSTRPT
     COMMON /INDSEQ/ FET(35), ERROR
     COMMON /INFORM/ INFO(35)
     INTEGER FLDNO, DATE, CMPANY, FLDESC, GROWER, SLCLAS, PLNTDT
     INTEGER CURVE, DAYPLT, BEHIND, LSTRPT
     LOGICAL RESPNS, ERROR, YES, IRRLVL, RECHRG, RUNOFF, ENDFYL
     EXTERNAL BOMB
     WRITE(6, 17)
  17 FORMAT(48HIS THIS TO BE THE FIRST FIELD ON THE WHOLE FILE?)
     YES=RESPNS(DUMMY)
     IF(YES)CALL OPENM(FET, 3LNEW, 1LR)
     IF(.NOT.YES)CALL OPENM(FET, 3LI-O, 1LR)
  11 WRITE(6, 1)
   1 FORMAT(26HWHAT NUMBER IS THIS FIELD?)
     CALL READNO(1HI, FLDNO)
     ERROR=.FALSE.
     CALL GET(FET, INFO, FLDNO, 0, 0, 0, BOMB)
     IF(ERROR)GO TO 12
     WRITE(6, 16)
  16 FORMAT(64HTHAT FIELD HAS ALREADY BEEN DEFINED; DO YOU WANT TO REDE
    +FINE IT?)
     IF(.NOT.RESPNS(DUMMY))GO TO 11
     CALL DLTE(FET, FLDNO, 0, 0, BOMB)
  12 WRITE(6, 2)
   2 FORMAT(13HCOMPANY NAME:)
     READ(5, 3)(CMPANY(I), I=1, 2)
   3 FORMAT(2A10)
     IF(.NOT.ENDFYL(DUMMY))GO TO 20
     CALL BEEP
     WRITE(6, 22)
  22 FORMAT(51HPRAY ANSWER THE QUESTION ERE EVER YOU HIT 'RETURN'.)
     GO TO 12
  20 WRITE(6, 4)
   4 FORMAT(12HGROWER NAME:)
     READ(5, 3)(GROWER(I), I=1, 2)
     IF(.NOT.ENDFYL(DUMMY))GO TO 21
     CALL BEEP
     WRITE(6, 22)
     GO TO 20
  21 WRITE(6, 6)
   6 FORMAT(18HFIELD DESCRIPTION:)
     READ(5, 3)(FLDESC(I), I=1, 2)
     IF(.NOT.ENDFYL(DUMMY))GO TO 23
     CALL BEEP
     WRITE(6, 22)
     GO TO 21
  23 WRITE(6, 7)
   7 FORMAT(44HSOIL CLASSIFICATION (UP TO FIVE CHARACTERS):)
     CALL READNO(1HA, SLCLAS)
     WRITE(6, 8)
   8 FORMAT(24HPLANTING DATE  (MMDDYY):)
```

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```fortran
   26 CALL READNO(1HI, PLNTDT)
      IF(PLNTDT.GE.10000.AND.PLNTDT.LE.123199)GO TO 5
      WRITE(6, 19)
   19 FORMAT(38HDATE IS UNACCEPTABLE.  PLEASE REENTER:)
      GO TO 26
    5 LSTIRR=PLNTDT
      LSTRPT=PLNTDT
      WRITE(6, 9)
    9 FORMAT(53HSOIL COEFFICIENT  (NUMERICAL; "1.00" FOR SANDY LOAM):)
      CALL READNO(1HR, SOILCO)
   25 WRITE(6, 10)
   10 FORMAT(37HBELLANI PLATE COEFFICIENTS #1 AND #2:)
      READ(5, *)BEL1CO, BEL2CO
      IF(.NOT.ENDFYL(DUMMY))GO TO 24
      CALL BEEP
      WRITE(6, 22)
      GO TO 25
   24 BEHIND=-1
      DO 18 I=1, 20
   18 CURVE(I)=0
      NCURVE=0
      CALL FRMVAR
      ERROR=.FALSE.
      CALL PUT(FET, INFO, 350, FLDNO, 0, 0, BOMB)
      IF(.NOT.ERROR)GO TO 14
      WRITE(6, 13)
   13 FORMAT(25H"PUT" ERROR OF SOME KIND.)
   14 WRITE(6, 15)
   15 FORMAT(33HDO YOU WANT TO ADD ANOTHER FIELD?)
      IF(RESPNS(DUMMY))GO TO 11
      CALL CLOSEM(FET)
      RETURN
      END
      SUBROUTINE DLTFLD
C*****************************************************************************
C                                                                           *
C     THIS ROUTINE DELETES A FIELD FROM THE INDEXED-SEQUENTIAL FILE.        *
C                                                                           *
C*****************************************************************************
      COMMON /INDSEQ/ FET(35), ERROR
      INTEGER FLDNO
      LOGICAL ERROR, RESPNS
      EXTERNAL BOMB
      CALL OPENM(FET, 3LI-O, 1LR)
    4 WRITE(6, 1)
    1 FORMAT(34HWHICH FIELD DO YOU WANT TO DELETE?)
      CALL READNO(1HI, FLDNO)
      IF(FLDNO.EQ.0)GO TO 5
      ERROR=.FALSE.
      CALL DLTE(FET, FLDNO, 0, 0, BOMB)
      IF(ERROR)WRITE(6, 2)FLDNO
```

```
    2 FORMAT(7HFIELD #,I3,37H IS NOT ON FILE--DELETION IMPOSSIBLE.)
      WRITE(6, 3)
    3 FORMAT(36HDO YOU WANT TO DELETE ANOTHER FIELD?)
      IF(RESPNS(DUMMY))GO TO 4
    5 CALL CLOSEM(FET)
      FLDNO=0
      RETURN
      END
      SUBROUTINE LSTFLD
C***********************************************************************
C                                                                     *
C     THIS ROUTINE LISTS THE REQUESTED NUMBER OF FIELDS ON THE IS FILE *
C  IN ASCENDING ORDER BEGINNING WITH FLDBEG.                           *
C                                                                     *
C***********************************************************************
      COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
     +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
     +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
     +IRRLVL, BEHIND, SLCLAS, LSTRPT
      COMMON /INDSEQ/ FET(35), ERROR
      COMMON /INFORM/ INFO(35)
      EXTERNAL BOMB
      INTEGER FLDNO, DATE, PLNTDT, CMPANY, FLDESC, GROWER, DAYPLT
      INTEGER CURVE, BEHIND, SLCLAS, LSTRPT, DAY, YEAR, OLDFLD, LSTRPT
      INTEGER MONAM2, DAY2, YEAR2, FLDBEG, FLDQTY
      LOGICAL RUNOFF, RECHRG, IRRLVL, ERROR
      WRITE(6, 5)
    5 FORMAT(16HHOW MANY FIELDS?)
      READ(5, *) FLDQTY
      WRITE(6, 6)
    6 FORMAT(16HBEGINNING WHERE?)
      READ(5, *) FLDBEG
      CALL OPENM(FET, 3LI-O, 1LR)
      ERROR=.FALSE.
      OLDFLD=0
      IF(FLDBEG.EQ.1)GO TO 7
      FLDBEG=FLDBEG-1
      CALL GET(FET, INFO, FLDBEG, 0, 0, 0, BOMB)
      IF(ERROR)GO TO 3
    7 DO 1 I=1, FLDQTY
      CALL GETN(FET, INFO, FLDNO, BOMB)
      IF(ERROR.OR.OLDFLD.EQ.FLDNO)GO TO 3
      CALL TOVARS
      PLNTDT=MMDDYY(JULIAN(PLNTDT), MONTH, DAY, YEAR)
      MONAM=MONAME(MONTH)
      LSTRPT=MMDDYY(JULIAN(LSTRPT), MONTH, DAY2, YEAR2)
      MONAM2=MONAME(MONTH)
      WRITE(6, 2)FLDNO, CMPANY(1), CMPANY(2), GROWER(1), GROWER(2),
     +(FLDESC(J), J=1, 2), SLCLAS, MONAM, DAY, YEAR, MONAM2, DAY2, YEAR2
     +, SOILCO, BEL1CO, BEL2CO
```

```
      2 FORMAT(/9HFIELD NO.,I4,4X,9HCOMPANY: ,2A10,3X,8HGROWER: ,2A10/
       +19HFIELD DESCRIPTION: ,2A10,4X,21HSOIL CLASSIFICATION: ,A5/
       +18HDATE OF PLANTING: ,A3,I3,1H,,I5,10X/
       +21HDATE OF LAST REPORT: ,A3,I3,1H,,I5,10X,18HSOIL COEFFICIENT: ,
       +F5.2/38HBELLANI PLATE COEFFICIENTS #1 AND #2: ,F5.2,1H,,F5.2)
        OLDFLD=FLDNO
      1 CONTINUE
      3 CALL CLOSEM(FET)
        FLDNO=0
        WRITE(6, 4)
      4 FORMAT(////)
        RETURN
        END
        SUBROUTINE TOVARS
C*******************************************************************************
C                                                                             *
C        THIS ROUTINE TAKES THE VARIABLES THAT ARE IN ARRAY "INFO" AND PUTS   *
C   THEM INTO THEIR RESPECTIVE MNEMONIC VARIABLE NAMES.  THE REASON THAT      *
C   ARRAY "INFO" EXISTS AT ALL IS: IT IS MUCH EASIER TO WORK WITH             *
C   INDEXED-SEQUENTIAL FILES IF ALL YOU INFORMATION IS IN ONE TIDY,           *
C   CONTIGUOUS BLOCK OF MEMORY, AND CONSECUTIVE ELEMENTS IN AN ARRAY          *
C   GUARANTEES THAT IT IS.                                                    *
C        NOTE:  I KNOW THAT THE TYPE DECLARATIONS IN THIS ROUTINE AND ITS     *
C   SISTER ROUTINE, "FRMVAR", DO NOT AGREE WITH THOSE OF THE REST OF          *
C   THE SUBROUTINES AND THE MAIN PROGRAM.  THIS IS INTENTIONAL.  I DID        *
C   IT TO AVOID ANY AUTOMATIC TYPE CONVERSION THAT THE HOST COMPUTER          *
C   MIGHT DO.  I CAN GET AWAY WITH IT BECAUSE FORTRAN COMPILERS (IN           *
C   GENERAL, AT LEAST) DO NOT COMPARE THE TYPES OF VARIABLES STORED IN        *
C   THE LOCAL COMMON BLOCK WITH THE TYPES OF THOSE SAME VARIABLES AS          *
C   USED IN OTHER SUBPROGRAMS.                                                *
C                                                                             *
C*******************************************************************************
        COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
       +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
       +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
       +IRRLVL, BEHIND, SLCLAS, LSTRPT
        COMMON /INFORM/ INFO(35)
        INTEGER CMPANY, GROWER, FLDESC, SLCLAS, PLNTDT, SOILCO
        INTEGER BEL1CO, BEL2CO, BEHIND, CURVE
        LSTIRR=INFO(1)
        CMPANY(1)=INFO(2)
        CMPANY(2)=INFO(3)
        GROWER(1)=INFO(4)
        GROWER(2)=INFO(5)
        FLDESC(1)=INFO(6)
        FLDESC(2)=INFO(7)
        SLCLAS=INFO(8)
        PLNTDT=INFO(9)
        SOILCO=INFO(10)
        BEL1CO=INFO(11)
        BEL2CO=INFO(12)
```

```
      BEHIND=INFO(13)
      DO 1 I=1, 20
    1 CURVE(I)=INFO(I+13)
      NCURVE=INFO(34)
      LSTRPT=INFO(35)
      RETURN
      END
      SUBROUTINE FRMVAR
C*******************************************************************************
C                                                                             *
C     THIS IS THE SISTER SUBROUTINE OF "TOVARS". IT TAKES THE MNEMONIC        *
C VARIABLE NAMES THAT ARE USED THROUGHOUT THE PROGRAM AND STUFFS THEM         *
C INTO ARRAY "INFO".  SEE ALSO ROUTINE "TOVARS" ABOVE.                        *
C                                                                             *
C*******************************************************************************
      COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
     +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
     +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
     +IRRLVL, BEHIND, SLCLAS, LSTRPT
      COMMON /INFORM/ INFO(35)
      INTEGER CMPANY, GROWER, FLDESC, SLCLAS, PLNTDT, SOILCO
      INTEGER BEL1CO, BEL2CO, BEHIND, CURVE
      INFO(1)=LSTIRR
      INFO(2)=CMPANY(1)
      INFO(3)=CMPANY(2)
      INFO(4)=GROWER(1)
      INFO(5)=GROWER(2)
      INFO(6)=FLDESC(1)
      INFO(7)=FLDESC(2)
      INFO(8)=SLCLAS
      INFO(9)=PLNTDT
      INFO(10)=SOILCO
      INFO(11)=BEL1CO
      INFO(12)=BEL2CO
      INFO(13)=BEHIND
      DO 1 I=1, 20
    1 INFO(I+13)=CURVE(I)
      INFO(34)=NCURVE
      INFO(35)=LSTRPT
      RETURN
      END
      SUBROUTINE SUMS
C*******************************************************************************
C                                                                             *
C     THIS ROUTINE FIGURES ALL THE SUMS OF VARIOUS COMBINATIONS OF X AND      *
C Y THAT ARE USED FOR THE THREE CURVE-FITTING ROUTINES.  THIS IS THE          *
C ALTERNATIVE TO HAVING EACH CURVE-FIT FIGURE ITS OWN SUMS, WHICH             *
C WOULD NECESSITATE TRUCKLOADS OF REDUNDANCY.                                 *
C                                                                             *
C*******************************************************************************
      COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
     +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
```

```
      +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
      +IRRLVL, BEHIND, SLCLAS, LSTRPT
       COMMON /STAT/ N, SUMX, SUMY, SUMXY, SUMX2, SUMY2, SUMX3, SUMX4, S
      +UMX2Y, SUMX5, SUMX6, SUMX3Y
       INTEGER FLDNO, DATE, PLNTDT, CMPANY, FLDESC, GROWER, DAYPLT
       INTEGER CURVE, BEHIND, LSTRPT, SLCLAS
       LOGICAL RUNOFF, RECHRG, IRRLVL
       REAL N
       N=FLOAT(NCURVE)
       SUMX=0.
       SUMX2=0.
       SUMY2=0.
       SUMX3=0.
       SUMX4=0.
       SUMX5=0.
       SUMX6=0.
       SUMY=0.
       SUMXY=0.
       SUMX2Y=0.
       SUMX3Y=0.
       DO 1 I=1, NCURVE
       XI=FLOAT(I)
       YI=FLOAT(CURVE(I))
       SUMX=SUMX+XI
       SUMY=SUMY+YI
       SUMXY=SUMXY+XI*YI
       SUMX2=SUMX2+XI*XI
       SUMY2=SUMY2+YI*YI
       SUMX3=SUMX3+XI*XI*XI
       SUMX4=SUMX4+XI*XI*XI*XI
       SUMX5=SUMX5+XI**5
       SUMX6=SUMX6+XI**6
       SUMX2Y=SUMX2Y+XI*XI*YI
       SUMX3Y=SUMX3Y+XI*XI*XI*YI
     1 CONTINUE
       RETURN
       END
       SUBROUTINE LINEAR(A, B, R2)
C*******************************************************************************
C                                                                             *
C     THIS DOES A LINEAR REGRESSION ON THE DATA.  MY REFERENCE FOR THIS       *
C ALGORITHM IS:  THE "STANDARD PAC" MANUAL FOR THE HEWLETT-PACKARD            *
C HP-67 PROGRAMMABLE CALCULATOR, (PART NO. 00067-90021) PAGE 03-02.           *
C                                                                             *
C*******************************************************************************
       COMMON /STAT/ N, SUMX, SUMY, SUMXY, SUMX2, SUMY2, SUMX3, SUMX4, S
      +UMX2Y, SUMX5, SUMX6, SUMX3Y
       REAL N
       T1=SUMXY-SUMX*SUMY/N
       T2=SUMX2-SUMX**2/N
       B=T1/T2
```

```
      A=SUMY/N-B*SUMX/N
      R2=T1**2/T2/(SUMY2-SUMY**2/N)
      RETURN
      END
      SUBROUTINE PARAB(A, B, C, R2)
C****************************************************************************
C                                                                          *
C     THIS ROUTINE DOES A PARABOLIC CURVE FIT ON THE DATA SPOKEN OF IN     *
C  SUBROUTINE "SUMS".  MY REFERENCE FOR THIS IS THE HEWLETT-PACKARD        *
C  "GENERAL STATISTICS" MANUAL, VOL. 1, FOR THE HP 9815A PROGRAMMBLE       *
C  CALCULATOR (PART NUMBER 09815-15001), PAGES 56-57.                      *
C                                                                          *
C****************************************************************************
      COMMON /STAT/ N, SUMX, SUMY, SUMXY, SUMX2, SUMY2, SUMX3, SUMX4, S
     +UMX2Y, SUMX5, SUMX6, SUMX3Y
      REAL N
      AA=(N*SUMX2-SUMX**2)*(N*SUMX2Y-SUMX2*SUMY)
      BB=(N*SUMX3-SUMX*SUMX2)*(N*SUMXY-SUMX*SUMY)
      C=(AA-BB)/((N*SUMX2-SUMX**2)*(N*SUMX4-SUMX2**2)-(N*SUMX3-SUMX*SUM
     +X2)**2)
      B=((N*SUMXY-SUMX*SUMY)-C*(N*SUMX3-SUMX*SUMX2))/(N*SUMX2-SUMX**2)
      A=(SUMY-C*SUMX2-B*SUMX)/N
      R2=(A*SUMY+B*SUMXY+C*SUMX2Y-SUMY**2/N)/(SUMY2-SUMY**2/N)
      RETURN
      END
      SUBROUTINE CUBIC(A, B, C, D, R2)
C****************************************************************************
C                                                                          *
C     THIS ROUTINE DOES A CUBIC CURVE FIT ON THE DATA COMING IN.  MY       *
C  REFERENCE IS:  APPLIED GENERAL STATISTICS, BY F. E. CROXTON AND         *
C  D. J. COWDEN, (NEW YORK, PRENTICE-HALL, INC. 1955) PP.494,497.          *
C                                                                          *
C****************************************************************************
      COMMON /STAT/ N, SUMX, SUMY, SUMXY, SUMX2, SUMY2, SUMX3, SUMX4, S
     +UMX2Y, SUMX5, SUMX6, SUMX3Y
      DIMENSION COEFFS(10, 5)
      REAL N
      COEFFS(1, 1)=N
      COEFFS(1, 2)=SUMX
      COEFFS(2, 1)=SUMX
      COEFFS(1, 3)=SUMX2
      COEFFS(2, 2)=SUMX2
      COEFFS(3, 1)=SUMX2
      COEFFS(4, 1)=SUMX3
      COEFFS(3, 2)=SUMX3
      COEFFS(2, 3)=SUMX3
      COEFFS(4, 1)=SUMX3
      COEFFS(2, 4)=SUMX4
      COEFFS(3, 3)=SUMX4
      COEFFS(4, 2)=SUMX4
      COEFFS(3, 4)=SUMX5
```

```
            COEFFS(4, 3)=SUMX5
            COEFFS(4, 4)=SUMX6
            COEFFS(1, 5)=SUMY
            COEFFS(2, 5)=SUMXY
            COEFFS(3, 5)=SUMX2Y
            COEFFS(4, 5)=SUMX3Y
            DO 1 I=1, 5
        1 COEFFS(5, I)=COEFFS(1, 1)*COEFFS(2, I)-COEFFS(2, 1)*COEFFS(1, I)
            DO 2 I=1, 5
        2 COEFFS(6, I)=COEFFS(1, 1)*COEFFS(3, I)-COEFFS(3, 1)*COEFFS(1, I)
            DO 3 I=1, 5
        3 COEFFS(7, I)=COEFFS(1, 1)*COEFFS(4, I)-COEFFS(4, 1)*COEFFS(1, I)
            DO 4 I=2, 5
        4 COEFFS(8, I)=COEFFS(5, 2)*COEFFS(6, I)-COEFFS(6, 2)*COEFFS(5, I)
            DO 5 I=2, 5
        5 COEFFS(9, I)=COEFFS(5, 2)*COEFFS(7, I)-COEFFS(7, 2)*COEFFS(5, I)
            DO 6 I=3, 5
        6 COEFFS(10, I)=COEFFS(8, 3)*COEFFS(9, I)-COEFFS(9, 3)*COEFFS(8, I)
            D=COEFFS(10, 5)/COEFFS(10, 4)
            C=(COEFFS(8, 5)-D*COEFFS(8, 4))/COEFFS(8, 3)
            B=(COEFFS(5, 5)-D*COEFFS(5, 4)-C*COEFFS(5, 3))/COEFFS(5, 2)
            A=(COEFFS(1, 5)-D*COEFFS(1, 4)-C*COEFFS(1, 3)-B*COEFFS(1, 2))/
          +COEFFS(1, 1)
            T1=A*SUMY+B*SUMXY+C*SUMX2Y+D*SUMX3Y-SUMY**2/N
            T2=SUMY2-SUMY**2/N
            R2=T1/T2
            RETURN
            END
            SUBROUTINE PRDICT(A, B, C, D, WHICH, R2)
C****************************************************************************
C                                                                          *
C      THIS ROUTINE CALCULATES, FROM THE A, B, C, AND D PASSED IN FROM      *
C   THE VARIOUS CURVE FITS, AND THE DATE OF THE LAST IRRIGATION, THE        *
C   IDEAL DATE OF THE NEXT IRRIGATION ROUNDED TO THE NEAREST DAY (AS        *
C   CLOSELY AS THE PROGRAM CAN CALCULATE FROM THE DATA GIVEN).  ALSO        *
C   IT PRINTS A LINE OF THE REPORT.                                         *
C                                                                          *
C****************************************************************************
            COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
          +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
          +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
          +IRRLVL, BEHIND, SLCLAS, LSTRPT
            INTEGER WKDAY, WHICH, DAY, YEAR, FLDNO, DATE, PLNTDT, LSTRPT
            INTEGER CMPANY, FLDESC, GROWER, DAYPLT, CURVE, BEHIND, DAYOWK
            INTEGER SLCLAS
            LOGICAL IRRLVL, RECHRG, RUNOFF
            X=0.
            Y=FLOAT(NEEDED)
            DO 2 I=1, 100000
            YHAT=A+B*X+C*X**2+D*X**3
            IF(YHAT.GE.Y)GO TO 3
```

```
      X=X+1.
    2 OLDYHT=YHAT
    3 IF(ABS(Y-OLDYHT).LE.ABS(Y-YHAT))YHAT=OLDYHT
      IF(YHAT.EQ.OLDYHT)X=X-1.
      IF(X.GE.39.5)GO TO 4
      IDAY=MMDDYY(JULIAN(LSTIRR)+IFIX(X+.5), MONTH, DAY, YEAR)
      MONAM=MONAME(MONTH)
      WKDAY=DAYOWK(IDAY)
      WRITE(6, 1)WHICH, R2, WKDAY, MONAM, DAY, YEAR
    1 FORMAT(5X,A4,1H:,F10.3,4X,A10,2H, ,A3,I3,2H, ,I4)
      RETURN
    4 WRITE(6, 5)WHICH
    5 FORMAT(5X,A4,1H:,5X,49HPREDICTED IRRIGATION DATE MORE THAN 40 DAYS
     + AWAY.)
      RETURN
      END
      FUNCTION JULIAN(DATE)
C*****************************************************************************
C                                                                          *
C     THIS FUNCTION FIGURES THE JULIAN DAY NUMBER FROM A DATE INPUT IN      *
C THE FORMAT MMDDYY.  REFERENCE: SAME AS "LINEAR". (PAGE 04-01)             *
C     THIS ROUTINE, AS WELL AS "MMDDYY" AND "DAYOWK", OPERATES COR-         *
C RECTLY OVER THE PERIOD FROM MARCH 1, 1900 THROUGH FEBRUARY 28 ,2100.      *
C                                                                          *
C*****************************************************************************
      INTEGER DATE, DAY, YEAR
      YEAR=INT(FRAC(.01+FLOAT(DATE)/100.)*100.)+1900
      DAY=INT(FRAC(.01+FLOAT(INT(FLOAT(DATE)/100.))/100.)*100.)
      MONTH=INT(FLOAT(DATE)/10000.)
      IF(MONTH.LE.2)YEAR=YEAR-1
      MONTH=MONTH+1
      IF(MONTH.LE.3)MONTH=MONTH+12
      JULIAN=INT(365.25*FLOAT(YEAR))+INT(30.6001*FLOAT(MONTH))+DAY+1720
     +982
      RETURN
      END
      FUNCTION MMDDYY(JULIAN, MONTH, DAY, YEAR)
C*****************************************************************************
C                                                                          *
C     THIS FIGURES THE MONTH, DAY, AND YEAR OF THE INPUT JULIAN DAY.        *
C REFERENCE: SAME AS "LINEAR". (PAGE 04-01).                               *
C                                                                          *
C*****************************************************************************
      INTEGER DAY, YEAR
      DAY=JULIAN-1720982
      YEAR=INT((FLOAT(DAY)-122.1)/365.25)
      MONTH=INT((FLOAT(DAY)-FLOAT(INT(365.25*FLOAT(YEAR))))/30.6001)
      DAY=DAY-INT(365.25*FLOAT(YEAR))-INT(30.6001*FLOAT(MONTH))
      MONTH=MONTH-1
      IF(MONTH.GE.13)MONTH=MONTH-12
      IF(MONTH.EQ.1.OR.MONTH.EQ.2)YEAR=YEAR+1
```

```
      MMDDYY=MONTH*10000+DAY*100+YEAR-1900
      RETURN
      END
      INTEGER FUNCTION DAYOWK(DAYNUM)
C*********************************************************************
C                                                                   *
C     THIS FUNCTION CALCULATES THE DAY OF THE WEEK A PARTICULAR DAY  *
C  FALLS ON.  THE INPUT FORMAT IS MMDDYY, AND MY REFERENCE IS THE    *
C  SAME AS FOR "JULIAN".                                             *
C                                                                   *
C*********************************************************************
      INTEGER DAYNUM, DAYS(7)
      DATA DAYS/10H    SUNDAY, 10H    MONDAY, 10H   TUESDAY,
     +10H WEDNESDAY, 10H  THURSDAY, 10H    FRIDAY, 10H  SATURDAY/
      I=IFIX(7.*FRAC(FLOAT(JULIAN(DAYNUM)-1720977)/7.)-.01)+2
      IF(I.EQ.8)I=1
      DAYOWK=DAYS(I)
      RETURN
      END
      FUNCTION MONAME(MONTH)
C*********************************************************************
C                                                                   *
C     THIS ROUTINE DETERMINES THE NAME OF THE MONTH FROM THE NUMBER  *
C  OF THE MONTH.                                                     *
C                                                                   *
C*********************************************************************
      DIMENSION MONTHS(12)
      DATA MONTHS /7HJANUARY, 8HFEBRUARY, 5HMARCH, 5HAPRIL, 3HMAY,
     +4HJUNE, 4HJULY, 6HAUGUST, 9HSEPTEMBER, 7HOCTOBER, 8HNOVEMBER,
     +8HDECEMBER/
      MONAME=MONTHS(MONTH)
      RETURN
      END
      SUBROUTINE BEEP
C*********************************************************************
C                                                                   *
C     THIS SUBROUTINE JUST GENERATES A "BEEP" AND SENDS IT TO THE INTER- *
C  ACTIVE TERMINAL AT WHICH THE OPERATOR IS WORKING.                *
C     THIS IS A SEPARATE ROUTINE SO PEOPLE CAN USE THE PROGRAM ON    *
C  WIDELY DIVERSE HOST COMPUTERS, AND ONLY HAVE TO CHANGE A FEW      *
C  THINGS.                                                           *
C                                                                   *
C*********************************************************************
      DATA BEEPER /00074007400740074007B/
      WRITE(6, 1)BEEPER
    1 FORMAT(A10)
      RETURN
      END
      LOGICAL FUNCTION RESPNS(DUMMY)
```

```
C*************************************************************************
C                                                                       *
C     THIS FUNCTION RETURNS A TRUE OR FALSE VALUE IN RESPONSE TO A YES-  *
C OR-NO QUESTION.                                                        *
C                                                                       *
C*************************************************************************
      INTEGER ANS
      LOGICAL ENDFYL
    3 READ(5, 1)ANS
    1 FORMAT(A3)
      IF(.NOT.ENDFYL(DUMMY))GO TO 4
      WRITE(6, 5)
    5 FORMAT(46HPLEASE DO NOT PUSH 'RETURN' WITHOUT ANSWERING./
     +25HNOW WHAT WAS YOUR ANSWER?)
      GO TO 3
    4 RESPNS=.FALSE.
      IF(ANS.EQ.2HNO.OR.ANS.EQ.1HN.OR.ANS.EQ.1HO)RETURN
      IF(ANS.EQ.3HYES.OR.ANS.EQ.1HY.OR.ANS.EQ.1H1)RESPNS=.TRUE.
      IF(RESPNS)RETURN
      CALL BEEP
      WRITE(6, 2)
    2 FORMAT(37HPLEASE ANSWER WITH A "YES" OR A "NO".)
      GO TO 3
      END
      FUNCTION FRAC(X)
C*************************************************************************
C                                                                       *
C     THIS MERELY FIGURES THE FRACTIONAL PART OF A NUMBER.               *
C                                                                       *
C*************************************************************************
      LOGICAL NEG
      NEG=.FALSE.
      IF(X.LT.0.)NEG=.TRUE.
      X=ABS(X)
      X=X-FLOAT(INT(X))
      IF(NEG)X=-X
      FRAC=X
      RETURN
      END
      SUBROUTINE READNO(MODE, IVALUE)
C*************************************************************************
C                                                                       *
C     THIS IS A SUBROUTINE THAT LESSENS THE NUMBER OF PLACES IN THE      *
C PROGRAM THAT HAVE TO HAVE LIST-DIRECTED READS.  WHEN IT IS CALLED,     *
C YOU CAN SPECIFY WHAT TYPE OF VARIABLE YOU WANT TO READ--INTEGER,       *
C REAL, OR ALPHA--AND IT WILL READ APPROPRIATELY AND RETURN YOUR         *
C VARIABLE.  OBVIOUSLY, THE ROUTINE THAT READ THE VALUE IN THE           *
C RESPECTIVE WAYS ARE:  "RDINT", "RDREAL", AND "RDALFA" (Q.V.).          *
C                                                                       *
C*************************************************************************
      IF(MODE.EQ.1HI)CALL RDINT(IVALUE)
      IF(MODE.EQ.1HR)CALL RDREAL(IVALUE)
      IF(MODE.EQ.1HA)CALL RDALFA(IVALUE)
```

```
      RETURN
      END
      SUBROUTINE RDINT(I)
C*******************************************************************************
C                                                                             *
C     SEE SUBROUTINE "READNO".                                                *
C                                                                             *
C*******************************************************************************
      LOGICAL ENDFYL
    3 READ(5, *)I
      IF(.NOT.ENDFYL(DUMMY))RETURN
      CALL BEEP
      WRITE(6, 1)
    1 FORMAT(62HPLEASE DO NOT HIT 'RETURN' UNTIL YOU'VE ANSWERED THE QUE
     +STION./21HWHAT WAS YOUR ANSWER?)
      GO TO 3
      END
      SUBROUTINE RDREAL(X)
C*******************************************************************************
C                                                                             *
C     SEE SUBROUTINE "READNO".                                                *
C                                                                             *
C*******************************************************************************
      LOGICAL ENDFYL
    3 READ(5, *)X
      IF(.NOT.ENDFYL(DUMMY))RETURN
      CALL BEEP
      WRITE(6, 1)
    1 FORMAT(62HPLEASE DO NOT HIT 'RETURN' UNTIL YOU'VE ANSWERED THE QUE
     +STION./21HWHAT WAS YOUR ANSWER?)
      GO TO 3
      END
      SUBROUTINE RDALFA(I)
C*******************************************************************************
C                                                                             *
C     SEE SUBROUTINE "READNO".                                                *
C                                                                             *
C*******************************************************************************
      LOGICAL ENDFYL
    3 READ(5, 2)I
    2 FORMAT(A10)
      IF(.NOT.ENDFYL(DUMMY))RETURN
      CALL BEEP
      WRITE(6, 1)
    1 FORMAT(62HPLEASE DO NOT HIT 'RETURN' UNTIL YOU'VE ANSWERED THE QUE
     +STION./21HWHAT WAS YOUR ANSWER?)
      GO TO 3
      END
      LOGICAL FUNCTION ENDFYL(DUMMY)
```

```
C*****************************************************************************
C                                                                           *
C     THIS LOGICAL FUNCTION RETURNS A "TRUE" IF AN END-OF-FILE CON-          *
C DITION IS ENCOUNTERED, THAT IS, IF THE OPERATOR HITS THE "RETURN"          *
C KEY BEFORE ENTERING AN ANSWER TO THE QUESTION.                             *
C     IT ALSO BEEPS IN DISMAY AND SHOCKED DISBELIEF.                         *
C                                                                           *
C*****************************************************************************
      LOGICAL X
      X=.FALSE.
      IF(EOF(5).NE.O.)X=.TRUE.
      ENDFYL=X
      IF(X)CALL BEEP
      RETURN
      END
      SUBROUTINE DIRECT
C*****************************************************************************
C                                                                           *
C     THIS ROUTINE PRINTS THE DIRECTIONS FOR THE PROGRAM.                    *
C                                                                           *
C*****************************************************************************
      WRITE(6, 1)
    1 FORMAT(
     +/62HTHIS IS AN ICEBERG LETTUCE IRRIGATION PREDICTION PROGRAM.
     +/62HTHERE ARE TWO MODES IN WHICH THE PROGRAM OPERATES:  FILE OP-
     +/39HERATIONS MODE AND PREDEFINED DATA MODE.
     +/62H    FILE OPERATIONS MODE:  IN THIS MODE, YOU ARE WORKING DI-
     +/62HRECTLY WITH THE INDEXED-SEQUENTIAL FILE, DOING ONE OF THE
     +/10HFOLLOWING:/
     +/62H    1. LIST ALL THE FIELDS ON FILE.  THIS WILL PRINT A LIST-
     +/62H       ING OF ALL THE FIELDS ON THE FILE, WITH THE ASSOCIATED
     +/41H       DATA, IN ORDER OF THE FIELD NUMBER.
     +/62H    2. ADDING A FIELD TO OR EDITING A FIELD ON THE IS FILE.
     +/62H       THE PROGRAM WILL ASK YOU WHETHER OR NOT THIS FIELD IS
     +/62H       TO BE THE FIRST ONE ON THE FILE; YOU ANSWER YES OR NO.
     +/62H       NOTE:  AN EMPTY FILE IS NOT THE SAME THING AS A NON-
     +/62H       EXISTENT FILE--I.E. IF YOU'VE HAD FIELDS ON THE FILE
     +/62H       BUT HAVE DELETED THEM ALL, YOU HAVE AN EMPTY FILE, BUT
     +/62H       THE FILE DIRECTORY STILL EXISTS.  THEREFORE, CONSIDER
     +/62H       IT TO HAVE HAD FIELDS BEFORE--THE FIELD YOU ARE ABOUT
     +)
      WRITE(6, 2)
    2 FORMAT(
     + 62H       TO PUT ON FILE IS NOT THE FIRST.  IF, HOWEVER, YOU ARE
     +/62H       RUNNING THIS PROGRAM FOR THE FIRST TIME EVER, OR THE
     +/62H       FIRST TIME THIS "SEASON", OR YOU HAVE ACTUALLY PURGED
     +/62H       THE "FIELDS" FILE, OR FOR ANY OTHER REASON THE FILE DOES
     +/62H       NOT EXIST, THEN YOU WOULD ANSWER "YES" TO THE QUES-
     +/62H       TION--THIS IS THE FIRST FIELD (BOTH LETTUCE FIELD AND
     +/62H       COMPUTER FILE FIELD) ON THE FILE. THE COMPUTER WILL
     +/62H       THEN SET UP THE FILE DIRECTORY AND OTHER BOOKKEEPING
     +/15H       SUNDRIES.
```

```
      +/62H          NOW THE PROGRAM WILL ASK YOU FOR A FIELD NUMBER.
      +/62H          THIS NUMBER WILL BE NEEDED EVERY TIME YOU ACCESS THE
      +/62H          FIELD.  OTHER THINGS, TOO, WILL BE ASKED FOR, SUCH AS
      +/62H          COMPANY, GROWER, AND FIELD DESCRIPTION (EACH OF WHICH
      +/62H          HAS A MAXIMUM OF TWENTY CHARACTERS), SOIL COEFFICIENT,
      +/10H          ETC.
      +)
        WRITE(6, 3)
      3 FORMAT(
      + 62H          IF YOU INPUT A FIELD NUMBER THAT ALREADY EXISTS, THE
      +/62H          PROGRAM WILL ASK YOU IF YOU WANT TO REDEFINE THE FIELD
      +/62H          (AS OPPOSED TO A TYPO).  ANSWER ACCORDINGLY.
      +/62H       3. DELETING A FIELD FROM THE FILE.  THIS IS QUITE STRAIGHT-
      +/62H          FORWARD; IT WILL ASK FOR A FIELD NUMBER, YOU ANSWER
      +/62H          ACCORDINGLY, AND THAT FIELD IS DELETED FROM THE FILE.
      +/46H          THERE IS NO WAY TO RECOVER DELETED DATA.
      +/62H          ENTERING A FIELD NUMBER OF 0 WILL GET YOU OUT OF THE
      +/14H          ROUTINE.
      +/62H       4. DELETE THE LAST DAY'S DATA FROM A PARTICULAR FIELD ON
      +/62H          THE FILE.  IF DATA WAS ENTERED ONTO A FIELD'S STORAGE
      +/62H          MISTAKENLY, IT IS POSSIBLE TO DELETE ONLY THE ERRANT
      +/62H          DATA.  ANSWER THE APPROPRIATE QUESTION "YES", THEN SPEC-
      +/62H          IFY THE FIELD NUMBER FROM WHICH YOU WANT TO DELETE THE
      +/62H          LAST DAY ENTERED'S DATA, AND IT WILL BE DONE.  IF YOU
      +)
        WRITE(6, 4)
      4 FORMAT(
      + 62H          WANT TO DELETE SEVERAL DAYS' DATA FROM A FIELD, JUST
      +/62H          INVOKE THE ROUTINE SEVERAL TIMES, SPECIFYING THE SAME
      +/12H          FIELD.
      +/62H          NOTHING WILL HAPPEN IF YOU TRY TO DELETE MORE DATA THAN
      +/62H          EXISTS FROM THE FILE, AND IF YOU DELETE N DAYS' WORTH
      +/62H          OF DATA, THE "DATE OF LAST REPORT" MAY BE OFF BY N DAYS.
      +//61H   PREDEFINED DATA MODE:  THIS IS THE MODE FOR WHICH THE PRO-
      +/62HGRAM WAS ACTUALLY MADE.  YOU WORK WITH A MIXTURE OF DATA;
      +/62HSOME FROM THE FIELDS FILE--BELLANI PLATE COEFFICIENTS, SOIL
      +/62HCOEFFICIENT, DATE OF LAST IRRIGATION, ETC.--AND SOME FROM THE
      +/62HKEYBOARD; ENTERED DAILY BY THE OPERATOR--AMOUNT OF RAIN, DATE,
      +/62HPLATE LOSS, ETC.
      +/62H   THE PROGRAM WILL ASK FOR A FIELD NUMBER, WHICH YOU SUPPLY.
      +/62HTHIS IS TO GET THE CORRECT FILE DATA WITH WHICH TO DO CAL-
      +/62HCULATIONS.  IT WILL LET YOU KNOW IF YOU SPECIFY A NONEXISTENT
      +/62HFIELD NUMBER.  AFTER OBTAINING SOME OF THE NECESSARY DATA
      +)
        WRITE(6, 5)
      5 FORMAT(
      +62HFROM THE FILE, YOU WILL BE ASKED SEVERAL QUESTIONS.  UPON
      +/62HYOUR COMPLETION OF THE QUESTION-ANSWERING, A REPORT
      +/62HWILL BE PRINTED WITH THE IRRIGATION DATE PREDICTIONS.
      +/62H   NOTE:  ONCE A "TODAY'S DATE" IS SPECIFIED BY YOUR ANSWERING
      +/62HOF THE ASSOCIATED QUESTION, IT REMAINS SPECIFIED UNTIL YOU
```

```fortran
      +/62HEXIT PREDEFINED DATA MODE.  TO CHANGE THE "DATE FOR WHICH
      +/62HPROCESSING IS TO OCCUR", YOU MUST EXIT AND REENTER PRE-
      +/62HDEFINED DATA MODE.
      +)
       RETURN
       END
       SUBROUTINE EDIT
C******************************************************************************
C                                                                            *
C     THIS IS THE ROUTINE THAT ENABLES THE OPERATOR TO DELETE THE            *
C DATA LAST ENTERED FOR THE SPECIFIED FIELD.  THE ONLY DATA THAT IS          *
C AFFECTED IS THE LOST MILLILITERS OF WATER, AND THIS ONLY INDI-             *
C RECTLY.  ACTUALLY, THE ONLY THING THAT IS DONE IS: NCURVE IS               *
C DECREMENTED.  THE NEXT DAY, HOWEVER, THE ERRANT DATA WILL BE               *
C REPLACED BECAUSE OF THE DECREMENTED VALUE OF "NCURVE".                     *
C     NOTHING HAPPENS IF NCURVE IS 0 OR 20, FOR OBVIOUS REASONS.             *
C                                                                            *
C******************************************************************************
       COMMON /VARS/ FLDNO, DATE, RAIN, RUNOFF, RECHRG, BEL1CO, BEL2
      +CO, BELL1L, BELL2L, PLNTDT, LSTIRR, SOILCO, CMP
      +ANY(2), FLDESC(2), GROWER(2), DAYPLT, NEEDED, CURVE(20), NCURVE,
      +IRRLVL, BEHIND, SLCLAS, LSTRPT
       COMMON /INDSEQ/ FET(35), ERROR
       COMMON /INFORM/ INFO(35)
       INTEGER FLDNO, DATE, PLNTDT, DAYPLT, CMPANY, GROWER, SLCLAS
       INTEGER FLDESC, CURVE, BEHIND
       LOGICAL RUNOFF, ERROR, RESPNS, RECHRG, IRRLVL
       EXTERNAL BOMB
   19 CALL OPENM(FET, 3LI-0)
       WRITE(6, 1)
    1 FORMAT(25HWHAT IS THE FIELD NUMBER?)
   15 CALL READNO(1HI, FLDNO)
       ERROR=.FALSE.
       CALL GET(FET, INFO, FLDNO, 0, 0, 0, BOMB)
       IF(.NOT. ERROR)GO TO 16
       WRITE(6, 14)FLDNO
   14 FORMAT(7HFIELD #,I3,39H IS UNDEFINED.  PLEASE SPECIFY ANOTHER:)
       GO TO 15
   16 IF(NCURVE.EQ.20.OR.NCURVE.EQ.0)GO TO 3
       CALL TOVARS
       NCURVE=NCURVE-1
       CALL FRMVAR
       ERROR=.FALSE.
       CALL REPLC(FET, INFO, 350, FLDNO, 0, 1LC, BOMB)
       IF(ERROR)WRITE(6, 21)
   21 FORMAT(27H"REPLC" ERROR OF SOME KIND.)
    3 CALL CLOSEM(FET)
       IF(.NOT.ERROR)WRITE(6, 2)FLDNO
    2 FORMAT(31HTHE LAST DAY'S DATA FOR FIELD #,I4,1H ,
      +30HHAS SUCCESSFULLY BEEN DELETED.)
       WRITE(6, 18)
```

```
      18 FORMAT(61HDO YOU WANT TO DELETE THE LAST DAY'S DATA FROM ANOTHER F
        +IELD?)
         IF(RESPNS(DUMMY))GO TO 19
         RETURN
         END
         SUBROUTINE BOMB
C******************************************************************************
C                                                                            *
C       THIS IS THE ROUTINE THAT IS PASSED TO, AND CALLED FROM, THE IN-       *
C    DEXED-SEQUENTIAL ROUTINES.  IT IS ONLY CALLED, HOWEVER, IF AND WHEN AN   *
C    ILLEGAL OPERATION IS DONE, SUCH AS TRYING TO ACCESS A NONEXISTANT        *
C    RECORD.  NOTICE THE "EXTERNAL" STATEMENTS IN THE FILE-ACCESSING          *
C    ROUTINES.                                                                *
C                                                                            *
C******************************************************************************
         COMMON /INDSEQ/ FET(35), ERROR
         LOGICAL ERROR
         ERROR=.TRUE.
         RETURN
         END
  /EOF
  READY.
```