A WATER, NUTRIENT AND SEDIMENT BUDGET FOR AN IRRIGATED FARM IN THE BOISE VALLEY

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ABSTRACT

During the summers of 1971 and 1972 the Agricultural Engineering and Soils Departments of the University of Idaho conducted a study on a gravity irrigated farm in the Boise Valley. The purpose of this study was to determine the quantities of total solids and selected nutrient materials that were lost from the farm as a result of irrigation. In order to obtain the necessary data, measuring devices were installed in all ditches and equipped with stage recorders to obtain a continuous record of the flows entering and leaving the farm. Water samples of the head- and tailwater were collected during each irrigation set. Samples of the ground water were periodically collected from ten twelve-foot piezometers located on the farm. During 1972, four sets of solution samplers were installed in each field. Samples of the soil solution at various depths were collected from these samplers after each irrigation. All samples were quick-frozen and sent to the laboratory for analysis. Each sample was analyzed for nitrate-nitrogen, ammonia, organic nitrogen, two forms of phosphorus and total solids. APHA Standard Methods and FWCA Standard Methods were employed in making these analyses.

Local climatological data were collected for use in estimating evapotranspiration and ultimately the soil moisture

depletion rate. The chemical analyses for the water samples, the ET data and the physical parameters for each field and crop were entered as parameters in a digital computer model. This model utilized the input data to calculate the quantities of the chemical constituents and solids that were transported across the boundaries of the study area by irrigation water.

These data indicated that the loss of all chemical constituents was generally low. The highest losses were for the nitrogen compounds. These losses were greatest during 1971 and were largely the result of nitrogen fertilizers being applied in the irrigation water.

Onions were the only crop that had a consistent and significant loss of water to deep percolation. The data indicate that nearly 57 pounds per acre nitrate was moved below the root zone as a result of onion irrigation in 1972.

Large amounts of solids were moved from the farm during both irrigation seasons. Onion irrigation resulted in the highest loss with losses of solids in excess of one ton per acre observed. The data indicate that a larger percentage of these solids may have been unaffected by retention in the settling pond than was the case for the other crops.

Settling ponds proved quite effective in removing sediments. Nearly 80 percent of the solids lost as a result of bean irrigation, during the 1972 season, were retained in the settling pond. However, the data indicate that very little retention of nutrient materials can be confidently credited to the ponds. This indication is due, in part, to the fact that nutrient concentrations of the water entering the pond are consistently low.

CHAPTER I

INTRODUCTION

The Apollo flights to the moon gave man the unique opportunity to stand back and take a look at the earth. From this vantage point in space he saw the earth as a spaceship; a spaceship on an infinite journey carrying only finite supplies. This new view of the earth caused a change of priorities and ushered in a new age, the age of the environment. Cars, factories, and dams once considered symbols of prosperity and a high standard of living are now seen as a curse on the environment. Agriculture has been condemned for using the pesticides and fertilizers that have made our adequate food production possible. Many private groups have been organized to focus public attention on their specific areas of concern. During the 1973 session Congress authorized the appropriation of 24.7 billion dollars for environmental programs. Most states have either established special environmental departments or expanded the duties of existing departments to include environmental protection programs.

The concern about the environment is well founded but there are dangers involved. The steps for achieving environmental quality are not well defined and all of the special interest groups espousing and promoting various causes tend to further cloud the issue. It is essential that we distinguish between the things we would like to do, those we need to do, those we must do and those we can not do. Ultimately the action taken to protect our resources from pollution will be paid for as higher priced goods and services or in shortages of goods and services. Thus the benefits received from environmental improvement must be greater than the incurred costs.

There are recent examples of governmental agencies taking action to protect the public and the environment when no danger or minimal danger was actually involved. Ten years ago cranberries were held off the market as a result of incomplete information. More recently there was a mercury scare because of mercury being detected in tuna fish. Later it was determined that some mercury can be found in all fish. In both cases the result of action taken on incomplete data resulted in shortages and higher prices in the market place. At the present time there is much complaining about high beef prices. Part of this price increase is due to federal restrictions on certain pesticides and feed supplements. If these banned materials are a threat to the environment and public health, then the restrictions are justifiable. If further study should prove these products are not the threat previously supposed then again the consumer has been making needless sacrifices.

Irrigated agriculture is now being accused of damaging the environment by returning salts, nutrient materials and sediments to water supplies with irrigation return flows. Undoubtedly keeping all rivers clean is one of the things we would like to do, but it is probably one of the things we can not do. It is practically impossible to use water without changing its quality. When it is used it will, in some way, be different than it was before it was used. Many rivers are over-appropriated and return flows must be relied on to fill many of the existing water rights. The flow in the Boise River at Notus, Idaho is almost entirely return flow during the summer months (50 & 51). There is no doubt that the water returned to the Boise River is of lower quality than that originally diverted. The "law of use" says it must be. The question is: Is the quality lower than can be accepted? If so, who is responsible and what can be done to improve it? And ultimately, how much are we willing to pay to improve it? These questions must be answered through diligent scientific research for it is essential that any action be based upon complete and unbiased data. This is the only way, in this age of the environment, that we can have a quality environment at a price we can afford to pay.

This study was conducted to answer some of these questions. At the present time very little factual information is available about the kinds and amounts of materials that are added to surface and ground water as a result of irrigation. Viets (45) states that the usual way to approach the eutrophication of water is to assign values to identifiable sources such as industries and sewage treatment plants and attribute the remainder to agriculture. In so assigning, agriculture has been held accountable for everything from feedlot runoff to naturally decomposing plant materials. The object of the research presented in this thesis was to determine the quantities of solids and certain inorganic compounds transported from an irrigated farm as a result of irrigation practices.

It is hoped that this study not only will give some idea of what the cost of irrigation is from an environmental point of view but also may shed some light on ways to improve farming practices to get the most benefit from valuable plant nutrients.

CHAPTER II

JUSTIFICATION FOR STUDY

In 1970 the Departments of Agricultural Engineering and Soils began a study of return flows in the Boise Valley (15). Samples collected contained various amounts of plant nutrients and dissolved solids; but because no flow data were available, the analyses of the water samples gave no information about the total quantities of materials in return flows that could be attributed to irrigation. Those involved in this study recognized the need for quantitative data and proposed doing a mass balance study on an irrigated farm in the Boise Valley. The Idaho Water Resources Research Institute contributed the financial support for the project. With the cooperation of a farmer in the Boise Valley the project got underway in May of 1971.

Statement of Problem

The Boise Valley in southwestern Idaho is one of the major agricultural areas in the state. It was selected for this study because conditions existed which might be conducive to serious contamination of both the surface and ground water supplies in the valley. Some of these conditions for which the Boise Valley was selected are: (1) Most of the farms in the valley are gravity irrigated; (2) commercial fertilizers are heavily used in producing the high-value crops grown in the valley; (3) many of the soils contain indurated hardpan layers which impede downward water movement and contribute to: (4) a fairly low irrigation efficiency; (5) high water tables exist in most of the valley increasing their potential for contamination and (6) the rapid population growth that the Boise Valley is experiencing makes water quality problems more critical.

The focus of this study was the establishment of a mass budget for an irrigated farm. This budget included: water, three forms of nitrogen, two forms of phosphorus, and total solids. This budget was developed for three of the fields in the study area. A budget for two settling ponds was also established in order to evaluate its value in removing nutrients and solid materials from the runoff water.

CHAPTER III

SEDIMENTS AND INORGANIC MATERIALS IN WATER

The water found in nature is never pure. Even a sparkling mountain stream will contain salts, sediments and plant nutrients. Generally the concentrations of these materials is low and present no problem; they are in fact essential to a healthy stream. However, if material is discharged into a stream that greatly increases the concentrations of plant nutrients, salts and/or sediments then the health of the stream and the ultimate usefulness of the water is decreased.

The Hazards Involved

When present in water in sufficient concentrations, nitrogen, phosphorus and dissolved solids can cause serious problems. High nitrate concentrations in water have been long recognized as a cause of infant cyanosis (methemoglobinemia) or blue babies. This is caused from nitrate being converted to nitrite in the intestinal tract. The nitrite is absorbed into the blood stream where it combines with the hemoglobin thus depriving the cells of needed oxygen (38). The same process takes place in ruminant animals and can lead to nitrite poisoning (48). There is also evidence that high nitrate water can produce intestinal pathological conditions resulting in chemical diahrrea (17). The U.S. Health Service established standards of 10 mg/l nitrate nitrogen (45 mg/l nitrate ion) as the upper limit for drinking water. However, there are some reports of harmful effects with concentrations as low as 5 mg/l nitrate nitrogen (44).

Phosphorus is known to accelerate eutrophication by stimulating algae blooms (39). It is reported that algae grows vigorously in water containing 0.1 part per million (ppm) phosphorus and is stimulated by 0.05 ppm phosphorus (47). Phosphorus and sediments are tied closely together in that phosphorus is generally transported adsorbed to soil particles (48).

Sediments are frequently referred to as our greatest pollutant (46). The sediment carried by streams disrupts the dissolved oxygen balance in water and reduces fish populations by blanketing spawning grounds. The storage capacity of the nation's reservoirs is reduced by four million acre feet annually be sedimentation. Each year about four million acres of topsoil are lost to erosion (29).

Sediment and Nutrient Behavior

The ease with which sediments and plant nutrients find their way from an irrigated field and into water supplies depends upon several variables. These variables include: soil conditions, soil type, temperatures and climate, depth to the water table, soil fertility, soil pH irrigation and other cultural practices. There are chemical properties of plant nutrients and sediments in water that allow generalizations about their behavior to be made.

Nitrate Nitrogen

Nitrogen fertilizers, regardless of the form in which they are applied, will eventually be converted to the nitrate form by natural soil processes under well-aereated conditions (11 & 50). Nitrate (NO_3) is the most mobile form of nitrogen and moves through the soil essentially with the wetting front (3). This mobility makes nitrate of primary concern from the standpoint of leaching losses and possible movement into water supplies. The magnitude of NO_3 leaching is difficult to estimate because it depends upon a number of variables which include: (1) the concentration of NO_3; (2) the amount of water applied and the time of application; (3) infiltration and percolation rates; (4) evapotranspiration; (5) water holding capacity of the soil and (6) the presence of growing plants (45).

Because of the high solubility of nitrate nitrogen any nitrate present at the surface of the soil at the beginning of an irrigation will be dissolved and carried into the soil by the first water reaching it (3). Unless significant erosion is involved, the nitrate content of surface runoff should be no greater than the content of the headwater.

If more water is applied in a given irrigation than is needed to bring the soil to field capacity there is a danger of moving nitrates below the root zone of the crop where they are lost as nutrients for the crop and become a threat to ground water supplies. Irrigation experts realize the desirability of applying only enough water during an irrigation to refill the root zone to field capacity; however, they also recognize that some water must percolate through a profile if a desirable salt balance is to be maintained (23). This means that, under certain circumstances, some enrichment of ground water may be unavoidable if economic agricultural operations are maintained.

Fitzsimmons, et al. (15) observed the nitrate content of ground water in the Boise Valley to be considerably higher than surface flows. While the major source of these nitrates is unknown, the proximity of the water table to the soil surface leaves little doubt that irrigated agriculture does contritute nitrates to the ground water of the Boise Valley.

Ammonia

The ammonia (NH_3-N) ions present in the soil as a result of microbial activity, or from application of fertilizers, can be adsorbed and fixed by clay minerals. This fixation can reduce the availability of NH_3-N to nitrifying micro-organisms and thereby to plants (43). This absorbtion by colloids may explain why an increase in NH_3-N has been observed in sediment laden surface return flows (15). It seems reasonable to expect sediment loads and NH_3-N content in surface return flows to be somewhat related.

Organic Nitrogen

Part of the nitrogen added to soils as fertilizers can be converted to organic forms in the soil. This organic N is only slowly mineralized and may persist in the soil for years. As long as nitrogen remains in the organic form it is comparatively safe from loss except through erosion (43).

Phosphorus

Phosphorus has been found to exist in water in at least five forms; soluble orthophosphates, soluble organics, insoluble organics, adsorbed on suspended material and as a component of suspended mineral and organic matter (26). This variability makes evaluation of phosphorus quite complicated. The movement of phosphorus in the soil solution depends upon the capacity of the soil to react with the phosphorus. In an experiment in Western Australia, it was observed that 38 days after 225 kg of P^{32}-labeled superphosphate per hectare (about 200 lb per acre) was applied on fallow siliceous sand, more than 50% of the labeled P had penetrated over a meter below the surface of the soil. The area received 23 cm (9.05 in) of rain during this time (4). This is probably an extreme condition. The water percolating through most less sandy soils will generally have a low P content. Drainage water from lysimeters, in which soil depth is usually no more than one meter, generally show concentrations in the soil solution to be less than 0.1 μg of P per millileter (4).

Phosphorus applied to the surface of the soil tends to be fixed by the soil colloids. If erosion takes place, P is removed with the sediments. Researchers have shown that sediments release P into solution until an equilibrium concentration is reached. If sediments with very little adsorbed P are added to the water, P will be removed from solution, and the concentration will decrease. Sediment loads of 10,000 ppm from a phosphorus deficient soil were found to be capable of reducing the P concentrations in solution from sewage effluent from 6.6 ppm to 4.3 ppm (36).

Sediment

Viets (46) proposes that sediment is the primary hazard to water quality. Sediment constitutes by far the greatest mass of material moved by water. These sediments have been shown to have significant quantities of plant nutrients associated with them (12). The nutrient load of sediments depends to a great extent upon the type of soil being eroded (18). Unfortunately the most fertile soil fractions are preferentially removed by erosion. These are generally fine sediments composed of silts, clays and organic materials (5). It is primarily coarse sediments that can be controlled with available technology. A method for controlling the amounts of clay and other colloidal fractions which constitute the bulk of our sediment problems is not yet known (18).

The amount of sediment transported by a stream depends upon the energy available to detach and transport solid material. Since all flowing water has energy, sediment will continually be produced and will carry available pollutants with it (37). Some experts feel that if, under furrow irrigation, erosion losses are held to only one ton per acre per year an acceptable level of erosion has been attained (36).

Phosphorus is generally adsorbed to the chemically active fractions in the soil. Since these are the ones most readily transported by moving water it is understandable that phosphorus and sediment losses are closely correlated. Each 1,000 tons of suspended sediment will carry about 1,000 pounds of phosphorus (46).

Because sediments are chemically active, they can also act as scavengers and remove pollutants from solution. The ability of sediment to adsorb pollutants from solution and deposit them in stream channels may be beneficial in some cases and detrimental in others. If this action tends to concentrate harmful pollutants it can have serious repercussions (37).

CHAPTER IV

EXPERIMENTAL WORK

Irrigation is generally defined as the application of water to soil for the purpose of supplying the moisture essential for plant growth (23). Several methods are used to apply needed water. The method used in a particular instance depends upon the crop, water supply, topography, soil conditions, climate, economic factors and, to a large degree, local customs. Most irrigation systems can be classified as being either sprinkler or gravity systems. The distinction between the two is that a sprinkler system delivers water through a network of tubing or pipes with sprinkler heads attached for spraying water over the soil surface (32). A gravity system, on the other hand, delivers water to the soil as a "flood". Frequently corrugations or furrows are constructed in the soil which confines the water to specific channels for better control of the water.

A gravity system was used on the farm used in this study. Furrow irrigation of sugar beets on this farm is shown in Figure 1. Water was left to run in a set of furrows from 12 to 24 hours per set depending upon the crop and field conditions. Each irrigation for a field consisted of three or four sets. The surplus water was removed from the farm by a system of drainage ditches and eventually returned to the Boise River.

Figure 1: Furrow irrigation of sugar beets

Conditions For Mass Budget

The development of the mass budget for this tract depended upon measuring all of the water entering and leaving the boundaries of the farm. From these data the mass flux of solids and chemical constituents on the tract could be established. In order to estimate deep percolation losses of water and dissolved nutrient materials it was essential to estimate daily evapotranspiration during the study period.

Soil Moisture

The objective of irrigation is to refill the soil moisture reservoir. The amount of water the root zone of a given crop will hold may be given as a percentage by weight, Pw, a percentage by volume, Pv, or as a depth, whichever is most convenient. The moisture holding capacity of a soil is usually given in inches of water per foot of soil depth (in/ft). Thus, if a crop has an effective root zone at depth, D, and will hold, i, inches of water per foot of depth, then the maximum amount of water that can be stored in the root zone is iD. When a flow of water, q, is applied during time, t, to a tract of size, a, then the tract will be covered to a depth, d, or,

$$d = qt/a. \qquad \text{(Eqn. 1)}$$

If q is in cfs, t, is in hours and, a, is in acres, d will be in inches. If d is greater than iD, more water has been added than the root zone will hold, and deep percolation will take place.

Once the root zone has drained to field capacity, the only methods for depleting the moisture are evaporation and transpiration. If a crop with a 3 foot root zone is growing on a soil that will hold 2.2 inches of available water per foot then 6.6 inches of available moisture are present in the root zone at field capacity. However, plants will show signs of stress well before the 6.6 inches are depleted. Generally it is desirable to irrigate when approximately one-half of the available moisture has been used. Suppose it is found from evapotranspiration (ET) data that 0.25 inches of water are being depleted each day. In this case the number of days until the crop should be irrigated again would be:

$$6.6/(2)(0.25) = 13.2 \text{ or } \quad 13 \text{ days}$$

If the soil is allowed to go for 13 days between irrigations it will take about 3.3 acre inches of water per acre to refill the root zone. If more than 3.3 inches is added, the excess will be lost to deep percolation. The analysis assumes that the soil is well drained, that there is no net upward movement of ground water into the root zone and that the ET rate is constant during the entire period.

Water Budget

When water is applied to the soil it will have one of four possible fates. It will either be lost as surface runoff, enter the air as water vapor due to evaporation or transpiration, be stored in the root zone, or percolate through the root zone. These possible fates are illustrated in Figure 2. When quantities are assigned to these four possible entities, the water entering the tract may be said to be "budgeted". This budget in its simplest form may be expressed as:

$$\text{Water on} - \text{water off} + \text{change in storage} = 0 \qquad \text{(Eqn. 2)}$$

By considering that water is applied as either precipitation, Q_P, or irrigation Q_A, and leaves as surface runoff, Q_R, evapotranspiration, Q_{ET}, or percolates below the root zone, Q_{DP}, equation 2 may be written as:

$$Q_P + Q_A - Q_R - Q_{ET} - Q_{DP} \pm \Delta S = 0 \qquad \text{(Eqn. 3)}$$

where ΔS is the change in soil moisture storage. The Q and ΔS terms may be expressed in any desired units, as long as they are consistent. Acre inches per hour or acre feet per day are commonly used units. To find the water budget totals for the study period, equation 3 must be integrated with respect to time from t = 0 to t = T; where T is the duration of the irrigation period. The form of this integral is given in equation 4.

$$\int_0^T Q_P \, dt + \int_0^T Q_A \, dt - \int_0^T Q_R \, dt - \int_0^T Q_{ET} \, dt - \int_0^T Q_{DP} \, dt + \int_0^T \Delta S \, dt = 0$$

(Eqn. 4)

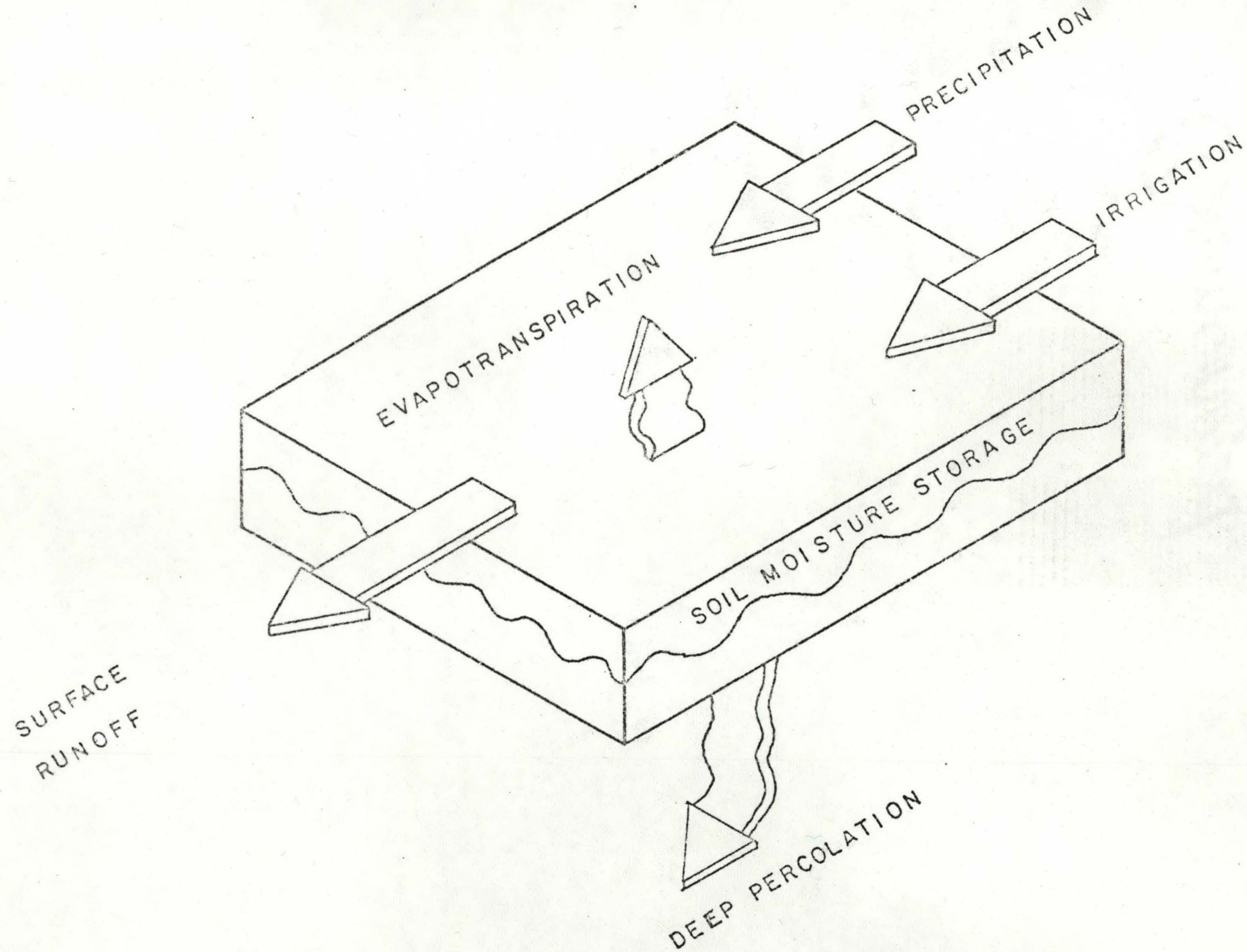


Figure 2: Flow parameters for mass budget

Since each term in equation 4 is a variable, the equation for which is unknown, the integration can only be approximated. This is accomplished by chosing a time period, ΔT, for which each term in equation 3 may be considered to be constant. The integration of equation 4 can now be approximated by summation. Equation 4 now becomes:

$$\sum Q_P \Delta T + \sum Q_A \Delta T - \sum Q_R \Delta T - \sum Q_{ET} \Delta T - \sum Q_{DP} \Delta T + \sum \Delta S \Delta T = 0$$

(Eqn. 5)

These calculations would be very tedious if done by hand but are well adapted to digital computer applications.

The surface flows, Q_P, Q_A, and Q_R can be measured directly. By installing measuring devices in the supply ditch, Q_A may be determined. Similarly, measuring devices in the drainage ditch will allow Q_R to be determined. The water from precipitation, Q_P, can be estimated from local rain gage data. The water lost to evapotranspiration, Q_{ET}, can be estimated from local climatological data. The Penman and Jensen-Haise equations are widely used methods for estimating Q_{ET} (33). Davis (10) developed a computer program which generates values using both the Penman and Jensen-Haise equations. The portion of the program using the Penman equation was used in this study.

The water in storage, S, can be estimated by knowing the root zone depth for the crop being grown. The number of inches going to evapotranspiration between irrigations determines the amount of water that must be added to again bring the soil to field capacity. For this theory to hold, the root zone must be defined and there must be nothing to impede downward movement of water.

Mass Budget

The water entering and leaving the boundaries of a field will transport various quantities of salts, plant nutrients, sediments and other materials. If the concentration, C_i, of any of these materials is known, it is possible to estimate the total amounts of these materials that are lost or gained during a specified period of time. When C_i is known in pounds of material per pound of water (lbm/lbw) and the flow rate, Q_M, of the water is known in pounds per unit time, the total amount of material, W_M, in pounds transported across the boundaries of the field during a time interval, Δt, will be given by the equation:

$$W_M = Q_M C_i \Delta t \qquad \text{(Eqn. 6)}$$

When the concentration of a specific material is known for the water in all the flow paths shown in Figure 2, equations 2 and 3 may be combined to give the following mass balance equation:

$$W_{ti} = (Q_{MP}C_{iP} + Q_{MA}C_{iA} - Q_{MR}C_{iR} - Q_{MDP}C_{iDP})^{\Delta t} \qquad \text{(Eqn. 7)}$$

This equation gives the total amount of material, i, in pounds which is lost from or gained by a field during a time period Δt. If the Q's or C's are not constant, then a Δt for which they may be considered constant must be chosen and the total loss or gain of material, W_T, is the sum of the individual W_t's or,

$$W_T = W_{t1} + W_{t2} + W_{t3} + \ldots$$

This mass budget considers only the removal of nutrient materials by water transport.

Physical Parameters

The farm selected for this study is located northeast of Nampa, Idaho in an area of intensive irrigated agriculture. It is operated by one of the more progressive farmers in the area.

The portion of the farm selected for this study was divided into three fields totaling 94.5 acres (38.2 hectares). All of the fields had been leveled for efficient furrow irrigation. Scraped spots resulting from this leveling can be seen in Figure 3, an aerial photo of the farm. Bark soil conditioner was applied to these areas in 1971 in an effort to improve soil tilth.

The soil on this farm is classified in the Purdam series. The Purdam series is a moderately deep, medium textured, level

Figure 3: An aerial photo of study site

to moderately sloping soil that has a weakly cemented duripan at a depth of 20 to 40 inches. These soils are extensive in the Nampa-Caldwell area of Canyon county. There are 39,334 acres of Purdam or Purdam in complex associations with Power and Sebree series.

The surface layer (A_p horizon) is a light brownish-grey silt loam about 8 inches thick. The subsoil (B horizon) is pale brown heavy silt loam to light silty clay loam that is 7 to 11 inches thick. Part of the B horizon is often mixed into the plow layer. The substratum (C horizon) included a moderately cemented duripan at 20 to 40 inches. Stratified medium or coarse textured alluvium or lacustrine sediment, or sand and gravel is found below the duripan.

High water tables are present under a large portion of this area. A drainage well located on the study farm was pumped continuously during the latter part of the irrigation season to lower the water table in the area. Even with continuous pumping, the water table under certain areas of the farm was observed to be at a depth of less than three feet.

Three sources of irrigation water were used on this farm. They included Boise River water, artesian water and water from a drainage well. The water from the artesian well, which was about 400 feet deep was of excellent quality although it was warm and had a sulfur smell. The water from the drainage well, which was about 65 feet deep, was generally better in quality than that delivered from the Boise River, but of poorer quality than the artesian water.

All of the delivery ditches on the farm were concrete lined. Water was transferred from the delivery ditches to the fields by means of siphon tubes as shown in Figure 4. Two sizes of tubes, one inch and one and one-quarter inch, were used depending upon the crop and the length of irrigation set.

Figure 6 is a map of the farm. The farm was divided into two parts by the ditch shown in the center of Figures 3 and 6. Sixty and one-half acres (24.48 hectares) were included in the north part while the south part totaled 47.4 acres (19.15 hectares), 13.5 acres (5.46 hectares) of which were not included in the study.

Sugar beets (Beta vulgaris L.), green lima beans (Phaseolus limensis), and white onions (Allium cepa L.) were the three crops grown each year. During the 1971 season, 33.5 acres of onions, 27 acres of beets and 34 acres of beans were grown. These crops were rotated in 1972 so that there was 33.5 acres of beets, 27 acres of beans and 34 acres of onions.

Beets and onions are generally planted in April in this area. Beets are harvested during October while onions are harvested during the first part of September. The variety of beans grown have a short growing season and are harvested green. They are planted in May and are generally harvested by the third week in August. The portion of the irrigation season studied in this project is indicated in Table 1.

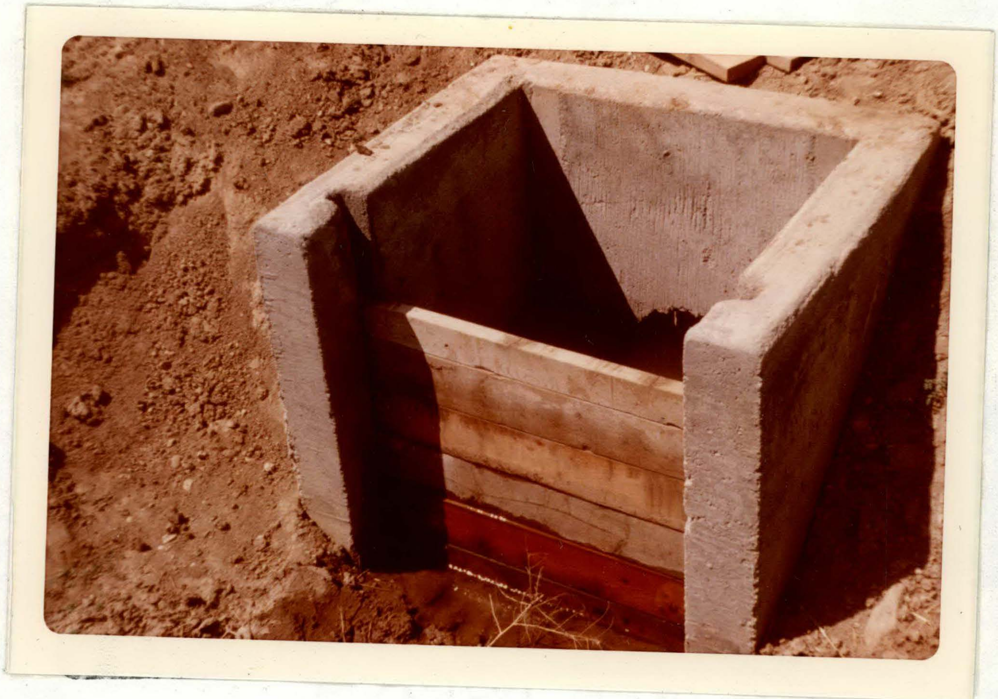
Table 1. The selected study period for each crop for the 1971 and 1972 seasons

Crop	Beets	Onions	Beans
Started 1971	June 11	June 7	--
Ended 1971	Aug 28	Aug 16	--
Started 1972	June 1	May 31	June 1
Ended 1972	Sept 30	Aug 31	Aug 20

Drainage ditches carried the surface runoff from the farm. Prior to the 1971 season, a settling basin was dug at the lower end of field C. This proved to be quite effective in trapping sediments; and, before the start of the 1972 season, an additional settling pond was dug at the lower end of fields A and B. Concrete structures, shown in Figure 5, were installed at the outlet end of each pond. The structures allowed the water in the pond to be backed up to any desired depth.

The farmer on this tract applied commercial fertilizer several times during the year. The first application was plowed down in the fall. The crops were later side dressed and some crops were given supplemental nitrogen through the irrigation water. The fertilization schedule for the two-year period is given in Tables 1 and 2 of Appendix A.

Figure 4: Water being diverted to an onion field by means of siphon tubes



A. Structure at the beginning of the season before the weir and recorder were installed

B. Structure after the two-foot adjustable cipolletti weir was installed

Figure 5: Sediment pond outlet structure

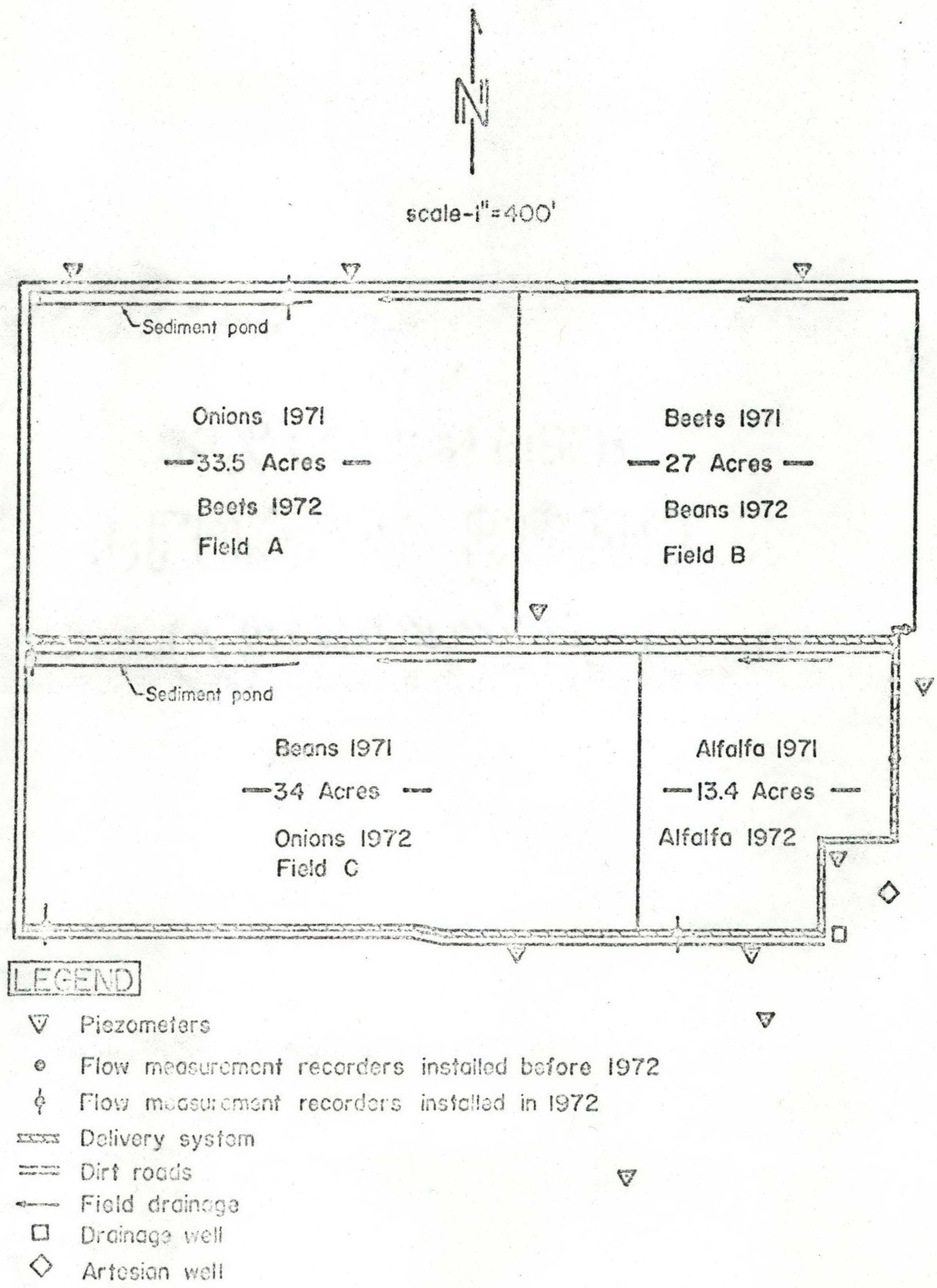


Figure 6: Site map

CHAPTER V

METHODS AND PROCEDURES

Developing a mass budget for the study farm depended upon: (1) continuous measurement of headwater and tailwater flows; (2) collection and analysis of periodic headwater and tailwater samples; (3) the collection of climatic data for estimating ET; and (4) the collection and analysis of ground water samples.

Surface Water Measurement

Several different devices were used during the two-year study for measuring headwater and tailwater flows. Figure 6 shows the location of all measuring devices.

Headwater

When the study started in 1971, Cipolletti weirs were used to measure all of the water entering the north supply ditch which supplied water for fields B and C of the study area. Stilling wells similar to the ones shown in Figures 7 and 8 were installed upstream from each weir. Stevens type-F recorders were attached to each stilling well for obtaining a continuous record of stage. The ditch along the east edge of the south half of the farm delivered water for the north half of this farm and an adjacent farm. During the peak of the irrigation season, the two-foot Cipolletti weir that was

Figure 7: Installation of stilling wells

Figure 8: Stilling well with Stevens type-F stage recorder attached

installed in this section of ditch was not adequate to carry the flows and had to be removed to prevent flooding upstream. As a result, continuous measurement of headwater became impossible, and for the remainder of the season single-row-60°-fiberglass-trapezoidal flumes were used to estimate irrigation applications. These flumes, which are shown in Figure 9, were placed in several rows during an irrigation set. From these measurements, an average application rate was estimated. Periodically the Cipolletti weir was reinstalled to check the small-flume data. Generally there was less than five percent discrepancy between the two measurements.

Before the start of the 1972 irrigation season, the weir shown in Figure 10 was installed to measure the headwater for fields A and B. This was not a standard weir design and had to be rated. This was done by installing a Cipolletti weir downstream until a stage-discharge relationship was established for the non-standard weir.

No attempt was made in 1971 to install controls in the south ditch. In 1972 a large 45° trapezoidal fiberglass flume, shown in Figure 10, was installed to measure the water entering the ditch and a two-foot rectangular weir was installed to measure the excess water leaving the ditch. Both of these weirs were equipped with stilling wells and stage recorders.

Figure 9: Individual row trapezoidal flumes

Figure 10: Two controls used to measure flows in supply laterals

The trapezoidal flume created some problems for the owner of the farm, and after the third onion irrigation the trapezoidal flume was removed. Once again the individual-row flumes were used to estimate irrigation applications.

Tailwater

In 1971 all runoff from the north fields (fields A and B), was measured through a six-inch Parshall flume. The Parshall flume, shown in Figure 11, was used because it could be easily installed in the erodible channel, required a relatively small head loss, was accurate with up to 90 percent submergence and was not subject to siltation (23). This Parshall flume was also equipped with a stage recorder.

During 1971 it was impossible to measure runoff from the south field; and, for this reason no bean data are included for 1971. In 1972 the settling pond below this field was equipped with a concrete structure which allowed all of the flows leaving the pond to be measured.

When a settling basin was dug at the lower end of fields A and B, it was desirable to measure the inflow and outflow of the pond. A six-inch Parshall flume was installed above the basin and a two-foot Cipolletti weir with an adjustable crest was installed in the concrete outlet box. Both were equipped to obtain a continuous record of flows. These two controls made it possible to establish a nutrient and sediment budget for the pond.

Figure 11: Six-inch Parshall flume used for measuring surface runoff

Evapotranspiration

The Penman method used for estimating ET is based on the correlation of measured evapotranspiration with several climatic factors. The climatic factors used for estimating evapotranspiration in this study were; maximum and minimum daily temperatures, solar radiation, two-meter wind speed and daily relative humidity.

In 1971 a recording thermometer and a rain gage were installed for an on-site record of temperature and precipitation. In 1972 a recording hygrothermograph (Figure 12) was installed making both temperature and relative humidity measurements possible. The missing parameters for estimating ET were obtained from USWS stations located at Boise and Kuna.

Deep Percolation

Eight 12-foot piezometers were installed prior to the 1971 irrigation season. Two others were installed on the site before the project began. The locations of the ten piezometers are shown in Figure 6. These piezometers were used to monitor fluctuations in the water table. Water samples taken from the piezometers were analyzed to obtain an estimate of the quality of water reaching the water table from deep percolation.
The quality of the water sampled at the ten piezometers tended to be quite variable between locations as indicated in Table 13 of Appendix A. The use of these data for estimating nutrient loss through deep percolation was complicated by denitrification,

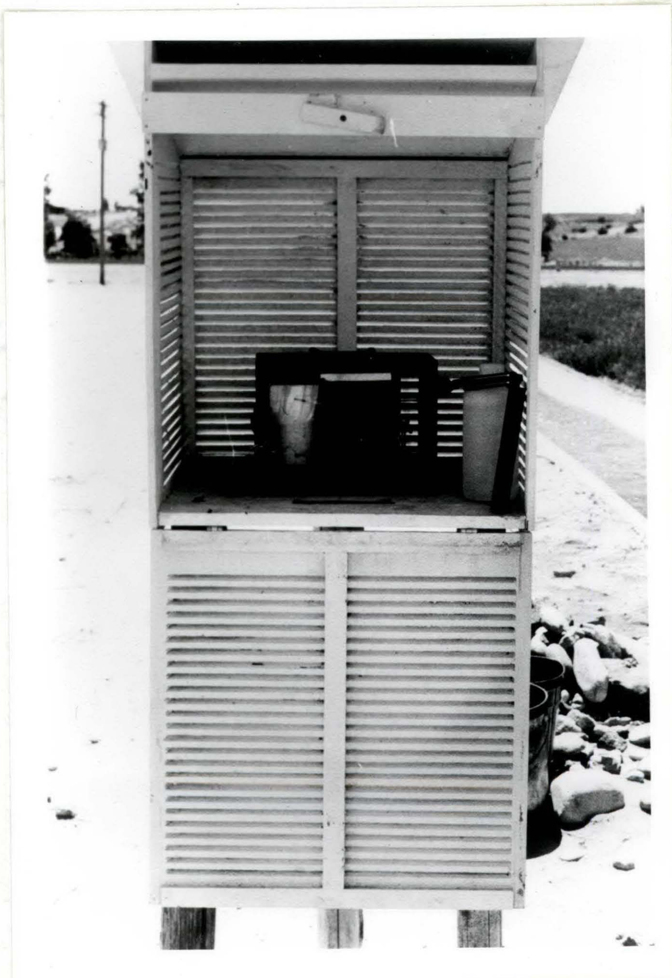


Figure 12: Recording hygrothermograph used during 1972 for a continuous record of temperature and relative humidity

mixing and lag due to slow travel times within the saturated zone. In an attempt to improve this estimate, four sets of solution samplers were designed and installed in each field prior to the 1972 study period.

These samplers, shown in Figures 13and 14, consisted of five tensiometer type samplers. Each sampler was connected to a separate collection chamber by nylon tubing (Figure 14). The sampler tubes were made from one-half inch nominal PVC pipe. The collection chambers were made from eight-inch lengths of two-inch diameter PVC pipe. Six of these sections were joined together and sealed with rubber stoppers to make the collection and vent chambers for each sampler set. A second tube was run from each tensiometer sampler and connected through a rubber stopper to a common vent chamber. This allowed air to enter the samplers when a sample was to be collected.

Samples were obtained by evacuating the system with a hand vacuum pump a few hours after the irrigation of a field was completed. Whenever possible the samplers remained under vacuum for 12 hours, after which time the solution in each sampler tube was collected in a small vial held in the proper collection chamber. Because of leaks that developed in the sampler systems, it was frequently not possible to retain a vacuum for 12 hours. As a result, the soil solution data obtained were somewhat incomplete. Since the five-foot samplers collected water below the water table in all locations, water

Figure 13 : Soil solution samplers. These samplers allowed samples of the soil solution to be taken at one foot increments, from one to five feet.

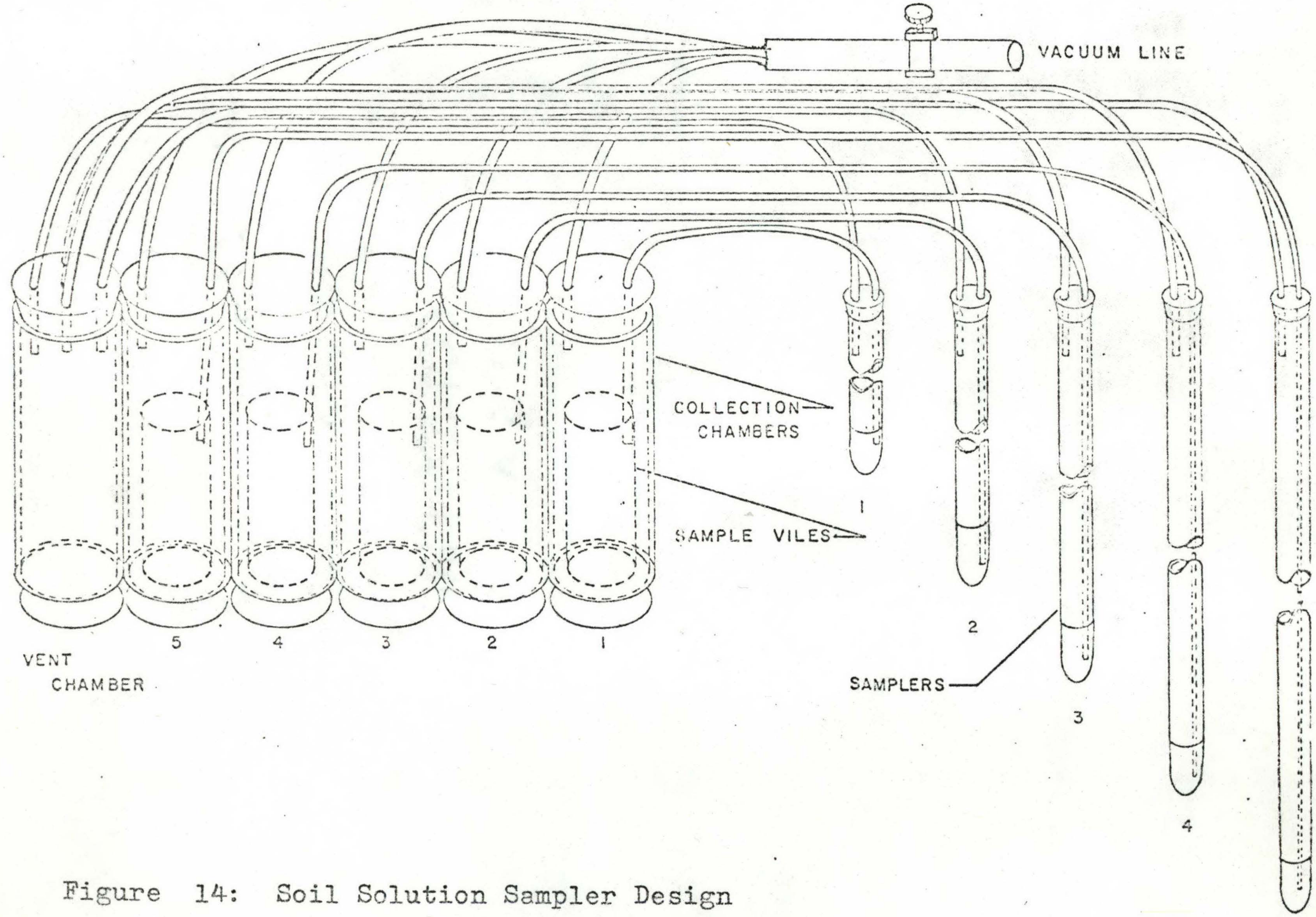


Figure 14: Soil Solution Sampler Design

quality data at this depth are complete. These data were assumed to represent the quality of the soil solution at the five-foot depth and were used in the computer model to estimate the quantities of NO_3 and soluble phosphorus moved into the saturated zone by deep percolation. Tables 5, 6, and 7 show deep percolation data for the five-foot and twelve-foot depth. The twelve-foot data were obtained from the analyses of water samples collected from ten twelve-foot piezometers. The analyses from piezometers 1, 3, and 4 were averaged and used as an estimate of the quality of ground water.

Sampling

One-liter grab samples of the head and tailwater were usually taken during each irrigation set. Runoff samples were collected at each control on the drainage ditch or settling pond. Samples were collected three or four times a day unless fertilizer was being added to the headwater in which case samples were collected hourly for the first four hours of the set and at about four-hour intervals thereafter. Figure 15 shows a sample of the runoff water being collected.

Because headwater samples quality tended to vary less than that of tailwater samples, headwater samples were collected less frequently than tailwater samples. All piezometers were sampled at least every two weeks. These were pumped dry using the apparatus shown in Figure 16 and allowed

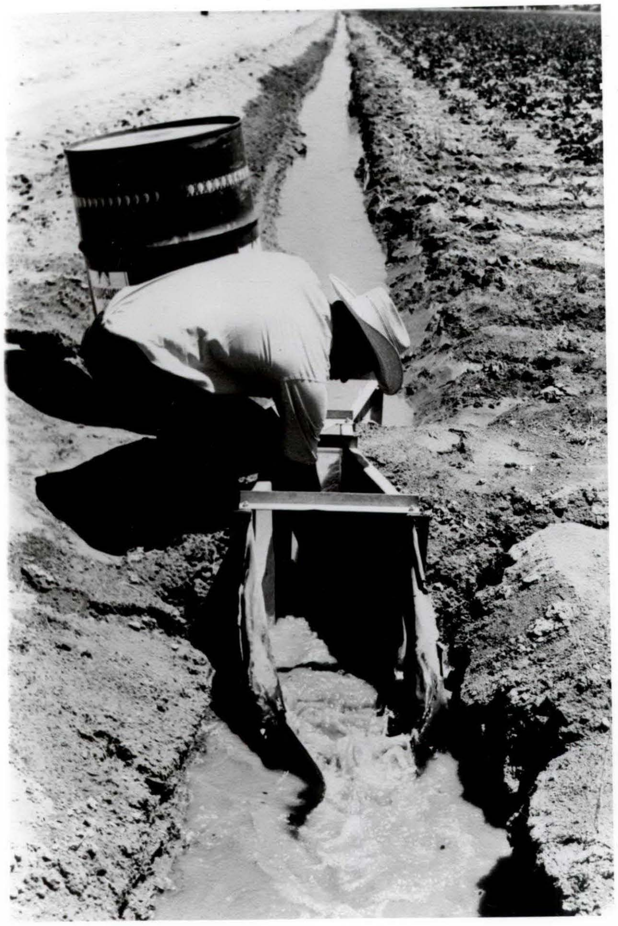


Figure 15: Sampling. One-liter grab samples were taken frequently at selected sampling sites.

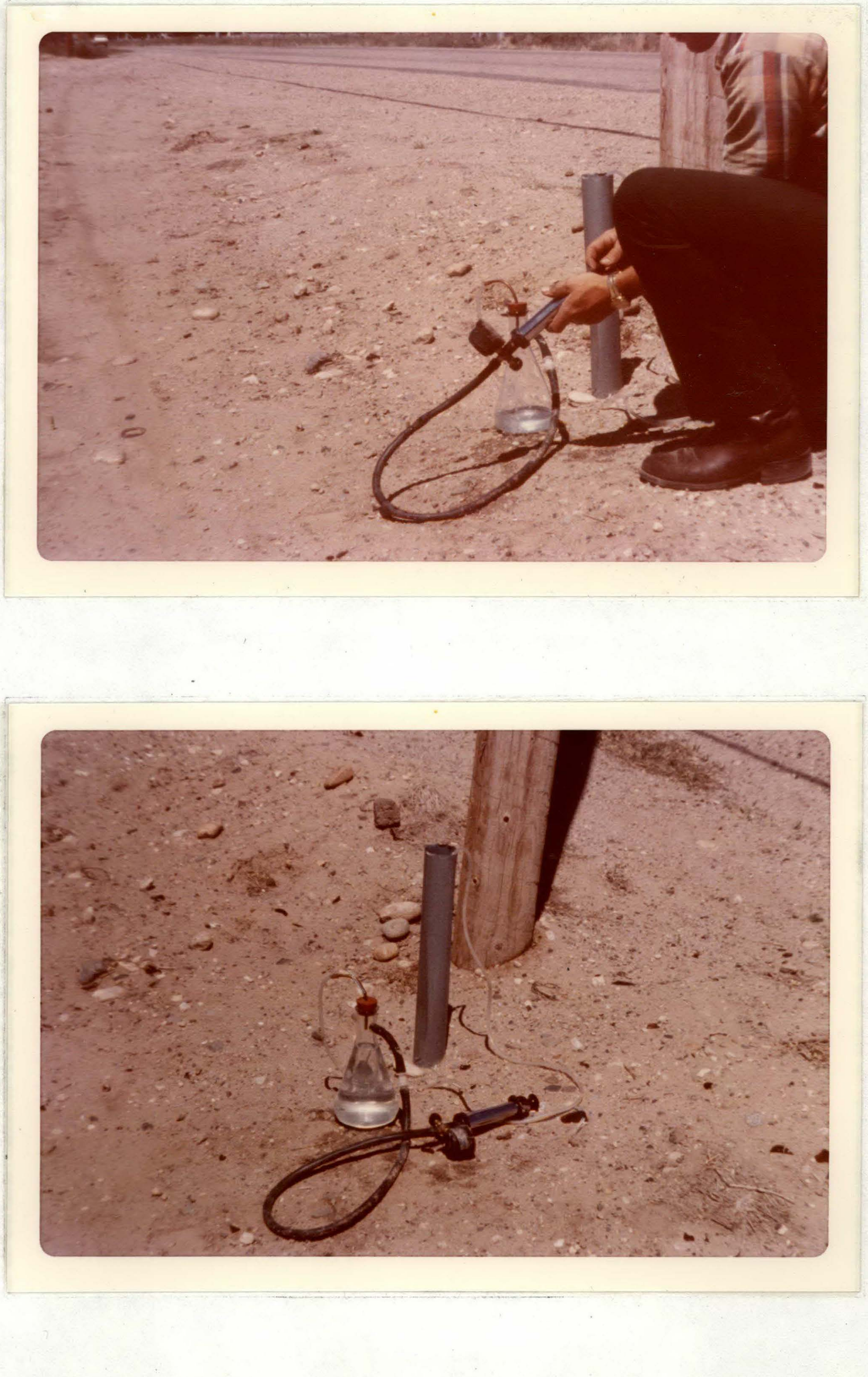


Figure 16: Groundwater sampling apparatus

to refill before collecting a sample. This eliminated the possibility of detecting non-typical changes which might have taken place in the water while standing in the piezometer tube for long periods of time.

All samples were immediately frozen for later transport to the laboratory for analysis.

Analysis

At the lab each sample was analyzed for NO_3 nitrogen, NH_3 nitrogen, organic nitrogen, soluble phosphorus, total phosphorus and total solids. The methods used in making the analyses were essentially those given in APHA Standard Methods (42) and EPA (13). Nitrate-nitrogen was determined by the phenoldisulphonic acid method after first removing the chlorides with silver sulfate. The samples were filtered through 0.45μ millipore filters for soluble phosphorus and digested with sulphuric acid and ammonium persulfate for total phosphorus. The phosphorus was determined colorimetrically in the filtrate and digestion mixture by the amino-naphthol-sulfonic acid method. Total solids were determined by weighing the residue after drying a sample for 24 hours at 110°C. All analyses were reported by constituent concentration in parts per million (ppm) by weight.

Data Processing

All of the raw data collected for an irrigation season were processed by a model 360-40 IBM digital computer, using a computer model developed by John R. Busch, Assistant Professor of Agricultural Engineering at the University of Idaho. A complete listing of the program used is given in Appendix B.

This model is designed to establish a water and chemical budget on an irrigated tract for several chemical constituents. Data for flow rates, chemical constituents and dates are read in by means of subroutines. Since the chart paper for the stage recorders was divided into two-hour intervals, it was convenient to use a two-hour increment for all computer calculations. This two-hour time increment is the value assigned to ΔT in equation 4. If the datum for each two-hour period is not available, the subroutine will linearly average between the given points and fill in the missing data. All data except those called for by the subroutine reading in the chemical data were read in at the beginning of the program. The computation and output sequence for the program is given in Figure 17.

The program first calculates the flow rates in cfs from the weir data and establishes the surface water budget. This is accomplished by the subroutine FLOWIN. These data are printed out by the main program. The flow data are

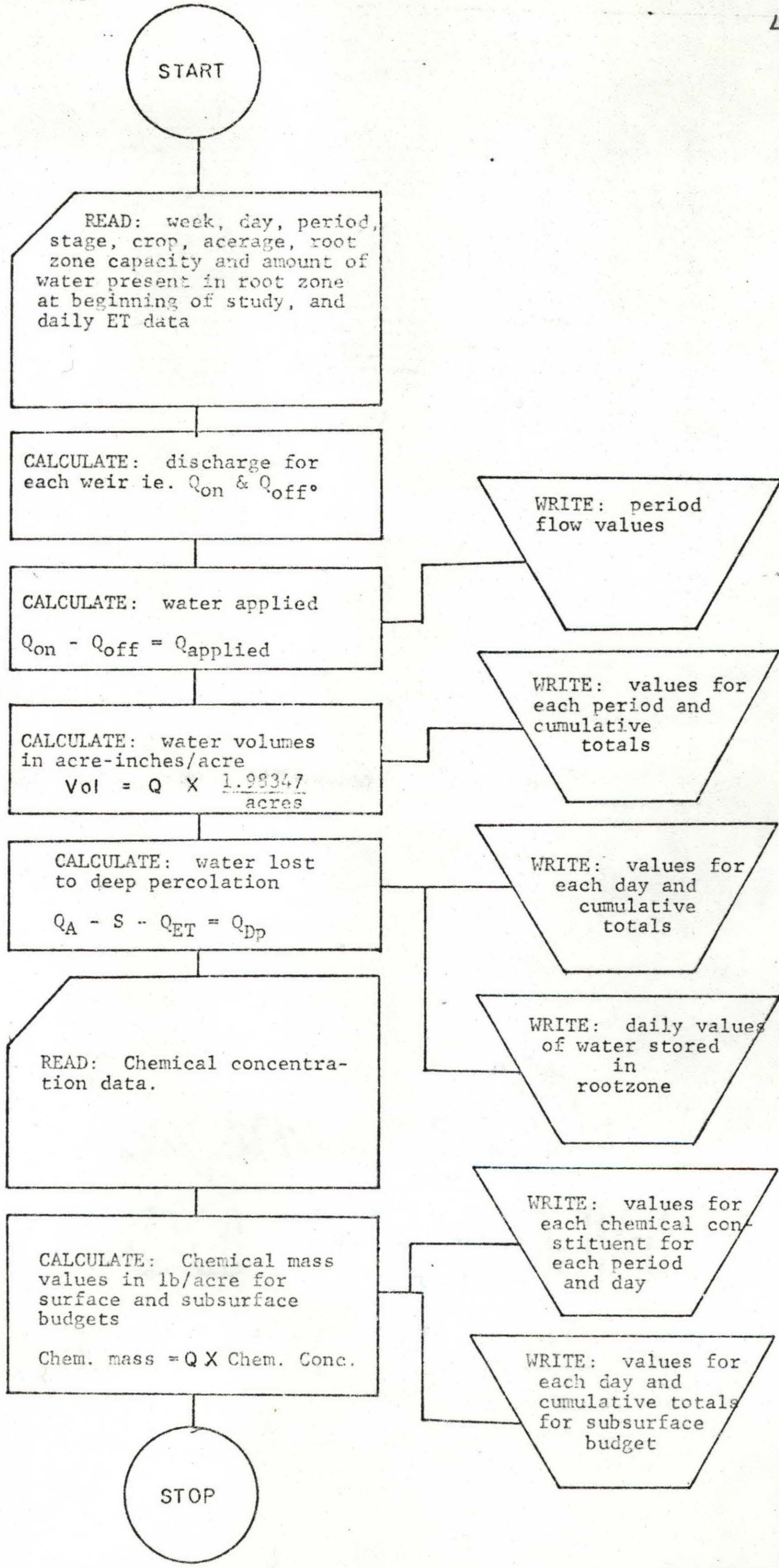


Figure 17: Computer program operation sequence

then multiplied by the appropriate factor to generate volumes in acre inches per acre for each two-hour time period and each day. These data, minus corresponding ET data and changes in soil moisture storage, allow deep percolation losses to be estimated. Because of the high water tables that existed under the study area, it was necessary to have the model be able to both add water to and withdraw water from ground water depending upon the amount of water in the root zone at the time. It was assumed that when the root zone capacity was one-half depleted, ground water would start moving into the root zone. The amount of water moving into the root zone in any one day will be equal to that day's ET loss and is printed out as negative deep percolation (DP).

After the flow rate data for each two-hour period are printed out, water volume data in inches of water for water on, water off, and water applied are then printed out for each two-hour period. Next, daily and cumulative values for water applied, water to ET, water to DP and water in the root zone are printed out.

Once these values have been printed out, they are no longer needed in that form in computer storage and are converted from acre inches per acre to pounds per acre for each time period. At this point the subroutine CHEMIN is called. The data for chemical concentrations and dissolved solids are read in and multiplied by the corresponding flow data and an appropriate factor to give quantities for the mass balance in pounds per acre for each period. The corresponding mass value for tailwater is subtracted from the headwater value for each two-hour period to give the amount of material retained or lost by the field during that period. These data are then printed out for each two-hour period and each day. When this is complete the deep percolation and corresponding data are combined to determine nutrient losses to deep percolation. The complete mass budget is then printed out.

The pond balance program is a modification of this same computer model. Subroutine FLOWIN was modified to calculate the difference between the quantity of water entering and leaving the pond. These flow data are then multiplied by the various chemical values when the subroutine CHEMIN is called into the main program to obtain the amount of material retained in the pond. The difference between the amounts of materials entering and leaving the pond is calculated for each two-hour period. These data are summed and the values for each two-hour period, each day, and the cumulative totals are printed out. The difference between the quantity of a given material entering and leaving the pond shows up on the computer printout as material "retained".

CHAPTER VI

RESULTS

The results of this two-year study are contained in 500 pages of computer printout. The complete evaluation of these data is a formidable task and has not been completed at this time. However, complete data analysis is not germane to establishing a mass budget for the study area since the totals are of more interest than individual datum points or statistical relationships. A summary of these data is given in Tables 3-12 of Appendix A.

The mass budget has three components: (1) the water budget; (2) the nutrient budget; and (3) the sediment budget. Each of these will be considered separately even though they are functionally related.

Water Budget

The water diverted for beet irrigation averaged 3.73 inches per irrigation in 1971. It was increased to 4.95 inches in 1972. This was the result of changing from 12-hour sets in 1971 to 20-hour sets in 1972. However, the average amount of water entering the soil was nearly identical both years with 2.53 inches applied per irrigation in 1971 and 2.54 inches applied per irrigation in 1972. As a result of the increased diversions in 1972, the average runoff increased from 1.20 inches in 1971 to 2.41 inches in 1972. It is interesting to note that the data show a decrease in the deep percolation (DP) losses in 1972. This decrease is probably even greater than indicated by Table 2 because the last two irrigations of beets were not included in the 1971 study period. Table 3 in Appendix A shows that the highest deep percolation loss from beets during 1971 occurred during the last irrigation. In 1972, the highest DP occurred during the last two irrigations. If this was the trend during the two missed beet irrigations of 1971 then the actual difference between the 1971 and 1972 deep percolation values would be greater. This decrease in DP is probably due to less permeable soil conditions on the field planted to beets in 1972. Lower intake rates also explain why more water was diverted in 1972 to attain an application rate similar to the 1971 rate.

Tables 3 and 7 in Appendix A show negative DP values occurring for all three crops. These negative values indicate that water moving from the water table into the root zone is supplying part of the crop's moisture requirement.

The data indicate that beets planted on this farm will obtain needed moisture from ground water between 25 and 40 percent of the time. It is probable that with the high water tables in this area, some sub-irrigation is always taking place. Beans may obtain as much as one-third of their total seasonal moisture requirement from sub-irrigation.

Table 2. Water Budget Totals, in Acre-Inches per Acre, for Beets, Onions, and Beans.

	Total On		Total Off		Total Applied		Total ET			Total DP	
	Ac-In / Ac	% On	Ac-In / Ac	% On	Ac-In / Ac	% On	Ac-In / Ac	% Ap	% On	Ac-In / Ac	% Ap
BEETS											
1971	29.82	100.00	9.59	32.10	20.23	67.90	18.76	92.80	62.91	1.05	5.19
1972	49.54	100.00	24.11	48.67	25.43	51.33	24.83	97.60	50.10	0.99	3.89
ONIONS											
1971	35.99	100.00	14.41	40.04	21.58	59.96	17.41	80.68	48.37	5.44	25.20
1972	43.38	100.00	18.96	43.71	24.83	56.20	19.43	78.20	44.79	6.05	24.37
BEANS											
1972	16.07	100.00	4.49	27.94	11.59	72.12	16.33	140.90	98.41	-3.19	-27.52

Unfortunately, there are no data for the 1971 bean crop to use for comparison with the 1972 data. Therefore, it is not known if this is always the case for different fields on this farm.

Of the three crops grown, onions were the most heavily irrigated. An average of 5.14 inches of water was diverted for onion irrigation in 1971; and, on the average, 6.20 inches was diverted in 1972. The average application was 3.47 and 3.54 inches respectively. Onions were irrigated in four 24-hour sets and had the highest runoff and deep percolation losses of the three crops. Table 2 shows the total seasonal deep percolation losses from onions for 1971 and 1972 to be 5.44 and 6.05 inches respectively. This deep percolation from onions may be important to the rotation scheme for this farm. It is conceivable that with the high water tables and low deep percolation losses that occur from beets and beans, the deep percolation from onions in the rotation may be valuable in preventing salt buildup in the soils. The water quality data presented in Tables 14 and 15 of Appendix A indicate fairly high concentrations of sodium and magnesium salts in the ground water. Since plants extract pure water from the root zone, the sub-irrigation which occurs on this farm would tend to concentrate salts in the soil profile. If these salts were not periodically flushed from the root zone the productive capacity of this farm would decline.

In all cases except for beans the highest deep percolation losses occurred during the first and last of the season. The zero DP value given for the last onion irrigation in 1971 (Table 4, Appendix A) is misleading because it was a light irrigation prior to harvest. The increased DP losses later in the irrigation season are probably due to decreased consumptive use by the crop.

The seasonal water budget totals are given in Table 2. The column under "% On" indicates the efficiency of irrigation on this farm. Because of the large percentage of their moisture requirement that beans obtain from sub-irrigation, the irrigation efficiency for beans is very high. The irrigation efficiencies for beets and onions tend to be slightly low but are more typical of efficiencies for furrow irrigation than that shown for beans.

Sediment and Nutrient Budget

Three forms of nitrogen and two forms of phosphorus were considered in the chemical portion of this mass budget. The totals for each chemical constituent for each irrigation are given in Tables 8 through 12 in Appendix A. Negative values indicate a net loss of a constituent from the field.

Nitrogen Budget

In every case the seasonal totals show that more nitrate and ammonia entered the farm with the irrigation water than was removed with the runoff water. Generally, there was no net gain or loss of organic nitrogen during an irrigation. The data indicate however, that there may have been a small net seasonal loss of organic-N from onions and beans. This is probably the result of organic matter and plant debris being picked up and carried from the field by the runoff water. This idea is supported by the data for the pond balance which indicate about one-half of the organic nitrogen lost from beet and bean irrigations was retained in the settling pond.

Liquid nitrogen fertilizer was applied to beets and onions through the irrigation water during June and July of 1971. In 1972 there was one application on sugar beets in July. The chemical analysis of this material (1972 analysis) is given in Table 3 below. The liquid fertilizer applied in 1971 was supposed to have been the same as that used during 1972 but was not analyzed. The material used in 1971 was held over from the previous year. The data indicate that chemical changes probably occurred during the period it was held over. The high concentration of organic nitrogen indicates the presence of urea in the material.

Table 3. The Chemical Composition of the Liquid Fertilizer Applied in Irrigation Water in 1972

Nitrate nitrogen	10.30%
Ammonia nitrogen	42.40%
Organic nitrogen	22.00%
Soluble phosphorus	00.06%
Total phosphorus	00.10%
Dissolved solids	00.13%

The data for 1972 indicate average application efficiencies for nitrogen to be generally lower than those observed during 1971. These efficiencies are summarized in Table 4. This lower efficiency for sugar beets in 1972 was to be expected because of the lower intake rates that were observed during that season. However, the difference may also be due, in part, to differences in sampling techniques and the resulting errors induced due to linear averaging in the computer model. If samples were not collected to accurately detect when maximum and minimum concentrations occurred, the linear averaging error is compounded.

Table 4. Fertilizer Application Efficiencies for Sugar Beets

Date	Percent NO_3 Applied	Percent NH_3-N Applied	Percent Organic-N Applied
June 1971			
Set 1	76.0	84.0	64.0
Set 2	60.0	78.4	--
July 1972			
Set 1	33.0	56.0	33.0
Set 2	79.0	74.0	50.0
Set 3	42.0	56.0	--

Ammonia generally was found in very low concentrations in the headwater unless nitrogen fertilizer was being added to the irrigation water. However, the concentrations of ammonia and organic nitrogen in the water delivered from the irrigation canal tended to increase during the latter part of the irrigation season. This increase was probably partly a result of the irrigation company's moss treatment program. Decomposing moss results in various nitrogenous compounds being released into the water. Because both organic nitrogen and ammonia nitrogen tended to increase and decrease together appears to lend support to the theory that the ammonia resulted from the decomposition of organic matter in the water.

Deep percolation from onion irrigations resulted in the highest net loss of nitrogen (NO_3). The solution samples taken at the five depths tended to be higher in nitrate nitrogen than ground water samples taken from the ten piezometers. However, the nitrate concentration was quite variable, at a given depth, between sampling locations within the same field. Table 5 in Appendix A indicates the NO_3 concentrations at each sampling site in the sugar beet field for three different sampling dates. The mean of the data for the five-foot samplers was used in estimating the nitrate concentration of the deep percolation water immediately below the root zone during that period. The mean concentrations for each sampler depth for beets is plotted in Figure 18.

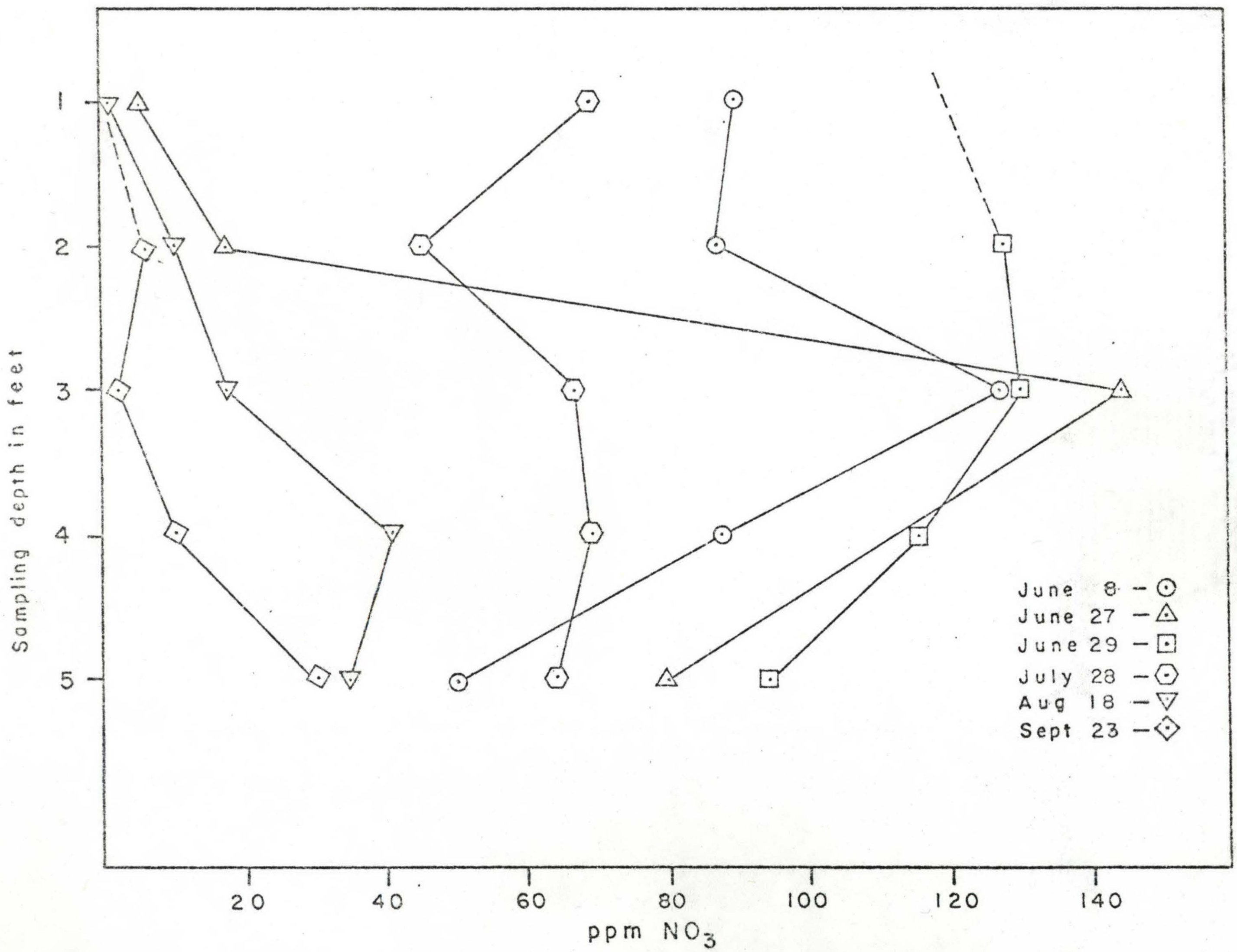


Figure 18: Changes in NO_3 concentrations with depth and time of solution samples collected in sugar beet field

The data plotted indicate a general decrease of nitrate in the soil profile during the growing season. They also indicate that the maximum nitrate concentrations tended to occur at the three-foot depth during the first weeks of the growing season. By the last of the season the maximum is found between the four and five-foot depths.

The data in Tables 5, 6, and 7 indicate that when the soil solution from the five-foot samplers was used as an indication of the quality of deep percolation water, onions were the only crop that showed a net nutrient loss for the season. This loss was quite large (about 56.7 lb/acre), representing about one-third of the nitrogen fertilizer applied to the onion field during 1972. Beans on the other hand gained (14.3 lb/acre) nitrogen from ground water equaling 18 percent of that applied. Beets gained about six pounds of nitrogen per acre. It must be remembered that these DP data are only estimates and should be used with caution.

Phosphorus Budget

The phosphorus budget data listed in Tables 5, 6, and 7 indicate very little movement of phosphorus with either surface or percolating water. Generally there was a small net loss of phosphorus during the irrigation of a field. Onions showed the highest seasonal loss both years with the 3.29 lb/acre total P loss observed in 1971 being the highest. As expected from the higher runoff onions also had the highest

Table 5. Totals for Nutrients and Solids, in Pounds per Acre, for Onions for the 1971 and 1972 Seasons

1971	NO_3-N	NH_3-N	Organic-N	Soluble-P	Total-P	Solids
Total on	9.32	33.87	24.00	0.97	1.55	897.05
Total off	3.96	11.40	27.27	1.39	4.84	3207.00
Net	5.36	22.47	-3.27	-0.24	-3.29	-2309.95
Total DP (12')	13.75	00.00	00.00	0.00	0.00	--
1972						
Total on	3.68	00.70	4.22	1.27	1.78	685.47
Total off	1.84	00.54	5.13	1.44	3.04	3361.61
Net	1.84	00.16	-0.91	-0.17	-1.26	-2676.14
Total DP (12')	10.77	00.00	00.00	0.34	0.00	--
Total DP (5')	56.74	00.00	00.00	0.92	0.00	--

Table 6. Totals for Nutrient and Solids, in Pounds per Acre, for Beets for the 1971 and 1972 Seasons

1971	NO_3-N	NH_3-N	Organic-N	Soluble-P	Total-P	Solids
Total on	4.57	19.94	14.65	0.69	1.12	849.72
Total off	1.77	3.97	15.56	0.88	1.45	1804.11
Net	2.80	15.97	-0.96	-0.19	-0.33	-945.39
Total DP (12')	2.02	0.00	0.00	0.00	0.00	---
1972						
Total on	9.45	3.41	7.72	1.28	1.69	1560.73
Total off	5.79	1.76	3.69	0.97	1.41	1750.94
Net	3.66	1.65	4.03	0.31	0.28	-190.21
Total DP (12')	1.93	00.00	00.00	0.12	0.00	---
Total DP (5')	-6.03	0.00	0.00	0.27	0.00	---

Table 7. Totals for Nutrient and Solids, in Pounds per Acre, for Beans for the 1972 Season

1972	NO_3-N	NH_3-N	Organic-N	Soluble-P	Total-P	Solids
Total on	0.85	0.24	0.69	0.46	0.69	363.08
Total off	0.53	0.17	1.33	0.34	0.70	621.64
Net	0.32	0.07	0.64	0.12	-0.01	-258.56
Total DP (12')	-5.10	0.00	0.00	-0.08	0.00	---
Total DP (5')	-14.27	0.00	0.00	-0.23	0.00	---

net sediment loss both years. The 1972 sediment pond data for beets and beans indicate that between 25 and 60 percent of the phosphorus leaving the field will be retained with the sediments in the settling pond.

Sediment Budget and Pond Balance

The material transported by moving water will either be the result of water's chemical (solvent) properties or will be the result of fluid energy due to motion. Most of the material transported by virtue of fluid velocity will be redeposited once the velocity of the water falls below some minimum value. On the other hand the materials that are transported due to the chemical properties of water will not be significantly influenced by changes in velocity. Generally the bulk of the material carried from a field with surface runoff will be the product of fluid velocity. However, the chemical and physical properties are not entirely separable. For example, many of the colloidal fractions that are suspended in water are picked up by fluid motion but will not precipitate when the water is ponded because of brownian movement; a chemical property. These inter-relationships between the physical and chemical properties of water make complete sediment removal extremely difficult.

Surface Sediment Balance

Generally it was observed that the solids removed from a field decreased as the erosion potential of that field decreased. During the cultivation season while the furrow is rough, the movement of sediments from the field will be high. Figure 19 indicates the amount of solids entering and leaving the beet field during both study seasons. The decrease in sediments leaving the tract after mid-July when cultivation is terminated is evident. This decrease in sediment movement is also, in part, the result of crop foliage impeding the flow of water in the furrows.

It was observed that not only is there a general decrease in the total solids removed from the tract as the irrigation season progresses but there may be a decrease with time during a given irrigation set. Figure 20 is a plot of solids leaving the onion field as a function of time during one irrigation set. These data suggest that, during the first half of the irrigation season, nearly 40 percent of the total solids removed with surface runoff may be lost during the first two hours of the set.[1] The general trend of the upper curve in Figure 20 tends to continue until cultivation is discontinued. By August 5, the data show the concentration of solids in the tailwater remained relatively constant during the entire set.

[1]The set illustrated by the upper curve of Figure 22 was selected because more water samples were collected during this period than were collected during most sets. The shorter sampling frequency tends to keep the errors due to linear averaging to a minimum.

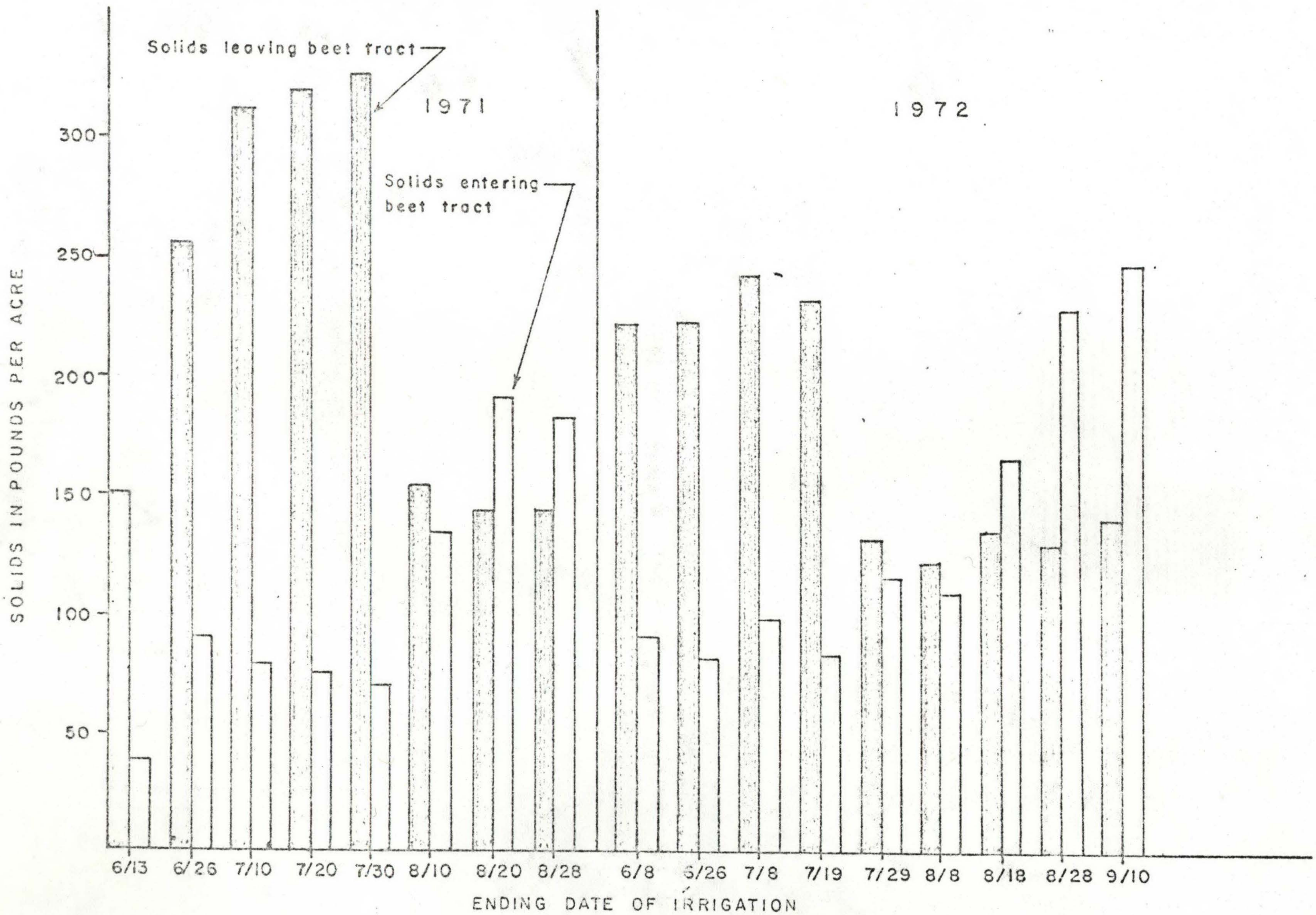


Figure 19: Solids entering and leaving tract during each sugar beet irrigation

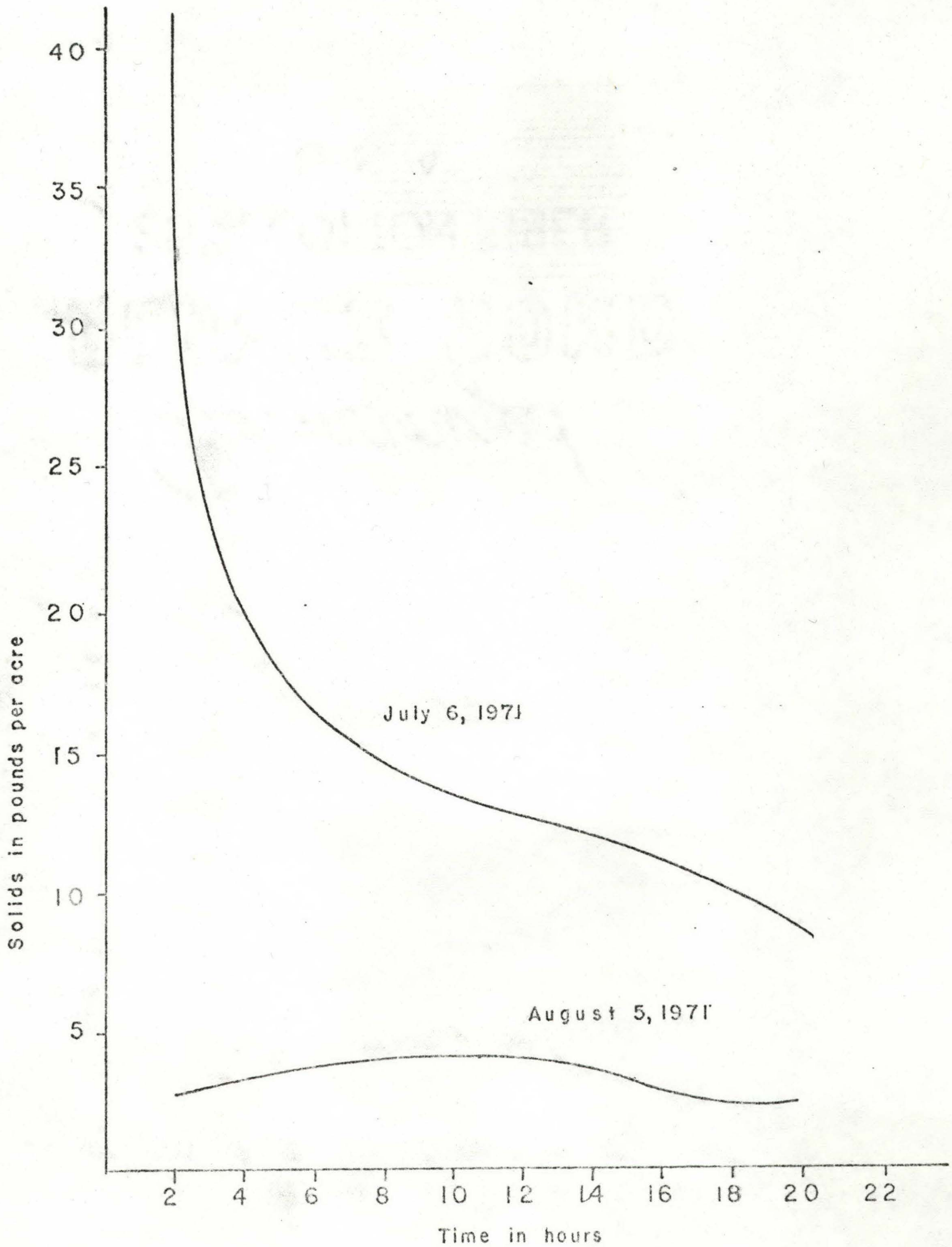


Figure 20: Solids leaving onion field during two selected sets

The data in Tables 5, 6, and 7 point out that the irrigation of onions resulted in the highest net loss of solids both years of the study. This result was to be expected since more water was diverted for onion irrigation than for either of the other two crops. When the ratio of water leaving the farm to solids leaving the farm is calculated for each crop, it is found that the solids removed per inch of runoff tended to be slightly higher for onions. The data given in Table 8 show the loss of solids per inch of runoff from onions to be consistently higher than the other two crops.

Table 8. The average amount of solids lost each season from beets, onions and beans, per inch of surface runoff

Season	Crop	Lb Solids / Inch Runoff
1971	Onions	220.5
1972	Onions	177.3*
1971	Beets	188.1
1972	Beets	72.6*
1972	Beans	138.9*

The starred quantities indicate those showing the influence of settling ponds.

The solids removed per acre-inch of runoff from onions decreased about 12 percent in 1972 from the 1971 level even though the total volume of runoff was about 32 percent greater in 1972. However, the loss of solids per acre-inch of runoff from sugar beets was decreased by 92 percent in 1972 while the total volume of runoff increased to about 2.5 times the 1971 seasonal total. The decrease observed during 1972 for both crops can be attributed to the settling pond. The apparent discrepancy in settling pond efficiency is more difficult to explain. These data appear to indicate that the runoff from onion irrigations carry more solids, which will not settle during retention in the pond, than does the runoff from sugar beets. This may be due to the fact that onions are irrigated with a smaller stream of water, which is set for a longer period of time thus allowing a longer period for materials in the irrigation furrow to go into solution.

In general, the greatest movement of sediments occurred at the head of the furrows where the water discharges from the siphon tubes into the furrows and at the end of the furrows where excess water discharges into the drainage ditch or settling pond. These are the areas where the water has the greatest velocity. Figure 21 shows a sediment fan at the end of one of the sugar beet furrows. A significant amount of down-cutting at the end of the furrow is apparent.

Figure 21: Sediment fan at the end of one irrigation furrow

During the later part of the season the movement of total solids from the farm tended to decrease while the total solids entering the farm tended to increase. The amount of solids carried onto the tract by the irrigation water was, on the average, higher in 1972 than in 1971. However, during both years the concentration of total solids in the headwater increased during the latter part of the irrigation season. There appear to be two probable explanations for this increase. During the latter part of the season the water from the drainage well represented a large percentage of the water used for irrigation. This water is always much higher in dissolved solids than the water delivered from the Boise River. For example in June of 1972 samples taken from the drainage well and the supply ditch showed 125.5 and 66.0 ppm. total solids respectively. There is also a normal increase in solids in the irrigation water as reservoir storage is depleted. When reservoirs are drawn down some of the water in bank storage flows back into the reservoir. This water generally is higher in total solids than water that has not been in such intimate contact with the soil. Frequently this water will flow through deposited sediments as it enters the reservoir which further increases its sediment load. As the reservoirs are drawn down the velocity of the water flowing into the reservoir from the river will increase and consequently increase its potential for transporting sediments.

It is difficult to treat the surface sediment balance without considering the influence of the settling ponds. This is because of the emphasis of this study. This emphasis was the determination of the materials that left through the outlet of the settling pond or drainage ditch from the farm and not necessarily those lost into the pond from a given field. For this reason it is more appropriate to continue the discussion of sediment loss in the pond balance section of this thesis.

Pond Balance

The settling ponds proved to be very effective in reducing the sediment loss from the farm. The data indicate that between 40 and 80 percent of the total solids carried from the fields by surface runoff were retained in the settling ponds. There was also a small general decrease in the nutrient load of the water during retention in the ponds.

During the 1972 season about one-half of the runoff from Field A ran directly into the sediment pond while the other half ran into the drainage ditch above the pond and thus could be measured. For this reason, all of the inflow measurements for beets were multiplied by a factor in the computer program to make total inflow volume equal total outflow volume.

The seasonal totals for the pond balance for the sugar beet and bean irrigations are given in Table 9. The data for the sugar beets indicate that while no nitrate retention was indicated a small net loss of ammonia may have occurred. The bean data on the contrary, show a net retention of every constituent. Because the pond balance for sugar beets was corrected making inflow and outflow volumes equal the estimates of the quantities of materials leaving the pond should be maximum values. Thus no less than 42 percent of the organic-N, 12 percent of the soluble phosphorus and 37 percent of the total-phosphorus should have been retained in the pond from the season's beet irrigations.

It would be expected that, while the other nutrients may be influenced to varying extents by the sediment settling out in the ponds, the nitrate nitrogen concentration of the water should remain constant. This assumption is supported by the sugar beet data, but the bean data indicate that nearly 50 percent of the nitrate entering the pond was retained. Approximately 19 percent of this change can be explained by water retention. The other 31 percent change, if it actually occurred, is difficult to explain. The data show 1.047 pounds per acre nitrate entering the pond during the season and only 0.529 pounds per acre leaving. While the percentage change is large, the quantity of change is small. Because the nitrate concentrations were generally low the experimental

Table 9: Pond balance for beets and beans for the 1972 season

	In	Out	Retained
BEETS			
Water $(\frac{A-In}{A})$	24.11*	24.11	0.00
NO_3-N (lb/A)	5.74	5.79	-0.05
NH_3-N	1.24	1.76	-0.52
Organic-N	6.36	3.69	2.67
Soluble-P	1.10	0.97	0.13
Total-P	2.25	1.41	0.84
Solids	2951.39	1726.26	1225.13
BEANS			
Water $(\frac{A-In}{A})$	5.53	4.49	1.04
NO_3-N	1.05	0.53	0.52
NH_3-N	0.20	0.17	0.03
Organic-N	3.02	1.33	1.68
Soluble-P	0.49	0.34	0.15
Total-P	1.75	0.70	1.05
Solids	3016.58	620.63	2394.95

*corrected to make inflow equal outflow

error may be quite high. The 1.047 pounds per acre nitrate that was estimated to have entered the pond represents an average value of 0.013 pounds per two-hour period. The average difference in nitrate value between inflow and outflow water is 0.006 pounds per two-hour period, or about 2.7 grams.

A simple analysis of variance was calculated using the nitrate and total phosphorus values for the bean pond data. These calculations are included in Tables 16 and 17 of Appendix A. They indicate that there is not a significant variance component added to the nitrate data due to retention in the pond. This statistical test implies that the difference in nitrate indicated in Table 9 is probably due to random error.

The analysis of variance for the total phosphorus data show a significant variance component added due to retention in the pond at all levels of significance. It appears from these tests that it is at least possible to determine statistically if the chemical constituent is affected by detention in a pond. If statistical significance is determined then the actual values estimated for that constituent may be presented with more confidence.

It is, of course, sediments that are of the most interest in the pond balance study. The quantities of sediments retained was quite variable. It was estimated that 1,225 pounds per acre (PPA) of the 2,951 PPA entering the pond from sugar beets were retained in the pond. This is a 41.5 percent retention rate. Beans on the other hand had 3,017 PPA entering the pond with 2,395 PPA retained or about a 79.4 percent retention rate. This indicates that a higher percentage of the total solids entering the pond from bean irrigation were sediments. This is possibly due to the fact that beans are cultivated for a larger percentage of their growing season than are the other two crops.

The ordinate values plotted in Figures 22 and 23 indicate the average quantity of solids, in pounds per acre, that enter and leave the pond for beets and beans during one irrigation. It is interesting to note that the average quantity of solids entering the pond from bean irrigation tends to increase as the season progresses while the average quantity of solids leaving the pond tends to decrease. The curves for sugar beets both have a negative trend. This is the tendency that would be normally expected.

Detention in the pond tends to damp out the magnitude of an event occurring at the pond inlet. The event, whether it be a sudden increase in sediment load or specific volume of fertilizer material entering the pond will be observed at the outlet for a longer period of time at a lower magnitude. During the sixth bean irrigation there is a peak in both curves of the bean data. Before this irrigation it was

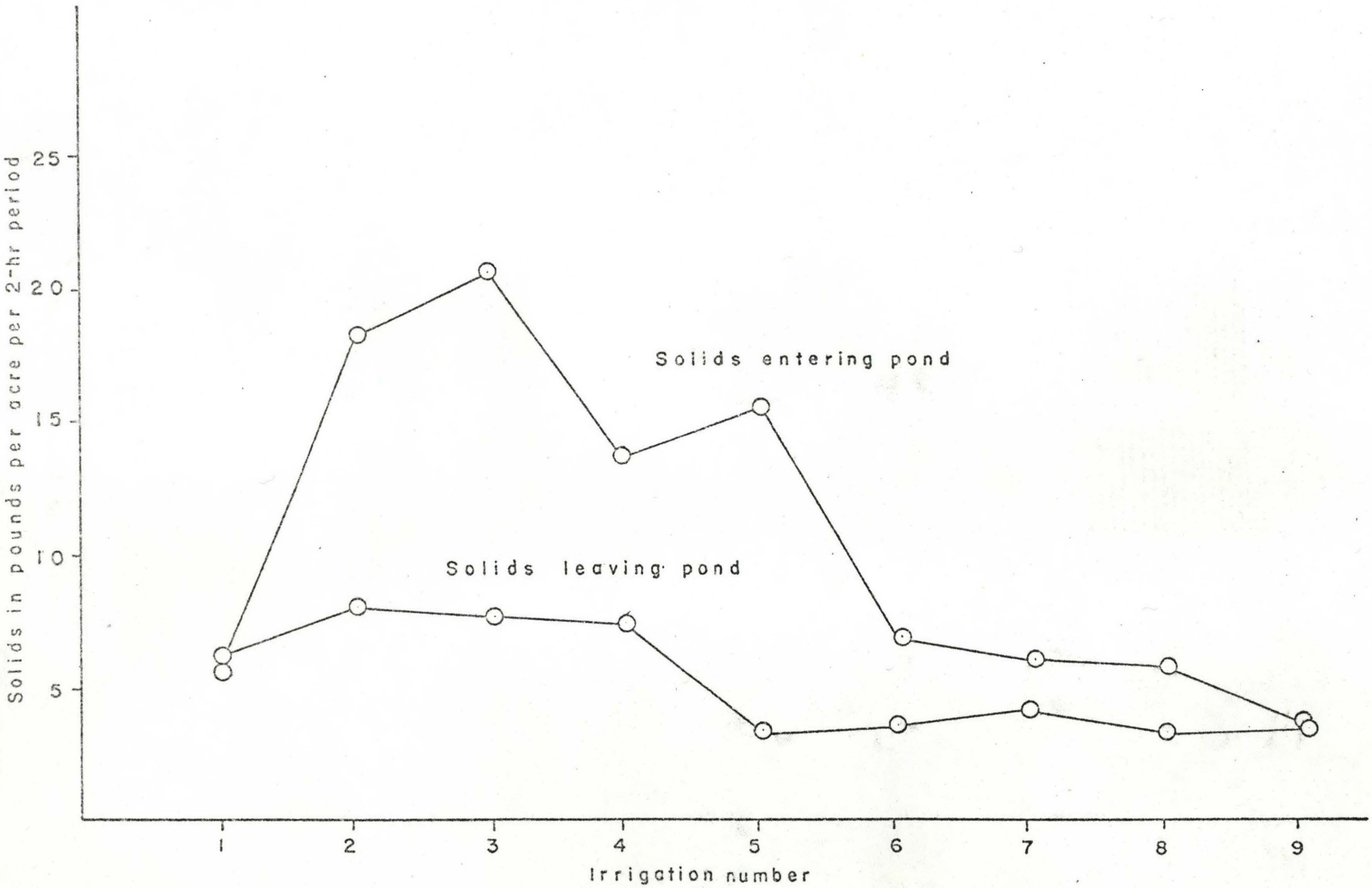


Figure 22: The average quantities of solids entering and leaving the pond during each sugar beet irrigation in 1972

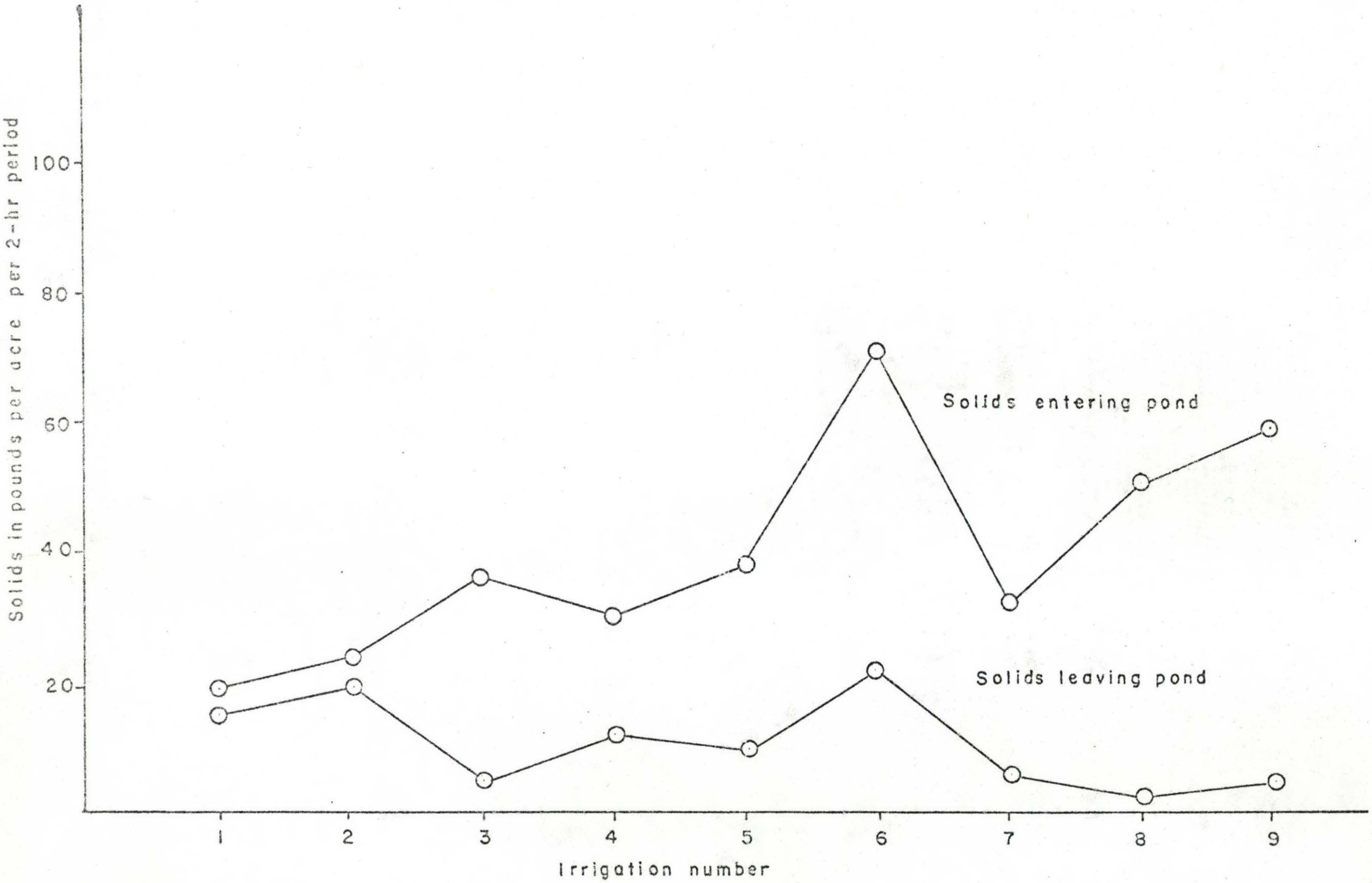


Figure 23: The average quantities of solids entering and leaving the pond during each bean irrigation of 1972

necessary to cultivate beans again as a disease control measure. This peak is probably the result of that cultivation.

Figure 24 shows two views of a sediment pond. The top picture was taken late in the season. The sediment build-up in the pond is apparent. The lower picture was taken facing west just above the point where the drainage ditch enters the pond. The channel extending into the pond is composed primarily of heavier sediments that were deposited when the velocity of the water was reduced upon entering the pond. This picture shows considerable erosion has taken place on the south side of the pond. This erosion takes place during each irrigation until the water in the pond is about at the same level as the individual irrigation furrows that drain directly into the pond. These eroded sediments probably account for the largest percentage of the sediments in the pond at the end of the season.

Figure 24: Entrance and outlet views of settling pond at the end of the 1972 irrigation season

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

The results of this study indicate that the amounts of nitrate present in surface irrigation runoff are not a serious threat to the environment and do not represent a significant loss to the farmer. Only on rare occasions were nitrate levels found to be higher than the levels allowed by EPA for human consumption. These occurred during periods that nitrogen was being added to the water. The nitrate concentrations declined rapidly after the application of nitrate to the headwater was stopped. However, it was observed that the actual loss of nitrate through surface runoff may be somewhat higher when liquid fertilizer is added to the water than when it is applied and plowed down or incorporated into the soil by side dressing.

Salts and sediments constituted the bulk of the material removed from the farm. The settling ponds installed in 1972 contributed substantially in reducing sediment loss. The removal of salts with the drainage water is important if this farm is to remain productive. Maintaining an acceptable salt balance is difficult under the poorly drained conditions that exist on this farm. However, the problem of salt build up appears to be well managed and is not yet a problem under the present management program.

DEFINITION OF TERMS

Control - the establishment of a condition where a definitive relationship exists between the stage and discharge of flow.

Drainage ditch - a ditch constructed to carry tailwater.

Evapotranspiration - the sum of the evaporation of water from plant and soil surfaces, and the transpiration of water extracted from the soil by the plant.

Field capacity - the amount of water a soil will retain against the pull of gravity.

Furrow irrigation - a method of irrigation in which furrows or corrugations (corrugations are generally considered to be smaller than a furrow) are constructed, at a definite spacing, parallel with the slope of the field, for the purpose of carrying the irrigation water to the crop.

Headwater - the water entering a field for the purpose of irrigation.

Infiltration rate - the rate at which water can enter the surface of a soil.

Irrigation efficiency - the ratio of water removed through evapotranspiration to the quantity of water delivered to the field during irrigation.

Percolation - the movement of water in the soil due to the pull of gravity.

Potential evapotranspiration - the maximum possible rate or evapotranspiration that could occur if soil moisture were not limiting and the crop canopy completely covering the soil.

A set - the specific combination of furrows into which water is being diverted at any one time.

Stage - the elevation or vertical distance of the free water surface above a datum.

Stilling well - a box or large-diameter pipe set vertically at one side of a connected stream or channel on which a water-level recorder is mounted. The purpose of the stilling well is to eliminate wave action and provide a still water surface.

Tailwater - excess irrigation water which leaves the field as surface runoff.

Water table - the locus of points in the saturated zone where the water pressure is atmospheric.

Wilting point - (permanent wilting point) - the soil-moisture content at which a plant will not recover after being placed in a saturated atmosphere where little or no evapotranspiration occurs.

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APPENDIX A

TABLE 1

FERTILIZATION SCHEDULE

1971 SEASON

33.5 ACRES OF ONIONS

TIME OF APPLICATION	METHOD OF APPLICATION	MATERIAL APPLIED	NO. OF LBS. (AVAILABLE) APPLIED
November (1970)	Broadcast	N - as Ammonium nitrate	60
November (1970)	Broadcast	P - as Super phosphate	140
November (1970)	Broadcast	K - as Potash	100
June (1971)	Sidedressed	N - as Anhydrous ammonia	80
June (1971)	In water	N - as Solution 32	16
July (1971)	In water	N - as Solution 32	21

TABLE 1 (Continued)

FERTILIZATION SCHEDULE

1971 SEASON

27 ACRES OF SUGAR BEETS

TIME OF APPLICATION	METHOD OF APPLICATION	MATERIAL APPLIED	NO. OF LBS (AVAILABLE) APPLIED
November (1970)	Broadcast	N as Ammonium nitrate	60
November (1970)	Broadcast	P - as Superphosphate	150
June (1971)	Sidedressed	N - as Anhydrous ammonia	100
June (1971)	In water	N - as Solution 32	14
July (1971)	In water	N - as Solution 32	4

TABLE 1 (Continued)

FERTILIZATION SCHEDULE

1971 SEASON

34 ACRES GREEN LIMA BEANS

TIME OF APPLICATION	METHOD OF APPLICATION	MATERIAL APPLIED	NO. OF LBS. (AVAILABLE) APPLIED
May (1971)	Broadcast	N - as Ammonium nitrate	80
May (1971)	Broadcast	P - as Superphosphate	50
May (1971)	Broadcast	Zn - as Zinc	8 (actual)

TABLE 2

FERTILIZATION SCHEDULE

1972 SEASON

34 ACRES OF ONIONS

TIME OF APPLICATION	METHOD OF APPLICATION	MATERIAL APPLIED	NO. OF LBS./ACRE (AVAILABLE) APPLIED
November (1971)	Broadcast	N - as Ammonium nitrate	80
November (1971)	Broadcast	P - as Superphosphate	150
November (1971)	Broadcast	K - as Potash	100
June (1972)	Sidedressed	N - as Anhydrous ammonia	90

TABLE 2 (Continued)

FERTILIZATION SCHEDULE

1972 SEASON

33.5 ACRES OF BEETS

TIME OF APPLICATION		METHOD OF APPLICATION	MATERIAL APPLIED	NO. OF LBS./ACRE (AVAILABLE) APPLIED
November	(1971)	Broadcast	N - as Ammonium nitrate	80
November	(1971)	Broadcast	P - as Superphosphate	180
June	(1972)	Sidedressed	N - as Anhydrous ammonia	100
July	(1972)	In water	N - as Solution 32	10

TABLE 2 (Continued)

FERTILIZATION SCHEDULE

1972 SEASON

27 ACRES OF GREEN LIMA BEANS

TIME OF APPLICATION	METHOD OF APPLICATION	MATERIAL APPLIED	NO. OF LBS./ACRE (AVAILABLE) APPLIED
April (1972)	Broadcast	N - as Ammonium nitrate	100
April (1972)	Broadcast	P - as Superphosphate	80
April (1972)	Broadcast	Zn - as Zinc	8 (actual)

Table 3 Crop-Beets Year-1971 Water Budget For Each Irrigation Given in Acre-Inches/Acre.

Irrigation Dates	Water On	Water Off	Water Applied	Water to ET (Between Irrigations)	Water To DP
June 11-13	3.22	0.95	2.27	1.50	0.35
June 25-26	3.27	0.90	2.37	2.86	0.00
July 9-10	2.99	0.88	2.11	3.35	0.00
July 19-20	2.98	1.18	1.79	2.22	0.00
July 29-30	3.17	1.11	2.06	2.64	0.00
Aug 8-10	4.55	1.36	3.19	2.66	-0.06
Aug 18-20	4.54	1.58	2.96	2.25	-0.41
Aug 26-28	4.73	1.58	3.15	1.29	1.16
Seasonal Average	3.73	1.20	2.53	2.34	--

Table 4 Crop-Onions Year-1971 Water Budget For Each Irrigation Given in Acre-Inches/Acre.

Irrigation Dates	Water On	Water Off	Water Applied	Water to ET (Between Irrigations)	Water To DP
June 7-11	5.97	2.08	3.89	0.98	2.48
June 21-25	4.74	2.59	2.15	2.93	-0.15
July 5-9	5.68	2.73	2.95	3.02	-0.71
July 15-19	6.14	2.56	3.58	2.05	1.55
July 25-29	6.23	2.34	3.88	2.45	1.42
Aug 4-8	5.91	1.56	4.35	1.13	2.07
Aug 15-16*	1.34	0.55	0.79	1.68	0.00
Seasonal Average	5.78	2.31	3.47	2.49	

*NOTE: Last irrigation is only included in the ET average because it was only a partial irrigation

Table 5 Crop-Beets Year-1972 Water Budget For Each Irrigation Given in Acre-Inches/Acre.

Irrigation Dates	Water On	Water Off	Water Applied	Water to ET (Between Irrigations)	Water To DP
June 5-8	3.61	1.48	2.14	1.00	0.64
June 23-26	4.20	1.98	2.22	3.07	0.00
July 5-8	3.64	2.13	1.51	3.20	0.00
July 16-19	3.89	2.04	1.85	2.97	-0.52
July 26-29	3.76	2.67	1.09	2.50	-0.76
Aug 5-8	4.97	2.67	2.31	2.52	-1.43
Aug 15-18	5.91	2.77	3.14	2.18	-0.11
Aug 25-28	6.45	2.66	3.78	2.31	0.00
Sept 7-10	6.56	2.93	3.63	2.43	1.11
Sept 19-22	6.56	2.80	3.77	1.72	2.05
Seasonal Average	4.95	2.41	2.54	2.48	

Table 6 Crop-Onions Year-1972 Water Budget For Each Irrigation Given in Acre-Inches/Acre.

Irrigation Dates	Water On	Water Off	Water Applied	Water to ET (Between Irrigations)	Water To DP
May 31-Jun 4	6.36	1.16	5.20	0.81	3.44
June 19-23	6.91	2.44	4.47	3.49	1.20
July 1-5	6.84	3.10	3.74	3.02	0.71
July 12-16	6.00	3.05	2.96	2.84	0.12
July 22-26	5.48	3.27	2.22	2.43	0.00
Aug 1-5	6.03	3.16	2.87	2.29	0.38
Aug 11-15	6.16	2.78	3.38	2.03	1.34
Seasonal Average	6.25	2.70	3.54	2.63	1.03

Table 7 Crop-Beans Year-1972 Water Budget For Each Irrigation Given in Acre-Inches/Acre.

Irrigation Dates	Water On	Water Off	Water Applied	Water to ET (Between Irrigations)	Water To DP
June 25-28	4.57	0.50	4.08	2.33	1.60
July 8-10	3.33	1.50	1.83	2.76	-0.39
July 19-21	2.53	0.86	1.67	3.18	-1.24
July 29-31	2.44	0.73	1.71	2.91	-1.40
Aug 9-11	3.20	0.90	2.30	3.21	-1.29
Seasonal Average	3.21	0.89	2.31	3.26	-0.63

Table 8 Year-1971 Mass Balance for Beets Given In Pounds Per Acre.

Date	Nitrate On	Nitrate Off	Nitrate Applied	Ammonia On	Ammonia Off	Ammonia Applied	Organic-N On	Organic-N Off	Organic-N Applied
June 11-13	0.11	0.11	0.00	0.67	0.27	0.40	3.22	1.12	1.10
June 25-26	2.79	0.90	1.89	11.16	2.09	9.07	1.39	1.31	0.08
July 9-10	0.68	0.14	0.54	2.83	0.75	2.08	2.66	5.25	-2.59
July 19-20	0.12	0.14	-0.02	0.37	0.28	0.09	1.62	2.65	-1.03
July 29-30	0.24	0.17	0.07	0.28	0.14	0.14	0.74	1.61	-0.87
Aug 8-10	0.25	0.12	0.13	1.50	0.13	1.37	2.09	0.94	1.15
Aug 18-20	0.18	0.08	0.10	1.62	0.15	1.47	1.46	1.34	0.12
Aug 26-28	0.18	0.10	0.08	1.54	0.15	1.39	1.46	1.34	0.12
Total	4.55	1.76	2.79	19.97	3.96	16.01	14.64	15.56	1.92

Table 8 (Continued) Year-1971 Mass Balance for Beets Given In Pounds Per Acre

Date	Soluble-P			Total-P			Solids		
	On	Off	Applied	On	Off	Applied	On	Off	Applied
June 11-13	0.12	0.08	0.04	0.16	0.27	-0.11	35.71	149.97	-114.26
June 25-26	0.14	0.09	0.05	0.15	0.14	0.01	88.13	255.38	-167.25
July 9-10	0.05	0.16	-0.11	0.14	0.43	-0.29	78.44	312.60	-234.16
July 19-20	0.06	0.12	-0.06	0.20	0.17	0.03	73.60	322.30	-248.70
July 29-30	0.06	0.17	-0.11	0.12	0.16	-0.04	67.78	324.63	-256.85
Aug 8-10	0.09	0.11	-0.02	0.10	0.09	0.01	133.28	153.40	-20.12
Aug 18-20	0.09	0.08	0.01	0.15	0.12	0.03	190.67	142.91	-47.76
Aug 26-28	0.09	0.07	0.02	0.10	0.05	0.05	182.10	142.91	-39.19
Total	0.70	0.89	-0.19	1.12	1.43	-0.31	859.71	1804.11	-944.40

Table 9 Year-1971 Mass Balance for Onions Given In Pounds Per Acre.

Date	Nitrate On	Nitrate Off	Nitrate Applied	Ammonia On	Ammonia Off	Ammonia Applied	Organic-N On	Organic-N Off	Organic-N Applied
June 7-11	0.23	0.32	-0.09	1.26	0.89	0.37	5.97	2.98	2.99
June 21-25	2.94	1.39	1.55	13.00	6.72	6.28	2.96	3.95	-0.99
July 5-9	4.74	1.03	3.71	16.15	2.78	13.37	4.95	9.00	-4.05
July 15-19	0.31	0.52	-0.21	0.95	0.54	0.41	4,81	7.50	-2.69
July 25-29	0.60	0.54	0.06	0.40	0.25	0.15	1.78	2.46	-0.68
Aug 4-8	0.44	0.12	0.32	1.66	0.17	1.49	3.10	0.89	2.21
Aug 15-16	0.06	0.03	0.03	0.44	0.05	0.39	0.44	0.49	-0.05
Total	9.32	3.95	5.37	33.86	11.40	22.46	24.01	27.27	-3.26

Table 9 (Continued) Year-1971 Mass Budget for Onions Given In Pounds Per Acre.

Date	Soluble-P On	Soluble-P Off	Soluble-P Applied	Total-P On	Total-P Off	Total-P Applied	Solids On	Solids Off	Solids Applied
June 7-11	0.22	0.20	0.02	0.26	0.35	-0.09	98.47	411.64	-313.17
June 21-25	0.18	0.24	-0.06	0.23	0.81	-0.58	167.92	590.08	-422.16
July 5-9	0.09	0.35	-0.26	0.21	2.34	-2.13	166.42	650.63	-484.21
July 15-19	0.24	0.26	-0.02	0.42	0.73	-0.29	142.92	744.84	-601.90
July 25-29	0.11	0.15	-0.04	0.29	0.48	-0.19	122.54	616.49	-493.95
Aug 4-8	0.11	0.15	-0.04	0.10	0.09	0.01	161.61	143.08	18.53
Aug 15-16	0.02	0.03	-0.01	0.04	0.04	0.00	37.15	50.22	-13.07
Total	0.97	1.39	-0.41	1.55	4.84	-3.29	897.05	3206.99	-2309.93

Table 10 Year-1972 Mass Balance for Beets Given In Pounds Per Acre.

Date	Nitrate On	Nitrate Off	Nitrate Applied	Ammonia On	Ammonia Off	Ammonia Applied	Organic-N On	Organic-N Off	Organic-N Applied
June 5-8	1.51	0.83	0.68	0.35	0.34	0.01	0.56	0.49	0.07
June 23-26	0.09	0.05	0.04	0.30	0.05	0.25	0.05	0.16	-0.11
July 5-8	1.77	0.93	0.84	2.10	0.84	1.26	1.23	0.45	0.78
July 16-19	0.06	0.06	0.00	0.16	0.21	-0.05	0.08	0.24	-0.16
July 26-29	0.28	0.19	0.09	0.02	0.07	-0.05	0.40	0.33	0.07
Aug 5-8	0.51	0.49	0.00	0.02	0.01	0.01	0.34	0.40	-0.06
Aug 15-18	0.98	0.62	0.36	0.03	0.01	0.02	0.37	0.28	0.09
Aug 25-28	1.53	0.73	0.80	0.03	0.01	0.02	2.96	0.31	2.65
Sept 7-10	1.42	0.77	0.65	0.02	0.02	0.00	0.91	0.48	0.43
Sept 19-22	1.30	1.09	0.21	0.36	0.20	0.16	0.81	0.55	0.26
Total	9.45	5.79	3.66	3.39	1.76	1.63	7.71	3.69	4.02

Table 10 (Continued) Year-1972 Mass Balance for Beets Given In Pounds Per Acre.

Date	Soluble-P			Total-P			Solids		
	On	Off	Applied	On	Off	Applied	On	Off	Applied
June 5-8	0.14	0.10	0.04	0.17	0.11	0.06	90.34	220.70	-130.36
June 23-26	0.14	0.12	0.02	0.22	0.27	-0.05	81.64	228.21	-146.60
July 5-8	0.16	0.15	0.01	0.31	0.35	-0.04	96.63	241.38	-144.75
July 16-19	0.14	0.15	-0.01	0.17	0.18	-0.01	83.20	229.62	-146.40
July 26-29	0.10	0.08	0.02	0.12	0.12	0.00	116.40	129.36	12.96
Aug 5-8	0.10	0.08	0.02	0.17	0.06	0.11	108.23	121.79	13.56
Aug 15-18	0.08	0.06	0.02	0.07	0.03	0.04	164.91	135.14	29.77
Aug 25-28	0.09	0.05	0.04	0.10	0.04	0.06	226.57	128.57	98.00
Sept 7-10	0.11	0.07	0.04	0.14	0.07	0.07	274.72	139.23	135.50
Sept 19-22	0.18	0.12	0.04	0.24	0.13	0.11	318.10	176.94	141.58
Total	1.24	0.98	0.24	1.71	1.36	0.35	1560.74	1750.94	-136.74

Table 11 Year-1972 Mass Balance for Onions Given In Pounds Per Acre.

Date	Nitrate On	Nitrate Off	Nitrate Applied	Ammonia On	Ammonia Off	Ammonia Applied	Organic-N On	Organic-N Off	Organic-N Applied
May 31-Jun 4	2.10	0.50	1.60	0.36	0.09	0.27	1.08	0.28	0.80
June 19-23	0.76	0.16	0.60	0.18	0.05	0.13	0.54	0.52	0.02
July 1-5	0.16	0.08	0.08	0.04	0.16	-0.12	0.23	0.50	-0.27
July 12-16	0.14	0.12	0.02	0.17	0.19	-0.02	0.76	1.20	-0.34
July 22-26	0.10	0.14	-0.14	0.03	0.02	0.01	0.60	1.08	-0.48
Aug 1-5	0.15	0.24	-0.09	0.03	0.02	0.01	0.56	0.17	0.39
Aug 11-15	0.75	0.60	0.15	0.03	0.01	0.69	0.44	0.47	-0.03
Total	3.68	1.84	1.84	0.70	0.54	0.16	4.22	5.12	-0.90

Table 11 (Continued) Year-1972 Mass Balance for Onions Given In Pounds Per Acre

Date	Soluble-P On	Soluble-P Off	Soluble-P Applied	Total-P On	Total-P Off	Total-P Applied	Solids On	Solids Off	Solids Applied
May 31-Jun 4	0.19	0.09	0.10	0.20	0.10	0.10	94.93	117.13	-22.20
June 19-23	0.23	0.17	0.06	0.31	0.24	0.07	72.05	287.01	-214.96
July 1-5	0.26	0.26	0.00	0.48	1.18	-0.70	143.95	525.31	-381.37
July 12-16	0.16	0.23	-0.07	0.20	0.45	-0.25	103.57	682.25	-300.15
July 22-26	0.38	0.30	0.08	0.24	0.63	-0.39	92.65	775.34	-682.69
Aug 1-5	0.19	0.30	-0.11	0.25	0.29	-0.04	91.08	814.40	-723.32
Aug 11-15	0.08	0.12	-0.04	0.08	0.14	-0.06	86.24	160.17	-73.93
Total	1.27	1.44	-0.17	1.78	3.04	-1.26	685.47	3361.61	-2676.14

Table 12 Year-1972 Mass Balance for Beans Given In Pounds Per Acre

Date	Nitrate On	Nitrate Off	Nitrate Applied	Ammonia On	Ammonia Off	Ammonia Applied	Organic-N On	Organic-N Off	Organic-N Applied
June 26-28	0.09	0.00	0.09	0.02	0.02	0.00	0.02	0.71	-0.69
July 8-10	0.05	0.06	-0.01	0.11	0.05	0.06	0.22	0.22	0.00
July 19-21	0.05	0.23	-0.18	0.09	0.08	0.01	0.02	0.15	-0.13
July 29-31	0.24	0.08	0.16	0.01	0.03	-0.02	0.14	0.12	0.02
Aug 9-11	0.41	0.15	0.26	0.02	0.00	0.02	0.27	0.14	0.13
Total	0.85	0.53	0.32	0.25	0.17	0.08	0.69	1.30	-0.61

Table 12 (Continued) Year-1972 Mass Balance for Beans Given
In Pounds Per Acre

Date	Soluble-P On	Soluble-P Off	Soluble-P Applied	Total-P On	Total-P Off	Total-P Applied	Solids On	Solids Off	Solids Applied
June 26-28	0.15	0.07	0.08	0.27	0.29	0.02	93.26	164.91	-71.65
July 8-10	0.11	0.10	0.01	0.15	0.10	0.05	67.95	172.88	-104.93
July 19-21	0.09	0.08	0.01	0.13	0.21	-0.08	58.13	152.97	-94.84
July 29-31	0.06	0.05	0.01	0.09	0.06	0.03	85.09	70.40	-14.69
Aug 9-11	0.05	0.04	0.01	0.04	0.04	0.00	58.65	60.49	-1.84
Total	0.46	0.34	0.12	0.69	0.70	0.01	363.08	621.64	-258.56

Table 13 The Analyses (in PPM NO_3) of Water from the Solution Samplers Installed in the Sugar Beet Field.

Date	Depth	Site 1 North	2 North	1 South	2 South
6/8	1	--	250.00	12.50	7.50
	2	200.00	--	25.50	36.50
	3	167.50	195.00	62.50	68.00
	4	87.50	--	120.00	40.50
	5	85.00	--	10.00	35.00
6/27	1	--	--	5.00	13.00
	2	170.00	--	23.00	13.50
	3	130.00	200.00	190.00	56.00
	4	190.00	147.50	47.50	58.00
	5	120.00	80.00	35.50	82.50
7/9	1	--	--	--	--
	2	78.13	250.00	--	12.50
	3	137.51	103.13	--	43.75
	4	103.13	81.26	40.63	28.13
	5	84.38	65.63	25.00	68.75

Table 14 Analyses of Ground Water Samples Collected During 1972. Piezometers Numbered as Shown in Figure 1 of Appendix A.

Sampling Date	Piezo-meter	pH	E.C.	ppm elec-trode NO_3-N	ppm NO_3-N	ppm NH_3-N	ppm Organic N	ppm Phos Soluble	ppm Phos Total	ppm Solids
2/3/72	1	8.00	0.55	5.80	5.80	0.220	0.480	0.10	0.22	408
	2	7.90	1.20	74.00	77.60	2.010	0.600	0.10	0.32	971
	3	7.80	0.70	17.00	16.80	0.010	0.600	0.36	0.80	666
	4	8.00	0.70	17.00	17.20	0.180	0.440	0.24	0.42	569
	5	7.75	0.55	15.00	15.20	0.010	0.060	0.24	0.46	492
	6	8.05	1.15	8.60	8.60	0.010	0.140	0.44	0.80	938
	7	7.40	0.85	12.00	12.80	0.010	0.380	0.20	0.70	834
	8	7.70	0.95	36.00	34.80	0.300	0.400	0.34	0.88	840
	9	8.40	0.70	7.60	7.60	0.140	0.200	0.40	0.54	498
	10	8.10	0.55	5.20	N.S.	0.560	0.080	0.48	0.64	419

Table 14 (con't) Analyses of Ground Water Samples Collected During 1972. Piezometers Numbered as Shown in Figure 1 of Appendix A.

Sampling Date	Piezo-meter	pH	E.C.	ppm elec-trode NO_3-N	ppm NO_3-N	ppm NH_3-N	ppm Organic N	ppm Phos Soluble	ppm Phos Total	ppm Solids
6/21/72	1	8.20	0.35	2.40	2.50	0.080	0.300	0.24	0.30	270
	2	8.20	1.15	44.00	56.00	0.080	0.360	0.22	0.32	1154
	3	8.20	0.65	16.00	12.60	N.S.	N.S.	0.40	0.72	595
	4	8.30	0.70	14.00	16.60	0.060	0.380	0.44	0.60	619
	5	8.15	0.45	8.50	8.70	0.060	0.200	0.32	0.52	441
	6	8.40	1.10	5.40	4.90	0.020	0.240	0.58	0.84	858
	7	8.00	1.00	9.20	9.70	0.060	0.240	0.32	0.68	1202
	8	8.15	0.80	25.00	21.20	0.140	0.360	0.38	0.66	1222
	9	8.35	0.60	6.00	6.60	N.S.	N.S.	0.48	0.68	467
	10	8.25	0.60	3.20	3.00	N.S.	N.S.	0.88	1.34	556

Table 14 (con't) Analyses of Ground Water Samples Collected During 1972. Piezometers Numbered as Shown in Figure 1 of Appendix A.

Sampling Date	Piezo-meter	pH	E.C.	ppm elec-trode NO_3-N	ppm NO_3-N	ppm NH_3-N	ppm Organic N	ppm Phos Soluble	ppm Phos Total	ppm Solids
7/20/72	1	8.50	0.35	2.95	2.35	0.015	0.030	0.08	0.08	284
	2	8.70	1.10	40.00	55.80	0.015	0.135	0.02	0.08	997
	3	8.30	0.70	11.00	12.45	1.005	0.100	0.14	0.38	572
	4	8.45	0.60	7.45	8.70	0.005	0.090	0.32	0.40	468
	5	8.10	0.55	4.00	4.15	0.015	0.070	0.10	0.24	434
	6	8.60	1.05	4.30	3.60	0.015	0.075	0.32	0.44	796
	7	8.10	0.90	8.60	8.85	0.005	0.095	0.02	0.36	640
	8	8.50	0.75	24.00	26.10	0.010	0.110	0.06	0.16	765
	9	8.60	0.65	6.60	6.10	0.005	0.095	0.10	0.60	976
	10	8.65	0.45	1.35	1.30	0.040	0.055	0.20	0.20	417

Table 14 (con't) Analyses of Ground Water Samples Collected During 1972. Piezometers Numbered as Shown in Figure 1 of Appendix A.

Sampling Date	Piezometer	pH	E.C.	ppm electrode NO_3-N	ppm NO_3-N	ppm NH_3-N	ppm Organic N	ppm Phos Soluble	ppm Phos Total	ppm Solids
8/23/72	1	8.50	0.40	1.40	0.50	0.100	0.080	0.10	0.12	286
	2	8.60	1.15	48.00	46.50	0.035	0.145	0.06	0.16	870
	3	8.70	0.70	14.00	12.50	--	--	0.14	0.32	587
	4	8.70	0.65	7.80	6.50	0.003	0.095	0.32	0.38	840
	5	8.80	0.45	3.20	2.30	0.003	0.080	0.08	0.36	1071
	6	8.80	1.05	4.30	3.45	0.003	0.080	0.34	0.38	780
	7	8.60	0.90	7.60	8.00	--	--	0.08	0.22	738
	8	8.55	0.95	27.50	32.00	0.095	0.120	0.10	0.30	865
	10	8.80	0.45	0.70	0.20	0.003	0.060	0.28	0.30	346
	Drain Well	8.60	0.40	2.20	1.70	0.003	0.035	0.10	0.10	322

Table 15 Cations and Anions (in ppm and meq/liter) Present in One Set of Ground Water Samples.

meq/liter

Sampling Date	Piezometer	Ca	Mg	Na	K	Total Cations	HCO_3	CO_3	Cl_2	SO_4	Total Anions
7/20/72	1	0.18	0.61	2.75	0.09	3.63	3.58	1.49	0.20	0.17	5.44
	2	0.72	4.31	4.50	0.12	9.65	0.67	1.94	0.89	4.22	7.72
	3	0.32	1.70	3.60	0.17	5.79	5.74	2.54	0.59	1.45	10.32
	4	0.16	0.93	4.65	0.06	5.80	4.55	2.24	0.20	0.91	7.90
	5	0.24	1.29	1.80	0.07	3.40	5.00	1.19	0.30	0.82	7.31
	6	0.15	2.36	7.95	0.04	10.50	7.39	3.13	0.69	3.62	14.83
	7	0.69	5.25	1.60	0.03	7.57	8.73	1.04	0.59	2.58	12.94
	8	0.29	2.98	3.00	0.10	6.37	3.81	2.84	0.99	1.09	8.73
	9	0.14	1.54	4.35	0.06	6.09	3.06	5.82	0.39	1.38	10.65
	10	0.07	1.80	1.25	0.11	3.23	2.91	2.69	2.09	0.37	5.97

Table 15 (con't) Cations and Anions (in ppm and meq/liter) Present in One Set of Ground Water Samples.

ppm

Sampling Date	Piezo-meter	Ca	Mg	Na	K	Total Cations	HCO_3	CO_3	Cl_2	SO_4	Total Anions
7/20/72	1	3.50	7.50	63.25	3.51	77.76	218.38	44.70	7.00	8.16	322.94
	2	14.40	52.50	103.50	4.69	175.09	40.87	58.20	31.15	202.56	332.78
	3	6.40	20.63	82.80	6.63	116.46	350.14	76.20	20.65	69.60	516.59
	4	3.20	11.25	106.95	2.34	123.74	277.55	67.20	7.00	43.68	395.43
	5	4.80	15.63	41.40	2.73	64.56	305.00	35.70	10.50	39.36	390.56
	6	3.00	28.75	182.85	1.56	216.16	450.79	93.90	24.15	173.76	742.60
	7	13.80	63.75	36.80	1.17	115.52	532.53	31.20	20.65	123.84	708.22
	8	5.80	36.25	69.00	3.90	114.95	232.41	84.20	34.65	52.32	403.58
	9	2.80	18.75	100.05	2.34	123.94	186.66	174.60	13.65	66.24	411.12
	10	1.40	21.88	28.75	4.29	56.32	177.51	80.70	23.15	17.76	275.97

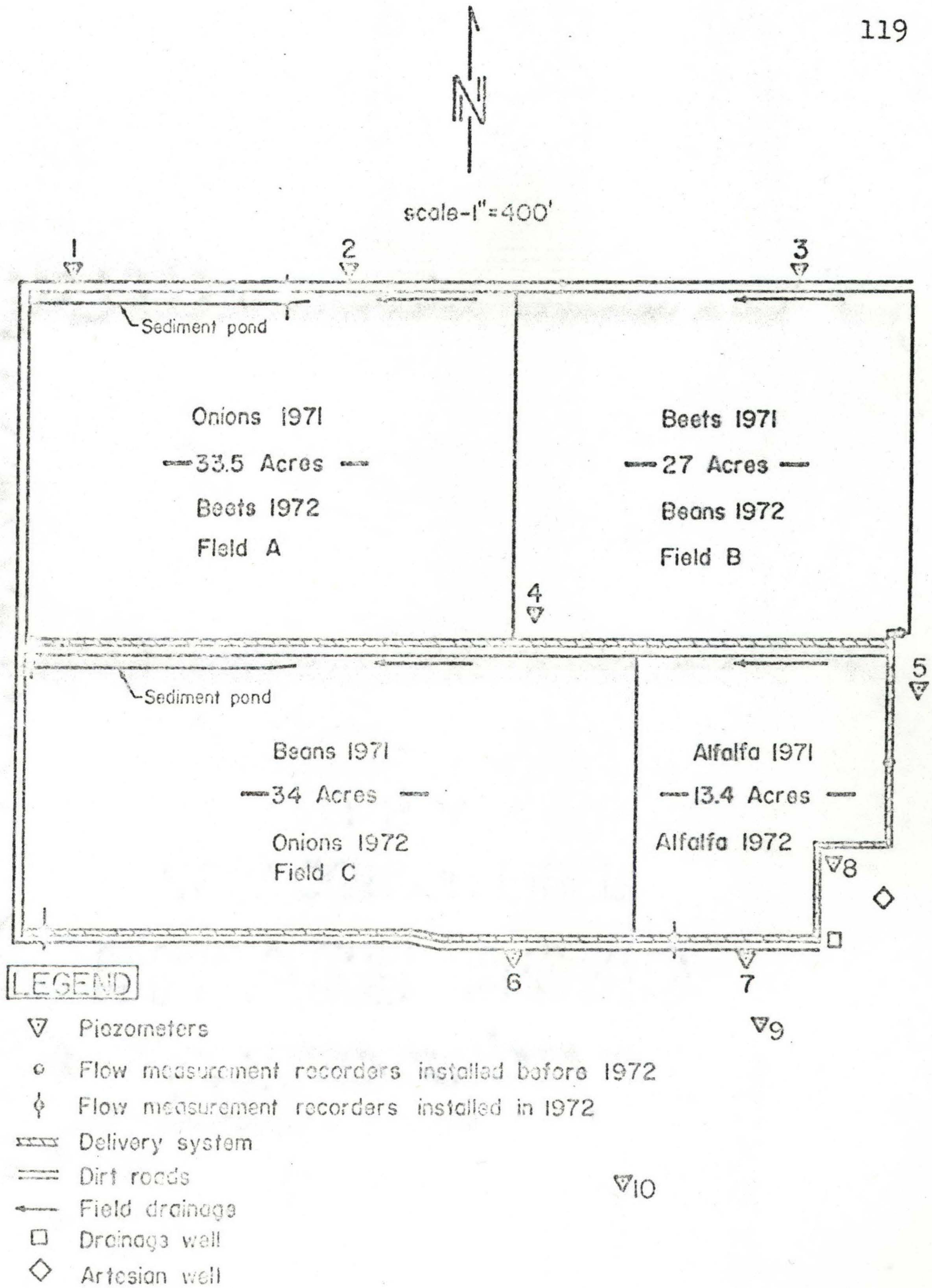

Figure 1: Site map showing piezometer numbering system

Table 16 Analysis of Variance Calculations For NO_3 From Bean Pond Balance Data

Design: Two locations (entrance and outlet of pond) with 82 entrance and 73 outlet samples.
$a = 2 \qquad n = 155$

1. Grand Total $= \sum^{a}\sum^{n} Yij = 1.047 + 0.529 = \underline{1.576}$

2. Sum of squared obs. $= \sum^{a}\sum^{n} Y^2 = 0.047095 + 0.063389$

$$\sum^{a}\sum^{n} Y^2 = \underline{0.110484}$$

3. Sum of squared group totals

$$\sum^{a} \frac{(\sum^{n} Y)^2}{ni} = \frac{1.096209}{82} + \frac{0.279841}{73} = \underline{0.0172018}$$

4. Correction term $= \dfrac{(\sum\sum^{an} Y)^2}{\sum^{a} ni} = \dfrac{2.483776}{155} = \underline{0.0160243}$

5. $SS_T = 0.110484 - 0.0160243 = \underline{0.0944597}$

6. $SS_6 = 0.0172018 - 0.0160243 = \underline{0.0011775}$

7. $SS_{W/IN} = SS_T - SS_6 = 0.0944597 - 0.0011775 = \underline{0.0926847}$

Source of Variation		df	SS	MS	FS
Y - Y	Between Sites	1	0.001157	0.00157	1.96
Y - Y	W/In Sites	153	0.092685	0.000606	

Table 16 (con't) Analysis of Variance Calculations For NO_3 From Bean Pond Balance Data

$F_{.05}[1,\infty] = 3.84$ $F_{.10}[1,\infty] = 2.71$

CONCLUSION: There is no significant added variance component due to retention of nitrate in the pond.

Table 17 Analysis of Variance Calculations For Total P From Bean Pond Balance Data

Design: Two locations (entrance and outlet of pond) with 86 entrance and 77 outlet samples.
$a = 2$ $n = 163$

1. Grand Total $= \sum^{a}\sum^{n} Yij = 1.754 + 0.703 = \underline{2.457}$

2. Sum of squared obs. $= \sum^{a}\sum^{n} Y^2 = 0.062485 + 0.0214407$

$$\sum^{a}\sum^{n} Y^2 = 0.083926$$

3. Sum of squared group totals $= \sum^{a} \frac{(\sum^{n} Y)^2}{ni}$

$$\sum^{a} \frac{(\sum^{n} Y)^2}{ni} = \frac{3.07652}{86} + \frac{0.49421}{77} = \underline{0.042192}$$

4. Correction term $= \frac{(\sum^{a}\sum^{n} Y)^2}{\sum^{a} ni} = \frac{6.03684}{163} = \underline{0.037036}$

5. $SS_T = 0.083926 - 0.037036 = \underline{0.0468899}$

6. $SS_{GP} = 0.042192 - 0.037036 = \underline{0.005156}$

7. $SS_{W/IN} = 0.046890 - 0.005156 = \underline{0.041334}$

Source of Variation	df	SS	MS	FS
Y - Y Between Sites	1	0.005156	0.005156	
Y - Y W/In Sites	161	0.041734	$\frac{0.041734}{161}$	19.89

Table 17 (con't) Analysis of Variance Calculations For Total P From Bean Pond Balance Data

$F_{.05}[1,\infty] = 3.84$ $F_{.10}[1,\infty] = 2.71$

CONCLUSION: There is a significant added variance component due to retention of Total P in the pond.

APPENDIX B

SUBROUTINE HDGEN

```
C
C*****************************************************************************
C
C    SUBROUTINE HDGEN  GENERATES PROPER ALPHAMERIC HEADINGS FOR THE
C    DATA TO BE PRINTED OUT FOR THE STUDY PERIOD
C
C    THE MONTHS, DAYS AND PERIODS ARE ARRANGED IN ARRAYS OF
C      ALPHAMERIC DATA THAT ARE USED FOR PRINTOUT HEADINGS
C      IN THE MAIN PROGRAM.
C
C
C    SUBROUTINE HDGEN WILL GENERATE HEADINGS FROM MARCH 1
C      TO NOVEMBER 30. THE MAX NUMBER OF DAYS ALLOWED IS 125.
C
C    DESCRIPTION OF VARIABLES
C      MB ----- NUMBER OF THE MONTH THE STUDY BEGAN
C      KDB ---- NUMBER OF THE DAYS WITHIN MB THE STUDY BEGAN
C      ME ----- NUMBER OF THE MONTH THE STUDY ENDED
C      KDE ---- NUMBER OF THE DAY WITHIN ME THE STUDY ENDED
C      NDAY --- NUMBER OF DAYS WITHIN THE STUDY PERIOD
C      NPD ---- NUMBER OF 2-HOUR TIME PERIODS IN STUDY PERIOD
C      LMP ---- PERIOD ARRAY OF MONTHS
C      LDP ---- PERIOD ARRAY OF DAYS
C      LPP ---- PERIOD ARRAY OF PERIODS
C      LMD ---- DAILY ARRAY OF MONTHS
C      LDD ---- DAILY ARRAY OF DAYS
C
C*****************************************************************************
C
      SUBROUTINE HDGEN (MB,KDB,ME,KDE,NDAY,NPD)
      COMMON Q(3,1500),CONC(3,1500),LMP(1500),LDP(1500),LPP(1500),
     *LMD(125),LDD(125)
      DIMENSION M(12)
```

```
      DATA M(3),M(4),M(5),M(6),M(7),M(8),M(9),M(10),M(11)/'MAR','APR',
     @'MAY','JUN','JUL','AUG','SEP','OCT','NOV'/
C
C  CALCULATE THE NUMBER OF PERIODS AND THE NUMBER OF DAYS IN THE STUDY
C
      NDAY=0
      IF(MB.EQ.ME) GO TO 8
      MB1=MB+1
      DO 10 MONTH=MB1,ME
      NDAYM=31
      IF(MONTH.EQ.5.OR.MONTH.EQ.7.OR.MONTH.EQ.10)NDAYM=30
   10 NDAY=NDAY+NDAYM
    8 NDAY=NDAY+KDE-KDB+1
      NPD=NDAY*12
C
C  CALCULATE HEADINGS OF MONTH, DAY, AND PERIOD WITHIN THE DAY WITH EACH
C     SUBSCRIPTED BY THE PERIOD OF THE TOTAL 1-D PERIOD ARRAY.
C     LIKEWISE THE DAILY HEADINGS OF MONTH AND DAY SUBSCRIPTED BY DAY OF
C     THE TOTAL 1-D DAY ARRAY.
C
      KSP=0
      KSD=0
      DO 30 MONTH=MB,ME
      NDM=31
      IF(MONTH.EQ.4.OR.MONTH.EQ.6.OR.MONTH.EQ.9)NDM=30
      IF(MONTH.EQ.ME)NDM=KDE
C
C   START FROM BEGINING DATE FOR FIRST MONTH
C
      NDMB=1
      IF(MONTH.EQ.MB)NDMB=KDB
C
C   GENERATE DATE-HEADING SUBSCRIPTS
C
      DO 30 KDY=NDMB,NDM
C
C   GENERATE DAILY SUBSCRIPTS
```

```
C
      KSD=KSD+1
      LDD(KSD)=KDY
      LMD(KSD)=M(MONTH)
C
C   GENERATE PERIOD SUBSCRIPTS
C
      DO 30 KPD=1,12
      KSP=KSP+1
      LMP(KSP)=M(MONTH)
      LDP(KSP)=KDY
      LPP(KSP)=KPD
   30 CONTINUE
C
      WRITE (3,99) NPD
   99 FORMAT(5X,'NPD = 'I4)
C
      RETURN
```

SUBROUTINE FLOWIN

```
C
C*******************************************************************************
C
C     SUBROUTINE FLOWIN READS THE STAGE FOR SPECIFIED TIME
C       INCREMENTS AS OUTLINED IN THE MAIN PROGRAM AND COMPUTES
C       THE DISCHARGE FOR THE PROPER WEIR.
C
C     IF THE DISCHARGE IS TO BE READ IN DIRECTLY, A '1' IS PLACED
C       IN COLUMN 5 OF THE SPECIFIED DATA CARD.
C
C     ONE CARD MUST BE USED FOR EACH DAY'S RECORD THAT IS ENTERED,
C       HOWEVER,NO DATA NEED BE ENTERED IF THE STAGE OR DISCHARGE
C       DOES NOT CHANGE FOR A PERIOD OF TIME RANGING FROM SEVERAL
C       2-HOUR TIME PERIODS UP TO SEVERAL WEEKS.  SUBROUTINE FLOWIN
C       WILL LINEARLY AVERAGE ALL MISSING DATA BETWEEN THE TWO
C       POINTS BOUNDING THE MISSING DATA.
C
C     SUBROUTINE FLOWIN CALCULATES THREE DISCHARGE RATES
C       FOR EACH TIME PERIOD, Q-ON, Q-OFF, AND Q-APPLIED.
C
C     THE DATA ARE PASSED TO THE MAIN PROGRAM AS A 2-D ARRAY,
C       IN COMMON STORAGE Q(LOCATION,TIME PERIOD).
C
C     A BLANK CARD IS USED TO SIGNAL THE COMPLETION OF DATA FOR A WEIR.
C
C     DESCRIPTION OF VARIABLES
C       NWEIR -- NUMBER OF DIFFERENT WEIRS FOR WHICH DATA ARE
C                TO BE READ IN
C       Q------- DISCHARGE ARRAY TO BE PASSED TO THE MAIN PROGRAM
C       QH ----- DISCHARGE OR STAGE DATA READ INTO FLOWIN
C       KWEIR -- THE NUMBER OF THE WEIR FOR WHICH DATA ARE
C                PRESENTLY READ AND CORRECT DISCHARGE COMPUTED
C       KMO ---- NUMBER OF THE MONTH
```

```
C       KDB ---- NUMBER OF THE DAY WITHIN THE MONTH THAT
C                THE STUDY BEGAN
C       MB ----- NUMBER OF THE MONTH THE STUDY BEGAN
C       NPD ---- NUMBER OF 2-HOUR TIME PERIODS IN THE STUDY
C                CALCULATED IN SUBROUTINE HOGEN
C       KPD ---- THE TIME PERIOD WITHIN THE Q-ARRAY
C       KDY ---- THE NUMBER OF THE DAY
C       KPER --- THE TIME PERIOD WITHIN THE DAY
C       KPD ---- THE TIME PERIOD WITHIN THE 2-D ARRAY
C       KWF ---- BRANCH CONTROL FOR THE PROPER WEIR FORMULA
C                VALUES OF KWF AND THE CORRESPONDING WEIR
C                  1 -- 2 FOOT CIPOLLETTI.
C                  2 -- 3 FOOT CIPOLLETTI
C                  3 -- 2 FOOT CONTRACTED RECTANGULAR
C                  4 -- 6 INCH PARSHALL FLUME
C                  5 -- 2 FOOT SUPPRESSED TRAPEZOIDAL WITH 1:1 SIDE SLOPES
C       KL1 ---- A COUNTER
C       KBD ---- A COUNTER
C
C*************************************************************************
C
        SUBROUTINE FLOWIN ( MB,KDB,NPD)
        COMMON Q(3,1500),CONC(3,1500),LMP(1500),LDP(1500),LPP(1500),
       *LMD(125),LDD(125)
        DIMENSION KPER(7),QH(7),MD(12)
        DATA MD/31,28,31,30,31,30,31,31,30,31,30,31/
C
C     INITIALIZE
C
        KMB=MB
        KPD=1
        DO 1 KZ=1,NPD
        DO 1 KQ = 1,3
      1 Q(KQ,KZ)=0.
C
C     READ IN 'NWEIR', THE NUMBER OF WEIRS FOR WHICH DATA ARE ENTERED
C       DATA FROM UP TO 3 WEIRS CAN BE USED TO DETERMINE THE HEADWATER
```

```
C       FLOW RATE.  THE SEQUENCING FOR 'KWEIR' WOULD BE AS FOLLOWS:
C            FOR 2 WEIRS -- 1 2
C            FOR 3 WEIRS -- 1 2 2
C            FOR 4 WEIRS -- 1 2 3 2
C
C                                 <----------------------------READ DATA------
        READ (1,100) NWEIR
C
C     READ IN THE PROPER WEIR NUMBER, AND READ AND ARRANGE
C       THE DATA FOR THAT WEIR.
C
        DO 40 KL1=1,NWEIR
        IF (KL1.LT.NWEIR) GOTO5
        DO 6 KQ=1,NPD
        Q(1,KQ)= Q(1,KQ)-(Q(2,KQ)+Q(3,KQ))
        Q(2,KQ) = 0.
      6 Q(3,KQ) = 0.
C
C                                 <----------------------------READ DATA------
      5 READ (1,100)KWEIR,KWF
    100 FORMAT (2I1)
C
C                                 <----------------------------READ DATA------
     10 READ(1,101)KMO,KDY,KDIR,(KPER(KPC),QH(KPC),KPC=1,7)
    101 FORMAT (2I2,I1,5X,7(I2,F8.0))
C
C     A BLANK CARD SIGNALS THE END OF DATA FOR A PARTICULAR WEIR
C
        IF (KMO) 40,40,11
C
C     CALCULATE THE NUMBER OF DAYS SINCE THE BEGINNING OF THE STUDY
C
     11 NODAY=0
        IF(KMO.LE.KMB) GOTO 71
     72 KMO1=KMO-1
        DO 70 KMD=KMB,KMO1
     70 NODAY = NODAY + MD(KMD)
```

```
   71 NODAY = NODAY + KDY-KDB
C
C   GIVE THE DATA PROPER SUBSCRIPTS FOR THE PASSING 2-D ARRAY
C
   12 DO 39 KPC=1,7
      IF(KPER(KPC))10,10,15
   15 KPD1=KPD
      KPD =(NODAY)*12 + KPER(KPC)
C
C   BRANCH TO THE PROPER WEIR FORMULA
C
      IF (KDIR)30,16,30
   16 GOTO (21,22,23,24,25),KWE
   21 Q(KWEIR,KPD)= 6.74*(QH(KPC)**1.5)
      GOTO 34
   22 Q(KWEIR,KPD) = 10.11*(QH(KPC)**1.5)
      GOTO 34
   23 Q(KWEIR,KPD) = 3.33*(2. -0.2*QH(KPC))*(QH(KPC)**1.5)
      GO TO 34
   24 Q(KWEIR,KPD) = 2.06*(QH(KPC)**1.58)
      GO TO 34
   25 Q(KWEIR,KPD)= 8.7 *(QH(KPC)**1.9)
      GO TO 34
   30 Q(KWEIR,KPD) = QH(KPC)
C
C   LINEARLY ARRANGE ALL MISSING DATA BETWEEN BOUND POINTS
C
   34 NPZ=KPD-KPD1
      IF (NPZ-1)39,39,35
   35 QINC=(Q(KWEIR,KPD)-Q(KWEIR,KPD1))/NPZ
      NPZ=NPZ-1
      DO 36 KBD=1,NPZ
      KBD1=KPD1+KBD
   36 Q(KWEIR,KBD1)=Q(KWEIR,KPD1)+KBD*QINC
```

```
   39 CONTINUE
      GOTO 10
   40 CONTINUE
C
C     CALCULATE THE PROPER FLOW RATE FOR THE PROPER LOCATION
C
   42 DO 45 KPD=1,NPD
   45 Q(3,KPD)= Q(1,KPD) - Q(2,KPD)
   50 CONTINUE
      RETURN
```

```
                  SUBROUTINE  CHEMIN

C
C*****************************************************************************
C
C
C     SUBROUTINE CHEMIN READS THE CONCENTRATION OF A CHEMICAL
C       CONSTITUENT FOR  SPECIFIED TIME INCREMENTS AS OUTLINED
C       IN THE MAIN PROGRAM.
C
C     ONE CARD MUST BE USED FOR EACH DAY'S RECORD THAT IS
C       ENTERED, HOWEVER, DATA NEED NOT BE ENTERED IF THE CON-
C       CENTRATION DOES NOT CHANGE OR IF DATA ARE MISSING.
C       SUBROUTINE CHEMIN WILL LINEARLY AVERAGE ALL MISSING DATA
C       BETWEEN POINTS BOUNDING THE MISSING DATA.
C
C     THE DATA ARE PASSED TO THE MAIN PROGRAM AS A 2-D ARRAY
C       IN COMMON STORAGE, CONC(LOCATION,TIME PERIOD)
C
C     A BLANK CARD IS USED TO SIGNAL THE COMPLETION OF THE
C       DATA FOR A PARTICULAR CONSTITUENT AT A PARTICULAR LOCATION.
C
C
C     DESCRIPTION OF VARIABLES
C       CNCP --- CONCENTRATIONS READ INTO SUBROUTINE CHEMIN
C       CONC --- CONCENTRATION ARRAY TO BE PASSED TO THE MAIN
C                PROGRAM
C       NOSITE - NUMBER OF SITES FOR WHICH DATA ARE TO BE
C                READ FOR THE PARTICULAR CONSTITUENT
C       MB ----- NUMBER OF MONTH THE STUDY BEGAN
C       KDB ---- NUMBER OF DAY WITHIN MB THAT THE STUDY BEGAN
C       NPD ---- NUMBER OF 2-HOUR TIME PERIODS WITHIN THE
C                STUDY PERIOD
C       KMO ---- NUMBER OF THE MONTH FOR WHICH DATA ARE BEING
C                READ IN
```

```
C       KCHEM -- THE NUMBER OF THE LOCATION FOR WHICH DATA ARE
C                PRESENTLY BEING READ AND ARRANGED
C     THE VALUES OF KCHEM AND THEIR CORRESPONDING LOCATIONS ARE:
C       KCHEM = 1 --- SURFACE FLOWS ON
C       KCHEM = 2 --- SURFACE FLOWS OFF
C       KCHEM = 3 --- GROUNDWATER
C       KDY ---- THE NUMBER OF THE DAY
C       KPER --- THE TIME PERIOD WITHIN THE DAY
C       KPD ---- THE TIME PERIOD WITHIN THE 2-D ARRAY
C       KL1 ---- A COUNTER
C       KPC ---- A COUNTER
C       KBD ---- A COUNTER
C
C*************************************************************************
C
      SUBROUTINE CHEMIN (NOSITE, MB,KDB,NPD)
      COMMON Q(3,1500),CONC(3,1500),LMP(1500),LDP(1500),LPP(1500),
     *LMD(125),LDD(125)
      DIMENSION KPER(7),CNCP(7),MD(12)
      DATA MD(1),MD(2),MD(3),MD(4),MD(5),MD(6),MD(7),MD(8),MD(9),
     *MD(10),MD(11),MD(12)/31,28,31,30,31,30,31,31,30,31,30,31/
C
C     INITIALIZE
C
      KMB=MB
      KPD=1
      DO 1 KPD =1,NPD
      DO 1 KCM=1,3
    1 CONC(KCM,KPD)=0.
C
C     READ IN THE PROPER LOCATION NUMBER AND ARRANGE THE
C       DATA FOR THAT LOCATION
C
      DO 40 KL1=1,NOSITE
      READ(1,100) KCHEM
  100 FORMAT(1XI1)
   10 READ(1,101)KMO,KDY,(KPER(KPC),CNCP(KPC),KPC=1,7)
```

```
  101 FORMAT (I2,I2,6X,7(I2,F8.0))
C
C    A BLANK CARD SIGNALS END OF DATA FOR A LOCATION
C
      IF (KMO) 40,40,11
   11 NODAY=0
      IF (KMO-KMB)71,71,72
   72 KMO1 = KMO - 1
      DO 70 KMD=KMB,KMO1
   70 NODAY = NODAY + MD(KMD)
   71 NODAY = NODAY + KDY-KDB
C
C    GIVE THE DATA PROPER SUBSCRIPTS FOR THE PASSING 2-D ARRAY
C
   12 DO 39 KPC=1,7
      IF(KPER(KPC))10,10,15
   15 KPD1=KPD
C
C    CALCULATE THE NUMBER OF DAYS SINCE THE BEGINNING OF THE STUDY
C
      KPD =(NODAY)*12 + KPER(KPC)
      CONC(KCHEM,KPD)= CNCP(KPC)
C
C    LINEARLY ARRANGE ALL MISSING DATA BETWEEN BOUND POINTS
C
   34 NPZ=KPD-KPD1
      IF (NPZ-1)39,39,35
   35 CINC=(CONC(KCHEM,KPD)-CONC(KCHEM,KPD1))/NPZ
      NPZ=NPZ-1
      DO36KBD=1,NPZ
      KBD1=KBD+KPD1
   36 CONC(KCHEM,KBD1)=CONC(KCHEM,KPD1)+(KBD*CINC)
   39 CONTINUE
      GOTO 10
   40 CONTINUE
      RETURN
   10 READ(1,101)KMO,KDY,(KPER(KPC),CNCP(KPC),KPC=1,7)
```

```
  101 FORMAT (I2,I2,6X,7(I2,F8.0))
C
C    A BLANK CARD SIGNALS END OF DATA FOR A LOCATION
C
      IF (KMO) 40,40,11
   11 NODAY=0
      IF (KMO-KMB)71,71,72
   72 KMO1 = KMO - 1
      DO 70 KMD=KMB,KMO1
   70 NODAY = NODAY + MD(KMD)
```

MAIN PROGRAM

```
C
C*********************************************************************
C
C    MAINPROGRAM FOR DETERMINING WATER AND MASS BALANCE FOR A
C      TRACT OF LAND.
C
C    AREA, ROOT ZONE CAPACITY, EVAPOTRANSPIRATION DATA, WEIR STAGE DATA,
C      AND CHEMCCAL CONCENTRATION DATA ARE COMBINED TO PROVIDE A WATER
C      AND MASS BALANCE FOR THE GIVEN AREA.
C
C    WRIR STAGE DATA AND CHEMICAL CONCENTRATION DATA ARE READ IN
C      BY SUBROUTINES FLOWIN AND CHEMIN RESPECTIVELY.
C
C    A DESCRIPTION OF THE VARIABLES USED IS GIVEN THROUGHOUT THE
C      PROGRAM AND IN THE SUBROUTINES.
C
C*********************************************************************
C
      COMMON Q(3,1500),CONC(3,1500),LMP(1500),LDP(1500),LPP(1500),
     *LMD(125),LDD(125)
C
      DIMENSION CROP(5),ET(125),QD(3,125),STORED(125),DCONC(3,125),
     *DP(125),CUM(3),CHMNM(5)
C
      DATA PRC/'PUNC'/
C
C    READ IN THE NUMBER OF CROPS THROUGH WHICH THE PROGRAM MUST LOOP
C
C
C                            <---------------------------READ DATA------
      READ (1,101) NOCP
      DO 999 KOCRP = 1,NOCP
C    READ IN NAME OF CROP FOR WHICH DATA ARE ENTERED
```

```
C
C                                   <---------------------------READ DATA------
      READ(1,100)CROP
  100 FORMAT(5A4)
C
C    READ IN BEGINNING AND ENDING DATES OF STUDY PERIOD
C
C                                   <---------------------------READ DATA------
      READ(1,101)MB,KDB,ME,KDE
  101 FORMAT(4I2)
C
C      READ IN NUMBER OF ACRES IN STUDY AREA, ROOT ZONE CAPACITY,AND
C      AMOUNT OF MOISTURE IN ROOT ZONE AT THE BEGINNING OF THE STUDY
C
C    TLIM = THE AMOUNT OF MOISTURE IN THE ROOT ZONE (IN INCHES) WHEN
C      GROUNDWATER COMMENCES MOVING UPWARD INTO THE ROOT ZONE
C
C                                   <---------------------------READ DATA------
      READ(1,102)ACRES,CAP,STORED(1),TLIM
  102 FORMAT (16F5.0)
C
C    READ IN PRINT CONTROL
C      IF THE FIRST WORD ON THE PRINT CONTROL BEGINNING IN COLUMN 1
C      IS 'PUNCH' THE DEEP PERCOLATION DATA WILL BE PUNCHED OUT ON
C      CARDS ACCORDING TO FORMAT 214.  ANY OTHER WORD IN THE FIRST
C      COLUMNS OF THE CARD WILL CAUSE THE PROGRAM TO BYPASS THIS OPTION.
C
C                                   <---------------------------READ DATA------
      READ(1,103) PRI
  103 FORMAT (A4)
      KPCN=2
      IF (PRI.EQ.PRC) KPCN=1
C
C    CALL SUBROUTINE HOGEN TO GENERATE DATES FOR TABLE ENTRIES AND
C      TO CALCULATE THE NUMBER OF DAYS AND 2-HOUR TIME PERIODS IN
C      THE STUDY
C
```

```
      CALL HDGEN (MB,KDB,ME,KDE,NDAY,NPD)
C
C   READ IN DAILY ET FOR THE CROP
C
C                                <---------------------------READ DATA------
      READ(1,105) (ET(KDY),KDY=1,NDAY)
  105 FORMAT(16XF5.3)
C
C   CALL SUBROUTINE FLOWIN TO READ IN FLOW DATA FROM MEASURING DEVICES
C
      CALL FLOWIN ( MB,KDB,NPD)
C
C   WRITE OUT A TABLE OF DISCHARGES OBTAINED FROM FLOWIN
C
      KNT=1
      KPD1=0
      DO 13 KPD=1,NPD
      IF(Q(1,KPD).EQ.0..AND.Q(2,KPD).EQ.0..AND.Q(3,KPD).EQ.0.) GOTO13
      IF(KNT.EQ.1) WRITE(3,200)CROP
      KPDD=KPD-KPD1
      IF(KPDD.GT.1.AND.KNT.GT.1) GOTO 11
      GOTO 12
   11 WRITE (3,201)
      KNT=KNT+1
   12 WRITE(3,202)LMP(KPD),LDP(KPD),LPP(KPD),(Q(J,KPD),J=1,3)
      KNT=KNT+1
      IF(KNT.GT.48)KNT=1
      KPD1=KPD
   13 CONTINUE
C
C   CALCULATE VOLUMES OF SURFACE WATER IN INCHES FOR PERIODS AND DAYS
C
      TOT=0.
      CONV= 1.98347/ACRES
      KOUNT=0
      DO 20 KQ=1,3
      KDY=1
```

```
      DO 20 KPD=1,NPD
      Q(KQ,KPD)=Q(KQ,KPD)*CONV
      TOT=TOT+Q(KQ,KPD)
      KOUNT=KOUNT+1
      IF(KOUNT.LT.12)GOTO20
      QD(KQ,KDY)=TOT
      TOT=0.
      KOUNT=0
      KDY=KDY+1
   20 CONTINUE
C
C   WRITE OUT RESULTS OBTAINED ABOVE ALONG WITH CUMULATIVE TOTALS
C
      DO 15 J=1,3
   15 CUM(J)=0.
C
C   WRITE OUT PERIOD RESULTS
C
      KNT=1
      KPD1=0
      DO23 KPD=1,NPD
      IF(Q(1,KPD).EQ.0..AND.Q(2,KPD).EQ.0..AND.Q(3,KPD).EQ.0.)GO TO 23
      IF(KNT.EQ.1) WRITE(3,206) CROP
      KPDD=KPD-KPD1
      IF(KPDD.GT.1.AND.KNT.GT.1) GOTO 21
      GOTO 22
   21 WRITE (3,201)
      KNT=KNT+1
   22 DO 16 J=1,3
   16 CUM(J)=CUM(J)+Q(J,KPD)
      WRITE(3,207)LMP(KPD),LDP(KPD),LPP(KPD),(Q(J,KPD),CUM(J),J=1,3)
      KPD1=KPD
      KNT=KNT+1
      IF(KNT.GT.48)KNT=1
   23 CONTINUE
C
C   WRITE OUT DAILY RESULTS
```

```
C
      DO 25 J=1,3
   25 CUM(J)=0.
      KNT=1
      DO 28 KDY=1,NDAY
      IF(KNT.EQ.1)WRITE(3,208)CROP
      DO 26 J=1,3
   26 CUM(J)= CUM(J)+QD(J,KDY)
      KNT=KNT+1
      WRITE(3,209)LMD(KDY),LDD(KDY),(QD(J,KDY),CUM(J),J=1,3)
      IF(KNT.GT.48)KNT=1
   28 CONTINUE
C
C
C    CALCULATE DEEP PERCOLATION LOSSES AND AMOUNT OF WATER STORED
C      IN THE ROOT ZONE FOR EACH DAY
C
      DO 30 J=1,3
   30 CUM(J)=0.
      DO 35 KDY=1,NDAY
      IF(KDY.EQ.1)GOTO31
      KX=KDY-1
      STORED(KDY)=STORED(KX)-ET(KDY)
   31 OVER=STORED(KDY)+QD(3,KDY)
      IF(OVER-CAP)32,32,33
   32 DP(KDY)=0.
      STORED(KDY)=OVER
      IF(STORED(KDY).GE.TLIM) GO TO 35
  300 DP(KDY)=STORED(KDY)-TLIM
      STORED(KDY)=TLIM
      GO TO 35
   33 DP(KDY)=OVER-CAP
      STORED(KDY)=CAP
   35 CONTINUE
C
C    WRITE OUT THE RESULTS CALCULATED
C
```

```
      KNT=1
      DO 40 KDY=1,NDAY
      IF(KNT.EQ.1)WRITE (3,212)CROP
C
C   SUM CUMULATIVE TOTALS AND WRITE OUT RESULTS
C
      CUM(1)=CUM(1)+ QD(3,KDY)
      CUM(2)=CUM(2)+ ET(KDY)
      CUM(3)=CUM(3) + DP(KDY)
      WRITE(3,213)LMD(KDY),LDD(KDY),QD(3,KDY),CUM(1),ET(KDY),CUM(2),
     *DP(KDY),CUM(3),STORED(KDY)
      GO TO (37,38),KPCN
   37 WRITE(2,214) LMD(KDY),LDD(KDY), QD(3,KDY),CUM(1),ET(KDY),CUM(2),
     *DP(KDY),CUM(3),STORED(KDY),KDY
   38 KNT=KNT+1
      IF(KNT.GT.48)KNT=1
   40 CONTINUE
C
C
C   THE FLOW DATA ARE COMBINED WITH CONSTITUENT CONCENTRATIONS TO
C     CALCULATE THE MASS BALANCE FOR EACH CONSTITUENT
C
C   AN END OF RECORD CARD DESIGNATES THE END OF ALL CHEMICAL
C     DATA FOR A CROP
C
      DO 80 KANL=1,100
C
C   READ IN NUMBER OF SAMPLING SITES AND CHEMICAL NAME PRIOR TO DATA
C     ENTERED FOR EACH CONSTITUENT
C     NOSITE = NUMBER OF SITES FOR WHICH DATA ARE ENTERED
C       IF NOSITE = 2, DATA ARE ENTERED ONLY FOR SURFACE FLOWS ON AND OFF
C       IF NOSITE = 3, DATA ARE ENTERED BOTH FOR SURFACE FLOWS AND DP
C       IF NOSITE = 1, DATA ARE ENTERED ONLY FOR DP AND UTILIZE THE
C                      SURFACE FLOW DATA ENTERED IMMEDIATELY
C                      PRECEEDING THROUGH SUBROUTINE CHEMIN
C
C   KSDT = DEPTH FROM WHICH DEEP PERCOLATION SAMPLES WERE OBTAINED
```

```
C     BY USING THE OPTION OF NOSITE = 1, DP CONCENTRATIONS FROM VARIOUS
C     DEPTHS CAN BE ENTERED TO DETERMINE THE INFLUENCE AT EACH DEPTH.
C
C                                 <----------------------------READ DATA------
      READ (1,106,END=81) NOSITE,KSDT,CHMNM
  106 FORMAT(I1,I2,5A4)
C
C   CALL SUBROUTINE CHEMIN TO INPUT THE CONSTITUENT CONCENTRATION DATA
C
      CALL CHEMIN (NOSITE, MB,KDB,NPD)
C
C   CALCULATE CONSTITUENT VALUES IN POUNDS/ACRE FOR EACH TIME PERIOD AND
C     EACH DAY
C
      IF(NOSITE.EQ.1)GOTO 60
      DO 43 J=1,3
   43 CUM(J)=0.
      DO 45  K=1,2
      KDY=1
      KNT=0
C
      DO 45 KPD=1,NPD
      CONC(K,KPD)=CONC(K,KPD)*Q(K,KPD)*0.226512
      CUM(K)=CUM(K)+CONC(K,KPD)
      KNT=KNT+1
      IF(KNT.LT.12)GO TO  45
      DCONC(K,KDY)=CUM(K)
      KDY=KDY+1
      CUM(K)=0.
      KNT=0
   45 CONTINUE
C
C   OUTPUT RESULTS OBTAINED FOR DAYS AND PERIODS
C
C   WRITE OUT PERIOD RESULTS
C
      KPD1=0
```

```
      DO 46 J=1,3
   46 CUM(J)=0.
      KNT=1
      DO 50 KPD=1,NPD
      IF(CONC(1,KPD).EQ.0..AND.CONC(2,KPD).EQ.0.) GOTO50
      IF (KNT.EQ.1)WRITE(3,220) CROP,CHMNM
C
      KPDD=KPD-KPD1
      IF(KPDD.GT.1.AND.KNT.GT.1) GOTO 47
      GOTO 48
   47 WRITE (3,201)
      KNT=KNT+1
   48 CUM(1)=CUM(1)+CONC(1,KPD)
      CUM(2)=CUM(2)+CONC(2,KPD)
      WRITE(3,221)LMP(KPD),LDP(KPD),LPP(KPD),(CONC(J,KPD),CUM(J),J=1,2)
      KNT=KNT+1
      IF(KNT.GT.48) KNT=1
      KPD1=KPD
   50 CONTINUE
C
C    DETERMINE WHICH FORMAT UNDER WIICH TO WRITE OUT DAILY VALUES
C      CONTROLLEC BY WHETHER OR NOT DP DATA ARE ENTERED
C
      IF(NOSITE.EQ.3.OR.NOSITE.EQ.1) GO TO 60
C
C    WRITE PUT DAILY RESULTS FOR NO DP DATA INCLUDED
C
      DO 51 J=1,3
   51 CUM(J)=0.
      KNT=1
      DO 55 KDY=1,NDAY
      IF(KNT.EQ.1)WRITE(3,225)CROP,CHMNM
C
      CUM(1)=CUM(1)+DCONC(1,KDY)
      CUM(2)=CUM(2)+DCONC(2,KDY)
      WRITE(3,226)LMD(KDY),LDD(KDY),(DCONC(J,KDY),CUM(J),J=1,2)
      KNT=KNT+1
```

```
      IF(KNT.GT.48)KNT=1
   55 CONTINUE
      GO TO 80
C
C   OBTAIN DAILY AVERAGES FOR DEEP PERCOLATION CONCENTRATIONS AND
C     COMPUTE DAILY VALUES LOST TO DP
C
   60 TDP=0.
      KDY=1
      KT=12
      DO 62 KPD=1,NPD
      TDP=TDP+CONC(3,KPD)
      IF(KPD.LT.KT)GO TO 62
      DCONC(3,KDY)=TDP/12.
      DCONC(3,KDY)=DCONC(3,KDY)*DP(KDY)*0.226512
      IF(KDY.GE.NDAY)GOTO65
      KDY=KDY+1
      KT=KT+12
      TDP=0.
   62 CONTINUE
   65 CONTINUE
C
C   WRITE OUT DAILY RESULTS FOR INCLUDED DP DATA
C
      KNT=1
      DO 66 J=1,3
   66 CUM(J)=0.
      DO 70 KDY=1,NDAY
      IF(KNT.EQ.1)WRITE(3,230) CROP,CHMNM,KSDT
      DO 68 J=1,3
   68 CUM(J)=CUM(J)+DCONC(J,KDY)
C
C   WRITE OUT RESULTS
C
      WRITE(3,231)LMD(KDY),LDD(KDY),(DCONC(J,KDY),CUM(J),J=1,3)
      KNT=KNT+1
      IF(KNT.GT.48)KNT=1
```

```
   70 CONTINUE
   80 CONTINUE
   81 CONTINUE
  150 FORMAT (I2)
C
C   FORMAT CARDS FOR PRINTOUT
C
  200 FORMAT('1'///10X,'CROP:  ',5A4,//10X,'TABLE OF FLOW RATES GIVEN IN
     * CFS',//11X'DATE  PERIOD    Q ON     Q OFF   Q APPLIED'/
     *'+' 9X,44('_')/)
  201 FORMAT (10X)
  202 FORMAT(10XA3,1XI2,3XI2,5XF6.3,2(4XF6.3))
  206 FORMAT('1'///5X'CROP:  ',5A4//5X'PERIOD AND CUMULATIVE TOTAL VOLUM
     *E'                                                                '
     *S OF SURFACE WATER GIVEN IN INCHES'//6X'DATE  PERIOD     WATER ON'
     *,11X,'WATER OFF',7X,'WATER APPLIED'/15X,3(5X'PERIOD   TOTAL')/
     *'+'4X,68('_')/)
  207 FORMAT(5XA3,1XI2,3XI2,3(3XF7.3,2XF7.3))
  208 FORMAT('1'///5X'CROP  ',5A4,//5X'DAILY AND CUMULATIVE TOTAL VOLUME
     *S OF SURFACE WATER GIVEN IN INCHES'//9X'DAY',11X,'WATER ON',11X,
     *'WATER OFF',8X,'WATER APPLIED'/15X,3(6X'DAILY',3X,'TOTAL')/
     *'+',6X,67('_')/)
  209 FORMAT(8XA3,1XI2,2X,3(3XF7.3,2XF7.3))
  212 FORMAT('1'///5X'CROP:  ',5A4,//5X'INCHES OF WATER APPLIED, LOST TO
     *',1X,                                                             '
     *EVAPOTRANSPIRATION, LOST TO DEEP'/5X'PERCOLATION, AND STORED IN TH
     *E ROOT ZONE'//4X'DAY       WATER APPLIED     WATER TO ET      WATER
     *TO DP      WATER IN'/9X,3(4X'DAILY   TOTAL'),4X'ROOT ZONE'/'+'
     *2X,70('_')/)
  213 FORMAT (3XA3,1XI2,1X,3(1XF7.3,2XF7.3),6XF4.2)
  214 FORMAT (A3,1XI2,3(1XF7.3,2XF7.3),3XF4.2,3XI3)
  220 FORMAT('1'///6X'CROP:  ',5A4,T30,'CONSTITUENT:  ',5A4,//5X'PERIOD
     *AND CUMULATIVE TOTAL AMOUNTS OF CONSTITUENT APPLIED'/5X'AND LOST T
     *HROUGH SURFACE FLOWS EXPRESSED IN POUNDS PER ACRE'//6X'DATE  PERIO
     *D',7X,'CONSTITUENT ON',6X,'CONSTITUENT OFF'/20X,2(5X'PERIOD    TOT
     *AL')/'+',4X,56('_')/)
  221 FORMAT (5XA3,1XI2,3XI2,5X,4(2XF8.3))
```

```
225 FORMAT('1'///5X'CROP:  ',5A4,T30,'CONSTITUENT:  ',5A4,//5X'DAILY A
   *ND CUMULATIVE TOTAL AMOUNTS OF CONSTITUENT APPLIED'/5X'AND LOST TH
   *ROUGH SURFACE FLOWS EXPRESSED IN POUNDS PER ACRE'//9X'DATE',T24,
   *'CONSTITUENT ON',6X,'CONSTITUENT OFF'/19X,2(5X'DAILY      TOTAL')/
   *'+',7X,52('_')/)
226 FORMAT(8X,A3,1XI2,5X,4(2XF8.3))
230 FORMAT('1'///5X'CROP:  ',5A4,T30,'CONSTITUENT:  ',5A4,//5X'DAILY A
   *ND CUMULATIVE TOTAL AMOUNTS OF CONSTITUENT APPLIED AND LOST'/5X
   *'THROUGH SURFACE FLOWS AND DEEP PERCOLATION EXPRESSED IN POUNDS PE
   *R ACRE'//6X'   DATE        CONSTITUENT ON      CONSTITUENT OFF   CON
   *STITUENT TO DP'/55X'(',I2,'-FT SAMPLING DEPTH)'/
   *                 15X,3(6X'DAILY    TOTAL')/'+',7X,65('_')/)
231 FORMAT(8XA3,1XI2,2X,3(2XF8.3,1XF8.3))
999 CONTINUE
    STOP
```

SUBROUTINE CHEMIN

```
C
C***************************************************************************
C
C
C    SUBROUTINE CHEMIN READS THE CONCENTRATION OF A CHEMICAL
C      CONSTITUENT FOR  SPECIFIED TIME INCREMENTS AS OUTLINED
C      IN THE MAIN PROGRAM.
C
C    ONE CARD MUST BE USED FOR EACH DAY'S RECORD THAT IS
C      ENTERED, HOWEVER, DATA NEED NOT BE ENTERED IF THE CON-
C      CENTRATION DOES NOT CHANGE OR IF DATA ARE MISSING.
C      SUBROUTINE CHEMIN WILL LINEARLY AVERAGE ALL MISSING DATA
C      BETWEEN POINTS BOUNDING THE MISSING DATA.
C
C    THE DATA ARE PASSED TO THE MAIN PROGRAM AS A 2-D ARRAY
C      IN COMMON STORAGE, CONC(LOCATION,TIME PERIOD)
C
C    A BLANK CARD IS USED TO SIGNAL THE COMPLETION OF THE
C      DATA FOR A PARTICULAR CONSTITUENT AT A PARTICULAR LOCATION.
C
C
C    DESCRIPTION OF VARIABLES
C      CNCP --- CONCENTRATIONS READ INTO SUBROUTINE CHEMIN
C      CONC --- CONCENTRATION ARRAY TO BE PASSED TO THE MAIN
C               PROGRAM
C      NOSITE - NUMBER OF SITES FOR WHICH DATA ARE TO BE
C               READ FOR THE PARTICULAR CONSTITUENT
C      MB ----- NUMBER OF MONTH THE STUDY BEGAN
C      KDB ---- NUMBER OF DAY WITHIN MB THAT THE STUDY BEGAN
C      NPD ---- NUMBER OF 2-HOUR TIME PERIODS WITHIN THE
C               STUDY PERIOD
C      KMO ---- NUMBER OF THE MONTH FOR WHICH DATA ARE BEING
C               READ IN
```

```
C        KCHEM -- THE NUMBER OF THE LOCATION FOR WHICH DATA ARE
C                 PRESENTLY BEING READ AND ARRANGED
C     THE VALUES OF KCHEM AND THEIR CORRESPONDING LOCATIONS ARE:
C        KCHEM = 1 --- SURFACE FLOWS ON
C        KCHEM = 2 --- SURFACE FLOWS OFF
C        KCHEM = 3 --- GROUNDWATER
C        KDY ---- THE NUMBER OF THE DAY
C        KPER --- THE TIME PERIOD WITHIN THE DAY
C        KPD ---- THE TIME PERIOD WITHIN THE 2-D ARRAY
C        KL1 ---- A COUNTER
C        KPC ---- A COUNTER
C        KBD ---- A COUNTER
C
C***********************************************************************
C
      SUBROUTINE CHEMIN (NOSITE, MB,KDB,NPD)
      COMMON Q(3,1500),CONC(3,1500),LMP(1500),LDP(1500),LPP(1500),
     *LMD(125),LDD(125)
      DIMENSION KPER(7),CNCP(7),MD(12)
      DATA MD(1),MD(2),MD(3),MD(4),MD(5),MD(6),MD(7),MD(8),MD(9),
     *MD(10),MD(11),MD(12)/31,28,31,30,31,30,31,31,30,31,30,31/
C
C     INITIALIZE
C
      KMB=MB
      KPD=1
      IF(NOSITE.EQ.1) GO TO 5
      DO 1 KPD =1,NPD
      DO 1 KCM=1,3
    1 CONC(KCM,KPD)=0.
      GOTO 8
C
    5 DO 2 KPD =1,NPD
    2 CONC(3,KPD) =0.
C
C     READ IN THE PROPER LOCATION NUMBER AND ARRANGE THE
C        DATA FOR THAT LOCATION
```

```
C
    8 DO 40 KL1=1,NOSITE
C
C                                   <----------------------------READ DATA------
      READ(1,100) KCHEM
  100 FORMAT(I1)
C
C                                   <----------------------------READ DATA------
   10 READ(1,101)KMO,KDY,(KPER(KPC),CNCP(KPC),KPC=1,7)
  101 FORMAT (I2,I2,6X,7(I2,F8.0))
C
C    A BLANK CARD SIGNALS END OF DATA FOR A LOCATION
C
      IF (KMO) 40,40,11
   11 NODAY=0
      IF (KMO-KMB)71,71,72
   72 KMO1 = KMO - 1
      DO 70 KMD=KMB,KMO1
   70 NODAY = NODAY + MD(KMD)
   71 NODAY = NODAY + KDY-KDB
C
C    GIVE THE DATA PROPER SUBSCRIPTS FOR THE PASSING 2-D ARRAY
C
   12 DO 39 KPC=1,7
      IF(KPER(KPC))10,10,15
   15 KPD1=KPD
C
C    CALCULATE THE NUMBER OF DAYS SINCE THE BEGINNING OF THE STUDY
C
      KPD =(NODAY)*12 + KPER(KPC)
      CONC(KCHEM,KPD)= CNCP(KPC)
C
C    LINEARLY ARRANGE ALL MISSING DATA BETWEEN BOUND POINTS
C
   34 NPZ=KPD-KPD1
```

```
      IF (NPZ-1)39,39,35
   35 CINC=(CONC(KCHEM,KPD)-CONC(KCHEM,KPD1))/NPZ
      NPZ=NPZ-1
      DO36KBD=1,NPZ
      KBD1=KBD+KPD1
   36 CONC(KCHEM,KBD1)=CONC(KCHEM,KPD1)+(KBD*CINC)
   39 CONTINUE
      GOTO 10
   40 CONTINUE
      RETURN
```

SUBROUTINE FLOWIN

```
C
C*****************************************************************************
C
C     SUBROUTINE FLOWIN READS THE STAGE FOR SPECIFIED TIME
C       INCREMENTS AS OUTLINED IN THE MAIN PROGRAM AND COMPUTES
C       THE DISCHARGE FOR THE PROPER WEIR.
C
C     IF THE DISCHARGE IS TO BE READ IN DIRECTLY, A '1' IS PLACED
C       IN COLUMN 5 OF THE SPECIFIED DATA CARD.
C
C     ONE CARD MUST BE USED FOR EACH DAY'S RECORD THAT IS ENTERED,
C       HOWEVER,NO DATA NEED BE ENTERED IF THE STAGE OR DISCHARGE
C       DOES NOT CHANGE FOR A PERIOD OF TIME RANGING FROM SEVERAL
C       2-HOUR TIME PERIODS UP TO SEVERAL WEEKS.  SUBROUTINE FLOWIN
C       WILL LINEARLY AVERAGE ALL MISSING DATA BETWEEN THE TWO
C       POINTS BOUNDING THE MISSING DATA.
C
C     SUBROUTINE FLOWIN CALCULATES THREE DISCHARGE RATES
C       FOR EACH TIME PERIOD, Q-ON, Q-OFF, AND Q-APPLIED.
C
C     THE DATA ARE PASSED TO THE MAIN PROGRAM AS A 2-D ARRAY,
C       IN COMMON STORAGE Q(LOCATION,TIME PERIOD).
C
C     A BLANK CARD IS USED TO SIGNAL THE COMPLETION OF DATA FOR A WEIR.
C
C     DESCRIPTION OF VARIABLES
C       NWEIR -- NUMBER OF DIFFERENT WEIRS FOR WHICH DATA ARE
C                TO BE READ IN
C       Q------- DISCHARGE ARRAY TO BE PASSED TO THE MAIN PROGRAM
C       QH ----- DISCHARGE OR STAGE DATA READ INTO FLOWIN
C       KWEIR -- THE NUMBER OF THE WEIR FOR WHICH DATA ARE
C                PRESENTLY READ AND CORRECT DISCHARGE COMPUTED
C       KMO ---- NUMBER OF THE MONTH
```

```
C      KDB ---- NUMBER OF THE DAY WITHIN THE MONTH THAT
C               THE STUDY BEGAN
C      MB ----- NUMBER OF THE MONTH THE STUDY BEGAN
C      NPD ---- NUMBER OF 2-HOUR TIME PERIODS IN THE STUDY
C               CALCULATED IN SUBROUTINE HDGEN
C      KPD ---- THE TIME PERIOD WITHIN THE Q-ARRAY
C      KDY ---- THE NUMBER OF THE DAY
C      KPER --- THE TIME PERIOD WITHIN THE DAY
C      KPD ---- THE TIME PERIOD WITHIN THE 2-D ARRAY
C      KWF ---- BRANCH CONTROL FOR THE PROPER WEIR FORMULA
C               VALUES OF KWF AND THE CORRESPONDING WEIR
C                 1 -- 2 FOOT CIPPOLLETTI
C                 2 -- 3 FOOT CIPPOLLETTI
C                 3 -- 2 FOOT CONTRACTED RECTANGULAR
C                 4 -- 6 INCH PARSHALL FLUME
C                 5 -- 2 FOOT SUPPRESSED TRAPEZOIDAL WITH 1:1 SIDE SLOPES
C      KL1 ---- A COUNTER
C      KBD ---- A COUNTER
C
C***********************************************************************
C
      SUBROUTINE FLOWIN ( MB,KDB,NPD)
      COMMON Q(3,1500),CONC(3,1500),LMP(1500),LDP(1500),LPP(1500),
     *LMD(125),LDD(125)
      DIMENSION KPER(7),QH(7),MD(12)
      DATA MD/31,28,31,30,31,30,31,31,30,31,30,31/
C
C    INITIALIZE
C
      NWEIR=2
      KMB=MB
      KPD=1
      DO 1 KZ=1,NPD
      DO 1 KQ = 1,3
    1 Q(KQ,KZ)=0.
C
C    READ IN THE PROPER WEIR NUMBER, AND READ AND ARRANGE
```

```
C     THE DATA FOR THAT WEIR.
C
      DO 40 KL1=1,NWEIR
    5 READ (1,100)KWEIR,KWF
  100 FORMAT (2I1)
   10 READ(1,101)KMO,KDY,KDIR,(KPER(KPC),QH(KPC),KPC=1,7)
  101 FORMAT (2I2,I1,5X,7(I2,F8.0))
C
C    A BLANK CARD SIGNALS THE END OF DATA FOR A PARTICULAR WEIR
C
      IF (KMO) 40,40,11
C    CALCULATE THE NUMBER OF DAYS SINCE THE BEGINNING OF THE STUDY
   11 NODAY=0
      IF(KMO.LE.KMB) GOTO 71
   72 KMO1=KMO-1
      DO 70 KMD=KMB,KMO1
   70 NODAY = NODAY + MD(KMD)
   71 NODAY = NODAY + KDY-KDB
C
C
C    GIVE THE DATA PROPER SUBSCRIPTS FOR THE PASSING 2-D ARRAY
C
   12 DO 39 KPC=1,7
      IF(KPER(KPC))10,10,15
   15 KPD1=KPD
      KPD =(NODAY)*12 + KPER(KPC)
C
C    BRANCH TO THE PROPER WEIR FORMULA
C
      IF (KDIR)30,16,30
   16 GOTO (21,22,23,24,25,26),KWF
   21 Q(KWEIR,KPD)= 6.74*(QH(KPC)**1.5)
      GO TO 34
   22 Q(KWEIR,KPD) = 10.11*(QH(KPC)**1.5)
      GO TO 34
   23 Q(KWEIR,KPD) = 3.33*(2. -0.2*QH(KPC))*(QH(KPC)**1.5)
      GO TO 34
```

```
   24 Q(KWEIR,KPD) = 2.06*(QH(KPC)**1.58)
      GO TO 34
   25 Q(KWEIR,KPD)= 8.7 *(QH(KPC)**1.9)
      GO TO 34
   26 Q(KWEIR,KPD) = 2.06*(QH(KPC)**1.58)/.52189
      GOTO 34
   30 Q(KWEIR,KPD) = QH(KPC)
C
C     LINEARLY ARRANGE ALL MISSING DATA BETWEEN BOUND POINTS
C
   34 NPZ=KPD-KPD1
      IF (NPZ-1)39,39,35
   35 QINC=(Q(KWEIR,KPD)-Q(KWEIR,KPD1))/NPZ
      NPZ=NPZ-1
      DO 36 KBD=1,NPZ
      KBD1=KPD1+KBD
   36 Q(KWEIR,KBD1)=Q(KWEIR,KPD1)+KBD*QINC
   39 CONTINUE
      GOTO 10
   40 CONTINUE
C
C     CALCULATE THE PROPER FLOW RATE FOR THE PROPER LOCATION
C
   42 DO 45 KPD=1,NPD
   45 Q(3,KPD)= Q(1,KPD) - Q(2,KPD)
   50 CONTINUE
      RETURN
```

MAIN PROGRAM FOR DETERMINING MASS BALANCE FOR A SETTLING POND

```
C    MAIN PROGRAM FOR DETERMINING MASS BALANCE ON SETTLING POND
       COMMON Q(3,1500),CONC(3,1500),LMP(1500),LDP(1500),LPP(1500),
      *LMD(125),LDD(125)
C
C
       DIMENSION CROP(5),QD(3,125),DCONC(3,125),CUM(3),CHMNM(5)
C
C
C    READ IN THE NUMBER OF CROPS THROUGH WHICH THE PROGRAM MUST LOOP
C
       READ (1,101) NOCP
       DO 60 KOCRP=1,NOCP
C    READ IN NAME OF CROP FOR WHICH DATA ARE ENTERED
C
       READ(1,100)CROP
   100 FORMAT(5A4)
C
C    READ IN BEGINNING AND ENDING DATES OF STUDY PERIOD
C
       READ(1,101)MB,KDB,ME,KDE
   101 FORMAT(4I2)
C
C    READ IN NUMBER OF ACRES IN STUDY AREA
C
       READ(1,102)ACRES
   102 FORMAT(F5.0)
C
C    CALL SUBROUTINE HDGEN TO GENERATE DATES FOR TABLE ENTRIES AND
C      TO CALCULATE THE NUMBER OF DAYS AND 2-HOUR TIME PERIODS IN
C      THE STUDY
C
       CALL HDGEN (MB,KDB,ME,KDE,NDAY,NPD)
C
```

```
C
C   CALL SUBROUTINE FLOWIN TO READ IN FLOW DATA FROM MEASURING DEVICES
C
      CALL FLOWIN ( MB,KDB,NPD)
C
C   WRITE OUT A TABLE OF DISCHARGES OBTAINED FROM FLOWIN
C
      KNT=1
      KPD1=0
      DO 13 KPD=1,NPD
      IF(Q(1,KPD).EQ.0..AND.Q(2,KPD).EQ.0) GO TO 13
      IF(KNT.EQ.1) WRITE(3,200)CROP
  200 FORMAT('1'///10X,'CROP:  ',5A4,//10X,'TABLE OF FLOW RATES GIVEN IN
     * CFS',//11X'DATE  PERIOD    Q IN     Q OUT   Q RETAINED'/
     *'+' 9X,44('_')/)
      KPDD=KPD-KPD1
      IF(KPDD.GT.1.AND.KNT.GT.1) GOTO 11
  201 FORMAT (10X)
      GOTO 12
   11 WRITE (3,201)
      KNT=KNT+1
   12 WRITE(3,202)LMP(KPD),LDP(KPD),LPP(KPD),(Q(J,KPD),J=1,3)
  202 FORMAT(10XA3,1XI2,3XI2,5XF6.3,2(4XF6.3))
      KNT=KNT+1
      IF(KNT.GT.48)KNT=1
      KPD1=KPD
   13 CONTINUE
C   CALCULATE VOLUMES OF SURFACE WATER IN INCHES FOR PERIODS AND DAYS
      TOT=0.
      CONV= 1.98347/ACRES
      KOUNT=0
      DO 20 KQ=1,3
      KDY=1
      DO 20 KPD=1,NPD
      Q(KQ,KPD)=Q(KQ,KPD)*CONV
      TOT=TOT+Q(KQ,KPD)
      KOUNT=KOUNT+1
```

```
      IF(KOUNT.LT.12)GOTO20
      QD(KO,KDY)=TOT
      TOT=0.
      KOUNT=0
      KDY=KDY+1
   20 CONTINUE
C    WRITE OUT RESULTS OBTAINED ABOVE ALONG WITH CUMULATIVE TOTALS
      DO 15 J=1,3
   15 CUM(J)=0.
C    WRITE OUT PERIOD RESULTS
      KNT=1
      KPD1=0
      DO23 KPD=1,NPD
      IF(Q(1,KPD).EQ.0..AND.Q(2,KPD).EQ.0)GO TO 23
      IF(KNT.EQ.1) WRITE(3,206) CROP
  206 FORMAT('1'///5X'CROP:   ',5A4//5X'PERIOD AND CUMULATIVE TOTAL VOLUM
     *E'
     *S OF WATER LOST IN POND GIVEN IN INCHES'//6X'DATE  PERIOD',6X,
     * WATER IN',11X,'WATER OUT',7X'WATER RETAINED'//15X,3(5X'PERIOD',
     *4X, 'TOTAL')/'+'4X,73('_')/)
      KPDD=KPD-KPD1
      IF(KPDD.GT.1.AND.KNT.GT.1) GOTO 21
      GOTO 22
   21 WRITE (3,201)
      KNT=KNT+1
   22 DO 16 J=1,3
   16 CUM(J)=CUM(J)+Q(J,KPD)
      WRITE(3,207)LMP(KPD),LDP(KPD),LPP(KPD),(Q(J,KPD),CUM(J),J=1,3)
  207 FORMAT(5XA3,1XI2,3XI2,3(4XF7.3,2XF7.3))
      KPD1=KPD
      KNT=KNT+1
      IF(KNT.GT.48)KNT=1
   23 CONTINUE
C
C    WRITE OUT DAILY RESULTS
      DO 25 J=1,3
   25 CUM(J)=0.
```

```
      KNT=1
      DO 28 KDY=1,NDAY
      IF(KNT.EQ.1)WRITE(3,208)CROP
  208 FORMAT('1'///5X'CROP: ',5A4,//5X'DAILY AND CUMULATIVE TOTAL VOLUME
     *S OF SURFACE WATER GIVEN IN INCHES'//9X'DAY',11X,'WATER IN',11X,
     *'WATER OUT',8X,'WATER RETAINED'/15X,3(6X'DAILY',3X,'TOTAL')/
     *'+',6X,67('_')/)
      DO 26 J=1,3
   26 CUM(J)= CUM(J)+QD(J,KDY)
      KNT=KNT+1
      WRITE(3,209)LMD(KDY),LDD(KDY),(QD(J,KDY),CUM(J),J=1,3)
  209 FORMAT(8XA3,1XI2,2X,3(3XF7.3,2XF7.3))
      IF(KNT.GT.48)KNT=1
   28 CONTINUE
C   READ IN THE NUMBER OF CONSTITUENTS FOR WHICH DATA ARE ENTERED
      READ(1,150)NANL
  150 FORMAT (I2)
      DO 60 KANL=1,NANL
C   READ IN THE NUMBER OF SAMPLING SITES AND CHEMICAL NAME PRIOR TO DATA
C   ENTERED FOR EACH CONSTITUENT
      READ(1,106)NOSITE,CHMNM
  106 FORMAT(I1,5A4)
C   CALL SUBROUTINE CHEMIN TO INPUT THE CONSTITUENT CONCENTRATION DATA
      CALL CHEMIN (NOSITE, MB,KDB,NPD)
C
C   CALCULATE CONSTITUENT VALUES IN POUNDS/ACRE FOR EACH TIME PERIOD AND
C     EACH DAY
C
C
      DO 43 J=1,3
   43 CUM(J)=0.
      DO 45  K=1,2
      KDY=1
      KNT=0
C
      DO 45 KPD=1,NPD
      CONC(K,KPD)=CONC(K,KPD)*Q(K,KPD)*0.226512
```

```
      CUM(K)=CUM(K)+CONC(K,KPD)
      KNT=KNT+1
      IF(KNT.LT.12)GO TO  45
      DCONC(K,KDY)=CUM(K)
      KDY=KDY+1
      CUM(K)=0.
      KNT=0
   45 CONTINUE
      DO 44 KPD = 1,NPD
   44 CONC(3,KPD) = CONC(1,KPD)- CONC(2,KPD)
      DO 64 KY=1,NDAY
   64 DCONC(3,KY)=DCONC(1,KY)-DCONC(2,KY)
C
C    OUTPUT RESULTS OBTAINED FOR DAYS AND PERIODS
C
      KPD1=0
      DO 46 J=1,3
   46 CUM(J)=0.
      KNT=1
      DO 50 KPD=1,NPD
      IF(CONC(1,KPD).EQ.0..AND.CONC(2,KPD).EQ.0.) GOTO50
      IF (KNT.EQ.1)WRITE(3,220) CROP,CHMNM
C
  220 FORMAT('1'///6X'CROP:  ',5A4,T30,'CONSTITUENT:  ',5A4,//5X'PERIOD
     *AND CUMULATIVE TOTAL AMOUNTS OF CONSTITUENT INTO, OUT OF AND'/5X,
     *'RETAINED IN THE SETTLING POND EXPRESSED IN POUNDS PER ACRE'
     *                                                       //6X'DATE  P
     *ERIOD   CONSTITUENT IN     CONSTITUENT OUT   CONSTITUENT RETAINED'
     */15X,3(5X'PERIOD     TOTAL')/'+',4X,71('_')/)
C
      KPDD=KPD-KPD1
      IF(KPDD.GT.1.AND.KNT.GT.1) GOTO 47
      GOTO 48
   47 WRITE (3,201)
      KNT=KNT+1
   48 CUM(1)=CUM(1)+CONC(1,KPD)
      CUM(2)=CUM(2)+CONC(2,KPD)
```

```
      CUM(3)=CUM(3)+CONC(3,KPD)
      WRITE(3,221)LMP(KPD),LDP(KPD),LPP(KPD),(CONC(J,KPD),CUM(J),J=1,3)
  221 FORMAT (5XA3,1XI2,3XI2,    6(2XF8.3))
      KNT=KNT+1
      IF(KNT.GT.48) KNT=1
      KPD1=KPD
   50 CONTINUE
C
C   WRITE OUT DAILY RESULTS
      DO 51 J=1,3
   51 CUM(J)=0.
      KNT=1
      DO 55 KDY =1,NDAY
      IF (KNT.EQ.1) WRITE (3,225) CROP,CHMNM
  225 FORMAT('1'///6X'CROP:  ',5A4,T30,'CONSTITUENT:  ',5A4,// 5X'DAILY
     *AND CUMULATIVE TOTAL AMOUNTS OF CONSTITUENT INTO, OUT OF AND'/5X,
     *'RETAINED IN THE SETTLING POND EXPRESSED IN POUNDS PER ACRE'
     *                                                        //6X'  DATE
     *          CONSTITUENT IN      CONSTITUENT OUT    CONSTITUENT RETAINED'
     */15X,3(5X'DAILY      TOTAL')/'+',4X,71('_')/)
      DO 52 J=1,3
   52 CUM(J)=CUM(J)+ DCONC(J,KDY)
      WRITE(3,226)LMD(KDY),LDD(KDY),(DCONC(J,KDY),CUM(J),J=1,3)
  226 FORMAT(7XA3,1XI2,2X,6(2XF8.3))
      KNT=KNT+1
      IF(KNT.GT.48) KNT=1
   55 CONTINUE
   60 CONTINUE
      STOP
```